CHAPTER 1

INTRODUCTION TO LOGISTICS

1. A *system* may be considered as a nucleus of elements structured in such a manner as to accomplish a function (mission) to satisfy an identified need. A system constitutes a complex combination of resources (e.g., hardware, software, people, facilities, real estate, data, etc.); is contained within some form of hierarchy; may be broken down into subsystems; and must have a purpose (i.e., must be "functional"). Systems may be categorized as *natural*, *human-made*, *physical*, *conceptual*, *static*, *dynamic*, *closed-loop*, and *open-loop* systems. However, the type of systems identified throughout this text are *man-made*, *dynamic*, and of the *open-loop* variety. Examples include a fleet of aircraft, a single airplane with its associated infrastructure, a manufacturing capability, a radar complex or a communications network, a data or information handling process, and so on. A system may be made up of both *products* and *processes*. It includes not only the prime mission-oriented equipment and operating personnel, but the maintenance and support infrastructure as well. Reference: Preface, Introduction to Logistics (pages 1-2).

2. The term "hierarchy" refers to a group of entities arranged in a graded top-down and bottom-up order. For example, one may be dealing with a massive air transportation system, an airline (and its components) in North America and within the larger system, a group of aircraft in a given geographical area and within the airline, a single airplane with its associated supporting elements and within the larger group, and so on. In addressing a particular "problem" (i.e., need), one needs to first define what is to constitute the "system;" where does it fit in some form of a hierarchy; the maintenance and support infrastructure for this system; and the upward/downward impacts on both the "larger" entity (upward) and the smaller entity (downward). It could be that the requirements for a specific system may be influenced by the requirements that have been specified for the higher-level entity, sometimes in a non-effective (or beneficial) manner. Reference: Introduction to Logistics.

3. The system "life cycle" includes the phases of *conceptual design*, *preliminary system design*, *detail design and development*, *production and/or construction*, *system utilization and support*, and *retirement and disposal*. Refer to Figures 1.6, 1.7, and 9.1. While the specific names given to each of these phases may vary from one program application to the next, the overall process leading from the initial identification of a consumer "need" to system "retirement" is basically the same! Given that a system has been developed and in use, the life-cycle of that system may refer to the length of time that the system will be in *operational use*. The trends today indicate that the "life cycle" for many of these systems currently in use is being ***extended***, primarily because the costs of replacement are too high. On the other hand, the life-cycles for many of the needed "technologies" that must be inherent within the design configuration in order for the system to perform as required are of ***limited duration*** (e.g., one to two years at most). Thus, systems in the future must be designed with an *open-architecture* approach in mind, allowing for the periodic insertion of new technologies as required.

4. Broadly defined, *logistics* includes those activities dealing with the initial acquisition of materials (purchasing, materials flow, inventory control), the distribution and installation of systems and their components (packaging, transportation, warehousing, installation of systems at customer sites, customer service), and the sustaining maintenance and support of systems throughout their planned life cycles. More specifically, logistics includes those activities shown in Figures 1.2 (page 5) and 1.3 (page 9). Logistics, in the context of the system life cycle, involves planning, analysis and design, testing, production operations, and the sustaining maintenance and support of the system throughout the utilization phase. The elements of logistics are shown in Figure 1.5 and described in Section 1.3 (pages 11-15).

5. I view the "logistics and maintenance support infrastructure" (i.e., the combined activities in Figures 1.2 and 1.3 as applicable, presented in the context of the flow in Figure 1.4) as being a major **element** of the system. Assuming that the objective is to develop a system to fulfill a need and accomplish a specific mission, there are logistics requirements in the initial acquisition of that system (i.e., the activities in Figure 1.2). Further, there is a continuing requirement associated with the support of that system throughout its entire life cycle (i.e., the activities in Figure 1.3). These activities need to be reliable and in-place when needed, as the absence of such will preclude the system from fulfilling its objectives. In other words, a "system" must be addressed in terms of ALL of its elements, and the various logistics elements must be included within.

6. Logistics activities are an integral part of each and all phases of the system life cycle. Refer to Section 1.4 (page 15) and the seven items on pages 17-18.

7. Referring to Section 1.2, page 4, logistics as practiced in the business-oriented *commercial* sector includes those activities associated with the physical supply of materials (purchasing and initial acquisition of component parts and raw materials), the flow of materials in support of manufacturing and production operations in the commercial factory, and the physical distribution of products from the factory to the applicable customer's site(s) -- refer to Figure 1.2 (page 5). These activities have been primarily oriented to the physical supply, materials flow, and distribution of relatively small products and consumables (versus "systems"). Recently, these activities have been expanded to include a more comprehensive approach involving those "business-related" issues associated with those activities in Figure 1.2; i.e., finance, accounting, information flow, and related areas now being addressed within the spectrum of supply chain management).

   Referring to page 7, logistics as practiced in the *defense* sector has included not only those commercially-related activities identified in Figure 1.2, but the sustaining system maintenance and support activities illustrated in Figure 1.3. The emphasis here has been primarily oriented to "systems" and the requirements associated with such over the life cycle. Additionally, logistics is addressed in the system design and development process through the *design for supportability* concept. In other words, logistics in the defense sector is addressed from a total system "life-cycle" perspective, which isn't the case in the commercial sector.

Areas of commonality include those activities shown in Figure 1.2, which are applicable in both the commercial and defense sectors.

8. Refer to Section 1.2 (pages 6-7). *Supply Chain (SC)* refers to a network of entities (organizations and/or individuals) directly involved in the upstream and downstream flow of materials, products, services, finances, and/or information from a source of supply to the customer. *Supply Chain Management (SCM)* pertains to the management of the supply chain, or a group of supply chains. With the introduction of SC and SCM, not only are the physical supply, movement, and physical distribution functions in Figure 1.2 included, but the added emphasis deals with the integration of these various SCs (networks) and the business issues that go along with such activities; i.e., marketing, financial management, information flow, etc.

   With regard to SC and traditional logistics in the commercial sector, the activities illustrated in Figure 1.2 are considered to be within the spectrum of the supply chain. On the other hand, in the defense sector many of the logistics activities are not in the spectrum of SC; i.e., the system design activities, the sustaining maintenance and support infrastructure.

9. Referring to Figure 1.4, there is a "reverse flow" which includes those activities pertaining to the phasing of items out of the inventory; i.e., the removal of items due to obsolescence, the removal of items which are beyond economic repair; etc. This reverse flow, and the resources required to accomplish such, is included within the concept of *reverse logistics*, which is popularly known as such in the commercial sector. Refer to pages 5 and 10.

10. *System engineering*, defined in a broad context, is "the effective application of scientific and engineering efforts to transform an operational need into a defined system configuration through the top-down process of requirements definition, functional analysis and allocation, synthesis, design optimization, test, and evaluation." It involves the <u>process</u> of bringing a system into being, promoting an integrated life-cycle approach. While there are several different definitions of system engineering, I prefer the one on page 29, with the major areas of emphasis as stated.

    The *system engineering process* is best illustrated through the steps shown in the bottom part of Figure 4.1 (page 124) and in Figure 4.2 (page 126). It should be emphasized that while a "top-down" approach is highlighted, there is also a very essential "feedback loop" that makes it work. Logistics, particularly from an engineering perspective (i.e., the *design for supportability*), is an integral activity within this process. One must initially define the requirements for logistics, identify logistics functions, allocate the top-level requirements to the appropriate elements of the logistics and maintenance support infrastructure, perform the necessary trade-offs in designing an optimum configuration, accomplish test and evaluation for the purposes of validation, and provide the necessary feedback for corrective action. Refer to Section 1.7.1 (page 28) and Chapter 4 (page 123).

11. *Performance-based logistics (PBL)* refers to the definition and establishment of quantitative "design-to" factors, included within the specification of top-down requirements for the overall system, which reflect the "performance" capability desired for the design of the logistics and maintenance support infrastructure. PBL, a concept being emphasized within the defense sector, pertains to the definition of specific design-to criteria for system logistics and support, and the requirements established for design must be based on specific "performance" objectives. Some examples are noted on page 22 and application of these pertains to the logistics elements identified in Figure 1.11 (page 23). Refer to Section 1.5 (page 21).

12. *Logistics engineering* includes those basic engineering design-related activities that are inherent within the overall system design and development process. Such activities are highlighted in the seven steps identified on pages 17 and 20, and illustrated in Figure 1.9 (page 19). Accomplishing these activities is important if one is to ensure that the ultimate system configuration is designed such that it can be effectively and economically supported throughout its life cycle. Logistics engineering is inherent (as an engineering discipline) within the system engineering process. Refer to Section 1.4 (page 15).

13. The term, *supportability*, pertains to those characteristics (or attributes) that should be incorporated within the system design configuration in such a manner as to ensure that the resultant product can be effectively and efficiently supported throughout its programmed life cycle. Such characteristics may include features as *good and direct accessibility to components, effective diagnostics, modularization for rapid component removal and replacement, the use of highly-reliable components, the incorporation of standardization in design*, and so on. The incorporation of these features is also an objective of *reliability* and *maintainability* in design, and the terms are often used interchangeably. In any event, the objective is to consider such design features from the beginning along with some of the more popular performance-related features dealing with size, weight, range, accuracy, throughput, etc. Reference: Preface (page x), Section 1.1 (page 8). Also, refer to Figure 1.14 relative to the "consequences" associated with NOT addressing *supportability* from the beginning.

14. The *logistics and maintenance support infrastructure*, as defined within the context of the text, refers to the entire overall support structure (or network) for a given system -- the elements of support (see Figure 1.5), their quantities and geographical location, transportation and material flow routes, the maintenance and support environment, and so on. It includes all of the activities associated with "business" logistics and the supply chain in the commercial sector and integrated logistic support (ILS) in the defense sector. Such as infrastructure is best illustrated through network shown in Figures 1.2 and 1.3 (also see Figures 4.12 and 4.15 in Chapter 4). The student should develop such an illustrated structure for a system of his/her choice.

15. Referring to Figure 1.7, the **top** "life cycle" is intended to represent the process for

bringing a system into being and is primarily directed to the major mission-oriented elements of a system. In order to realize the objectives illustrated in the top bar, there is a requirement for the construction of a single entity and/or the production process for a multiple quantity of items; i.e., the **second** "life cycle." This, in turn, requires some design, leading to production operations. The **third** "life cycle" pertains to the design, development, and implementation of a maintenance and support infrastructure required to support both the prime elements of the system throughout the utilization phase and the production/construction process during its utilization phase. Finally, there is the **fourth** "life cycle" that includes the design, development, and implementation of a capability to support system retirement and the recycling and/or disposal of obsolete materials. The requirements (as an input) to each of these life cycles stems from the design and management decisions made during the early stages of the top life cycle. The initial selection of an overall technical design approach for the prime elements of the system, the selection of materials, the specification of "technologies," etc., will have an impact on the requirements for manufacturing (the second life cycle), the requirements for system maintenance and support (the third life cycle), and the requirements for retirement and the disposal of materials (the fourth life cycle). Additionally, activities leading to the implementation of the second life cycle can have a feedback effect (either "positive" or "degrading") on systems operations during the utilization phase (i.e., top life cycle). An unreliable support capability can have a "degrading" impact on both the system during the utilization phase and the production process. In essence, all four of these life cycles are interrelated, each having an impact on the others, and all must be addressed an an entity throughout system design and development. A change in any one area can have an impact on the activities in the other areas.

16. (a) Reliability is a characteristic of design which basically determines the frequency of system maintenance. Maintainability is a characteristic of design which basically determines the degree of inherent supportability in the system (i.e., the extent of maintenance and the supporting resources required). If the reliability of an item is poor, maintainability becomes extremely important as the frequence of maintenance is high and emphasis on supportability is paramount. Thus, reliability can have a significant impact on maintainability. Conversely, if equipment maintainability is poor (i.e., poor accessibility to components, inadequate diagnostics, etc.), the accomplishment of maintenance becomes difficult and failures can be readily induced by maintenance personnel. Thus, the reliability of equipment can be degraded as a result of poor maintainability.

(b) Human factors deals with the man-machine relationships in the accomplishment of system operation and maintenance functions. The objective is to design equipment such that the man-machine interface is optimum. This objective, oriented to maintenance functions, directly ties in with maintainability objectives. In fact, maintainability and human factors criteria in design are extremely complementary, both having the common goal of designing for optimum support. Maintainability tends to be somewhat more oriented toward equipment design and logistic support while human factors is oriented more to the "human" in the system. Generally speaking, if maintainability is poor, then the human factors aspect of the system is poor and vice versa.

(c) Reliability impacts logistic support from the standpoint of frequency of maintenance. If the frequency of maintenance is high, then the logistic support resources required are extensive (i.e., more test and support equipment, more spare/repair parts, etc.). Conversely, if the right type of support is not available, the system reliability can be degraded.

(d) Maintainability impacts logistic support from the standpoint of maintenance times, maintenance labor hours, supportability characteristics in design (i.e., accessibility, diagnostic provisions, etc.), and maintenance costs. If equipment maintainability is poor, then the logistic support resources required are extensive and the maintenance costs are high. Conversely, if the right type of support is not available, system maintainability can be degraded.

(e) Human factors impacts logistic support primarily from the standpoint of personnel and training requirements and the content of technical data procedures (i.e., operating and maintenance instructions). The object is to reduce the personnel skills and training required and to simplify technical procedures to the maximum extent possible. If the human factors in design is poor, higher personnel skills and a greater amount of training are required. Also, the procedures will have to be comprehensive. Conversely, if the support capability does not include properly trained personnel or adequate procedures, then the operator and maintenance man in performing various system functions are likely to induce faults into the system.

The numerous aspects of reliability, maintainability, human factors, and logistic support are all very closely interrelated, and it's difficult within the scope of a few words to adequately define the extent to which this relationship exists. If this relationship is not thoroughly understood, a more in-depth review of both the material in this chapter plus additional material covering reliability, maintainability, and human factors is recommended. Actually, each area significantly impacts and is impacted by the others.

17. Maintainability is the inherent ability of an equipment to be maintained versus maintenance which constitutes a series of actions to be taken to restore or retain an item in an effective operational state. Maintainability is a design parameter and maintenance is the result of design. Refer to Section 1.7.7 (page 34).

18. The maintenance concept constitutes a "before-the-fact" series of statements and/or illustrations defining criteria covering maintenance levels, maintenance responsibilities, major functions accomplished at each level of maintenance, basic support policies, effectiveness factors, and primary logistic support requirements. The maintenance concept is defined at program inception and is a prerequisite to system/product design and development.

The maintenance plan is a detailed plan specifying the methods, resources, and procedures to be followed for system/product support throughout the life cycle during the consumer use period. The plan defines specific requirements for all elements of logistic support (e.g., spares and repair parts, test and support equipment, etc.). The maintenance plan is basically the result of system design and is developed from the supportability analysis (SA) data.

19. *Total productive maintenance (TPM)* is a Japanese developed concept involving an integrated, top-down, life-cycle approach to maintenance as applied primarily to the commercial manufacturing environment. The approach became popular in Japan in the early1970s when it became evident that a good percentage of the total cost of products was traceable back to the maintenance costs of the equipment in the factory used in producing the product. An objective of TPM is to improve productivity in the factory through the reduction of maintenance requirements and the improvement of the processes in accomplishing those maintenance tasks that are required. The basis objectives and elements of TPM are noted in Section 1.7.8 (item 5, page 36), and the measures (metrics) of TPM are described in Section 3.1.1 (pages 79-81).

20. Referring to Figure 1.16, the logistics activities within each of the blocks include:

(a) identify current deficiency/need and determine logistics and the "design for supportability" requirements from operational requirements and the maintenance concept, identify and prioritize technical performance measures for the maintenance and support infrastructure (top-left block); (b) identify maintenance functions from the defined operational functions, allocate system-level supportability requirements and criteria to the subsystem level and below as necessary, assist in the preparation of subsystem specifications (B, C, D, and E specifications) to ensure adequate coverage of logistics and supportability criteria (second block-left); (c) accomplish supportability analyses (SA) on an iterative and continuing basis as part of the overall systems analysis effort, develop the detailed maintenance plan and define specific resource requirements for system maintenance and support -- i.e., spares, test equipment, personnel and training, maintenance facilities, etc. (third block-left); (d) accomplish system evaluation, provide assessment relative to the supportability characteristics in design, and verify that all design requirements have been met (fourth block-left); (e) determine facility requirements from a supportability perspective, assist in supplier evaluation and selection of capital items, assist in the procurement and installation of equipment/software (fifth block-left); (f) produce and/or procure the identified elements of logistics for the maintenance and support of the system during user operations in the field (bottom block-right); (g) install the appropriate support infrastructure/elements in the field in preparation for system operations (fourth block down-right); (h) provide a sustaining maintenance and logistics support capability for the system throughout its planned period of use, collect and analyze data for the on-going assessment of the effectiveness of the maintenance and support infrastructure, make recommendations for improvement where appropriate (third block down-right); (i) evaluate and assess impact of proposed system modifications in terms of supportability requirements, initiate changes as required to the support infrastructure for compatibility with system modifications (second block down-right); and (j) determine supportability requirements for system retirement and for the processing of materials for recycling and/or disposal, implement the necessary steps required and assess the effectiveness and efficiency of this "phase-out" capability (top block-right).

21. Refer to the response for Problem 7 (above). Also, refer to Section 1.2 (page 7).

22. *Supportability analysis (SA)* constitutes an iterative analytical process by which the the supportability criteria and the logistic support for a new (or modified) system are identified and evaluated. It initially aids in the determination of supportability requirements; then is used to help evaluate the design from a supportability perspect-tive; aids in the determination of logistics resource requirements (spares, test equip-ment, personnel, etc.); and aids in the evaluation and assessment of a given design configuration as it is used in the field. Inherent within the SA effort is the conductance of numerous trade-off studies involving the use of such techniques as life-cycle cost analyses (LCC), level-of-repair analyses (LORA), reliability and maintainability analyses (predictions, FMECA/FTA/RCM), maintenance task analy-ses (MTA), and so on. Supportability analysis (SA) is accomplished in each phase and throughout the system life-cycle, but must be "tailored" to the specific need at the time. The SA should be considered as an integral part of the overall system analysis effort during the system design and development process. Reference: Figure 1.9 (page 19), Section 1.7.3 (page 30), and Chapter 5 (page 191).

23. *Agile logistics* refers to a logistics and support capability (infrastructure) that incorporates a high degree of flexibility and be readily adapted to meet a specific support need in a rapidly-changing environment. Refer to page 2.

24. *Concurrent engineering* is a concept introduced by the Department of Defense (in 1988) with the intent to emphasize the importance of communications and the establishment of closely-knit teams to enhance the "design and development" of systems. Also, an objective is to promote "concurrency" in the accomplishment of design activities where applicable (versus assuming a serial approach in the conductance of design activities). The subsequent application of IPPD/IPTs (Integrated Product and Process Development/Integrated Product Teams - see page 420) is intended to support concurrent engineering objectives. Concurrent engineering should be an inherent activity within the systems engineering process. Reference: Section 1.7.4 (page 32).

25. The *design for producibility* objectives include designing the system and its components such that they can be assembled/installed economically and with relative ease. Inherent is the goal of ensuring complete functional and physical *interchangeability* such that, in the event of maintenance, the appropriate items can be removed and replaced rapidly and without affecting the other elements of the system. If, on the other hand, producibility requirements are not addressed and it becomes difficult to assemble/disassemble items, then the objectives of support-ability are not met. Reference: Section 1.7.11 (page 39).

26. The *design for disposability* objectives include designing system components such that, when obsolete, they can either be completely recycled or disposed of econom-ically and without causing any degradation to the environment. Referring to Figure 6.21, Chapter 6, complete recycling for additional use is a preferred option. In accomplishing such it is hoped that any necessary "reconfiguration" can be done

without requiring any supporting special equipment/software/facilities. If complete recycling/reuse is not possible, the intent is to be able to dispose of the residue easily and without requiring extensive logistic support resources (i.e., a new disintegration facility). The lack of considering *disposability* in the design process can lead to the necessity for extensive logistic support requirements during the system retirement phase. Reference: Section 1.7.12 (page 39) and Section 8.4 (page 368).

27. *Total quality management (TQM)* can be described as a total integrated management approach that addresses system/product "quality" during ALL phases of the life cycle and at each level in the overall system hierarchy. It deals with QUALITY from a broad perspective - initially design it in, measure it, and initiate changes on a "continuous product/process improvement" basis (versus an after-the-fact emphasis on "inspection"). Reference: Section 1.7.14 (page 40).

28. *Configuration management (CM)* is a management approach used to identify the functional and physical characteristics of a system in the early phases of its life cycle, control changes to those characteristics, and report change processing and implementation status. It includes configuration identification, configuration control, configuration status accounting, and configuration audits. It basically describes a system design ***baseline*** upon which to evaluate and determine logistic support resource requirements. Obviously, the implementation of good ILS is heavily dependent on the implementation of CM principles and practices. Reference: Section 1.7.13 (page 39).

29. *System effectiveness (SE)* refers to the measure of a system in terms of its "technical" capability. Referring to Figure 1.17 (page 41), it reflects and includes such factors as system performance, availability, dependability, supportability, and related factors that (when combined) are a measure-of-effectiveness (MOE) for the system when considerating all of its technical parameters. Refer to Section 3.1.1 (page 79) for an illustration.

30. Life cycle cost (LCC) includes all costs associated with the system life cycle to include research and development (R&D) cost, production and construction cost, operation and maintenance cost, and system retirement and phase-out cost. Actually, life-cycle costs may be categorized many different ways depending on the type of system and the sensitivities desired in cost effectiveness measurement. Refer to Section 1.7.16 (page 42), Section 3.1.2 (pages 81-87 for the LCC process, and Appendix D (pages 465-495 for an illustration of the LCC process)

LCC can be employed as a management tool in the evaluation of alternative operational requirements and mission scenarios, alternative maintenance concepts and support policies, alternative design configurations, alternative production schemes, and alternative logistic support requirements and maintenance plans. Life-cycle cost analyses are accomplished to varying degrees throughout all phases of the system life cycle (from the early definition of system requirements to the ultimate evaluation of a system being used by the consumer in the field). LCC analysis is an excellent tool for use in support of the management decision-making process throughout the system life cycle and, in particular, during the early phases of advanced planning and conceptual design where the decisions made significantly impact logistic support requirements and the ultimate life-cycle cost of a system.

31. The advent of *electronic commerce (EC)* methods has obviously had a great impact on logistics and system support -- enabling faster, more comprehensive, and reliable communications; enabling the rapid transfer and distribution of digital data to many different locations worldwide and on a concurrent basis (through *electronic data interchange*); facilitating the procurement process and the rapid acquisition of items from the various applicable suppliers; the rapid processing of information worldwide (through *information technology*); and enabling the "tracking" of components and materials in transit. The utilization of the latest *bar coding* techniques has enabled the inclusion and transfer of a great deal of information about products and the rapid processing of data describing these products. The utilization of *radio-frequency identification (RFID)* tags has facilitating the identification and "tracking" of items in transit. The utilization of *global positioning systems (GPS)* has facilitated the transportation process and the identification of material/item location(s). These are just a few of the relatively new technologoies that have had a great impact on the implementation of logistics requirements. Refer to pages 3, 6, 14, and 15.