INCOSE

INTERNATIONAL COUNCIL ON SYSTEMS ENGINEERING

Systems Engineering Applications Technical Committee

Systems Engineering Applications Profiles
Version 3.0

July 2000

Commercial and Public Interest Working Group

INCOSE

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Commercial and Public Interest Working Group

SEATC Chairman: Dr. William F. Mackey
Computer Sciences Corporation
7700 Hubble Drive
Lanham-Seabrook, MD 20706 USA
Voice: 301-794-2138
Fax: 301-794-9480
E-mail: wmackey@csc.com

CPIWG Chairman: Jerry Bauknight
G.C. Bauknight & Associates
654 Cuesta Drive
Los Altos, CA 94024-4134 USA
Voice: 650-948-9161
Fax: 650-948-0595
E-mail: g.bauknight@ieee.org

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- Scott Ankrum, University of Maryland University College (UMUC)
- Mark Austin, University of Maryland
- LeRoy Botten, CSC
- Carolyn Buford, CSC
- Edward Connor, Analytic Services, Inc. (ANSER)
- Rebecca Cook, UMUC
- Lawrence M. Dolton, Viewpoint
- Theodore Dolton, Lockheed Martin
- Jean Duverne, UMUC
- Kailash Gangar, UMUC
- Ralph Gibson, SAIC
- Venugopal Gopinathan, UMUC
- Bill Henderson, Sverdrup Technology
- Amy Hsiao, UMUC
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NASA has a history of supporting technology transfer to the general public. The Computer Software Management and Information Center (COSMIC) at the University of Georgia facilitates transfer of NASA-developed computer code and documentation. The monthly *NASA Tech Briefs* magazine provides descriptions of new technology and applications developed or sponsored by NASA and sources for additional appropriate information. NASA's National Technical Transfer Center (NTTC) provides information to potential users regarding technology developments made by NASA and its contractors. NTTC information is customized to meet each user's needs and provides information on contractor contracts, licensing, cooperative agreements, and other aspects of the NASA technology transfer program.

NASA has been a key player in creating and maintaining strong technical capabilities in the U.S. economy. In an environment of reduced Federal budgets for science and technology, NASA is developing additional methods for technology transfer, commercializing its technology, and expanding its partnerships and other cooperative efforts with commercial firms, universities, and international partners. Most recently, a Space Systems Working Group (SSWG) has been formed within the Systems Engineering Applications Technical Committee (SEATC) to examine the unique applications of the aerospace industry.

This document benefits all organizations interested in the discipline and practice of systems engineering. It also offers the opportunity for technology transfer across application domains. This document will continually mature and provide a written forum for the primary systems engineering issues in each application domain.

History of the SEAP

The SEAP document was first disseminated to INCOSE members at the 1995 International Symposium, discussed at the symposium, and revised for general INCOSE Technical Committee distribution after the symposium. This release was under the title Emerging Applications White Paper, Draft 2, dated July 24, 1995. The Emerging Applications White Paper, Draft 1, was a skeletal document released at the International Workshop in January 1995. Neither of these documents is considered a primary product of the SEATC, but they are necessary to understand the history of the document. The documents that have led to the present release are shown in the following table.

Product Name	WG/IG	Type	Publication Date	Distribution Date
1. Emerging Applications White Paper	CPIWG	Report		
Draft 1			January 27, 1995	Limited distribution January 1995 in an unbound copy
Draft 2			July 24, 1995	Limited distribution July 1995 in a bound hardcopy format
2. Systems Engineering Applications Profiles (SEAP) Document	CPIWG	Report		
Version 1.0			May 1, 1996	July 1996, Vol. 2 INCOSE Proceedings
Version 2.0			July 1, 1998	August 1998 INCOSE Web pages
Version 2.0a			January 20, 1999	February 1999 INCOSE Web pages
Version 3.0			July 1, 2000	August 2000 INCOSE Web pages
2. SEAP Writing Guide	CPIWG	Report	April 1, 1996	July 1996, Volume 2. INCOSE Proceedings Appendix B of SEAP, Version 3.0
3. Multilevel Participation Plan	SEATC	Report	July 1, 1998	August 1998 INCOSE Web pages Appendix C of SEAP, Version 3.0

1. *Emerging Applications White Paper, Draft 1*, was a skeletal paper with virtually no content. There were no sample profiles or materials useful for the next draft. Limited photocopy distribution was made to the few Emerging Application Working Group (EAWG) members attending the meeting on January 24–27, 1995, in Houston, TX.

2. *Emerging Applications White Paper, Draft 2*, was a complete hardbound paper with five chapters and two appendixes. These were as follows:

   - Chapter 1 – NCOSE Technical Activities
   - Chapter 2 – Emerging Applications Technical Activities
   - Chapter 3 – Systems Engineering in the Emerging Applications
   - Chapter 4 – Sector-by-Sector Summary
   - Chapter 5 – Future Directions for the EAWG
   - Appendix A – NCOSE Working Groups
   - Appendix B – EAWG Membership

   Sample profiles were provided for the following 14 application domains:

   - 4.1 Agriculture
   - 4.2 Motor Vehicles
   - 4.3 Commercial Aircraft
   - 4.4 Commercial Avionics
   - 4.5 Environmental Restoration
   - 4.6 Health Care
   - 4.7 Highway Systems
   - 4.8 Information Systems
   - 4.9 Medical Devices
   - 4.10 Natural Resource Management
   - 4.11 Telecommunications
   - 4.12 Manufacturing
   - 4.13 Energy
   - 4.14 Criminal Justice System and Legal Processes

   Highway Systems, Medical Devices, Energy, and Criminal Justice System and Legal Processes had complete entries. All other sections were partial entries with most tables remaining to be completed. Limited distribution was made to all attendees of the EAWG meeting held on July 24, 1995, in St. Louis, MO.

3. *Systems Engineering Applications Profiles, Version 1.0*, was completed on May 1, 1996, and was included in Volume 2 of the July 1996 symposium proceedings. Version 1.0, also a

complete hardbound document with five chapters, had expanded to include five appendixes. These were as follows:

- Chapter 1 – INCOSE Technical Activities
- Chapter 2 – Applications Forum Technical Activities
- Chapter 3 – Systems Engineering Applications
- Chapter 4 – Profiles of Systems Engineering Application Domains
- Chapter 5 – Future Directions for the AFWG
- Appendix A – INCOSE Working Groups
- Appendix B – Charter of the AFWG
- Appendix C – Goals of the AFWG
- Appendix D – AFWG Membership
- Appendix E – AFWG Author's Writing Guide

Profiles were provided for the following 16 application domains:

- 4.1 Agriculture
- 4.2 Commercial Aircraft
- 4.3 Commercial Avionics
- 4.4 Criminal Justice System and Legal Processes
- 4.5 Energy Systems
- 4.6 Environmental Restoration
- 4.7 Geographic Information Systems
- 4.8 Health Care
- 4.9 Highway Transportation Systems
- 4.10 Information Systems
- 4.11 Manufacturing
- 4.12 Medical Devices
- 4.13 Motor Vehicles
- 4.14 Natural Resource Management

- 4.15 Space Exploration
- 4.16 Telecommunications

Many of the profiles were significantly improved and two new profiles were added including Geographic Information Systems and Space Exploration. Commercial Aircraft was totally rewritten and several other profiles were either rewritten or changed to be quite different from those in the previous Draft version. Also by this time the National Council on Systems Engineering (NCOSE) had changed its name to the International Council on Systems Engineering (INCOSE). The Emerging Applications Working Group (EAWG) had changed its name to the Applications Forum Working Group (AFWG).

The first attempt to organize the AFWG resulted in the following appendixes being written for this release:

- Appendix B – Charter of the AFWG
- Appendix C – Goals of the AFWG
- Appendix D – AFWG Membership
- Appendix E – AFWG Author's Writing Guide

Appendix E was provided to give any potential author the opportunity to contribute to a specific industry application domain in a format useful to the SEAP.

4. *Systems Engineering Applications Profiles, Version 2.0*, was completed on July 1, 1998, and by August 1998 was included in the INCOSE Web pages. Version 2.0, also a complete hardbound document with five chapters, had expanded to include nine appendixes:
   - Chapter 1 – INCOSE Technical Activities
   - Chapter 2 – Systems Engineering Technical Committee Activities
   - Chapter 3 – Systems Engineering Applications
   - Chapter 4 – Profiles of Systems Engineering Application Domains
   - Chapter 5 – Future Directions for the SEATC
   - Appendix A – INCOSE Technical Committees, Working Groups, and Interest Groups
   - Appendix B – INCOSE Strategic Plan
   - Appendix C – Charter of the CPIWG
   - Appendix D – Goals of the SEATC
   - Appendix E – INCOSE SEATC Membership
   - Appendix F – SEAP Author's Writing Guide
   - Appendix G – Multilevel Participation Plan

- Appendix H – INCOSE Systems Engineering Applications References by Year Published
- Appendix I – INCOSE Systems Engineering References by Applications Domain

Profiles were provided for the 17 application domains; they included the 16 listed for the SEAP, Version 1.0, and a new profile:

- 4.7 Facilities Systems Engineering

Note: The order of presentation of the profiles within the document had changed for this version.

Also by this time the AFWG had again changed its name to the Commercial and Public Interest Working Group (CPIWG). An attempt to organize the SEATC as a committee and the CPIWG resulted in all of the following appendixes being written for this release:

- Appendix A – INCOSE Technical Committees, Working Groups, and Interest Groups
- Appendix B – INCOSE Strategic Plan
- Appendix C – Charter of the CPIWG
- Appendix D – Goals of the SEATC
- Appendix E – INCOSE SEATC Membership
- Appendix F – SEAP Author's Writing Guide
- Appendix G – Multilevel Participation Plan
- Appendix H – INCOSE Systems Engineering Applications References by Year Published
- Appendix I – INCOSE Systems Engineering References by Applications Domain

The SEAP authors writing guide (Appendix F) was again provided to give any potential author the opportunity to contribute to a specific industry application domain in a format useful to the SEAP. Appendix G was written to explain how INCOSE members with minimal travel money could contribute to the creation of all SEATC products. Appendixes H and I were new; they included the systems engineering papers listed in INCOSE symposia proceedings, journals, etc. The papers were clustered by systems engineering application domain for each year from 1992 in Appendix H and then broken out into systems engineering application domains in Appendix I.

5. *Systems Engineering Applications Profiles, Version 2.0a*, was completed on January 20, 1999, and by February 1999 was included in the INCOSE Web pages. Version 2.0a was also a complete hardbound document with the same five chapters and nine appendixes listed under SEAP, Version 2.0.

Version 2.0a provided profiles for the 17 application domains. No new profiles were written for this release; however, editorial changes were made to many of the profiles. All chapters of the document were updated to reflect more recent occurrences in the SEATC. Appendixes A, D, H, and I were significantly affected.

6. *Systems Engineering Applications Profiles, Version 3.0,* was completed on July 1, 2000, for release at the INCOSE Symposium in July and by August 2000 is expected to be included in the INCOSE Web pages. Version 3.0 was also a complete hardbound document with five chapters, but the appendixes were reduced to five. These are as follows:

   - Chapter 1 – INCOSE Technical Activities
   - Chapter 2 – Systems Engineering Technical Committee Activities
   - Chapter 3 – Systems Engineering Applications
   - Chapter 4 – Profiles of Systems Engineering Application Domains
   - Chapter 5 – Profiles of Systems Engineering Cross-Application Domains
   - Appendix A – INCOSE Technical Committees, Working Groups, and Interest Groups
   - Appendix B – SEAP Author's Writing Guide
   - Appendix C – Multilevel Participation Plan
   - Appendix D – INCOSE Systems Engineering Applications References by Year Published
   - Appendix E – INCOSE Systems Engineering References by Applications Domain

   The following chapters of SEAP, Version 2.0a, were dropped from SEAP, Version 3.0, to reduce document size and because they had been incorporated into the Systems Engineering Organization Report, Version 1.0, which was released in January 2000.

   - Chapter 5 – Future Directions for the SEATC
   - Appendix B – INCOSE Strategic Plan
   - Appendix C – Charter of the CPIWG
   - Appendix D – Goals of the SEATC
   - Appendix E – INCOSE SEATC Membership

   A major change in format has been made to accommodate many new profiles written by graduate students at the University of Maryland University College. Congratulations and much gratitude is owed to these students who have written profiles in most cases about their area of expertise to contribute to the professional literature of INCOSE. Chapter 4 contains profiles written for specific industry application domains, and Chapter 5 contains profiles that may have groups of government, academic, and commercial industries developing them, but often support more than one of the industries included in Chapter 4. Profiles are provided for the 18 application domains addressed in Chapter 4.

- 4.1 Agriculture
- 4.2 Commercial Aircraft
- 4.3 Commercial Avionics
- 4.4 Criminal Justice System and Legal Processes
- 4.5 Emergency Services
- 4.6 Energy Systems
- 4.7 Environmental Restoration
- 4.8 Facilities Systems Engineering
- 4.9 Geographic Information Systems
- 4.10 Health Care
- 4.11 Highway Transportation Systems
- 4.12 Information Systems
- 4.13 Manufacturing
- 4.14 Medical Devices
- 4.15 Motor Vehicles
- 4.16 Natural Resource Management
- 4.17 Space Systems
- 4.18 Telecommunications

Many of the profiles were slightly improved and two new profiles were added, including Emergency Services and Information Systems. Information Systems had been included before, but only as a small profile. The profile Space Exploration was changed to Space Systems.

Chapter 5 contains all new profiles that may have groups of government, academic, and commercial industries developing them, but that often support more than one of the industries included in Chapter 4. Chapter 5 provides profiles for the following seven cross-application domains that were addressed:

- 5.1 E-Commerce
- 5.2 High-Performance Computing

- 5.3 Human Factors Engineering
- 5.4 Internet-Based Applications
- 5.5 Internet Banking
- 5.6 Logistics
- 5.7 Modeling and Simulation

Editorial changes were made to some of the already existing profiles. All chapters of the document were updated to reflect recent occurrences in the SEATC. Appendixes A, D, and E were significantly affected.

It is expected that this document will continue to evolve and expand the discipline of systems engineering to emerging and existing application domains for the foreseeable future.

To the Reader

Abstract

This Systems Engineering Applications Profiles (SEAP) document introduces the technical activities of the International Council on Systems Engineering (INCOSE) on the Systems Engineering Applications Technical Committee (SEATC) and the Commercial and Public Interest Working Group (CPIWG). It also discusses the current breadth of systems engineering applications and analyzes individual industry application domains to identify strengths, weaknesses, and use of systems-engineering-related methods and standards.

Purpose

This document introduces the technical activities of INCOSE and INCOSE's SEATC, introduces the current state of systems engineering in a broad spectrum of applications, and discusses the current state of systems engineering in several cross-industry applications domains.

This document was first disseminated to INCOSE members at the 1995 International Symposium, discussed at the symposium, and revised for general INCOSE Technical Committee distribution after the symposium. A previous release was under the title *Emerging Applications White Paper*, Draft 2, dated July 24, 1995. At the 1996 INCOSE International Workshop, the SEAP document was proposed by the then Applications Forum Working Group (subsequently renamed the Commercial and Public Interest Working Group) as an information paper in accordance with INCOSE communications policy. Version 1.0 was released in May 1996 and included in Volume 2 of the 1996 symposium proceedings. Version 2.0 was released in July 1998 and published on the INCOSE Web site in August 1998. Version 2.0a was released in January 1999. This Version 3.0 is intended for release in July 2000.

Organization

This paper has five chapters and five appendixes:

- Chapter 1 introduces INCOSE and its technical board, technical committees, and supporting groups.
- Chapter 2 introduces INCOSE's SEATC and the CPIWG.
- Chapter 3 provides an overview of systems engineering applications.
- Chapter 4 discusses systems engineering applications in several specific industry application domains.
- Chapter 5 discusses systems engineering applications in cross-industry application domains.
- Appendix A lists INCOSE's working groups and working group contacts.
- Appendix B contains the SEAP Authors Writing Guide.
- Appendix C contains the SEATC Multilevel Participation Plan.

- Appendix D contains the INCOSE systems engineering applications references by year published and a summary table that lists the references by applications domain for the years 1992 through 1999.
- Appendix E contains the INCOSE systems engineering applications references by applications domain.

How To Receive More Information

For further information regarding INCOSE, including membership, location of local chapters, international symposium materials, etc., contact

International Council on Systems Engineering
2033 Sixth Avenue, Suite 804
Seattle, WA 98121 USA
Voice: 206-441-1164 or 800-366-1164
Fax: 206-441-8262
E-mail: incose@halycon.com
Web URL: http://www.incose.org

For further information on the SEATC or the CPIWG, including being added to the mailing list, contact

Dr. William F. Mackey, SEATC Chairman
Computer Sciences Corporation
7700 Hubble Drive
Lanham-Seabrook, MD 20706 USA
Voice: 301-794-2138
Fax: 301-794-9480
E-mail: wmackey@csc.com

Jerry Bauknight
G.C. Bauknight & Associates
654 Cuesta Drive
Los Altos, CA 94024-4134 USA
Voice: 650-948-9161
Fax: 650-948-0595
E-mail: g.bauknight@ieee.org

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1 INCOSE Technical Activities

The International Council on Systems Engineering (INCOSE) is a professional organization that has grown to more than 3,200 members in 18 countries, 38 chartered chapters (with an additional 4 in formation), and 31 corporate sponsors.

INCOSE's mission is to foster the definition, understanding, and practice of world-class systems engineering in industry, academia, and government.

The goals of INCOSE are to

- Provide a focal point for disseminating systems engineering knowledge
- Promote collaboration in systems engineering education and research
- Ensure the establishment of professional standards for integrity in the practice of systems engineering
- Improve the professional status of all persons engaged in the practice of systems engineering
- Encourage governmental and industrial support for research and educational programs that will improve the systems engineering process and its practice

The overall direction of INCOSE is the responsibility of an executive committee consisting of the President, the President Elect, the Secretary, and the Treasurer. The executive committee and directors compose the board, which guides INCOSE activities. Administrative committees include Ways and Means, Symposium, Membership, Communications, and Chapters. All INCOSE technical activities fall under the direction of the INCOSE Technical Board.

1.1 Technical Board

The Technical Board directs the technical activities of INCOSE and is focused outward. It examines the technical requirements of the INCOSE Corporate Advisory Board (CAB), the Board of Directors, other professional organizations (e.g., IEEE, ASME, AIAA, SEI), and the INCOSE membership. The goal of the Technical Board is to produce INCOSE products that meet the needs of these groups—the customers. The board meets its goal through its technical committees.

1.2 Corporate Advisory Board

CAB members are senior representatives from corporate sponsors that have provided financial support to INCOSE. The CAB articulates the voice of the customer and provides guidance on the direction of the organization. The current corporate sponsors are

- Aerojet
- Aerospace Corporation
- AlliedSignal Inc.

- BAE Systems
- Boeing Company
- Boeing Company–Military Aircraft & Missile Systems
- Charles Stark Draper Laboratory
- Daimler Chrysler Aerospace/AG Dornier Satellitensysteme Gmbh
- Defence Evaluation and Research Agency
- Delphi Automotive Systems
- Department of Energy – Idaho
- General Dynamics Corporation
- Honeywell Inc.
- Hughes Space and Communications Company
- Jet Propulsion Laboratory
- Litton/PRC
- Litton/TASC
- Lockheed Martin Corporation
- Mitre Corporation
- Motorola
- Naval Air Systems Command
- Naval Surface Warfare Center Dahlgren Division
- Northrop-Grumman Corporation
- Raytheon Systems Company/HAC
- Raytheon Systems Company/RES
- Raytheon Systems Company/RTIS
- Rockwell Collins Avionics & Communications
- Science Applications International Corporation (SAIC)
- Software Productivity Consortium
- TRW Systems & Information Technology Group
- United Technologies

One way that the CAB expresses the needs of the corporate customer is with a list of CAB priority needs. These needs are assigned to a specific technical working group and are closed with the acceptance of an INCOSE product that meets the need. New needs are added and previous needs are closed at the two CAB meetings held each year. The CAB has expressed its needs through the INCOSE Strategic Plan. The primary strategic objectives of that plan are listed in Table 1–1.

Table 1–1. INCOSE Strategic Objectives

Objective		Description
1	INCOSE customers	Identify, describe, and understand the customers and their systems engineering related needs. Seek to ensure that INCOSE's membership strives to understand both the diversity of the customers and the variations in their needs.
2	Products and services	Identify, develop, provide, and continually improve a diverse and expanding set of products and services that meet or exceed the expectations of INCOSE's customers. Strive to create new and innovative products and services.
3	Communication	Become so publicly recognized and so reliable a source of information about systems engineering development and use that INCOSE is the primary reference for the industry, academia, government, and the media.
4	Membership	Attract, retain, and engage individual members and corporate sponsors from all organizational levels in the engineering, manufacturing, and service sectors from industry, academia, and government throughout the industrialized world.
5	Outreach and collaboration	Increase INCOSE's ability to raise awareness of systems engineering principles and increase their application through collaboration, partnership, and support of related efforts by other technical societies and organizations.
6	Theory, research, and education	Identify opportunities for, facilitate sponsorship of, and disseminate rigorous professional research in typical areas that are or could become important to systems engineering and society at large. Seek to expand both the quantity and quality of academic and industrial research that is focused on growing the body of systems engineering theory and knowledge. Promote education and training on the systems engineering discipline.
7	International, national, and regional involvement	Become a known and respected presence and resource in the advocacy and support of international, national, and regional initiatives that would benefit from world-class systems engineering.
8	Structure and operations	Evolve INCOSE's structure and operations to effectively and efficiently support a growing membership and constituency.

1.3 Technical Committees

Many INCOSE members participate on one or more of the numerous technical working groups organized under the following technical committees:

- Education and Research
- Measurement
- Modeling and Tools
- Systems Engineering Applications
- Systems Engineering Management
- Systems Engineering Processes and Methods

The technical committees are focused inward. They implement the technical needs in their respective areas and review the results and help establish goals and budgets. Their primary tools are chartering and coordinating working groups.

1.4 Working Groups and Interest Groups

Working groups examine topics related to the practice of systems engineering, such as risk management, requirements management, concurrent, engineering, system integration, standards and handbooks, process description, architecture definition, metrics, benchmarking tools, capability assessment, and commercial practices. The working groups focus on a particular need, doing the technical and definition work to solve that need. They produce the results.

Interest groups also exist, sometimes within a local geographic area for rapid progress. Because of the nationwide nature of working groups, they may charter interest groups to create specific products. Interest groups may also form bottom up to address perceived needs and thereby influence the board and committees to charter formal groups. Any technical activity organized at a local chapter level is an interest group activity. Appendix A lists the current working groups and interest groups and a contact person for each.

1.5 Local Chapter Activity

Local chapters are the heart of INCOSE. These chapters exist in different geographic areas to further meet INCOSE’s objectives at the local level. Table 1–2 lists the current active chapters.

Table 1–2. Current INCOSE Chapters

Region	Name	Location
I	Heartland	Cedar Rapids, IA
	Snake River	Idaho Falls, ID
	North Star	Twin Cities, MN
	Midwest Gateway	St. Louis, MO
	Tri-Cities	Richland, WA
	Seattle Metro	Seattle, WA
	Vancouver	Vancouver, British Columbia, Canada
II	Central Arizona	Phoenix, AZ
	Southern Arizona	Tucson, AZ
	Inland Empire	San Bernardino, CA
	Los Angeles Area	Los Angeles, CA
	San Diego	San Diego, CA
	San Francisco Bay Area	Silicon Valley, CA
	Colorado Front Range	Denver, CO
	Silver State	Las Vegas, NV
	Wasatch	Salt Lake City, UT
III	France (AFIS)	Paris, France
	Germany	Munich, Germany
	The Netherlands (Northwest Europe)	The Netherlands
	Norwegian SE Council	Oslo, Norway
	Sweden (Emerging)	Stockholm, Sweden
	United Kingdom	United Kingdom
IV	Constitution	Hartford, CT
	New England	Boston, MA
	Tri-State	Detroit, MI
	Liberty	Whippany, NJ
	Wright-Patterson AFB	Dayton, Ohio
	Delaware Valley	Philadelphia, PA
	Montreal (Emerging)	Montreal, Quebec, Canada
V	Huntsville	Huntsville, AL
	Space Coast	Melbourne, FL
	Central Florida	Tampa, FL
	Chesapeake	Columbia, MD
	Southern Maryland	Patuxent River, MD
	Central Savannah River	Aiken, SC
	North Texas	Dallas/Ft. Worth, TX
	Texas Gulf Coast	Houston, TX

Region	Name	Location
	Central Virginia	Fredericksburg, VA
	Hampton Roads Area	Hampton Roads, VA
	Washington Metro	McLean, VA
VI	Systems Engineering Society of Australia (affiliate with four chapters)	Australia
	Israel (Emerging)	Israel

1.6 Technical Products

INCOSE has a communications policy on the form and approval requirements for different technical products. The products include proceedings from the annual symposia in the formats of printed volumes and CD-ROM, handbooks and guidebooks, a systems engineering journal, and the INCOSE Internet offerings. The quarterly newsletter, *INCOSE INSIGHT*, has grown to 32 pages per issue and serves as one of the many ways INCOSE communicates with its membership. INCOSE has a presence on the World Wide Web at **www.incose.org** and conducts online discussions through an Internet listserver.

Publications related to technical products and available from the INCOSE Web site are shown in Table 1–3.

Table 1–3. Publications

Reference No.	Title	Release	Date
INCOSE-TB-001	INCOSE Technical Community Organization	97-1	May 15, 1997
INCOSE-TB-002	INCOSE Technical Community Procedures Handbook	1.1	August 1, 1997
INCOSE-TB-003	INCOSE Technical Products and Services Plan	97-1	May 15, 1997

2 Systems Engineering Applications Technical Committee

The Systems Engineering Applications Technical Committee (SEATC) of INCOSE is concerned with expanding the use of systems engineering in all application domains. Although business with defense is not excluded, the focus of the committee is on commercial and public interest activities. INCOSE's technical activities to date in this area have been concerned with information exchange and planning. The *Systems Engineering Applications Technical Committee Organization Report* serves as the documentation of the charter, 1-year goals, membership, and products for each SEATC working group and interest group. This product may be found on the INCOSE Web site under SEATC products. The *Systems Engineering Applications Profiles* document is an effort of the Commercial and Public Interest Working Group to define the boundaries, functions and processes, technologies, and systems engineering challenges for special application domains and cross-application domains.

2.1 History

The concept of INCOSE technical activities in systems engineering applications started at the 1992 symposium in Seattle with the creation of the Commercial Applications Working Group led by Randy Iliff. A separate Resource Management Working Group was started at the same time by Fred Martin. Early discussions centered on the different industry segments and applications areas where systems engineering (in many cases under a different name) was being successfully practiced. The importance of not simply transferring the defense model of systems engineering to other applications areas was stressed. The various interest groups decided in 1993 to meet as a single body under the Emerging Applications Technical Committee. Bob Coyne became chairperson of the group at the 1993 symposium. Rich Mintz volunteered to facilitate the group's efforts for 1994. The group merged onto the information highway in April 1994 with the first distribution of its monthly activity report by E-mail. At the January 1995 annual business meeting, William Mackey and Cecilia Schuster agreed to create their first draft of the *Emerging Applications White Paper* and to direct the Emerging Applications Working Group (EAWG) efforts in the near term. The EAWG approved its charter, set goals for 1995–96, and released the *Emerging Applications White Paper* at the July 1995 symposium. At that symposium, William Mackey was elected to a 2-year term as chairperson and Carolyn Buford was appointed as cochairperson. In January 1997, William Mackey became the chairperson of the SEATC and has continued in that role to the present time. During this period, the working groups and interest groups have expanded from 3 in 1995 to 10 in 2000.

2.2 Charter

The SEATC promotes the application of systems engineering to the cost-effective development and management of commercial and public interest systems and issues. The SEATC often coordinates with other INCOSE technical committees and working groups to achieve its objectives.

The SEATC achieves its objectives by providing a forum through INCOSE for education and focused exchanges among the international aerospace and defense practitioners of systems engineering; their counterparts in other commercial enterprises; and national and local government planning and policymakers, particularly those who affect the deployment of resources and the quality of the environment.

The SEATC attempts to understand the unique needs of commercial and public interest users of systems engineering and disseminate these needs to the other parts of INCOSE.

The SEATC articulates and disseminates the fundamental principles and benefits of systems engineering to commercial and public interest users and transfers the lessons learned from these systems engineering applications to the other parts of INCOSE.

2.3 Historical Legacy

Refer to the *SEATC Organization Report*.

2.4 Future Goals

The SEATC uses a goal-driven basis for carrying out its activities. Each year a new set of goals is established by the working and interest group chairpersons, and the activities are monitored against those goals. The goals for the years 1995 to the present are discussed in the *SEATC Organization Report*.

2.5 Membership

Refer to the *SEATC Organization Report*.

2.6 Operating Procedures

The operating procedures of the SEATC are to

- Select chairpersons to moderate and direct all other working group and interest group activities
- Meet, at a minimum, at the annual international symposium and the annual international business workshop
- Maintain a list of SEATC members

2.7 Organization

William Mackey is the current chairperson of the SEATC. The Commercial and Public Interest Working Group (CPIWG), chaired by Jerry Bauknight, is the core working group in the SEATC. The CPIWG maintains the INCOSE *Systems Engineering Applications Profiles* document and acts as the core working group for newly generating interest groups in each application domain. Once an application domain has gained sufficient momentum and a nucleus of members with the same interest, a special interest group is formed. The SEATC coordinates the activities of all working and interest groups and is represented on the Technical Board by William Mackey, Scott Jackson, and Ralph Godau.

The SEATC has divided into sectors of responsibility, as meaningful groups of application domains, and the three cochairpersons of the SEATC each take three working/interest groups to assist and monitor. This responsibility gives the working/interest group chairpersons the attention that may be required from time to time. The application domain divisions that have been decided upon are as follows:

- Transportation Sector – Scott Jackson
  - Joint Commercial Aircraft Working Group (JCAWG) – Greg Mathers and Erwin Duurland
  - Motor Vehicles Interest Group (MVIG) – Paul Berry
  - Railway Transportation Interest Group (RWTIG) – John Williams and Jeff Allan
- Resources Sector – Ralph Godau
  - Environmental Systems Working Group (ESWG) – Ralph Hill
  - Infrastructure Systems Engineering Working Group (ISEWG) – Pat Sweeney and Ralph Godau
  - Resource Management Working Group (RMWG) – Ted Dolton and Bill Cutler
- Public Services Sector – William Mackey
  - Commercial and Public Interest Working Group (CPIWG) – Jerry Bauknight and William Mackey
  - Space Systems Working Group (SSWG) – Raymond Granata and William Mackey
  - Telecommunications Working Group (TELWG) – Tom Bagg and Martin Warner
  - Health Care Interest Group (HCIG) – John Zaleski

2.8 CAB Requirements

One active CAB priority need is assigned to the SEATC:

Describe examples of engineering and management process that led to successful complex commercial products.

This priority need is used by the SEATC to focus its activities on commercial and public interest applications.

2.9 Evolution of SEATC Working Group/Interest Group Development

To understand the status of the SEATC organization, the SEATC established a set of criteria in 1997 for the evolution of working/interest groups. Every year they evaluate each of the SEATC working/interest groups against the criteria. The eight-step criteria shown in the Table 2–1 may be useful to other INCOSE technical committees. The recently formed MVIG and HCIG are just beginning these steps. After completing the first four steps, an interest group is reevaluated as a potential working group.

The present status of each of the nine working/interest groups is shown in Table 2–2. For each criterion, the particular working/interest group has been judged fully compliant, partially compliant, or not-yet compliant based on the evidence available.

Table 2–1. Steps for the Progression of Working/Interest Groups

Interest Group Progression
Step 1: Develop charter for working/interest groups
Step 2: Develop 1-year goals
Step 3: Create nucleus of 3 to 6+ interested members
Step 4: Identify list of potential working group products
Working Group Progression
Step 5: Create profile for SEAP document
Step 6: Develop working group product(s)
Step 7: Communicate working group activities (via INSIGHT, symposia, journal)
Step 8: Create liaisons (with local chapters, universities, companies, societies)

Table 2–2. Status of SEATC Working/Interest Group Evolution

STEP	CPIWG	ESWG	ISEWG	JCAWG	RMWG	SSWG	TELWG	HCIG	MVIG	RWTIG
Interest Group Progression										
1	●	●	●	●	●	●	●	–	–	–
2	●	●	●	●	●	●	●	●	●	●
3	●	●	●	●	●	●	●	●	●	●
4	●	●	●	●	●	●	●	–	–	●
Working Group Progression										
5	●	●	●	●	●	●	●	●	●	–
6	●	●	●	●	●	–	●	–	–	●
7	●	●	●	●	●	–	●	●	●	●
8	●	●	–	●	●	–	–	–	–	●

● Fully compliant

● Partially compliant

– Not-yet compliant

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3 Systems Engineering Applications

Systems engineering is defined by INCOSE as an "interdisciplinary approach and means to enable the realization of successful systems" (approved by the INCOSE Technical Board at the International Business Workshop, January 1996).

Systems engineering in the applications context can be summarized as the application of the "systems" approach to the design of complex systems or the solution of complex problems in various industry and business domains. Systems engineering in commercial endeavors sometimes uses alternative names; for example, front-end engineering, design control, optimal decision making, or operations research.

3.1 Evolution of Systems Engineering

Another definition of systems engineering that might meet with universal agreement has several components: (1) it is an interdisciplinary approach and means to establish a sound system concept, (2) it defines and validates clear and concise system requirements, (3) it creates an effective system design or solution, and (4) it ensures that the developed system meets client and user objectives in the operational environment. This definition focuses on the efforts of the systems engineering team in the early phases of the system development life cycle (SDLC), and it ensures their participation throughout the SDLC.

The discipline of systems engineering was conceived, contrary to common belief, in the commercial industries rather than in defense and aerospace. Unconfirmed reports claim that Werner von Braun learned systems engineering from engineers at Mercedes-Benz in the automotive industry.

The discipline of systems engineering was developed in the communications industry at Bell Laboratories in the United States to meet the networking challenges of the 1950s. It grew in the space, defense, and computer industries during the 1960s through the 1990s in response to the hardware and software system integration complexities of those eras. By 1965, the DOD mandated the use of Military Standard for Systems Engineering 490 (MIL-STD-490) for the development of all military systems using a systems engineering approach. The National Aeronautics and Space Administration (NASA) and the Department of Energy (DOE) soon followed with systems engineering guidelines for the civilian aerospace and energy programs of the 1970s. The 1980s and 1990s have shown an expansion of the discipline to many domains with systemic challenges, the growth in integrated systems engineering toolsets, and an expansion of industry standards through (EIA 632, IEEE 1220, and EIA/IS 731.

3.2 Increasing Challenge

The systems engineering discipline of the 21st century will be expanded to include nontraditional systems engineering and even nonengineering disciplines. By definition, systems engineering is not specifically confined to communications, space, defense, energy, or computer development. It seems likely that the imminent engineering problems of the early 21st century, such as transportation, housing, infrastructure renewal, and environmental systems, could benefit from a systems approach. In addition, the systems engineer of the 21st century will find other areas (e.g., criminal justice process, drug abuse prevention, health care) ready for systems engineering application.

The complexity of systems and the strict requirements on performance and reliability will challenge the development of a methodology or approach to efficiently balance user's needs, technological capability, and limited resources.

The recognition of systems engineering as a dynamic engineering discipline in various application domains is due to similar factors: increased system and product complexity, greater technological capability, more challenging customer requirements in terms of reliability and performance, and greater product interoperability with other products and systems.

3.3 Standards

Standards information is critical to keeping on the cutting edge of technology. Standards are classified as they are developed for emerging application technologies. Many standard organizations exist worldwide, one of which is the International Organization for Standardization (ISO). The key standards organizations are as follows:

- Association Française de Normalisation
- Association for Information and Image Management (AIIM)
- American National Standards Institute (ANSI)
- ANSI and AIIM Joint Standard
- ANSI and Electronic Industries Association (EIA) Joint Standard
- ANSI and EIA/TIA Joint Standard
- ANSI and Institute of Electrical and Electronic Engineers (IEEE) Joint Standard
- ANSI and ISO Joint Standard
- ANSI and McDonnell Douglas Corporation (MDC) Joint Standard
- ANSI and MIL-STD Joint Standard
- ANSI and TIA/EIA Joint Standard
- British Standard(s) Institution
- International Radio Consultative Committee
- International Telegraph and Telephone Consultative Committee
- Code of Federal Regulations
- European Computer Manufacturers' Association
- Electronics Industries Association
- EIA/TIA Technical Systems Bulletin

- U.S. Federal Standard
- U.S. Federal Information Processing Standard
- Federal Property Management Regulations
- International Alphabet
- IEEE
- ISO
- Japanese Industrial Standards Committee
- U.S. Military Standard
- National Bureau of Standards
- National Electrical Code
- National Telecommunications and Information Administration
- Quadripartite Standardization Agreement
- Standard Industrial Classification
- NATO Standardization Agreement
- U.S. Naval Observatory

The Uniform Resource Locator (URL)

http://sneffels.its.bldrdoc.gov/out-d3.html

identifies the Internet World Wide Web home page that contains information. Each line of the organizations listed can be selected to provide listings of standards maintained by that organization.

The following list provides a sampling of the indexes of one representative organization, the IEEE. The URL is

http://stdsbbs.ieee.org:70/0/pub/ieeestds.htm

The list identifies the specific areas of interest that can be selected, and then associated standards, codes, descriptions, and other relevant information will be provided.

- Aerospace and Electronics
- Gyro and Accelerometer Panels
- Radar Systems
- Antennas and Propagation
- Broadcast Technology
- Circuits and Systems

Systems Engineering Applications

- Communications
- Information Technology
- Abbreviated Test Language for All Systems (ATLAS)
- Bus Architectures and Microprocessors/Microcomputers
- Design Automation
- Local and Metropolitan Area Networks
- Portable Applications
- Software Engineering
- Standards Coordinating Committee of the Computer Society
- Test Technology
- Dielectric and Electrical Insulation
- Dispersed Power Generation
- Electrical Insulation
- Electricity Metering
- Electromagnetic Compatibility
- Electron Devices
- Graphic Symbols and Designations
- Industry Applications
- Cement
- Energy Systems
- Industrial Control
- Marine Transportation
- Petroleum and Chemical
- Power System Engineering
- Power System Protection
- Static Power Converters
- Instrumentation and Measurement
- Insulation Coordination
- Magnetics
- Medical Device Communications
- Microwave Theory and Techniques

- National Electrical Safety Code
- Non-Ionizing Radiation
- Nuclear and Plasma Sciences
- Photovoltaics
- Power Electronics
- Power Engineering
- Electric Machinery
- Energy Development and Power Generation
- Insulated Conductors
- Insulation Coordination
- Nuclear Power Engineering
- Power System Communications
- Power System Engineering
- Power System Instrumentation and Measurements
- Power System Relaying
- Substations
- Surge-Protective Devices
- Transformers
- Transmission and Distribution
- Quantities, Units, and Letter Symbols
- Radiation Instrumentation
- Rotating Electrical Machinery
- Time and Frequency
- Ultrasonics, Ferroelectrics, and Frequency Control
- Standards with Electronic Media
- Adopted/Endorsed IEEE Standards
- International Electrotechnical Commission
- International Organization for Standardization
- Battery Council International
- Battery Council International
- Canadian Standards Organization

- Department of Defense
- Federal Information Processing Standards
- Standards Association of Australia
- IEEE Standards Withdrawn
- IEEE Standards Press

In addition to approved standards, there are also draft standards, documents, training material, videos, models, and white papers that recommend a select grouping of standards for a particular purpose. All of these alter constantly due to the dynamic changes in the areas of emerging technologies.

3.3.1 Finding Appropriate Standards

The general process of selecting appropriate standards requires diligence in evaluating the framework within which the standard would be applied and addressing aspects of usage. Great care must be taken in selecting standards, especially new ones. Key emphasis should be placed on the following recommended guidelines:

- Standards should be validated in interoperable, commercially available products and services before they are selected for critical projects.
- Standards should be as simple as possible.
- Standards should be open and published in accessible complete form.
- Standards should support mission effectiveness.
- Standards should provide for migration of systems as underlying subsystems change.
- Standards should support efficiency among the users.
- Standards should have international support.
- Standards should avoid lock-in to a specific vendor.
- Standards should be relatively simple to install and verify.

In selecting good standards, there are two inherent conflicts. If the purpose of a standard is to maximize interoperability, then commonality must be given more weight than technical excellence. The choice between a popular but proprietary practice and a less popular but formal consensus-based standard, is harder to make. On the one hand, proprietary but widespread standards promote ease of interoperability, and users may not care who benefits from their propagation. Experience suggests that consensus standards, even if slower to catch on, may have greater staying power.

Users who need to inter work should be the ones to lead the process to select their standards. Such groups of users are called “affinity groups” in the *National Performance Review*.

With that in mind, the following considerations are advisable:

- Affinity groups should be correctly defined.
- Affinity groups require representation from experts familiar with the technology and the extant standards.
- Affinity groups must recognize that what seems to be a common set of technical requirements may vary depending on application.
- It may be necessary to construct a metric to determine marketplace acceptance in consultation with relevant parties.
- Mandated standards should be replaced if no longer supported or outdated.

3.3.2 ISO Standards

Published by the Geneva-based ISO, a worldwide federation of national standards bodies, ISO standards are concerned with developing total quality management and continuous improvement processes They are generic and not specific to any product or service. They consist of a family of 9000 series standards and successive subsets and other families to satisfy certain 9000 series requirements.

3.3.2.1 ISO 9000 Series

The ISO 9000 series includes the following:

- ISO 9000—Quality management and quality assurance standards – guidelines for selection and use
- ISO 9001—Quality systems – model for quality assurance in design and development, production and installation, and servicing
- ISO 9002—Quality systems – model for quality assurance in production and installation
- ISO 9003—Quality systems – model for quality assurance in final inspection and test
- ISO 9004—Quality management and quality systems elements – guidelines

ISO 9004 examines each of the quality system and management elements in the ISO 9000 series. The key standards used for successful implementation are those that model and describe the key process elements, namely ISO 9001 through ISO 9003. Table 3–1 shows the key process elements that are discussed in these three ISO documents and, in some instances, the relative amount of discussion.

Because of its broader coverage, ISO 9001 is generally used as the key document to implement the ISO 9000 quality process. ISO 9001 was prepared by the Quality Management and Quality Assurance Technical Committee (ISO/TC 176). It specifies quality system requirements for use where a supplier’s capability to design and supply conforming products needs to be demonstrated.

Table 3–1. Coverage of Process Elements in ISO 9001 Through ISO 9003

ISO 9000 Standard Elements	9001	9002	9003
Management responsibility	yes	< 9001	< 9002
Quality system principals	yes	yes	< 9001
Auditing the quality system	yes	< 9001	–
Economics	–	–	–
Contract review	yes	yes	–
Design control	yes	–	–
Purchasing	yes	yes	–
Quality in production	yes	yes	–
Control of production	yes	yes	–
Product identification and traceability	yes	yes	< 9001
Inspection and test status	yes	yes	< 9001
Inspection and testing	yes	yes	< 9001
Control of measuring and test equipment	yes	yes	< 9001
Control of nonconforming product	yes	yes	< 9001
Corrective action	yes	yes	–
Handling and postproduction function	yes	yes	< 9001
After sales servicing	yes	–	–
Document control	yes	yes	< 9001
Quality records	yes	yes	< 9001
Personnel training	yes	< 9001	< 9002
Product safety	–	–	–
Use of statistical methods	yes	yes	< 9001
Customer-supplied product	yes	yes	–

The ISO 9001 requirements specified are aimed primarily at achieving customer satisfaction by preventing nonconformity at all stages from design to servicing. This international standard is applicable in the following situations:

- Design is required and the product requirements are stated principally in performance terms or they need to be established
- Confidence in product conformance can be attained by adequate demonstration of a supplier’s capabilities in design, development, production, installation, and servicing

Some of the specific activities that an organization would undertake include establishing and maintaining procedures for design, development, production, and installation. In addition, work instructions and workmanship criteria would be documented and processes controlled, monitored, and approved prior to use.

The intent in implementing ISO 9000 is to identify, control, segregate, and eliminate where practical all nonconforming products. This is accomplished in many instances by preventing inadvertent or incorrect processes.

Figure 3–1 illustrates a high-level workflow process that ultimately could be decomposed into individual work instruction procedures. (This process may be considered for a task study group.) The key factor in the ISO 9000 methodology is to ensure that all individuals follow this workflow process as appropriate with exceptions noted and documented. Appropriate standards are referenced and, at selected points in the process, documentation is generated and maintained in the database. The principal aim of the methodology is for an organization to specify the processes that individuals require to accomplish the organizational mission and then to follow through with sufficient documentation that the activity can be audited.

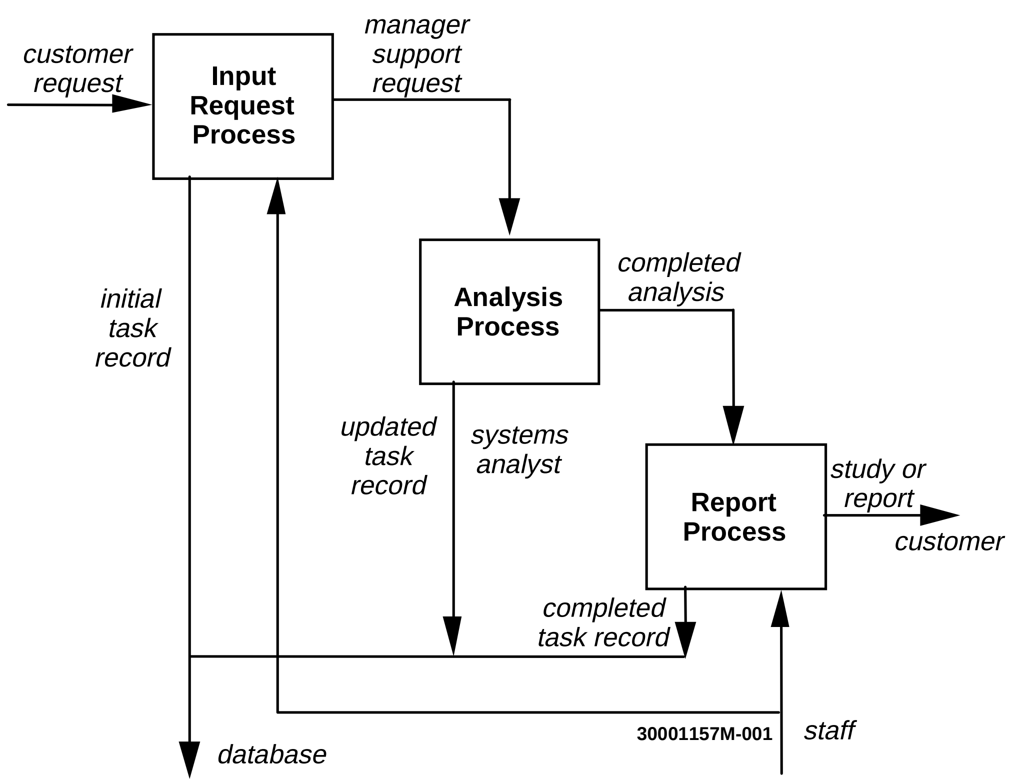

Figure 3–1. Typical Workflow Process

The ISO 9000 series has been specifically constructed to be amenable to auditing by a third party (neither the supplier nor the customer). A successful, noninternal audit by an organization is now a key factor for many corporations in keeping their old and/or obtaining new customers, especially in European operations. However, unlike other third-party audit standards, ISO 9000 assumes that the best group to identify the processes for an organization's mission is the organization itself. The audit will allow successful registration of an organization and is made against processes defined by that organization and is based on documentation provided by the organization to show that the processes are followed with deviations noted, rationalized, and documented.

The key elements called out in ISO 9000 are related to the major process areas that, based on DOD and other agency programs, are generally considered to be the purview of the systems engineer. For example, ISO 9000 elements have a great deal in common with the key process areas as expressed in the systems engineering capability models being developed by several groups. In fact, the foundation of ISO 9000 with process definition, documentation at key points in the process, and audit trails are essentially the same foundation that system engineers use in accomplishing their work assignments.

3.3.2.2 ISO 10007

ISO 10007, Quality Management – Guidelines for Configuration Management, is a management process that is applied over the life cycle of a product to provide visibility and control of its functional and physical characteristics. The activities described are a way of satisfying certain requirements found in the ISO 9000 family of standards. This standard is intended to enhance common understanding of the subject, encourage organizations applying configuration management to improve their performance, align the approach throughout industry and improve national and international cooperation. There are four functions of configuration management:

- Identify products through documentation (e.g., specifications, drawings, associated lists, logic diagrams, flow charts, interface control documents) that describes the products' functional and physical characteristics during their life cycles.
- Maintain configuration control of products through the systematic proposal, justification, evaluation, coordination, approval, and disapproval of proposed changes to products and the implementation of all approved changes to the configuration of products.
- Maintain a record of approved changes, documentation, identification numbers, and the status of approved changes and configuration of products.
- Plan and document the examination of compliance of products with baselined documentation describing functional and physical characteristics.

3.4 Future Trends

Some key future trends in the practice of systems engineering in the emerging applications are

- More recognition of technical discipline of systems engineering
- More systems engineering tools specifically targeted at commercial applications domains
- Merging commercial, DOD, and NASA systems engineering standards
- Greater and greater system complexity

- Increasing need for multidisciplinary approaches with engineering and nonengineering skills
- Need to understand stochastic processes with people and natural organisms as part of the systems

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4 Profiles of Systems Engineering Application Domains

A systems engineering application domain is broadly defined here as a sphere of influence or activity to which the systems engineering interdisciplinary approach is applied to create systems and solutions within the domain. Each profile is written by different experts available to the INCOSE SEATC. An authors writing guide contained in Appendix B provides a detailed outline of each section. The common structure for each profile follows.

4.x Application Domain

The application domains are listed alphabetically in Table 4–1. Those application domains with section numbers are included in this document. Other application domains will be added in future versions.

4.x.1 Introduction

A brief summary of the application domains (e.g., Agriculture, Highway Transportation) introduces the subject matter. Two tables summarize the industry companies or domain participants and the systems engineering activities.

4.x.2 Industry Functions and Processes

This section shows how domains are decomposed into individual functions and processes that represent the primary activities of the industry or application domain. For example, a highway transportation system is decomposed into topographical coordination and requirements, corridor study and design, preliminary design, and detailed design.

4.x.3 Technology Profiles

Selected technologies that can benefit the application domain are discussed. For example, highway transportation systems focus on the automation processes of computer-aided drafting and design, software applications, and highway design automation steps.

4.x.4 Systems Engineering Challenges

The primary challenges that could be met by using systems engineering are discussed. For example, in the Highway Transportation Systems section, the Intelligent Vehicle Highway System (IVHS) or Intelligent Transportation System (ITS) and technology challenges are discussed.

4.x.5 Contacts

The author, INCOSE contacts, and industry contacts are listed.

Table 4–1. Systems Engineering Application Domains

Systems Engineering Application Domain	Section Number
1. Agriculture	4.1
2. Commercial Aircraft	4.2
3. Commercial Avionics	4.3
4. Criminal Justice System and Legal Processes	4.4
5. Drug Abuse Prevention	
6. Emergency Services	4.5
7. Energy Systems	4.6
8. Environment Restoration	4.7
9. Facilities Systems Engineering	4.8
10. Food Service	
11. Geographic Information Systems	4.9
12. Health Care	4.10
13. Highway Transportation Systems	4.11
14. Housing and Building Systems	
15. Information Systems	4.12
16. Manufacturing	4.13
17. Medical Devices	4.14
18. Motor Vehicles	4.15
19. Natural Resources Management	4.16
20. Political and Public Interest Applications	
21. Service Industries	
22. Space Systems	4.17
23. Telecommunications	4.18
24. Transportation	
25. Urban Planning	
26. Waste Management and Disposal	

4.x.6 References

Citations from INCOSE presentations and papers, general literature, and other key sources are listed.

Note that each section follows the above outline, but in some cases adapts the structure to fit the application domain. The sophistication of each section in this document also varies.

4.1 Agriculture

4.1.1 Introduction

Agriculture has been an important industry in the United States since the Colonial period. Technology has allowed U.S. agricultural production to provide high-quality, low-cost food products for domestic consumption and export. Although the number of persons engaged in agricultural production has steadily declined during this century, agricultural products remain the largest single U.S. export category. Agriculture is also the basis for derivative products (e.g., fuels, plastics, building materials) of increasing importance.

Risks in this application domain include the impact of political constraints on critical technologies and effects of the industry on the environment.

Table 4.1–1 summarizes the agriculture industry. Table 4.1–2 focuses on the application of systems engineering in the agriculture application domain. (Note: These tables will be added at a later date.)

4.1.2 Industry Functions and Processes

Technology has contributed to increased productivity of land and labor through plant breeding, soil conservation methods, development of improved fertilizers and pesticides, production mechanization, and improved storage and transportation methods.

Recognition that agricultural products and by-products represent a major renewable resource has led to their growing importance as raw materials in the chemical, fuel, and materials industries.

4.1.3 Technology Profiles

Plant breeding has been successful in producing increased yield, often at the cost of reduced hardiness. The favorable climate patterns and use of improved fertilizers and pesticides has offset the reduced robustness of some hybrid plants. There is concern that a change in climate could have serious consequences to U.S. agricultural production.

The rapid development of genetic engineering offers opportunities for development of plants that have the desirable characteristics of hybrids without sacrificing robustness.

4.1.4 Systems Engineering Challenges

There are serious challenges to the introduction of agricultural technology. Resistance to use of manufactured fertilizers, pesticides, and preservatives has been a political and market force for many years. Inadequate or inaccurate information heavily promoted by activists can lead to serious mistakes in application of political power (e.g., the Alar incident). Complex and sometimes apparently arbitrary government regulations also impact existing and prospective agricultural production.

Systems Engineering Applications

On the whole, the success of U.S. agriculture has been well supported by systems engineering efforts (e.g., production mechanization, transportation, wholesale and retail distribution and sales). Perhaps the greatest systems engineering challenge lies in helping to increase the awareness of the pros and cons of effective new technologies.

Conducting tradeoff studies is an essential part of systems engineering practice. The challenge is to use tradeoff study methods to identify costs, risks, and benefits of proposed technologies so that decisions to use or reject technologies are made on the basis of accurate and complete information.

As an example, irradiation of food products offers safe, cost-effective sterilization without changing the taste or appearance of food products. Existing ventures have been under heavy attack by persons who clearly do not understand the difference between the effects of gamma (i.e., high-energy X-ray) and neutron irradiation. Neutron irradiation may produce radioactive isotopes within the irradiated material and has never been proposed as a method for treatment of food products. On the other hand, gamma irradiation kills microorganisms and pests without changing the nuclear structure of the product. Although chemical changes may occur, they are smaller in effect than most cooking processes.

Incidents of food poisoning have been increasing at an alarming rate, and health authorities believe that most incidents are not reported unless they affect large numbers of persons or result in death or hospitalization. Gamma irradiation reduces spoilage of food products, such as eggs, poultry, dairy products, and fresh produce. Although gamma irradiation does not destroy existing toxins, early treatment prevents toxin production (e.g., by bacteria, fungi) and product damage by bacteria, fungi, and pests. Produce safety and storage life is dramatically increased without sacrificing product appearance, flavor, or quality.

Techniques for hydroponics, aeroponics, and aquaculture offer advantages with respect to traditional methods. Ultraviolet lights and controlled temperature-humidity environments can optimize growth of plants indoors. The indoor environment also contributes to control of pest infestation and limits use of pesticides and fertilizers. Hydroponic tomatoes, aquaculture catfish, and greenhouse flowers are already commercial successes. Another project grows carrots on a continuous cycle (i.e., a slow but continuously moving belt). Because these methods are highly localized, often indoors, they lend themselves to automation. Application of machine intelligence optimizes the production of tree seedlings in greenhouses. Growth of protein-rich yeast in bulk has been demonstrated. Application of genetic engineering may further improve the quality, quantity, and acceptability of such products as food and chemical feedstock. In analyzing the need for products that are a renewable resource, availability of arable land, effects of fertilizer and pesticide runoff, and production capacity and costs, systems engineers are challenged to utilize emerging technologies on a wider scale.

4.1.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

LeRoy Botten
3715 Capulet Terrace
Silver Spring, MD 20906
Voice: 301-985-8726
Fax: 301-985-8909

4.1.6 References

To be supplied.

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4.2 Commercial Aircraft

4.2.1 Introduction

The commercial aircraft industry in the United States and throughout the world is evolving into a small group of large companies. Some of the risks in this sector include the financial cost of new product development and the financial health of airlines and other customers. Large established firms have had to merge to meet the high costs and risks of doing business. This competitive environment and the complex nature of aircraft design and construction make commercial aircraft prime subjects for the application of systems engineering. In particular, systems engineering is uniquely suited to the evaluation of advanced technologies for possible introduction into commercial aircraft design.

Although the term “commercial aircraft” generally refers to jet-powered aircraft carrying approximately 100 passengers or more distances of 2000 miles or more, the systems engineering principles outlined in this paper also apply to freight-carrying aircraft and smaller propeller-driven, or commuter, aircraft as well. These principles also apply to general aviation, that is, small privately owned aircraft.

Table 4.2–1 summarizes the commercial aircraft industry. Table 4.2–2 focuses on the application of systems engineering in the sector. (Note: These tables will be added at a later date.)

4.2.2 Industry Functions and Processes

High volume and modest profit margin contribute to the complexity of motor vehicle design and manufacture. Although many steps in the manufacturing process of commercial aircraft parallel those for motor vehicles, design and manufacture of commercial aircraft is even more complex. Although low volume, aircraft manufacturing complexity arises from dependency on highly integrated high-technology subsystems, use of advanced materials, detailed specifications, and extremely rigorous testing. Although assembly line processes and highly automated computer-aided design, engineering, manufacturing, and testing support (including robotics) are used in aircraft manufacturing, these techniques must be supplemented by substantial, experienced craftsmanship during manufacture. Systems engineering is especially suited to addressing these issues.

4.2.3 Aircraft Technology Profiles

Advanced Technologies on Aircraft. To meet design goals for reduced weight, noise, and emissions; robust systems; and safe and economic operation, many advanced technologies are routinely incorporated into commercial aircraft, for example, heads-up displays (HUDs), voice recognition, global positioning system (GPS) receivers, point-to-point inertial navigators, reconfigurable instrument displays based entirely on digital video displays, Doppler radar, fly-by-wire (FBW) or fly-by-light (FBL), and real-time computer fault detection and isolation. A key technology in weight reduction is composite materials. Systems engineering has the capability of evaluating the introduction of advanced technology for both subsonic and supersonic aircraft. Discussion and description of some of these technologies, in part by Kehlet[1], follow.

Advanced Subsonic Transports. For subsonic transports, key advanced technology applications include center of gravity management systems, for example, with vertical stabilizer tanks; composite primary and secondary structures; supercritical wings with high-load alleviation, hybrid laminar flow control, and high-lift systems; advanced turbofan engines; FBW and power-by-wire (PBW); titanium landing gears; aluminum-lithium or metallic composite fuselage structures; and stability augmentation.

Advanced Supersonic Transports. For supersonic transports, key advanced technology applications include synthetic vision, sidestick control, advanced lightweight materials, mixed flow turbofan engines, negative static margin, mixed compression inlets, arrow wing for supersonic cruise efficiency, FBL and PBW flight controls, and auto control in pitch.

Airframe Technology. Improvements in the technology of the wing, empennage, and fuselage structures will come from advanced materials and integration techniques. Integrated computer codes will allow the aerodynamics and strength aspects to be addressed simultaneously. Thus, computer-aided design becomes an advanced tool for the evaluation of physical interfaces within the systems engineering framework. The use of composite materials allows for both a decrease in weight and an increase in performance through higher aspect ratios. Advanced machining techniques allow for the design to minimize parts.

Aerodynamic Improvements. Enabling technologies in aerodynamics include the use of pressure sensitive paint and computational fluid dynamics. These technologies allow for the development of a multipoint wing design capability that attains the lowest cruise drag characteristics and the highest realistic buffet onset boundary. Another goal is the development of efficient aerodynamic profiles for wings with large high-bypass ratio engine installations. Another effort is the development of aerodynamically efficient but low-cost high lift systems.

Noise Control. Active noise control has shown great promise as a method of reducing cabin noise without severe weight penalties. Active noise control introduces a secondary noise source of comparable amplitude but opposite phase to the primary noise. The challenge is to control noise over a wide range of frequencies to counteract both engine noise and boundary layer noise. It will be especially important to control boundary layer noise on high-speed civil transport (HSCT).

Fly-by-Light, Fly-by-Wire, and Power-by-Wire Technologies. FBL introduces multiplex photonically based subsystems into the aircraft. FBL reduces wiring weight, reduces exposure to electromagnetic interference (EMI) hazards, and simplifies certification by eliminating the need for full aircraft subsystem tests. FBW and PBW result in significant weight savings and eliminate the need for engine bleed air and variable speed drives for secondary power subsystems. FBL,

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[1] Kehlet, Alan, "Major Advances in Aircraft Technologies Expected in the Future," *Innovate Bulletin*, McDonnell Douglas, Vol. 26, No. 4, 4th Quarter, 1995.

FBW, and PBW result in higher reliability, lower maintenance costs, lighter weight, and immunity to EMI.

Synthetic Vision Capabilities. A synthetic vision subsystem would enable pilots to use visual imagery and guidance cues to penetrate weather and compensate for low levels of illumination. These subsystems would use satellite-based navigation, imaging sensors, and high-resolution display media to operate with a high degree of autonomy.

Propulsion Controlled Aircraft. An aircraft controlled by differential engine modulation rather than control surfaces would be more likely to survive catastrophic events, including terrorist actions; perform better in partial failure conditions; and result in simplified control subsystems.

Autonomous Cargo Handling. Improved methods for airlift cargo handling (IMACH) is an integrated group of technologies for improving cargo handling. They focus on handling functions, on the handling of large and more complex loads, and on automation features. In its simplest form, IMACH would completely automate the movement of palletized loads.

High-Speed Civil Transport. The current HSCT baseline is a 300-passenger aircraft cruising at Mach 2.4 over water and Mach 0.95 over land, with a supersonic cruise range of 5500 nautical miles. The drive toward HSCT has focused on many new advanced technologies. These technologies center around advanced propulsion systems and advanced materials that can manage the high temperatures of supersonic flight. Research is being conducted in aerodynamics and technology integration; propulsion; structures and materials; flight deck systems; and key environmental issues, including sonic boom, airport and community noise, and emissions.

Human Factors. Human factors have long been critical to aircraft design, especially in-flight deck layout. Use of computer modeling as part of the systems engineering process in combination with design tools provides cost-effective, rapid prototyping to evaluate and adjust the design.

Advanced Design Tools. The complexity of aircraft design led the aircraft industry to develop sophisticated design and simulation tools. In many cases, such tools provide design information more quickly and cheaply than total reliance on wind tunnel testing. These tools, combined with advanced visualization techniques, are sufficiently mature to provide a basis for research, as well as aircraft design and engineering. There is a strong synergism between the computer-aided design tools and the training for each aircraft type. The modeling of flight characteristics for new aircraft types is so accurate that type checkout based only on trainer experience is anticipated. Simulation has been established as one of the primary systems engineering verification techniques in the commercial aircraft industry.

4.2.4 Systems Engineering Challenges

The key systems engineering principle is that commercial aircraft must be considered as a whole and not as a collection of parts that can be independently developed and integrated. Further, all requirements for the subsystems and components of the aircraft are derived from a top-level set of functions, the requirements associated with these functions, and constraints on these requirements. The principle of requirements flow-down is dependent on viewing the aircraft architecture as a hierarchy in which all elements are subordinate to higher-order elements, such as subsystems, the aircraft, and a higher-level system called the aircraft system, which includes the aircraft itself and all its supporting systems. Another principle is that traditional aircraft processes, such as certification, can be considered to be part of the larger process of verification, in which all requirements, either economic or regulatory, are verified by testing, demonstration, analysis, or inspection. Also of importance is systems engineering management in which a thorough review process is essential to ensure that all requirements are validated, that the design meets the requirements, and that the requirements are verified, both at the aircraft level and the subsystem level.

The requirements for the development of a new, derivative, or change-based aircraft design fall into two primary categories: regulatory and economic. Regulatory requirements are those that pertain to the safety of the aircraft and its occupants and are established by the Federal Aviation Administration (FAA) and documented in Federal Aviation Regulations (FARs). Economic requirements are those driven by the airline customer and pertain to the cost of purchasing, operating, maintaining, and servicing the aircraft. The systems engineering process accommodates both categories of requirements.

Regulatory Requirements. Traditionally, the regulatory requirements have been passed to the aircraft manufacturers through the FARs and have been verified in a Certification Plan submitted by the manufacturer. A major part of the Certification Plan is a Functional Hazard Assessment (FHA), which identifies hazard categories for identified components so that the proper designs and redundancies can be implemented.

The FAA, in cooperation with the Society of Automotive Engineers (SAE), has taken a major step toward incorporating the principles of systems engineering into the certification process with the publication of SAE ARP 4754 (in a draft version at the time of publication of this document)[2]. The guidelines of this paper are recommended rather than mandatory processes. The paper suggests that a thorough systems engineering functional analysis be conducted for all levels of aircraft systems and that the hazard category be established for each function. It also recommends that combinations of functions be identified for potential hazards. It is expected that this process will result in increased aircraft safety. Ultimately, these recommended practices may be incorporated into an FAA advisory circular and eventually into a FAR.

Economic Requirements. The major economic requirements of a commercial aircraft can be derived from a single parameter, called direct operating cost (DOC). DOC can be decomposed into its elements, which can be associated with different aspects of aircraft design. These elements are as follows:

- Navigation fees
- Insurance
- Landing fees

[2] SAE ARP 4754, “Guidelines for the Certification of Highly-Integrated and Complex Aircraft Systems,” SAE in cooperation with the FAA (to be published)

- Ground handling
- Crew (cabin, flight deck)
- Ownership (depreciation and interest)
- Maintenance (engine, airframe)
- Fuel and oil

Using the principle of allocation, the systems engineer can derive the requirements for the subsystems of the aircraft from this parameter. This allocation is discussed by Jackson[3].

As new technologies are incorporated (see Section 4.2.3), the impact on DOC can be directly determined. For example, as composite materials are introduced, the cost of ownership may increase because of the increased cost of the materials. However, the total DOC may decrease because of the reduced weight and the resulting reduction in fuel and oil.

Indirect Costs. In addition to DOC, there are indirect costs to the manufacturer and to the customer that would be significantly reduced with the application of systems engineering.

For the manufacturer the following cost savings apply:

- Project management cost reduction from using automated systems engineering tools
- Cost reduction from fewer redesigns and after drawing release, both in engineering and manufacturing
- Reduced warranty claims
- Improved sales

The airline customer will realize the following savings:

- Savings in reservations and ticket sales
- Savings in advertising and publicity
- Reduced maintenance and depreciation of non-flight items
- Reduced general and administrative costs
- Reduced passenger services (transportation and hotels)

An example of a major parameter that drives many economic factors, especially ticket sales, is dispatch reliability. Dispatch reliability is the probability that the aircraft will be able to take off within 15 minutes of the scheduled departure time. The required dispatch reliability normally approaches 100 percent. Using the principle of allocation, the systems engineer can derive the required dispatch reliability contribution of each major subsystem.

Customer Requirements. Unlike the automobile industry, the requirements for an individual airline customer may result in a product that is highly focused on the customer. The process of

[3] Jackson, Scott, "Systems Engineering and the Bottom Line," *INCOSE Proceedings*, 1995.

capturing those requirements, negotiating with the customer, and incorporating the requirements into an aircraft is a highly complex process.

One method of capturing customer requirements is Quality Function Deployment (QFD). QFD is a structure methodology for conducting dialog with a customer, prioritizing the customer's needs, identifying solutions to those needs, and scoring those solutions. QFD has been used successfully in the automobile industry and shows great promise for the aircraft industry.

Levels of Systems Engineering Application. In the aircraft industry, engineering efforts are conducted at three broad levels. Each level demands different aspects of systems engineering. The levels are as follows:

- *Level 1 – New Aircraft.* Development of new aircraft allows systems engineering to be applied in a "blank slate" fashion, that is, to start from the inception of the requirements for an aircraft and the development of initial concepts. Discussions with "launch" customers are held and analyses of range, number of passengers, noise, emissions, and other top-level requirements are developed. Economic, technical, and regulatory criteria are analyzed against all potential concepts. Requirements flow down to the aircraft subsystems.
- *Level 2 – Derivative Aircraft.* A derivative aircraft uses major components of existing aircraft as the basis for the development of an aircraft that meets new requirements. The derivative aircraft may have increased performance or carry more or fewer passengers than the baseline aircraft. The challenge of systems engineering is to develop requirements and to synthesize and verify solutions to those requirements within the constraints of the baseline aircraft.
- *Level 3 – Change-Based Aircraft.* A change-based aircraft is an aircraft for a specific customer that may have a large number of requested changes. Although each change may be small in itself, the systems engineering methodology must be applied to each change to ensure that the performance requirements of the affected subsystems are met and that the accumulated changes for the whole aircraft allow the aircraft to meet its performance requirements.

Aircraft System Architecture. To employ systems engineering on commercial aircraft, the aircraft system must be defined. The aircraft system consists of the following four elements:

- The aircraft
- Training equipment
- Support equipment
- Facilities

Hence, the systems engineering process must be applied to all of these elements, not to only the aircraft.

Aircraft Subsystems. There are many ways to decompose the aircraft into its subordinate elements. The following decomposition is typical:

- *Mechanical subsystem*, which includes landing gears, flight controls, hydraulic power, and cargo loading equipment
- *Propulsion subsystem*, which includes the engine pod and its components, fuel components, engine pylons, and thrust management equipment
- *Environmental subsystem*, which includes air conditioning, ice and rain protection, cabin pressure, pneumatic supply, and oxygen supply equipment
- *Airframe subsystem*, which includes the wing, fuselage, and tail
- *Avionics subsystem*, which includes the communications, navigation, indicating and recording, and auto flight equipment
- *Interiors subsystem*, which includes crew accommodations; passenger accommodations; water, lavatories, galleys, and plumbing; emergency provisions; and interior signs and lights
- *Electrical subsystem*, which includes electrical power and shipside lighting
- *Auxiliary subsystem*, which includes any auxiliary power supply for generating electrical or pneumatic power, for example

Each of these subsystems can also be decomposed into its subordinate components. The hierarchical decomposition of the aircraft system allows the flow-down of requirements to all subsystems and components in the classical systems engineering manner.

Allocation of Requirements. The hierarchical nature of the aircraft system and the aircraft architecture is compatible with the systems engineering principle of requirements allocation. The following parameters are examples of requirements that can be allocated to the subordinate elements of an aircraft:

- Weight
- Nonrecurring (development) cost
- Recurring (unit) cost
- DOCs
- Dispatch reliability
- Maximum allowable probability of failure
- Internal noise (sound levels)
- External noise
- Electrical loads
- Air distribution
- Fuel consumption
- Emissions

Verification of Requirements. Verification of requirements in the commercial aircraft industry is an extremely complex process. As mentioned previously, verification of certification-related requirements is controlled by FARs and thoroughly conducted and monitored. These requirements and the balance of the requirements are verified by a variety of methods, including ground tests, simulations, analyses, inspections, and flight tests. Similarity analyses are based on flight histories of specific components and subsystems. In any event, the systems engineering principle of complete verification is paramount.

4.2.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

Scott Jackson
Boeing Company
2401 East Wardlow Road
MS C071-0307
Long Beach, CA 90807-5309
Voice: 562-496-5049
Fax: 562-593-8625
E-mail: scott.jackson@boeing.com

LeRoy Botten
3715 Capulet Terrace
Silver Spring, MD 20906
Voice: 301-985-8726
Fax: 301-985-8909

4.2.6 References

Kehlet, Alan, “Major Advances in Aircraft Technologies Expected in the Future,” *Innovate Bulletin*, McDonnell Douglas, Vol. 26, No. 4, 4th Quarter 1995

SAE ARP 4754, “Guidelines for the Certification of Highly-Integrated and Complex Aircraft Systems,” SAE in cooperation with the FAA (to be published)

Jackson, Scott, “Systems Engineering and the Bottom Line,” *INCOSE Proceedings*, 1995

4.3 Commercial Avionics

4.3.1 Introduction

The commercial avionics industry in the United States and throughout the world is growing rapidly. As technology becomes available for improving performance, cost, and safety of aircraft operations, there is immediate competition to meet known and anticipated customer needs. Established firms as well as startup ventures participate in this application domain.

Risks in this application domain include product liability claims; building robust, complex hardware and software systems on a tight schedule; and integrating heterogeneous systems on a single platform.

Table 4.3–1 summarizes the commercial avionics industry. Table 4.3–2 focuses on the application of systems engineering in the application domain. (Note: These tables will be added at a later date.)

4.3.2 Industry Functions and Processes

The following steps for developing avionics products are similar to those encountered in creating and marketing other electronics systems:

- Concept development
- Commitment of external and internal funding
- Detailed design development
- Proof-of-concept and engineering prototype development
- Marketing
- Manufacturing prototype development
- Manufacturing
- Material
- Personnel
- Facilities
- Process
- Distribution
- Installation and coordination and field support
- Product improvement

Requirements for reliability, robustness, and accuracy of function usually exceed those for electronic consumer products. Regulatory requirements and exposure to product liability suits place additional demands for stringency in the design, testing, and manufacturing processes for avionics and for documenting adherence to those processes.

4.3.3 Technology Profiles

The FAA modernization program is making changes at an admittedly deliberate pace. Progress in modernizing ground facilities impacts avionics. The modernization program includes emphasis on improving flow control (i.e., spacing departures to ensure en route spacing and availability of landing facilities), en route control (i.e., interaction with avionics to ensure traffic horizontal and vertical separation is maintained), and departure sequencing (i.e., refinement of flow control to deal with congestion in crowded areas such as the vicinities of Los Angles and New York).

With the increased capability of avionics to exploit the GPS, improved radar systems (e.g., detection of altitude, wind shear, dangerous weather), compact and powerful computers, and geographic information systems (GIS), it does not seem unreasonable to expect that fully automated routine flight might be safer than flight controlled by human pilots. Certainly, human judgment remains essential, but fully automated control by redundant, robust systems is not subject to boredom, tiredness, and the human tendency to err.

There is an interesting contrast between the successful effort, more than 20 years ago, that resulted in fully automated takeoff, flight, and landing that is long since accepted in Europe but not in the United States. The contrast between automated technology and the elusive search for a successful collision avoidance system is interesting. A truly effective collision avoidance system probably would be mandated immediately by regulators.

The communications industry has provided reliable and effective communications avionics for many years, including automated digital communication (e.g., automatic transponders that provide controllers with accurate altitude and position information essential to safety in contested traffic areas).

Cockpit instrumentation now includes digital video displays that are context-sensitive and can be reformatted during use. Improvement of user interface and implicit redundancy have made such systems standard equipment on some commercial aircraft types. Further technology advances are expected (e.g., use of advanced sensors and heads-up displays for commercial aircraft).

One of the latest developments—if one stretches the meaning of avionics a bit—is seat backs with cellular telephones and individual passenger video displays for in-flight movies and electronic games. A reasonable extension of this is in-flight personal computer (PC) and modem support as well.

4.3.4 Systems Engineering Challenges

Application of trusted machine intelligence lags behind the proven capabilities. The potential for such applications is tremendous for preflight preparation (e.g., aircraft fault detection and filing of flight plans, including checking for internal consistency and consistency with other flight plans); in-flight monitoring of aircraft systems (e.g., failure diagnosis and resolution, fuel management, detection of out-of-envelope flight operation); and assessing factors in the external environment (e.g., traffic, vertical clearance, atmospheric disturbances).

Fuel and time are already being saved by the use of free flight (i.e., direct point-to-point rather than via Victor airways) for oceanic trips. With capabilities provided by existing inertial navigators and VORs, especially when supplemented by GPSs and GIS, free flight offers relief from congestion. The challenges of systems engineering are to resolve differences in the definition of free flight among pilots, controllers, and others in the aviation community; resolve the transition to and from free flight and congested traffic areas, and provide appropriate models and systems for collision avoidance systems and monitoring of free flight operations by controllers.

Systems engineering techniques for tradeoff studies should also resolve tradeoffs related to automated flight systems (i.e., takeoff, flight, and landing). Available technology currently exceeds that used. Some people argue that if pilots do not use their skills, their skills will not be finely honed if an automatic flight system fails. Properly evaluating and balancing all relevant factors to produce avionics that lead to effective, reliable, robust, and cost-effective flight systems is a systems engineering challenge.

4.3.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

LeRoy Botten
3715 Capulet Terrace
Silver Spring, MD 20906
Voice: 301-985-8726
Fax: 301-985-8909

4.3.6 References

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4.4 Criminal Justice System and Legal Processes

4.4.1 Introduction

The 21st century will see expansion of systems engineering to nontraditional engineering applications and its farther expansion to nonengineering disciplines. Nothing in the definition of systems engineering is limited to communications, space, defense, energy, or computer development. Much of the national interest in the early 21st century may focus on other engineering areas that can benefit from the systems approach, such as genetic engineering, mass transportation, housing, infrastructure renewal, and environmental systems. In addition, the application of systems engineering to areas such as the criminal justice process, drug abuse prevention, medical evaluations, and economics are fertile areas for the systems engineer of the 21st century.

The systems engineering community has already begun structuring the major aerospace programs to address interests of the international scientific community and to focus on the environmental concerns of the planet. As more and more international scientific investigators provide near real-time feedback to the orbiting sensors and direct information-gathering efforts from their workstations, the more stochastic and similar to the people-intensive criminal justice system the entire aerospace system will become. As systems engineers learn to design for people-intensive, complex systems, the more ways they will find to apply engineering disciplines to meet the challenges of nonlinear, probabilistic, and multivariable input; processes; and output.

4.4.2 Legal System Functions and Processes

In approaching the legal process as a system and analyzing it on a consistent basis, the three main components—input, process, and output—of a traditional linear system with feedback response are useful. The ease with which the systems engineering concept can be applied to the legal process and the obvious ability for communicating legal issues to an engineering community in familiar terms are two advantages to this approach (Figure 4.4–1).

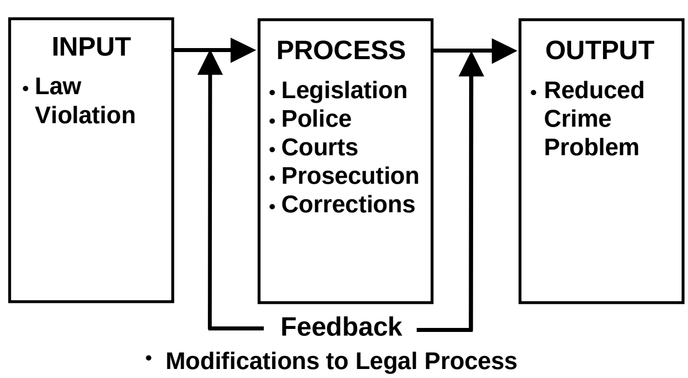


Figure 4.4–1. The Legal Process as a Traditional System With Feedback Response

Distinguishing the major systematic parts of the criminal justice system in terms of input, process, and output is a useful example of systemizing the legal process (Figure 4.4–2). The civil procedures, contract negotiations, and corporate formation processes could be analyzed in a similar way. Input to the criminal justice system is individual violations of the law. The process of the system refers to the many activities of police, attorneys, judges, probation and parole officers, and prison staff. The process of the criminal justice system is familiar and visible. Output of the criminal justice system may be described as the success or failure of society to cope with crime. The feedback response is useful in changing input to effectively provide the desired output, that is, a reduction in the amount of crime.

The role an attorney plays in developing a legal case and preparing for the eventual trial and/or negotiation is not unlike that of a systems engineer. The systems engineer determines and validates the requirements of a system and creates a system architecture for SDLC implementation. The legal team also has a legal process life cycle, just as the systems engineering team must conform to an SDLC (Table 4.4–1).

The systems engineer identifies and validates the requirements of a system; the lawyer identifies and validates the issues of a case. Just as the systems engineer creates a system design, the lawyer develops a design for the case using legal research. The system implementation has a corollary in the pleadings preparation and lawsuit initiation. The systems engineer finds out during system integration and testing whether the system design actually validates the requirements. The attorney finds out during the trial or negotiations whether the case presentation has been successful and whether it was based on the correct issues. The acceptance of the system is like the verdict of a jury or the acceptance of the settlement by opposing counsel. Finally, just as the systems engineer must be prepared to maintain the system for the remainder of the life cycle, the attorney must be prepared to enforce the judgment or verdict decree after the trial is finished.

There are apparent differences between the legal and systems engineering processes in the discreteness with which every input to the legal process is treated and the judgment that many persons responsible for executing the legal process use. For example, in the criminal justice system, the individual who commits a crime does so for motivations that may be quite different from the next person who commits the same crime. Similarly, a police officer, who is responsible for exercising judgment daily, uses his/her discretion to determine whether the criminal justice process is invoked against an individual.

Among the factors influencing a police officer’s discretion are a large volume of violations, the limited resources of the police, the overgeneralizing legislative enactments that define criminal conduct, and various local pressures reflecting community values and attitudes [Coffey et al., 1974].

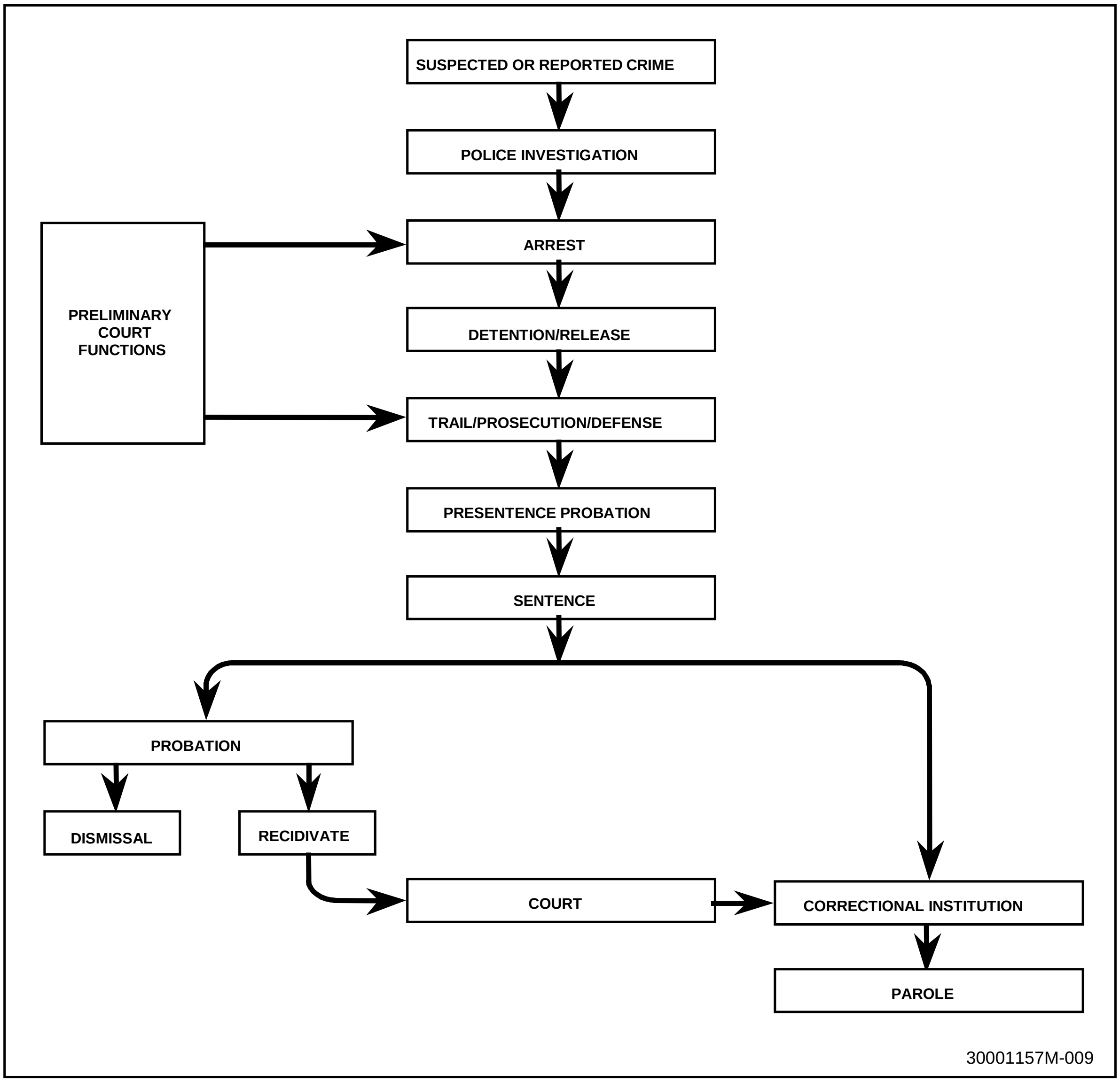


Figure 4.4–2. Major Parts of the Criminal Justice System

Table 4.4–1. Corollary Life Cycles of the Lawyer and the Systems Engineer

Systems Engineering Phases	Legal Process Corollary
1. System concept and requirements definition	1. Client discussions and issue identification
2. System design	2. Legal research, discovery process, and case development
3. System implementation	3. Pleadings preparation and/or law-suit initiation
4. System integration and test	4. Negotiations and/or trial
5. System installation and acceptance	5. Verdict or settlement
6. System operation and maintenance	6. Enforcement of judgment or verdict decree

In systems that are well designed and engineered, output is more predictable—given a specified input. Technically sophisticated systems can also be subject to a range of probabilistic outcomes. How safely an aircraft is operated, given unpredicted circumstances, or whether a weapons system actually hits a target often depends on the individuals who exercise discretion at the controls.

In the 21st century, the systems engineering community will be called on to apply its discipline to new areas. Systems engineers will be developing increasingly complex systems that involve multiple users and support large portions of the population. At the same time, the legal community is beginning to systematically address needed improvements in the criminal justice system. Both communities must seek out areas of mutual interest and begin to work together to meet the challenges of the new century.

4.4.3 Technology Profiles

To be supplied.

4.4.4 Systems Engineering and Legal Challenges

An attorney can assist the engineering process through participation in the following activities:

- Understand the SDLC by creating contracts that focus on risk mitigation during development and participate in the engineering process to ensure mutual agreement and an equitable outcome.
- Revitalize the intellectual property protection mechanisms, that is, patents, copyrights, and trade secrets, with the objectives of stimulating creativity and reducing infringement of property rights.
- Apply principles of regulation to achieve the goals of regulating while providing incentives to achieve desired results.

Likewise, a systems engineer can assist the legal process through participation in the following activities:

- Understand the criminal and civil legal processes, apply allocation of resources, and optimize techniques so processes might run more efficiently.
- Provide simulation models for the criminal justice system and the legal enforcement process showing how criminals could be more easily identified and brought to justice.
- Identify appropriate tradeoff analyses and prototyping efforts to ensure regulations enacted by the legal community, balance diverse interests (for example, the environment versus the economy), while providing incentives for advancing the technologies of society.

Table 4.4–2 lists some actions that both the engineering and legal communities might take to better train and provide incentives for the people in those professions. It also lists activities to improve the processes with which each profession operates and the tools of each profession. Several of these topics are discussed more fully in the remainder of this section.

Table 4.4–2. Selected Activities for Improving People, Process, and Tools of the Profession

	Engineering	Law
People	Participation in educational community Stimulating development of systems engineering textbooks Incentives for engineering profession	Participation in educational community Joint MS/JD degree programs
Process	Adversarial process for concept development Self-assessment of systems engineering process	Evolution of intellectual property protections Participation in SDLC
Tools	Automation of systems engineering process	Simulation models for criminal justice process

Rather than providing definitive answers to all the issues presented, this paper is intended to initiate a dialogue between the legal and the engineering communities on how best to address some of the pressing issues of this century.

4.4.4.1 Use of the Adversarial Process for Concept Development

The first task of a competent systems engineer or a systems engineering team is to conduct a meaningful system concept definition phase for a potential mission. The primary goals of this phase are to

- Rigorously define a system concept that will meet mission requirements and external user and system operations needs
- Assess the technical and economic feasibility of the system

After completing this phase, the system concept should provide the initial top-level description of the system. This description is used to assess the end-to-end system scope and the feasibility of proceeding with the development effort. The identification of potential risks and high-cost areas are also important results of this phase.

Tradeoff analyses, cost-benefit analyses, and even prototyping are useful methods for weighing one concept against another. With well-trained engineers performing these analyses, one would expect a solid system concept to emerge with most of the high-risk questions answered. How is it possible then that in the last 30 years we have witnessed significant technical and management lapses in many of the systems of the 20th century? Examples could include the virtual collapse of the nuclear reactor steam supply system industry, the loss of a space shuttle, the chemical process systems that foul our water supplies and destroy our environment, failure of the Mar's missions, and systemic problems in the hospitals of the United States.

Several factors influence the outcomes of these system concepts, which have led to undesirable results. The lack of economic resources has limited the amount of tradeoff studies, as has the limited understanding of complex systems, such as ecology. Also, the desire to meet schedules permits risks to be accepted when they should be more carefully evaluated. I submit that we as engineers are not thoroughly completing the system concept definition phase of the life cycle and, in many cases, the tradeoff analyses and other critical analyses that would uncover many of the risks are not in fact being performed.

Most of us have noticed in our careers that, once an effort gets some funding, there is great impetus to move the development process along. Any views that might slow the process or risk the loss of future funding for one's company or agency are unlikely to be expressed. The debates that should occur in technical forums often do not happen. The important tradeoff analyses that should appear in technical journals are also lacking. As a result, the tough questions get asked in public forums and congressional committees, and we as technical bodies are unprepared to answer them.

For the 21st century, the engineering community and systems engineering teams should structure a debate process, particularly for the system concept definition phase, with forums, such as INCOSE, where all facets of the system can be examined. These forums could ensure that valid tradeoff analyses have been conducted, that technical evaluation criteria include social and economic values, and that advocates for most views have been heard. While such forums are more familiar to the legal community, they could greatly benefit the technical community by identifying and addressing the system risks and by permitting eventual convergence on a system concept that can be supported by users in the scientific, engineering, and general public communities that it is to serve.

4.4.4.2 Evolution of Intellectual Property Protections

During the past several years, there have been significant changes in the intellectual property protection mechanisms of patents and copyrights. The percentage of patents issued by the U.S. Patent and Trademark Office is no longer dominated by submissions from U.S. inventors. As a result of the International Bern Convention of 1989, notices are no longer required for copyrights. Further, an evolution is underway for patents to protect software as well as hardware and for copyrights to protect hardware as well as software. The legal area of intellectual protection could benefit from the interaction of systems engineers and attorneys, both to stimulate the invention process in the United States and to assist in creating the most meaningful protection mechanisms. A little history of the traditional domains of copyrights and patents illustrates the evolution that has been taking place in the law relating to the core of every system—the computer (i.e., computer law).

Traditional Domain of Patents. The traditional domain of patents has been hardware and hardware function. If function is the objective of protection, the patent is the mechanism of choice. To acquire a patent, an invention must pass the tests of patentability, which include novelty, nonobviousness, and utility (35 U.S. Code Sections 101–103). The invention must also pass the test of no prior disclosure to the public in the year prior to patent application. The patent submission consists of three parts: (1) the specification, (2) claims that define the boundaries of ownership rights, and (3) any drawings. The advantage of a patent is that it provides sole rights to inventors for 17 years; a high percentage (e.g., 80 percent of patents recently being litigated) are being held valid. A patent protects function regardless of whether the infringer copied the protected hardware or software. The disadvantages of patents are that the registration process is relatively complex and therefore expensive, and there is a long patent-pending timeframe of 18 to 27 months [Mackey, 1991].

Traditional Domain of Copyrights. The traditional domain of copyrights has been documentation and more recently computer software. If expression is the objective of protection, the copyright is the mechanism of choice. To obtain a copyright, an author needs only to document the expression on some media. No formal registration or public notice is required; however, it is desirable to register a copyright with the U.S. Copyright Office because the registration establishes the right to sue in case of infringement; it also establishes *prima facie* evidence of ownership. The advantages of copyrights are that they are inexpensive to register; the copyright is immediate upon putting pen to paper; and the registration process is simple. The disadvantages of copyrights are that they are perceived to provide protection at a lower level than patents and that there is some very limited public disclosure.

Traditional Domain of Trade Secret. A third intellectual property mechanism is the trade secret. Some businesses, such as Coca-Cola and Kentucky Fried Chicken, have used this method quite successfully. The advantages of this method are that it can be controlled by business management, it is sometimes less expensive, and it can sometimes be combined with the other protective mechanisms of copyrights and patents. The disadvantages of the trade secret mechanism are that the need to maintain secrecy may constrain the technical team, it can be hard to implement and enforce, and it does not protect from reverse engineering.

Evolution of Software Patent Protection. Intellectual property protection with regard to computers has been possible only in recent years. In 1969, the courts established that natural, mathematical, and mental processes could not per se be claimed in a patent (in re *Prater* vs. *Wei*; on rehearing, 1969). Also in the same year, the court held that programmatic changes to machines may be patentable (in re *Bernhardt* vs. *Fetter*, 1969). Again, the courts upheld that some computer processes are patentable (in re *McIlroy*, 1971), whereas a year later, in *Gottschalk* vs. *Benson*, 1972, the ruling was that computer programs are not patentable [Siegel, et al. 1989]. In *Diamond* vs. *Diehr*, 1981, it was ruled that processes embedded in computer programs are patentable. While the final word has not established the precise boundaries of a patent, the trend of the U.S. Patent and Trademark Office from 1971 to the present has permitted most software that passes the patent tests of novelty, nonobviousness, and utility to be patented.

Evolution of Hardware Copyright Protection. Copyrights were initially applied to software in the early 1980s. The Third Circuit Court, in *Apple Computer* vs. *Franklin Computer Corp.*, 1983, established that software (source code and object code) is copyrightable. In addition, screen displays were deemed copyrightable under the “look-and-feel” decision stated in *Midway Mfg. Co.* vs. *Arctic Int’l Inc.*, 1982. The copyright was ruled to extend beyond the literal program to the sequence, structure, and organization in *Whelan* vs. *Jaslow*, 1983. In *NEC Corp.* vs. *INTEL Corp.*, 1989, the courts held that microcode is similar enough to software to warrant copyright protection [Siegel, et al.].

Evolution of the Computer Control Unit and Software Program Storage. From the late 1950s through the 1970s, the computer control unit and the manner in which software programs are stored in the computer have changed significantly. The computer control units in the earliest machines were wire patch panels with vacuum tubes, followed by discrete logic units (e.g., transistors, diodes, resistors, capacitors, gates, and operations research gates).

In the late 1960s, these same units used integrated circuitry microprogramming; in the 1970s and 1980s, the computer control unit became very large-scale integrated (VLSI) circuitry. Program storage in the first-generation machines was accomplished by the manner in which patch panels were wired, which evolved to software stored in the main memory of the computer. By the third-generation computers, control storage read-only memory (ROM) microinstructions were added, followed by writeable, control store, programmed logic arrays (PLAs). In summary, intellectual property mechanisms of patents protecting hardware and copyrights protecting software have evolved over the past 2 decades. During this same period, computer engineers complicated the situation by storing computer programs first in hardware patch panels, then in software code, and more recently in microcode firmware. Microcode firmware is defined as a multilevel instruction set that can be implemented in hardware or software (or both) and provides the logic sequences to activate the hardware elements.

State of Case Law on Software and Microcode. Figure 4.4–3 illustrates the evolution of the case law on software and microcode. If one views a computer system as a vertical continuum of hardware to software, there is a gray boundary, somewhere near microcode and PLAs, where hardware ends and software begins. This boundary will not remain static in the coming years. The figure shows that from 1971 to 1981, the patent protection of function evolved from hardware to some software. During the 1980s, the copyright protection of expression was in the process of evolving from software to microcode. Several questions remain unanswered:

- Will copyright evolve to protect hardware?
- Has engineering created a gray area where something historically called hardware has now taken on the characteristics of something historically called software?

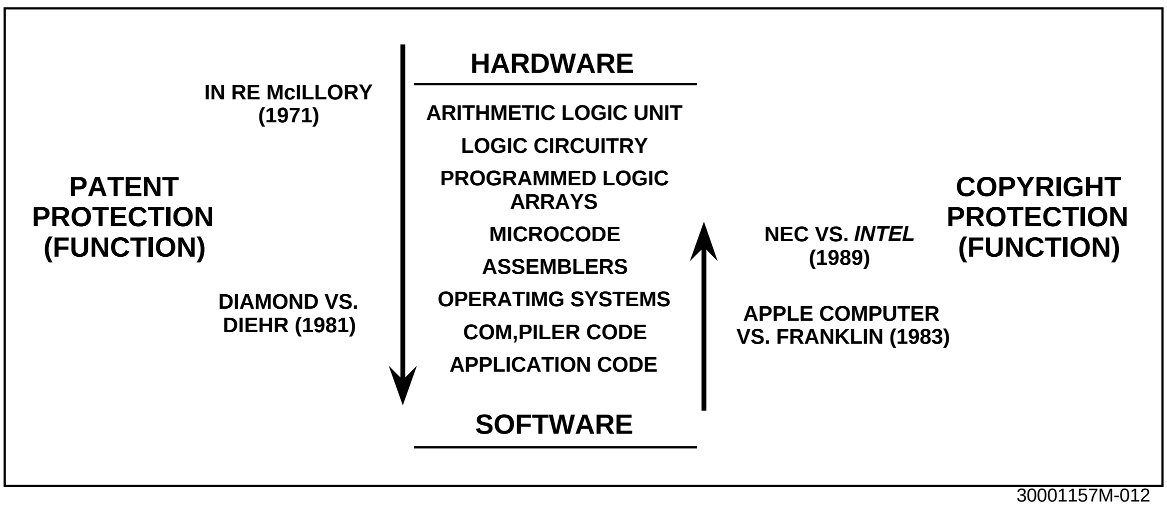


Figure 4.4–3. The Evolution of Hardware Copyright Protection: State-of-the-Case Law on Software and Microcode

How the Systems Engineer Can Assist the Invention Process. The patent attorney and those who regulate the patent process could benefit from the assistance of professional systems engineers who would be willing to study the invention and intellectual property processes for the purpose of improving the effectiveness of these processes. Yet, other questions remain:

- Are there ways to increase the numbers of patents that U.S. inventors will create by reducing the costs of protection?
- Is there a way to provide incentives to the creative scientist or engineer in a large corporation so that they gain significant rewards from a successful invention without making the royalties paid too burdensome for the corporation?
- Should we encourage the creation of millionaire inventors, such as those of the early 20th century (Thomas Edison, the Wright Brothers, and Henry Ford)?

The engineering community could also advise the legal profession on technology forecasting. Questions to be answered include:

- Is the present evolution of patents from hardware to software and copyrights from software to hardware a good result?
- Isn't copyright protection of software/microcode implemented in ROM/PLA form simply a "backdoor patent" way of gaining protection for hardware inventions?
- Don't the "look-and-feel" decisions for copyright protection, if extended to microcode, offer more protection to hardware than could be achieved through specific claims in any hardware patent?
- Won't the copyrighting of ROM-based software and microcode become a major deterrent to clone manufacturing?

There are many avenues of mutual interest to attorneys and engineers in the intellectual property protection arena.

4.4.4.3 Legal Participation in the System Development Life Cycle

The systems engineer is very familiar with the activities of the SDLC. A well-managed SDLC requires the complete cooperation of the project management team, the systems engineering team, and all other line organizations. Often forgotten in the project organization are the legal advisors. Legal advisors are usually called on to draft the contract and subcontract documents, and then they fade into the background until the project encounters difficulty. This event could occur early in the contract or, more likely, several months or even years after contract initiation. At that point, the project is so interwoven with actions taken by contractor and client that it is often difficult to determine how to allocate those losses that result from risks.

The most significant risks involved in large projects are usually related to the development of initial system concepts, ensuring specificity and the agreement of system requirements and design, and the management of the SDLC [Mackey, 1991]. A competent legal counsel can add value to the activities of the project organization. A legal advisor should therefore be involved in the project to ensure that the interests of the organization are being monitored.

A legal advisor can assist the project management team in the following activities:

- Participate in all project reviews where most binding technical and management agreements are reached.
- Assist in identifying and allocating the risks.
- Ensure that all requirements in the system requirements specification are written in simple English statements that are easily understood by persons skilled in the appropriate subject.
- Monitor the completion and proper transfer of all contract deliverables.

- Ensure that all appropriate contract requirements are passed on to individual subcontractors.
- Assist in identifying system changes that impact the contract and are out of scope from the contract's original intent.

In summary, the legal counsel can be invaluable to the project without understanding all the technical details. Such counsel can assist the project manager and the line managers in managing the SDLC and mitigating potential risks.

4.4.4.4 Improving the Image of Engineering and Law

In addition to the present lack of opportunities for scientists and engineers in the United States, there is a need to improve the image of the engineering and legal professions. The engineering profession often lacks visible rewards for a job well done and the legal profession often is the butt of unkind jokes. The entertainment and sports communities have learned the lessons that the scientific, engineering, and legal communities have yet to understand. The present heroes of American youth are the sports figures, singers, musicians, and actors who are viewed daily on television in most homes. While television occasionally portrays attorneys, scientists, and engineers, these youths admire the stage figure, not the actual person being portrayed.

Weekly television spectaculars honor performers with Oscars, Emmys, Grammys, Tonys, and so on. These honors are funded by the industries that benefit from the images these honors create. Sports figures are similarly honored in all-star appearances, Super Bowls, most valuable player awards, or Olympic performances. I recommend the receipt of similar awards by members of the scientific, engineering, and legal professions.

Visible Awards for Science, Engineering, and Law. We should support the attempt to stimulate the desire to obtain a technical education by annually honoring those who have contributed most to chemistry, mechanical engineering, mathematics, law, and other disciplines. The presentation could be interesting and informative and done with all the flair and elegance of an Academy Awards presentation. Music, dance, and visual effects could all be combined to make these presentations a pleasure to watch. We would need the support of those industries that may be honored to fund a National Academy of Sciences and Engineering or a National Academy of Law. We, as scientists, engineers, and attorneys, would also have to be willing to fund such an organization. The rewards for doing so would be to provide visible awards for science, engineering, and law; improve the image of our professions; and stimulate a desire in our youth to study science, engineering, and law.

4.4.4.5 Simulation Models for the Criminal Justice System

Components of the Criminal Justice System. Society uses the criminal justice system to enforce standards of conduct. If prosecution and defense are viewed as separate entities from the court, the criminal justice system can be considered to have four parts: the police, the court prosecution, the defense, and corrections, each with its own distinct activities [Coffey, 1974].

The police are concerned with control, apprehension, and support for the criminal justice system. The role of the police in the administration includes

- Prevention of crime
- Detection of crimes committed
- Identification of the person(s) responsible for crimes
- Apprehension of the person(s) responsible for crimes
- Detention of the person(s) for processing by the judiciary
- Presentation of evidence to the prosecutor

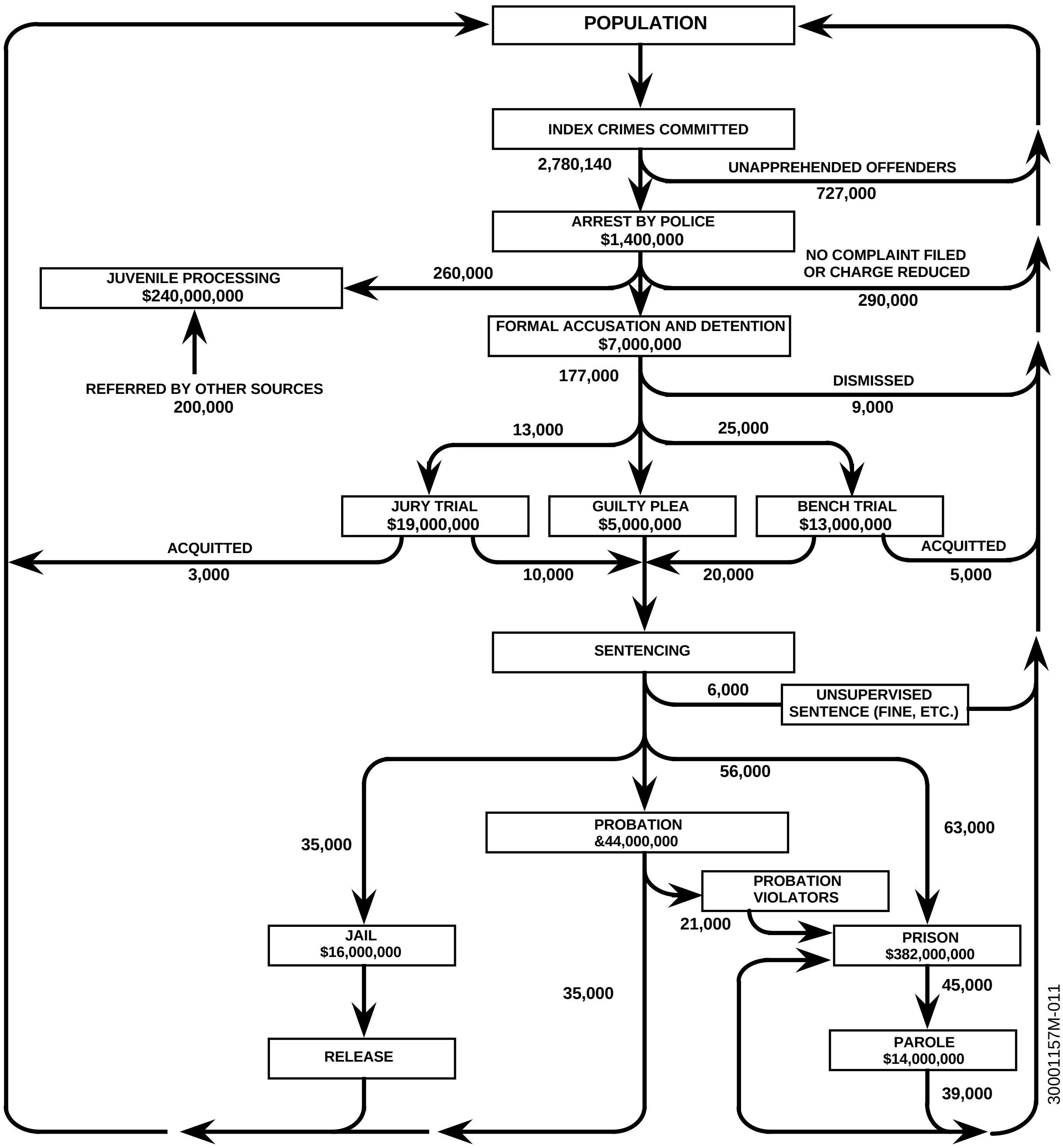
The court includes the roles of prosecutor and defense as two distinct interrelated phases of the administration of justice. The key administrative officer in the processing of cases is the prosecutor. The prosecutor's decisions significantly affect the arrest practices of the police, the volume of cases in courts, and the number of offenders cleared through the correctional system. Thus, the prosecutor is in the most favorable position to bring about the needed coordination among the various law enforcement and correctional agencies in the community. The defense counsel provides clients with the right to be heard and achieves the most appropriate disposition of clients.

Corrections involves implementing the orders that the court gives to probation departments or parole agencies and institutions. Corrections includes U.S. prisons, jails, juvenile training schools, and probation and parole machinery.

How Can the Systems Engineer Help? The systems engineer can help by perceiving that the criminal justice system with its component hierarchy could be modeled just as any other probabilistic system might be. Therefore, the opportunity exists for simulating the criminal justice system at any level. Figure 4.4–4 shows a typical model of the criminal justice system with estimates of offenders and operating costs (in 1965 dollars) for index crimes in the United States [President's Commission, 1967].

Modeling the criminal justice system could be useful in many ways. A new statute or other measure could be modeled and understood before implementation to determine its effectiveness in reducing crime or numbers of persons convicted of a particular crime. Corrections methods or court processes could be simulated to evaluate their efficiency. The fairness of sentences according to a defendant's level of education, race, and income could be examined in great detail. Reductions of the court load, prison population, and resources spent on maintaining the criminal justice system could be measured.

Understanding the criminal legal processes and applying the allocation of resources and optimization techniques so that those processes might run more efficiently could all be enhanced with simulation models built by systems engineers with a background in law. By creating simulation models for the criminal justice system and the legal enforcement process, systems engineers would be helping to quickly bring criminals to justice.



NOTE: NUMBERS OUTSIDE BOXES INDICATE ESTIMATED FLOW OF PERSONS ARRESTED FOR INDEX CRIMES. NUMBERS INSIDE BOXES INDICATE ESTIMATED COSTS (IN 1965 DOLLARS) INCURRED DURING PROCESSING STAGES.

Figure 4.4–4. Criminal Justice System Model (President's Commission, 1967)

4.4.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

William F. Mackey, Esquire
Computer Sciences Corporation
7700 Hubble Drive
Lanham-Seabrook, MD 20706
Voice: 301-794-2138
E-mail: wmackey@csc.com

4.4.6 References

Alford, M., "Systems Engineering: The Last Engineering Discipline To Be Automated." AIAA Space Programs and Technologies Conference, March 1992, Huntsville, AL

Coffey, Alan, Eldefonso, Edward, and Hartinser, Walter, *An Introduction to the Criminal Justice System and Process*. Prentice–Hall, Englewood Cliffs, NJ, 1974

Computer Sciences Corporation, *Digital System Development Methodology*, Version 3.0, December 1989

Department of Defense, MIL-STD-490, Military Standard for Systems Engineering, 1965

Mackey, W.F., "Systems Engineering and the Legal Profession," *NCOSE Proceedings, Second Annual International Symposium of NCOSE*, Seattle, Washington, July 20-22, 1992

Mackey, W. F., "Technical Issues in Computer Contracting." Presentation at the Intellectual Property Symposia, Marco Island, FL, March 1991

Poulin, D. C., *Systems Engineering Process Self-Assessment*. Computer Sciences Corporation, September 1991

The President's Commission on Law Enforcement and the Administration of Justice, "The Challenge of Crime in a Free Society." U.S. Government Printing Office, Washington, D.C., 1967

Wolff, M., "Walking Small at Munich: Why George Bush Won't Be Signing any Autographs at the Summit." *The Washington Post*, July 5, 1992

Siegel, D., and R. Laurie, "Beyond Microcode: Alloy vs. Ultratek—The First Attempt to Extend Copyright Protection to Computer Hardware," *Computer Lawyer*, April 1989

4.5 Emergency Services

4.5.1 Introduction

Many of today's business enterprises are very dependent on information technology. Preparation for emergency situations that may cause processing outages may be critical to enterprise survival. The goal of business continuity and recovery (BC&R) is to maintain continuity of critical business processing or to restore such functions in a minimal amount of time. Planning and implementation of BC&R preparations can be done in-house or through a company that provides business continuity services. Assessing emergencies and making the decisions that lead to effective mobilization of resources to cope with emergencies are areas that can benefit from systems engineering-based methods and practices. Table 4.5–1 summarizes the systems engineering activities in the emergency services applications domain.

Table 4.5–1. Application Summary for Emergency Services

Number of Companies (U.S./Non-U.S.)	TBD
Representative Firms	(U.S.) SunGard, Guardian, DRI (training), Comdisco, IBM Business Recovery Services, BMC Software, Contingency Management Consultants/(U.K.) SG-RS, Adam Associates, First Base, Business Assurance Scheme, Continuity Systems Ltd./(Australia) The VR Group.
Annual Sales	TBD
Products/Services	Remote data mirroring, recovery facilities, operations monitoring, transaction replication, electronic vaulting, mobile recovery services, planning assistance
Technical Challenges	Maintaining current data/algorithms in archives
Business Challenges	Accurate identification of critical activities and the effect of an interruption on business
Major Customer Groups	Information-dependent businesses such as banks, finance industry, retail, transportation, communications, government, and health care
Regulatory Groups	Federal Emergency Management Agency (FEMA) (not a regulatory agency) publishes a guide for business. American Management Association has an interest
Growth	Rapid as business and industry rely more and more on information technology

4.5.2 Functions and Processes

An emergency situation is a serious, adverse event that has an impact on critical business processing. It may be caused by a natural disaster, fire, explosion, aircraft crash, or terrorist attack. It may also be due to sabotage by a dissident employee, Year 2000 (Y2K) problems, hardware or software failures, communications failures, or power outages. The cost of BC&R planning and implementation may determine the degree of protection afforded. Costs associated with transition to BC&R operations, and subsequent return to normal operations can be significant.

A sound BC&R implementation anticipates the general consequences of likely emergencies and provides resources for recovery. The particulars of each emergency situation differ. Usually, a contingency site is implemented to ensure rapid response, and a disaster recovery site is implemented to ensure recovery capability in the case of a devastating adverse event.

A contingency site may be implemented as a hot site (i.e., systems, current data, communications, software, and hardware are installed and operational). It may not be necessary or feasible to fully duplicate the primary site or fully staff it at the contingency location. A contingency site should be distant enough from the primary site to avoid the adverse effects, yet close enough that it may be used for routine testing or overload processing during normal operations. Operations personnel from the primary site, if they are available, may be able to report to the contingency site to support critical operations.

A disaster recovery site is usually implemented as a cold site. In this case the processing systems and infrastructure elements (e.g., communications, power, and archived data) are either installed or can be activated promptly. Typically, contracts and service level agreements are negotiated with systems vendors and service providers for installation of specific operational configurations within a few days. At a contingency site, processing for some deferrable applications may not be provided. The functionality of a disaster recovery site usually duplicates the functionality of its primary site. A disaster recovery site is chosen far enough away from the primary and contingency sites it supports to provide protection even in the case of very severe, large-scale disasters, and is located preferably in a hardened facility.

A typical, high-level BC&R architecture is summarized in Figure 4.5–1.

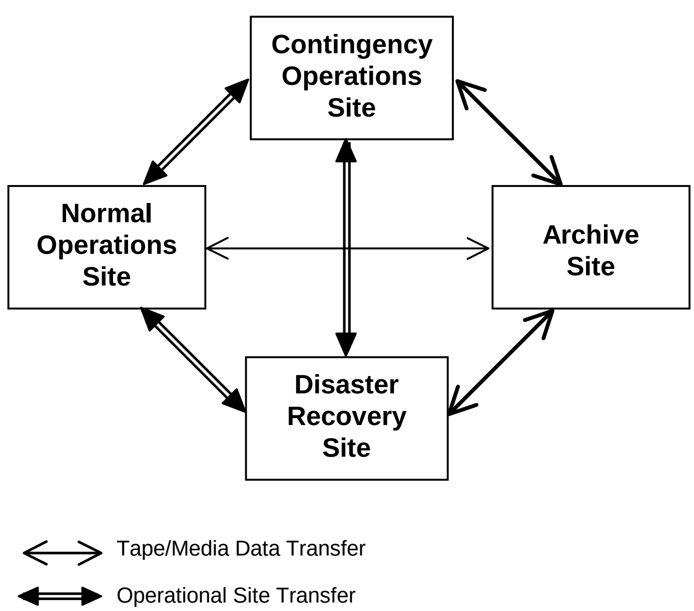


Figure 4.5–1. Typical BC&R Architecture

4.5.3 Technology Profiles

The Emergency Response Team (ERT) is responsible for identifying and analyzing the impact of adverse events. Team members follow a process described in the local- and enterprise-level BC&R plans. Using assessment tools, systems engineering judgement, and management experience, they formulate response recommendations for the designated authority. Although this task is heavily human dependent, there are tools that can be used to support the emergency assessment. Following an emergency, ERT personnel may be unable to travel to the site or otherwise be unavailable because of the chaos surrounding an emergency. Tools that preserve and apply the knowledge gained during BC&R planning can assist untrained personnel and facilitate information sharing among ERTs in these circumstances.

Two examples of these tools are the BC&R Outage Estimation Tool, and the BC&R Assessment Decision Support Tool. Both of these use Microsoft Excel spreadsheets and are designed for use on laptops to permit remote use by key personnel, and to serve as backup if workstations at the site of the emergency are unusable.

- The BC&R Outage Estimation Tool implements an estimation model designed to provide a consistent method for combining outage information obtained from various sources to estimate total critical service outages. It also provides a rapid, interactive means for updating and displaying outage estimates.
- The BC&R Assessment Decision Support Tool helps to develop and summarize local assessment results. These are obtained from ERT members in a question-and-answer format using the tool. Subsequent analysis performed by the tool generates findings and recommendations for restoring normal operations.

4.5.4 Systems Engineering Challenges

BC&R planning for a particular enterprise is typically based on systems engineering analyses such as the following:

- Identification of critical applications and resources
- BC&R requirements analysis
- Determination of risk (i.e., probability of occurrence of adverse events)
- Evaluation of vulnerability (i.e., impact of identified adverse events should they occur) of critical resources (e.g., key personnel; critical applications hardware, software, data and documentation; facilities, and infrastructure)
- Development of candidate concepts and architectures for BC&R storage, communications, and processing resources
- Analysis of scenarios for identified vulnerabilities and architectures
- Performance of cost-benefits tradeoff studies for candidate architectures

Systems Engineering Applications

Specific technical knowledge may be required to assist a particular business with continuity and recovery planning and procedures, in addition to the high availability services mentioned in Table 4.5–1. Many more businesses are increasingly reliant on the Internet for critical applications. Knowledge of client/server environments, distributed systems, networks, and voice communications may be needed. Specific technical knowledge is required for protection of data warehousing systems and e-commerce. Financial institutions, securities firms, and banks may need specialized "trading floor" continuity provisions. Distributed environments present special challenges to disaster recovery planning in the identification of enterprise-critical processes and data, and in the rapid pace of hardware, software, and configuration changes. However, a distributed architecture may have built-in redundancy and replication that could be leveraged by a disaster recovery plan using systems engineering techniques. Finally, new technologies such as storage area networks are emerging, which will offer more options for managing data and transaction backup. Table 4.5–2 describes the systems engineering challenges in the emergency services application domain.

Table 4.5–2. Systems Engineering in the Emergency Services Application

Systems Engineering Requirements	Whole-system view for cost-effective and enterprise-tailored BC&R solution
Systems Engineering Strengths	Facilitate identification of critical processes, data through systems engineering techniques such as functional analysis
Systems Engineering Challenges	Plan and build for BC&R during system life cycle; keep pace with new technologies for data backup
Unique Systems Engineering Tools or Techniques	Assessment and decision support tools
Systems Engineering-Related Standards	None known; on-going discussion on how to integrate BC&R with quality-oriented standards such as ISO 9001, TQM

4.5.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

Rebecca Cook
E-mail: rcook@erols.com

LeRoy Botten
3715 Capulet Terrace
Silver Spring, MD 20906
Voice: 301-985-8726
Fax: 301-985-8909

Drew Riggs
10008 Branch View Court
Silver Spring, MD 20903

4.5.6 References and Regulations

Drew Riggs and Botten, LeRoy, "Assessing Emergencies and Making Disaster Recovery Decisions," *Proceedings of the Eighth Annual International Symposium of the International Council on Systems Engineering*, INCOSE '98, Vancouver, July 1998, pp. 161–168.

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4.6 Energy Systems

4.6.1 Introduction

One of the most difficult systems problems facing the world today is the escalating imbalance between energy supply and demand. The multidimensionality of the problem threatens to disrupt the economic, social, and political structures of all countries heavily dependent on the use of petroleum and natural gas. In the 1970s, the energy problem manifested itself in the form of long lines at gasoline stations, rising prices for all products dependent on petroleum supplies, and a resultant depressed world economy. In the United States, the root cause of the problem has been stated, almost universally, as the "insatiable demand of the American public for energy as reflected in the exponential growth of its demand." Energy consumption in the United States between the years 1900 and 1970 is illustrated in Figure 4.6–1, along with projections to the year 2000. From 1900 to 1970, the consumption of energy in the United States grew from approximately 7 quadrillion British thermal units (BTUs) to 70 quadrillion BTUs, a tenfold increase. Between 1970 and the year 2000, just 30 years, the United States is projected to consume more energy than it has in its entire history. This figure shows a significant jump in the rate of increase of energy consumption since 1965, generally attributed to the rapid growth of air conditioning of homes and office buildings, the expansion in the use of home heating appliances, and the increased use of energy in industrial processes. Most important, the total energy consumption was more than 70-percent dependent on the use of oil and gas in 1975, both of which are in domestic short supply. Both nuclear energy and coal via gasification or liquefaction are expected to play a more significant role in energy use.

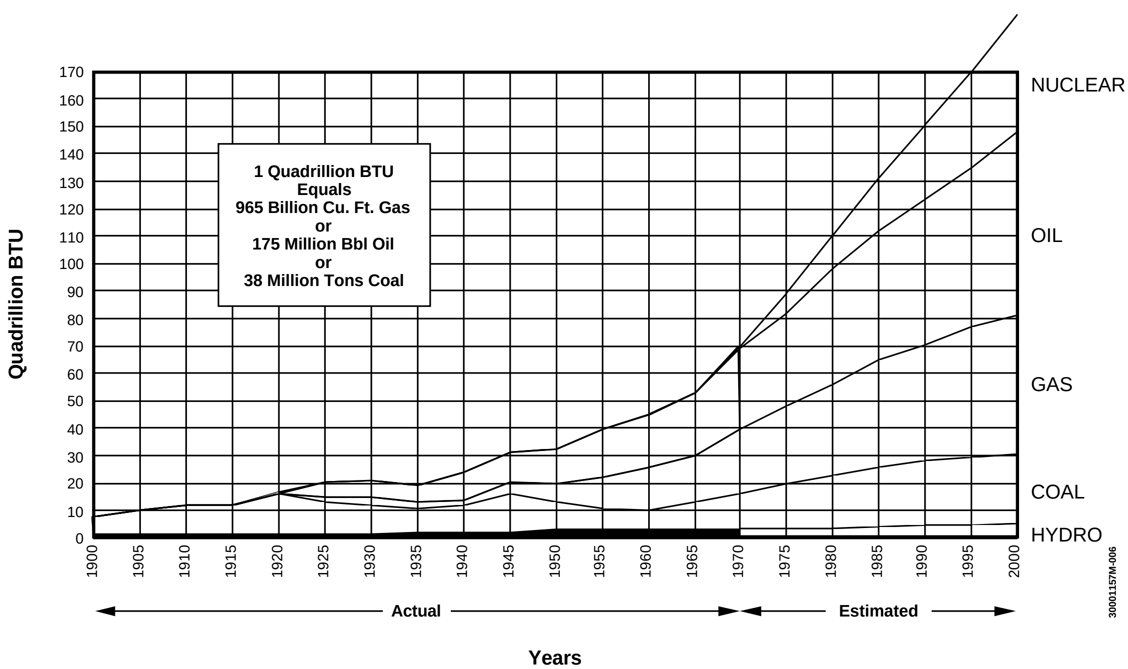


Figure 4.6–1. U.S. Energy Consumption in the 20th Century

Systems Engineering Applications

The link between energy consumption and a nation's economy is demonstrated in Figures 4.6–2 and 4.6–3. Figure 4.6–2 illustrates a close correlation between the gross national product (GNP) and energy consumed and implies that any change in energy consumption will reflect itself as a corresponding change in GNP. Figure 4.6–3 illustrates a rough correlation between per capita consumption of energy and per capita GNP on a global basis. In general, high per capita energy consumption is a prerequisite for high output of goods and services. If the position of the United States is considered to establish an arbitrary straight line, plotted from the origin most countries lie along that line. The left side of the figure shows a cluster of developing countries of the world—countries with a low per capita use of energy and a low per capita GNP. The majority of the developed nations are in the center of the chart, while the United States stands alone, by far the world's largest per capita user of energy with the highest per capita GNP.

In addition to understanding the energy demand (particularly of petroleum and natural gas) and the importance of energy resources to a growing economy, it is appropriate to examine the development of the U.S. energy problem. In 1960, the net imports equaled about 1.6 million barrels of oil per day. The spare productive capacity, or the amount of oil the United States was capable of producing in excess of the amount used, was about 2.6 million barrels. Had the supply of foreign oil been cut off, the United States would have been more than capable of taking up the slack. Sometime during 1967, this self-sufficiency was lost and the United States became dependent on foreign oil. Thus began the energy problem; namely, growing demand for oil accompanied by a decreasing ability to domestically supply it. Unfortunately, the future gives only further evidence of a rapid erosion of oil independence.

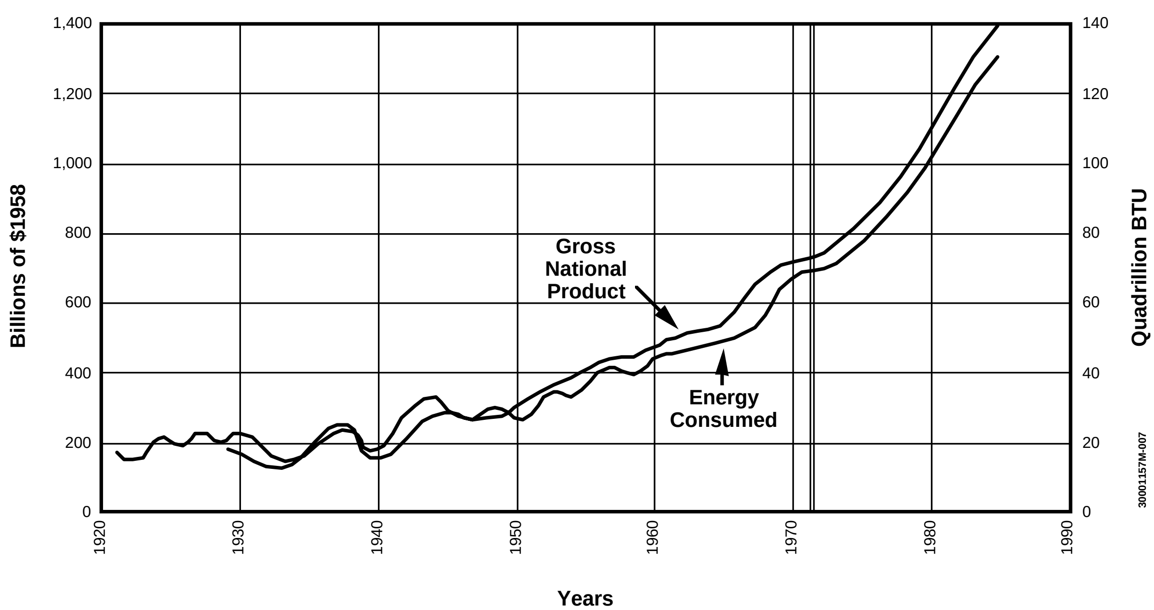


Figure 4.6–2. Energy Use and GNP Are Closely Related

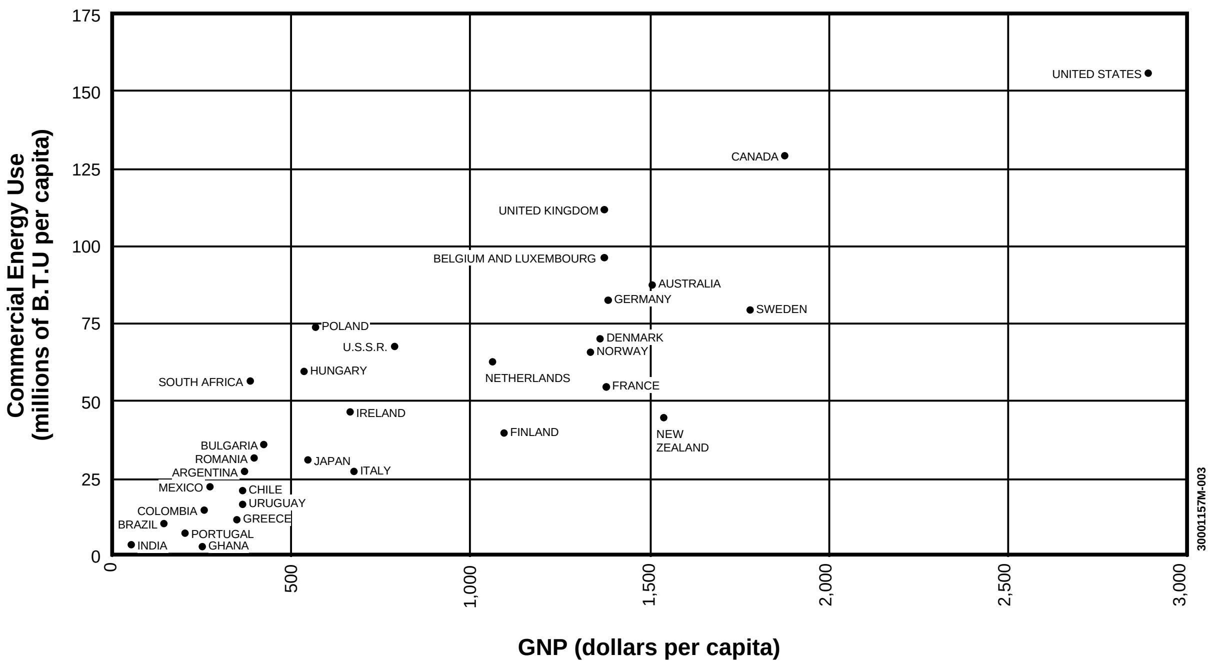
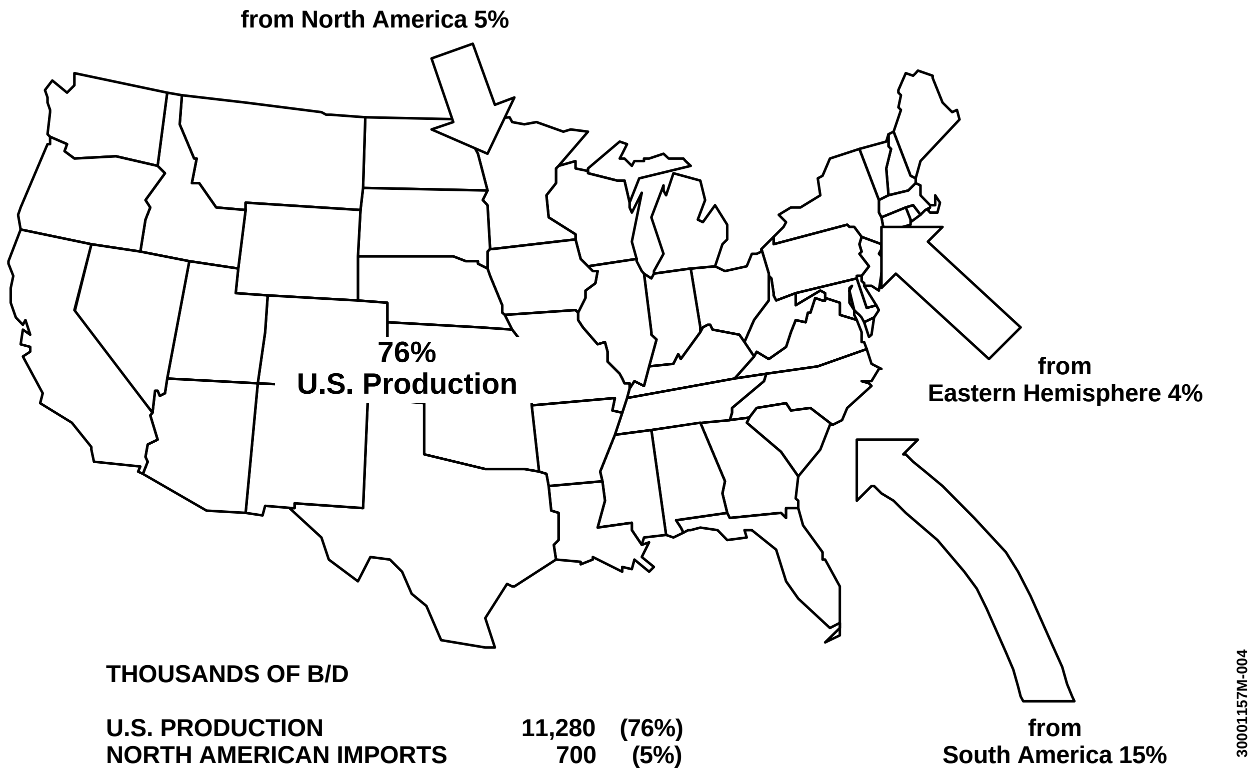


Figure 4.6–3. Per Capita Energy Use Versus GNP

The U.S. dependency on oil imports is further illustrated by 1970 and 1985 profiles (Figures 4.6-4 and 4.6–5, respectively). In 1970, 24 percent of the oil used in the United States came from foreign sources and was therefore outside effective political and economic control. The dominant reliance was on South America, which supplied 15 percent of the total, and on Canada, which supplied 5 percent. United States reliance on the Middle East and on North and West Africa combined was only 4 percent. For 1985, two possibilities for oil import dependency are illustrated in Figure 4.5–5. With the Alaska North Slope producing 2 million barrels per day (or 8 percent of the total requirement), 57 percent of the oil used in the United States would need to be imported, 36 percent of which would be supplied by the Middle East. Without the Alaska North Slope production, the additional 8 percent would be required from the Middle East, or 44 percent in all. This, in essence, means that the Middle East would have been the major source of supply. Fortunately, the United States chose to develop the North Slope resources. Unfortunately, oil tanker disasters such as the Exxon Valdez compromised the environmental integrity of the Alaskan Prince William Sound.

A map produced by the Office of Oil and Gas, Department of Interior, reveals why so much foreign oil must come to the United States from the Middle East. A 1975 estimate of world oil reserves listed in Table 4.6–1 indicates that there are approximately 667 million barrels of proven reserves, more than 80 percent of which are located in the Middle East, Africa, or the former Soviet Union.

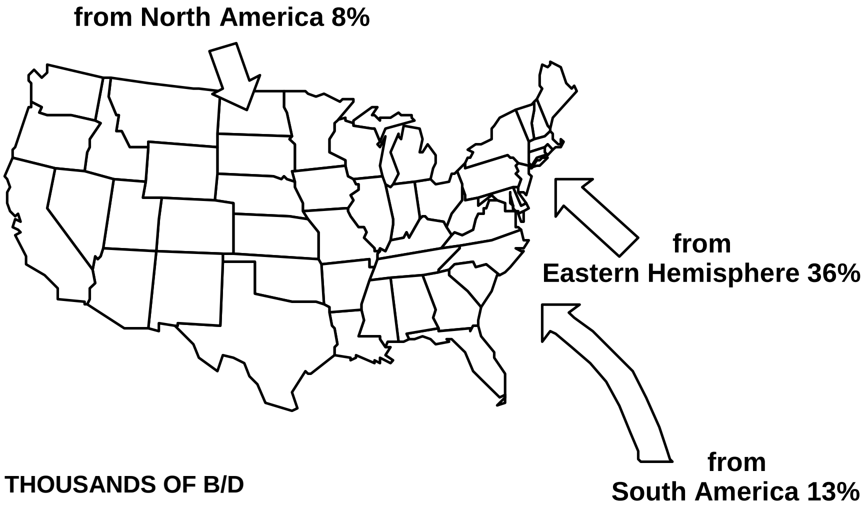
It is apparent that there is an abundance of oil, but it is under the control of only a few countries. Moreover, these oil-exporting countries have joined in a price-fixing cartel sometimes called “the greatest monopoly in history" [Burck, 1973]. By 1980, the oil-important countries transferred more than $200 billion to the members of the Organization of Petroleum Exporting Countries (OPEC)—Abu Dhabi, Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, and Venezuela.



THOUSANDS OF B/D

U.S. PRODUCTION	11,280	(76%)
NORTH AMERICAN IMPORTS	700	(5%)
SOUTH AMERICAN IMPORTS	2,200	(15%)
EASTERN HEMISPHERE IMPORTS	530	(4%)
TOTAL SUPPLY	14,710	

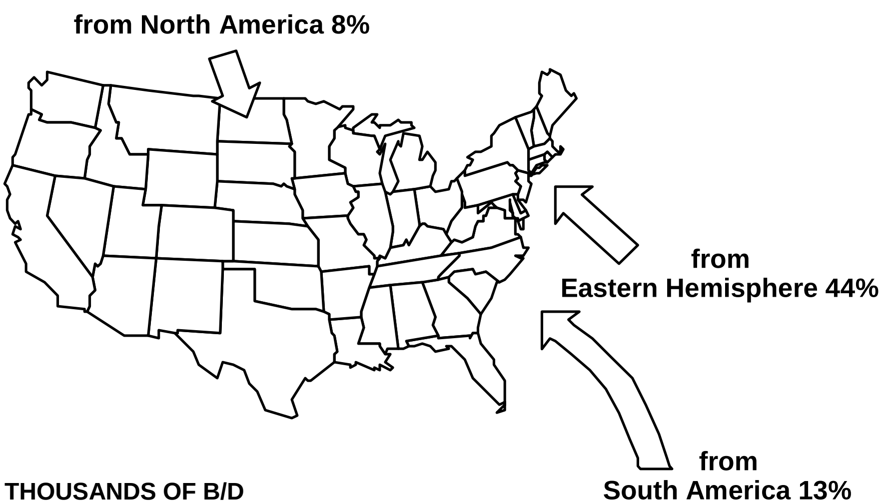
Figure 4.6–4. 1970 U.S. Dependency on Oil Imports



THOUSANDS OF B/D

WITH NORTH SLOPE

U.S. PRODUCTION	9,165	(35%)
ALASKA NORTH SLOPES	2,000	(8%)
NORTH AMERICAN IMPORTS	2,200	(8%)
SOUTH AMERICAN IMPORTS	3,500	(13%)
EASTERN HEMISPHERE IMPORTS	9,585	(36%)
TOTAL SUPPLY	26,450	



THOUSANDS OF B/D

WITHOUT NORTH SLOPE

U.S. PRODUCTION	9,165	(35%)
ALASKA NORTH SLOPES	---	---
NORTH AMERICAN IMPORTS	2,200	(8%)
SOUTH AMERICAN IMPORTS	3,500	(13%)
EASTERN HEMISPHERE IMPORTS	11,585	(44%)
TOTAL SUPPLY	26,450	

30001157M-

Figure 4.6–5. 1985 U.S. Dependency on Oil Imports

Table 4.6–1. The World's Oil (1975)

	Proven Reserves (millions of barrels)	Percent of World Total	1972 Production (millions of barrels)	Production as Percent of Reserves
Middle East	355,852	53.3	6,611	1.9
Africa	106,402	15.9	2,172	2.0
Soviet Union	75,000	11.2	2,876	3.8
United States	36,823	5.5	3,455	9.4
South America	27,782	4.2	1,540	5.5
China	19,500	2.9	186	1.0
Canada	10,200	1.5	554	5.4
Indonesia	10,005	1.5	387	3.9
Western Europe	8,582	1.3	113	1.3
Other	16,737	2.5	674	4.0
Total	666,883	100.0	18,568	2.8

Although the dimensions of what was termed an "Energy Crisis" in 1973 had been plotted by energy researchers for decades, the inattention by government and industry to fuel and energy problems, along with a sudden increased interest in environmental matters, caused the United States and other industrialized nations to become more dependent on oil-exporting countries for petroleum supplies. The Arab oil embargo from October 1973 until March 1974 served to bring the implications of that dependence into focus. A major result of the imposition of the embargo was the announcement in November 1973 of Project Independence.

Project Independence originally set 1980 as the year by which the United States was to achieve self-sufficiency in energy. The definition and timetable for Project Independence were later modified to achievement by 1985 of operating self-sufficiency, defined as limiting oil imports to 15 percent or less of demand by means of rapid development of domestic off-shore reserves [U.S. Atomic Energy Commission, 1973]. In addition, rapid large-scale development of other domestic sources such as coal, nuclear power, natural gas, and oil shale would have had to occur, and total energy demand growth would have to decline from about 4.3 percent per year to about 3 to 3.5 percent per year [Putnam and O'Brien, 1975].

In summary, the exponential growth in demand for energy, an energy economy centered about the oil and gas resources, and the inability to supply those energy resources domestically led to a greater dependence on foreign sources for oil. The monopolistic practices of OPEC raised the price of oil from $4 to $10 per barrel and caused a drastic shift in the flow of money to the Middle East [*New York Times*, 1975]. These practices contributed to a worldwide energy crisis in 1973, a general economic depression throughout the world, and an increase in political tensions surrounding the Middle East. The road to energy self-sufficiency is long and expensive, but offers the technological community the opportunity to reshape the manner in which humans live.

4.6.2 Energy Systems Functions and Processes

A national emphasis on energy research and development began to take shape in the form of an Energy Research and Development Administration (ERDA) established by Congress as of February 14, 1975. ERDA combined the energy research and development functions of the former Atomic Energy Commission, as well as the Department of Interior, NASA, National Science Foundation, and other agencies having energy activities. ERDA later became the Department of Energy under the Carter administration.

The mission of Department of Energy is to manage The National Energy Research and Development Program needed to regain and maintain energy self-sufficiency. As a result of this effort, five tasks were recommended for the United States to regain and sustain energy self-sufficiency. These tasks, in order of importance, were to

- Conserve energy by reducing consumption, and conserve energy resources by increasing the technical efficiency of conversion processes.
- Increase domestic production of oil and natural gas as rapidly as possible.
- Increase the use of coal, first to supplement and later to replace oil and natural gas.
- Expand the production of nuclear energy as rapidly as possible, first to supplement and later to replace fossil energy.
- Promote, to the maximum extent feasible, the use of renewable energy sources (e.g., hydro, geothermal, solar), and pursue the promise of fusion and central station solar power.

From these tasks, the sources of energy in their order of development as a major energy supply are petroleum and gas, coal, nuclear, and renewable energy sources. In more recent years, the focus of the DOE has been on environmental restoration resulting from the nuclear weapons program of the United States.

The computer has become a fundamental tool in the exploitation of two of these energy sources: petroleum and gas, and nuclear. Table 4.6–2 illustrates some of the major scientific computer applications within the energy and power industries broken down by the following market segments:

- *Exploration and Extraction*—Exploration is defined as the process of conducting a systematic search for petroleum, gas, or uranium ore. Extraction is defined as the separation of petroleum, gas, or uranium ore from its deposit locations.
- *Refining and Fabricating*—Refining (of petroleum) is defined as the processes of fractional distillation and organic cracking to produce a marketable petroleum end product. Fabricating (of uranium) is defined as the processes of milling, gaseous diffusion, and fuel pellet compaction required to produce fuel rods, bundles, and the reactor core.

Table 4.6–2. Scientific Computer Applications Within the Energy and Power Industries

Energy and Power Market Segments	Petroleum and Gas	Nuclear
Exploration and extraction	Seismic signal processing image (or picture) processing	Seismic signal processing
Refining and fabricating	Linear programming	Reactor core analysis
Utility conversion		Nuclear fuel management and nuclear reactor monitoring
Energy and power transmission and distribution	Fuel allocation and pipeline network control	Power systems simulation and electric network monitoring

- *Utility Conversion*—Utility conversion is defined as the process of changing heat obtained from fossil or nuclear fuel consumption into electrical power. The fuel of specific interest here is nuclear fuel (fissionable uranium and plutonium).
- *Energy and Power Transmission and Distribution*—Transmission is defined as the transport of large volumes of energy over high-voltage electrical power lines and high-flow petroleum or gas pipeline lines. Distribution of electricity is defined as the transport of power over that part of an electric supply system between bulk power sources (such as generating stations or transformation stations tapped from transmission lines) and the consumer’s service switches. Distribution of petroleum or gas is defined as the transport of the end product from bulk sources (e.g., petroleum depots or pipeline substations) to the consumer.

4.6.3 Technology Profiles

The rest of this section discusses the computer requirements of the energy and power applications listed in Table 4.6–2. Matrix solution methods used to solve these problems are illustrated in Table 4.6–3.

Table 4.6–3. Energy and Power Applications Versus Matrix Solution Methods

Energy and Power Computer Applications	Matrix Solution Methods (Matrix Characteristics)
Seismic signal processing	Convolution, fast Fourier transform, linear interpolation (filled vector arrays)
Image processing	Fast Fourier transforms, fast Hadamard transforms, Haar and Walsh transforms (filled vector arrays)
Linear programming (refining and fuel allocation)	Simplex method (nonpatterned sparse matrixes) (packed arrays)
Reactor core analysis and nuclear fuel management	Partial differential equation solution methods
Power systems simulation	Newton-Raphson method (nonpatterned sparse matrixes) (packed arrays)

4.6.4 Systems Engineering Challenges

The challenges in energy development are enormous, and only a few such challenges can be related here. The challenges selected are all computer-related and are related to such areas as safety, resource removal, environmental restoration, and distribution:

- Petroleum systems
  - Secondary and tertiary recovery techniques
  - Prevention of oil spillage
  - Environmental restoration after oil catastrophes
  - Oil shale recovery systems
- Coal systems
  - Coal gasification system development
  - Coal liquification system development
  - Clean coal combustion systems
- Nuclear fission systems
  - Nuclear reactor safety
  - Nuclear safeguards of strategic nuclear material
  - Nuclear waste management
- Nuclear fusion systems
  - Proof of principal magnetic confinement
  - Proof of principal laser implosion experiments
- Renewable fuel systems
  - Economic solar photovoltaic systems
  - Wind exploitation systems
  - Geothermal system development
  - Tidal systems development
- Conservation systems
  - Building designs with integrated conservation techniques
  - Reengineering of existing structures
  - Economic conservation measures

4.6.4.1 Seismic Signal Processing

Because there are no direct means of detecting petroleum and gas deposits, seismic signal data processing is the primary geophysical method used to explore for new sources of petroleum and gas. As exploration for uranium deposits moves to depths greater than 500 feet, seismic signal processing becomes more significant as an exploration method for this energy source. Seismic methods measure the time taken by seismic waves to travel from an explosion, or shot point, through subsurface rocks and reflect back to surface-based sound sensors, or geophones. The purpose of seismic data processing is to reduce large amounts of data and to reconstruct a graphical cross-section of the Earth substructure at the exploration site.

The volume of seismic data is enormous. For example, a single seismic shot on land measured for 6 seconds and sampled at one-thousandth of a second may produce a seismic record of 144,000 data elements. The data elements consist of 24 traces with 6000 points per trace. To calculate one point of the autocorrection function of a trace requires 6000 multiply-adds. Data also is gathered on marine exploration ships used for exploration offshore over the continental shelf. A single seismic shot can generate one record of 48 traces, and each trace may consist of 9000 points. To perform a convolution in data reduction on this set of points requires some 864 million multiply-add operations. A third-generation 1-MIP computer required 3 hours 36 minutes to perform this convolution.

4.6.4.2 Image (or Picture) Processing

A relatively new field of image processing has emerged from the aerospace industry as a large data processing problem. Geologists have explored for oil, geothermal sites, copper, and other metals by studying Earth Resources Technology Satellite (ERTS) imagery of Alaska, Oklahoma, and the Rocky Mountains [*U.S. News and World Report*, 1974]. A complete image processing system has three primary processes: the image enhancement process, image compression process, and image classification process. These processes are illustrated in Figure 4.5–6 and discussed in great detail by Rosenfield, 1969, and Andrews, 1970.

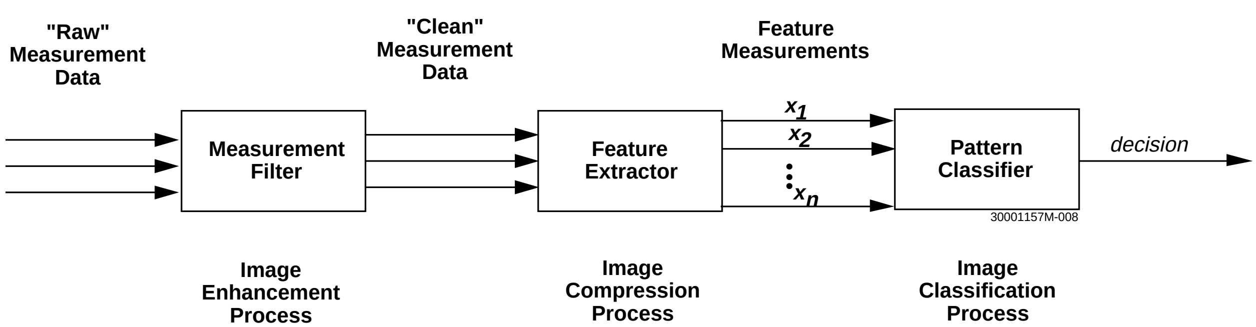


Figure 4.6–6. Image Processing System

The purpose of data enhancement is to take raw measurement image data and perform filtering operations, fast Fourier, Walsh, Haar, and Hadamard transformations, which make the image cleaner and sharper. The end product of an image enhancement process is a clear picture. ERTS imagery enhancement has been performed by hybrid computing systems; however, all-digital systems using the high-speed array processor concept have been suggested [Honikman et al., 1973, and Andrews, 1970] and implemented. The image compression and classification processes replace the original image by concise feature measurements and classify the images into pattern groups.

4.6.4.3 Linear Programming

Linear programming applications in the oil industry are many and varied; they include product distribution, gasoline refining and blending, capital investment planning, energy balancing, inventory optimization, refinery scheduling, crude oil evaluation, grass roots refining and chemical facility planning, integrated crude supply—refining production—distribution systems, and refined process planning [Capp et al., 1970]. Linear programming is used to determine the optimum allocation of resources (e.g., capital, crude oil, pipelines, plant capacities) to obtain a particular objective (e.g., maximum profit, minimum cost, maximum production, minimum tetraethyl lead) when there are alternative uses for the resources and physical or business restrictions on the use of each resource.

The basic linear programming algorithm, known as the SIMPLEX algorithm, was formed by Dr. George B. Dantzig at the Rand Corporation. To solve a problem using the linear programming algorithm, the problem must be mathematically described by a set of linear equations that represent the real physical or economic situation being studied.

Large third-generation computers (e.g., IBM 370/158, UNIVAC 1110, CDC 6600) have been required to solve a typical 4000-equation and 10,000-variable linear programming problem. Even such computers require 20 hours to solve a 4000-equation model.

4.6.4.4 Reactor Core Analysis, Nuclear Fuel Management, and Nuclear Reactor Monitoring

The application of high-speed computers to nuclear reactor calculations dates from the beginning of the parallel development of high-speed digital computers and nuclear chain reactors [Cuthill, 1964]. Digital computers have become a basic tool in nuclear reactor design. Nuclear calculations analyze the neutron flux primary to the nuclear reaction, calculate the rate of nuclear fuel burnup, and determine the economics of the nuclear power plant. Other miscellaneous applications in reactor design result in nuclear codes to analyze heat transfer, structural design, hydrodynamics, radiological safety, and data reduction studies. Nuclear reactor designers are interested in the engineering details required for reactor core analysis and the electric utilities are concerned with nuclear fuel management to obtain optimum reactor and fuel performance.

Digital computers also are used to control the nuclear reactor. These control computers monitor the reactor, calculate its performance, and control the moderating rods of each reactor. Such computers are small and usually sold as part of the instrumentation.

The reactor design and engineering segments of the nuclear industry use the largest computers commercially built to perform the exhaustive engineering calculations. Typical three-dimensional multigroup diffusion problems can require 1 to 2 hours on a large computer (e.g., CDC 6600, IBM 370/158, UNIVAC 1110) [Butler et al., 1969].

4.6.4.5 Power Systems Simulation and Electric Network Monitoring

The most important, often used, and time-consuming power engineering computer applications are those that simulate the operation of the power system. Power system simulation studies are performed on load flow, transient stability, and fault analysis problems.

Digital computers also are being used to monitor and control transmission and distribution networks via high-speed data acquisition subsystems. The control systems combine the functions of generation dispatch and supervisory control integrated into a hierarchical structure of computer systems and control functions. This hierarchical structure requires large computers with multiprocessing capability at the highest level and several layers of midsize and minicomputers at transmission substation and generation station levels.

While most load flow problems can be processed with the present generation of computers, the trend toward integrated power networks may require a larger computing capability to fully simulate the power systems. In addition, there is an urgent need for improvement in transient stability computation because the time-domain simulation is prohibitively slow. For a detailed study of a 2000-bus, 500-generator system, at least 30 minutes of computing time is required to simulate 1 second of real time using a CDC 6400 computer [Tinney and Enns, 1974].

4.6.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

William F. Mackey
Computer Sciences Corporation
7700 Hubble Drive
Lanham-Seabrook, MD 20706
Voice: 301-794-2138
E-mail: wmackey@csc.com

4.6.6 References

Andrews, H.C., *Computer Techniques in Image Processing*, Academic Press, 1970

Argonne Code Center: Compilation of Program Abstracts, Argonne National Laboratory, 9700 South Cass Ave., Argonne, Illinois 60439

Atomic Energy Commission Data (December 31, 1973), *Business Week*, February 16, 1974, p. 58E

Birkoff, G., “Some Mathematical Problems of Nuclear Reactor Theory,” *Frontiers of Numerical Mathematics* (R.E. Langer, ed.), University of Wisconsin Press, Madison, Wisconsin, 1960

Bourgeois, A. J., and Jones, C., "How Shell Configures EDP Equipment for Exploration," *Oil and Gas Journal*, February 14, 1972, pp. 105–110

Burck, G., "The Greatest Monopoly in History," *Fortune*, April 1973, pp. 153–154

Butler, M. et al., *Argonne Code Center: Compilation of Abstracts*, ANL-7411, Supplement 3, Abstract 275-PDQ7, April 1969

Capp, W. B. et al., *Applications of Linear Programming and Extensions in the Oil Industry*, Gulf R&D Company, Report GA-9926, February 1, 1970

Cooley, J. W., and Tukey, J. W., "An Algorithm for the Machine Calculation of Complex Fourier Series," *Math of Computers*, Vol. 19, April 1965, pp. 297–301

Cuthill, E., "Digital Computers in Nuclear Reactor Design," *Advances in Computers*, Volume 5, 1964, pp. 291–293

Darby, E. K., Mercado, E. J., and Zoll, R. M., Seismic Data Processing Operating Procedures, Gulf General Atomic, G.A.-10177, June 1, 1970

Darby, E. K., et al., *Seismic Data Processing Routines*, Gulf Oil Corporation, G.A.-10386, October 1, 1970

DyLiacco, T. E., "Real-Time Computer Control of Power Systems," *Proceedings of the IEEE*, July 1974, pp. 884–891

Energy Resources, The President's Message to the Congress, June 4, 1971

Friedlander, G. D., "Managing Megawatts: A Case History," *IEEE Spectrum*, May 1972, pp. 39–42

Gentleman, W. M., and Sande, G., "Fast Fourier Transform – for Fun and Profit," *Proceedings – Fall Joint Computer Conference*, 1966, p. 563

Graham, W. R., "The Parallel and the Pipeline Computers," *Datamation*, April 1970, pp. 68–71

Healy, T. J., "Convolution Revisited," *IEEE Spectrum*, April 1969, pp. 87–93

Hobbs, L. C., and Theis, D. J., "Survey of Parallel Processor Approaches and Techniques," *Parallel Processor Systems, Technologies, and Applications*, Spartan Books, New York, 1970

Honikman, T., McMahon, E., et al., *Image Data Processing System Requirements Study*, General Research Corporation, Arlington, Virginia, Report WGRC 73-3273, October 1973

Instrumentation Market Analysis, Stanford Research Institute, March 1968, pp. 184–185

Krause, Paul C., Lipo, T. A., and Carroll, D. P., "Applications of Analog and Hybrid Computation in Electric Power Systems Analysis," *Proceedings of the IEEE*, July 1974, pp. 994–1009

Lindsey, J. P., and Herman, A. J. (Geocom, Inc.), “Multiprocessing of Seismic Data Is Gaining Acceptance,” *Oil and Gas Journal*, February 14, 1972, pp. 99–104

Mackey, W. F., *A New Concept in Power Systems Computation*, Edison Electric Institute, Engineering and Technical Systems Computer Committee Seminar, Boston, Mass., June 11, 1974

Mackey, W. F., *Array Processing of Large Scale Energy Systems*, Doctoral Dissertation in Systems Engineering, University of Pennsylvania, 1975

On-Line Computer Automates BPA System, *Electrical World*, July 1, 1972, pp. 60–62

Petrodollar Outlook, *The New York Times*, February 13, 1975

Proceedings of Symposia in Applied Mathematics, Volume XI, Nuclear Reactor Theory (G. Berkoff and E. P. Wigner, eds.), American Mathematical Society, Providence, Rhode Island, 1961

Putnam, B. M., and O’Brien, P. J., *Outlook for the Oilfield Service and Supply Industries Through 1985*, A. D. Little, Inc., January 1975

“Record $6.2-Billion is Bid for U.S. Offshore Leases,” *New York Times*, May 20, 1973, p. 55

Rosenfield, A., *Picture Processing by Computer*, Academic Press, 1969

“Servants in Space,” *U.S. News and World Report*, July 29, 1974, p. 45

Shanks, J. L., and Kerns, T. W., “Use of a Digital Convolution Device to Perform Recursive Filtering and the Cooley-Tukey Algorithm,” *IEEE Transactions on Computers*, Volume C-17, No. 10, October 1968, pp. 943–949

“Spreading Across the U.S., A Feverish Search for Oil,” *U.S. News and World Report*, July 29, 1974, pp. 24–26

Stagg, G. W., and El-Abiad, A. H., *Computer Methods in Power System Analysis*, McGraw-Hill, Inc., 1968

Stewart, H. G., PJM Center Analyses, Control System, *Electrical World*, November 1, 1970

The Frantic Bidding for Offshore Leases, *Business Week*, September 16, 1972, p. 32

The 1970 National Power Survey, Guidelines for Growth of the Electric Power Industry, Federal Power Commission, U.S. Government Printing Office, Washington, DC, December 1971

The Nation’s Energy Future, U.S. Atomic Energy Commission, WASH-1281, U.S. Government Printing Office, Washington, DC, December 1, 1973

The Nuclear Industry – 1971, WASH 1174-71, USAEC, Division of Industrial Participation, U.S. Government Printing Office, Washington, DC

Tinney, W. F., and Enns, M. K., Controlling and Optimizing Power Systems, *IEEE Spectrum*, June 1974, pp. 56–60

Tinney, W. F., and Hart, C. E., Power Flow Solution by Newton's Method, *IEEE Transactions (Power App. Syst.),* Volume PAS-86, November 1967, pp. 1449–1456

Tinney, W. F., and Walker, J. W., Direct Solutions of Sparse Network Equations by Optimally Ordered Triangular Factorization, *Proceedings of the IEEE*, Vol. 55, November 1967, pp. 1801–1809

"Utilities Strive for Fuel Management," *Electrical World*, November 24, 1969

Winger, J. G., et al., *Outlook for Energy in the United States to 1985*, The Chase Manhattan Bank, Energy Economics Division, June 1972

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4.7 Environmental Restoration

4.7.1 Introduction

The new environmental restoration industry in the United States and throughout the world was brought about by the environmental problems associated with past actions. Some of the risks in this application domain include obtaining political and societal support of complex technical issues and developing technologies and systems to effectively deal with the problems.

Table 4.7–1 summarizes the environmental restoration industry. Table 4.7–2 focuses on the application of systems engineering in the environmental restoration industry. (Note: These tables will be added at a later date.)

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4.8 Facilities Systems Engineering

4.8.1 Introduction

Facility is defined as "something created to serve a particular function." In this context, facilities have existed since the emergence of mankind. In the context used in this document, facilities are defined as "any fixed assets used in the creation of a product or service." A typical facility system is illustrated in Figure 4.8–1. In this context, facilities are not industry sectors, but rather the enabling basis for each sector's product or service.

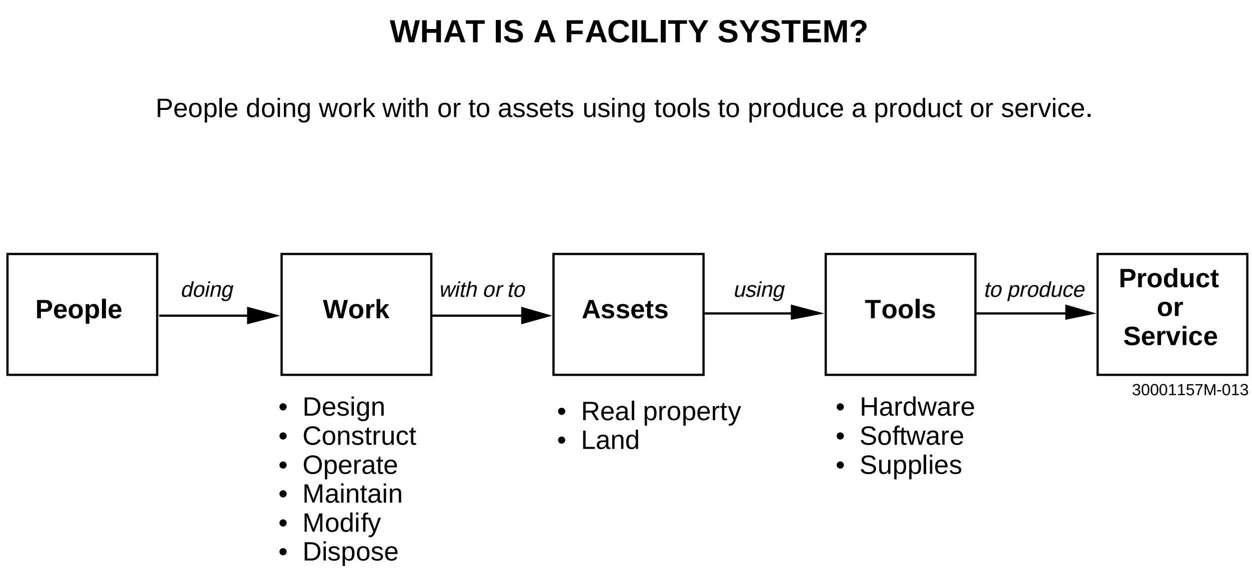

Figure 4.8–1. Typical Facility System

From medieval times until the beginning of the industrial revolution, facilities were little more than simple, easily managed households. Around the beginning of the 20th century, the complexity of facilities began to increase dramatically. Today, with the use of automation, our facilities have become highly productive and complex. Risks in this sector include human safety, impact to the environment, quality of product or service, and cost containment.

4.8.2 Systems Engineering Challenges

The application of systems engineering to facilities can be broken down as presented in Figure 4.8–2.

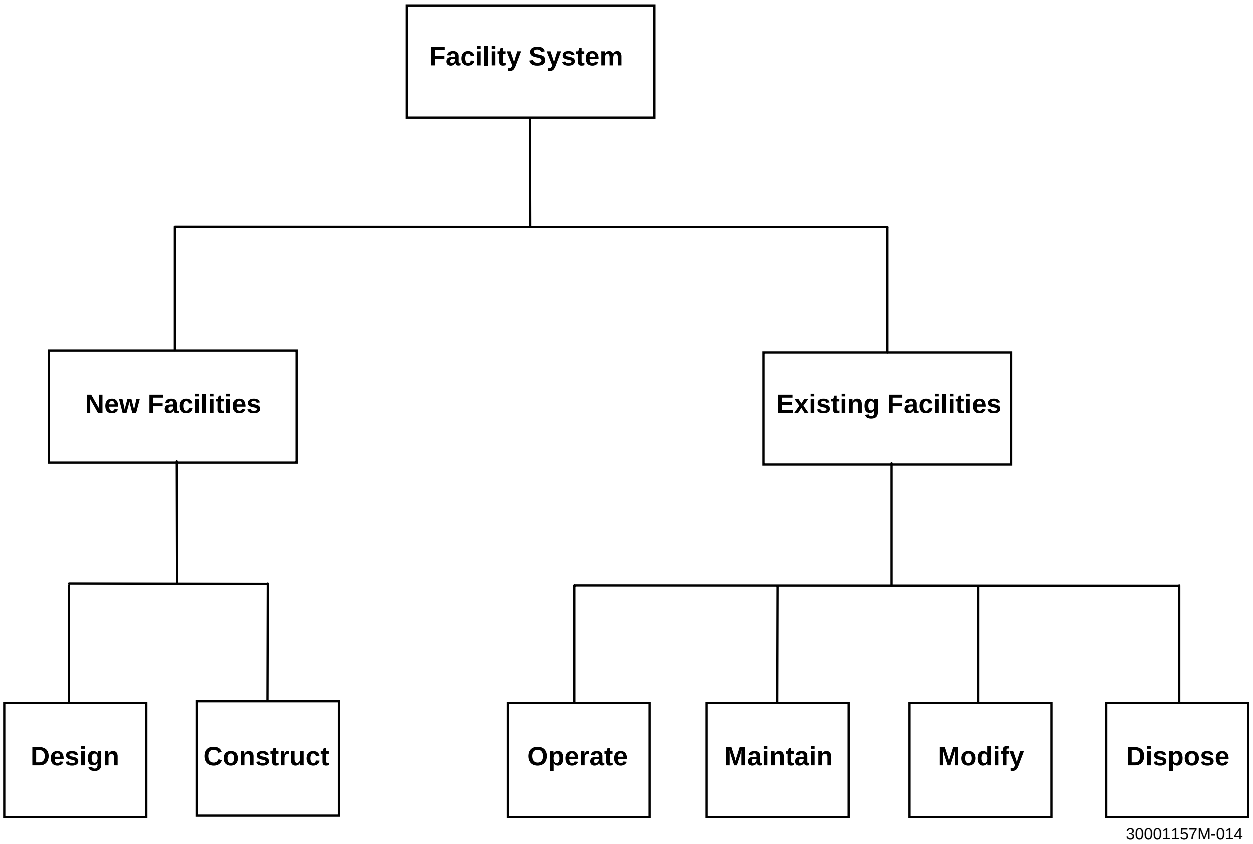

Figure 4.8–2. Breakdown of Systems Engineering Application to Facilities

4.8.2.1 New Facilities

In many government programs, money is appropriated for various facility elements and must be used within a certain timeframe. If not used within the allotted time, the funding is lost. This forces the applicable effort to be schedule driven with no apparent regard for other dependent element efforts. A recent example of this is the schedule-driven design and construction of a building to house a yet-to-be-designed, large simulator. An early concept subscale version of the simulator was used to predict the full-scale simulator dimensions and as a basis for the building design. As the building was nearing completion, it was discovered that the full-scale simulator was going to be larger than predicted and would not fit in the allotted space. Consequently, costly rework was required.

In both commercial and government sectors, facilities are usually designed by one concern and constructed by another. This “over-the-wall” design and build causes numerous problems. The current move is toward “design-and-build” concerns that offer “turn-key” facilities ready for operation.

The challenge to systems engineering is to establish schedules that are event driven rather than events that are schedule driven and to integrate the needed disciplines into the effort.

4.8.2.2 Existing Facilities

As shown in Figure 4.8–2, existing facilities have four predominant efforts:

- Within the modify effort, the same problems and challenge to systems engineering exist as for new facilities discussed in Section 4.8.2.1.
- In the operate, maintain, and modify efforts, strict configuration control must be emphasized because any change will have some impact. However, operation and maintenance data may indicate the need for changes necessary to make the facility more efficient, reliable, supportable, or capable to meet new requirements. Some of these changes may reduce the cost of operations, operating hazards, or impact to the environment.
- Many existing facilities were designed and constructed before the advent of systems engineering. Configuration and data management were nonexistent or haphazard. Documentation defining the facilities is not available or is not current. The lack of accurate, complete, and current documentation is costly to and impedes all four efforts.
- Until the past few years, the disposal effort was rarely considered. Facilities were abandoned and left to be consumed by natural decay. However, the advent of nuclear facilities and the rise of environmental awareness have forced this effort to be addressed early in the planning phase.

The greatest challenge to systems engineering is to convince management that there is a need for systems engineering and that there will be value added with its use.

4.8.3 Technology Profiles

To be supplied.

4.8.4 Systems Engineering Challenges

To be supplied.

4.8.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

Bill Henderson
Sverdrup Technology
430 Second Street
Arnold Air Force Base, TN 37389-4200
Voice: 615-454-5295
E-mail: hendersonwf@hap.arnold.af.mil

4.8.6 References

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4.9 Geographic Information Systems

4.9.1 Introduction

GIS is a relatively new industry that uses computers to provide a variety of information about spatially related items. Industries as diverse as banking, transportation, and government use GIS in their planning, sales territory strategies, and problem solving. Any company with a sales force can benefit from GIS in planning and operations.

GIS is a rapidly growing industry in both products (e.g., software such as GIS tools and hardware such as global positioning systems) and services (e.g., helping companies accomplish GIS projects). GIS projects have included tracking the thousands of homes and properties burned in the 1991 Oakland Hills fire and analyzing city crime patterns and trends.

Table 4.9–1 summarizes the GIS industry.

4.9.2 Industry Functions and Processes

This subject area of GIS includes the following functions: creating and marketing software for geographically based information, providing information on directional links between and among different geographically based locations, conducting projects to meet objectives for which there is a need for geographic information, and creating maps in digital form.

4.9.3 Technology Profiles

Technology profiles that constitute the subject area include information databases of all types that can be used to make available the data needed on the computerized maps. The technology profiles for the databases can include many scientific and engineering fields. Biology, botany, forestry, hydrology, zoology, chemistry, and environmental sciences are key specialty areas that play a technical role. As in most industries, the explosion of information sciences is used in GIS. Satellite technology is increasingly being directed to provide information for these database resources.

Client/server technology will become important in business geographics. It will be used to build geography servers that manage spatial data distribution in mega applications, or applications where a client needs an up-to-the-minute map (e.g., navigational information to personal digital assistants and in-car systems). Client/server technology is in its infancy in the GIS industry, but will grow in importance as the industry expands.

GIS technology is used more and more because of business pressure, such as site selection and increased competition. Retail and banking, for example, need to effectively project the success or failure of a new store location. Sophisticated geographic modeling techniques can improve their probability of success.

Table 4.9–1. GIS Industry Summary

Number of Companies (U.S./non-U.S.)	U.S.—Twenty major companies and hundreds of smaller companies as consultants Non-U.S.—Significant GIS activity being developed
Representative Firms	Strategic Mapping, Inc.; MapInfo Corp.; Environmental Systems Research Institute (ESRI); Intergraph Incorporation of GIS into databases – Lotus Development Corp.; into Lotus 123 – Oracle; into next database – Microsoft: possibly in future applications
Annual Sales (U.S./non-U.S.)	U.S.—GIS software for PCs – $378 million (includes $150 million for desktop mapping) in 1992; $317 million in 1991; total for GIS/GPS software, hardware, and services – $5.5 billion in 1993; $7.2 billion anticipated in 1998 Non-U.S.—Unknown, but probably slightly less than United States
Products	Digital mapping; city planning, resource management (e.g., tracking oil drilling production), vehicle tracking (e.g., taxis and delivery trucks), target marketing, sales management, data visualization; nationwide geocoding (address matching); business expansion location planning
Technical Challenges	Ease-of-use interface; integration of multiple platform and database formats; shift to PC level; use of client/server architecture; staying current with PC architecture; incorporating imagery, both aerial photos and satellite images; anticipation of 3- and 1-meter satellite images
Business Challenges	Providing excellent customer service; breaking into mainstream markets; applying software products to new projects
Major Customer Groups	Businesses such as banking, health care, insurance, retail, transportation, and telecommunications; federal, regional, and local governments
Regulatory Groups	U.S. Patent and Trademark Office, Securities and Exchange Commission (SEC), Software Engineering Institute (SEI)
Growth	30% annual growth expected

In its initial stages, GIS industry concentrated on creating mapping products and undertaking projects using those products. However, GIS by itself has a limited growth curve. It is a technology in which its principles and results can be leveraged substantially when combined with other major systems components, such as accounting, sales, and distribution. As a result, another newer trend is to be heading into component mode. GIS analytical capabilities and/or data are more often being delivered as a component of a larger system.

Geographic technology is playing a major role in helping to determine which markets are most promising in the telecommunications industry. The routing of lines and the networks being considered involve extensive geographic understanding. Competing firms with the telephone companies are planning to offer local telephone service at significantly lower rates than current local phone companies. They are using GIS to determine the most promising market locations, for example, households and businesses near existing cable networks.

A current development in GIS is enterprise-wide GIS. This effort involves bringing GIS into all functional divisions or departments of a company. It gives each division access to a principal GIS database that is centrally available. This principal GIS database is created by tailoring a GIS software product to a set of companywide requirements. In addition to these requirements, division-specific requirements are included. For example, a marketing department uses the GIS data differently than a technical planning department. This new development is being tested in early applications. Commercial real estate is among the first to test enterprise-wide GIS.

Health care is another industry testing enterprise-wide GIS in a major way. For example, the industry uses GIS to manage physician networks, match patients to physicians, and maintain accountability of home-care providers.

4.9.4 Systems Engineering Challenges

Many areas within GIS are systems related, and systems engineering does have a role. As in many industries, systems engineering's role may currently be implicit rather than explicit. The overall systems engineering challenge is to help make the GIS industry more efficient and its products more compliant with customer needs.

Table 4.9–2 focuses on the application of systems engineering in GIS.

Table 4.9–2. Systems Engineering in the GIS Industry

Systems Engineering Requirements	None, unless SEI has some; software domain expertise is needed
Systems Engineering Strengths	Systems integrators provide resources to GIS teams for large information projects (e.g., National Forest Service with GIS contractors) and EDS, General Dynamics, Unisys, and IBM
Systems Engineering Challenges	Systems engineering processes not used sufficiently in applying GIS to projects; concentration has been on creating GIS tools
Unique Systems Engineering Tools or Techniques	Need to understand the domain; learn GIS tools
Systems Engineering Related Standards	None, unless SEI has some

Systems engineering can play an increasingly important role in GIS. The field is relatively new, and almost no formal systems engineering processes are being employed. In working with the GIS industry at the industry level, systems engineering could help by becoming involved with national or international GIS professional societies. As in many industries, systems engineering can provide the structure to ensure that the practices, rules, and customs that are slowly evolving in the GIS field are, where appropriate, formulated into standards.

Systems Engineering Applications

The GIS industry, in addition to producing GIS products, is increasingly involved in the use of the products. There are GIS projects of various types and in many industries. These projects have a management structure and are often organized into teams, just as are the large defense and space projects and programs.

The integration of hardware, software, and networks is a challenge for systems engineering. Integration is being accomplished in planning new projects, such as new building sites for retail stores and banks. It also can be used to manage the operations of businesses. The enterprise-wide GIS will involve integrating GIS into the whole business: marketing, sales, and the management structure.

Another systems engineering challenge is to help large projects introduce GIS as a component or element. In this way, GIS may, depending on the type of project, be treated as an element for which there is a set of requirements that flows down from the mission statement and top specification of the project.

Systems engineering could be used to formulate requirements for various types of GIS, just as it is used for other types of information systems. As in other applications of systems engineering, individuals need to learn the GIS domain and become conversant in its terminology and technology. They can then make the necessary contributions to ensure that the requirements are flowed down and implemented in a way that complies with laws and requirements. Close attention to customer needs and ensuring project design traces to those needs are always systems engineering challenges.

Other trends in the GIS industry are relevant to systems engineering. Continuing challenges exist in the technology of GIS. For example, operational uses of GIS require customization not only of systems, but of the underlying data. Much of the underlying data are out of sync from a time perspective with respect to geographic definitions.

Windows 98 will make a big impact on the industry. GIS must always support mainstream operating systems platforms. That means continually upgrading the software to keep up with the operating systems changes.

Systems engineers also will be used in simulation of systems. Where geographical distributions and analyses are involved, GIS software will be merged with systems simulations. The systems engineer will be interpreting results, as well as performing the simulations and the integration with GIS. This is all in its early stages of formulation.

4.9.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

Theodore A. Dolton
1570 Dana Avenue
Palo Alto, CA 94303
Voice: 650-321-5950
E-mail: alanjoanne@aol.com

Lawrence M. Dolton
5400 Broadway Terrace
Oakland, CA 94618
Voice: 510-923-0204
E-mail: doltonlm@hooked.net

4.9.6 References

GIS World Magazine

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4.10 Health Care

4.10.1 Introduction

The health care industry in the United States and throughout the world is becoming more complex because of technology and evolving political and societal views toward health care requirements. Some of the risks in this application domain include impact of governmental regulation, justifying the cost of high-technology capabilities, and exposure to liability suits.

Table 4.10–1 summarizes the health care industry. Table 4.10–2 focuses on the application of systems engineering in the application domain. (Note: These tables will be added at a later date.)

4.10.2 Industry Functions and Processes

The health care industry includes physicians, dentists, nurses, and therapists in private practice; clinics; health maintenance organizations; hospitals; extended care facilities; hospices; pharmacies; pharmaceutical and medical device manufacturers; insurance carriers; government regulators; politicians; and others. The viewpoints of various individuals and segments in the health care industries differ widely on many issues, particularly on what constitutes acceptable levels of medical care, how the cost of such care can be controlled (e.g., should care be rationed), and how and by whom should the cost be borne.

The spectrum of new technology that has been applied to medical practice even in the past decade is too broad to discuss in this short profile. Only a few selected examples and categories of health care that are clearly impacted by emerging technology are described.

4.10.3 Technology Profiles

Biology, neurobiology, immunology, genetics, computer technology, and materials science have played a major part in the explosive growth of technology in health care.

Improved photographic emulsions have permitted X-rays to be used with increased safety. Computer-aided tomography (CAT) scans provide cross-sectional views that can be combined to produce three-dimensional images that are readily accessible via advanced visualization techniques. The recent introduction of electronic charge-coupled devices has allowed an order-of-magnitude reduction in dosage for typical X-ray examinations while also improving image detail. Because charge-coupled devices are readily interfaced to computers that can apply advanced image processing, that further enhances image quality.

For many examinations, sound-wave echoes can be used to image internal organs without requiring exposure to X-rays. Heralded as the most significant advance in diagnostic tools in decades, the magnetic resonance imaging (MRI) technique uses strong magnetic fields and low-energy radio frequency signals to produce images that are similar to the CAT scan, except that they clearly reveal soft tissue boundaries (a problem that is only partially solved by use of contrast mediums in X-ray examinations). A newer technique, positron emission tomography

(PET) scans, makes it possible to study electrochemical behavior in living tissue (a particular boon to neurobiological research and diagnostics).

It has been known for some time that body chemistry is largely regulated by enzymes. Endocrine gland secretions in concentrations of parts per billion and neurotransmitters at somewhat higher concentrations produce major systemic effects. The armory of sensitive chemical tests has led to major advances in diagnostics. Nuclear medicine provides specific treatments and exquisitely sensitive nuclear-chemical diagnostic tests.

Nuclear technology also has produced batteries, based on thermoelectric conversion of radionuclide decay heat, that are sufficiently long-lived and reliable that they may be implanted to support prosthetic devices (e.g., cardiac pacemakers).

Advances in immunology and materials technology have permitted extraordinary therapeutic results to become common (e.g., organ transplants, autologous tissue culture implants, electro-mechanical implants, artificial skin). Materials technology also has produced adhesives and composite materials important to health care, such as dental repair materials and extremely light and strong prosthetic devices.

Communications and computer technology have combined to permit rapid transmission of images and other diagnostic data for consultation (e.g., EKG and EEG interpretation). Recently, these methods are creating a capability of remote, real-time, patient diagnostic consultation—neither the consultant nor the patient has to travel to permit such consultations. Extensions of this concept, including tactile feedback and virtual reality technology, are leading to the imminent capability of assisting in or performing surgery remotely (e.g., battlefield surgery). The existing applications of robotic tools for delicate surgery (e.g., brain surgery) is expected to be synergistic with the remote virtual reality techniques. Virtual reality methods also contribute to realistic training methods that present no risk whatever to human patients.

Computer and microelectronics technology have led to sensors and monitoring devices, common in intensive care units, that provide real-time alarms without requiring the continuous presence of a nurse. Such devices, carried by emergency medical technicians on emergency calls, are commonly linked via radio to emergency rooms. During stabilization and transportation, the emergency room staff can provide consultation and prepare for treatment of critically ill or trauma patients. Portable devices for monitoring, recording, and transmitting outpatient status also are commonly used. Information system technologies permit storage, rapid retrieval, and appropriate display of large information stores (e.g., during surgery and as diagnostic support tools).

Direct application of mathematical models, particularly those based on chaos theory, have led to improved understanding of physical (e.g., neural, cardiac) and cognitive functions. Such models have contributed to an explosive growth in understanding of neurobiology and cognition. These models, in turn, provide insights into machine intelligence that have significant medical applications. Automated context-sensitive history acquisition systems provide expert advice to physicians on potential drug interactions, significant patterns of symptoms, and recommended tests for differential diagnosis. Systems of this type have been demonstrated more to diagnosticians than to physicians (and probably for that reason alone have not been widely implemented).

Machine intelligence also is providing major assistance to persons with disabilities (e.g., speech recognition and robotic assistance, use of nerve signal sensing and microcomputers to implement smart prosthetic devices, Cochlear implants, conversion of printed text to artificial speech), often allowing individuals an independence that was not imagined even a few years ago.

A typical application of neural networks that recently underwent clinical trials (and is probably commercially available at this time) screens histology slides from Pap tests. A neural network recognizes, classifies, and ranks the 50 or so most irregular cells on the slide. A human expert then inspects the irregular cells and determines whether malignancy is present. Results based on this system have been superior to human screening of slides that contain thousands of cells; people become bored, get tired, and sometimes just miss critical cues. This system has been well-accepted not only because it is clearly effective, but also because it makes intelligent use of human expertise in the diagnostic process.

Advances in analysis of DNA have led to major advances in prediction, diagnosis, and treatment of genetic disorders, as well as in criminology applications. The synergistic application of computer structure modeling, advanced visualization techniques, recombinant DNA techniques, and tissue culturing provide dramatic new approaches for developing and manufacturing pharmaceuticals. These technologies promise continued development of medications tailored for specific purposes that also minimize side effects, safer and more effective vaccines and antibiotics that keep up with bacterial adaptation, and safer and more effective psychoactive medications.

The inspiration of biological models has led to many advances in machine intelligence, including a powerful problem-solving technique based on genetic modeling. In an interesting turnabout, a complex mathematical problem was recently solved based on translation of the problem into analysis of mutation in live tissue cultures.

Medical device technology, described in another section, is developing rapidly (e.g., cytoscopic surgery, laser surgical and dental tools).

4.10.4 Systems Engineering Challenges

Since the end of the second World War, accelerating technology has provided a basis for improved health care. Unfortunately, the cost of such care may be high. With increased patient expectations leading to escalating levels of malpractice suits, the cost is further increased (e.g., through liability insurance and the practice of "defensive medicine"). The current environment is unsettled, heavily regulated, and with no clear agreement even within industry segments as to how to provide high-quality care at reasonable cost. Furthermore, the definitions of high-quality care and reasonable cost are quite unclear at present.

To further add to the unsettled environment in which medicine is practiced, divisive ethical and moral practices such as abortion and euthanasia are practiced, argued within the legislatures, and settled in courts. The days when Galen's advice to "do no harm" and the Hippocratic Oath established a commonly acknowledged (if not always observed) basis for medical ethics are considered by some as gone.

Strongly held views, lack of consensus, and activists with opposing views make evaluating and adopting rapidly changing technology incredibly difficult. Finding solutions that are superior (or even adequate) and acceptable to the many viewpoints that now exist is an extreme challenge to systems engineers in the medical field.

4.10.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

LeRoy Botten
3715 Capulet Terrace
Silver Spring, MD 20906
Voice: 301-985-8726
Fax: 301-985-8909

4.10.6 References

To be supplied.

4.11 Highway Transportation Systems

4.11.1 Introduction

The highway transportation system industry in the United States and throughout the world is just now being impacted by the challenges associated with the integration of high technology. Some of the risks in this application domain include integrating high technology into the existing infrastructure and the impact of environmental concerns.

Until now, highway systems have been the domain of civil engineers concerned with highway structures, materials loading, traffic patterns, and supporting facilities. However, the growing need for an IVHS or ITS requires that traditional civil engineering disciplines be integrated with computers, communications, and eventually fully automated vehicles. The complex highway transportation of the 21st century can benefit from the collaboration of systems engineers and civil engineers.

4.11.2 Industry Functions and Processes

The differences between the highway design process and the systems engineering process are primarily differences in nomenclature (refer to Figure 4.11–1). For example, the equivalent of the system requirements definition phase in the highway design process may be termed “topographical coordination and requirements.” The system design phase is termed “corridor study and design.” System implementation consists of a preliminary design that includes horizontal design, vertical design, cross-sectional design, and earth work. Detailed design includes developing right-of-way and final construction plans. It appears that the highway engineering community accepts and practices many of the key principles embodied in systems engineering, but expresses these principles using different terminology.

A major difference between most military or aerospace systems and a highway or transportation system is the number of users the highway system will have in its lifetime and the environmental, cultural resource, visual, and economic constraints it must satisfy. As a result, highway engineers must consider factors such as human interface, environmental engineering, aesthetics, local economics, public persuasion, and politics. The remainder of this section discusses the individual segments of the highway design process.

4.11.2.1 Topographical Coordination and Requirements

During the topographical coordination process, the highway engineering team assesses the available data and the constraints. If surveyors or photogrametry subconsultants are to perform the work, they must coordinate and sample-test to ensure compatible data formats. If the surveyors need to create a Digital Terrain Model (DTM), then they need to research both the kind of data to be imported into the terrain model and its accuracy. Such data include spot elevations, break lines (those of longitudinal reference), contours (two-and-a-half- or three-dimensional), or a survey database. If they need to perform mapping, they investigate and test the legend (usually provided by the agency for whom the work is being done). All software input and output must be compatible. Topographical coordination almost always requires a survey, and the surveyors' work is explicitly defined both in hardcopy (paper plot) and digital form.

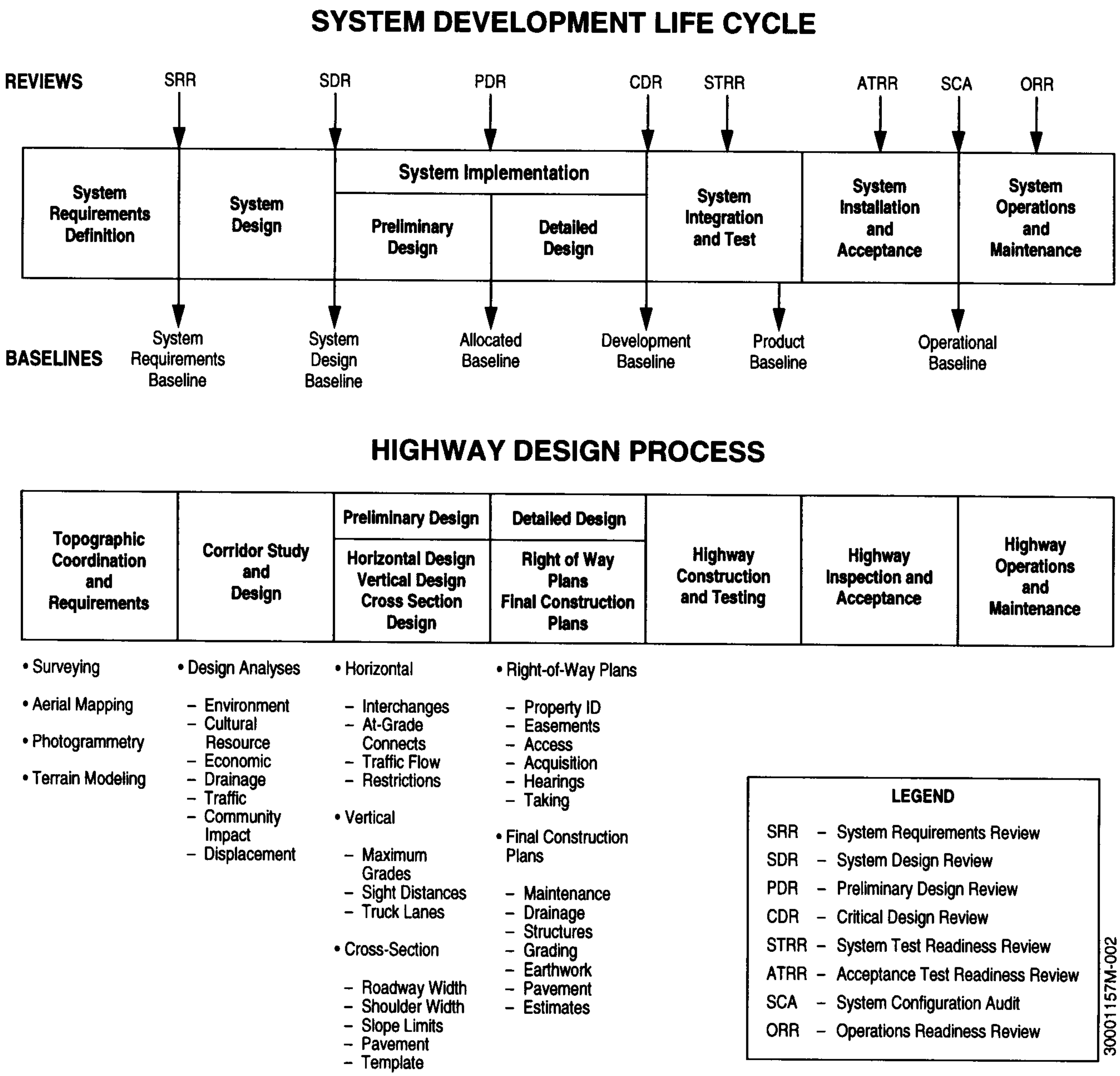

Figure 4.11–1. Corollary Life Cycles of the Highway Engineer and the Systems Engineer

4.11.2.2 Corridor Study and Design

A corridor study determines whether a proposed roadway is needed in a particular area. The following factors are considered:

- Environmental constraints, which are assessed in an environmental impact study, include wetland delineation, potential mitigation sites, air and water quality, water body modifications, wildlife, flood plains, wild and scenic rivers, coastal barriers and zones, threatened or endangered species, and hazardous waste sites.
- Cultural resource constraints include local, state, and national points of interest; historic sites that are significant because of the period in which they were built or their relationship with a certain event; and archaeological preservation.
- Economic constraints include whether farmland or land use is affected, how local short-term use relates to long-term productivity, and if resources are irreversibly and irretrievably committed to another use.
- Visual constraints address the design, quality, and art of a highway project; scenic overlooks; and whether a project is visually displeasing.
- Displacements, or relocation, can affect households, neighborhoods, and public facilities.
- Community impact includes how social (for example, neighborhoods, school districts, changes in property values), noise, and air quality standards are affected and how construction alone may affect a community.
- Traffic analysis quantifies existing operating conditions to provide a baseline for comparison of future traffic conditions and highway capacity.
- Drainage analysis takes into account major stream crossings, bridge modeling, Federal Emergency Management Agency studies, backwater effects, storm water management, and migration sites.
- Design criteria considerations address road classifications, which include the design velocity, maximum vertical gradient, maximum degree of curvature, maximum percentage of super elevation (that is, bank or crown) to include the method of transition computation, and earthwork analysis.

4.11.2.3 Preliminary Design

After adopting a particular alignment for the highway during a corridor study, several factors become important in the actual engineering of the preliminary design. For example, a road classification must be chosen, such as freeway or interstate. Strict design criteria accompany this classification and are applied to the four major aspects of the preliminary design: horizontal alignment, vertical alignment, cross-section, and pavement designs.

Horizontal Alignment Design. Road classification is often dictated by average daily vehicle traffic, traffic type, and vehicle velocity. In determining this type of design, the engineer adheres to criteria such as the maximum degree of curvature, maximum super elevation rate, method of computing super elevation transitions, type of super elevation, and length of spirals. The engineer must also investigate at-grade connections to side roads, utility impact, scenic road restrictions, and horizontal design interchange locations to engineer a good design.

Vertical Alignment Design. In addition to classifying the road, the engineer must set vertical parameters. The vertical parameters are a maximum gradient; sight distances for intersections, passing, stopping, and turning; and truck-climbing lanes and/or runaway truck ramps if the grade becomes too steep. The engineer must also address a roadway's cross-drainage as a significant criteria in the design.

Cross-Section Design. The engineer defines a template and side slopes for the roadway. The template is defined using standard lane width(s), minimum shoulder widths, slopes of the roadway ditches, and slopes of the roadway. The engineer factors in maximum super elevation and the type of elevation. A good design indicator of vertical grade is the balance of fill to excavation of earthen materials. The engineer needs to take into account the amount of shrinking or swelling of the removed excavation material before placing it back into the fill area.

Pavement Design. The engineer determines a pavement design. In this process, the engineer defines both the thickness and type of pavement layers of the roadway. The first step in this design process is to perform a geotechnical study of the ground quality in the area of the project. The results of this study are compared with the known factors of the roadway, such as the type of traffic. This information provides the engineer with the necessary data for designing the pavement.

Throughout the preliminary design, the engineers generate engineering field reviews and studies to yield the best design. Several such studies are necessary and include survey point settings, utility test hole borings, and additional environmental investigations.

4.11.2.4 Detailed Design

During the detailed design, engineers develop right-of-way plans as well as final construction plans.

Right-of-Way Plan. A right-of-way plan further develops the preliminary plan, but is used to acquisition the right-of-way or easement in the vicinity of the roadway project. During this stage, communities voice their opinions and express concerns to right-of-way agents at public hearings. To develop a right-of-way plan, the engineer must identify property owners and any information related to the property; delineate permanent and temporary easements caused by utility relocation, road maintenance, or drainage outfalls; and provide proper access to land-locked properties or acquisition the property outside the construction limits.

Final Construction Plan. A final construction plan includes all of the plans that have been developed and have evolved to this point in the cycle. The design should be relatively complete now and the right-of-way in the process of being purchased. During this stage of the detailed design, several products will be produced. These include traffic maintenance (detour construction and stages of construction); detailed designs for pavement, drainage, major structures, earthwork (grading); incidental items such as a guardrail; and road side development such as seeding and erosion control. After the detailed design is completed, the engineer prepares a cost estimate. The client uses this estimate to evaluate the bids received from construction contractors. The client may also request miscellaneous corrections, which can range from results of field findings to changes in construction policy.

It is clear that in the 21st century the systems engineering community will be asked to specify and develop more complex systems involving many more users. These systems will also need to address larger portions of the population. The engineering community cannot be content to maintain ineffective transportation systems, but must address their improvements systematically to serve the interests of the population. All of the engineering disciplines, therefore, must seek out areas of mutual interest and begin to work together to meet the transportation challenges of the 21st century.

4.11.3 Technology Profiles—Automating the Highway Design Process

The highway design process has changed very little over the years. However, the tools used to initiate and expedite the data within the process have developed significantly, and the technology for producing design plans continues to advance. Within the last 5 to 10 years, the focus on civil engineering has led highway designers from using the dated technology of formatted input (similar to the old card readers) to working with interactive design tools that use computer-aided drafting and design (CADD) and software applications to support the design process.

4.11.3.1 Computer-Aided Drafting and Design

Highway designers use two major CADD packages as accepted formats: (1) AutoDesk's AutoCAD and (2) Intergraph's MicroStation, which is preferred by most government agencies. Intergraph created the MicroStation Developmental Language (MDL) so users could write detailed code to dynamically alter and reference vector elements within two- or three-dimensional design planes. Because most design software packages use MDL, they must use the MicroStation platform. This use enhances MicroStation's presence within the marketplace.

4.11.3.2 Software Applications

Of the design packages available to highway designers, the forerunners appear to be GEOPAK (endorsed by the Federal Highway Administration), Intergraph's Inroads, the American Association of State Highway and Transportation Officials' IGRDS, and Eagle Point. Generally speaking, these packages are very similar, and their design processes are relatively equivalent to one another. It is difficult to assess the advantages and disadvantages of each package, however, because their products are ever changing.

4.11.3.3 Highway Design Automation Steps

Step 1: Terrain Data Processing—The first step of the design is to process the terrain data associated with the project. Most advances in highway design made in recent years have been in processing terrain data. The engineer can use several formats to collect the topographic data, but must use the one(s) dictated by each project's required level of accuracy. For example, widening an existing road requires very accurate data; therefore, it requires a survey to provide the necessary information. On the other hand, creating a new road does not require the same level of accuracy, so photo interpretation may suffice. The difference between these two methods is a tolerance of a few hundredths of a foot, as opposed to a few tenths. The collected data are typically translated into random spot elevations (that is, XYZ values) and longitudinal references. A longitudinal reference is a three-dimensional vector often used to determine the existing pavement edge. The data are then processed into a DTM that can be expressed in a two- or three-dimensional MicroStation design file or other format (the standard is the Triangular Irregular Network). These two formats typically contain triangulated data within user-defined tolerances. The software package determines which format is more useful.

Step 2: Roadway Baseline Development—During the second step of the design, the engineer develops the centerline, or baseline, of the roadway either by using a coordinate geometry method or interactively by placing a dynamically changing element within the MicroStation environment or design file. The centerline is then stationed on even increments, called stations. If imperial units are used, 100-foot increments are standard. These stations simply provide the means to reference a point along a centerline and are represented in the form of 10+80.03, translating 1080.03 units from either a real or imaginary starting point. The software defines the simplest way to encode or place the centerline, and the engineer makes the appropriate calculations on the curves and spirals within the alignment.

Once a centerline is established, the process becomes two concurrent engineering processes. In the first process, the engineer extracts the existing ground profile from the previously created DTM. This activity is usually completed in a matter of seconds, as opposed to the grueling task of manually picking elevations off of contour maps, as was the case until a few years ago. Once the ground line is extracted, the engineer sets the vertical alignment within the tolerances of the state or local government-accepted standards. Once again, this vertical grade may be set by either encoding the alignment or placing the elements within the design file.

The second process is similar to extracting the existing ground profile. Here, the engineer extracts the existing ground cross-sections from the DTM, another process that has sped up highway design immensely. The engineer gathers cross-sections as a series of vectors along an interval that is based on the project’s requirement for accuracy. This series of vectors is expressed in a unique form that is later used to overlay and test certain roadway parameters, which are used to evaluate and construct the proposed roadway template. The engineer can develop these parameters at the same time he is extracting the cross-sections. The government agency requesting the design usually establishes the parameters. They include the width of the shoulder, slope, and depth of any cut ditch or the varying slopes of the fill, depending on either the vertical or horizontal differences between the proposed roadway and the existing ground cross-sections. One of the most important parameters is the super elevation of the roadway. Most of the aforementioned software packages provide a system capable of calculating super elevation for a normal section. However, the more complex the scenario, the less the engineers can rely on software making their decisions for them.

Step 3: Cross-Section Development—In the third step, the engineer creates proposed cross-sections by combining the horizontal alignment (along with the existing ground cross-sections), the vertical alignment, and the series of roadway parameters the engineer set. The engineer, once again, formulates a template from these criteria and then tests its optional parameters against the existing ground system extracted from the first step. For the most part, the software creates the proposed cross-sections and incorporates them into the MicroStation design file. The cross-sections show the slope stakes or limits of construction on the horizontal plans. Software packages that can alter the cross-sections as the engineer deems appropriate and reference the altered section in the same fashion that the engineer referenced the original sections have an advantage over those packages that cannot.

Step 4: Construction Limits Development—As the final step in the design process, the engineer creates the horizontal slope limits of the design. These limits are the offset, referenced from the outermost intersections of the proposed cross-section, with the existing sections produced in the last step. These lines help the engineer delineate the needed right-of-way and disturbed ground if environmental issues exist.

Demonstrating the construction limits for the entire alignment, having the capability to change a portion of the design’s cross-section, and seeing this change reflected in the horizontal design is indeed a luxury. Software packages that offer this feature are said to have “intelligent cross-sections.” In summary, CADD software has increased the productivity of the earlier highway draftsmen. When integrated with other design software, it significantly reduces the time needed to process terrain data, develop roadway baselines, extract the ground profiles and cross-sections needed to create horizontal and vertical alignments, and perform the many other tasks in highway design.

4.11.4 Systems Engineering Challenges

Table 4.11–1 summarizes the highway transportation system industry. Table 4.11–2 focuses on the application of systems engineering in the application domain.

4.11.4.1 Technology Challenges

The highway transportation vehicle systems differ from military and aerospace vehicle systems in that humans, not computers, provide the primary source of intelligence in commanding and controlling the vehicles. As a result, the range of outcomes for decision making is more stochastic and, therefore, often less predictable. In the same vein, systems engineers have already begun to structure major aerospace programs to address interests of the international scientific community and focus on environmental concerns of the planet. As more and more international scientific investigators provide near real-time feedback to the orbiting sensors and direct information-gathering efforts from their workstations, the more stochastic and similar to the people-intensive vehicle and highway system the entire aerospace system will become. As systems engineers learn to design for people-intensive, complex systems, the more ways they will find to apply engineering disciplines to meet the challenges of nonlinear, probabilistic, and multivariable input; processes; and output.

Table 4.11–1. Highway Transportation System Industry Summary

Number of Companies (U.S./non-U.S.)	More than 100
Representative Firms	Michael Baker, Jr., Inc.; Loral; TRW; Rockwell; Parsons: Brinkeroff; JHK & Assoc.; Hughes; Kimley-Horn and Assoc.
Annual Sales (U.S./non-U.S.)	$40 billion
Products	Varied
Technical Challenges	Interoperability between states, standardized data
Business Challenges	Need personal contact with many customers
Major Customer Groups	State and local Departments of Transportation (DOTs)
Regulatory Groups	No national group (although Federal Highway Administration would like to be); state DOTs provide some regulation at state level

Table 4.11–2. Systems Engineering in Highway Transportation

Systems Engineering Requirements	Minimized life-cycle costs, automated operations standardization
Systems Engineering Strengths	Need to be developed
Systems Engineering Challenges	• Customer understanding of systems engineering benefits • Protecting investment in existing systems, system evolution • Consideration of entire systems
Unique Systems Engineering Tools or Techniques	• Simulation • Prototyping • Field test
Systems Engineering Related Standards	None

4.11.4.2 Intelligent Vehicle Highway System

While the nationwide system of interstate highways has benefited intrastate travel, most of the nation’s major highways near urban centers overflow with traffic, not only in the morning and evening rush hours but for most of the day. The IVHS in the United States and the European Community’s Road Transport Informatics projects under development offer some reason to believe that applying an overall systems engineering approach to highway transportation may eventually relieve these problems (see Figure 4.11–2). More recently, the IVHS has been termed the Intelligent Transportation System (ITS).

The IVHS program consists of a range of advanced technologies and ideas that, if implemented in an integrated fashion, can improve mobility and transportation productivity, enhance safety,

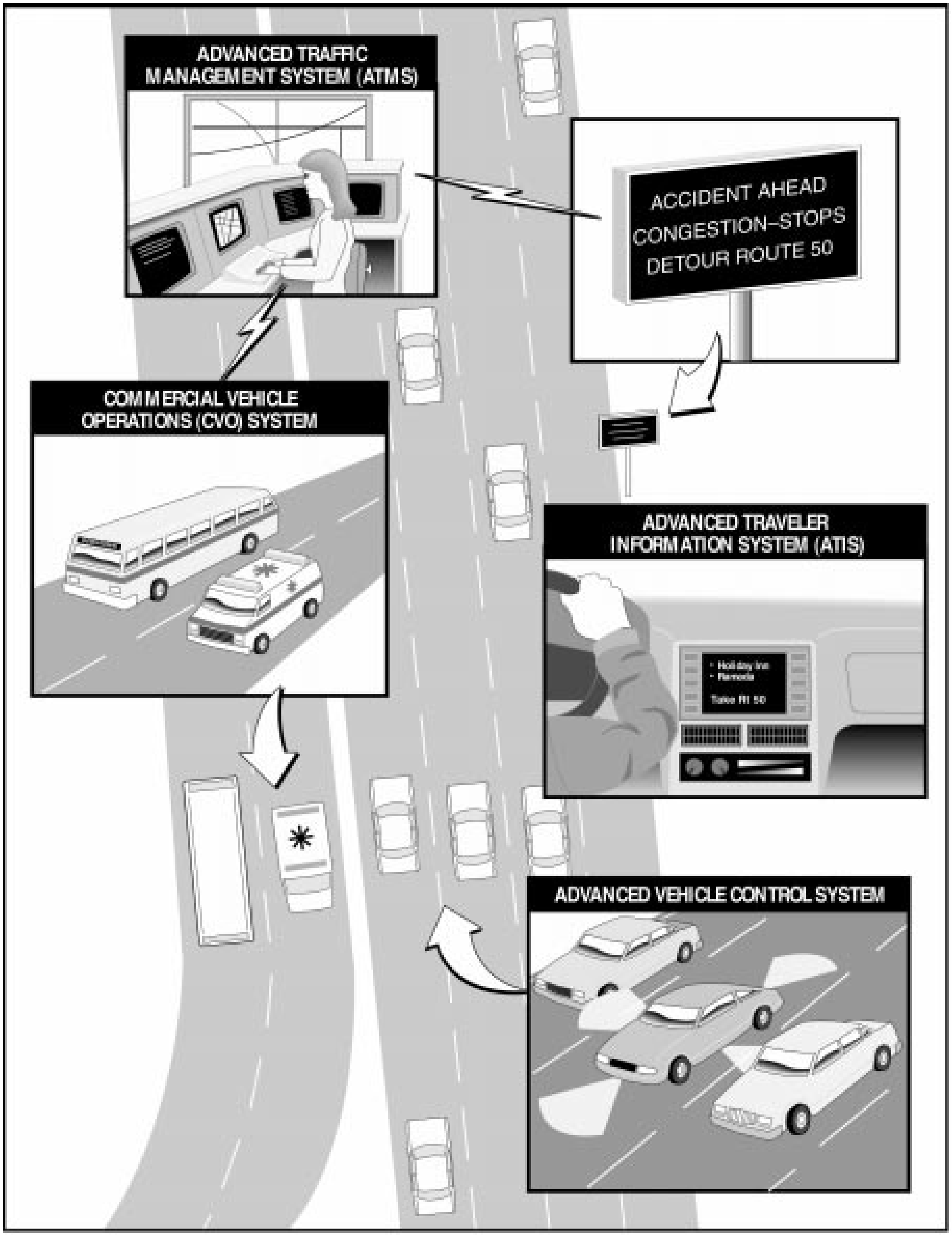

Figure 4.11–2. The Intelligent Vehicle Highway System

maximize the use of existing transportation facilities, conserve energy resources, and reduce adverse environmental effects. The aim of the national IVHS program is to deploy advanced technologies to help solve transportation problems and improve safety. The rapid progress in computers, communications, and vehicle controls makes this program feasible in the near future.

Some IVHS subsystems and components are already in place on a limited operational basis, such as traffic signal controls, vehicle identification systems, automatic toll charging, and driver information and navigation aids. These advances lead to an ultimate scenario of smart automobiles on smart highways. Present limitations on full implementation of IVHS are more related to the need for large capital investment from Federal, state, and local government agencies than to limitations of existing technology.

Congress passed a Federal program to develop technology for IVHS as part of the Intermodal Surface Transportation Act of 1991. As a result of this act, Federal contracts have been awarded in four broad, interrelated IVHS program areas.

The Advanced Traffic Management System (ATMS) permits real-time adjustment of traffic control and variable message signs for driver advice. Its application in selected corridors is aimed at reducing delay, travel time, and accidents. A recent list of IVHS projects compiled by two agencies—the Federal Highway Administration, Office of Traffic Management and IVHS (HTV-1), and the Federal Transit Administration, Office of Technical Assistance and Safety (TTS-1)—lists no fewer than 14 such ATMS efforts.

The Advanced Traveler Information System (ATIS) performs several functions, including navigation using electronic maps; route selection and guidance; information on services such as gas stations, restaurants, lodging, and hospitals; and real-time traffic information based on communication between drivers and the ATMS. A Federal Highway Administration and Federal Transit Administration report lists seven such ATIS efforts.

The Commercial Vehicle Operations (CVO) System adds to ATIS those features critical to commercial and emergency vehicles. This system expedites deliveries, improves operational and regulatory efficiency, and increases safety. The CVO System will eventually interface with the ATMS. The Federal Highway Administration and Federal Transit Administration report lists two CVO projects underway.

The Advanced Vehicle Control System (AVCS) provides an intelligent vehicle with automatic functions, such as adaptive cruise control, night-vision sensors, radar, and automatic braking. The AVCS identifies obstacles and adjacent vehicles and prevents collisions with them. The AVCS will interface with the ATMS to provide automatic vehicle operations. The Federal Highway Administration and Federal Transit Administration report does not list any existing AVCS projects underway. The rapid progress in computers, communications, and vehicle controls makes the capabilities of the AVCS feasible in the near future. In addition to these four emerging systems, the Federal Highway Administration's Federal and Highway System lists efforts and studies underway in an advanced public transportation system, IVHS deployment projects, Federal Highway Administration research activities, and Federal Transit Administration evaluation and research activities.

4.11.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

William F. Mackey, Jr.,
Kimley-Horn and Associates
501 Independence Parkway
Suite 300
Chesapeake, VA 23320
757-548-7300
E-mail: bmackey@kimley-horn.com

Dr. William F. Mackey
Computer Sciences Corporation
7700 Hubble Drive
Lanham-Seabrook, MD 20706
301-794-2138
E-mail: wmackey@csc.com

4.11.6 References

Federal Highway Administration and Federal Transit Administration, *Intelligent Vehicle-Highway System (IVHS) Projects in the United States*, Publication No. FHWA-SA-92-036, May 1992

Federal Highway Administration Technical Advisory T6640.8A, October 30, 1987

Jenkins, James T., “The Story of Roads,” *American Road Builder*, Special Issue, September 1967

Jurgen, Ronald K., “Smart Cars and Highways Go Global,” *IEEE Spectrum*, May 1991

Mackey, David E., Mackey, William F., Jr. and Mackey, William, “A System Concept for an Advanced Vehicle Control System,” *INCOSE Proceedings, Sixth Annual International Symposium of INCOSE,* Boston, MA, July 7–11, 1996

Mackey, William F. and Mackey, William F., Jr., “A Systems Engineering Approach to Highway Design,” *INCOSE Proceedings, Fourth Annual International Symposium of INCOSE*, San Jose, CA, August 10-12, 1994; also *INCOSE Proceedings, Sixth Annual International Symposium of INCOSE,* Boston, MA, July 7–11, 1996

Rose, Albert C., *Public Roads of the Past, American Association of State Highway Officials,* two volumes, 1947

Sundstrom, Geoff, “The Paving of America: Mud and Macadam to Superhighways,” *Automotive News,* Centennial Celebration Issue, October 30, 1985

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4.12 Information Systems

4.12.1 Introduction

The information systems industry is very diverse, serving enterprises of many sizes. Enterprises from a single office employing a few people to the largest multinational corporation use information systems. In addition to serving different size organizations, information systems serve all different types of organizations. Businesses, government agencies, religious and nonprofit organizations, schools, and military organizations use information systems.

4.12.2 Industry Functions and Processes

Enterprises use information systems for managing different kinds of information for many different purposes. A partial list of information systems applications that are common to several different enterprises follows:

- Payroll
- Accounts payable
- Accounts receivable
- Billing
- Inventory management
- Order entry and tracking
- Information systems scheduling and support

In addition to the applications listed above, there are many more applications that manage a database peculiar to a specific type of enterprise that uses information systems. The database being managed can take the following forms:

- Sequential files
- Indexed files with keyed access
- Hierarchical or network database
- Relational database

The application managing some industry-specific database must perform or support at least some of the following functions:

- Data entry
- Updates to existing data
- Deletions of existing entries
- Periodic purgings of entries by date or age

- Displaying or printing of selected entries
- Summary or aggregate of sets of data

There are three classes of development projects and all three can be used in information systems, in one way or another.

- **Contracted Development**

  An enterprise, the client, contracts with a development company for it to build a custom application to the client's specifications.

- **Internal Development**

  Most medium to large enterprises maintain their own information systems development department. This department develops and maintains many of the enterprise's information systems applications.

- **Open Market Product Development**

  Applications to serve different information systems needs are developed and marketed by many companies. For most small enterprises, this is their only source of information systems applications. Many larger enterprises fill some of their information systems needs with purchased products.

Most information systems can be grouped into one or a combination of the following forms:

- **Scheduled Batch**

  The information systems department within the enterprise is responsible for running the batch jobs of the application on their scheduled days. Applications usually include a combination of daily, weekly, biweekly, semimonthly, monthly, quarterly, semiannual and annual jobs. Reports and other end-user results from the jobs are delivered or made available to the end users by the information systems department. The information systems department tracks errors or other problems. Depending on the type of problem, either the failing job is corrected and rerun by the information systems department or they work with the user department to correct the problem.

- **User-Managed Batch**

  Jobs are submitted or run by a person in the user department. Job progress is tracked and results retrieved by that person. Problems, corrections, and reruns are the sole responsibility of the user department.

- **Transaction Processing**

  This is an online system that supports an information systems application. Many different kinds of applications run on transaction processing systems, and sometimes several run on the same system. Each application is well defined such that only predefined functions can be performed. A transaction processing system allows a large number of end users, sometimes hundreds or thousands, to share a small number of files or databases. The execution profile of a particular transaction processing application is usually consistent, allowing it to be well-tuned for predictable performance. Online information systems applications are generally not true real-time systems.

- **Decision Support**

  This kind of online system differs from the previous one in that it does not consist of predefined functions. The applications are more often general purpose, rather than custom built. Rather than executing predefined functions, the end users execute ad hoc queries. A decision support system does have a consistent execution profile, so its performance is not very predictable.

A typical information systems department for a medium to large enterprise includes most or all of the application types described above. Table 4.12–1 and Table 4.12–2 provide the application summary and systems engineering activities of the information systems applications domain.

4.12–1. Application Summary for Information Systems

Number of Companies	Almost every business, government agency, or enterprise of significant size uses information systems
Representative Firms	It is impossible to describe a typical user of information systems because so many different types of enterprises use these systems
Annual Sales	This area does not apply to many of the enterprises using information systems, like government agencies or noncommercial organizations, and because businesses are so diverse, an answer would not be meaningful.
Products	(See previous row)
Technical Challenges	Addressing the choice of hardware platform or platforms, and not having it chosen by default. Keeping up with user demands for new systems and applications
Business Challenges	The businesses are too diverse to address this and many users are not businesses
Major Customer Groups	(Previously addressed)
Regulatory Groups	(Not applicable)
Growth	Exploding in some areas, moderate in others

4.12–2. Systems Engineering in Information Systems

Systems Engineering Requirements	Apply the interdisciplinary systems engineering methods to match a planned software subsystem to the most appropriate hardware platform(s)
Systems Engineering Strengths	Provides a methodical approach to selection of the most appropriate pre-existing hardware platform(s)
Systems Engineering Challenges	(See section “Systems Engineering Challenges”)
Unique Systems Engineering Tools or Techniques	The tools used for information systems are those used for most software engineering projects
Systems Engineering-Related Standards	The standards applied in information systems are those that apply to software engineering, such as the International Standards Organization (ISO) 9001, Software Engineering Institute (SEI) Capability Maturity Model (CMM), Electronic Industries Association (EIA) 632, and EIA 731.

4.12.3 Technology Profiles

Information systems applications exist on one or more of a number of noninterchangeable hardware platforms. In all cases, a standardized prebuilt operating system is also used. Almost all online applications use one of the available prebuilt online subsystems. The most common families of hardware and operating systems used for information systems are listed in Table 4.12–3.

Table 4.12–3 Common Platforms

Platform	Typical Hardware	Typical Operating System
Mainframe	IBM System/390	OS/390 (formerly MVS)
Small mainframe	IBM System/390	DOS/VSE
Midrange or mini mainframe	IBM AS/400	OS/400
Reduced Instruction Set Computer (RISC)* (mini)	Various manufacturers	Unix
Personal computer (PC)	Intel 80486 or Pentium	Windows or OS/2
PC server	Intel Pentium	Windows or OS/2

Each of the four forms of information system applications can be found on any of the platforms listed, except that scheduled batch is usually only seen on mainframe platforms and transaction processing is new to the Intel (personal computer) platforms.

4.12.3.1 Database Managers

4.12.3.1.1 Relational Data Bases

For many information system applications, the data is stored in a relational database. These are built around a two-dimensional table paradigm, where the smallest data increment is the intersection of a row and a column. Each column is a type of data element, or a field. Each row is a collection of related columns representing one entity. The term relational comes from the fact that two or more tables can be related in that they have a similar column. That column is used to “join” rows from one table with related rows in another table. Besides being used for individual applications, relational databases are increasingly used to maintain an enterprise’s data warehouse, where data from several applications are stored for decision support or application use. Some examples of relational database managers are IBM’s DB2, Oracle, and Informix.

4.12.3.1.2 Hierarchical Databases

Less important than they used to be are hierarchical databases. In this paradigm, each entity’s data elements are structured in a hierarchy of data segments. A root segment is at the top of the hierarchy and can have any number of child-segment types under it. Each of these child-segment types can, in turn, have child segments under it. The root segment can occur any number of times, one for each basic entity that it represents. Each child-segment type can also occur multiple times under its parent. These relationships are maintained by pointers that the application programs never see directly. The application navigates through a hierarchical database by using specialized calls to the database manager like “Get Next” and “Get Next Within Parent.” Hierarchical databases are still used in information systems, but their use is being supplanted by relational databases. The best known hierarchical database manager is IBM’s Information Management System (IMS).

4.12.3.1.3 Network Databases

A network database is similar to a hierarchical database except that its structure is more complex than a simple hierarchy. These too are largely supplanted by relational databases. A well-known network database manager is Integrated Data Management System (IDMS) from Computer Associates.

4.12.3.2 Transaction Processors

One of the most important software technologies, after operating systems, for information systems has been Online Transaction Processing (OLTP) systems. These are a subsystem layer between the operating system and the application. They provide a structure in which the application executes, and provide services much like an operating system. The purpose of an OLTP is to allow a large number of interactive users to share a small number of resources like data files, while maintaining short response times. Normally, an operating system allows applications to allocate main storage and open files for its use. The OLTP allocates these resources itself and “sublets” them to the applications. For example, an application can allocate main storage from the OLTP with a far shorter instruction path length than from the operation system. It can read from or write to files without going through the overhead of opening them because the transaction processing system has opened them. The vast majority of Fortune 500 companies have one or more information systems applications running in Customer Information Control System (CICS), IBM’s premier OLTP.

4.12.3.3 Printers

There are many types of printers on the market today with a wide range of printing quality, speed, and capabilities. Printers may be described in two basic categories: impact and nonimpact. Impact printers print by striking the type against a ribbon and the paper to produce output as an original hardcopy of a document. Many impact printers are bidirectional (print in both directions). The print mechanism prints first from left to right and then from right to left. It can do this because the text has already been keyed and stored. A dot-matrix printer is an impact printer. It prints a series of closely spaced dots in a matrix to form each letter, number, symbol, etc.—a technology particularly adapted to printing graphics. A dot-matrix printer has a printhead with a matrix of tiny pins or wire bristles. As the printhead shuttles back and forth, the wires change position and form the characters before they strike the ribbon and paper. Another, high-speed type of impact printer prints an entire line at a time. It uses a set of preformed characters that travel around a chain or train at high speed. As the character to be printed speeds past its position on the line, the hammer for that position strikes it against the ribbon and paper.

The other class of printers is the nonimpact printer. Because the print head does not actually hit or embed print on the paper, nonimpact printers cannot produce multiple or carbon copies. Nonimpact printers produce one copy at a time. One type of nonimpact printer, the ink-jet printer, sprays electrically charged ink onto paper. Ink-jet printers can shape characters in a variety of type styles and sizes. They have several advantages over impact printers. They are practically noiseless, need little or no maintenance, may print several colors on a page, and are very fast. A popular type of nonimpact printer is the laser printer. Laser printers vary in size from desktop to large floor models. Using focused light instead of ink and ribbon to create images on paper, lasers print high-quality characters extremely fast. Laser printing equipment has become cost-effective for individuals, small businesses, and large corporations.

4.12.3.4 Magnetic Disk Storage

Magnetic disks are flat, circular plates coated with a magnetic material. There are two types: hard disks and floppy disks or diskettes. Both types of disks come in diameters of 5 ¼ and 3 ½ inches for personal computers. Because the disk medium is sensitive, it is encased in a protective cover. Some diskettes can hold about 400 pages of information. In terms of storage space, this means that a file drawer of paper is equal to about six floppies—a smaller amount of space than the space taken up by one or two paperback books.

Magnetic hard disk storage is a popular storage medium for computer data. A hard disk is sometimes called a fixed disk because it is permanently encased in its drive to avoid exposure to dust and other particles that might affect the medium. More then 75,000 pages of information, or about 33 file drawers of paper document, can be stored on a single hard disk. The amount of storage and the sizes of hard disks vary among computer systems.

4.12.3.5 Magnetic Tape Storage

Magnetic tapes have greater memory capacity than disks, but their access time is far slower because they are sequential-access memories. Data in consecutive addresses are sequentially read or written, as a tape is unwound. Magnetic tape provides a compact, economical means of preserving and reproducing varied forms of information. Recordings on tape can be played back immediately and are easily erased, permitting the tape to be reused many times without a loss in quality of recording. For these reasons, tape is the most widely used of the various magnetic recording mediums. It consists of a narrow plastic ribbon coated with fine particles of iron oxide or other readily magnetizable material. In recording on tape, an electrical signal passes through a recording head as the tape is drawn past, leaving a magnetic imprint on the tape's surface. When the recorded tape is drawn past the playback or reproducing head, a signal is induced that is the equivalent of the recorded signal. This signal is amplified to the intensity appropriate to the output equipment.

4.12.3.5.1 Mainframe Cartridge Tape

Computer storage can be thought of as being in a hierarchy, and is often managed like that. From an application program's perspective, there is main storage at the top, then magnetic disk storage, magnetic tape storage, and, maybe, optical disk storage. In information systems, magnetic tape storage has played an important roll for many years, and continues to be important. In mainframe systems, magnetic tape began as open reels that had to be manually loaded and threaded on the tape drives, to automatic threaders, and, today, to cartridges that are queued up and automatically loaded. These cartridges look and load much like the old 8-track audio tape cartridges did. All tape storage is strictly sequential. Indexed files and databases cannot be stored on tape. Other than that, a file on tape looks to an application like a sequential file on disk. Whatever language the application program is written in, it cannot tell the difference between a sequential file on tape and one on disk. Only the Job Control Language (JCL), the link between an application program and the operating system, is written differently for tape or disk storage. The basic uses of tape have not changed since the open-reel days. They are as follows:

- Large files for which expensive disk storage is not justified
- Seldom used files, such as those used only once a year
- Files sent off site, such as to archival storage or to another enterprise

The only recent adjustment is the introduction of hierarchical storage management systems. These automatically move a file from disk to tape storage based on its size, the tie since its last access and other factors.

4.12.3.5.2 Small System Streaming Tape

On smaller computers, a medium called streaming tape is sometimes used. This medium has the ability to read or write whole files only. It is used to back up or archive disk files.

4.12.3.6 Network Technology

The utility of computers is vastly augmented by their ability to communicate with one another, so as to share data and its processing. Local-area networks (LANs) permit the sharing of data, programs, printers, and electronic mail within offices and buildings.

In wide-area networks, such as the Internet, which connect thousands of computers around the globe, computer-to-computer communication uses a variety of media such as transmission lines—electric-wire audio circuits, coaxial cables, radio and microwaves (as in satellite communication), and, most recently, optical fibers. The latter are replacing coaxial cable in the Integrated Services Digital Network (ISDN), which is capable of carrying digital information in the form of voice, text, and video simultaneously. To communicate with another machine, a computer requires data circuit-terminating equipment (DCE), which connects it to the transmission line. When an analog line such as a dial-up telephone line is used, the DCE is called a modem (for modulator/demodulator); it also provides the translation of the digital signal to analog and vice versa. By using data compression, the relatively inexpensive high-speed modems currently in use can transmit data at speeds of more than 100 kilobits per second (kbps). When digital lines are used, the DCE allows substantially higher speeds.

There are several basic LAN topologies. Each place where a terminal, printer, or peripheral is located is called a node. Each node is connected to the LAN by a separate cable. The connecting path between two nodes is called a link. The simplest network is a shared logic system linking three nodes to one CPU. In a star network, a central controlling node is called a hub or central controller. Instead of people communicating with each other directly, messages go first to the hub, which routes them to the receiving node. In a ring network, messages are communicated from one node to the next, similar to a group of people passing a note from one to the next at a round table.

Computer networks are complex entities. Each network operates according to a set of procedures called the network protocol. The proliferation of incompatible protocols during the early 1990s has been brought under relative control by the Open Systems Interconnection (OSI) Reference Model formulated by the International Organization for Standardization. To the extent that individual protocols conform to the OSI recommendations, computer networks can now be interconnected efficiently through gateways.

Computer networking facilitates the current trend toward distributed information systems. At the corporate level, the central database may be distributed over a number of computer systems in different locations, yet its querying and updating are carried out simultaneously against the composite database. An individual searching for public-access information can traverse disparate computer networks to peruse hundreds of autonomous databases and within seconds or minutes download a copy of the desired document into a personal workstation.

4.12.3.7 Optical Storage

The optical disc became available during the early 1980s. The optical disc makes use of laser technology: digital data are recorded by burning a series of microscopic holes, or pits, with a laser beam into thin metallic film on the surface of a 4 3/4-inch (12-centimeter) plastic disc. In this way, information from magnetic tape is encoded on a master disc; subsequently, a process called stamping replicates the master. In the read mode, low-intensity laser light is reflected off the disc surface and is “read” by light-sensitive diodes.

The radiant energy received by the diodes varies according to the presence of the pits, and the diode circuits digitize this input. The digital signals are then converted to analog information on a video screen or in printout form.

Since the introduction of this technology, three main types of optical storage media have become available: (1) rewritable, (2) write-once read-many (WORM), and (3) compact disc read-only memory (CD-ROM). Rewritable discs are functionally equivalent to magnetic disks, although the former is slower. WORM discs are used as an archival storage medium to enter data once and retrieve it many times. CD-ROMs are the preferred medium for electronic distribution of digital libraries and software. The high-storage capacities and random access of the magneto-optical, rewritable discs are particularly suited for storing multimedia information in which text, image, and sound are combined.

4.12.4 Systems Engineering Challenges

The challenge to systems engineering in the information systems industry is brought by a two-dimensional diversity. There is a wide diversity of enterprises using information systems, and often a wide diversity of application types within any one enterprise. This challenge is mitigated by the fact that information system applications do not use custom-built hardware. (If there are exceptions to this rule, they are very rare.) For most information systems projects, either the use of existing installed hardware is a stated requirement, or a standard hardware platform is designated and selection of the hardware size is left open. This reduces the systems engineering problem to a software engineering problem, once the standardized hardware platform (or platforms) is chosen.

Information systems is often viewed as the sole realm of software engineers, simply because the hardware platform is usually a given. One challenge for systems engineering is to make the choice of the hardware platform an engineering issue and not just a marketing issue. Executives responding to the marketing efforts of hardware manufacturers today often decide whether a new application should reside on one platform or be distributed across two or more platforms and what those platforms should be. The call for client/server platforms by small platform manufactures and trade-magazine writers cost many users of information systems millions of dollars before many of them learned that one large platform is sometimes a cheaper and better answer.

As all information carriers (text, video, and sound) can be converted to digital form and manipulated by increasingly sophisticated techniques, the ranges of media, functions, and capabilities of information systems are constantly expanding. Besides, computer visualization, a new field that has grown expansively since the early 1990s, deals with the conversion of masses of data emanating from instruments, databases, or computer simulations into visual displays—the most efficient method of human information reception, analysis, and exchange. Therefore, one of the challenges for systems engineering would be keeping up with new technologies.

Currently, systems engineering is employed inconsistently by the information systems department. Many organizations do not attempt a structured development process. This is why information systems departments do not enjoy a high rate of success. Those information systems departments that do employ a structured development approach, from problem identification through requirements, design, code, and testing phases may not use the term systems engineering.

4.12.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

T. Scott Ankrum
19109 Grotto Lane
Germantown, MD 20874
Voice: (301)-916-0265
E-mail: ankrum@erols.com

Amy Hsiao
E-mail: amyhsiao@yahoo.com

4.12.6 References and Regulations

To be supplied.

4.13 Manufacturing

4.13.1 Introduction

Clearly, many manufacturers, such as those in microelectronics or pharmaceuticals, depend on emerging technologies as a matter of course. Other segments of the manufacturing industry are slower to evaluate and adopt new technology, while still others take a much more conservative approach. There is also well-established technology that is unknown in some environments despite excellent potential for applications (e.g., genetic algorithms and neural networks as techniques for generating optimal schedules). The following subsections provide a sampling of environments that could benefit from emerging technologies.

More specific details regarding manufacturing in other industry application domains may be found in other sections of this document.

Table 4.13–1 summarizes the manufacturing industry. Table 4.13–2 focuses on the application of systems engineering in the application domain. (Note: These tables will be added at a later date.)

4.13.2 Industry Functions and Processes

4.13.2.1 Materials and Inventory Management

Manufacturers who deal in high-volume production of complex products (e.g., automobile industry) have been leaders in developing and applying inventory management methods to optimize return on investment. Based on reduced cost of computer systems and increased availability of inventory management products, the automation of the following inventories is becoming much more common:

- Materials—Raw materials and components purchased from other suppliers as a basis for manufacturing activities
- In-process components—Identifiable, completed subassemblies created as part of the manufacturing process
- Products—Final products prepared for resale

4.13.2.2 Scheduling

Operations research methods developed following the second World War have been well-accepted in scheduling manufacturing processes. Again, as a result of low-cost computer systems, more complex scheduling methods are emerging as follows:

- Just in Time—The risk of scheduling delivery of even critical raw materials and components purchased from suppliers is useful in minimizing the cost of inventory and storage. With suitable computer support, it is possible in some situations to identify and manage this process so that the benefit of cost reduction exceeds the risk.

- Complex scheduling—Emergent techniques based on machine intelligence have been applied with great success to solving scheduling problems so complex that unaided humans could not resolve them. These methods (e.g., genetic algorithms, neural networks, expert systems) are emerging as supplement operations research methods in situations for which no operations research method is known.

4.13.2.3 Process Control

There is a rich potential, and a successful history, for application of machine intelligence to process control. Candidates for such applications often include one or more of the following characteristics:

- Problems traditionally solved by experts—Such solutions (e.g., process step termination, problem diagnosis) often use intuition based on long experience. Frequently, the experts themselves may not be able to clearly explain the basis for their decision process. Dependence on these solution methods presents a serious management problem as such experts retire or accept other employment. Knowledge engineering may be used to capture such knowledge from individuals, resolve differences among experts on teams, resolve internal decision process conflicts, and provide a basis for preserving expert knowledge that is often a critical corporate asset. The knowledge engineering process also provides a basis for training and for automating (e.g., expert systems) such expert knowledge.
- Nonlinear (i.e., mathematically chaotic) processes—Intuition of local experts may not be captured by traditional analysis or knowledge engineering methods. However, the expertise usually can be captured by neural networks and implemented as stable, robust, automated processes.
- Pattern recognition—Although humans are excellent in performing pattern recognition processes (e.g., rapid visual inspection and those that require extended periods of concentration, such as inspection of fresh produce, bottles, and histology slides or monitoring for data anomalies), they make mistakes as they become tired or bored. Furthermore, at reasonable production rates, people often err even when attentive (often at an error rate of 0.5 to 1.5 percent). Neural networks have been found to be exceptionally accurate and cost-effective in real-time pattern recognition inspection processes. Monitoring of alarms, a somewhat easier process, often may be performed using expert systems.
- Fault isolation, detection, and repair—Even unskilled operators can successfully manage automated testing of complex systems: scripting of tests, interpretation of anomalies, diagnosis, repair instructions, and required retest. Such methods are already well-established in high-technology industries, such as electronic equipment manufacturing.
- Process control—Many manufacturing processes require real-time monitoring and automated process control to achieve high yield. The influence of variations in raw materials, tool wear, local environment, etc., has been effectively automated in many

industries (e.g., commercial baking, steel mills). The ability of machine intelligence to rapidly and accurately analyze and predict is an essential element of such process control.

4.13.3 Technology Profiles

4.13.3.1 Robotics and Neural Networks

Despite a long history of robotics manipulation of hazardous materials (e.g., production of fissionable nuclear material by the Manhattan Project) and highly publicized current applications (e.g., welding and painting by robots in automobile plants), the emerging technology is even more promising in cost-effective manufacture of high-quality products. Neural networks are the key for the following reasons:

- Autonomous robots that mirror many aspects of human cognition are most easily implemented by neural networks. Neural networks generalize, learn by example, readily cope with data errors, are relatively insensitive to over- or under-specification of problem information, provide data fusion, provide excellent pattern recognition and classification ability, and inherently implement fuzzy logic functions. Difficult problems (e.g., inverse kinematics, scheduling plagued by combinatorial explosion) are readily resolved by neural networks.
- Most process-related problems can be resolved in real-time limits by neural networks.
- Neural networks are extraordinarily robust. If a neural network is implemented using hardware, it is possible to remove a large fraction of the microcircuit chips in the system without seriously reducing system capability.
- Although the most neural networks are “frozen” in use (i.e., after training and testing is complete, the network weights remain fixed), even frozen networks can resolve problems outside the original training domain. Furthermore, neural networks may be implemented as adaptive systems that compensate for changes in the problem-solution environment.

4.13.3.2 Computer-Aided Design, Engineering, Manufacturing, and Testing

Important emerging technologies that impact manufacturing include the following:

- Virtual reality, often dismissed as a medium for entertainment, offers major benefits to manufacturers who must integrate complex physical systems. The cost of building expensive mock-ups to ensure that components fit within very limited spaces (e.g., submarines, aircraft) can be avoided by using production design drawings and specifications to build a virtual system prior to manufacturing. Furthermore, virtual reality can be used during manufacturing to increase productivity and prevent errors (e.g., projection of connections and routing for wiring to be installed in a virtual space coincident with equipment under construction).
- Neural networks have been applied successfully to many complex process control tasks to increase productivity and quality (e.g., automated milling controllers that compensate for tool wear and differences in composition of work pieces).

- Laser scanning to form solid polymers in liquid materials permits three-dimensional models to be created from numeric data (e.g., computer-aided design files, MRI output). The resulting models may be used for visualization or as the basis for making molds (and are already in use in medicine), creation of special cinematic special effects, and industry. Because the data used to produce the models is numeric, scaling, image processing, and other computer operations are easily applied.
- Although computer-aided design techniques (e.g., drafting, dimensioning, rendering) are well-established, their use in conjunction with machine intelligence is creating even greater potential for their application (e.g., automated checking of internal consistency and compliance with codes and requirements).
- The refinement of software engineering practice (e.g., agent, domain, object methods; package reuse; improved metrics) continues the strong trend of using innovative technology to improve usability, reliability, productivity, cost-effectiveness, and defect reduction.
- Integrating the computer-aided design, engineering, manufacturing, and testing techniques discussed previously offers major advantages in productivity, cost reduction, defect prevention, and quality improvement.

4.13.3.3 Other Computer and Information System Technologies

In addition to the computer-aided design, engineering, manufacturing, and testing issues mentioned, other important emerging information system technologies are described in Section 4.12, Information Systems. Several emerging computer technologies are also important within the manufacturing application domain:

- Fuzzy logic controllers, often embedded in products, may be used to dramatically improve performance of those products.
- Digital signal processor microelectronics may be used for appropriate applications to produce high-capacity processing systems at low cost (e.g., neural network controllers, image processors).
- Emerging machine intelligence methods, such as case-based reasoning tools, are extending knowledge-based systems technology. For example, case-based reasoners store and process more complex factual and temporal information than established knowledge-based systems. Use of case-based reasoners as help desk assistance is already established in support of the manufacturing application domain.
- Except for detailed mathematical analysis of chaotic systems (i.e., determination of the attractor), no method other than neural networks currently is known for determining chaotic system behavior to the limits of the prediction horizon.

4.13.3.4 Materials and Fabrication Techniques

Materials technology, for both materials and fabrication, has long played an important part in the manufacturing application domain. Within the last few decades, ceramics have become important materials in high-technology systems (e.g., high-intensity permanent magnets, superconductors, precision gyroscope bearings, structural materials in very high temperature environments). Specialized adhesives also are used in production of high-technology assemblies in challenging environments (e.g., honeycomb composites used in high-Mach aircraft surfaces). Metallurgy has long been critical in high-technology applications (e.g., jet engines, nuclear reactors) and continues to develop innovative materials (e.g., woven titanium fabric used as the basis for composite materials).

The use of fibers to strengthen composite materials is well established; however, recent study of Buckeyballs revealed yet another form of carbon: microtubules. The microtubules have already been used to fabricate unusually fine carbide filaments that show promise of improving exotic composite materials. The same fabrication technique also is anticipated to have important application to the development of advanced microelectronics.

Microelectronics fabrication techniques have been adapted for the creation of microelectronic-mechanical systems. Minute motors, valves, and sensors have been constructed that provide an enabling technology for new technology sensors and effectors. Such devices are anticipated to be useful in medicine, precision manufacturing, space exploration, and other areas where small-scale, low-weight devices are necessary.

4.13.4 Systems Engineering Challenges

About 150 years ago, Congress proposed that the U.S. Patent and Trademark Office be closed because it was "obvious that everything that was going to be invented had already been invented."

About 75 years ago, the researchers in a British laboratory concluded that they had succeeded in creating the thinnest wire yet produced. They proudly mounted a length of wire on a microscope slide and sent it to a rival Swiss laboratory group. The Swiss group promptly drilled a series of holes in the wire, threaded a finer wire through the holes, and returned it to the British. The era in which such a series of events can occur seems truly to be at end with the emergence of nanotechnology. Recent developments in fabrication at the atomic level permit the precise movement of single atoms to desired locations on a substrate (e.g., a derivative of the field emission scanning microscope was used to write "IBM" in characters only a few atoms tall). There is obvious application of this technology to research in reducing the size of electronic microcircuits.

History thus indicates that it is risky to assume that technology will plateau in the foreseeable future. The challenge to systems engineering is to remain aware of emerging technology and apply it appropriately. If an established method serves well, it is seldom useful to use emerging technology (pioneers take lots of arrows). However, some new applications that could solve existing problems can be implemented only by applying emerging technology. On the personal level, a further challenge is to enjoy the march of technology without yielding to future shock. History and the currently accelerating rate of technology development indicate that we can anticipate continuing technological developments that are well beyond our present imagination.

4.13.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

LeRoy Botten
3715 Capulet Terrace
Silver Spring, MD 20906
Voice: 301-985-8726
Fax: 301-985-8909

4.13.6 References

To be supplied.

4.14 Medical Devices

4.14.1 Introduction

The medical device industry in the United States and throughout the world is a highly competitive application domain in which both small and large companies create products to support health care providers. The growth in technology, particularly computing technology, has dramatic improvements in commercial medical devices. Risks in this application domain include the impact of product-related litigation and the cost of advanced medical devices.

Table 4.14–1 summarizes the medical device industry. Table 4.14–2 focuses on the application of systems engineering in the application domain.

4.14.2 Industry Functions and Processes

The medical device application domain has generally combined research and development with manufacturing to rapidly bring advanced technologies to production. In this process, the application domain uses processes similar to those described in Section 4.13, Manufacturing. From a systems engineering viewpoint, this application domain differs from most manufacturing efforts in that defects in design or production often have life-threatening impact on users and product liability exposure for the device manufacturer.

Table 4.14–1. Medical Device Industry Summary

Number of Companies (U.S./non-U.S.)	7000/TBS
Representative Firms	Advanced Technology Laboratories, General Electric, Hewlett-Packard, NeoPath, Physio-Control Corporation, Siemens, Leksell, Inc.
Annual Sales (U.S./non-U.S.)	$33.7 billion/$37.2 billion (1991)
Products	Diagnostic equipment, resuscitation equipment, patient data management systems, implantable devices
Technical Challenges	Complexity of software based functionality, safety assurance, user interface for medical personnel
Business Challenges	Health care regulation, medical versus technical needs, liability, external governmental regulation
Major Customer Groups	Hospitals, doctors, pre-hospital providers, governmental health agencies, health corporations
Regulatory Groups	Food and Drug Administration (FDA), European community, safety agencies

Table 4.14–2. Systems Engineering in the Medical Device Industry

Systems Engineering Requirements	FDA Good Manufacturing Practices section on design control, ISO 9001 quality system requirements for design control, potential software process certification (TickIt, SPICE, or SQSR)
Systems Engineering Strengths	Understanding user needs, balanced design
Systems Engineering Challenges	Integration of embedded software, interface management, integration of explicit and implicit external product requirements (e.g., AAMI, IEC, TUV)
Unique Systems Engineering Tools or Techniques	Clinical trials to validate the technology and the proposed protocol; user trials with prototype devices prior to final marketing
Systems Engineering Related Standards	FDA Good Manufacturing Practices (21 CFR Part 820) ISO 9001 Medical Devices Directive (Council Directive 93/42/EEC)

4.14.3 Technology Profiles

Medical technology and supporting medical devices described in Section 4.10, Health Care, include the following:

- X-ray technology
  - CAT scans
  - Charged-coupled device imaging
  - Improved X-ray film
- Noninvasive imaging techniques
  - MRI
  - Sonograms
  - PET scans
- Virtual reality technology
  - Convenient and effective remote consultation
  - Enhanced surgical and nursing training
- Advanced prosthetic devices
  - Smart prosthetic devices (e.g., sensing of nerve signals in stumps that are processed by microcomputers and used operate life-like artificial hands; recovery of the ability to walk by use of computer-generated signals that actuate muscles otherwise isolated by nerve damage; aids for paraplegics)
  - Cochlear implants

- Virtual reality and robotics
  - Remote performance of surgery
  - Surgical tools that interact with computer images (e.g., brain surgery)
- Communications
  - Real-time EKG, EEG, and EMG analysis
- Information system technology permits storage, rapid retrieval, and appropriate display of complex data from large information stores (e.g., during surgery)
- Machine intelligence
  - Diagnostic devices that do not get bored or tired and that generate reproducible test results (e.g., neural network supported histology analysis of Pap smears)
  - Conversion of printed text to artificial speech
- Exquisitely sensitive chemical and nuclear-chemical diagnostic tests
- DNA/genetics
  - Genetic counseling
  - New approaches to manufacturing of pharmaceuticals (e.g., growth of bacteria with tailored genes-based on gene splicing that create desired antibodies or pharmaceutical agents)
- Computing support and advanced visualization
  - Structural analysis of interaction of tissues, disease agents, immune functions, drugs, etc. (e.g., clues to fighting retroviruses, bacterial adaptation to antibiotics, and autoimmune diseases)
  - Computer modeling and design of tailored molecules for pharmaceuticals that produce desired effects while minimizing side effects (e.g., psychoactive medication, safer and more effective vaccines and antibiotics)

In treating deep tumors, gamma radiation (i.e., high-energy x-ray) beams have long been used to preferentially destroy diseased tissue. Unfortunately, gamma radiation damages all tissue in its path. By using mechanical devices to move the beam or the person being treated, it is possible to concentrate tissue damage to the region of the tumor. However, the ability to create a sharp physical boundary between the tissue preserved and that destroyed by gamma radiation is not possible. However, with newer radiosurgery devices such as the Gamma Knife System, it is possible to lower the radiation per beam and allow multiple beams (e.g., 201) target the tissue to be damaged. Certain elementary particles, such as pions, display a useful property—they do not have a high probability for interaction with human tissue unless they are traveling below a known critical velocity (i.e., a known energy level). Using a particle accelerator, a very small pion beam of precisely known energy may be created. Such a beam initially interacts with human tissue by slowing down (losing energy mostly through interactions with hydrogen nuclei in human tissue). The slowing process itself does little damage and the rate of energy loss can be accurately predicted. However, at the point in space where the beam reaches critical speed, the nature of its interaction with tissue changes dramatically. At this point, which can be precisely controlled, almost total tissue destruction occurs. Using this technique, otherwise inoperable tumors (e.g., those buried deeply in critical brain tissue) may sometimes be overcome.

Applied physics and materials science are making important contributions to medical device technology:

- Advanced adhesives and composite materials
- Improved MRI magnets
- Improved understanding of fluid flow and materials interaction leading to artificial heart valves that last longer and do not damage blood cells
- Improved electron microscopy (e.g., false colors, stereo imaging)
- Improved implant technology
  - Specialized materials (e.g., joints, skin, and soon ligaments with durable, tailored mechanical and chemical properties)
  - Pre-formed materials for replacement and reconstructive surgery tailored materials molded in forms prepared from MRI and computer-aided design files. Such files can be used to control laser scanning of liquid materials to form solid polymers that create three-dimensional models from the numeric data. The resulting models may be used to prepare molds for implants and prosthetic devices. These techniques are already in use in medicine, for creation of special cinematic special effects, and in industry.
- Improved surgical tools (e.g., laser cutting and abrasion, laser dental drills, tools and imaging for cytoscopic surgery)
- Advanced batteries (i.e., nuclear decay for implanted power sources)

Real-time analysis of brain waves by neural networks may be used to control a PC in lieu of a mouse. Using commercially available microelectronics permits the sensors and processors to be extremely compact. PC interfaces to robotics, communications, and other devices allow paraplegics to interact with and control their environment.

Microelectronics fabrication techniques have been adapted to create microelectronic-mechanical systems. Minute motors, valves, sensors, etc., have been constructed that provide an enabling technology for new technology sensors and effectors. Such devices are anticipated to be useful when small-scale, low-weight, precision-control devices are necessary.

4.14.4 Systems Engineering Challenges

The challenges to systems engineering in the medical device application domain include attention to risk assessment and mitigation (e.g., efficacy, reliability, and safety for patients; product liability for manufacturers and health care providers), and careful tradeoff of costs, benefits, and risks. Sensitivity to human interactions is also a major challenge because people often are threatened by new technology (e.g., machine intelligence, anything with the “nuclear” label).

4.14.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

LeRoy Botten
3715 Capulet Terrace
Silver Spring, MD 20906
Voice: 301-985-8726
Fax: 301-985-8909

Dr. William F. Mackey
Computer Sciences Corporation
7700 Hubble Drive
Lanham-Seabrook, MD 20706
Voice: 301-794-2138
Fax: 301-794-8920
E-mail: wmackey@csc.com

4.14.6 References

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4.15 Motor Vehicles

4.15.1 Introduction

The motor vehicle industry in the United States and throughout the world is consolidating to a small group of worldwide companies. The high technology content of the product is increasing due to regulatory and customer demands. The successful companies also have been leaders in introducing technology into the manufacturing process (e.g., computer-aided design, engineering, manufacturing, and testing; robotics; scientific visualization; virtual reality; scheduling and inventory control). Additional comments related to this industry segment are included in Section 4.13, Manufacturing.

Risks in this industry segment include the introduction of advanced electronics and the future role of the motor vehicle in a society with environmental concerns.

Table 4.15–1 summarizes the motor vehicle industry. Table 4.15–2 focuses on the application of systems engineering in the application domain. (Note: These tables will be added at a later date.)

4.15.2 Industry Functions and Processes

4.15.2.1 Materials and Inventory Management

Automotive manufacturers have been leaders in developing and applying inventory management methods. Vehicles are assembled from subassemblies and parts that are often produced under contract at locations remote from assembly sites. To avoid very costly interruption of the assembly line process, it is critical that parts and subassemblies be available where and when required. However, the cost of procuring and storing excess inventory of subassemblies and parts may seriously impact profitability.

Established methods for successfully managing availability of materials and inventory heavily depend on automated process management. System engineering tradeoff studies of cost, benefits, and risks are essential in developing these process.

For example, bringing together subassemblies and parts at the correct point on the assembly line when they are needed is critical in sustaining the process within floor space constraints. This just-in-time approach has been extended to delivery of parts and subassemblies at the manufacturing plant with particular success in Japan because suppliers tend to locate in the immediate vicinity of assembly plants where their products are used. Although more risky in the American environment, careful analysis has permitted selective application of just-in-time methods within the United States.

4.15.2.2 Scheduling

The scheduling of manufacturing and assembly equipment and delivery of required parts and subassemblies heavily depends on automated operations research and machine intelligence methods. The system engineering for such scheduling is based on highly automated integration of functions provided by support and design functions (e.g., parts breakdown, inventory management).

4.15.2.3 Computer-Aided Design, Engineering, Manufacturing, and Testing

The previous descriptions of inventory management and scheduling are components of computer-aided manufacturing. For objects as complex as contemporary motor vehicles, the ability to use computer tests is crucial, not only on the production lines, but to support field repairs in a rapidly changing environment. Many phases of design and engineering depend on automation. For example, the remarkable reliability of contemporary vehicles is facilitated by the high level of computer-aided engineering support used in design process and quality control processes. The variation of style and function in a manufacturing product line would not be possible without the existing base of computer-aided design, drafting, and rendering tools.

Advanced visualization techniques often are used for mechanical, thermal, and thermodynamic visualization during analysis and design.

An important emerging development is the use of virtual reality to visualize integration and ensure fit of components into a completed design. This process, accomplished from computer-aided design files before creation of tooling begins, increases productivity and prevents costly errors. Development of tools and dies using automated milling leads to precision and uniformity.

Models and molds can be created directly from computer-aided design files by using laser-driven polymerization methods. Human engineering and styling of products is facilitated by use of such models and molds, especially when combined with virtual reality and advanced visualization techniques.

4.15.2.4 Process Management

For complex processes that are highly interdependent, it is essential that metaprocesses (i.e., processes dealing with management of processes) and metrics be well-developed and fully utilized. The automotive industry has been a leader in developing and using process control, defect management, and total quality management.

4.15.3 Technology Profiles

Many assembly line processes are automated to increase the speed and reproducibility of process steps (e.g., welding, painting). The robot’s articulation problems encounter the difficult problem of specifying inverse kinematics. [Given a robot and the position (extension and rotation) of all joints, it is easy to specify the position and orientation of tools manipulated by the robot.] However, given a required position and orientation, it is difficult to specify appropriate positioning of joints while avoiding gimble locks (the inverse kinematics problem.) Traditionally, this problem was resolved by using specified sequences of joint extensions and rotation stored as files. This approach is generally successful; however, problems such as joint sensor misalignment, joint wear, and damage (e.g., bending of a robot arm) can lead to costly and sometimes dangerous malfunctions. The application of neural networks to robotics control provides a much more robust and effective solution to this problem.

4.15.4 Systems Engineering Challenges

Successful motor vehicle manufactures are already leaders in applying new technology. Systems engineering challenges in this industry segment include application of virtual reality and use of adaptive neural network controllers for robotics.

4.15.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

LeRoy Botten
3715 Capulet Terrace
Silver Spring, MD 20906
Voice: 301-985-8726
Fax: 301-985-8909

4.15.6 References

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4.16 Natural Resources Management

4.16.1 Introduction

Natural resources management in the context of the systems engineering applications profiles includes the management of those resources under the jurisdiction of the U.S. National Park Service (NPS), the National Forest Service, and the Bureau of Land Management (BLM). These resources, their extent, current issues, and how they can be treated as systems are addressed in the following subsections.

The natural resources of the United States are tremendous. The United States has 740 million acres of public land – nearly one-third of the nation. In addition, the country has more than 1 billion acres of outer-continental shelf. Oil and gas reserves are 36 billion barrels and 178 trillion cubic feet of gas. Some statistics on the subject lands are as follows:

- Under the Department of Interior, the NPS is responsible for the following:
  - 50 national parks composed of 44.3 million acres
  - National preserves composed of 22.1 million acres
  - 18 recreation areas composed of 3.6 million acres
  - 79 national monuments composed of 4.8 million acres
  - Other smaller-size lands include wild and scenic rivers and river ways, scenic trails, national memorials, historical parks and sites, battlefields, and lake shores and seashores.
- Under the Department of Agriculture, the National Forest Service has 191 million acres (86.5 percent of which are commercial timberlands), 156 national forests, and 19 grasslands. The National Forest Service is divided into nine regions.
  - The BLM is composed of 250 million acres.
  - Wilderness areas are composed of 90.7 million acres. They are part of National Forest Service and BLM lands.

Numerous subjects reside within the context of Natural Resources Management. The management of the above lands and the issues currently under discussion are systems challenges of the first order. The resources themselves are systems, as are the management systems and processes needed to manage and control the lands and the resources on the lands.

This task necessitates having knowledge of the governing laws and Congressional Acts to be implemented on these lands and with these resources. It often involves public participation in setting the goals and priorities for land use within the laws.

Section 4.16.4 provides insight into how these public resources can be treated as systems. It shows how systems engineering techniques and processes can be used to establish and improve the management and design of the land uses and how systems engineering can contribute toward solving the many problems that exist with these systems.

Related natural resources topics addressed in other sections of this document are environmental restoration, waste management and disposal, and GIS.

Table 4.16–1 summarizes the natural resource management industry.

Table 4.16–1. Natural Resources Management Industry Summary

Number of Companies (U.S./non-U.S.)	20 major companies; hundreds of smaller companies as consultants
Representative Firms	Usually conducted by Federal Government personnel, specifically in the Department of Agriculture (National Forest Service) and Department of Interior (BLM and NPS)
Annual Sales (U.S./non-U.S.)	TBD
Products	Planning documents, maps, guides, regulations, databases, brochures, and presentation materials
Educational Materials	Informal public materials and formal training
Technical Challenges	Ease of use interface, integration of multiple platform and database formats, shift to PC level, use of client-server architecture, staying up-to-date with PC architecture
Business Challenges	Obtaining consensus and agreement among stakeholders with divergent interests
Major Customer Groups	Businesses such as lumber products, mining, and grazing; federal, regional, and local governments; environmental non-Governmental organizations (NGOs) such as the Sierra Club and the Wilderness Society; and public regulatory groups.
Regulatory Groups	Congress, Executive Branch departments
Growth	Low (< 10 percent) annual growth expected

4.16.2 Industry Functions and Processes

The application domain of natural resource management includes planning for areas under natural resource control, providing trained personnel to manage the areas, and managing the lands in national forests, national parks, and BLM and wilderness areas. Work in this application domain involves coordinating with Congress and other political agencies to achieve new laws and regulations. It also includes reviewing the lands under public jurisdiction and periodically adding to or subtracting from the total inventory. Applicable jurisdictions for natural resource management include the BLM, the Environmental Protection Agency (EPA), the NPS, and the National Forest Service.

The brief history presented shows the evolution of natural resource management and describes the various roles and functions these agencies play in natural resource management.

Prior to the 1960s, natural resource management was under the jurisdiction of the NPS, the National Forest Service, and the Geological Survey. The Wilderness Act of 1964 started a trend toward a large-scale bureaucracy for land use management. More than 3000 public-land laws have been passed by Congress.

An important related agency is the EPA, which was established in 1970. In 1970, Congress passed air pollution controls acts, and in 1972 it passed water pollution acts. The laws governing the EPA were broadened in 1977. Endangered species acts were passed in 1973 and 1978. The National Environmental Policy Act (NEPA), passed in 1970, radically changed the process of developing natural resources. It forced public decision-making onto the Federal land bureaucracy.

Alaska's admission to the Union in 1959 significantly increased U.S. public lands. Alaska's total land area is 104 million acres; 28 percent of that are public. A major controversial issue is Native peoples' claims versus land developers' plans. Arizona Congressman Morris Udall passed a law that added the public to the two-way situation of the State and the Native peoples dividing up the land.

In 1976, two major bills passed by Congress had a significant impact on how lands are managed:

- The National Forest Management Act (NFMA) of 1964 formalized a complex system of land planning and management on National Forest Service lands. This act adds professional resource managers to the National Forest Service. The NFMA also allows new standards for marginal lands in the national forests, for example, more sensible economic development in public lands and a process to allow a reasonable timber supply.
- The Federal Land Policy and Management Act (FLPMA) of 1976 imposed regulations on the BLM, the agency that controls overgrazing and provides forage for livestock, wildlife, and wild horses.

The Department of Interior is a controversial agency that needs reassessment. It has virtually unlimited power to sell energy resources on the public lands.

4.16.2.1 National Park Service

Created in 1916, the NPS contrasts with the National Forest Service in many significant ways. Steven Mather, its first director, garnered business support. The NPS historically has never been involved with science and land management training. Its mission statement, which is simpler than that of the National Forest Service, is to preserve the land in its natural state. Some of the problems within the NPS jurisdiction are

- Tourist overload
- Introduced plants and animals
- Urban industrial development outside the lands (e.g., air pollution)
- Archeological sites

4.16.2.2 National Forest Service

The National Forest Service has a highly trained professional staff who have mastered public relations and bring public involvement into the planning and decision processes. The National Forest Service manages 191 million acres of land and is dominated by the forest products industry.

4.16.2.3 Bureau of Land Management

Prior to the creation of the BLM in 1946, there were other public land laws. The Taylor Grazing Act of 1934 was the most important law established to manage the public land. The act encompassed most of the remaining public domain outside of the national parks and forests, and primarily served ranchers. In 1946, the Geological Survey and the General Land Office were merged to become the BLM. The FLPMA ended 200 years of public-land disposal by the Federal Government. The remaining lands were to be held in public trust. The Sagebrush Rebellion that resulted caused land users to find means of leasing, buying, or otherwise obtaining ways to use the lands for commercial purposes.

In the early 1980s, Interior Secretary James Watt planned to sell off large segments of the public lands under privatization. He also began a program of leasing energy resources that included oil, coal, and gas, including oil on the outer continental shelf. In 1 year, 44 million acres were leased to oil companies. These low-priced leases were noncompetitive and granted for 40 to 50 years. The public earned $1 per acre. After the lease period, corporations were to return lands to the public. This leasing program caused considerable controversy. To some, it violated the idea that protecting resources is a moral obligation to future generations. Some superficial Environmental Impact Reports were generated.

4.16.2.4 Other Agencies

The Fish and Wildlife Service administers the national wildlife refuge system. It protects endangered species, protects wetlands, and guards against illegal imports of endangered species. Since its inception, the service has been loyal to its mission, a type of management that has not been true in all agencies.

The U.S. Army Corps of Engineers is the largest of the resource agencies. This old, professional agency is less sensitive to environmental concerns. Its principal responsibilities are flood control; recreation; and maintaining navigation on streams, rivers, and harbors.

The Bureau of Reclamation is newer and smaller than most other agencies. Its mission is to develop water resources and irrigate farmland.

4.16.3 Technology Profiles

The following technology profiles constitute the subject area. Work in this field, by definition, uses the sciences heavily. Biology, botany, forestry, hydrology, zoology, chemistry, and environmental sciences are key specialty areas. Because much of the land is multiple-use, a technical knowledge of those uses is needed in many cases. These uses include mining and agricultural. As in most industries, the explosion of information sciences is benefiting natural resources management. Specifically, computers are used for databases on the many forms of data to be compiled, manipulated, and reported.

Satellite technology is increasingly being used to provide information on the state of the forests and on Earth's condition. Satellite data also will be used for specific metrics on the condition of the resources.

4.16.4 Systems Engineering Challenges

The preceding sections discussed the many controversial issues in natural resource management. Table 4.16–2 summarizes the application of systems engineering in natural resources management.

Table 4.16–2. Systems Engineering in Natural Resources Management

Systems Engineering Requirements	Numerous federal and state laws and regulations, e.g., Wilderness Act of 1964 (amended 1978), NEPA, and FLPMA
Systems Engineering Strengths	Systems analyses to determine land use, both existing and planned; requirements traceability; formal trades; specific writing; and determination and quantification of metrics
Systems Engineering Challenges	Government agencies to sufficiently use systems engineering processes in planning and regulating natural resource use; obtaining data on conceptualized metrics
Unique Systems Engineering Tools or Techniques	Standardized systems engineering tools can be used for most applications
Systems Engineering Related Standards	None
Systems Engineering Requirements	Laws cited earlier form the basis of the requirements for natural resource systems; they flow down to lower levels of land use management plans
Systems Engineering Strengths	Systematic processes used in resource management*

*For example, the National Forest Service uses a process in its wilderness area planning called "The Limits of Acceptable Change" [U.S. Department of Agriculture, 1985]. This process contains some elements of requirements traceability from the requirements documents (laws) to the proposed actions. It also contains metrics to ensure that the proposed designs for the land are being implemented. INCOSE standard processes [Dolton et al., 1995] are being used to complement the process of the U.S. Department of Agriculture.

Another systems engineering strength is in tradeoffs. A more formalized trade process can be employed to provide better visibility into items being traded and provide a basis for decision.

Another systems engineering challenge is that the parts of the plans must be demonstrated to be traceable to the law and regulations. While current practices show some traceability, they are not demonstrated in a rigorous manner. A formal process would greatly enhance the thoroughness and credibility of compliance with requirements and laws. Another challenge is to organize the key points of the federal regulations into clear requirements statements that can be verified. Metrics then need to be further developed to provide the verification.

Systems engineering can ensure that the management process is implemented in a consistent and thorough manner. It can provide the structure to ensure that the laws, where applicable, are formulated into requirements. Systems engineering provides the tools and methodology to ensure that the requirements are flowed down and implemented in a way that can be shown to comply with laws and requirements.

Systems engineering also can be instrumental in mediating controversies by having facts organized in ways that can bring them to light readily and in useful form. Thorough assessment of requirements using databases and requirements management tools is vital. Performing objective trades to make clear the issues and uncover the relevant parameters is an area in which systems engineering can help. Quantitative decision-making tools can also be useful.

4.16.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

Authors:

Theodore A. Dolton
1570 Dana Avenue
Palo Alto, CA 94303
Voice: 650-321-5950
E-mail: alanjoanne@aol.com

Fred Martin
375 San Mateo Drive
Menlo Park, CA 94025
Voice: 415-323-4019
E-mail: fmartin@best.com

Natural Resource Professional Personnel:

Garry Oye, Regional Manager, National Forest Service, Pacific Region
630 Sansome Street, Suite 849
San Francisco, CA 94105
Voice: 415-705-2646

Jay Watson, Regional Director, The Wilderness Society
116 New Montgomery, Suite No. 526
San Francisco, CA 94105
Voice: 415-541-9144
Fax: 415-541-0346

4.16.6 References

U.S. Department of Agriculture, "The Limits of Acceptable Change," *General Technical Report*, INT-176, January 1985

Dolton, T. A., J. P. Hoy, and F. Martin, “Systems Engineering in Wilderness Areas Management,” *Proceedings of the Fifth Annual INCOSE Symposium*, 1995

Other Reading Material

National Forest Service, *National Forest Service Manual 2300*, Chapter 2320, “Wilderness Management,” June 21, 1990

Dolan, Edward F., *The American Wilderness and Its Future: Conservation Versus Use*, Franklin Watts Press, 1992

Shanks, Bernard, *This Land is Your Land: The Struggle To Save America’s Public Lands, Sierra Club Books*, 1984

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4.17 Space Systems

4.17.1 Introduction

In 1915, Congress established the National Advisory Committee for Aeronautics (NACA) to supervise and direct study and development of flight technology in the United States. Forty-three years later, NACA was absorbed into NASA, and 54 years later NASA astronauts set foot on the moon. NASA continues to support U.S. leadership in supporting space science and developing aviation and space technologies.

For many years, NASA, the military, and the National Oceanic and Atmosphere Administration (NOAA) led in development of space technologies applicable to commercial applications (e.g., imaging, remote sensing, communications, satellite operations). From its inception, NASA was directed to develop and transfer technologies appropriate for commercial applications within the United States. To that end, NASA developed close working relationships with other Federal agencies, universities, the commercial sector, and foreign governments. The use of commercial contractors and university personnel to support space missions necessarily led to broadening the base of advanced technology in the United States. The NASA Small Business Innovation program continues to provide support for many successful technical development efforts for technically innovative small and startup businesses. NASA also organizes and participates in many technical conferences and symposia each year. Because these readily available resources emphasize unclassified applications of space research and related technologies, they are highly recommended.

NASA implemented the Computer Software Management and Information Center (COSMIC) at the University of Georgia to facilitate transfer of NASA-developed computer code and documentation. Each month, the *NASA Tech Briefs* magazine provides descriptions of new technology and applications developed or sponsored by NASA and sources for additional appropriate information. NASA's National Technical Transfer Center (NTTC) provides information to potential users regarding technology developments made by NASA and its contractors. NTTC information is customized to meet each user's needs and provides information on contractor contracts, licensing, cooperative agreements, and other aspects of the NASA technology transfer program.

Although NASA has been a key player in creating and maintaining strong technical capabilities in the U.S. economy, the economic importance of commercialization of NASA-developed technologies has probably not been as widely recognized as it should be. In an environment of reduced Federal budgets for science and technology, NASA is challenged to perform its missions "better, faster, and cheaper." To reduce mission costs and encourage broader opportunities for technology transfer, NASA is developing additional methods for contracting its work, commercializing its technology, and expanding its partnerships and other cooperative efforts with commercial firms, universities, and international partners.

During the next several years, we can expect several trends in NASA management of both manned and unmanned space flight projects:

- Increased use of low-cost unmanned missions (e.g., smaller instrument packages, smaller boosters, less complex ground stations—often at university sites, and increased usage of commercial communications facilities)
- Increased contracting of development and operations work formerly performed by NASA to industrial and university contractors
- New methods of contracting and new avenues for cooperative, shared-cost projects with industry and universities

This extended discussion of NASA is not intended to slight the many contractors that have played a major role in space programs. In fact, the already active commercial space industry will assume an increasing share of the functions and responsibilities traditionally carried out by NASA.

4.17.2 Industry Functions and Processes

Traditional elements supporting space science include the following:

- Satellite guidance, navigation, and control (e.g., mission planning, inertial navigation systems, orbit and attitude monitoring and control)
- Power systems (e.g., booster propulsion; maneuvering power systems; vehicle and satellite onboard electrical power generation, storage, and control systems)
- Structures and thermal design [e.g., high strength to weight ratio construction that can survive hostile launch and space environments (including high boost forces and vibration, high temperature gradients, space radiation) while protecting onboard systems including delicate instruments and volatile fuels and cryogenic fluids]
- Communications and data handling (e.g., interplanetary constraints requiring capture of low power telemetry and return of control signals at great distances; low Earth orbit constraints, including capture of very large of volumes of telemetry data during restricted periods of line-of-sight communications)
- Remote sensors (e.g., although major missions have included human and robotic landers, most space science is conducted using sophisticated, sensitive yet robust remote sensors)

Many important technologies, including those described in Section 4.17.3, have been derived from advances in the listed space flight functions and processes. As a result of increasingly challenging mission requirements and severe budget limitations, a number of critical systems engineering challenges, described in Section 4.17.4, have been identified.

4.17.3 Technology Profiles

4.17.3.1 Basic Space Science

NASA has identified six basic space science areas as follows [Haggerty, 1996]:

- Solar System Exploration—study of the Sun; and the planets, moons, comets, and asteroids of the solar system
- Astronomy and Astrophysics—study of stars and galaxies aimed at understanding the origin and evolution of the universe
- Space Physics—study of the Earth/Sun system, including plasmas and ionized gases in the solar system and beyond
- Earth Science Enterprise (ESE) (formerly the Mission to Planet Earth)—understanding of total Earth system and changes in the global environment
- Life and Biomedical Sciences—advancing medical and biological knowledge, and utilization of that knowledge to protect humans in space and in beneficial Earth applications
- Microgravity Sciences and Applications—advancing knowledge of materials and processes for application in a wide variety of applications (e.g., pharmaceuticals, semiconductors, materials)

4.17.3.2 Technology Application Areas

In addition to rapid advances in knowledge of the six basic science areas, space science research has resulted in major advances in related science and technology application areas, including at the very least the following:

- Remote and local sensing
- Computation and data processing
- Communications
- Robotics
- Medicine and biology
- Materials
- Aviation

Although this brief summary cannot do justice to the rapid advances being made in even this limited set of science and technology areas, the following sections describe a few of the more important emerging technology applications in each area.

4.17.3.3 Remote and Local Sensing

For many years we have benefited from improved weather forecasts made possible by NOAA weather satellites; today we enjoy 5-day forecasts as accurate as overnight weather forecasts of the mid-1950s. Such weather predictions have significantly improved crop yields. Early warning of major storm systems, facilitated through tracking of storm systems by weather satellites, has saved many lives and also allowed time to protect property that might otherwise have been damaged or destroyed.

Significant further extension of accurate, detailed weather forecasts (to perhaps an 8-day forecast) is prevented by the chaotic nature of weather systems. However, seasonal forecasts can benefit from detailed knowledge of phenomena such as the El Niño, a large mass of warm water in the tropical Pacific Ocean that often persists for a year or two. El Niño affects weather in the continental United States, often producing very damaging storms. In the April 15, 1996, *Journal of Geophysical Research*, D. V. Hansen and H. F. Bezdek announced results of their study of a similar mass of cold water in the Atlantic Ocean. This mass persisted for up to 5 years, with significant weather and climatic impact on Europe. As an early component of the ESE, the TOPEX/Poseidon project addresses such ocean circulation by monitoring sea surface height to within a few centimeters using an orbiting radar altimeter.

ESE is a long-term project that began in 1991 with shuttle missions (e.g., two flights of the Space Radar Laboratory that measured forestation and its relation to atmospheric heat, water, carbon dioxide, and other trace gases). Phase 1 studies were also based on data collected by the Upper Atmosphere Research Satellite that has long investigated the role of the upper atmosphere in climate and climatic change. Phase 2 of ESE began in December 1999 with the launch of the first Earth Observing System (EOS) satellite, Terra (formerly EOS AM-1), that will observe how air, water, and land masses of the Earth interact with life and began development of a 15-year baseline for evaluating global changes.

Virtually all satellites depend on remote sensing to monitor weather, create images, observe astronomical objects, and provide information for orbit and attitude control of the satellite. Although military surveillance satellites images are reputed to be superior in definition to commercially available Landsat and SPOT images, these images have important commercial applications in exploration and assessment of agricultural, mining, and petroleum resources (often combining imaging in radar, infrared, optical, and ultraviolet bands).

As late as the 1950s, major portions of the Earth's surface had not been accurately mapped. Perturbations in satellite orbits are an important method for determining the average shape of the Earth. Optical and radar information, combined with such information, is used to prepare high-precision maps that are, as previously mentioned, often combined with data from other remote sensors.

The GPS is a constellation of satellites managed by the military that provides precise time and location information anywhere on Earth by passively using data received from several satellites in the constellation. Tactical hand-held units provide individual military personnel with very accurate locations. Civilian GPS receivers are not able to exploit coded precision timing information embedded in the satellite signals and are, therefore, less accurate than military systems. However, even the degraded accuracy is fully usable for air, land, and sea navigation. GPSs are now being used to monitor commercial truck movements. GPSs, coupled with computerized maps, are being demonstrated as a means of precisely guiding automobiles, usable on city streets. Such applications should become fairly common in automobiles within the next few years, especially because innovative techniques have been devised to implement civilian GPS receivers of increased accuracy.

The GPS also has important applications within the space industry as a basis for determining satellite orbits.

4.17.3.4 Computation and Data Processing

Development of high-speed telemetry systems have enabled huge volumes of data to be gathered by low Earth orbit satellites, particularly for such comprehensive programs as ESE. Twelve years ago, a terrabyte (10^{12} bytes) database was considered very large. Today, distributed petabyte (10^{15} bytes) and exabyte (10^{18} bytes) databases are being implemented.

Because telemetry data is often received only during scheduled periods when satellites are “visible” to the ground station, internal recorders usually store data during the extended periods when satellite transmissions cannot be received by the ground stations. [Some military and research missions maintain almost continuous on-orbit communications by using the Tracking and Data Relay Satellite System (TDRSS). TDRSS consists of three synchronous relay satellites and has largely replaced the network of ground stations used in the early space program. Although the ground network was very expensive to maintain, TDRSS is not cheap.] During periods when telemetry is not available to a satellite, data is normally stored on a tape recorder. To minimize onboard power usage and delay time, data is often read and transmitted while the tape moves in the direction opposite to which the recording was made. The processing of large volumes of telemetry data places severe demands on existing ground processing systems (e.g., to ensure data is complete, time-ordered, and accurate.) Fortunately, several emerging technologies are helping to resolve this problem:

- Space-certified solid state recorders use large arrays of random access memory (RAM) and no moving parts, and are protected against the radiation and temperatures encountered in the space environment. Reliability is improved and data can be read in the same order in which it was recorded without paying a power of time delay penalty. The availability of this technology is an argument for performing several steps in telemetry processing onboard rather than at the ground station.
- Useful telemetry format standards are one of several reasons that the traditional custom-built ground stations are being replaced by systems integrated from commercial off-the-shelf (COTS) hardware and software products.
- A variety of excellent data compression methods exist and permit the designer to optimize data compression throughout the lifetime of telemetry data and the information products derived from that data.

- Special-purpose VLSI microchips permit implementation of inexpensive hardware to perform specialized data processing functions (e.g., data compression and decompression) at extremely high data rates, either onboard or on the ground.
- Space-rated (e.g., hardened to survive high radiation, robust under temperature variations and power transients), capable digital systems are available; for many years, the only available space-rated digital systems were very limited in capacity.

Progress is being made in using emerging techniques (e.g., genetic algorithms, neural networks) to perform optimization, scheduling, and processing functions that are either impossible or impractical using traditional methods.

4.17.3.5 Communications

The importance of synchronous satellites to the communications and entertainment industries is well known. Recent improvements in transmission power capability have made direct satellite reception of television signals at individual homes on inexpensive, small ("pizza pan") antennas a commercial reality.

The next major phase in satellite communications will involve constellations of satellites orbiting at less than synchronous altitude. Three versions are now being implemented based on different philosophies of orbit configuration and operation. The basic model for all three systems is the same: the cellular phone system. However, rather than have the customer move through fixed zones in the service area of a cellular phone provider, the zones (i.e., footprint of the individual satellites) move with respect to fixed or slow-moving customers. These systems are designed for whole-Earth coverage via hand-held units. If suitable ground carriers are not available (e.g., for a customer far at sea), signals are routed via other satellites in the constellation until a suitable ground link (or perhaps even a direct satellite-to-ground link) is available to complete call routing. A particularly interesting application of these systems planned to support space science research is to use them as a relatively low-cost method for maintaining continuous contact between science satellites and experimenters when cost-effective (e.g., ability to implement much simpler, small research satellites) or necessary (e.g., timely onboard problem resolution and repair, critical data capture).

4.17.3.6 Robotics

Although industrial robots [e.g., automated tape librarians, automated (perhaps programmable) assembly devices used on assembly lines, handlers for dangerous substances] are already a valuable tool in industry, robots capable of at least limited autonomy are required for key space applications. For example, the time delay inherent in direct commanding of sophisticated vehicles or landers at very great distances (e.g., Mars and beyond) can increase the danger of damage to such vehicles and may also waste limited fuel or other consumables otherwise available to meet mission goals. Furthermore, humans have great difficulty in direct commanding if there is such a time lag. Robots that can accept goals rather than commands, and respond to their environment based on visual or other cues will help overcome these problems. This technology is progressing and should have interesting and significant impacts when introduced into our culture (several are described in Section 4.17.3.7).

Other issues related to autonomy are discussed in Section 4.17.4.

4.17.3.7 Medicine and Biology

Perhaps less well known than the dramatic achievements of Apollo and Voyager, space research has yielded a steady and important increase in understanding human physiology. Such understanding is critical for extended space flight (e.g., to Mars) or long-term habitation on a space station and is making a significant contribution to human medicine (e.g., bone calcium loss, motion sickness).

A particularly pleasing contribution is being made by space research in helping persons overcome handicaps and injuries, such as the following examples:

- NASA participated in successful development of the Low Vision Enhancement System [Haggerty, 1996] designed to aid persons afflicted with what ophthalmologists call "low vision." This problem affects some three million Americans and is not correctable surgically, medically, or by use of glasses.
- Light-weight materials that are extremely strong have been an essential research topic in support of space flight. Some of the materials are providing an excellent basis for prosthetic devices. Sensor technology developed in the space program has also been used to provide control for prosthetic arms and hands.
- Use of controlled, direct electrical muscle stimulation may provide the ability to walk for persons with severe spinal cord problems. The robotics and sensor technologies developed for space research have contributed to this promising research.
- Speech recognition, remote manipulators, robotics, and other technologies have been developed to assist astronauts working in a weightless environment. Such developments are directly applicable to devices that allow bedridden or otherwise immobilized persons to independently interact with their environment.

4.17.3.8 Materials

Materials technology has always been important to space flight. As previously mentioned, composite materials have particular value in creating usable, comfortable prosthetic devices. Advances in heat insulation technology, ceramics, and other materials research have been applied widely by industry.

NASA developments and sponsorship of shape memory metal should see application in easily assembled and disassembled space station structures [Haggerty, 1996]. It is also used to build bathtub and shower faucets with built-in protection against scalding accidents.

The importance of microgravity and high-vacuum facilities to crystal, semiconductor, metallurgy, biological, and physiological research and applications, among others, has been widely publicized. Significant impact on the economy should occur when microgravity manufacturing facilities are readily available in space.

4.17.3.9 Aviation

Ignoring the charter that NASA has for supporting a broad spectrum of aviation technologies, there is significant cross-over with space research in development of the hypersonic scramjet. The development of aircraft launchers for small, low-Earth orbiting satellites is an interesting concept.

Aviation also enjoys many benefits from the space program including applications of technology relating to materials, navigation aids (e.g., GPS), communications, and cartography.

4.17.4 Systems Engineering Challenges

Increased commercial application of space systems and sophistication of space science missions (as science support declines) leads to several emerging systems engineering challenges for space flight and space science systems, including the following:

- The need for well-integrated, robust, low-cost low-Earth orbiting systems—Such systems require proper allocation of functions among onboard, other satellite, and ground support systems. Advanced mission requirements and available technology are clearly leading to revisions in traditional allocations, for example, there is a trend to place more functions and autonomy onboard the spacecraft.
- The need for reduced time and cost to develop and implement missions—Recent advances in integration of COTS components have been demonstrated to yield very large cost and time savings in implementing satellites and ground support systems.
- The need for increased autonomy in onboard and ground support system operations—Operations is a major component of mission life-cycle costs. Major savings through use of autonomous, or semi-autonomous, systems that permit extended unattended, or partially unattended, operations allow more and/or longer missions to be flown on restricted budgets.
- The need for increased autonomy of robotic landers and sensors on interplanetary flights—The time delay inherent in direct commanding of sophisticated vehicles or landers at very great distances can increase the danger of damage to such vehicles and may also waste limited fuel or other consumables otherwise available to meet mission goals.
- The development of petabyte- and exabyte-distributed databases intended to provide long-baseline data (e.g., for global change and astronomical research)—New management methods to cover problems of staging data, managing media degradation, preserving ability to read bit streams at the device level, preserving ability to convert bit strings to useful information, and indexing data and data products, among others, require automated solutions to be manageable.

- The development of smaller, less-expensive spacecraft involves the development of methodologies for designing, implementing, testing, and operating systems quickly and economically (e.g., in the near term probably based on object-oriented design and implementation, COTS integration, intelligent agents, object resource broker architectures, and use of evolving prototype methods to improve the ability to introduce new technology while avoiding undue risk).

4.17.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

LeRoy Botten
3715 Capulet Terrace
Silver Spring, MD 20906
Voice: 301-985-8726
Fax: 301-985-8909
E-mail: lbotten@csc.com

For additional information on Landsat, contact

Drew Riggs
Voice: 301-985-8718
Fax: 301-985-8909

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Athens, GA 30602
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4.17.6 References

Haggerty, James J., *Spinoff 1995*, Document NP-217, NASA: Washington, DC, 1996

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4.18 Telecommunications

4.18.1 Introduction

The telecommunications industry in the United States and throughout the world continues to grow rapidly in capacity and functionality. Such growth has been made possible largely by application of advanced technology. Risks in this application domain include limited spectrum for some types of communication (e.g., broadcast radio), limited availability of synchronous orbit slots, and integration of new systems with the existing telecommunications infrastructure.

Table 4.18–1 summarizes the telecommunications industry. Table 4.18–2 focuses on the application of systems engineering in the application domain.

Table 4.18–1. Telecommunication Industry Summary

Number of Companies (U.S/non-U.S.)	
Representative Firms	Lucent, Nortel, Ericsson, Nokia, Cisco, Siemens AT&T, BT, Vodaphone AirTouch, Sprint, Nextel
Annual Sales	$3 trillion
Products	• Switching and multiplexing equipment • Transmission equipment • Radio equipment • User terminals • Management equipment • Voice, supplementary, and data services to users
Technical Challenges	Provide the telecommunication infrastructure necessary to maintain the growth in demand for bandwidth while increasing the reliability of all networks to that of the current switched telephone network
Business Challenges	Price and package telecommunication services such that they provide value for telecommunication users, offer profits for telecommunication service and equipment providers, and maintain a manageable increase in demand for bandwidth
Major Customer Groups	Domestic and business users, and telecommunications service providers
Regulatory Groups	ITU, ETSI, ISO, ANSI, IETF, ATMF, Bellcore
Growth	Less than 20% per annum in some sectors

Table 4.18–2. Systems Engineering in Telecommunications

1. Elements of Systems Engineering Current Practices in the Domain	
a. Stakeholder Definition	Stakeholders include telecommunication users, service providers, equipment manufacturers, and regulatory agencies.
b. Technical Problem/Mission Statement	The mission of telecommunications is to provide fast and reliable communication between parties separated by distance.
c. System Engineering Requirements and Drivers	The key requirements are cost, reliability, ease of use, and compliance with national and international standards.
d. Functional Analysis and Architecture	
e. Solution Definition	
f. Trades (Assessment and Selection)	
g. Integration	
h. Verification and Validation	Validation of systems dominates with emphasis on feature-based incremental validation. Verification of regulatory requirements and other requirements is an increasing trend.
i. System Operation	
j. System Maintenance	
2. Systems Engineering Strengths	
3. Systems Engineering Challenges	
4. Systems Engineering Tools	Systems engineering tools are not used extensively; however, modeling and analysis tools are used.
5. Systems Engineering-Related Standards	None
6. Domain-Motivated Systems Engineering Opportunities	

4.18.2 Industry Functions and Processes

The communications industry is a core infrastructure application domain of the world economy. This domain is characterized by a wide variety of established services and rapid development of new services based on emerging technology. Although society is highly dependent on the communications application domain, this domain is often taken for granted. Yet from an engineering viewpoint, the performance, reliability, cost effectiveness, and range of services offered is truly remarkable.

4.18.2.1 Stakeholders

The telecommunications domain comprises the following stakeholders:

- Users—End users and operators of the system.
- Service providers—Those offering a basic telecommunications service in voice or data, and those offering value-added services making use of the basic telecommunications structure.
- Equipment manufacturers—A wide range of companies that produce telecommunications equipment.
- Regulatory agencies—All types of agencies, including those involved with basic safety and compatibility issues and those involved with national and international interface standards. Telecommunication equipment manufacturers and operators are themselves stakeholders in the regulatory process.

4.18.2.2 Mission Statement

The mission of telecommunications is to provide fast and reliable communications between parties separated by distance. The importance of speed and reliability has affected every aspect of telecommunication design. Speed is reflected in the convenience of direct dialing and fast setup for voice calls, and the ever-increasing demand for data throughput. Newer technologies using all digital transmissions (wire or wireless) have resulted in a huge rise in data speed and reliability. High reliability (for single equipment is often less than a minute a year downtime) is now the expected norm for most users. This performance in the commercial field compares favorably with that achieved by military equipment (although, generally, in a less harsh environment).

4.18.3 Technology Profiles

A grouping of telecommunication sectors is useful in describing the existing and emerging technology (see Figure 4.18–1).

The services provided to users allow the following types of activity:

- Voice
- Voice messaging
- Voice supplementary services
- Video conferencing
- Streaming audio/video
- Fax
- Interactive games
- E-commerce
- Web browsing

- Intranet browsing
- E-mail access
- File Transfer Protocol (FTP) (including E-mail with attachments)

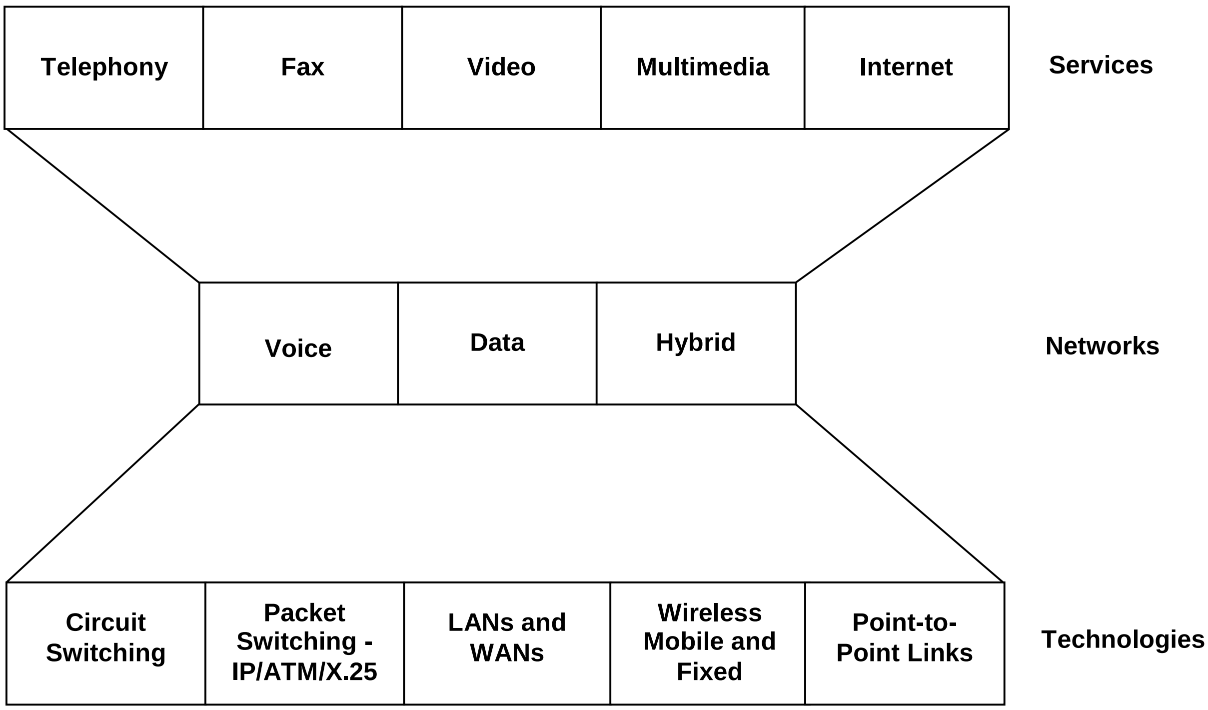

Figure 4.18–1. Telecommunication Sectors

Although much of the present telecommunications systems emerged from systems carrying voice only over a voice network using circuit-switching technology, this is no longer the case. It is now possible that almost any of the services shown can be carried by any of the network types and use any of the technologies. This convergence and flexibility is a characteristic of modern telecommunications systems.

4.18.3.1 Circuit Switching

Telephone networks currently in use depend on buried copper, microwave links, fiber-optic networks, and commercial satellite links to provide both analog and digital communications. The link between the telephone and the local exchange may depend on copper wires carrying analog signals for many years, especially in established European and North American countries where the infrastructure is already in place.

The circuit-switched network provides the backbone for other services and its access links are being developed to provide digital interfaces using Integrated Services Digital Network (ISDN) or other technologies. These still use the copper line for connections. For many users, the copper link to the local exchange is still the first link in the connection to all digital services (Internet, fax, data exchange); the access to the data network is via the circuit-switched voice network.

The circuit-switched network differs from many data networks in that a continuous connection is maintained between originating and terminating terminals during the length of the call, irrespective of the amount of data transmitted (voice or data passed as voice traffic). The characteristics of a voice, circuit-switched network are low and consistent delay between transmission and reception of information, acceptance of a level of errors with digital systems or noise on analog systems, and delivery of information in the same order as sent. These characteristics make the system suitable for voice, but need significant technology (in the form of modems) to provide adequate performance (speed, bit-error rate) for use as a data network bearer.

Cellular mobile phones, which have seen a rapid increase in use, make use of the circuit-switching network to provide a switched voice service. The trend to providing data facilities to mobile users is a challenge that requires integration of voice and data service switching facilities.

For reasons of capacity, cost-effectiveness, and signal quality, common carriers are rapidly converting trunk circuits in the United States and oceanic cables to optical fiber links carrying digital signals. For long hauls to remote areas (e.g., some international calls), the use of digital links via commercial satellites is cost-effective.

Common carriers also provide leased line services that share links used by switched networks. Based on leased lines and satellite links (commercially leased or privately owned), it is possible to establish reliable high-speed communications among any desired locations on Earth (and, as demonstrated by NASA, well beyond).

4.18.3.2 Packet Switching and Internet Protocol

Packet switching and Internet Protocol (IP) technology has been driven by the need to conserve bandwidth by making use of the “bursty” nature of data, and the ever increasing demands of the Internet to provide data services to users.

4.18.3.3 LANs and WANs

To be supplied.

4.18.3.4 Wireless, Fixed and Mobile

Use of cellular technologies for supporting both fixed and mobile access has increased rapidly in the last 10 years. The current technologies for mobile access are based on digital techniques, with the older analog system being phased out. The present digital techniques provide voice and limited data facilities; future technologies will provide for extended data techniques to support all of the uses listed in Section 4.18.3. Fixed wireless, although developing less rapidly than mobile wireless, provides an opportunity to support voice and data communications in areas where a copper infrastructure is unavailable and rapid deployment is needed.

4.18.3.5 Radio Frequency Broadcast

Radio frequency broadcast methods are well established and used for many purposes. Broadcasts vary greatly in range, depending on power and frequency. Ground wave propagation coverage extends from the deliberately limited range of a local AM broadcast station to the worldwide coverage of an extremely low frequency (ELF) station supporting ballistic missile submarines.

Commercial broadcast entertainment networks (e.g., AM, FM, TV, satellite TV) are ubiquitous. Radio frequency broadcasts also support many commercial enterprises (e.g., aircraft, ships, pagers, taxicab, and onsite repair dispatch services), emergency and public services (e.g., police, fire, ambulance communications), science support (e.g., NASA's Deep Space Network). Radio frequency broadcasts are essential to the military in peacetime coordination, as well as for tactical and strategic coordination during wartime. The safety and convenience of many persons are enhanced by use of the citizens band radio. Although noncommercial, the activity of amateur radio operators in many bands and modes (e.g., radio telephones, networking, TV, AM, FM, single sideband, satellite links) has been extremely important in developing and establishing emerging technologies.

4.18.3.6 Beamed Networks

For many years, beamed microwaves were used to implement high-capacity, cross-country telephone links. Although many of these links have been replaced by fiber-optic and satellite communication links, the technology remains very useful for implementing line-of-sight links (e.g., between studios and transmitter sites; networks among local but separated enterprise locations, such as state police or forest ranger stations). Infrared laser technology also is used for short links (e.g., digital equipment distributed in various buildings), but may become unreliable in some weather conditions.

A beamed network broadcast method that may become more important is satellite-to-ground transmission with a well-defined footprint.

4.18.3.7 Hybrid Systems

Three hybrid systems based on emerging technologies have become particularly important:

- Cellular telephone services
- Cable TV services
- Internet (and similar) networks

Cellular telephone systems have been available in metropolitan areas and heavily populated corridors for years. A combination of limited-range broadcast stations, the telephone network, and computer technology permit access to telephone services from automobiles and aircraft. In the existing system, the coverage for portable instruments is limited to cells served by fixed-radio transmitter/receiver facilities that provide links to the telephone system. The Globalstar, Teledesic, and Iridium systems, as well as other communications satellite clusters now under development, will provide worldwide coverage by using overlapping, moving cells served by a network of several hundred satellites.

The forerunner of the cable TV industry was based on rebroadcasting TV signals from high terrain to locations remote or shielded from the main transmitter. (This technique is still in use in some areas for both TV and radio signals.) Problems with spectrum crowding led to broadband cable systems. The industry is now moving toward fiber optics that connect users to both national cable TV networks and local broadcast stations.

The immense capacity of fiber-optic links is motivating development of interactive cable TV functions not previously available. For example, a demonstration project that is well underway permits cable TV subscribers to access the Internet at high data rates via their cable hookup. Telephone operating companies are eager to enter the cable TV and interactive applications market. Based on recent legislative debate, competition may open soon between telephone operating companies and cable TV operations.

The Internet is based on a network backbone funded by the National Science Foundation, volunteer technical and administrative support services, and links and servers provided at their own expense by network users. The open information-sharing paradigm implemented by the Internet is seen as major resource by some and a menace to the young by others. Although, the Internet as it stands is an important asset for many persons, development continues. Current issues include appropriate uses of the Internet for commercial purposes (e.g., advertisements, placing orders), legal liability for information posted to or transmitted via the Internet (e.g., since the Bern Convention, copyright protection has been greatly extended), use of the Internet to support illegal activities (e.g., child pornography, narcotics traffic), and user information security (e.g., use of unauthorized encryption algorithms). As these issues are resolved, the nature of the Internet will evolve. It does seem clear that the modes of information transfer and exchange are undergoing an important evolution at this time.

4.18.4 Systems Engineering Challenges

There are a number of sociopolitical and technical systems engineering challenges within the telecommunications application domain.

The challenge of properly using the physically limited broadcast spectrum and synchronous orbit slots will not disappear. The good news is that the bandwidth of fiber-optic links is extremely high, and the number of available links is growing rapidly. It is clear that emerging technology is providing vastly increased capacity for information transfer as the need arises.

Sociopolitical problems related to information exchange in a free society are viewed quite differently by various individuals. The challenge to systems engineering is to suggest solutions and tradeoffs that preserve benefits of free information exchange while discouraging activities considered harmful to society. The idea that only encryption schemes that can be broken by the National Security Agency should be allowed on the Internet provides one answer to detecting illegal information exchange. The “V-chip,” proposed as a means of allowing parents to control viewing of violent or explicit material on television, suggests a possible approach for the Internet that is less draconian than direct monitoring by Federal agencies. Finally, there are those who propose total freedom of information exchange. There is no consensus for resolving the immediate issues, and debate will surely continue as other issues arise.

4.18.4.1 Types of Applications

The types of applications being used on the Internet have changed radically in the last few years. The vast majority of applications were used by universities and educational institutions for "pulling down" files or transferring files, using FTP. FTP has recently been superseded by a protocol called “hypertext transaction protocol.” It is now the largest. About 30 percent of Internet traffic is hypertext and 25 percent is FTP; the rest consists of other types of mail and ways of using the Internet. Commercialization on the Internet was considered taboo for years; under Government-funding regulations, users could not use the Internet for commercial purposes. This changed during the late 1980s, and now there are many commercial users on the Internet.

World Wide Web Sites. Appearing at the rate of approximately 1,500 to 2,000 per day are Web sites or Web pages that promote a business, product, or nonprofit institution. They are similar to electronic billboards. Many companies are now promoting products and services on the Internet using Web pages with counters for access, link usage, and other information relative to the business being presented. As more Web pages become interactive in the exchange of information and goods for customer use, additional flexible metrics systems can be incorporated to feed useful and strategic information directly to related businesses.

Electronic Money. Reengineering in many areas is improving the efficiency of monetary transactions. For example, GO-Net financial services are crucial to the reengineering of the Ontario ministry program delivery using modern tools. The tools include electronic data transfer (EDT), electronic data interchange (EDI), and financial tools that enable credit and debit card service convenience at ministry service counters, at kiosks, or by telephone. Ministries are improving customer service by offering a choice of payment methods, including Visa and MasterCard, for government services. The technology supports authorization, settlement, reconciliation, and reporting for the cards. With EDI, ministries can exchange standard business documents, such as invoices, forms, and purchase orders, electronically without the need for paper copies. EDI is a tool for reengineering the government’s financial transaction system to provide faster service at lower cost. It is also a key tool for private sector development, enabling Ontario companies to be globally competitive. GO-Net EDI service was developed in partnership with the private sector and allows for electronic connection to networks that service corporate Canada and the banking system. With electronic funds transfer, funds can be transferred electronically into an individual’s bank account without the costly production and distribution of a change. The service is now used for 60 percent of social assistance payments and it is expected to expand to 90 percent. GO-Net EDI is also used for the government’s internal payroll. Ministries also use this service to distribute information electronically to government trading partners. For example, the Ministry of Transportation uses electronic funds transfers to make driver transcripts available electronically to insurance companies. The Ministry of Health uses this service to connect pharmacists throughout Ontario, and plans to receive claim submissions from 17,000 doctors across the province.

Marketing on the Internet. This phase has already started. A customer is looking for a specific product from the XYZ company. The customer points to the company page, goes to the products page, points to the particular product, and the screen shows that product. The customer enters a credit card number, and 2 days later, has the product. This process works for any type of physical product that can be ordered. If the XYZ company is promoting some published item, such as music, a photograph, or a piece of software, a customer can point and click on that item and have the item downloaded to his/her computer. This medium both markets and sells and is an excellent location for gathering metrics-related data. This process facilitates the collection and delivery of products. The cost of goods sold is dramatically reduced because one product is sold many times and there are no transportation costs.

Supposedly, 8 million out of the 35 million people who shop at home shop on the Internet or on other network shoppers. That is not such a large number, considering that more than 130 million PCs are installed throughout the world. However, the number of network shoppers is growing because of security; credit card gateway processing; and the enormous increase in numbers of PCs, local area networks, and modems. Home PC sales have exceeded business PC sales. Internet commerce allows companies to promote themselves on the network, which saves support costs. Selling something is not the only way to make money on the Internet. Companies can increase revenue or decrease expenses. Many companies use the Internet to decrease expenses by running help-desk type applications, where previously they had operators standing by to answer questions.

4.18.4.2 Future Trends

As the World Wide Web becomes more popular, new ways of marketing products are evolving. For example, an author used to have to contact various publishing firms to find one that would release a book on the open market. Now, individuals can publish their own books to the open marketplace, bypassing the publishing companies. With this change in process, publishing companies are scrambling to offer more varied and valuable services to the public. This type of change has had a dramatic impact on doing business as usual.

Already, thousands of developers are building products on top of other vendor products. This becomes an application development platform—everything that can run on a PC or larger computer can run on this. Applications that use visually exciting graphics or catchy, need-to-know information, such as financial reporting, will move toward this type of medium because it is cross-platform, open-standard, worldwide, and inexpensive. At the turn of this century, more than half of the homes in the United States were equipped with such products. With this kind of capability and new machines at lower prices, PCs will make televisions and telephones seem outdated.

4.18.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

LeRoy Botten
3715 Capulet Terrace
Silver Spring, MD 20906
Voice: 301-985-8726
Fax: 301-985-8909

Carolyn Buford
Computer Sciences Corporation
15245 Shady Grove Road
Rockville, MD 20850
Voice: 301-921-3203
Fax: 301-840-8934
E-mail: cbuford@cscmail.csc.com

Martin Warner
Lucent Technologies
Greenway Business Park
Building 1, Bellinger Close
Chippenham, Wilts
SN15 1 BN, UK
Voice: +44 1666 833568
Fax: +44 1666 832442
E-mail: mw15@lucent.com

4.18.6 References

Buford, C., Computer Sciences Corp., "The Emerging Role of Telecommunications: Creative Applications of Systems Engineering," *INCOSE Proceedings, Sixth Annual International Symposium*, July 7–11, 1996, Boston, MA, pp. 171–8

Nguyen, D., Loral AeroSys, and Mackey, William F., Computer Sciences Corp., "Use of Internet Retrieval and Access Tools in Support of the Goddard Space Flight Center," *INCOSE Proceedings, Sixth Annual International Symposium*, July 7–11, 1996, Boston, MA, pp. 179–86

Mackey, W. CSC, and Bagg, Thomas C. III, TCBIII Systems Analysis, "System Issues Related to Implementing on the Internet," *INCOSE Proceedings, Ninth Annual International Symposium*, June 6–11, 1999, Brighton, England, pp. 679–86

5 Profiles of Systems Engineering Cross-Application Domains

A systems engineering cross-application domain is broadly defined here as a sphere of influence or activity to which the systems engineering interdisciplinary approach is applied to create systems and solutions within several specific application domains (e.g., e-commerce may be used in commercial aircraft, energy, financial services). Each profile is written by the different experts who are available to the INCOSE SEATC. The common structure for each profile is as follows:

5.x Cross-Application Domain

The cross-application domains are listed alphabetically in Table 5–1. Those cross-application domains with section numbers are included in this document. Other cross-application domains will be added in future versions.

5.x.1 Introduction

A brief summary of the application domains (e.g., e-commerce, human factors) introduces the subject matter. Two tables summarize the industry companies or domain participants and the systems engineering activities.

5.x.2 Industry Functions and Processes

This section shows how domains are decomposed into individual functions and processes that represent the primary activities of the industry or cross-application domain. For example, Internet-based applications address the use of the Internet in health care, environment, government, law enforcement, etc.

5.x.3 Technology Profiles

Selected technologies that can benefit the cross-application domain are discussed. For example, Internet-based applications address evolution, architecture, and standards used on the Internet.

5.x.4 Systems Engineering Challenges

The primary challenges that could be met by using systems engineering are discussed. For example, Internet-based applications address challenges in requirements definition, security, and scalability.

5.x.5 Contacts

The author, INCOSE contacts, and industry contacts are listed.

Table 5–1. Systems Engineering Cross-Application Domains

Systems Engineering Cross-Application Domain	Section Number
E-Commerce	5.1
High-Performance Computing	5.2
Human Factors Engineering	5.3
Internet-Based Applications	5.4
Internet Banking	5.5
Logistics	5.6
Modeling and Simulation	5.7

5.x.6 References

Citations from INCOSE presentations and papers, general literature, and other key sources are listed.

Note that each section follows the above outline, but in some cases adapts the structure to fit the cross-application domain. The sophistication of each section in this document also varies.

5.1 E-Commerce

5.1.1 Introduction

As we enter the new millennium, everything business related that has been carefully learned in the 20th century is about to be completely undone by the new form of commerce for the 21st century – electronic commerce, or e-commerce. [Ernst & Young, 1999]

Most people think e-commerce means online shopping. But Web shopping is only a small part of the electric commerce (e-commerce) picture. E-commerce is the paperless exchange of business information or ideas using Electronic Data Interchange (EDI), electronic mail (E-mail), electronic bulletin boards, Electronic Funds Transfer (EFT), and other similar technologies. [Department of Defense, 1996]

The term electronic commerce was first used in the early 1960s in connection with applications like electronic data interchange, or EDI, but it has since become a catchall term for any form of electronic communication among enterprises, trading partners, or customers. Today, e-commerce applications can employ multiple technologies such as computer telephony, smart cards, EFTs, electronic payment mechanisms, knowledge management, wireless communications, workflow applications, and the Internet.

An e-commerce site can be as simple as a catalog page with a phone number or as complex as a real-time credit card processing site where customers can purchase downloadable goods and receive them on the spot. E-commerce merchants can range from the small business with a few items for sale all the way to a large online retailer.

An effective e-commerce system extends beyond the computer screen back into the structure of the company, streamlining manual tasks, and extending information available for rich decision making. This extension beyond the point of sale is termed by IBM as eBusiness and by Microsoft as the creation of a "Digital Nervous System."

The advent of e-commerce provides a major opportunity for companies to use the Internet to build stronger relationships with customers and partners. That's because the Internet is such a good communications channel—it is fast, reasonably reliable, low in cost, and widely accessible. [Forrester Research, 1998]

- Over 20 million people are currently buying products and services through the Internet.
- In 1998, online retail shoppers spent $ 4.8 billion, and by 2001, online retail sales are expected to top $17.8 billion.
- Currently, the frequent online shopper spends an average $672 per year online and this is expected to grow to $773 per year by 2001.
- Consumers are gaining confidence in the security of the Internet, which will further increase the growth in sales.

The Internet is maturing, and merchants who experiment today have the opportunity to grow with the Web and become the giants of tomorrow.

5.1.2 Industry Functions and Processes

The business processes most widely accepted as more successful in the e-commerce landscape including the following:

- Purchasing/Procurement
- Advertising
- Customer Support/Call Center
- Finance/Administration
- Warehouse Operations
- Distribution/Logistics

5.1.2.1 Government Involvement

Governments have the important role to ensure the smooth development of e-commerce. [Department of Defense, 1996]

Government has taken initiative to ensure that the full potential benefit of advances in information and telecommunications technologies are realized for all citizens. Under the Global Information Infrastructure (GII), the U.S. Government has developed a framework for global e-commerce outlining Government's role versus the private sector's role and defining how to deal with such issues as security, tariffs, and intellectual property protection.

5.1.2.2 Government Regulation on E-Commerce

In 1998, the Senate overwhelmingly approved the Internet Tax Freedom Act, which imposed a 3-year moratorium on new Internet taxes. This act bars state or local governments from imposing new taxes on access to the Internet and data flowing over the Internet, as well as prohibits any new e-commerce taxes.

Local legislators are eager to get a share of the e-commerce action, and they are not all waiting for the end of the 3-year moratorium. Recently, the National Association of Counties unanimously approved a resolution asking Congress to impose a sales tax on all online purchases.

Local governments estimate that $5 billion annually are already lost to out-of-state mail order business, and with the rapid rise of e-commerce, this number will only increase. While there have been some rumblings of impatience in Congress, the Federal Government has been urging local and state officials to respect the ban imposed by the Internet Tax Freedom Act.

When the moratorium expires, the taxation situation will most likely experience some changes. An advisory committee is already meeting to work on post-moratorium issues, and is discussing many ideas. The Advisory Committee on Electronic Commerce was mandated by the Internet Tax Freedom Act, and it will consider such topics as a flat, national Internet tax and ways to simplify sales tax for online purchases.

While the Federal Government favors no additional taxes for now, state governments are grappling with the issue individually. Texas taxes not only Internet access charges, but also all of the money collected when content providers sell online subscriptions, and the fees charged by Web developers for building sites. On the other hand, New York decreed that Internet access charges are not subject to state sales or telecommunications taxes. Currently nine states tax Internet services, and six states, including California, have moratoriums on Internet taxes.

Most states still do not know what to do, according to the accounting and consulting firm Deloitte & Touche, which published the comprehensive guide *Taxation in Cyberspace*.

For now, e-commerce providers such as AT&T are treating Web purchases much like mail-order sales. The providers collect taxes if the merchant has a significant presence in the state where the buyer resides.

Another problem with such taxes is that the Internet crosses international borders as easily as it skips over state lines. President Clinton wants to turn the Internet into a free-trade zone. Japan agrees, but other countries have already indicated a willingness to regulate the Internet. For example, France has long tried to mandate the use of French on Web sites, while Germany has attempted to stamp out both pornography and neo-Nazi materials online, and Australia has regulated pornography as well. Getting international agreement on Internet taxes may be the biggest hurdle to overcome.

5.1.2.3 Companies Threatened To Lose From Moving Online

The companies most directly threatened by e-commerce include travel agencies, entertainment ticket operations, mail-order catalogs, and retail stores, particularly software stores. E-commerce already is successfully invading their territories. A recent Forrester Research report predicts that sales of entertainment and travel tickets on the Internet will climb from $475 million in 1997 to more than $10 billion by the year 2001. Forrester says that figure represents 8 percent of all travel tickets.

As Bill Gates puts it, e-commerce is about to eliminate the middleman. The buzzword of the day is disintermediation—a way of saying that anyone between the seller and the buyer is in big trouble. But a closer look reveals that e-commerce may be creating of a new kind of middleman. Some of the most talked-about e-commerce success stories, such as Amazon.com and Virtual Vineyards, are really a new kind of intermediary. Amazon.com does not publish books, after all, and Virtual Vineyards does not make wine. They are simply online distributors.

But these e-middlemen must demonstrate that they add value to the buying process through marketing, customer service, or some other method. If they do not, customers will vote with their modems and cut them out of the loop.

5.1.3 Technology Profiles

From cheap and simple to expensive and complex, a wide range of products has been designed to get e-commerce sites up and selling in a matter of days or weeks.

Small businesses may not have to look beyond their local Internet service providers for a bare-bones solution. For example, Brooklyn-based Forman Interactive offers Internet Creator for less than $150. The software uses a series of wizards to help customers create secure pages for selling their products. Plus, Forman handles electronic payments via CheckFree for customers whose pages reside on the company's servers.

If a user is ready to step up, he/she can use Yahoo's Yahoo Store, which allows the creation of a transactional business Web site from the user's browser. Yahoo hosts the site, and the cost is based on number of items—$100 per month for a store selling 50 items and $300 per month for up to 1,000 items.

However, most e-commerce development tools targeted at small and midsize businesses cost $5,000 to $10,000. They generally include templates for online catalogs and databases, so it is easy to change items and prices. Dynamic database searches can serve different information when an item is out of stock or "on special," and they can be hooked up to existing back-end systems for order fulfillment and a range of automatic payment options.

Companies that have a high volume of sales—especially those that deliver soft goods such as articles, reports, software, or music over the Internet—require industrial-strength solutions that cost from $10,000 to $100,000 or more.

Of course, the software sticker price is only a small fraction of the cost to run an e-commerce site. Many high-end e-commerce products are used by third-party companies to provide services for individual merchants.

5.1.3.1 Technology Standards for E-Commerce

In addition to the "alphabet soup" of standards that governs the Internet, e-commerce employs several of its own standards, most of which apply to business-to-business transactions. [Weiss, 1999]

Electronic Data Interchange (EDI): Created by the Government in the early 1970s and now used by 95 percent of Fortune 1,000 companies, EDI is a common document structure designed to let large organizations transmit information over private networks. EDI is now finding a role on corporate Web sites as well.

Open Buying on the Internet (OBI): This standard, created by the Internet Purchasing Roundtable, is supposed to ensure that all of the different e-commerce systems can "talk" to one another. Leading technology companies such as Actra, InteliSys, Microsoft, Open Market, and Oracle backs OBI, which was released by the OBI Consortium.

Open Trading Protocol (OTP): OTP is intended to standardize a variety of payment-related activities, including purchase agreements, receipts for purchases, and payments. It was created as a competing standard to OBI by a group of companies, including AT&T, CyberCash, Hitachi, IBM, Oracle, Sun Microsystems, and British Telecom.

Open Profiling Standard (OPS): A standard backed by Microsoft and Firefly, OPS lets users create a personal profile of preferences and interests to share with merchants. The idea behind OPS is to help consumers protect their privacy without banning online collection of marketing information.

Secure Sockets Layer (SSL): This protocol is designed to create a secure connection to the server. SSL uses public key encryption, one of the strongest encryption methods around, to protect data as it travels over the Internet. Netscape has now been published in the public-domain-created SSL.

Secure Electronic Transactions (SET): SET encodes the credit card numbers stored on merchants' servers. This standard, created by Visa and MasterCard, enjoys wide support in the banking community. The first SET-enabled commerce is already being tested in Asia.

Truste: This partnership of companies seeks to build public trust in e-commerce by putting a Good Housekeeping-style seal of approval on sites that do not violate consumer privacy.

5.1.4 Systems Engineering Challenges

5.1.4.1 Challenges in Implementing E-commerce

E-commerce and the benefits resulting from its implementation are easy to describe, but e-commerce systems are not easy to develop and deploy. Companies have faced significant hurdles in these efforts.

- **Cost:** E-commerce requires sophisticated, distributed systems based on new technologies that can touch many of a company's core business processes. As with all major business systems, e-commerce systems require significant investments in hardware, software, staffing, and training. Businesses need comprehensive solutions that are easy to use and thus help enable cost-effective deployment.
- **Value:** Businesses want to know that their investments in commerce systems will produce a return. They deploy e-commerce systems to achieve business objectives such as lead generation, business process automation, and cost reduction. They want to ensure that these objectives are met. Businesses also need flexible solutions so that they can easily adapt a system to meet changing business conditions.
- **Security:** Because the Internet provides almost universal access, a company's assets must be protected against misuse, whether accidental or malicious. At the same time, that protection should not compromise a site's usability or performance nor make its development too complex. There is an additional security issue: Because e-commerce

systems enable the collection and usage of sensitive information about individual customers, companies also need to protect the privacy of their customers.

Existing systems companies need to be able to harness the functionality of existing applications into e-commerce systems. Most companies new to electronic commerce already use information technology to conduct business in non-Internet environments—in existing marketing, order management, billing, inventory, distribution, and customer service systems.

The Internet represents an alternative and complementary way to do business. It's imperative that Internet commerce systems integrate existing systems in a manner that avoids duplicate function and maintains usability, performance, and reliability.

- **Interoperability:** Interoperability here means the linking of trading partners' applications in order to exchange business documents. These systems must work together well to achieve business objectives. For example, the order-management application of a business partner must interoperate with the inventory applications of its suppliers. Interoperation between businesses reduces costs and improves performance. It enables the implementation of more dynamic value chains.

5.1.4.2 Barriers to E-Commerce

According to a survey conducted by CommerceNet, shoppers do not trust e-commerce, they cannot find what they are looking for, and there is no easy way to pay for things. Other than these concerns, all runs well.

Customers are worried about credit card theft, the privacy of their personal information, and unacceptable network performance. Most shoppers still are not convinced that it is worthwhile to hook up to the Internet, search for shopping sites, wait for the images to download, try to figure out the ordering process, and then worry about whether their credit card numbers will be filched by a hacker.

As for business-to-business systems, the issues are less emotional but still serious. Businesses do not yet have good models for setting up their e-commerce sites, and they have trouble sharing the orders and information collected online with the rest of their business applications. Many companies continue to grapple with the idea of sharing proprietary business information with customers and suppliers—an important component of many business-to-business e-commerce systems.

The key to solving the business model is for merchants to stop relying on fancy Java applets and to restructure their operations to take advantage of e-commerce. For merchants, e-commerce is just like any automation—it amplifies problems they already had with their operation.

5.1.4.3 Business Challenges

Business challenges include the following:

- High learning curve
- Supply chain integration
- Customer acceptance
- Integration of inventory and service management
- Alignment with strategy
- Employee skills and attitudes
- Threat to business assumptions and models
- Effective linkage with business partners

5.1.4.4 The Future—Meeting the Systems Engineering Challenges

With all the current focus on the Internet, it is sometimes easy to forget that e-commerce is still in its infancy. Even so, the Digital Age is already producing profound effects in numerous businesses. Change is evident in conventional book and music retailing, computer sales, and office-supply purchasing: New companies or new category leaders have emerged and existing sellers have had to adjust their business models dramatically.

These changes will continue to accelerate in the coming years as more and more people connect online and become comfortable with digital transactions, and as companies figure out new and better ways to conduct business online, such as customizing Web sites to fit customer preferences. The companies that make the adjustment and employ a digital nervous system effectively and imaginatively stand to emerge at the forefront in a networked economy.

E-commerce has a bright future. Once the details of online commerce are worked out, it and the Internet, in general, could reshape the structure of the business world.

5.1.5 Contacts

Venugopal Gopinathan
E-mail: venugo@hotmail.com

Kailash H. Gangar
E-mail: gangark@hotmail.com

5.1.6 References

Department of Defense, *Electronic Commerce (EC) Requirements, Systems, and Implementation Strategy Version 1.4 Dated 17 October 1996.* http://www.disa.mil/D7/onlnpubs/strategy/

Ernst & Young LLP, *The Second Annual Ernst & Young Internet Shopping Study 1999.* January 1999

Forrester Research, Inc., *The Forrester Report: Retail's Growth Spiral*, Vol. 1, No. 8, November 1998

Weiss, Jiri, *10 Questions on eCommerce,* August 31, 1999 http://www.builder.com/Business/eCommerce20/ss01.html

Attachment: The Vocabulary of E-Commerce

E-commerce is rife with terms and catchphrases. Below are some of the terms used in e-commerce. [Weiss, 1999]

Digital or electronic cash: Also called e-cash, these terms refer to any of several schemes that allow a person to pay for goods or services by transmitting a number from one computer to another. The numbers, just like those on a dollar bill, are issued by a bank and represent specified sums of real money. One of the key features of digital cash is that it is anonymous and reusable, just like real cash. This is a key difference between e-cash and credit card transactions over the Internet.

Digital money: This term is for the various e-cash and electronic payment schemes on the Internet. Yahoo lists 21 companies offering a form of digital money.

Disintermediation: Disintermediation is the process of cutting out the middleman. When Web-based companies bypass traditional retail channels and sell directly to the customer, traditional intermediaries (such as retail stores and mail-order houses) may find themselves out of a job.

Electronic checks: Currently being tested by CyberCash, electronic checking systems such as PayNow take money from users' checking accounts to pay utility and phone bills.

Electronic wallet: This is a payment scheme, such as CyberCash's Internet Wallet, that stores the user's credit card numbers on his/her hard drive in an encrypted form. The user can then make purchases at Web sites that support that particular electronic wallet. When the user goes to a participating online store, he/she clicks a Pay button to initiate a credit card payment via a secure transaction enabled by the electronic Wallet Company's server. The major browser vendors have agreed to arrangements for including electronic wallet technology in their products.

Extranet: This extension of a corporate intranet connects the internal network of one company with the intranets of its customers and suppliers making it possible to create e-commerce applications that link all aspects of a business relationship from ordering to payment.

Micropayments: Transactions in amounts between $0.25 to $10, typically made in order to download or access graphics, games, and information, are known as micropayments. Pay-as-you-go micropayments were supposed to revolutionize the world of e-commerce. One early scheme, for example, let visitors to ESPN SportsZone use their CyberCash CyberCoin accounts to buy a $1-day pass to the site's premium content without having to pay for a full month's subscription. But many potential customers have been unwilling to use micropayments.

5.2 High-Performance Computing

5.2.1 Introduction

With the marketplace demise of Cray Research, the High-Performance Computing (HPC) arena has witnessed a shift of vector processing technology leadership away from the United States to Japan.[1] In its place there has arisen a broad market for massively parallel processor (MPP) architectures, including those from Cray/Silicon Graphics, Inc. (SGI), which are based on large arrays of commodity microprocessors. However, there exists a class of scientific problems that do not scale well to the MPP approach, achieving only five to six percent efficiencies. This presents the systems engineer with a significant challenge when configuring a flexible, scalable HPC center with a rather limited palette of commercial off-the-shelf (COTS) supercomputing elements from which to choose.

Table 5.2–1 summarizes the major commercial HPC products available from U.S. manufacturers. The primary architecture choices represented are MPP, clustered symmetrical multiprocessor (SMP) nodes, cache-coherent non-uniform memory architecture (CcNUMA), and the parallel vector processors from Cray.[2]

Table 5.2–1. U.S. Commercial HPC Offerings (Not Including "Special" Architectures[3])

Manufacturer	Model	Architecture	Number of CPUs	CPU Type	Memory Type
IBM	SP	MPP	2048	Scalar	Distributed
SGI	Origin 2000	CcNUMA[4]	512	Scalar	Shared
Cray	T3E	MPP	1324	Scalar	Distributed
Cray	SV1, T90	PVP	32	Vector	Shared
Compaq	Beowulf	Cluster	256	Scalar	Distributed
Sun	E10000	Cluster SMP	256	Scalar	Shared

[1] Japanese manufacturers Fujitsu, NEC, and Hitatchi are effectively banned from the U.S. markets by protective tariffs that will remain in force as long as any domestic *vector* processor manufacturer exists.

[2] At the time of this writing, SGI has just announced the sale of the Cray business unit to Tera Computer, an emerging HPC vendor that is seeking to bring a new multi-threaded machine architecture (MTA) to the market.

[3] The most powerful computer is the "ASCI Red" machine at Sandia Laboratories, which has 9632 (Intel) processors and a sustained Rmax of nearly 2.4 trillion floating-point operations per second (Teraflops). Advanced "research" machines at other national laboratories extend some of the above model-architectures to larger configurations than those listed.

[4] The CcNUMA architecture is very powerful because it runs a *single* memory image upon which many processing elements operate. However, there is a knee in the performance curve of this architecture for extremely large domain problems that do not fit the single image model.

5.2.2 Industry Functions and Processes

HPC applications are concentrated in those areas that have very large problem domains (due, for example, to simulation of molecular or astronomical scale phenomena), or very complex computational demands such as vortex generation in moving fluids. The primary fields where HPC resources are now directed include the following:

- Computational fluid dynamics
- Molecular interactions
- Computational simulation and modeling
- Climate, weather, and ocean modeling
- Astrophysics
- Large data visualization
- Nanoelectronic modeling (quantum mechanical phenomena)
- Genetic algorithms
- Earth geodynamics (core and mantle simulations)

5.2.3 Technology Profiles

- The Advanced Strategic Computing Initiative (ASCI) is a U.S. Government-sponsored program to develop, build, and operate machines that can simulate a nuclear weapon explosion. This requires computational power in the Teraflop region (10^{12} floating point operations per second).
- The commercial MPP architectures from IBM and Cray consist of large size arrays (1000s) of commodity reduced instruction set computer (RISC) microprocessors (in this case, the Power PC and the Dec Alpha chip, respectively.)
- Beowulf and the Hondshew Consortium are names associated with the interconnection of clusters of discrete workstations configured for rapid communications by means of a fast external network. The Beowulf is simply an array of 256 Linux PCs connected by Myrianet, a fast local area network.
- The Multi-Threaded Architecture (Tera Computer Corp.) is an emerging technology aimed at developing machines that can have hundreds of parallel execution threads instead of a single, pipelined thread that must rely on predictive branching and advanced compiler techniques to achieve optimal throughput.
- Continuum Computer Architecture is a very new approach wherein large arrays of gate-level arithmetic and logic units are dynamically reconfigured to achieve optimal hardware configurations for specific problems. No commercial machine of this type is presently available.

- Clustered SMP node architectures are machines that have several CPUs and some aggregate of memory and disk storage on each *node*, but which interconnects the nodes by some bus architecture that lets a CPU in one node access memory in some other node (albeit not as quickly as local memory). The distinction between an SMP cluster and an MPP machine is that the MPP systems must pass messages between nodes to share information.
- The parallel vector processor is a multi-CPU machine that has the special capability of performing a synchronous mathematical operation (say a multiply) on a whole series of data values (a *vector*) in the same clock cycle. Such machines often have the *highest* throughput on fine-grained *capability* problems, achieving 30 percent efficiency on weather prediction, for example.
- The Linear Algebra Package (Linpack) is not a technology, per se, but it is one of the most widely used comparative benchmarks to evaluate competing technologies. The Top 500 List (see Web sites listed below) maintained by Jack Dongarra and others ranks the world's fastest machines according to their performance on the Linpack.

5.2.4 Systems Engineering Challenges

- Global file systems represent performance bottlenecks for large domain problems. Traditionally, computer system performance has been limited by input/output (I/O) speed, and indeed, that is still the case. The Moore's law progress rate in CPU speed has not been matched by similar increases in I/O bandwidth. For some classes of computationally intensive problems, this does not matter because the ratio of time spent "loading and storing" the problem data set to time spent working on it is small. Other problems such as numerical weather prediction involve *writing out the entire problem domain* at periodic intervals, which results in a high degree of sensitivity to I/O performance.
- Edge-of-envelope designs can, and usually do, stress manufacturer software to limits never encountered in testing. This can lead to nasty surprises from things that have never before been experienced. For example, compilers may "break" due to *extreme* array bounds specifications or memory allocation demands imposed by global problem domains.
- Very large HPC systems can be too expensive to replicate to achieve backup redundancy. However, these same systems may perform *mission critical* functions that cannot be interrupted by failures. Often the only viable strategy in such cases is to broker an agreement with another HPC site to serve as a contingency backup. This is not easy to do, however, because the alternate site must be capable of running the same applications, in the same configuration, and with the same data. If the data in question happens to be the "*instantaneous state of the atmosphere*," then an obvious problem to overcome is how to keep a current operational context at the backup site.
- Some problems scale poorly due to granularity or unpredictable convergence properties. This illustrates one of the key concepts that differentiate HPC applications: *Capacity* versus *Capability*. A large number of PCs may have a very high capacity. The

SETI@home project that employs idle, off-hours CPU cycles from over 1.6 million volunteer PC owners is a good example. The search for statistical significance in the enormous volume of radio telescope data is a *capacity* problem because it can easily be partitioned and worked in parallel by many systems *without* intersystem communications. Weather prediction, on the other hand, requires exchange of computational results for adjacent grid-points at every time step of the integration. These problems—known as *capability* problems, when divided among many processors, will still run slowly if the interprocessor communications are significant when compared with the computational load.

5.2.5 Contacts

- Profile author

Bruce Webster
National Centers for Environmental Prediction
5200 Auth Road
Camp Springs, MD 20746
Voice: 301-763-8000
E-mail: bwebster@ncep.noaa.gov

- Organizations
  - RCI, Ltd., The Global Consortium for the High Performance Computing and Communications (HPCC) Community
  - International Data Corporation
  - National High Performance Computing Integrated Process Team (IPT)
- Individuals
  - Dr. Jeffrey M. Mohr, CSC
  - Dr. Bill Buzbee, Buzbee Enterprises, Ltd.
  - Dr. Larry Smarr, NCSA, University of Illinois
  - Dr. John Stephens, Logicon
  - Dr. Thomas Sterling, CACR, California Institute of Technology
  - Dr. Jack Dongarra, ORNL and University of Tennessee
  - Dr. Howard Elman, UMIACS, University of Maryland
  - Dr. Bruce Ross, GFDL, NOAA
  - Dr. Stephen Lord, NCEP, NOAA
  - Dr. Sid Karin, UCSD
  - Dr. William F. Mackey, CSC

- Web sites
  - http://www-hpc.jpl.nasa.gov/
  - http://www.cacr.caltech.edu/Research/index.html
  - http://www.netlib.org/benchmark/top500.html

5.2.6 References

To be supplied.

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5.3 Human Factors Engineering

5.3.1 Introduction

Human factors engineering is an evolving interdisciplinary science that focuses on methodologies for the effective and intuitive interface of humans and complex systems. This cross-application domain includes cognitive processes and perceptual relationships that affect system controls and the person who operates in the loop. Whether an operator, a maintainer, or a decision-maker in a complex environment, the human-machine interface cannot be overemphasized. The systems engineering challenge is to make the appropriate ergonomic consideration early enough in the design phase to optimize the human component in the system.

Risks in this application domain include product liability, complex hardware and software solution sets, varying system perceptual models, and the challenge of meeting man-machine physical requirements for the broad range of anthropometric types.

Table 5.3–1 summarizes the scope of human factors engineering.

Table 5.3–1. Human Factors Engineering Summary

Number of Companies (U.S./non-U.S.)	Can be very large if inclusive of all companies that design and manufacture complex systems with human interfaces
Representative Firms	Boeing, Lockheed, Ford, General Motors, Honeywell, Universal, Aerospatiale, Sikorsky, Airbus Industries, Rockwell Collins, Microsoft
Annual Sales (U.S./non-U.S.)	Revenue as a result of successful human-machine interface directly results in the tens of billions of dollars annually
Products (representative)	Aircraft, automobiles, avionics display systems, flight control display systems, information display systems, human-centered manufacturing systems
Technical Challenges	Designing and integrating the most effective and efficient human-machine interface for the system, subsystem or configuration item contained in the solution set
Business Challenges	Budgeting to provide adequate emphasis on human factors engineering during the design phase of the systems engineering process
Major Customer Groups	All companies employing complex systems requiring human interface
Regulatory Groups	Federal—Occupational Safety and Health Agency (OSHA)
Growth	Proportional to the growth of industries using man-machine interface in complex systems

5.3.2 Industry Functions and Processes

As identified by the Center for Human-Machine Systems Research (CHMSR) at the Georgia Institute of Technology, "[human factors engineering] uses and/or develops techniques and methodologies based on systems engineering, artificial intelligence, cognitive sciences, psychology, mathematical and computational modeling, and empirical evaluations." It is imperative to implement human-factor solutions when perceptual and cognitive processes are identified as critical design phase requirements.

5.3.3 Technology Profiles

Also, as pointed out by CHMSR, human factors engineering includes research and design in the following areas:

- Supervisory control
- Human-centered automation
- Aircraft flight decks
- Information systems
- Communication networks
- Computer integrated manufacturing systems
- Power plants
- Space command control systems
- Models of human operator activities
- Operator environments

As is characteristic of systems engineering disciplines that do not have numerous academic institutions producing undergraduate and graduate degrees, human factors engineering expertise is made up of interdisciplinary groups with backgrounds in engineering, behavioral and social sciences, and computer science that conduct research and design in human-machine systems.

5.3.4 Systems Engineering Challenges

The systems engineering approach to the use of human factors engineering highlights optimization of the human-machine interface. The use of varying systems engineering design methodologies should support incorporation of human factors engineering early in the design process. This early inclusion of human factors engineering will ensure appropriate requirements identification and lessen the occurrence of dramatic requirement changes later in the system, subsystem, or configuration item development and integration. In addition, the recognition of and use of human factors engineering can provide for the early use of prototyping to design and test for human-machine optimization.

Table 5.3–2 summarizes systems engineering activities as they relate to human factors engineering.

Table 5.3–2. System Engineering in the Human Factors Engineering Domain

Systems Engineering Requirements	Any complex system that uses a human interface should focus specific design requirements towards optimizing the operator’s function in the mission environment
Systems Engineering Strengths	Appropriate analysis in the design phase allows for the early use of prototyping and system interface testing to validate system optimization
Systems Engineering Challenges	Systems engineering processes many times do not include the “human factor” in system design and therefore must redesign later in development, or in some cases develop systems that require extensive operator compensation in the work environment
Unique Systems Engineering Tools or Techniques	System prototyping, interface mock-ups, and preliminary-design operator testing are some of the ways systems engineering can be employed.
Systems Engineering-Related Standards	The Occupational Safety and Health Act (OSH Act) of 1970 (29 U.S.C. □651 et seq.; 29CFR 1900 to end)

5.3.5 Contacts

Robert A. Johnson
3818 Charles Ave.
Alexandria, VA 22305
Voice: 703.739.8211
E-mail: johnson109@aol.com

5.3.6 References

Military Specification MIL-STD-46855, *Human Engineering Requirements for Military Systems, Equipment, and Facilities*

DOD-HDBK-763, *Human Engineering Procedures Guide*

NASA-STD-3000, *Man-Systems Integration Standards (MSIS)*

The Occupational Safety and Health Act (OSH Act) of 1970 (29 U.S.C. § 651 et seq.; 29CFR 1900 to end)

Georgia Institute of Technology Center for Human-Machine Systems Research (CHMSR) Web Site, http://www.chmsr.gatech.edu

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5.4 Internet-Based Applications

5.4.1 Introduction

The Internet is a global network of networks connecting millions of users worldwide via many computer networks using a simple standard common addressing system and communications protocol called Transmission Control Protocol/Internet Protocol (TCP/IP). This includes federal, regional, educational, and some foreign networks. Connections between the different networks are called "gateways." These gateways serve to transfer electronic data worldwide. The Internet has changed drastically the computer and communications system and is considered as a world-wide broadcasting capacity, a mechanism for information dissemination, a medium for interaction between individuals, and a means for shopping and banking at competitive rates. The Internet represents one of the most successful information and infrastructure advances in the world economy. It may become almost impossible to compete effectively without Internet accesses.

Internet-based information applications today range from static browser-based reports and views to full Java application programs and Web-based database applications. Typical applications are listed in Table 5.4–1. Table 5.4–2 focuses on the application of systems engineering in the Internet-based applications.

5.4.2 Industry Functions and Processes

The Internet and the World Wide Web are synonymous, but also are different. The Internet is the physical and low-level software communications network (i.e., the phone lines, switches, channels that link the world together), whereas the World Wide Web, commonly known as the Web, is simply an application on the Internet. The Web, File Transfer Protocol (FTP), Archie, Simple Mail Transfer Protocol (SMTP), and Gopher are all applications on the Internet.

Three of the most fundamental and powerful features of the Web are the following:

- Capacity to incorporate all types of media objects (video, sound, images, text, etc.) into a single document.
- Utilization of hypertext or hypermedia-oriented architecture in which a single document has embedded links to other documents that can exist locally or anywhere in the world.
- Ability to span the depths of heterogeneous client/server platforms. One can view from any client platform (DOS, UNIX, etc.) a data object stored on virtually any server platform.

Table 5.4–1. Internet Applications Summary

Application Domain	Description
Health Care	• Consumer health information • Computer-based patient records • Unified electronic claims • Public health information systems
Government	• Information about government agencies • Business opportunities with government • Emergency management
Computer Based Training	• Multimedia-based training for students • Professional career-based training
Environmental	Networks of low-cost wireless sensors for real-time monitoring of air and water quality
Law Enforcement	Secure interoperable wireless networks to enable seamless cooperation between federal, state, and local law enforcement
Arts, Culture, and the Humanities	Archives, museums, and performances online
Intelligent Transportation Systems	• Reduced congestion, accidents, and fatalities • Increased energy efficiency
Distributed Work	• Telecommuting • Collaboration by geographically distributed teams
Third World Economic Development	• Telecenters in developing countries • Microenterprises online • “Global knowledge networks” of development practitioners
Science and Engineering	• Computational science • “Collaboratories” that connect researchers • Scientific instruments, supercomputers, and very large databases
IT Applications	• Business information systems • Electronic commerce • Geographical Information systems • Financial systems

Table 5.4–2. Systems Engineering in the Internet Applications

Systems Engineering Requirements	• Internet application mission and objectives • Common access to multiple applications • Platform/location independence • Flexible information distribution and presentation
Systems Engineering Strengths	Simplify application development and deployment
Systems Engineering Challenges	• Understanding of customer requirements • Understanding of Internet technologies • Customer understanding of systems engineering benefits • Integration with existing systems
Unique Systems Engineering Tools and Techniques	Need to understand the domain
Systems Engineering Related Standards	None

The Web provides a viable alternative to the traditional System Network Management Protocol (SNMP) platform, with intuitive navigation of multivendor management systems, as well as flexibility, ease of use, and simpler administration. Some of the benefits of the Web include the following:

- *Common access to multiple applications*. A single browser can access many management applications, without requiring cumbersome and labor-intensive client configurations.
- *Web integration/links among multivendor applications*. Hyperlinks directly reference specific pages on other management applications or a vendor's technical support site, so they are more flexible and useful than an application launch from a platform.
- *Platform/location independence and remote monitoring*. Any local or remote desktop in the enterprise can support instant access to management information, improving the flexibility and productivity of the management staff. Remote monitoring need not be limited to text screens and telnet sessions.
- *Flexible information distribution and presentation with push technology*. Push technology enables a management application server to distribute information in real time directly to clients logged on to any browser. Java programs support extensive customizations of user-access rights. Web applications, therefore, can support a broad range of users, including business end users, network operators, and network administrators.
- *Ease of administration*. Browser-based access to multiple applications eases the distribution and administration of client software, since the required client components can be dynamically downloaded to the browser at log-on time.

The Internet is divided into four different categories: The Internet, the Intranet, the Extranet, and the Hybrid Network.

The Internet allows users to be connected to the outside world to exchange data and retrieve external information. It also provides a means to having an open standards-based communications infrastructure, client architecture, Web-server architecture, database gateway, and security architecture.

While the Web may be the Internet's best-known (but not the only) medium to publish information for external consumers, it has also become an increasingly common vehicle for distributing data in-house over corporate networks called "Intranets." Intranets use Web servers, Web browsers, and hypertext markup language (HTML) documents as a means to publish enterprise information such as employee phone lists, policy manuals, and events and news alerts. Web browsers are simple to use. More and more people have this skill because so many Management Information System (MIS) departments have capitalized on this simple and well-known interface.

An Extranet exists when a company offers password-protected, limited access to a portion of its Intranet to select companies outside its firewall. The intent is to enable external communications, document exchange, and even collaborative design.

The Hybrid Network is the combination of the Intranet and Extranet. The users have internal and external e-mail capability. The users have also access to internal and external information on the same network. The hybrid has the TCP/IP address to allow the network system to filter the information. The hybrid network uses a bridge or router to allow the system to control the authenticity of the data.

5.4.3 Technology Profiles

5.4.3.1 Evolution of Internet

The Internet's pace of adoption eclipses all other technologies that preceded it. Radio was in existence 38 years before 50 million people tuned in; TV took 13 years to reach that benchmark. Sixteen years after the first PC kit was introduced, 50 million people were using one. Once it was opened to the general public, the Internet crossed that line in 4 years. In 1973, the U.S. Defense Advanced Research Projects Agency (DARPA) initiated a research program to investigate techniques and technologies for interlinking packet networks of various kinds. The objective was to develop communication protocols that would allow networked computers to communicate transparently across multiple, linked packet networks. This was called the Internetting project, and the system of networks, which emerged from the research, was known as the "Internet." The system of protocols, which was developed over the course of this research effort, became known as the TCP Protocol Suite, after the two initial protocols developed—TCP and IP.

In 1990, HTML, a hypertext Internet protocol that could communicate the graphic information on the Internet, was introduced. An individual could create graphic pages (a Web site), which then became part of the World Wide Web. A number of different services have been developed over the years to facilitate the sharing of information between the many sites on the Internet. Figure 5.4–1 shows the Hobbes' Internet Timeline for the growth in the number of Web sites since June 1993. Figure 5.4–2 shows the Hobbes' Internet Timeline for the growth in the number of Web hosts since October 1990.

Despite these impressive trends, the digital revolution is just beginning. Growth could accelerate in the coming years not only in the information technology (IT) sector itself, but across all sectors of the economy as the number of people connected to the Internet multiplies and as its commercial use grows. Five types of economic activity that drive the growth are as follows:

1. *Building out the Internet*. In 1994, three million people, most of them in the United States, used the Internet. In 1998, 100 million people around the world used the Internet. Some experts believe that one billion people may be connected to the Internet by 2005. This expansion is driving dramatic increases in computer, software, services, and communications investments.

2. *Electronic commerce among businesses*. Businesses began using the Internet for commercial transactions with their business partners about 2 years ago. Early users already report significant productivity improvements from using electronic networks to

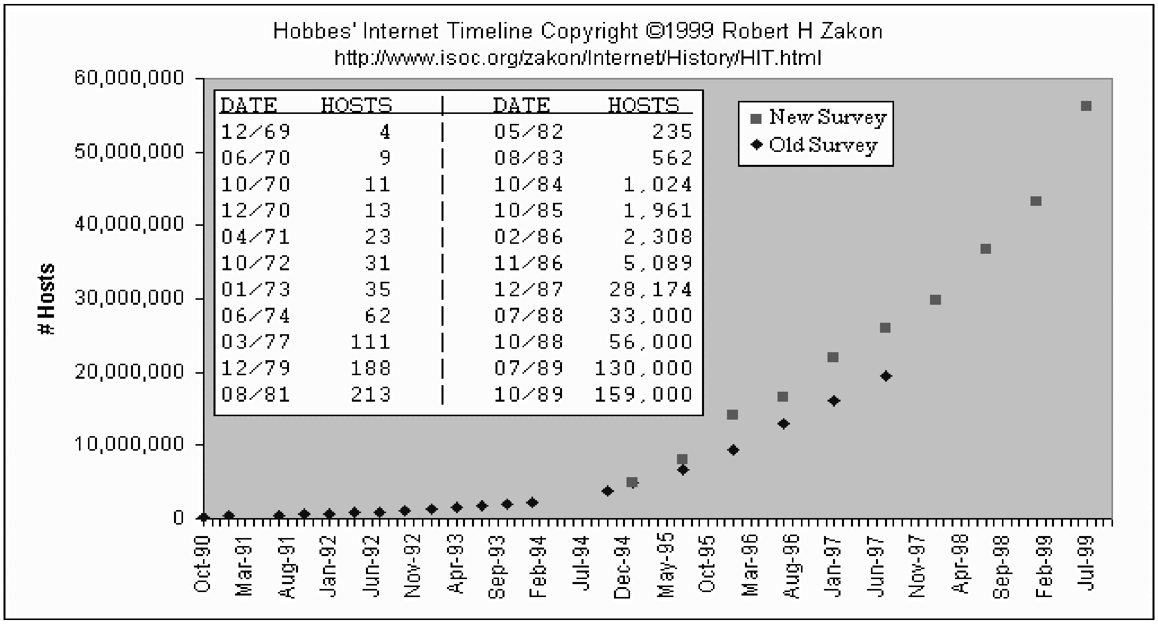

Figure 5.4–1. Web Site Growth

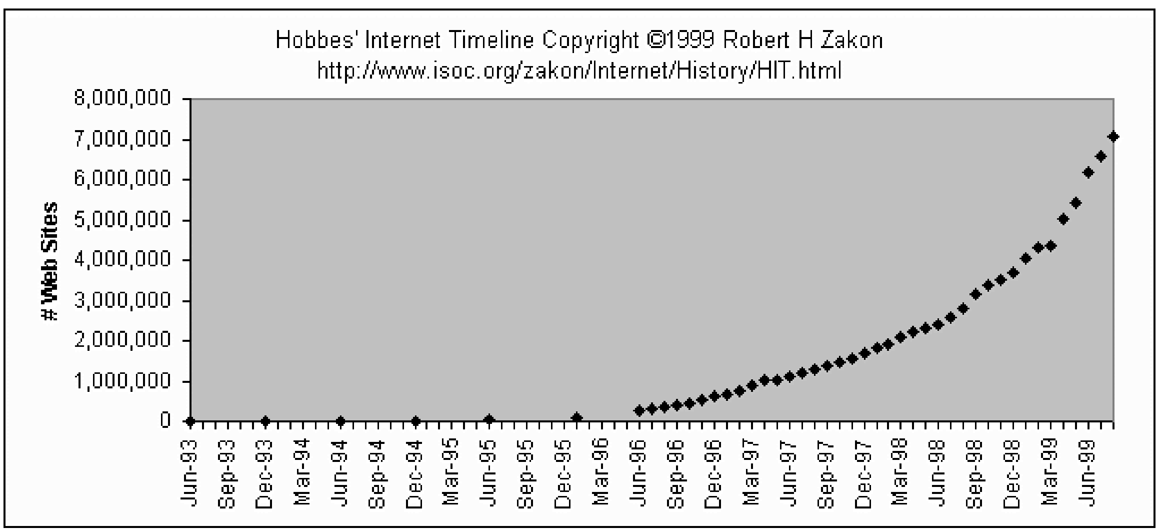

Figure 5.4–2. Web Hosts Growth

create, buy, distribute, sell, and service products and services. By 2002, the Internet may be used for more than $300 billion worth of commerce between businesses.

3. *Digital delivery of goods and services.* Software programs, newspapers, and music CDs no longer need to be packaged and delivered to stores, homes, or news kiosks. They can be delivered electronically over the Internet. Airline tickets and securities transactions over the Internet already occur in large numbers. Other industries such as consulting services, entertainment, banking and insurance, education, and health care face some hurdles but are also beginning to use the Internet to change the way they do business. Over time, electronic sale and transmission of goods and services is likely to be the largest and most visible driver of the new digital economy.

4. *Retail sale of tangible goods*. The Internet can also be used to order tangible goods and services that are produced, stored, and delivered physically. Though Internet sales are less than one percent of total retail sales today, sales of certain products such as computers, software, cars, books, and flowers are growing rapidly.

5. *E-mail.* Communicating over the Internet or using E-mail has provided better communication service in terms of timing and reliability. It has helped in keeping better records and faster response. The Internet E-mail features are important and provide more insurance and reliability than any other delivery service.

5.4.3.2 Internet Technology Architecture

There are essentially only two ways to access databases over the Internet:

1. Using Web browser (and forms) as the client. That is, to develop Web form applications using Web server backend tools. This architecture typically relies heavily on the Common Gateway Interface (CGI). This approach grants access to anyone with a Web browser.

2. Using a programming language such as Visual Basic (VB) as the client. This alternative permits developing an application on a local database, then deploying the application using the Internet to access the database. In addition to the above primary access themes, various technology components are identified in Table 5.4–3.

5.4.3.3 Internet Standards

The standards that make the Internet so compelling and powerful include the following:

- *Common language and naming.* All computers on the Internet speak the same language (TCP/IP), and resources are easily accessed through a common naming scheme using Domain Name Service DNS (DNS) and Universal Resource Locators (URLs).
- *Common format and protocols.* A significant amount of the content is stored in a common format (HTML), and files are transferred using standard protocols [hyper text transmission protocol (HTTP), FTP, and SMTP].

- *Consistent and powerful user model.* All browsers on the Web use URLs, hyperlinks, and in-frame navigation, providing an efficient user paradigm for traversing the world's largest library.
- *Server-side processing extensions.* Through standard methods, such as CGI, Web servers can be extended to communicate with backend scripts, dynamically produce the content of a Web page, store information the user has provided, or purchase goods.

Table 5.4–3. Internet Technology Components

Technology	Components	Technology	Components
Infrastructure	Connectivity	Applications	Relational Database
	Network		Workflow Environments
	Servers		Document Management
	Browsers		Information Management
	Indexes		Indexes
Security	Firewalls	Management	Policies
	Passwords		Standards
	Encryption		Publishing Systems
Tools	Authoring	Content	Data
	Development		Templates
	Link Checking		Navigational Interface
	Traffic Analysis		
	Search Engines		
	Software Revision		
	Standards		

5.4.4 Systems Engineering Challenges

The Internet has changed greatly in the two decades since it came into existence. It was conceived in the era of timesharing, but has survived into the era of personal computers, client-server and peer-to-peer computing, and the network computer. It was envisioned as supporting a range of functions from file sharing and remote login to resource sharing and collaboration, and has spawned electronic mail, the Web, and more recently electronic commerce. With the success of the Internet has come a proliferation of stakeholders—stakeholders now with an economic as well as an intellectual investment in the network. In the debates over control of the domain name space and the form of the next generation IP addresses has emerged a struggle to find the next social structure that will guide the Internet in the future. If the Internet stumbles, it will not be because of lack for technology, vision, or motivation. It will be because a direction has not been set for moving collectively into the future. The systems engineering mission should be to "facilitate and coordinate the successful development, deployment and operation of advanced, Internet-based applications and network services, and accelerate the availability of new services and applications on the Internet."

Systems Engineering Applications

This section highlights the systems engineering challenges that will be faced by systems engineers throughout the systems engineering life-cycle process. The intention is to provide a pathway to further discussions and establish priorities and result in partnerships across education, government, and industry, addressing areas of joint concerns to challenges identified below. Establishing that list requires a dialogue among members of the systems engineering community.

5.4.4.1 Understanding Internet Applications Requirements

A necessary investigation is understanding user requirements for the quality of service. No single approach applies to the process of systems engineering requirements. However, consideration should be given to the interactions between HTML pages, TCP/IP communications, Internet connections, firewalls, applications that run in Web pages (such as applets, Javascript, plug-in applications), and applications that run on the server side (such as CGI scripts, database interfaces, logging applications, dynamic page generators). Additionally, there is a wide variety of servers and browsers having various versions with small but sometimes significant differences between them, variations in connection speeds, rapidly changing technologies, and multiple standards and protocols. The requirement challenges include answers to the following questions:

1. *What?* What is the need of the Web site? Understanding application needs is an important step to understanding which solution is right. The right solution is based on answers to the following questions:
   - Does the business currently sell to consumers, other businesses, or both?
   - Is the business considered to be subscription based, such as a utility company?
   - Does the business currently have an existing payment-processing mechanism?
   - Does the business currently have hardware and software to deploy a Web site?
   - What are the business risks involved in launching a Web site?
2. *Who?* Who are the stakeholders? What kinds of browsers will they be using? What kinds of connection speeds will they by using? Are they intraorganization (with high-connection speeds and similar browsers) or Internetwide (with a wide variety of connection speeds and browser types)? List the stakeholders' background, their interests, skills, values, and knowledge.
   - When do they want to start their site? How often do they plan on updating their site—daily, weekly, twice a month, or monthly?
   - Where is the site going to be hosted? At their existing Internet Service Provider (ISP), free-hosting service, or a commercial hosting service?
   - How extensive or customized are their server logging and reporting requirements; are they considered an integral part of the system and do they require testing?
   - How does the user plan to research material for the Web site? If the user is not sure, he/she should visit other sites on the Internet. The user should do research first.

- How much downtime for server and content maintenance/upgrades should be allowed?
- How reliable is the site's Internet connections required to be? And how does that affect backup system or redundant connection requirements?
- How will internal and external links be validated and updated? How often?
- How are CGI programs, applets, Javascripts, and ActiveX components to be maintained, tracked, controlled, and tested?
- What are the expected loads on the server (e.g., number of hits per unit time), and what kind of performance is required under such loads (such as Web server response time, database query response times)? What kinds of tools will be needed for performance testing (such as Web load-testing tools, other in-house tools that can be adapted, and Web robot downloading tools)?
- What kind of performance is expected on the client side (e.g., how fast should pages appear, how fast should animations, applets, etc., load and run)?
- What processes will be required to manage updates to the Web site's content, and what are the requirements for maintaining, tracking, and controlling page content, graphics, links, etc.?
- What kinds of security (firewalls, encryption, passwords, etc.) will be required and what are they expected to do? How can they be tested?
- Which HTML specification will be followed? How strictly? What variations will be allowed for targeted browsers?
- Will there be any standards or requirements for page appearance and/or graphics throughout a site or parts of a site?
- Can testing be done on the production system, or will a separate test system be required? How are browser caching, variations in browser option settings, dial-up connection variability, and real-world Internet "traffic congestion" problems to be accounted for in testing?

5.4.4.2 Infrastructure Components

One of the greatest strengths of the existing Internet is the ability of any node to communicate with any other node in a compatible transport format. However, Internet applications will require both the most cost-effective services and services with predictable costs. The systems engineering model for the Internet project infrastructure must benefit deploying Internet applications and end-user management of costs as well as services.

5.4.4.3 Internet Technologies Education

The pace of technological development and the environment created by the Internet drives a new paradigm for the systems engineering professional's responsibilities. Internet application must support streaming audio and video, digital signatures, secure transactions, shared virtual environments for collaboration, intelligent agents, tools for discovering and retrieving information, and speech recognition. Internet Web browsers must support a universal medium for deploying virtually any distributed application. Systems engineers need to know these technologies and ask the right questions to stakeholders when applying a systems engineering approach to developing an Internet-based application.

The best weapon is to educate system engineers as part of the degree course or provide on-the-job training. The better informed they are, the less likely they will fail in their role as systems engineers. Clearly, more can and should be done to define and advance the systems engineering applications agenda. Activities include developing white papers that describe the potential of systems engineering in Internet-based technologies, suggesting systems engineering approaches for developing the application, and fostering interaction of executives responsible for Internet application development with systems engineers.

5.4.4.4 Internet Security

Despite the various Internet types (Intranet, Extranet and Hybrid Network) and different security enforcement devices (routers, bridges, firewalls, and techniques such as encryption), security remains the main weak point of computing over the Internet. Security over the Internet is one of the most important factors; it harms the expansion of Internet communication. The only way to have complete peace of mind is to keep sensitive data away from the Internet. The security-related technologies and applications need to be evaluated by systems engineers before they are implemented.

5.4.4.5 Scalability

A distributed environment with international applications connectivity must support hundreds to thousands of simultaneous users per application and millions of users overall. Thus, we must undertake systems engineering modeling efforts with such inputs as user behavior, quality of service attributes, and caching strategies. The modeling must consider the number of simultaneous users per application.

5.4.4.6 Conclusion

The Internet/intranet will serve as the infrastructure for a wide range of TCP/IP-based client/server applications that link businesses more efficiently to their customers, partners, and suppliers. The infrastructure will fulfill the original expectations of deploying client/server computing. Managers can now focus less on plumbing and more on solving business problems, using flexible client/server technologies.

Systems engineering has already begun to create demand for highly skilled systems engineers. However, as the Internet becomes more widespread, it will drive further changes in the labor market. The INCOSE, private sector and governments must work together to create new human resources policies that better prepare systems engineers to meet the challenges of the emerging digital economy.

5.4.5 Contacts

Bharat Shah
MASS, Inc.
15008 Eastway Drive
Silver Spring, MD 20905
E-mail: Bharat@massintl.com

Jean Frantz Duverne
U.S. Department of Commerce
Patent & Trademark Office
Washington, DC

5.4.6 References

Baum, David, "Intranet Politics and Technologies," *Byte,* May 1997

Constantine, Larry, "Web Time Software Development," *Software Development,* October 1998

Kalil, Thomas A., Special Assistant to the President for Economic Policy, White House National Economic Council, *The Case for Putting Internet Applications on the Policy Agenda*

Leiner, Barry M. and Vinton G. Cerf, *A Brief History of the Internet, Internet Society*

Patrick, Chuck, "Deploying Enterprise Intranets," *Unix Review,* January 1998

Puranik, Rajesh, "Is the Web the Platform?" *Communications News*

Roberts-Witt, Sarah, "Internet Technology—The Infrastructure," *Internet World*, October 1999

U.S. Department of Commerce, *The Emerging Digital Economy, Secretariat for Electronic Commerce*

"Hobbes' Internet Timeline," Vol. 4.2, *Robert Hobbes' Zakon*, *Internet Histories*, www.isoc.org.

The Internet and The Web, www.internet.com

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5.5 Internet Banking

5.5.1 Introduction

Industry analysts say it is not a question of "whether" financial institutions will offer Internet banking, it is a question of "when." As the pace of customer-oriented Web services quickens, a growing challenge for banks, brokerage firms, insurance companies and other financial service providers is how to align swiftly and efficiently their information technology (IT) strategy with their business strategy. Specifically, an Internet strategy—a plan to extend and broaden customer services using the Web as a platform—is required to compete in today's market.

Many financial institutions are forging ahead, deciding that the benefits of Web banking outweigh the risks. The Internet not only allows for a greater geographic reach to increase the customer base, it can also offer institutions—particularly smaller ones—the potential to diversify their asset portfolios across multiple regions, thus leaving them less exposed to the economic volatility of any single region. Furthermore, the lower cost of Internet delivery can have direct financial savings. Taking the paper out of the process could save U.S. companies billions of dollars a year, according to Department of Commerce estimates. Table 5.5–1 provides a summary of the Internet banking industry.

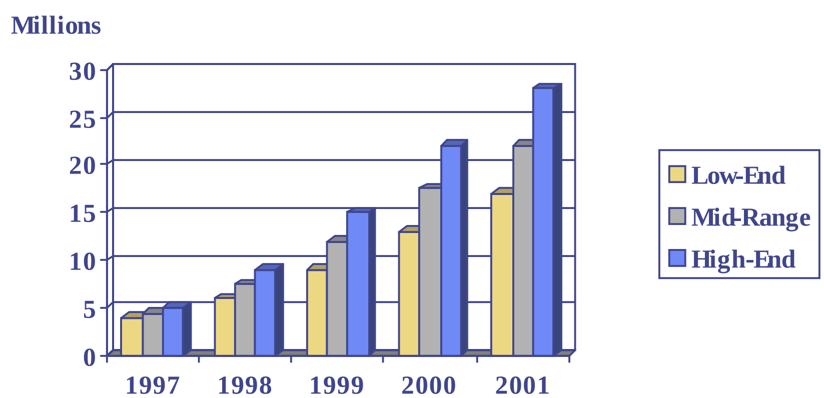
Table 5.5–1. Internet Banking Industry Summary

Number of U.S. Companies	Eleven of the top 27 banks offer transactional Internet banking services
Representative Firms	Citigroup, First Internet Bank of Indiana
Annual Sales	TBD
Products	ATMs, checking, credit cards, customer service, home equity loans/lines, investments, sales, mortgages, privacy/security services, savings/CDs
Technical Challenges	Security and reliability
Business Challenges	Lack of personal contact with customers
Major Customer Groups	General public
Regulatory Groups	Federal Deposit Insurance Corporation (FDIC)
Growth	Very rapid

5.5.2 Industry Functions and Processes

For banks, credit-card issuers, and other financial institutions, Internet banking is one of the most promising areas of electronic commerce because it cuts costs, automates manual processes, increases sales potential, and creates a new way to cross-sell to customers. There are clear indicators that Internet banking is building momentum rapidly. Consumers are becoming more confident in the security and reliability of online banking. According to the latest research from CyberDialogue/FIND/SVP and American Banker/Gallup, there will be 17.5 million U.S. households using online banking and/or bill payment by the end of 2000. Internet services are starting to pay off.

The burgeoning growth of Internet banking services means the competitive risks now outweigh the operational risks for many institutions. Competition is mounting: of the top 27 banks in the country, 42 percent offer transactional Internet banking services. According to a study done by the Office of the Comptroller of the Currency (OCC), 40 percent of banking customers now have accounts at banks that offer Internet banking service. This statistic leads analysts to believe the escalation of Internet banking users may favor brick-and-mortar institutions versus Internet-only banks. Furthermore, about 75 percent of Internet transactional sites are hosted by banks with less than $1 billion in assets, suggesting that cost considerations are not holding back smaller financial institutions. Figure 5.5–1 shows the estimation ranges of online banking trends.



Millions of U.S. households using online banking.
Source: Online Banking Report, January 1998

Figure 5.5–1. Millions of U.S. Households Using Online Banking

The Web makes great sense for any company that's involved in recurring billing and account-based services—telecommunications, utilities, banking, financial services, insurance, and credit cards. Taking the paper, or even just a percentage of the paper, out of the billing and statement process could save U.S. companies billions of dollars a year, according to Department of Commerce estimates.

The direct financial benefit of reducing paper is not the only reason that banks are implementing Internet services. Banks are looking to tap into the huge customer base potential the Internet provides. Banks can now service the local customer as well as the customer on the other side of the country. The Internet not only allows for a greater geographic reach to increase volume, it offers the potential to diversify assets. With the Internet opening up a worldwide marketplace, banks can more easily reach their target demographics. Table 5.5–2 summarizes system engineering activities as they relate to banking on the Internet.

From the customers' prospective, the most visible aspect of their financial institution is monthly billing and statements. It may be the only interaction they have with these institutions in a given month. Smart organizations are targeting this interaction and leveraging the Web to gain a competitive advantage. Increasingly, organizations are moving away from paper-based billing

Table 5.5–2. Systems Engineering in Internet Banking

Systems Engineering Requirements	FDIC Division of Supervision Electronic Banking Safety and Soundness Examination Procedures
Systems Engineering Strengths	Iterative and incremental development approach to continually expand existing functionality
Systems Engineering Challenges	Risk mitigation
Unique Systems Engineering Tools or Techniques	Standardized software tools can be used.
Systems Engineering-Related Standards	None

and payment processes, and turning to the Web as a means to service customers and to improve marketing.

The real attraction of Internet banking is that it offers a new means for interacting with customers. The customer may return to the bank's Web site several times a month to monitor account balances, transfer funds, pay bills, and even check on bills presented. This offers a huge marketing advantage. Banks can use online services as a marketing tool (promoting credit cards, mutual funds, etc.) while the consumer is interacting with the service.

5.5.3 Technology Profiles

Despite the potential for lower transaction costs, increased efficiency, greater asset diversification, and improved marketing, there are operational exposures that convincingly argue against rushing headlong into cyberbanking. A danger always exists that a rush to technology will outpace measures to keep it secure. However, incorporating prudent risk management into the corporate IT/business strategy can properly mitigate the operational risks.

There is a proven set of sophisticated technologies in use by today's Internet services participants that are targeted directly to minimizing operational risks. The foundation must be set, however, with appropriate system architecture and design. A strong access control methodology and sound system design will contribute more to the mitigation of these risks than any single security technology.

A variety of interrelated technologies, standards, and controls are used to manage the risks associated with providing Web services. Technologies and controls for protection of data privacy and confidentiality, data integrity, authentication, and non-repudiation include the following:

- Firewalls—Provides protection against attacks for Internet sites and internal networks.
- Data Encryption—Provides end-to-end protection against attacks during transmission of data.
- Digital Signatures—Digital code that can be attached to an electronically transmitted message that uniquely identifies the sender.
- Digital Certificates—Provides verification of an organization's authenticity through a third-party "Certificate Authority."

The following are major operational risks associated with the use of Internet services. The level of these risks is commensurate with the level of services offered, the value of assets at risk, and the type of Internet service involved. Briefly summarized, the major risks are as follows:

- Internal Data Security—Intrusion of data privacy or theft of sensitive information held on internal data storage systems. Firewalls, network security configurations, and access control methods can limit such exposures.
- External Transmission Security—Alteration or theft of data during transmission. Data encryption (128-bit) is becoming the industry standard approach to managing this risk.
- Transaction Fraud—Fraud takes two forms: misrepresentation during a transaction and repudiation following it. Encryption protocols, which include digital signatures validating consumer identification and digital certificates validating the institution identity, are common methods of mitigating transaction fraud.
- Difficulties with Virtual Underwriting—Even if the Internet customers are who they claim to be, there remain difficulties in establishing their creditworthiness. The lack of a personal relationship is one factor. The limited knowledge of referenced employers and credit grantors is another. These difficulties could force banks to tighten their credit scoring models.

New risks demand new supervision techniques and the FDIC's Division of Supervision (DOS) has responded with guidelines (Electronic Banking Safety and Soundness Examination Procedures) to assist institutions in risk management and planning. Under the guidelines, institutions having Internet sites are placed into one of three tiers based on the "maturity" of their site. Safety and soundness examination procedures focus on bank policies, procedures, and planning. The examination procedures are cumulative, each successive tier adds an additional level of scrutiny (see Table 5.5–3), and do not require a technical knowledge of Internet systems.

Table 5.5–3. The Division of Supervision Classifications for Internet Banks

Tier	Description	Specialist Examination Requirement
Level 1	An information-only site	Information specialist review required only if site is tied into internal bank systems
Level 2	A site permitting electronic submission of loan or deposit applications	Consultation with information specialist required to determine whether further review is warranted
Level 3	Transactional site offering electronic bill payment or funds transfer services	Concurrent information specialist examination required

5.5.4 Systems Engineering Challenges

The systems engineering challenge is to provide an optimally effective solution through organization and approach to address Internet banking. A standard system engineering approach is recommended to achieve the most optimally effective solution. The Internet banking system can be partitioned into components to facilitate concurrent development. The main system can be subdivided into five subsystems: account access, payments and transfers, customer services, credit and loan services, and investment services. Figure 5.5–2 shows the Internet banking system architecture hierarchy.

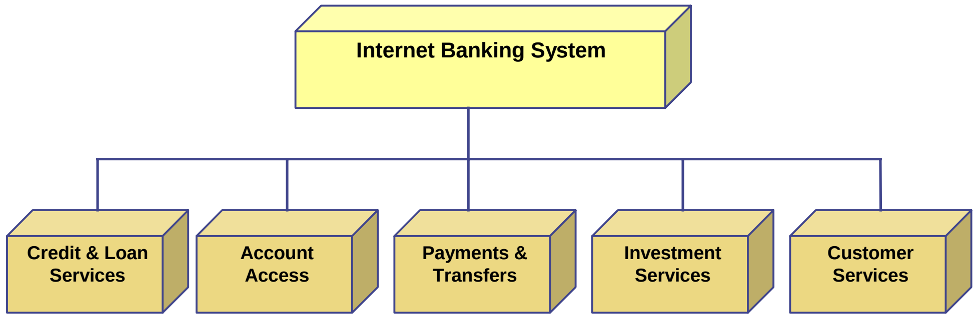


Figure 5.5–2. System Architecture Hierarchy

Additionally, each component can be further segmented into subsystems. Each of the main subsystems is composed of a hardware configuration item (CI), software CI, and a communication CI (see Figure 5.5–3).

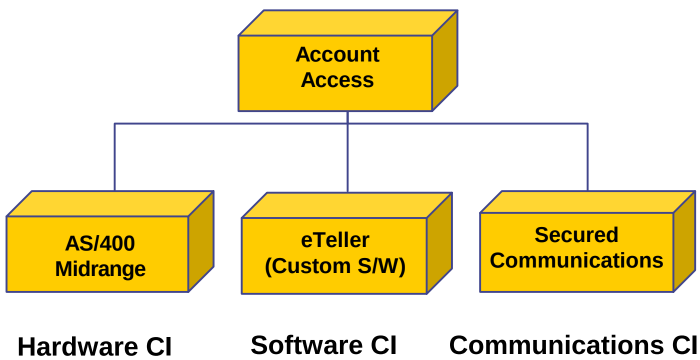


Figure 5.5–3. Subsystem Configuration Items

It is proposed that an iterative and incremental approach to development be taken. This approach effectively isolates risks, defects, and fixes within the boundary of a single build, making them easier to find and correct. Additionally, this development methodology helps management plan, organize, monitor, and control the project.

The bank should deliver an initial version of the system that includes only the basic Web services, implement a plan to roll out significant upgrades every quarter, and watch the doors open to a whole new demographic of online-savvy consumers. The key to success is to develop a solid foundation in Web services and expand it to meet consumer demand.

Table 5.5–4 lists the recommended Internet services for banking activities.

Table 5.5–4. Recommended Internet Services

Product/Function	Web Service	Schedule	Risk Mitigator	Outsourcing Option(s)
ATMs	ATM locator with descriptive addresses	Q1	N/A	InfoNow
	ATM locator with mapping and pricing	Q2	N/A	InfoNow
	ATM transaction confirmations	Q3	N/A	
Checking	Balance and transaction history	Q1	Firewall, Data Encryption, Digital Certificate	Q-UP, Online Resources, nFront, Edify/S1
	Download to OFX-enabled software applications	Q2	Firewall, Data Encryption, Digital Certificate	Q-UP, Online Resources, nFront, Edify/S1
	Custom report generation	Q2	Firewall, Data Encryption, Digital Certificate	Q-UP, Online Resources, nFront, Edify/S1
	Archival searches	Q3	Firewall, Data Encryption, Digital Certificate	Q-UP, Online Resources, nFront, Edify/S1
	Balance alerts	Q3	N/A	Q-UP, Online Resources, nFront, Edify/S1
	Activity alerts	Q3	N/A	Q-UP, Online Resources, nFront, Edify/S1
	Deposit confirmations	Q3	N/A	Q-UP, Online Resources, nFront, Edify/S1
	Automatic payment services	Q3	Firewall, Data Encryption, Digital Certificate	Q-UP, Online Resources, nFront, Edify/S1
	100% electronic bill payment	Q3	Firewall, Data Encryption, Digital Certificate	BlueGill, edocs, Transpoint, @Work Technologies, Bell & Howell, CyberCash, IBS, NetDelivery, Pitney Bowes, CheckFree, Billserv
	Bill presentment	Q4	Firewall, Data Encryption, Digital Certificate	BlueGill, edocs, Transpoint, @Work Technologies, Bell & Howell, CyberCash, IBS, NetDelivery, Pitney Bowes, CheckFree, Billserv

Product/Function	Web Service	Schedule	Risk Mitigator	Outsourcing Option(s)
Credit Cards	Transaction history and available credit	Q1	Firewall, Data Encryption, Digital Certificate	Q-UP, Online Resources, nFront, Edify/S1
	Online skip-pay request form	Q1	Firewall, Data Encryption, Digital Certificate	
	Online balance transfer form	Q1	Firewall, Data Encryption, Digital Certificate	
	Online bill payment option	Q2	Firewall, Data Encryption, Digital Certificate	
	Available credit alerts	Q3	N/A	
	Abnormal activity alerts	Q3	N/A	
	Payment due notification	Q4	N/A	
	Charge confirmations	Q4	N/A	
	Transaction history reports	Q4	Firewall, Data Encryption, Digital Certificate	Q-UP, Online Resources, nFront, Edify/S1
Customer Service	Frequently asked questions (FAQs)	Q1	N/A	N/A
	Fill-in-the-blank customer service queries (e-forms) for common requests	Q1	Firewall, Data Encryption, Digital Certificate	
	Telephone transfer confirmations (alert)	Q3	N/A	
	Stop payment confirmations (alert)	Q3	N/A	
	NSF/OD notices (alert)	Q3	N/A	
	Change of address alerts	Q3	N/A	
	Request a callback	Q4	N/A	AT&T
	Real-time online chat with CSR	Q4	N/A	
Home Equity Loans/Lines	Payment calculators	Q1	N/A	
	Balance and transaction history	Q2	Firewall, Data Encryption, Digital Certificate	
	Balance transfer form	Q2	Firewall, Data Encryption, Digital Certificate	
	Loan advance form	Q2	Firewall, Data Encryption, Digital Certificate	
	Rate history	Q2	N/A	
	Transaction confirmations	Q3	N/A	
	Available credit alerts	Q3	N/A	
	Payment due notification	Q3	N/A	

Systems Engineering Applications

Product/Function	Web Service	Schedule	Risk Mitigator	Outsourcing Option(s)
Investments	Portfolio tracking	Q2	N/A	
	Investment news link	Q2	N/A	
	Portfolio values alerts	Q2	N/A	
	Interest rate updates/alerts	Q3	N/A	
Sales	Online applications for checking, savings, and mutual funds	Q1	Firewall, Data Encryption, Digital Certificate	
	NewsCast Infomercial	Q1	N/A	
	Interactive loan application	Q1	Firewall, Data Encryption, Digital Certificate	
	Sales wizard for suite of products	Q2	Firewall, Data Encryption, Digital Certificate	
	Instant online approval	Q2	Firewall, Data Encryption, Digital Certificate	
	Application status alerts	Q2	N/A	
Mortgages	Extra principal payment form	Q2	Firewall, Data Encryption, Digital Certificate	
	Escrow account analysis	Q2	Firewall, Data Encryption, Digital Certificate	
	Refinance analysis	Q3	N/A	
	Home value reports	Q3	N/A	
	Interest rate update alert	Q3	N/A	E-Loan
	Transaction confirmations	Q3	N/A	
Privacy/Security Services	Post information on obtaining credit report	Q1	N/A	N/A
	Credit report access	Q2	Firewall, Data Encryption, Digital Certificate	
	Credit bureau negative information alerts	Q3	N/A	
	Credit bureau inquiry alerts	Q3	N/A	
	Zero liability for e-commerce	Q1	N/A	N/A
	Bank-branded Cybercash wallets	Q1	Firewall, Data Encryption, Digital Certificate	Cybercash, Brodia, Microsoft, eWallet, IBM
	Digital certificates	Q4	N/A	Verisign

Product/Function	Web Service	Schedule	Risk Mitigator	Outsourcing Option(s)
Savings/CDs	Saving/retirement calculators	Q1	N/A	
	Automatic savings plans that can be fine-tuned on the Web	Q2	N/A	
	Status reports/reminders for automatic savings plans	Q3	N/A	
	Interest rate updates/alerts	Q3	N/A	

Electronic banking and e-commerce offers the single greatest potential for gaining new customers and holding onto current ones. Web banking is one of the most promising areas of electronic commerce because it cuts costs, automates manual processes, increases sales potential, and creates a new way to cross-sell to customers. Enterprising financial companies need an E-business strategy so they do not end up eating their competitors' dust.

Making life easier by providing convenient and easy-to-use services will not only keep customers happy but will allow banks to compete in the online industry. Bank services should start with a solid foundation in the basics and progress towards implementing significant functionality upgrades every quarter. The development of services requires a joint effort between the bank and the technology group. In a combined effort, they should stay well informed of what the competition is doing, analyze feedback of the customers, and keep an eye on future trends and technologies.

Internet banking offers institutions almost endless opportunities to improve the way they do business. It also offers new risks. Recognizing this tradeoff, many banks have entered this territory with calculated steps. Those who have not embraced this new means of business by securing an Internet foothold are facing a different sort of risk: they face the risk that their business will pass to more innovative opponents—institutions with the drive to accomplish old business in new ways.

5.5.5 Contacts

Patrick J. McGowen
1142 North Pitt Street
Alexandria, VA 22314
Voice: 703-519-6990
E-mail: patrickm@infostrat.com

Kristy Sanders
5804 C Lantana Circle
Frederick, MD 21703
Voice: 301-228-2268
E-mail: kristy_sanders@yahoo.com

5.5.6 References and Regulations

"Banking on the Internet," *San Francisco Regional Outlook – Second Quarter 1997,* http://www.fdic.gov/bank/analytical/regional/ro19972q/sf/Int_bank/Int_bank.html, September 9, 1999

Breune, J., "Virtual Checking Accounts," *Online Banking Report*, June/July 1999, pp. 1–7

Breune, J., "Anatomy of a Start-Up," *Online Banking Report*, June/July 1999, pp. 8–16

Dalton, Gregory, "Online Billing Vendors Launch Web Initiate," *TechWeb,* http://techweb.com/wire/finance/story/INV19990907S0001, September 9, 1999

Dalton, Gregory, "Net Billing On The Rise," February 8, 1999, *InformationWeek*, http://www.informationweek.com/720/payment.htm, August 9, 1999

Dalton, Gregory, "Billing Middleman," April 5, 1999. *InformationWeek*, http://www.informationweek.com/728/bilserve.htm, September 15, 1999

Glascock, Stuart, "IBM and MasterCard Team on E-Wallets," September 14, 1999, *TechWeb*, http://techweb.com/wire/story/TWB19990914S0018, September 15, 1999

Jones, Lydia A., "Decrease Your Risk of Legal Liability," *e-Business Advisor*, November 1999, pp. 20–21

Long, T., "Financial Firms Face E-Business Challenge," *TechWeb*, http://www.techweb.com/se/directlink.cgi?ENP19990809S0016, August 9, 1999

McGarr, Michael S., "Banks Finally Embracing the Internet," *Electronic Commerce World*, November 1999, pp. 44–58

Mills, Matthew, "Online Banking Explosion," *PC Computing*, September 1999, p. 14

Online Financial Solutions, http://www.citibank.com, September 12, 1999

Orenstein, A., *Internet Banking: A Core Sales Tool for Banks?* http://www.banktech.com/db_area/archives/bst/1998/9802/costp24_30.htm, February 1998

Orr, Bill, *E-Banks or E-Branches? Both are in play as early adopters make them work*, http://www.banking.com/aba/feature1_0799.asp, July 01, 1999

Patel, J., G. Desai, J. Bromberek, and J. Levitt, "Electronic Billing: Postage Due," *InformationWeek*, http://www.informationweek.com/711/11olddue.htm, November 30, 1998

Patel, J., G. Desai, and J. Bromberek, *High-Profile Vendors*, November 25, 1998, http://www.webtools.com/story/TLS19981125S0001, September 10, 1999

Real Online Banking That Works For You! http://www.firstib.com, September, 15 1999

Risk Assessment Tools and Practices for Information System Security, FDIC FIL-68-99, July 7, 1999

Ternullo, G., *Banking on the Internet*, http://www.fdic.gov/bank/analytical/regional/ro19972q/sf/Int_bank/Int_Bank.html, Second Quarter, 1997

Violino, Bob, "Banking on E-Business – Citigroup Is Dramatically Expanding Its Internet Presence in an Effort To Approach Its Target of 1 Billion Customers," *InformationWeek*, http://www.techweb.com/se/directlink.cgi?IWK19990503S0038, May 3, 1999

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5.6 Logistics

5.6.1 Introduction

The word logistics has its roots in the Greek *logistike*, which means "to count." The modern context appears to have originated in the French, "*la logistique*," with the Baron Antoine Henri Jomini who stated, "Logistics comprises the means and arrangements which work out the plans of strategy and tactics. Strategy decides where to act; logistics brings the troops to this point." [Heinl, 1966 (1a)]

There have been a number of attempts at a modern definition, most of which appear to have been invented by committees. Definitions should be succinct. Perhaps the best is Webster's "the handling of the details of an operation." "Handling of the details" suggests that logistics is a function, like "operations" or "administration." "The details" suggests that logisticians keep lists, and count. In the modern context, logisticians depend heavily on automated information systems (AIS). "The details of an operation" suggests that logistics is an inherent part of operations.

An interesting definition was once overheard at an International Society of Logistics (SOLE) symposium: "Logistics is the applied science of keeping things going"—an illuminating phrase because logisticians are very much concerned with two different kinds of movement—the (often electronic) movement of information, and the physical movement of goods.

Logistics is practiced principally in the business and military sectors. Business logistics deals with the creation of time-and-place utility in goods—engineering and production create functional utility; marketing, ownership utility; and logistics, time-and-place utility. Business logistics supports two customers. "Incoming" and "in-process" inventory—piece parts and raw materials—supports production, and finished goods inventory supports marketing.

Military logistics deals with the creation and sustained support of combat forces. Although time and place utility are certainly of central concern to military logisticians, the domain goes beyond that. In the military, logistics keeps our forces fed, clothed, armed, fueled, operational, and on the move. It also helps to keep them commanded, informed, paid, and healthy.

One characteristic that distinguishes business from military logistics is the relative ubiquity of logistics infrastructure. The business logistics infrastructure—from the grocery store to the electronics repair shop—is physically very close to the consumer and served by transportation channels that reach into every consumer's home. Military logistics, on the other hand, must be practiced in places that are somewhat more inhospitable. It used to be said, "The army moves on its belly." Today it moves on its gas. One does not often find open gas stations at the FEBA (forward edge of the battle area). While one can rely in part on what is available in the area of conflict, a great deal of what one needs, from gas to guns to butter, has to be deployed with the troops, and resupplied from home. It is called the "logistics footprint." In addition to gas, guns and butter, the logistics footprint includes spares, repair parts, tools, test equipment, maintenance technicians, and all the human support—the "butter"—that these "loggies" require.

Systems Engineering Applications

While some modern business logistics theorists hope for a more exalted future, logistics is generally considered to be a cost of doing business and, in fact, in both sectors is increasingly being outsourced. The term "logistics" is becoming popular in the transportation industry, as this industry increasingly offers a variety of services in addition to carriage; and in the military, where some depot-level maintenance has been outsourced, and military depots are now commonly competing for work with the depots of other services.

Logistics is not a "limelight," but it is certainly a necessary, profession. As Admiral King is supposed to have said, "I don't know what the hell this logistics is that Marshall is always talking about, but I want some of it." [Heinl, 1966 (1b)] (so this statement does not appear disrespectful to the Navy, it must be pointed out that it is not an Army or an Air Force or a Marine Corps person, but a Navy Admiral—Henry J. Eccles—who is called "the father of modern logistics" and it was a Navy Captain, William Dwyer, who pointed out that, "Logistics is as broad as the seven seas, and just as fluid.")

Logistics is big: "…even in this golden age of technology, there are still more people in this world *and in this country* (USA) lifting and transporting things than are engaged in any other principal job assignment." [Heskett, et al., 1964] (original emphasis)

Table 5.6–1 provides a summary of the scope of the logistics application industry.

Table 5.6–1. Logistics Application Summary

Number of Companies	Every company and every governmental activity that buys, makes, sells, distributes, warehouses, transports, maintains, or manages products or people is engaged, in whole or in part, directly or indirectly, in logistics.
Representative Firms	There are five modes of transportation: air, highway, rail, water, and pipeline. In the United States, there are four legal forms of carriage—common, contract, private, and exempt. Warehouses include private, leased, and public. There are a number of large management consulting firms that offer logistics expertise as an afterthought, and a few small firms that specialize in it.
Magnitude [Heskett, et al., 1964]	In 1970, employment in U. S. transportation-related industries amounted to 13.2% of persons employed (of which 72% was highway related). Net U. S. logistics investment in 1965 accounted for 18.5% of the national wealth. Of this amount, 80% was private, not public; 65% was in freight as opposed to passenger movement; and 65% was non-transportation investment—i.e., inventory, warehousing, and order processing.
Services	Logisticians engage in operations (supply, maintenance, transportation, warehousing, and acquisition); engineering (supportability design of products and design of logistics systems); and analysis (of products, to derive the resources and services needed to sustain them, and of elements or aspects of the logistics infrastructure, to identify opportunities for improvement).
Technical Challenges	In logistics engineering, front-end analysis is critical to supportability as a design characteristic, but it requires a certain creativity, an ability to "analyze by analogy." Such skills are not common among people who work with details. "Uncertainty," it is said, "is the enemy of logistics." Uncertainty—e.g., variability in demand and lead-time—is a major technical challenge.

Business Challenges	Logistics is fundamentally interorganizational. In logistics operations, queues at the organizational boundaries, the movement of both information and goods, are a challenge. Diminishing manufacturing sources is another modern challenge. Some parts do not fail often enough to maintain an adequate volume of demand once the Original Equipment Manufacturer (OEM) market dries up. The product owner then faces a Hobson's Choice: redesign the product to eliminate the need for the failed part, or try to make a "minimum lot quantity" buy, often far in excess of projected need. The latter, of course, requires an institutionalized redistribution and marketing function, for the excesses. A challenge peculiar to business logistics is product substitutability. When brand loyalty is weak, product availability—keeping the shelves stocked—is of paramount concern.
Major Customer Groups	The business logistics customer is the consumer; the military logistics customer is the warfighter.
Regulatory Groups	The primary regulator of business logistics is the buyer. In the United States, the Interstate Commerce Commission (ICC) is also important. The primary regulator of military logistics is the warfighter. Congress provides the funds.
Growth	"The evolution of logistics management has just begun; as with all adolescents, its greatest excitement, opportunities, and rewards lie ahead." [Heskett, et al., 1964]

5.6.2 Industry Functions and Processes

SOLE certifies professional logisticians (CPL) who demonstrate a combination of academic degrees and professional experience and who pass an 8-hour examination, which is on a Master's degree-level of difficulty. To sit for the examination, the typical applicant (depending on academic qualifications) must demonstrate experience in at least two of the four major areas of logistics, each of which is covered by one of the four parts of the examination. The four major areas are (1) Systems Management, (2) Systems Design and Development, (3) Acquisition and Production Support, and (4) Distribution and Customer Support. Recommended reading for the examination partitions these areas as follows:

- Systems Management
  - Logistics Systems Management
    - Physical Distribution
    - Materials Management
    - Integrated Logistics Support
  - Logistics Information Systems
  - Systems Analysis and Management Science Techniques
  - Site Selection and Requirements Analysis
  - Interdisciplinary Communications
  - Life-Cycle Costing

  - Project Management
  - Organization
- Systems Design and Development
  - Maintainability Analysis
  - Reliability Analysis
  - Logistics Support Analysis
  - Systems Design
  - Product Design, Development and Test
  - Facility Planning
  - Value Engineering
  - Human Factors
- Acquisition and Production Support
  - Pricing, Negotiation and Contracting
  - Initial Provisioning
  - Production Planning, Scheduling and Control
  - Forecasting
  - Budgeting, Auditing and Cost Control
  - Quality Assurance
  - Aggregate Planning
- Distribution and Customer Support
  - Inventory Management
  - Traffic and Transportation
  - Maintenance
  - Packaging, Handling and Warehousing
  - Order Processing and Control
  - Data Management and Technical Publications
  - Redistribution and Marketing of Excess and Surplus Inventory
  - Recycling, Waste Processing and Disposal

- Personnel Support Services (including Training)
- Customer Service

5.6.2.1 Systems Management

Many people, working in narrow specialties, practice logistics. For example, one occasionally finds a CPL applicant who identifies his/her former occupation as falling into the category of “distribution and customer support” because, as the applicant says, “I used to be a parts lister.” Now, however, the applicant claims to be working in systems management because, as the applicant says, “I am now a *supervisory* parts lister.” The myriads of people working in narrow specialties depend on many other specialists, and their work affects many others. For the good of all, these specialists need to understand how their actions affect the enterprise as a whole. Johnson, et al. opine, “The antonym of systematic is chaotic. A chaotic situation is one in which everything is related to everything else, but the underlying structure is not well understood.” [Johnson, et al., 1967]

5.6.2.2 Systems Design and Development

Logistics supportability is best designed *ab initio* into the products that people use. Supportability can be defined as how much it costs to get out of a product the amount of use one needs to get. Usability is also called availability, a function of reliability and maintainability. Reliability defines the periodicity of the stochastic component of unavailability. The deterministic component is scheduled maintenance—the unavailability owing to the need to inspect, clean, lubricate, calibrate, etc. Among other things, maintainability defines the duration of unavailability. It is also used at times to define the amount of work that needs to be done to keep the product available, or to restore its availability when it fails.

Reliability, maintainability, and availability are necessary but not sufficient components of supportability. Affordability—as measured by life-cycle cost (LCC)—is also necessary. Availability approaches an inherent limit—determined by the product’s design—asymptotically as resource expenditures increase without limit. Hence, one needs to know how much one will have to spend on energy, spares and repair parts, tools and test equipment, facilities, training, and technical data, in order to get out of the product the amount of use one needs. One would like to acquire the alternative that yields the requisite amount of use at least cost—or conversely, the alternative that yields the greatest amount of use at a fixed cost.

Reliability and supportability can sometimes work at cross-purposes: One way to increase reliability is through redundancy. But two assemblies will generally fail more often and—especially if they are repairable—require more logistics support than one.

5.6.2.3 Acquisition and Production Support

Business logistics, in particular, supports production through inventory of incoming purchased items and raw materials, through in-process inventory, and through inventory of finished products. Military logistics is also concerned with production because it is easy to lose, in production, the logistics attributes that were designed into the product. Statistical quality control is a key concern. So is produceability, which affects not only the up-front cost of the product, but also the costs of the spare boxes and boards that are needed to keep the product in operation during the time it takes to fix the broken ones.

5.6.2.4 Distribution and Customer Support

While the movement of information has enjoyed—and continues to enjoy—a lot of attention in this "information age," it is the physical movement of the goods that takes more time and, therefore, offers the greater opportunity for improvement. There are two major components to the physical movement of goods: transportation and inventory. Significant improvements were made in transportation with the advent of Federal Express. There is a classical tradeoff between many, widely distributed warehouses with slow, low-cost transportation on the one hand, and a few, centralized warehouses with fast, expensive transportation on the other. Federal Express offered to ship small packages overnight at a reasonable cost. The effect on distribution channels was revolutionary.

Inventory is the other major component in the physical movement of goods. Inventory is a buffer—a shock absorber. It protects against variations in demand and lead time. If, as Magee suggests, demand varies as the 0.6 to 0.9 power of average, then one way to reduce variation is to increase demand—the higher the demand, the less variation. [Magee, 1968] The principal of postponement—postpone the final form of the product to the farthest point in the distribution channel—can effectively lessen variability by increasing the demand for expensive product components. One stocks expensive appliances, sans colored panels, and installs the inexpensive colored panels just before delivery to the consumer. Because demand for a basic appliance is considerably greater than demand for a particular color of that appliance, its demand variability is also less, and therefore requires less capital investment for a given safety level.

Another useful method for mitigating demand variability is central visibility and control of enterprise-wide inventories. All stocks of an item of supply—wherever those stocks are located—could be managed as a single, enterprise-wide inventory, and every individual demand could be recorded from point of sale (POS) data as a demand on the enterprise's inventory. Then all local inventories could be dynamically balanced relative to local demand, by the issue of redistribution orders; and one could predict, with less uncertainty, when and how much one will need to reorder for the entire enterprise.

Lead-time variability is also under attack. One way to reduce the variability of lead time is to eliminate queues in the movement of information. Intra-enterprise inter-organizational queues are attacked by such integrated information systems as Enterprise Resource Planning (ERP), sometimes called Manufacturing Resource Planning (MRP-II).

Inter-enterprise queues are another target. Potential vendors can be qualified in advance of need to reduce or eliminate the bureaucratic wait time between failure and acquisition of the failed part. Sometimes vendors are awarded Basic Ordering Agreements (BOAs) and Indefinite Delivery, Indefinite Quantity (IDIQ) contracts to further reduce or eliminate wait time. So-called POS (e.g., at the cash register) data can be sent to prequalified vendors, allowing them to anticipate when an order will be received, and for how much. In that case, the buyer may have a right to expect near instantaneous delivery.

Table 5.6–2 summarizes system activities as they relate to logistics.

Table 5.6–2. Systems Engineering in the Logistics Domain

Systems Engineering Requirements	Logistics must be recognized as a necessary part of systems engineering. Operations and maintenance being the longest part of the system development life cycle, logistics support is generally the most significant component of affordability.
Systems Engineering Strengths	Just as systems engineering is multidisciplinary, so is logistics engineering. It draws heavily on reliability, maintainability, human factors, safety, and produceability engineering, as well as economics.
Systems Engineering Challenges	One of the major systems engineering challenges is getting the up-front investment needed to save money later in the life cycle. Another challenge is getting to advanced technologists to make sure that new technologies are reliable and maintainable ab initio. Another challenge is getting into the minds of system developers ab initio—for up-front logistics analysis—to find and mitigate the support cost drivers while the system is still in the concept development stage. Other problems include minimum lot quantities and diminishing manufacturing sources. Another problem is overcoming the interorganizational nature of logistics, wherein queues develop at the boundaries.
Unique Systems Engineering Tools or Techniques	Logistics engineering tools and techniques are primarily mathematical: EOQ and optimization in general; tradeoff analysis; probability theory and statistical distributions such as the Poisson, Weibull, and log-normal (the normal curve is generally less useful); curve-fitting and the learning curve; economics in general and return on investment in particular.
Systems Engineering-Related Standards	MIL-PRF-49506, "Performance Specification: Logistics Management Information" prescribes the information needed to prepare the military logistics infrastructures to support a new system.

5.6.3 Technology Profile

The primary disciplinary underpinnings of logistics are the engineering disciplines, especially systems engineering, reliability, maintainability, testability, produceability, human factors, software, and safety engineering; mathematics, especially operations research and statistics; economics; communications and information technology; and the management sciences.

5.6.4 Systems Engineering Challenges

Movement—keeping things going—is fundamental to logistics. There are two very different kinds of movement that logistics is concerned with—the (usually) electronic movement of information, and the physical movement of goods and people.

But logistics is also fundamentally interorganizational. "The management of logistics activities … involves the coordination of activity among … other organizational entities to an extent that no other functional area of business can match." [Heskett, 1965] Dearden supports this assertion: "If you examine carefully the description of a typical total system, you will find that it is concerned almost exclusively with the logistics system." [Dearden, 1965] Organizational boundaries have been recognized for a long time as a major obstacle in systems engineering, and no less so in logistics.

In systems engineering, a serious concern is the tendency of system proponents to frame a solution to fit within their own organizational boundaries. In logistics, the problem surfaces in the form of queues. In part, the queues are intra-enterprise. Each functional area of the business builds an information system that is optimal for its function, but not necessarily optimal for the enterprise as a whole. As Jacobsen says, "Queues develop at the boundaries." [Jacobson, 1992] It does little good to move a requisition at the speed of light to the inboxes of a finance clerk and a buyer, only to see them languish there until the finance clerk and buyer can get around to processing it. Enterprise Resource Planning (ERP) is a modern effort to combat intra-enterprise queues.

But there are inter-enterprise queues as well. Supply chain management, Just In Time (JIT) inventory management, Electronic Data Interchange (EDI), and Extensible Markup Language (XML) are just a few of the modern reactions to the existence of these queues. The prequalification of suppliers in advance of need, and the movement of POS data to those "suppliers of last resort," are additional modern efforts to mitigate the queues that develop in the inter-enterprise movement of information. These modern initiatives—often called Supply Chain Management—affect the physical movement of goods, because the supplier who receives POS data is able to predict, with significantly improved confidence, just when the buyer is likely to place an order, and for how much. The supplier, in that case, is far more likely to be ready to deliver the goods just as soon as the order is placed. In fact, all other things being equal, the availability component of the "price and availability" query might be the winning factor among competitors.

The notion of "Time Definite Delivery" is beginning to catch on. It catches the lead-time variability problem discussed above. The problem with "Time Definite Delivery" as an unqualified term is the classic problem of unconstrained optimization. All deliveries can be time-definite, if one is willing to wait long enough.

5.6.5 Contacts

Author: Edward A. Connor, CPL
Analytic Services, Inc. (ANSER)
1215 Jefferson Davis Hwy Ste 800
Arlington, VA 22202-3251
Voice: 703-416-8467
Fax: 703-416-3329
Email: connore@anser.org
The International Society of Logistics at http://www.sole.org/
The Council on Logistics Management at http://www.clm1.org/

5.6.6 References and Regulations

5.6.6.1 Cited References

1(a). Jomini, Antoine Henri, "Precis de l'Art de la Guerre," as quoted in Robert Debs Heinl, Jr. [Ed.], *Dictionary of Military and Naval Quotations*, Annapolis, MD, United States Naval Institute, 1966, p. 315

(b). Attributed to Admiral Ernest J. King in Heinl, op. cit., p. 175

2. Heskett, James L., Nicholas A. Glaskowsky, Jr., and Robert M. Ivie, *Business Logistics: Physical Distribution and Materials Management*, 2^{nd} Ed., New York: The Ronald Press Company, 1964

3. Johnson, Richard A., Fremont E. Kast, and James E. Rosenzweig, *The Theory and Management of Systems*, New York, NY, McGraw Hill, 1967 (quoted from memory).

4. Magee, John F., *Industrial Logistics*, McGraw-Hill Book Co., 1968

5. Dearden, John, "How To Organize Information Systems," *Harvard Business Review*, March-April, 1965, p. 70

6. Jacobson, Ivar, *Object-Oriented Software Engineering: A Use-Case Driven Approach*, Addison Wesley Longman, Inc., 1992

5.6.6.2 Other References

Ballou, R.H., *Business Logistics Management: Planning, Organizing, and Controlling the Supply Chain*, 4th Ed., Prentice Hall, 1998 (ISBN 0137956592).

Blanchard, B.S., *Logistics Engineering and Management*, 5th ed., Prentice Hall, 1998 (ISBN 0139053166).

Bowersox, D.J. and D.J. Closs, *Logistical Management: The Integrated Supply Chain Process*, McGraw Hill, 1996 (ISBN 0070068836).

Christopher, M. and H. Peck, *Marketing Logistics*, Butterworth-Heinemann, 1997 (ISBN 0750622091).

Copacino, W.C., *Supply Chain Management: The Basics and Beyond*, The St. Lucie Press/APICS Series on Resource Management.

Coyle, J.J. and E.J. Bardi, *Transportation*, Southwestern Pub, 1998 (ISBN 0538881801).

Coyle, J.J., E.J. Bardi, and R.A. Novack, *Transportation*, 4th Ed., West/Wadsworth 1994 (ISBN 0314028536).

Defense Systems Management College (DSMC), *Integrated Logistics Support Guide*, DSMC, Fort Belvoir, VA 22060 (latest edition).

Glaskowski, N.A., D.R. Hudson, and R.M. Ivie, *Business Logistics*, 3rd Ed., Wadsworth Pub, 1992 (ISBN 0534510353).

Handfield, R.B. and E.Z. Nichols, *Introduction to Supply Chain Management*, Prentice Hall, 1998 (ISBN 0136216161).

Jones, J.V., *Integrated Logistics Support Handbook*, Special Reprint Ed., McGraw Hill, 1998 (ISBN 0070331391).

Kasilingam, R.G., *Logistics and Transportation: Design and Planning*, Kluwer Academic Pub, 1999 (ISBN 0412802902).

Lambert, D.M., J.R. Stock, L.M. Ellram, and J. Stockdale, *Fundamentals of Logistics Management*, McGraw Hill, 1997 (ISBN 0256141177).

Langford, J.W., *Logistics: Principles and Applications*, McGraw Hill, 1994 (ISBN 007036415X).

MIL-HDBK-502, Department of Defense Handbook, *Acquisition Logistics*, Department of Defense, Washington, DC (latest edition).

MIL-HDBK-59A, Military Handbook, *Computer-Aided Acquisition Logistic Support (CALS) Implementation Guide*, Department of Defense, Washington, D.C. (latest edition).

MIL-PRF-49506, Performance Specification, *Logistics Management Information*, Department of Defense, Washington, D.C. (latest edition).

Ministry of Defence, Defence Standard 00-60, *Integrated Logistic Support*, Kentigern House, 65 Brown St., Glasgow G2 8EX, United Kingdom (latest ed.).

Nerseian, R.L. and G.B. Swartz, *Computer Simulation in Logistics*, Quorum Books, 1996 (ISBN 0899309852).

Patton, J.D., *Logistics Technology and Management: The New Approach- A Comprehensive Handbook for Commerce, Industry, Government*, Solomon Press, 1986 (ISBN 0934623023).

Pooler, V.H. and D. Pooler, *Purchasing and Supply Management: Creating the Vision*, Chapman & Hall, 1997 (ISBN 0412106019).

Robeson, J.F. (Preface) and W.C. Copacino (Editor), *The Logistics Handbook*, Free Press, 1994 (ISBN 0029265959).

Stock, J.R. and D.M. Lambert, *Strategic Logistics Management*, 3rd Ed., Irwin Professional Pub, 1992 (ISBN 0256088381).

Tilanus, B., *Information Systems in Logistics and Transformation*, 2nd Ed., Elsevier Science Ltd., 1997 (ISBN 0080430546).

Wood, D.F., D.L. Wardlow, P.R. Murphy, and J.C. Johnson, *Contemporary Logistics*, Prentice Hall, 1999 (ISBN 0137985487).

5.7 Modeling and Simulation

5.7.1 Introduction

Modeling and simulation in the United States and throughout the world is growing in use. Led primarily by the aerospace industry and the military, modeling and simulation is gaining a wider variety of uses. Growth has been fueled by the need for less expensive methods of developing new systems to offset the increased cost of developing physical systems. With increased capability in modeling and simulation systems, physical systems can be used to validate the simulation data, reducing the cost of overall project development.

With the development of secure high-speed digital communications, there is a need for better interfaces to allow distributed simulations. This allows the participants to remain in their respective locations and with their specialists readily available, yet connect to a simulation that can test all the various parts with less difficulty and cost. The Department of Defense is using this method extensively for research and development, test and evaluation, and integration verification and validation. Risks in this use of modeling and simulation involve finding a common architecture or developing an interface capability to handle the diverse protocols and languages used in the development of the different components of the simulation.

Table 5.7–1 summarizes the modeling and simulation industry. Table 5.7–2 focuses on the application of systems engineering in the application domain.

Table 5.7–1. Modeling and Simulation Industry Summary

Number of Companies (U.S./non-U.S.)	More than 100
Representative Firms	United States Army, United States Navy, United States Air Force, Boeing, McDonnell Douglas, United Airlines, Singer-Link, Flight Safety Corporation, Science Applications International Corporation, Department of Commerce, National Aeronautics and Space Administration
Annual Sales (U.S./non-U.S.)	TBD
Products	War plans, simulators, test plans, design specifications, comparisons between options
Educational Materials	Formal training
Technical Challenges	Integration of multiple platforms, distributed simulations, integration of live players with simulation components
Business Challenges	Higher fidelity, larger capability, cheaper costs
Major Customer Groups	Department of Defense, aircraft manufacturers, airline companies, civil engineering firms, interstate trucking firms
Regulatory Groups	
Growth	Medium (10–20 percent) annual growth expected

5.7.2 Industry Functions and Processes

The use of modeling and simulation has increased greatly over the past several years. Primarily used by the Department of Defense for training, modeling and simulation has grown into other areas of the government and industry. With the wide variety of uses, systems engineering is becoming a major force in the research and development of new modeling and simulation systems, as well as the continual expansion of current modeling and simulation systems.

Table 5.7–2. Systems Engineering in the Modeling and Simulation Application

Systems Engineering Requirements	Software process certification using the Configuration Maturity Model (CMM), ISO 9001 quality system requirements for design control
Systems Engineering Strengths	Developers work closely with user community
Systems Engineering Challenges	Increased demand for higher fidelity simulations, constant increases in hardware capability, changes in software languages, very specific simulation designs inhibit multiple uses
Unique Systems Engineering Tools or Techniques	Even though there are no standards for language or interfaces for simulation hardware or software, high-level architecture protocols are increasingly being used for Department of Defense distributed simulations.
Systems Engineering-Related Standards	ISO 9001

5.7.3 Technology Profiles

The Federal Government, particularly the Department of Defense, is beginning to use the concept of Simulation-Based Acquisition (SBA) for purchasing large-scale projects. The Joint Strike Fighter program is relying heavily on SBA for the initial research and development of the aircraft. SBA utilizes modeling and simulation to model the potential aircraft and all its systems. The model is “flown” through several scenarios with the output maintained in a data file. All the various phases of flight, configurations, system combinations, and other different test scenarios are “flown.” Once the actual aircraft is built, the aircraft is flown on profiles similar to the test profiles. The data from the flight is compared to the data from the simulations. If the flight follows the simulation, then the simulation is used as the basis for the selection. This saves millions of dollars in test flights and test aircraft.

Another area where the Department of Defense is taking the lead in modeling and simulation is in distributed simulation. Distributed simulation allows the participants in the simulation to be in widely distributed areas, yet connected to a central simulation core. The emerging distributed simulation system uses High-Level Architecture (HLA) as the connecting system. By using distributed simulation, a pilot sitting in a manned simulator in Maryland can be flying against an aircraft in the air over California and defending ground forces in Texas, with all the ground and air threats simulated by computers and equipment in several other locations. This allows the system developers to stay in the lab and work out the problems in their systems without having to ship the unit to the range and pay for the travel of technicians, a very large expense during development.

Another major use for modeling and simulation is teaching procedures to users of advanced technology. This is another major area where the Department of Defense is a leading user. Other transportation sectors, such as airlines and railroads, are using modeling and simulation in their training programs. These users use modeling and simulation to teach normal procedures, emergency procedures, system operations, and system applications throughout the worker's lifecycle. This allows the worker to "die" while practicing procedures, thus teaching the worker how to function when faced with a real emergency.

In the construction industry, modeling and simulation helps the architect design structures that will withstand the forces of nature, including tornadoes, earthquakes, hurricanes, and typhoons. However, even with the best simulation models, some failures do occur as in the last Bay Area earthquake, when major highway bridge sections collapsed, even though they were designed to be earthquake proof.

The National Aeronautics and Space Administration (NASA) uses modeling and simulation for all phases of the development life cycle. From the initial design to testing to mission rehearsal, modeling and simulation is used to assist all the participants in accomplishing their tasks. It would be financially impossible for NASA to perform all the necessary actions to put objects into space without the extensive simulation necessary to ensure all systems are operational and will function properly after the significant forces of launch and the harsh environment of space. Astronauts use simulation to extensively practice prior to their mission so there is little wasted time and effort due to the limited space and supplies and the need for specialized training for the particular mission.

Recent airline accidents have demonstrated the use of modeling and simulation as a tool of the investigation process. Using the information available from the flight data recorder, cockpit voice recorder, and radar images from ground radar stations, accident investigators are able to feed the data into a simulation system and watch the movements of the flight controls and aircraft body. This aids the investigators in determining possible causes of the accident and can lead to fixes to the aircraft.

Weather forecasting is another area where modeling and simulation is growing. With high-speed computers and satellite imagery, weather forecasts are better in the short range and getting better in the long range.

Understanding the geological forces that shaped the Earth and continue to change the structure and surface features is another area where modeling and simulation has played a significant role. Many of the current geological theories have been tested using modeling and simulation to show their applicability to the shaping of the Earth.

5.7.4 Systems Engineering Challenges

Modeling and simulation are high users of new technology. As computers get faster and more powerful, modeling and simulation systems continually grow in capability and applicability. With the advent of distributed simulation, more participants are able to connect into the simulation and play a role in its execution. Systems engineering challenges in modeling and simulation are to keep up with the emerging technology, utilize current high-technology systems such as virtual reality, and work closely with the user community to ensure the models developed are viable for the application intended.

The integration of hardware, software, and networks is a challenge for systems engineering. Integration is being accomplished through the use of distributed simulation technologies such as HLA. This allows varying operating systems and software architectures to communicate during a simulation without all the components having to be resident on the same machine or written in the same language.

The Systems Engineering Capability Maturity Model (SE-CMM) and the Systems Engineering Capability Assessment Model (SECAM) are increasingly being used by modeling and simulation developers to ensure quality system development. The SE-CMM and SECAM describe the essential elements necessary to ensure the practice of good system engineering. Because of the diverse and distributed simulation environment, good systems engineering practices need to be followed for best use of increasing technology, developer time and talent, and management of time and resources.

5.7.5 Contacts

For more information on the material discussed in this section (or to provide comments and suggestions), contact

Ralph Gibson
SAIC
22299 Exploration Drive Ste 200
Lexington Park, MD 20653
Voice: 301-342-6901
Fax: 301-342-6381
E-mail: Ralph.D.Gibson@saic.com

5.7.6 References and Regulations

To be supplied.

Appendix A—INCOSE Technical Committees, Working Groups, and Interest Groups

Technical Board

Chairperson:	John Snoderly 703-805-5258 snoderly@home.com
Cochairperson:	Rich Harwell 770-740-0907 insight@sysview.com
Cochairperson:	Heinz Stoewer (49) 2241-345940 heinzstoewer@compuserve.com

Education and Research Technical Committee

Chairperson:	Dennis Buede 703-933-1727 dbuede@gmu.edu

Working Groups and Interest Groups:

Concepts and Terms Working Group	Sten Dahlberg 206-655-6192 sten@connectexpress.com
Education Development Working Group	Dennis Buede 703-933-1727 dbuede@gmu.edu
Education Measurements Working Group	Peter Sydenham (61) 8-8365-7643 sydenham@senet.com.au
Systems and Supportability Interface Research Working Group	Wolter Fabrycky 540-231-6147 fabrycky@vt.edu

Note: The information contained here is under continual change and is enclosed as an initial reference. Please check the INCOSE Web site (www.incose.org) for the most recent information.

Systems Engineering Applications Technical Committee

Chairperson:	William Mackey 301-794-2138 wmackey@csc.com
Co-Chairperson:	Scott jackson 562-496-5049 scott.jackson@boeing.com
Co-Chairperson:	Ralph Godau 61-3-9341-3809 ralph.godau@ogs.vic.gov.au

<u>Working Groups and Interest Groups:</u>

Commercial and Public Interest Working Group	Jerry Bauknight 408-756-4265 g.bauknight@ieee.com
Environmental Systems Working Group	Ralph Hill 702-794-1331 ralph_hill@ymp.gov
Infrastructure Systems Engineering Working Group	Pat Sweeney 615-454-4709 sweeney@hap.arnold.af.mil
Joint Commercial Aircraft Working Group	Greg Mathers 425-717-1020 Gregory.Mathers@pss.boeing.com
Resource Management Working Group	Ted Dolton 650-321-5950 alanjoanne@aol.com
Space Systems Working Group	Ray Granata 301-286-3702 ray.granata@gsfc.nasa.gov
Telecommunications Working Group	Tom Bagg 301-867-0063 tom.bagg@gsfc.nasa.gov
Health Care Interest Group	John Zaleski 610-354-5379 john.zaleski@lmco.com

Motor Vehicles Interest Group	Paul Berry 313-323-0906 pberry1@ford.com
Railway Transportation Interest Group	John Williams 011-44-181-392-9776 jsw@netcomuk.co.uk

Measurement Technical Committee

Chairperson:	Sarah Sheard 703-742-7106 sheard@software.org

<u>Working Groups and Interest Groups:</u>

Capability Assessment Working Group	Curt Wells 512-787-6316 cwells@i-metrics.net
Measurement Working Group	Garry Roedler 610-531-7845 garry.j.roedler@lmco.com

Modeling and Tools Technical Committee

Chairperson:	Mark Sampson 972-669-9937, ext. 215 sampson@tdtech.com

<u>Working Groups and Interest Groups:</u>

Tools Database Working Group	Bill McMullen 972-344-5781 w-mcmullen@raytheon.com
Tools Integration and Interoperability Working Group	John Nallon 972-669-9937 (x220) nallon@tdtech.com
Information Model and Process Interest Group	Rick Steiner 619-725-1008 fsteiner@west.raytheon.com
Model Driven System Design Interest Group	Bob Cohen 860-610-7436 cohenrm@utrc.utc.com

Systems Engineering Management Technical Committee

Chairperson:	Jim Armstrong 703-742-7185 armstrong@software.org

<u>Working Groups and Interest Groups:</u>

Requirements Working Group	David Jones 972-344-5780 djones@raytheon.com
Risk Management Working Group	Elaine Hall 407-728-7475 drehall@aol.com
Systems Engineering Management Methodology Working Group	Jim Armstrong 703-742-7185 armstrong@software.org
Verification and Validation Interest Group	Steve Wolf 319-295-1958 sawolf@collins.rockwell.com

Systems Engineering Processes and Methods Technical Committee

Chairperson:	Dick Wray 330-796-9931 richard.wray@lmco.com

<u>Working Groups and Interest Groups:</u>

Principles Working Group	Sam Alessi 208-526-1326 alesrs@inel.gov
Systems Architecture Working Group	Mark Maier 703-633-5350 mark.w.maier@aero.org
Systems Engineering Handbook Working Group	Dorothy McKinney 408-742-8790 dorothy.mckinney@lmco.com
Systems Engineering Reengineering Working Group	Jack Fisher 818-225-8710 seajnf@aol.com

Design Process Interest Group	Ray Jorgensen 319-295-2615 rwjorgen@collins.rockwell.com
Human Systems Interest Group	Bill Ewald 301-572-0808 ewald@macroint.com
Systems Engineering Internet Processes Interest Group	Larry Pohlmann 703-442-5374 pohlmann-wma@erols.com

Standards Technical Committee

Chairperson:	James Martin 972-575-0182 j-martin@raytheon.com

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Appendix B—SEAP Authors Writing Guide

SYSTEMS ENGINEERING APPLICATIONS PROFILES (SEAP)
AUTHORS WRITING GUIDE

Prepared by Theodore A. Dolton, INCOSE San Francisco Bay Area Chapter, April 1996.
Revised by Scott Jackson, Los Angeles Chapter, with help from Cecilia Haskins, Norway Chapter and Theodore Dolton, May 2000

Included herein is a guide for authors on writing an application section of the SEAP document. The document is a product of the Commercial and Public Interest Working Group (CPIWG) of the SEATC of INCOSE. The purpose of this Authors Writing Guide is to provide a structure and uniformity to the Applications section (Sections 4 and 5) of the document.

Sections 4 and 5 are a compilation of multiple subsections, each one addressing a particular application or cross-application domain. The purpose of the CPIWG, stated here, shows the breadth of the applications domains: "To (1) facilitate introduction and use of systems engineering principles, techniques and practices to application domains in Government, private industry and academia; and (2) provide INCOSE a forum to exchange the successful practices which result in high-quality goods and services at affordable and appropriate cost."

The outline of each application subsection of Sections 4 and 5 is

- 4.x Domain Title
- 4.x.1 Introduction
- 4.x.2 Functions and Processes
- 4.x.3 Technology Profiles
- 4.x.4 Systems Engineering Challenges
- 4.x.5 Contacts
- 4.x.6 References and Regulations

Guidelines on each subsection follow:

4.x Domain Title

4.x.1 Introduction

The *Introduction* gives an overview of the application area or domain. It defines the application domain and the scope of the material about the domain that is being presented in this paper. It gives some indication of the systems engineering challenges that exist for the area.

Two tables are standard for each of the domains: 4.x–1, Domain Summary, and 4.x-2, Systems Engineering in the _________ Domain. One or both of these tables may be used in the Introduction. The first one, on the domain overall, may be the only table in the Introduction. It may be best to use the Systems Engineering in the _________ Domain table in the Systems Engineering Challenges section, 4.x.4. The Introduction can be brief.

As stated previously, the Introduction includes at least an overview, plus Table 4.x–1, which has the sections indicated below. The table is structured to give the reader an idea of the scope and content of a particular domain. It is recognized that not of all the domains will be industries, although many will be. The table can be tailored or modified as necessary to meet the subject of a domain that is not an industry. To preserve a common structure of for each section of the paper, it is best to keep the headings in the table, and put NA if not applicable, and add others as necessary. A TBD can be used if the block is “to be determined” in the future.

The following sample table has the standard format in the first column and an example of Natural Resources Management application in the second column.

Table 4.x–1. Domain Summary (or ----, Industry Summary)

Number of Companies (U.S./Outside U.S.)	U.S.: 20 major companies; hundreds of smaller companies as consultants International: TBD
Representative Firms	Usually conducted by Federal Government personnel, specifically in the Departments of Agriculture (Forest Service) and Interior (BLM; National Park Service)
Annual Sales	TBD
Products	Planning documents, maps, guides, regulations, databases, brochures, presentation materials
Technical Challenges	Ease of use interface; integration of multiple platform and database formats; shift to PC level; use of client/server architecture; staying up-to-date with PC architecture
Business Challenges	Obtaining consensus or agreement among stakeholders with divergent interests
Major Customer Groups	Businesses: lumber products, mining, grazing Governments: Federal, regional , and local Environmental NGOs: Sierra Club, Wilderness Society The public
Regulatory Groups	U.S. Congress, Executive Branch departments
Growth	Very low (<10%) annual growth expected

The second table to be used for each domain, Table 4.x–2, summarizes systems engineering as practiced in the application. It is probably the key table in the subsection, and combines with the Systems Engineering Challenges text section, 4.x.4, to give an indication of systems engineering currently being practiced in the domain. The table and the Systems Engineering Challenges section, also present what the systems engineering process in general and INCOSE in particular can learn from the domain. It may sometimes be practical in the table to refer to parts of Section 4.x.4 because more lengthy text may be required. It may sometimes also be practical to place Table 4.x–2 in the Systems Engineering Challenges section.

The following sample table has the standard format in the first column and an example of Natural Resources Management domain in the second column.

Table 4.x–2. Systems Engineering in the _________ Domain

Systems Engineering Requirements	Numerous Federal and state laws and regulations govern the management of U.S. natural resources. Some examples are as follows: TBS These form the bases of the requirements for the land "systems." They flow down to the lower levels of land-use management plans. The parts of the plans must be shown to be traceable to the law and regulations.
Systems Engineering Strengths	Systems analyses to determine land use, both existing and planned; requirements traceability; formal trades; specification writing; determination and quantification of metrics. Systems engineering is not practiced formally in Resource Management.
Systems Engineering Challenges	Systems engineering processes are not used sufficiently by Government agencies in planning and regulating natural resource use. Refer to Section 4.x.4 for details.
Unique Systems Engineering Tools or Techniques	Standardized systems engineering software tools can be used for most applications; however they usually are not. Noncomputerized processes are employed.
Systems Engineering-Related Standards	None.

Table 4.x–2 was updated to include additional information (see Table 4.x-2a). It is recommended that profiles developed in the future incorporate this information. However, this information is optional. The example is for the Commercial Aircraft domain.

Table 4.x–2a. Systems Engineering in the _________ Domain (alternative version)

1. Elements of Systems Engineering Current Practices in the Domain	Blocks 1a through 1j describe systems engineering practices that currently exist in the domain.
a. Stakeholder Definition	Stakeholders include the flying public, airlines and cargo carriers, regulatory agencies (FAA, JAA, OSHA, FDA), shareholders, suppliers, and aircraft manufacturers.
b. Technical Problem/ Mission Statement	The mission of commercial aircraft is to transport passengers and cargo safely and as economically as feasible.
c. Systems Engineering Requirements and Drivers	The key requirements and drivers are the aircraft performance (range, payload, weight), safety, cost (direct operating and life cycle, reliability (especially dispatch), and fleet commonality (training and maintenance).

d. Functional Analysis and Architecture	Functional analysis is employed primarily in safety analysis as recommended by ARP 4754. A standard aircraft architecture called the ATA (Air Transport Association) Index is accepted throughout the commercial aircraft domain.
e. Solution Definition	Aircraft sizing and design is normally accomplished by employing performance parameters as the driving requirements with appropriate constraints, such as field length. Final design is evaluated for direct operating cost (DOC) for acceptability.
f. Trades (Assessment and Selection)	Trade studies normally employ cost and weight as the two primary evaluation criteria.
g. Integration	Avionics are integrated using integration laboratories. Physical structural integration by development fixtures (physical mockups) is being replaced by electronic 3D models.
h. Verification and Validation	Verification of safety-critical requirements is accomplished in accordance with rigorous Government certification criteria. Validation by airline customers is accomplished through customer assessment of the product against the design specification (DS), a contractual document.
i. System Operation	Little systems engineering practiced in system operation other than Government scrutiny of airline operations and the application of lessons from accidents for aircraft improvements.
j. System Support	Allocation of maintenance requirements (maintenance man-hours per flight hour) to subsystems by ATA Index number.
2. Systems Engineering Strengths	Certification and software development are in the closest alignment with systems engineering principles.
3. Domain-Motivated Systems Engineering Opportunities and Challenges	Need exists for requirements management and top-level review of derivative and change-based (custom) designs. Supplier-driven industry requires rigorous supply chain requirements and interface processes. Functional analysis needed for total system analysis, especially for cognitive human factors functions and other safety-related areas. Strong market-dominated domain stimulates need for systems engineering to find new ways to synthesize aircraft with significantly lower direct operating costs (DOC). Although industry is already strongly safety oriented, systems engineering provides opportunity to make significantly safer products.
4. Systems Engineering Tools	Popular requirements management tools find occasional use. Electronic 3-D modeling tools increasingly are used for physical interface management.
5. Systems Engineering-Related Standards	SAE ARP 4654, “Guidelines for the Certification of Highly-Integrated and Complex Aircraft Systems” (in cooperation with the FAA) and RTCA/DO-178B, “Software Considerations in Airborne Systems and Equipment Certification,” and “Guidelines for the Practice of Systems Engineering in the Commercial Aircraft Domain” (under development by the Joint Commercial Aircraft Working Group).

The different parts of Tables 4.x–2 and 4x–2a are explained as follows:

Systems Engineering Requirements. This should list the requirements, or types of requirements, that regulate or govern the practice of systems engineering in the domain. Federal, military or other standards, such as IEEE or EIA, that are in common use should be listed if applicable.

Systems Engineering Strengths. This block summarizes where systems engineering is used in the domain, if it is in deed used. If systems engineering is used formally, that should be noted. If an explanation of the maturity level of systems engineering is needed, it can be noted in this part of the table and further explained in the Systems Engineering Challenges section, 4.x.4.

Systems Engineering Challenges. This block shows where systems engineering could be applied, but is currently not being applied. It may also list where there are practices in the domain that, in effect, perform systems engineering functions under different terminology. It can show what systems engineering needs from the domain area. This section block should definitely be explained in more detail in Section 4.x.4. It is the heart of explaining how INCOSE can learn more from the practices of the industry/domain.

Unique Systems Engineering Tools or Techniques. The systems engineering tools used in the domain can be listed here. The listing can be generic types of tools, computerized or not, and/or can name specific tools.

Systems Engineering-Related Standards. This block names published systems engineering standards that pertain to the domain.

Elements of Systems Engineering Current Practice in the Domain. Sections 1a through 1j describe specific areas of systems engineering that may be currently practiced in the domain.

Stakeholder Definition. This section describes the domain stakeholders. Stakeholders may include customers, regulatory agencies, or the organization itself and its shareholders, if any.

Technical Problem/Mission Statement. This block describes the mission of the system or the problem being addressed by the system.

Systems Engineering Requirements and Drivers. This block lists the key requirements and other factors that determine the nature of the system. This block is the same as System Engineering Requirements in Table 4.x-2)

Functional Analysis and Architecture. This block describes how functional analysis may be practiced in the domain, if at all. While functional analysis is commonly performed in software development, its use in system development is also possible.

Solution Definition. This block described any unique methodologies for arriving at a system design in the domain. Quality Function Deployment (QFD) is an example.

Trades (Assessment and Selection). This block describes any unique methods commonly used in the domain for conducting and assessing the results of trade studies.

Integration. This block discusses any methods used in the domain for conducting system integration.

Verification and Validation. This block discusses any unique verification and validation processes in the domain. This includes also certification by government or other agencies.

System Operation. This block discusses any unique systems engineering aspects of practiced during the operational phase of the system.

System Support. This block discusses any systems engineering approaches to the development or operations of support systems, including maintenance, supply, etc.

Systems Engineering Strengths. This block lists any areas in the domain that have strong systems engineering practice at the current time. (This block is also in Table 4.x-2.)

Domain-Motivated Systems Engineering Opportunities and Challenges. This block lists any areas that would benefit by systems engineering improvement in the domain. (This block is also in Table 4.x-2.)

Systems Engineering Tools. This block lists any systems engineering tools that may find occasional or frequent use in the domain. These include either requirements management tools or other modeling or simulation tools. (This block is also in Table 4.x-2.)

Systems Engineering-Related Standards. This block lists any systems engineering-focused standards or guidelines that are currently used in the domain. These standards or guidelines can be either domain-specific or general. (This block is also in Table 4.x-2.)

4.x.2 Functions and Processes

This section describes the domain in some detail. There can be as much supporting material as necessary, including figures and tables. The section may include a brief history of the domain. It may emphasize the domain scope, its functions and its interfaces with other industries or government. It should state the extent of the practice of the domain internationally as well as domestically.

A description of how the functions are executed can be given in this section. Any description of some of the techniques and tools in general (not for systems engineering because that is covered in Section 4.x.4) can be included. The processes used can be described here.

4.x.3 Technology Profiles

This section names and possibly describes the sciences and technologies used in the domain. Its purpose is to give the reader an indication of the level of technical sophistication of the domain. The section could include the level of training of professionals who work in the domain.

4.x.4 Systems Engineering Challenges

This section is the major contribution of INCOSE in this SEAP document. Its purpose correlates directly with the purpose of the CPIWG of the SEATC; that is, to "Facilitate introduction and use of systems engineering principles, techniques, and practices to domain domains in Government, private industry, and academia." And, secondly, to "provide INCOSE a forum to exchange the successful practices that result in high-quality goods and services at affordable and appropriate cost."

This section can be subdivided into the topics listed in the Table 4.x–2. It can also be organized as the author wishes to relate in the most sensible way to the particular domain. The point is that this section should bring out the ways systems engineering can or does contribute to the success of the domain. It should describe what the domain has to contribute to the practice of systems engineering and to INCOSE.

Also included is an understanding of the maturity level of systems engineering, the tools used, and what the domain can teach INCOSE.

The section can and should also discuss ways that the domain can be explored further by INCOSE members. Some suggestions follow. One is to sponsor local chapter forums, bringing speakers in from the domains, or holding a panel discussion among several professionals in the domain. Other ideas are symposium papers and invited speakers on the subject at the symposium; insight articles; INCOSE Journal articles; and special seminars sponsored by the chapters. The writing can bring out specifics about example topics and what INCOSE and systems engineering needs to and can learn from the experts in the field.

4.x.5 Contacts

Contacts are in three types: the author(s), INCOSE members who are practitioners in the field, and other experts in the field who are willing to have their name used. Include name, address, telephone number, fax number, and E-mail address.

4.x.6 References and Regulations

These are references used in writing the section or references that are useful in understanding the domain. Also included are industry and professional society documents and regulations. This should be divided into two parts: General and Systems Engineering specific.

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Appendix C—Multilevel Participation Plan

SYSTEMS ENGINEERING APPLICATIONS TECHNICAL COMMITTEE (SEATC) MULTILEVEL PARTICIPATION PLAN

Prepared by Scott Jackson, INCOSE Los Angeles Area Chapter

C.1 Introduction

At the International Workshop in Dallas, Texas, January 26–29, 1998, the SEATC identified the strengths and weaknesses of the committee. This discussion resulted in a list of injections (i.e., solutions) that might correct many of the weaknesses. The primary need addressed was how to increase participation in committee activities. This need is particularly acute in view of the fact that both the past and present INCOSE presidents list emphasis on non-defense applications as one of the top priorities of the organization. This plan spells out the features of a plan to address this need.

C.2 Background

The committee listed both the strengths and weaknesses of the committee. Present were William Mackey (SEATC chair), Scott Jackson (SEATC co-chair), Patrick Sweeney (Facilities System Engineering Working Group), and Terry Robar (Business Domain Analysis Working Group).

C.2.1 Strengths

The following strengths were listed:

- Strong expertise of members in a number of applications domains
- Ability to structure symposia to the advantage of systems engineering applications
- A Systems Engineering Applications Profile document with ability to expand in multiple application domains
- Ability to create liaisons with academic institutions

C.2.2 Weaknesses

The following weaknesses were identified:

- Lack of travel money
- Limited volunteer time
- Limited number of committed people
- Limited number of invitations to winter workshop
- Conflicts with other committees
- Not enough public relations

- No time during summer workshop to attract and sign up new people
- The commercial industries (and public interest organizations) that we study seem to provide minimal representation

This plan addresses primarily the first five weaknesses.

C.3 Plan Features

The features of the plan are as follows:

- Networks
- Participation
- Leadership
- Communication
- Teleconferences
- Meetings
- Workshop invitations

C.3.1 Networks

The plan envisions that the system of working groups and interest groups would function as networks with the members participating at multiple levels of participation (Section C.3.2) with leaders functioning as points of contact and communicating by E-mail (Section C.3.4) and teleconferences (Section C.3.5). The current emphasis on meetings (Section C.3.6) would be de-emphasized. This system is seen as the primary method for involving people whose time commitments and organizations do not permit them to travel.

C.3.2 Participation

The concept of multilevel participation is envisioned as the primary mechanism for allowing anyone, even members of other committees and working groups, to participate at their own level without committing to travel to meetings or conferences.

C.3.2.1 Level 1, Comment

The comment level is the lowest level of participation. It addresses those members whose commitments to other priorities are most restrictive. For example, a person may be a member of another committee, but have a special interest in a particular application domain. This level allows those persons to comment on products being produced. If any person at this level wishes to contribute from time to time at a higher level, that participation would not be discouraged. Persons at this level can also participate in the teleconferences if they wish. No travel commitments are associated with this level.

C.3.2.2 Level 2, Contributory

The contributory level is directed at those persons who may wish to write a paragraph, a section, or even the entire text of any SEATC product. These contributions can be accomplished entirely by E-mail. No travel is expected, but it is welcome.

C.3.2.3 Level 3, Coordination

The coordination level is directed at those persons who may be willing to coordinate a particular SEATC product. This coordination would involve exchanging E-mail with the various contributors and ensuring the continuity and integrity of the product. This level does not necessarily imply any writing; however, the development of an outline would be a logical task, along with editing to ensure continuity of the sections. Like other levels, this task can also be conducted entirely by E-mail; hence, no travel is required.

C.3.3 Leadership

As discussed in Section C.3.1, the leadership concept would allow working group and interest group leaders to function as points of contact and reduce their need to attend meetings. Hence, working group or interest group leaders may function entirely without attending symposia or international workshops (formerly called winter workshops). The primary function of a leader is to determine what the products of the group are and to coordinate their production. The leader may function as a coordinator and also may contribute material. The SEATC chair and co-chair would normally be expected to attend symposia and international workshops. Working and interest groups would also be encouraged to attend, but attendance would not be required.

C.3.4 Communication

It has been noted that other technical committees have begun to function almost entirely through E-mail, which is also the SEATC's goal. Coordination, contributions, and comments can all be accomplished by E-mail. Teleconferences are another communication method.

C.3.5 Teleconferences

An increased emphasis on teleconferences is envisioned for members at all levels of participation. We propose bi-monthly teleconferences, with the first one taking place the first week of March 1998. The conferences should be early (e.g., 8:00 a.m. Pacific time) so that European members (4:00 p.m. Greenwich mean time) can participate. The teleconferences should be structured with an agenda and last no more than 1 hour. Typical topics would be the status of deliverables, and upcoming conferences and meetings. The teleconference chair will publish a meet-me number that all members can call at the appointed hour. As each member calls in, he or she should briefly introduce himself or herself (e.g., "This is Joe Smith from the XYZ corporation in ABC, Texas."). The chair will periodically summarize who is on the line.

C.3.6 Meetings

Although the chair and co-chair are the only SEATC members expected to be at annual symposia and international workshops, others are strongly encouraged to attend. Lack of attendance will not affect their performance in any level of participation.

C.3.7 Workshop Invitations

One weakness cited is that the invitation-only policy for international workshops may discourage many SEATC members from attending. This plan calls for the SEATC chair to arrange for invitations for any SEATC members who wish to attend. In the unlikely event that there are too many requests, a limit may have to be set. The current plan is to arrange invitations for any SEATC member who requests one.

C.4 Schedule

C.4.1 Prepare Plan Draft

The deadline for the preparation of this plan was February 15, 1995. The responsibility was Scott Jackson's. (The plan was completed and approved.)

C.4.2 Approve Plan

The date for the approval of this plan is the teleconference during the first week of March 1998. The approval is required by the chair, co-chair, and current working group and interest group chairs. NOTE: This plan was unanimously approved during the teleconference on March 4, 1998.

C.4.3 Teleconference

Scott Jackson will poll members for the most convenient day for a teleconference during the first week of March. He also will chair the teleconference and notify the members of the meet-me number. William Mackey will prepare the agenda. (The teleconferences have been held every 2 to 3 months, on the second Tuesday of the month, since 1998. Approximately 10 such teleconferences have been held as of May 2000.)

C.4.4 Publicity

Following the approval of this plan, the appeal for members will be made in various forms:

- Insight – Pat Sweeney, theme editor for the *INSIGHT* issue, will ensure that a notice of the multilevel participation concept is included in that issue. Suspense date is March 17, 1998. (Two such issues have been completed. They were focused on commercial and public interest issues and were led by Pat Sweeney.)
- Reflector – Scott Jackson will prepare and send a reflector message. Suspense date is also March 17, 1998.

- Other – The SEATC, under direction of the chair, will determine other methods of publicity.

C.4.5 Task Assignments

Prior to plan approval, we envision that appeals for help will focus on current tasks, such as completing sections of the SEAP document.

Following plan approval, members will be assigned to the various levels of participation they request. The chair will be responsible for level, working group, and interest group assignments.

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Appendix D—INCOSE Systems Engineering Applications References by Year Published

The references in this appendix are from INCOSE symposia proceedings, journals, etc. They have been clustered by systems engineering application domain within each year from 1992–1999. Table D–1 demonstrates that a large number of publications has been completed in many domains since INCOSE's first symposium in 1991.

Table D–1. Summary of Systems Engineering Applications by Year

Systems Engineering Application Domain	Year								Total
	1992	1993	1994	1995	1996	1997	1998	1999	
Agriculture	0	3	2	0	0	0	0	0	**5**
Aviation/Avionics	1	4	0	2	1	7	8	7	**30**
Commercial	1	3	3	1	4	4	2	6	**24**
Criminal Justice and Legal Systems	1	0	1	0	0	0	0	0	**2**
Defense	0	0	0	0	0	0	1	8	**9**
Emergency Services	0	0	0	0	0	0	0	1	**1**
Energy	0	1	1	1	0	0	0	1	**4**
Environmental Restoration	0	0	1	1	3	1	0	0	**6**
Facilities	0	0	0	0	0	0	0	2	**2**
Health Care	0	0	0	0	0	0	2	0	**2**
Information Systems	0	0	0	0	3	1	1	5	**10**
International Commercial	0	0	0	1	0	0	4	0	**5**
Medical Devices	0	0	0	1	0	0	0	1	**2**
Natural Resource Management	0	0	0	1	0	0	0	0	**1**
Political and Public Interest Systems	1	0	0	0	2	0	1	0	**4**
Space Systems	0	4	3	8	7	1	4	8	**35**
Telecommunications	0	1	0	0	3	0	3	5	**12**
Transportation	1	1	1	1	3	7	1	2	**17**
Urban Planning	0	1	2	1	0	3	0	0	**7**
Waste Management and Disposal	1	0	3	2	3	3	3	5	**20**
Totals	**6**	**18**	**17**	**20**	**29**	**27**	**30**	**51**	**198**

1992: *Proceedings of the Second Annual International Symposium of the National Council on Systems Engineering*, Volume 1, July 20–22, 1992, Seattle, Washington

Title	Page	Author(s)	Application Domain
777 Operational Requirements Development Methodology	589	Hubert H. Underwood	Aviation
Mapping Systems Engineering Principles and Practices to Commercial Sector Activity	201	Randall C. Iliff	Commercial
Systems Engineering and the Legal Profession		William F. Mackey	Criminal justice and legal systems
Systems Engineering in the Regulatory Environment	287	D. Ted Romine	Political and public interest systems
Systems Engineering in the Automotive Industry	501	George S. Percivall	Transportation
Functional Analysis of a Nuclear Waste Repository System	293	F. J. Schelling R. P. Sandoval	Waste management and disposal

1993: *Proceedings of the Third Annual International Symposium of the National Council on Systems Engineering*, Volume 1, July 26–28, 1993, Arlington, Virginia

Title	Page	Author(s)	Application Domain
A Systems Engineering Approach to Improving the Peanut Grading System	427	Floyd E. Dowell, et al.	Agriculture
Implementation of a Bait Adulticide Technology for Corn Rootworm in Integrated Farm Management Systems: A Systems Engineering Approach	435	John K. Westbrook, et al.	Agriculture
Systems Engineering Case Study: A Software-Driven Whole-Farm Management Information System	845	R. Samuel Alessi, et al.	Agriculture
Integrated Modeling: An Avionics Case Study	151	Mark W. Maier	Aviation/avionics
McDonnell Douglas Aerospace Avionics Engineering Process Handbook	787	Charles Hlavaty, et al.	Aviation/avionics
Systems Engineering the Fault Analysis Process for Commercial Avionics Application	729	C. Steven Spangler	Aviation/avionics
Working Together: The Boeing 777 Cabin Management System	245	Arthur F. Morrison	Aviation/avionics
A Systems Oriented Development Approach for Commercial Enterprises	697	Arthur G. Stone, III	Commercial
State of the Practice—Commercial Systems Engineering	29	Randall C. Iliff	Commercial
Toward a Useful Best Commercial Practice	693	Charles L. Weaver	Commercial
Life Cycle and Production Unit Cost Analysis Techniques for System Configuration Selection in the Norwegian Offshore Oil and Gas Industry	705	David F. Plummer	Energy
Cost Effectiveness Enhancement Initiative for the Space Shuttle Contract	121	Mina Akhavi, et al.	Space systems
Real Time Systems/Software Methodologies for Large Aerospace Systems	113	Bhadra K. Patel, et al.	Space systems
System Integration Applications of Information Systems in the Space Station Freedom Program	553	L. Dale Thomas, et al.	Space systems
The NASA SEPIT Life Cycle	89	A. D. Fragomeni, et al.	Space systems
System Integration Via Telecommunication	467	Morton Andresen, et al.	Telecommunications
SYSTEMS ENGINEERING Applications in Transportation Planning	713	Theodore A. Dolton, et al.	Transportation
Systems Engineering Design of a Suburb	459	Karen Heidel, et al.	Urban planning

1994: *Proceedings of the Fourth Annual International Symposium of the National Council on Systems Engineering*, Volume 1, August 10–12, 1994, San Jose, California

Title	Page	Author(s)	Application Domain
AGUAS: Design of an Agricultural Water Quality System	837	Wayne Wymore, et al.	Agriculture
Application of Systems Engineering Methodology to the Design of an Agricultural Research Program	851	Sally M. Schneider, et al.	Agriculture
A Life Cycle for Commercial and Aerospace Systems Discovery	733	David W. Oliver	Commercial
Applying Object Oriented Methodology to Commercial Systems Engineering	867	Matthew Lukaszewski	Commercial
Emerging Applications Technical Committee	V2, 1	Richard B. Mintz	Commercial
The Morphological Approach: Its Role in Systems Engineering and Its Application to Solar Energy Conversion	255	Scott Jackson, et al.	Energy
Life Cycle Systems Engineering: A Global Environmental Imperative	831	Joseph Fiksel, et al.	Environmental restoration
A Systems Engineering Analysis for Re-Engineering an Organization	299	Raymond L. Granata, et al.	Space systems
An Operations Concept Development Methodology Using a Graphic Process Flow Technique	141	William F. Mackey, et al.	Space systems
Development of a Systems Perspective for Long Duration Space Flight Missions Using a Crew Systems Interactions Model (CSIM)	239	Kathy S. Upshaw	Space systems
A Systems Engineering Approach to Highway Design	633	William F. Mackey, et al.	Transportation
Landfill NIMBY and Systems Engineering: A Paradigm for Urban Planning	991	G. Fred Lee, et al.	Urban planning
Systems Engineering in a Social Application: Designing an Evolved System of Education	859	Mark A. Ottenberg	Urban planning
Application of Systems Engineering Into an Ongoing Operation	845	Bernard G. Morais, et al.	Waste management and disposal
Applying Systems Engineering and Icon-Driven Simulation Techniques to the Waste Disposal Problem at Hanford, WA	873	Alan Keizur, et al.	Waste management and disposal
Systems Engineering Looks at AB939: The California Integrated Waste Management Act of 1989	1039	Masoud Kayhanian, et al.	Waste management and disposal

1995: *Proceedings of the Fifth Annual International Symposium of the National Council on Systems Engineering*, Volume 1, July 22–26, 1995, St. Louis, Missouri

Title	Page	Author(s)	Application Domain
Development of Operating Concepts	127	T. E. Thompson	Aviation/avionics
SAFER – A Case Study, the Lessons Learned on a Flight Test Project	417	C. W. Hess, et al.	Aviation/avionics
Principles of Commercial Systems Engineering	155	E. C. Honour	Commercial
Tailoring the Military Systems Engineering Methodology for the Commercial Market: A Case Study of the Westinghouse StreetLINK™ System	217	B. L. Holub	Criminal justice and legal systems
A Systems Engineering Approach to Life Extension Planning for the Strategic Petroleum Reserve	147	R. P. Pikul, et al.	Energy
Environmental Impact Design Tool for Systems Engineers	103	E. T. Frisbee	Environmental restoration
A Systems Engineering Capability in the Global Market Place	809	H. Rochecouste	International commercial
FDA Good Manufacturing Practices (GMP) for Medical Devices	81	G. N. Farrell	Medical devices
Systems Engineering in Wilderness Areas Management	87	Theodore A. Dolton, et al.	Natural resource management
A Systems Engineering Approach to Technology Management	741	William F. Mackey, et al.	Space systems
A Systems Engineering Approach to the Analysis of a Planetary Mission Ground System in Terms of Science Objectives	781	R. R. Wessen	Space systems
Application of ANSI Standards to Space Station Resources	461	I. Taylor	Space systems
Maintenance Budget Allocations in Fiscally Constrained Environments Using Risk Constrained Optimized Maintenance Planning (RCOMP)	95	F. Douglass, III, et al.	Space systems
Practical Issues for Including Manufacturing During Space System Concept Development	727	S. C. Ruth	Space systems
Spacecraft Performance Requirements Tracking and Verification for the Tropical Rainfall Measuring Mission	121	R. C. Carter, et al.	Space systems
The Transition of Functional Organizations to Integrated Product Teams on the Space Station Program	467	J. F. Peters	Space systems
Use of Prototyping in Developing Operational Systems	263	Charisse Sary	Space systems
Systems Engineering of Renewals and Extensions in Mass Transit Railways	109	J. S. Williams, et al.	Transportation

Title	Page	Author(s)	Application Domain
Social Systems Engineering and Management	139	Mark W. Maier	Urban planning
Developing a Systems Engineering Approach for the Hanford Retrieval, Treatment, and Immobilization Division Based on DOD Standards	131	V. L. Saladin	Waste management and disposal
The Application of Systems Engineering Techniques in a Regulatory Environment: NRC High-Level Waste Regulatory Program	115	P. C. Mackin, et al.	Waste management and disposal

1996: *Proceedings of the Sixth Annual International Symposium of the National Council on Systems Engineering*, Volume 1, July 7–11, 1996, Boston, Massachusetts

Title	Page	Author(s)	Application Domain
Implementation of Dynamic Aircraft Models Using MATRIXx	901	T. J. Redling	Aviation/avionics
Introducing Systems Engineering Into a Traditionally Commercial Organization	83	S. Jackson	Commercial
Reengineering Process of a Corporate Financial System: A Systems Engineering Solution	163	B. Ghahramani	Commercial
Systems Engineering Application Profiles, Version 1.0	V2	William F. Mackey, et al.	Commercial
The Briar Patch: From DOD to Commercial Systems Engineering	97	P. Hale	Commercial
Collaborative System Engineering Approach to an Evolutionary Oceanic System Development	45	W. N. Feerrar	Environmental restoration
Integration of the Idaho National Engineering Laboratory Environmental Management Activities Using Systems Engineering	19	J. A. Murphy	Environmental restoration
Systems Engineering and Integration for DOE Environmental Management	3	G. Power. et al.	Environmental restoration
A Practical Approach to Failure Mode, Effects, and Criticality Analysis (FMECA) for Computing Systems	145	J. C. Becker, et al.	Information systems
Business Reengineering for Information Technology: From Business Process to System Requirements	109	S. A. Bohner, et al.	Information systems
Specification for “Century Compliance”	89	R. Loutoap	Information systems
Leveraging Limited Research and Development (R&D) Resources in the Public Sector	75	M. E. Senglaub	Political and public interest systems
System Engineering Application to Local Governments—Part I: Identifying the Mission	71	T. J. Nagle	Political and public interest systems
Conducting a Technology Management Assessment	153	William F. Mackey	Space systems
Design Analysis Cycle Application to the International Space Station Design	51	G. L. Brown	Space systems
IMAACS: A Demonstration in Reengineering Ground Data Systems Development	63	M. R. Bracken, et al.	Space systems
International Space Station Performance Metrics	1005	A. F. Rice	Space systems
Qualification Strategies for the International Space Station U.S. Laboratory	1109	B. Purves	Space systems
Space Mission Operations Concept	459	G. F. Squibb	Space systems

Title	Page	Author(s)	Application Domain
The Application of Risk Management to the NEO Threat	103	G. J. Friedman	Space systems
Systems Engineering on the Internet Highway—Roadkill or Road Runner?	125	L. A. Lee, et al.	Telecommunications
The Emerging Role of Telecommunications: Creative Applications of Systems Engineering Metrics	171	Carolyn Buford	Telecommunications
Use of Internet Retrieval and Access Tools in Support of the Goddard Space Flight Center	179	William F. Mackey, et al.	Telecommunications
A System Concept for an Advanced Vehicle Control System	137	William F. Mackey, et al.	Transportation
A Systems Engineering Approach to Highway Design	27	William F. Mackey, Jr., et al.	Transportation
Introduction of Systems Engineering and Appropriate Tools to a Mass Transit Railway Project	37	J. Allen, et al.	Transportation
Privatizing Government Operations – A Systems Approach	55	M. A. Duffy, et al.	Waste management and disposal
Systems Engineering for the DOE SNF Program	13	C. L. Beebe	Waste management and disposal
Systems Engineering in a Management and Operations (M&O) Environment	131	S. J. Flowers	Waste management and disposal

1997: *Proceedings of the Seventh Annual International Symposium of the National Council on Systems Engineering*, Volume 1, August 3–7, 1997, Los Angeles, California

IEEE Transactions on Aerospace and Electronic Systems, Volume 33, Number 2, ISSN 0018-9251, April 1997

Title	Page	Author(s)	Application Domain
777 Flight Controls Validation Process	IEEE 656	H. Buus, et al.	Aviation/avionics
A Framework for a Decision Support System (DSS) Architecture for Air Traffic Management	71	A. N. Sinha, et al.	Aviation/avionics
Boeing Systems Engineering Experiences from the 777 AIMS Program	IEEE 642	S. L. Pelton, et al.	Aviation/avionics
Developing the 777 Airplane Information System (AIMS): A View from Program Start to One Year of Service	IEEE 637	B. Witwer	Aviation/avionics
Development of Laboratories Capabilities for the Integration of Global Positioning Satellite (GPS) System onto the F-14 Aircraft	79	H. K. Chan, et al.	Aviation/avionics
System Engineering for the 777 Autopilot System	IEEE 649	M. J. Gries	Aviation/avionics
Systems Engineering for Commercial Aircraft	63	S. Jackson	Aviation/avionics
Barriers to Bringing System Engineering into the Commercial Market Place	3	E. V. LaBudde	Commercial
Developing a System Solution in a Commercial Environment	15	C. J. Gutierrez, et al.	Commercial
System Engineering Online Documentation	23	C. Etcheverry, et al.	Commercial
Systems Engineering in Commercial Industries (Panel Session)		W. Mackey, et al.	Commercial
System Modeling and Possible Applications for the Social Sciences	117	A. Koehler, et al.	Environmental restoration
Applying Systems Engineering to VLSI Design	9	J. R. Gardner	Information systems
Application of a System Architecture Standard to a Federated Information System	85	G. S. Percivall	Space systems
A Course on Systems Engineering for Railway Projects	475	J. Q. Jin, et al.	Transportation
On Architecting and Intelligent Transport Systems	IEEE 610	Mark W. Maier	Transportation
A Total Systems Approach to Automotive Development	31	D. Hatley, et al.	Transportation
Overcoming Problems in the Development of an Automated Car Park System by Introducing Systems Engineering Methods	47	F. Harzenetter, et al.	Transportation

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The Air Bag System: What Went Wrong with the Systems Engineering?	55	D. M. Buede	Transportation
The Science of Railway Systems Engineering	39	J. S. Williams	Transportation
Using Systems Engineering for Automotive Advanced Development	149	W. H. Wittig	Transportation
An Interface Control Approach to Land-Use Management	101	R. S. Carson	Urban planning
Systems Engineering and the Architectural Design of Buildings	93	D. G. Langston	Urban planning
Systems Process for Public Policy Application	109	W. H. Cutler	Urban planning
Department of Energy Environmental Management Complex-Wide Integration Using System Engineering	133	P. Fairbourn	Waste management and disposal
Development of the Environmental Management Integrated Baseline at the Idaho National Engineering Laboratory Using Systems Engineering	141	J. A. Murphy, et al.	Waste management and disposal
Rebaselining of the Plutonium Residue Elimination Project at Rocky Flats Environmental Technology Site	125	W. C. Sailor, et al.	Waste management and disposal

1998: *Proceedings of the Eighth Annual International Symposium of the International Council on Systems Engineering*, Volume 1, July 26–30, 1998, Vancouver, British Columbia, Canada

Title	Page	Author(s)	Application Domain
An Experience with a Multiformalism Specification of an Avionics System	723	I. Traore, et al.	Aviation/avionics
FAA Investment Analysis: A Systems Engineering Application	429	N. T. Fujisaki, et al.	Aviation/avionics
Practical Experience Applying Formal Methods to Air Traffic Management Software	359	R. Yates, et al.	Aviation/avionics
Simulation Use During the Development of an Aircraft Cargo Handling System	437	S. Salzetti, et al.	Aviation/avionics
Synthesis of an Anti-Terrorist Air Transportation Security System	31	M. A. Woodhead, et al.	Aviation/avionics
Traceability for the Development of Assessment of Safe Avionic Systems	445	S. Pearson, et al.	Aviation/avionics
Use of QFD as an Integrated Product Team Tool to Select Concepts Based on Requirements	453	D. Hess, et al.	Aviation/avionics
Using Systems Engineering on a C-17 Performance Improvement Project	461	J. C. Hsu	Aviation/avionics
A Systems Approach Toward Design for RAMS/LCC: Lessons Learned from Cases within Aerospace, Chemical Process, and Automotive Industry	49	R. J. van Baaren, et al.	Commercial
Design Review Checklist for a Business Process Model	497	J. Ring	Commercial
Cost as an Independent Variable (CAIV) on the Joint Helmet-Mounted Cueing System (JHMCS) Program	469	B. Kembitzky	Defense
Designing Client-Server Systems for the Intensive Care Unit: An Application of Performance-Driven Design	521	J. R. Zaleski, et al.	Health care
Systems Engineering in the Intensive Care Unit: A Model of Post-Operative Patient Reawakening Time	517	J. R. Zaleski	Health care
Leading Indicators of Rework: A Method of Preventing Software Defects	489	R. Stewart, et al.	Information systems
Introducing System Engineering into a Traditional Steel-Making Environment	565	P. J. Duggan, et al.	International commercial
Systems Engineering in Developing Nations	537	J. D. Applegate	International commercial
The Global Information Infrastructure, the Global Information Society—Is It a Reality?	551	G. Piedras	International commercial
The World Economic System	943	T. V. Carver	International commercial

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Applying Systems Thinking to Expatriate Selection	545	G. G. Chapin, et al.	Political and public interest systems
Commissioning a Distributed Operational Information Management System	483	A. Eagles, et al.	Space systems
Deep Space One Spacecraft System Engineering Techniques and the Application of Heuristic Reasoning	475	R. R. Basilio	Space systems
Implementation of System Requirements Models for Space Missions	285	S. D. Wall, et al.	Space systems
The Systems Engineering Process Definition as Part of the European Cooperation for Space Standardization (ECSS)	171	R. Hartman	Space systems
Modeling Communication Satellite Protocols with a System Design Automation Tool	391	R. Colligan	Telecommunications
Systems Engineering to Sydney	511	J. E. Kasser, et al.	Telecommunications
Web-Based Systems Engineering Application Profiles	503	M. A. Austin	Telecommunications
Revisiting Accumulated Wisdom After 100 Years of Engineering Railway Systems	559	J. S. Williams, et al.	Transportation
Development of the Reference Design Description for a Geologic Repository	843	R. B. Daniel, et al.	Waste management and disposal
Integrated Control Process for the Development of the Mined Geologic Disposal System	855	R. B. Daniel, et al.	Waste management and disposal
System Engineering for Informal Regulation	531	A. C. Koehler, et al.	Waste management and disposal

1999: *Proceedings of the Ninth Annual Symposium of the the International Council on Systems Engineering*, Volumes 1 & 2, June 6–11, 1999, Brighton, England

Title	Page	Author(s)	Application Domain
A Method for Design and Analysis of Next Generation Aircraft Computer Systems	293	A. Grigg, N. Audsley, M. Fletcher, A. Wake	Aviation/avionics
Airbus System Engineering Policy	341	A. Jeffroy, R. Ashpole, M. Cambet, J. Gonzalez, P. Heller, T. Nevelling, J. M. Nogue	Aviation/avionics
An Implementation of the Analytic Hierarchy Process (AHP) on a Large Scale Integrated Launch Vehicle Avionics Systems Engineering Architecture Trade Study	1395	J. F. Wagner	Aviation/avionics
Collaborative Methods Applied to the Development and Certification of Complex Aircraft Systems	565	R. Langton, G. Jones, S. O'Connor, P. Dibella	Aviation/avionics
Cost Effectiveness of Formal Methods in the Development of Avionics Systems at Aerospatiale	281	F. Pilarski	Aviation/avionics
Developing a Flight Simulator for the Aerospace Extended Enterprise Product Introduction Process	581	R. Mason-Jones, S. Wingrove, I. Alexander, M. Naim	Aviation/avionics
Optimizing Systems Engineering for a Commercial Product Line: A Case Study in International Air Traffic Control	515	K. Mcguire	Aviation/avionics
Application of System Engineering Principles in the Development of the Advanced Photo System	641	G. A. Mason, W. E. Mcgrath, C. K. Rutter, W. B. Sherwood, F. G. Silva, J. P. Spence, H. J. Tsao	Commercial
Designing Standards for Open Simulation Environments in the Chemical Industries: A Computer-Supported Use-Case Approach	69	M. Jarke, A. Becks, C. Tresp, J. Koller, B. Braunschweig	Commercial
Initial Lessons of Model-Based Systems Engineering for Small Commercial Product Development in the Electrical Domain (for Uninterruptible Power Supply System)	1181	C. De Paoli, O. Parrot, A. Rouge, C. Dutey	Commercial
Introducing and Maintaining Systems Engineering in a Medium Sized Company	633	R. J. Hamann, W. Van Leeuwen	Commercial
Systems Engineering Across Commercial and Public Interest Domains	625	S. Jackson	Commercial
Taming the Expanding System Complexity of a Commercial Product: Embracing Systems Engineering Principles in a Commercial Development Environment	1437	P. R. Miller	Commercial

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A Human Centered Design Environment for Complex Systems	415	H. E. Crisp, N. T. Hoang, R. Schmidt	Defense
A New Approach to Marine Programmable Systems Assessment	303	J. Earthy	Defense
An Application of Object Oriented Systems Engineering (OOSE) to an Army Command and Control System: A New Approach to Integration of System and Software Requirements and Design	1213	A. Meilich, M. Rickels	Defense
From Research to Development: Specifying a Future Command and Control System	135	J. M. Lamers, M. Streng	Defense
Incorporating Cost into the Front End of the Radar Systems Engineering Process	531	D. G. Church	Defense
Integrating Human Factors Within Systems Engineering	399	S. R. Harmer, G. Ward	Defense
Simulation Based Acquisition: An Ongoing Look	409	R. Frost, D. Thomen	Defense
Systems Engineering and the Joint Strike Fighter: The “Flagship” Program for Acquisition Reform	553	R. G. Struth, Jr.	Defense
Assessing Emergencies and Making Disaster Recovery Decisions	161	D. A. Riggs, L. H. Botten	Emergency services
Systems Engineering and Statoil Natural Gas Transport Operations	791	H. J. Dahl	Energy
Construction Engineering Within a Prime Contract Engineering Organisation	559	P. J. Ward	Facilities
Systems Engineering Applied to Integrated Safety Management for High Consequence Facilities	947	R. H. Barter, B. G. Morais	Facilities
A “Systems of Systems” Perspective of the Year 2000 Problem	11	L. M. Walker	Information systems
A Systems Approach to the Year 2000 (Y2K) Issue	153	P. D. R. Moore, A. G. Fairbairn	Information systems
Embedded Systems: The Forgotten Y2K Problem	145	G. H. Fisher	Information systems
System Engineering and Information Management – A Local Need in a Global Perspective	389	T. Fossnes	Information systems
Year 2000 Triage for Non-IT and Embedded Systems	169	B. B. Biggs, H. Jackson	Information systems
Ensuring Medical Device Industry Quality System Standards Compliance	841	B. M. Mccay	Medical devices
Design and Implementation of a System Engineering Standard Process for Satellite Development	1385	M. Rudolph, R. Hartmann, E. Fricke, H. Negele	Space systems

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Designing an Optimal Product Introduction Process for an Extended Enterprise in the Aerospace Sector	573	B. Clegg, J. Boardman, A. Boardman, R. Mason-Jones	Space systems
Mussat – A Tool for Model-Based System Engineering of Commercial Satellite Systems	217	M. Wilke, O. Quirmbach, H. Negele, E. Fricke, E. Igenbergs	Space systems
Parametric Cost Modeling of Space Missions Using the Develop New Projects (DNP) Implementation Process	313	L. Rosenberg, J. Hihn, K. Roust, K. Warfield	Space systems
Shuttle Orbiter Production Change Impact Assessment Process: A Collaborative Team Effort	1151	J. E. Hines, T. P. Mccallister, D. P. Weeks, F. A. Ouellette	Space systems
Summary of Results From the Risk Management Program for the Mars Microrover Flight Experiment	503	R. Shishko, J. R. Matijevic	Space systems
The Transition From Spacecraft Development to Flight Operations: Human Factor Considerations	1303	R. R. Basilio	Space systems
Workgroup Software Tools Applied to the Space Shuttle Orbiter Configuration Change Impact Assessment Study Process	1365	T. P. Mccallister, J. E. Hines, D. P. Weeks, F. A. Ouellette	Space systems
A Requirements Driven Approach to Synthesis of Military Satellite Communications Payloads	1373	T. G. Henkle	Telecommunications
Development of Internet in Latin America: The Role of Academic Network Systems and Their Future	673	S. R. Aguilar	Telecommunications
System Issues Related to Implementing on the Internet	679	W. Mackey, T. C. Bagg, III	Telecommunications
Telecom and Defense Systems: Exploring Differences in the Practice of Systems Engineering	1191	J. N. Martin	Telecommunications
The Sociological Impact of Computers and the Internet on the Elderly	687	E. E. Ward	Telecommunications
A Systems Engineering Framework for Integrated Automotive Development	1173	G. Loureiro, P. G. Leaney, M. Hodgson	Transportation
Systems Analysis of Personal Transport	1165	M. V. Lowson	Transportation
Implementing Systems Engineering on a CERCLA Project	1199	G. A. Beitel	Waste management and disposal

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Infrastructure Operations Technical Baseline Development at the Idaho National Engineering and Environmental Laboratory Using Systems Engineering	1339	R. M. Caliva	Waste management and disposal
Systems Engineering in the Development and Implementation of the Savannah River Site Transuranic Waste Disposition Program	1333	R. R. Fayfich	Waste management and disposal
Technology Assessment Tool (A Systems Engineering Approach to Assessing U. S. Department of Energy Technology Proposals)	799	M. A. Rynearson	Waste management and disposal
Using RDD-100 To Develop Technical Baseline at the Idaho National Engineering and Environmental Laboratory	1207	P. L. Gibson	Waste management and disposal

Appendix E—INCOSE Systems Engineering References by Applications Domain

The following references are from INCOSE symposia proceedings, journals, etc. They have been clustered by systems engineering application domain for the years 1992 to 1999.

Agriculture

Title	Page	Author(s)	Year Published
A Systems Engineering Approach to Improving the Peanut Grading System	427	Floyd E. Dowell, et al.	1993
Implementation of a Bait Adulticide Technology for Corn Rootworm in Integrated Farm Management Systems: A Systems Engineering Approach	435	John K. Westbrook, et al.	1993
Systems Engineering Case Study: A Software-Driven Whole-Farm Management Information System	845	R. Samuel Alessi, et al.	1993
AGUAS: Design of an Agricultural Water Quality System	837	Wayne Wymore, et al.	1994
Application of Systems Engineering Methodology to the Design of an Agricultural Research Program	851	Sally M. Schneider, et al.	1994

Aviation/Avionics

Title	Page	Author(s)	Year Published
777 Operational Requirements Development Methodology	589	Hubert H. Underwood	1992
Integrated Modeling: An Avionics Case Study	151	Mark W. Maier	1993
McDonnell Douglas Aerospace Avionics Engineering Process Handbook	787	Charles Hlavaty, et al.	1993
Systems Engineering the Fault Analysis Process for Commercial Avionics Application	729	C. Steven Spangler	1993
Working Together: The Boeing 777 Cabin Management System	245	Arthur F. Morrison	1993
Development of Operating Concepts	127	T. E. Thompson	1995
SAFER – A Case Study, the Lessons Learned on a Flight Test Project	417	C. W. Hess, et al.	1995
Implementation of Dynamic Aircraft Models Using MATRIXx	901	T. J. Redling	1996
777 Flight Controls Validation Process	IEEE 656	H. Buus, et al.	1997

Title	Page	Author(s)	Year Published
A Framework for a Decision Support System (DSS) Architecture for Air Traffic Management	71	A. N. Sinha, et al.	1997
Boeing Systems Engineering Experiences from the 777 AIMS Program	IEEE 642	S. L. Pelton, et al.	1997
Developing the 777 Airplane Information System (AIMS): A View from Program Start to One Year of Service	IEEE 637	B. Witwer	1997
Development of Laboratories Capabilities for the Integration of Global Positioning Satellite (GPS) System onto the F-14 Aircraft	79	H. K. Chan, et al.	1997
System Engineering for the 777 Autopilot System	IEEE 649	M. J. Gries	1997
Systems Engineering for Commercial Aircraft	63	S. Jackson	1997
An Experience with a Multiformalism Specification of an Avionics System	723	I. Traore, et al.	1998
FAA Investment Analysis: A Systems Engineering Application	429	N. T. Fujisaki, et al.	1998
Practical Experience Applying Formal Methods to Air Traffic Management Software	359	R. Yates, et al.	1998
Simulation Use During the Development of an Aircraft Cargo Handling System	437	S. Salzetti, et al.	1998
Synthesis of an Anti-Terrorist Air Transportation Security System	31	M. A. Woodhead, et al.	1998
Traceability for the Development of Assessment of Safe Avionic Systems	445	S. Pearson, et al.	1998
Use of QFD as an Integrated Product Team Tool to Select Concepts Based on Requirements	453	D. Hess, et al.	1998
Cost Effectiveness of Formal Methods in the Development of Avionics Systems At Aerospatiale	281	F. Pilarski	1999
A Method for Design and Analysis of Next Generation Aircraft Computer Systems	293	A. Grigg, N. Audsley, M. Fletcher, A. Wake	1999
Airbus System Engineering Policy	341	A. Jeffroy, R. Ashpole, M. Cambet, J. Gonzalez, P. Heller, T. Nevelling, J. M. Nogue	1999
Optimizing Systems Engineering for a Commercial Product Line: A Case Study in International Air Traffic Control	515	K. Mcguire	1999
Collaborative Methods Applied to the Development and Certification of Complex Aircraft Systems	565	R. Langton, G. Jones, S. O'Connor, P. Dibella	1999

Title	Page	Author(s)	Year Published
Developing a Flight Simulator for the Aerospace Extended Enterprise Product Introduction Process	581	R. Mason-Jones, S. Wingrove, I. Alexander, M. Naim	1999
An Implementation of the Analytic Hierarchy Process (AHP) on a Large Scale Integrated Launch Vehicle Avionics Systems Engineering Architecture Trade Study	1395	J. F. Wagner	1999

Commercial

Title	Page	Author(s)	Year Published
Mapping Systems Engineering Principles and Practices to Commercial Sector Activity	201	Randall C. Iliff	1992
A Systems Oriented Development Approach for Commercial Enterprises	697	Arthur G. Stone, III	1993
State of the Practice—Commercial Systems Engineering	29	Randall C. Iliff	1993
Toward a Useful Best Commercial Practice	693	Charles L. Weaver	1993
A Life Cycle for Commercial and Aerospace Systems Discovery	733	David W. Oliver	1994
Applying Object Oriented Methodology to Commercial Systems Engineering	867	Matthew Lukaszewski	1994
Emerging Applications Technical Committee	IEEE 1	Richard B. Mintz	1994
Principles of Commercial Systems Engineering	155	E. C. Honour	1995
Introducing Systems Engineering Into a Traditionally Commercial Organization	83	S. Jackson	1996
Reengineering Process of a Corporate Financial System: A Systems Engineering Solution	163	B. Ghahramani	1996
Systems Engineering Application Profiles, Version 1.0	IEEE	William F. Mackey, et al.	1996
The Briar Patch: From DOD to Commercial Systems Engineering	97	P. Hale	1996
Barriers to Bringing System Engineering into the Commercial Market Place	3	E. V. LaBudde	1997
Developing a System Solution in a Commercial Environment	15	C. J. Gutierrez, et al.	1997
System Engineering Online Documentation	23	C. Etcheverry, et al.	1997
Systems Engineering in Commercial Industries (Panel Session)		W. Mackey, et al.	1997

Title	Page	Author(s)	Year Published
A Systems Approach Toward Design for RAMS/LCC: Lessons Learned from Cases within Aerospace, Chemical Process, and Automotive Industry	49	R. J. van Baaren, et al.	1998
Design Review Checklist for a Business Process Model	497	J. Ring	1998
Designing Standards for Open Simulation Environments in the Chemical Industries: A Computer-Supported Use-Case Approach	69	M. Jarke, A. Becks, C. Tresp, J. Koller, B. Braunschweig	1999
Systems Engineering Across Commercial and Public Interest Domains	625	S. Jackson	1999
Introducing and Maintaining Systems Engineering in a Medium Sized Company	633	R. J. Hamann, W. Van Leeuwen	1999
Application of System Engineering Principles in the Development of the Advanced Photo System	641	G. A. Mason, W. E. Mcgrath, C. K. Rutter, W. B. Sherwood, F. G. Silva, J. P. Spence, H. J. Tsao	1999
Initial Lessons of Model-Based Systems Engineering for Small Commercial Product Development in the Electrical Domain (For Uninterruptible Power Supply System)	1181	C. De Paoli, O. Parrot, A. Rouge, C. Dutey	1999
Taming the Expanding System Complexity of a Commercial Product: Embracing Systems Engineering Principles in a Commercial Development Environment	1437	P. R. Miller	1999

Criminal Justice and Legal Systems

Title	Page	Author(s)	Year Published
Systems Engineering and the Legal Profession		William F. Mackey	1992
Tailoring the Military Systems Engineering Methodology for the Commercial Market: A Case Study of the Westinghouse StreetLINK™ System	217	B. L. Holub	1995

Defense

Title	Page	Author(s)	Year Published
Cost as an Independent Variable (CAIV) on the Joint Helmet-Mounted Cueing System (JHMCS) Program	469	B. Kembitzky	1998
From Research to Development: Specifying a Future Command and Control System	135	J. M. Lamers, M. Streng	1999

Title	Page	Author(s)	Year Published
A New Approach to Marine Programmable Systems Assessment	303	J. Earthy	1999
Integrating Human Factors Within Systems Engineering	399	S. R. Harmer, G. Ward	1999
Simulation Based Acquisition: An Ongoing Look	409	R. Frost, D. Thomen	1999
A Human Centered Design Environment for Complex Systems	415	H. E. Crisp, N. T. Hoang, R. Schmidt	1999
Incorporating Cost Into the Front End of the Radar Systems Engineering Process	531	D. G. Church	1999
Systems Engineering and the Joint Strike Fighter: The "Flagship" Program for Acquisition Reform	553	R. G. Struth, Jr.	1999
An Application of Object Oriented Systems Engineering (OOSE) to an Army Command and Control System: A New Approach to Integration of System and Software Requirements and Design	1213	A. Meilich, M. Rickels	1999

Emergency Services

Title	Page	Author(s)	Year Published
Assessing Emergencies and Making Disaster Recovery Decisions	161	D. A. Riggs, L. H. Botten	1999

Energy

Title	Page	Author(s)	Year Published
Life Cycle and Production Unit Cost Analysis Techniques for System Configuration Selection in the Norwegian Offshore Oil and Gas Industry	705	David F. Plummer	1993
The Morphological Approach: Its Role in Systems Engineering and Its Application to Solar Energy Conversion	255	Scott Jackson, et al.	1994
A Systems Engineering Approach to Life Extension Planning for the Strategic Petroleum Reserve	147	R. P. Pikul, et al.	1995
Systems Engineering and Statoil Natural Gas Transport Operations	791	H. J. Dahl	1999

Environmental Restoration

Title	Page	Author(s)	Year Published
Life Cycle Systems Engineering: A Global Environmental Imperative	831	Joseph Fiksel, et al.	1994
Environmental Impact Design Tool for Systems Engineers	103	E. T. Frisbee	1995
Collaborative System Engineering Approach to an Evolutionary Oceanic System Development	45	W. N. Feerrar	1996
Integration of the Idaho National Engineering Laboratory Environmental Management Activities Using Systems Engineering	19	J. A. Murphy	1996
Systems Engineering and Integration for DOE Environmental Management	3	G. Power. et al.	1996
System Modeling and Possible Applications for the Social Sciences	117	A. Koehler, et al.	1997

Facilities

Title	Page	Author(s)	Year Published
Construction Engineering Within a Prime Contract Engineering Organisation	559	P. J. Ward	1999
Systems Engineering Applied to Integrated Safety Management for High Consequence Facilities	947	R. H. Barter, B. G. Morais	1999

Health Care

Title	Page	Author(s)	Year Published
Designing Client-Server Systems for the Intensive Care Unit: An Application of Performance-Driven Design	521	J. R. Zaleski, et al.	1998
Systems Engineering in the Intensive Care Unit: A Model of Post-Operative Patient Reawakening Time	517	J. R. Zaleski	1998

Information Systems

Title	Page	Author(s)	Year Published
A Practical Approach to Failure Mode, Effects, and Criticality Analysis (FMECA) for Computing Systems	145	J. C. Becker, et al.	1996
Business Reengineering for Information Technology: From Business Process to System Requirements	109	S. A. Bohner, et al.	1996

Title	Page	Author(s)	Year Published
Specification for “Century Compliance”	89	R. Loutoap	1996
Applying Systems Engineering to VLSI Design	9	J. R. Gardner	1997
Leading Indicators of Rework: A Method of Preventing Software Defects	489	R. Stewart, et al.	1998
A “Systems of Systems” Perspective of the Year 2000 Problem	11	L. M. Walker	1999
Embedded Systems: The Forgotten Y2K Problem	145	G. H. Fisher	1999
A Systems Approach to the Year 2000 (Y2K) Issue	153	P. D. R. Moore, A. G. Fairbairn	1999
Year 2000 Triage for Non-IT and Embedded Systems	169	B. B. Biggs, H. Jackson	1999
System Engineering and Information Management – A Local Need in a Global Perspective	389	T. Fossnes	1999

International Commercial

Title	Page	Author(s)	Year Published
A Systems Engineering Capability in the Global Market Place	809	H. Rochecouste	1995
Introducing System Engineering into a Traditional Steel-Making Environment	565	P. J. Duggan, et al.	1998
Systems Engineering in Developing Nations	537	J. D. Applegate	1998
The Global Information Infrastructure, the Global Information Society—Is It a Reality?	551	G. Piedras	1998
The World Economic System	943	T. V. Carver	1998

Medical Devices

Title	Page	Author(s)	Year Published
FDA Good Manufacturing Practices (GMP) for Medical Devices	81	G. N. Farrell	1995
Ensuring Medical Device Industry Quality System Standards Compliance	841	B. M. Mccay	1999

Natural Resource Management

Title	Page	Author(s)	Year Published
Systems Engineering in Wilderness Areas Management	87	Theodore A. Dolton, et al.	1995

Political and Public Interest Systems

Title	Page	Author(s)	Year Published
Systems Engineering in the Regulatory Environment	287	D. Ted Romine	1992
Leveraging Limited Research and Development (R&D) Resources in the Public Sector	75	M. E. Senglaub	1996
System Engineering Application to Local Governments—Part I: Identifying the Mission	71	T. J. Nagle	1996
Applying Systems Thinking to Expatriate Selection	545	G. G. Chapin, et al.	1998

Space Systems

Title	Page	Author(s)	Year Published
Cost Effectiveness Enhancement Initiative for the Space Shuttle Contract	121	Mina Akhavi, et al.	1993
Real Time Systems/Software Methodologies for Large Aerospace Systems	113	Bhadra K. Patel, et al.	1993
System Integration Applications of Information Systems in the Space Station Freedom Program	553	L. Dale Thomas, et al.	1993
The NASA SEPIT Life Cycle	89	A. D. Fragomeni, et al.	1993
A Systems Engineering Analysis for Re-Engineering an Organization	299	Raymond L. Granata, et al.	1994
An Operations Concept Development Methodology Using a Graphic Process Flow Technique	141	William F. Mackey, et al.	1994
Development of a Systems Perspective for Long Duration Space Flight Missions Using a Crew Systems Interactions Model (CSIM)	239	Kathy S. Upshaw	1994
A Systems Engineering Approach to Technology Management	741	William F. Mackey, et al.	1995
A Systems Engineering Approach to the Analysis of a Planetary Mission Ground System in Terms of Science Objectives	781	R. R. Wessen	1995
Application of ANSI Standards to Space Station Resources	461	I. Taylor	1995

Title	Page	Author(s)	Year Published
Maintenance Budget Allocations in Fiscally Constrained Environments Using Risk Constrained Optimized Maintenance Planning (RCOMP)	95	F. Douglass, III, et al.	1995
Practical Issues for Including Manufacturing During Space System Concept Development	727	S. C. Ruth	1995
Spacecraft Performance Requirements Tracking and Verification for the Tropical Rainfall Measuring Mission	121	R. C. Carter, et al.	1995
The Transition of Functional Organizations to Integrated Product Teams on the Space Station Program	467	J. F. Peters	1995
Use of Prototyping in Developing Operational Systems	263	Charisse Sary	1995
Conducting a Technology Management Assessment	153	William F. Mackey	1996
Design Analysis Cycle Application to the International Space Station Design	51	G. L. Brown	1996
IMAACS: A Demonstration in Reengineering Ground Data Systems Development	63	M. R. Bracken, et al.	1996
International Space Station Performance Metrics	1005	A. F. Rice	1996
Qualification Strategies for the International Space Station U.S. Laboratory	1109	B. Purves	1996
Space Mission Operations Concept	459	G. F. Squibb	1996
The Application of Risk Management to the NEO Threat	103	G. J. Friedman	1996
Application of a System Architecture Standard to a Federated Information System	85	G. S. Percivall	1997
Commissioning a Distributed Operational Information Management System	483	A. Eagles, et al.	1998
Deep Space One Spacecraft System Engineering Techniques and the Application of Heuristic Reasoning	475	R. R. Basilio	1998
Implementation of System Requirements Models for Space Missions	285	S. D. Wall, et al.	1998
The Systems Engineering Process Definition as Part of the European Cooperation for Space Standardization (ECSS)	171	R. Hartman	1998
Mussat – A Tool for Model-Based System Engineering of Commercial Satellite Systems	217	M. Wilke, O. Quirmbach, H. Negele, E. Fricke, E. Igenbergs	1999
Parametric Cost Modeling of Space Missions Using the Develop New Projects (DNP) Implementation Process	313	L. Rosenberg, J. Hihn, K. Roust, K. Warfield	1999

Title	Page	Author(s)	Year Published
Summary of Results From the Risk Management Program for the Mars Microrover Flight Experiment	503	R. Shishko, J. R. Matijevic	1999
Designing an Optimal Product Introduction Process for an Extended Enterprise in the Aerospace Sector	573	B. Clegg, J. Boardman, A. Boardman, R. Mason-Jones	1999
Shuttle Orbiter Production Change Impact Assessment Process: A Collaborative Team Effort	1151	J. E. Hines, T. P. Mccallister, D. P. Weeks, F. A. Ouellette	1999
The Transition From Spacecraft Development to Flight Operations: Human Factor Considerations	1303	R. R. Basilio	1999
Workgroup Software Tools Applied to the Space Shuttle Orbiter Configuration Change Impact Assessment Study Process	1365	T. P. Mccallister, J. E. Hines, D. P. Weeks, F. A. Ouellette	1999
Design and Implementation of a System Engineering Standard Process for Satellite Development	1385	M. Rudolph, R. Hartmann, E. Fricke, H. Negele	1999

Telecommunications

Title	Page	Author(s)	Year Published
System Integration Via Telecommunication	467	Morton Andresen, et al.	1993
Systems Engineering on the Internet Highway—Roadkill or Road Runner?	125	L. A. Lee, et al.	1996
The Emerging Role of Telecommunications: Creative Applications of Systems Engineering Metrics	171	Carolyn Buford	1996
Use of Internet Retrieval and Access Tools in Support of the Goddard Space Flight Center	179	William F. Mackey, et al.	1996
Modeling Communication Satellite Protocols with a System Design Automation Tool	391	R. Colligan	1998
Systems Engineering to Sydney	511	J. E. Kasser, et al.	1998
Web-Based Systems Engineering Application Profiles	503	M. A. Austin	1998
Development of Internet in Latin America: the Role of Academic Network Systems and Their Future	673	S. R. Aguilar	1999
System Issues Related to Implementing on the Internet	679	W. Mackey, T. C. Bagg, III	1999
The Sociological Impact of Computers and the Internet on the Elderly	687	E. E. Ward	1999

Title	Page	Author(s)	Year Published
Telecom and Defense Systems: Exploring Differences in the Practice of Systems Engineering	1191	J. N. Martin	1999
A Requirements Driven Approach to Synthesis of Military Satellite Communications Payloads	1373	T. G. Henkle	1999

Transportation

Title	Page	Author(s)	Year Published
Systems Engineering in the Automotive Industry	501	George C. Percivall	1992
SYSTEMS ENGINEERING Applications in Transportation Planning	713	Theodore A. Dolton, et al.	1993
A Systems Engineering Approach to Highway Design	633	William F. Mackey, et al.	1994
Systems Engineering of Renewals and Extensions in Mass Transit Railways	109	J. S. Williams, et al.	1995
A System Concept for an Advanced Vehicle Control System	137	William F. Mackey, et al.	1996
A Systems Engineering Approach to Highway Design	27	William F. Mackey, Jr., et al.	1996
Introduction of Systems Engineering and Appropriate Tools to a Mass Transit Railway Project	37	J. Allen, et al.	1996
A Course on Systems Engineering for Railway Projects	475	J. Q. Jin, et al.	1997
On Architecting and Intelligent Transport Systems	IEEE 610	Mark W. Maier	1997
A Total Systems Approach to Automotive Development	31	D. Hatley, et al.	1997
Overcoming Problems in the Development of an Automated Car Park System by Introducing Systems Engineering Methods	47	F. Harzenetter, et al.	1997
The Air Bag System: What Went Wrong with the Systems Engineering?	55	D. M. Buede	1997
The Science of Railway Systems Engineering	39	J. S. Williams	1997
Using Systems Engineering for Automotive Advanced Development	149	W. H. Wittig	1997
Revisiting Accumulated Wisdom After 100 Years of Engineering Railway Systems	559	J. S. Williams, et al.	1998

Title	Page	Author(s)	Year Published
Systems Analysis of Personal Transport	1165	M. V. Lowson	1999
A Systems Engineering Framework for Integrated Automotive Development	1173	G. Loureiro, P. G. Leaney, M. Hodgson	1999

Urban Planning

Title	Page	Author(s)	Year Published
Systems Engineering Design of a Suburb	459	Karen Heidel, et al.	1993
Landfill NIMBY and Systems Engineering: A Paradigm for Urban Planning	991	G. Fred Lee, et al.	1994
Systems Engineering in a Social Application: Designing an Evolved System of Education	859	Mark A. Ottenberg	1994
Social Systems Engineering and Management	139	Mark W. Maier	1995
An Interface Control Approach to Land-Use Management	101	R. S. Carson	1997
Systems Engineering and the Architectural Design of Buildings	93	D. G. Langston	1997
Systems Process for Public Policy Application	109	W. H. Cutler	1997

Waste Management and Disposal

Title	Page	Author(s)	Year Published
Functional Analysis of a Nuclear Waste Repository System	293	F. J. Schelling R. P. Sandoval	1992
Application of Systems Engineering Into an Ongoing Operation	845	Bernard G. Morais, et al.	1994
Applying Systems Engineering and Icon-Driven Simulation Techniques to the Waste Disposal Problem at Hanford, WA	873	Alan Keizur, et al.	1994
Systems Engineering Looks at AB939: The California Integrated Waste Management Act of 1989	1039	Masoud Kayhanian, et al.	1994
Developing a Systems Engineering Approach for the Hanford Retrieval, Treatment, and Immobilization Division Based on DOD Standards	131	V. L. Saladin	1995
The Application of Systems Engineering Techniques in a Regulatory Environment: NRC High-Level Waste Regulatory Program	115	P. C. Mackin, et al.	1995
Privatizing Government Operations – A Systems Approach	55	M. A. Duffy, et al.	1996

Title	Page	Author(s)	Year Published
Systems Engineering for the DOE SNF Program	13	C. L. Beebe	1996
Systems Engineering in a Management and Operations (M&O) Environment	131	S. J. Flowers	1996
Department of Energy Environmental Management Complex-Wide Integration Using System Engineering	133	P. Fairbourn	1997
Development of the Environmental Management Integrated Baseline at the Idaho National Engineering Laboratory Using Systems Engineering	141	J. A. Murphy, et al.	1997
Rebaselining of the Plutonium Residue Elimination Project at Rocky Flats Environmental Technology Site	125	W. C. Sailor, et al.	1997
Development of the Reference Design Description for a Geologic Repository	843	R. B. Daniel, et al.	1998
Integrated Control Process for the Development of the Mined Geologic Disposal System	855	R. B. Daniel, et al.	1998
System Engineering for Informal Regulation	531	A. C. Koehler, et al.	1998
Technology Assessment Tool (A Systems Engineering Approach to Assessing U. S. Department of Energy Technology Proposals)	799	M. A. Rynearson	1999
Implementing Systems Engineering on a CERCLA Project	1199	G. A. Beitel	1999
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Infrastructure Operations Technical Baseline Development At the Idaho National Engineering and Environmental Laboratory Using Systems Engineering	1339	R. M. Caliva	1999