DRAFT
(Strawman)

Framework for the Application of Systems Engineering in the Commercial Aircraft Domain

DRAFT
Version 1.2a

July 28, 2000

DRAFT
(Strawman)

ACKNOWLEDGMENTS

This document was developed by a working group with persons affiliated with the following organizations:

1- American Institute for Aeronautics and Astronautics (AIAA)
2- Society of Automotive Engineers (SAE)
3- Institute of Electrical and Electronic Engineers (IEEE)
4- Federal Aviation Authority (FAA)
5- International Council on Systems Engineering (INCOSE)

Individual Contributors to this guideline:

<u>Version 0.1 - January 21, 1999</u>

Greg Mathers	Boeing Company
Joseph J. Simpson	Boeing Company

<u>Version 0.2 - April 8, 1999</u>

Erwin Duurland	ADSE b.v.
Ashok Jain	Allied Signal
Greg Mathers	Boeing Company
Scott Jackson	Boeing Company
Joseph J. Simpson	Boeing Company
Mary J Simpson	Boeing Company

<u>Version 0.3 - August 12, 1999</u>

Cheryl Atkinson	ADSE b.v.
Erwin Duurland	ADSE b.v.
Ashok Jain	Allied Signal
Greg Mathers	Boeing Company
Scott Jackson	Boeing Company
Joseph J. Simpson	System Concepts
Mary J Simpson	Boeing Company

<u>Version 0.4 - February 25, 2000</u>

Cheryl Atkinson	ADSE b.v.
Erwin Duurland	ADSE b.v.
Ashok Jain	Honeywell
Greg Mathers	Boeing Company
Scott Jackson	Boeing Company
John Povacz	Rockwell Collins
Joseph J. Simpson	System Concepts
Mary J Simpson	Battelle, PNW National Laboratory

Version 1.0 – June 1, 2000

Cheryl Atkinson	ADSE b.v.
Erwin Duurland	ADSE b.v.
Ashok Jain	Honeywell
Greg Mathers	Boeing Company
Scott Jackson	Boeing Company
John Povacz	Rockwell Collins
Joseph J. Simpson	System Concepts
Mary J Simpson	Battelle, PNW National Laboratory

Version 1.1 – July 1, 2000

Cheryl Atkinson	ADSE b.v.
Erwin Duurland	ADSE b.v.
Ashok Jain	Honeywell
Greg Mathers	Boeing Company
Scott Jackson	Boeing Company
John Povacz	Rockwell Collins
Joseph J. Simpson	System Concepts
Mary J Simpson	Battelle, PNW National Laboratory

Version 1.2 & 1.2a – July 28, 2000

Cheryl Atkinson	ADSE b.v.
Erwin Duurland	ADSE b.v.
Ashok Jain	Honeywell
Greg Mathers	Boeing Company
Scott Jackson	Boeing Company
John Povacz	Rockwell Collins
Joseph J. Simpson	System Concepts
Mary J Simpson	Battelle, PNW National Laboratory

Individual Reviewers of this guideline:

Version 1.2– July 11, 2000

Paul Kostek	TekSci
Pierre DeChazelles	Airbus-Aeromatra

PREFACE

The *Guidelines for the Application of Systems Engineering in the Commercial Aircraft Domain* provide additional domain-specific guidance to generic standards developed to date by the standards communities. Individual contributing authors have received advisory support from their respective corporate management. This information is in draft form and is under continuing development. Extensive review and dialogue is still required internally within INCOSE as well as externally by manufacturers, suppliers, airlines, and other interested parties.

The Guidelines are directed towards persons experienced in systems engineering and avoid duplicating material found in other industry standards. Persons new to systems engineering (SE) will find a brief description of SE principles as well as references to more detailed documents on that subject in Appendix C.

This document is intended to span the gap between Systems Engineering Standards which are not industry specific (which include ISO 15288, EIA 632, and IEEE 1220), and Commercial Air Transport domain guidelines which have generally focussed on safety and certification considerations (SAE ARP 4754/4761, DO-178B, and the FAR and JAR regulations).

This Guideline excludes materials considered sensitive and/or of a proprietary nature specific to any aircraft manufacturer, regulatory agency, or other organization. In addition, the Guidelines do not reflect or recommend specific organizational structures to support Systems Engineering processes in the Commercial Aircraft domain.

1.0 INTRODUCTION

The *Guidelines for the Application of Systems Engineering in the Commercial Aircraft Domain* define the scope, requirements, and interfaces needed to implement systems engineering at the aircraft level for a Commercial Aircraft. The Guidelines capture the "technical" aircraft-level end products and their associated functions resulting from the application of the EIA-632 planning process.

EIA-632 establishes the need for guidelines at a domain specific level. These Guidelines provide a linkage between the EIA-632, the Commercial Aircraft Domain, and systems engineering (SE) processes. In addition, the Guidelines describe what is needed to be done at the aircraft-level by its subsystems, and outline criteria to follow to prioritize development activities.

1.1 Scope

The Guidelines define **what** the aircraft does – at the aircraft level, and provide a high-level view of the essential end products that perform these tasks. These same views are provided for the primary subsystems at the aircraft level. The Guidelines incorporate input from the Commercial Air Transport Domain as performance requirements to help define the initial end products and their subsystems. These Guidelines create a high-level mapping between a functional view of the aircraft and safety-related standards – to develop and share a common perspective with manufacturing, supplier, airline and regulatory groups concerned with development, production and operations of Commercial Aircraft.

1.2 Purpose

These Guidelines provide a framework within which the Commercial Aircraft Industry can determine **how** they implement specific aircraft designs (end products) and tailor development and production (enabling end products) to suit their enterprise needs. The framework also establishes a common set of technical concepts that can be used across all interfaces in the Commercial Aircraft Domain – promoting integration across the industry.

1.3 Basic Assumptions

The Guidelines offer a common perspective for understanding, integrating and communicating technical aspects of commercial aircraft to all interested parties. One assumption is that each particular enterprise within the commercial aircraft industry will use tailored management and organizational practices to enhance their own competitive advantage and to reflect the values of their particular business. Another assumption is that information contained in these guidelines forms a sufficient technical framework to provide the basis for tailoring technical products by individual companies.

1.4 Document Roadmap

The *Guidelines for the Application of Systems Engineering in the Commercial Aircraft Domain* describes what commercial aircraft do, and what requirements they must meet to satisfy Commercial Air Transport needs. For Commercial Aircraft, this Guideline addresses:

What You'll Find in the Guidelines

- **Aircraft-Level Context** Section 2 describes the overall commercial aircraft system and its boundaries in the context of the "system of systems" within which it exists. This section also provides the logical context that forms the basis for drawing boundaries, and for assigning requirements to the aircraft.

- **Time Frames for Aircraft** Section 3 depicts the various kinds of life cycles that need to be considered, and incorporated in commercial aircraft development, production and support efforts and activities.

- **Commercial Processes** Section 4 describes the primary processes which may be applied in the aircraft industry, and indicates what kinds of methods and tools help provide clarity to process implementation.

- **System Description** Section 5 contains a high-level summary of the commercial aircraft as an end product as well as a set of its primary subsystems. This section includes an overall description of **what** these systems need to contain and **why,** leaving application specifics to the individual enterprise.

- **Management of SE Context** Section 6 describes activities commonly used by systems engineers to control and manage technical efforts on aircraft systems.

1.5 Table of Contents

1.6 List of Figures

2.0 COMMERCIAL AIRCRAFT DOMAIN

A commercial passenger aircraft is viewed in the context of the "System of Systems" within which it exists. An examination of the World Air Transport and Commercial Air Transport Systems as the macro context provides valuable insights into establishing boundaries for our primary system of interest - the Commercial Aircraft System. This context analysis also provides a fresh perspective regarding the external inputs to the Commercial Aircraft System, and a logical basis for identifying requirements that apply to the aircraft.

2.1 System Context

Within the context of the Commercial Aircraft domain, the World Air Transport System is the highest level (or all-encompassing) system. As shown in Figure 2.1-1, the World Air Transport System (WATS) consists of three primary end products:

- Things That Fly (commercial, military and other aircraft)
- Places to Depart From and Return To (airports and other launch facilities)
- Traffic Control (commercial, military and private/other traffic control)
- Things That Handle People and Cargo

The next hierarchical level of system - the Commercial Air Transport System - contains one subset of each of the end products of the World Air Transport System. The Commercial Air Transport System (CATS) is composed of (see Figure 2.1-1).

- Commercial Aircraft (passenger, cargo and both passenger/cargo aircraft),
- Airports (departure/landing surfaces and airport facilities), and
- Commercial Air Traffic Control.

The primary system of interest for these guidelines is the Commercial Aircraft System. A partial notional mapping from the World Air Transport System to the Commercial Air Transport System to the Commercial Aircraft System (CAS) is shown in Figure 2.1-1.

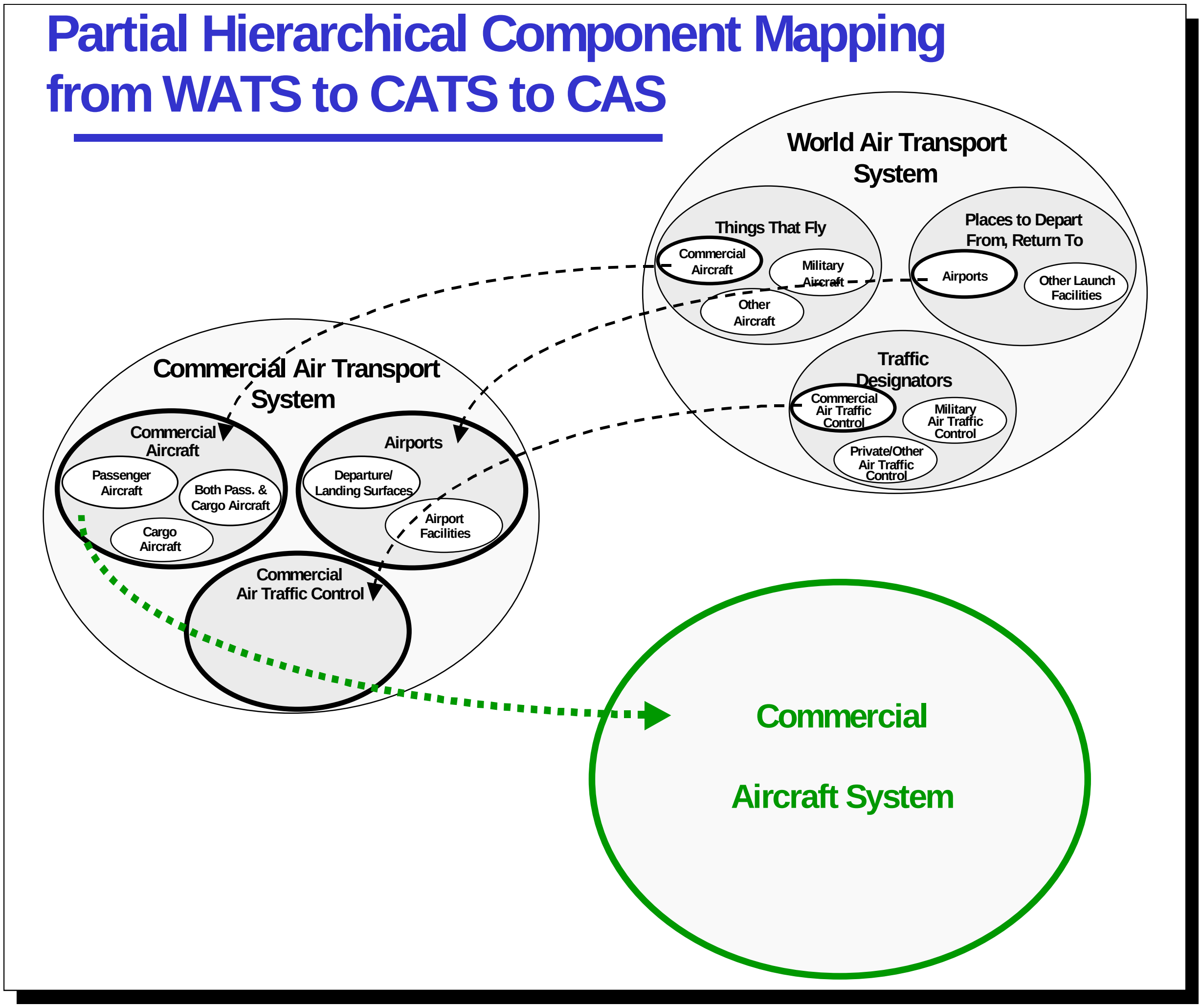
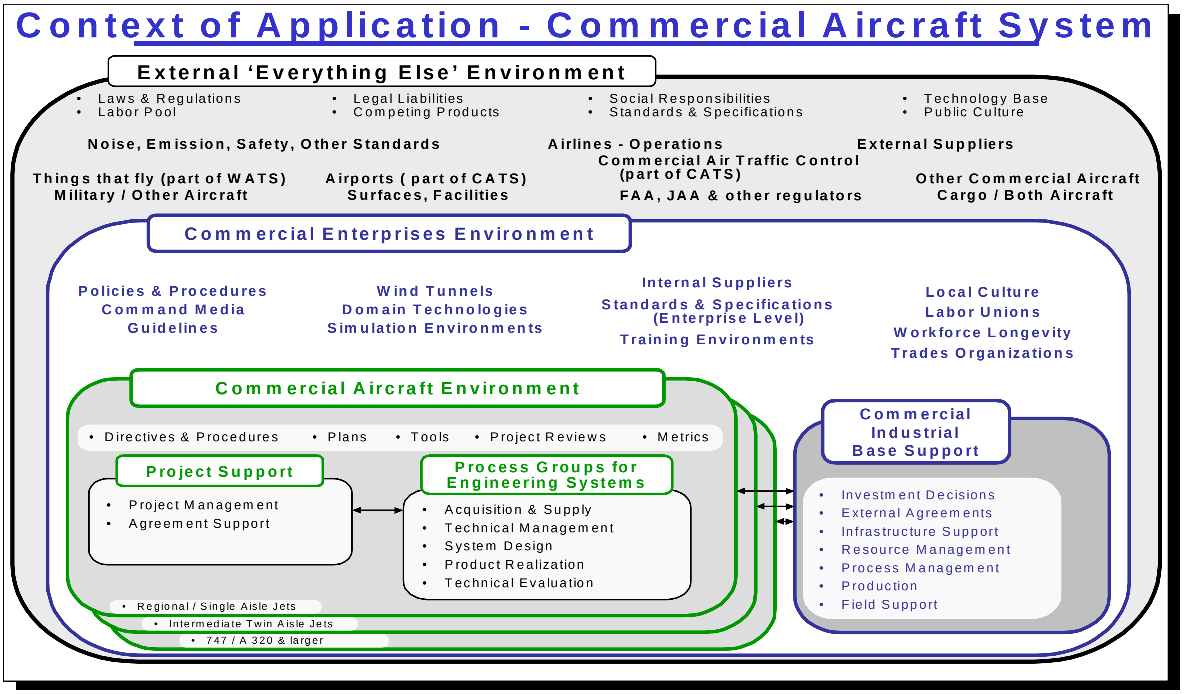


Figure 2.1-1 Component Mapping from WATS to CATS to CAS

2.2 Domain and System Boundaries

The commercial aircraft system - our primary end product - forms its boundaries internal to an enterprise environment which includes many individual business enterprise entities. The enterprise environment in turn forms its boundaries internal to the larger, external environment. EIA-632 provides a template titled "Context for Application of this Standard" that shows the external, enterprise, and project factors that have the potential to affect, or to be affected by, project interfaces. As EIA-632 states, the systems and their products operate with organizations and personnel who use the products, and with other operational entities that provide input to the system, but are not part of the system under development and are not controlled by the developer. The interaction and interfaces between the system products and their external operational environment can affect the implementation of the processes used for engineering the project system. Changes in the operational environment can strongly affect system effectiveness and functionality. In addition, system performance and adequacy are impacted by the system's ability to respond both to the operational environment and to changes in that environment. The EIA-632 Application Context Template is shown in Figure 2.2-1.

Although the Context for Application of the EIA-632 Standard provides an overall depiction of the System of Systems environment, it represents a snapshot in time. It is helpful in the Commercial Aircraft Domain to take a high-level look at the Aircraft System over time, particularly with respect to its overall environment. This provides a way to envision activities



that spread over time within the contextual framework, and a way to specify more clearly the Context for Application for the Commercial Aircraft System. A clear separation between the end product itself - the Commercial Aircraft System - and its external operational environment becomes pivotal to subsequent efforts in engineering the processes needed to build our products. This also provides part of the logical context that forms the basis for drawing boundaries, and for identifying requirements that apply to the aircraft. A notional depiction over time of three system environments is shown in the Venn diagram in Figure 2.2-1.

(1) the End Product (Aircraft) System
(2) the Aircraft (End-Product) Production System
(3) the Overall Environment (in which the End Product operates)

For the Commercial Aircraft System, the external environment includes the World Air Transport System and the Commercial Air Transport System. It also includes customer airlines, external suppliers and regulatory agencies that levy requirements on the end-product system and the process system within which the product is produced. It encompasses - quite simply - everything else.

For political, safety, economic and other reasons, major corporate entities within the commercial aircraft domain comply with a relatively integrated set of safety standards throughout the world. As a result, aircraft are developed, produced, operated and disposed of as a part of the cultural, legal and social boundaries imposed within the Commercial Air Transport System. The FAA, the JAA, and additional regulatory agencies around the world determine which aircraft can fly legally in air space under their various jurisdictions. Policies and procedures, standards and specifications, guidelines, transport technologies and air transport cultures are all factors that impact the Commercial Aircraft System. Figure 2.2-1 shows the application-specific context for the domain of the Commercial Aircraft System.

Figure 2.2-1 Context of Application - Commercial Aircraft System

2.3 System Interactions

System interactions with the Commercial Aircraft System (CAS) originate in its two context Environments: the External Environment (in which the aircraft operates) and the Commercial Enterprises Environment (aircraft production system). Five significant factors, or values, determine the external interactions, inputs and interfaces to CAS, and more clearly define these two context environments. These factors are:

- Natural, Ecological,
- Economic (Profit/Loss),
- Political, Legal, Policy,
- Technological Capability, and
- Cultural, Personal, Behavioral.

All of these factors/values reflect the worth in importance or usefulness ascribed by the external environment. They impact CAS requirements and constraints, the CAS structure that emerges, the number and complexity of CAS interfaces that must be managed to be successful, and the phases through which CAS evolves.

2.3-1 Five Factors That Shape CAS Environments

Natural and ecological environmental factors cannot be controlled by man. Examples of these factors include the location of land and oceans; the atmosphere and its different characteristics from one altitude to another; climate; flora and fauna; and the laws of physics and the sciences. Atmospheric flight dynamics, aircraft performance (including speeds and compressibility) and aerodynamics are constrained by laws of our physical universe. These laws dictate requirements that must be satisfied by CAS regardless of any other factors from the CAS environments.

Economic environmental factors derive from a determination of the economic structure (including profit and loss) that exists in the specific environment. In the External Environment, the economic health, structure, and distribution of resources of CAS customers (whether Airlines, external suppliers, or other) have direct impacts on the Aircraft itself (independent of the company that builds it). Inputs from these sources are most likely to determine what gets built. From a Commercial Enterprise Environment perspective, the economic health, structure and distribution of resources of a specific company (whether business units, internal suppliers, or other) also impact CAS. Inputs from Commercial Enterprise Environment sources determine how the product is built.

Political, legal, and policy factors substantially influence the kind of organizations that can succeed in technology development and manufacturing. Regulatory policies, rules, and laws coupled with international agencies mandate the range of manufacturing activities and labor practices that are allowable in a given industry and vary from country to country. The extent of oversight (in part delineated by a given legal infrastructure) in conjunction with public interest factors (in part delineated by a given political infrastructure) combine to levy strong constraints and requirements on the Commercial Aircraft domain.

Technological capability factors continue to shape the direction of the Commercial Aircraft domain. The existing state of commercial aircraft aerodynamic, structural, and manufacturing technologies have remained largely unchanged in the last 25 to 30 years. In terms of the actual technology applied, most newly introduced commercial aircraft have incorporated relatively small changes to their existing systems. Major changes being experienced in this domain are found in the electronic and information systems of the aircraft. Operational practices developed by airlines, corporate, and other customers over the last decade continue to require new control systems and communications capabilities of the aircraft. In addition, operational practices are requiring new and improved manufacturing capabilities, particularly in the area of supply chain management.

Cultural, personal, and behavioral factors influence the Commercial Aircraft domain. Evolving knowledge of the health impacts of noise, air, and electronic emissions, coupled with changing patterns in population growth and land use present continuing challenges to which the domain must adapt and respond to meet customers needs. Public consciousness and awareness, aesthetics and human interest, the view and biases of power brokers, the need of the individual versus the need of the public, even demographic features, all these factors/values determine important aspects of the External Environment and the Enterprise Environment.

Figure 2.3-1 gives a notional representation of the cascading impact of these five factors from the External Environment through the Commercial Enterprises Environment to the Commercial Aircraft itself.

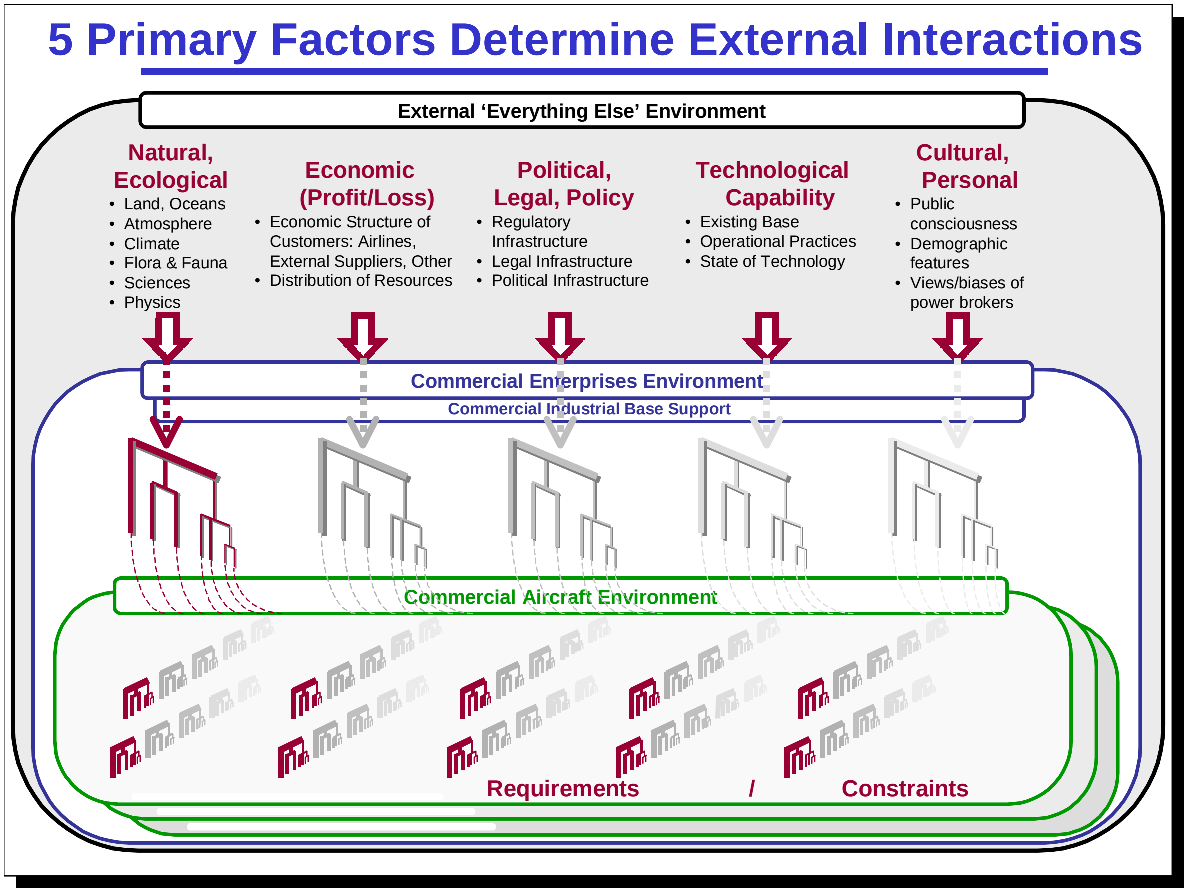


Figure 2.3-1 Primary Factors Determine External Interactions

2.3.2 Implications to CAS Life Cycle, Process Relationships and Structure

The Natural/Ecological, Economic, Political/Legal, Technological Capability, and Cultural/Behavioral factors that exist in the External Environment are transformed at the Enterprise Environment boundary. That is, each enterprise interprets, describes and mandates the way in which each of these factors will be treated by the individual Enterprise. A second transformation occurs at the boundary of the Commercial Aircraft System. Many of these factors substantively impact the Aircraft itself and **are not engineered.** They are not man-made, planned and/or controlled by man so that the engineered systems must include acceptable responses to these factors. A direct consequence is that there are a substantial number of critical aspects (even underlying assumptions) of the External and the Commercial Enterprises Environments that should be identified to ensure success while applying engineered processes. In addition, not everything in the External Environment can be dealt with - that environment is simply too complex. Consequently, each enterprise develops a focus based on specific factors with which they wish to deal, and in so doing, creates their competitive advantage. Since EIA-632 deals with processes for "engineering" a system, material consideration of the impacts and risks as well as of the integration and planning for "non-engineered" factors is essential.

For the engineered systems, EIA-632 describes two basic concepts - the System Concept and the Building Block (Figures 6.1 and 6.1.1 from EIA-632) that are recommended to be used.

The System Concept establishes the high level logic from which the Building Block is derived. At the Building Block level, configuration identification, costs to be collected, specifications, work statement, identification of interfaces (inside and outside the building block), and other relevant agreement information are identified and documented as a part of the 'Requirements Definition Process' in system design.

For this guideline, the end product described in the System Concept is the Commercial Aircraft itself. The Enabling Product Sets (Development, Production, Test, Training, Deployment, Support and Disposal) are shown specifically in the Building Block. Both of these basic concepts are depicted as a moment in time (at any one point in time, all of these activities are occurring). As the sequencing of activities is reviewed, it becomes clear that the level of activity and related amount of resources needed to perform each of these processes will vary widely - dependent on where the aircraft is in time. Figure 2.3-2 depicts a notional perspective of where in time the greatest emphasis is likely to occur. The actual definition of these activities will be based on: (1) the **level** of the ‘system of interest’ at which the function is performed and (2) the **time** in the ‘aircraft-life-cycle’ at which the function is performed. These distinctions need to be clearly defined and understood by the team(s) addressing these items.

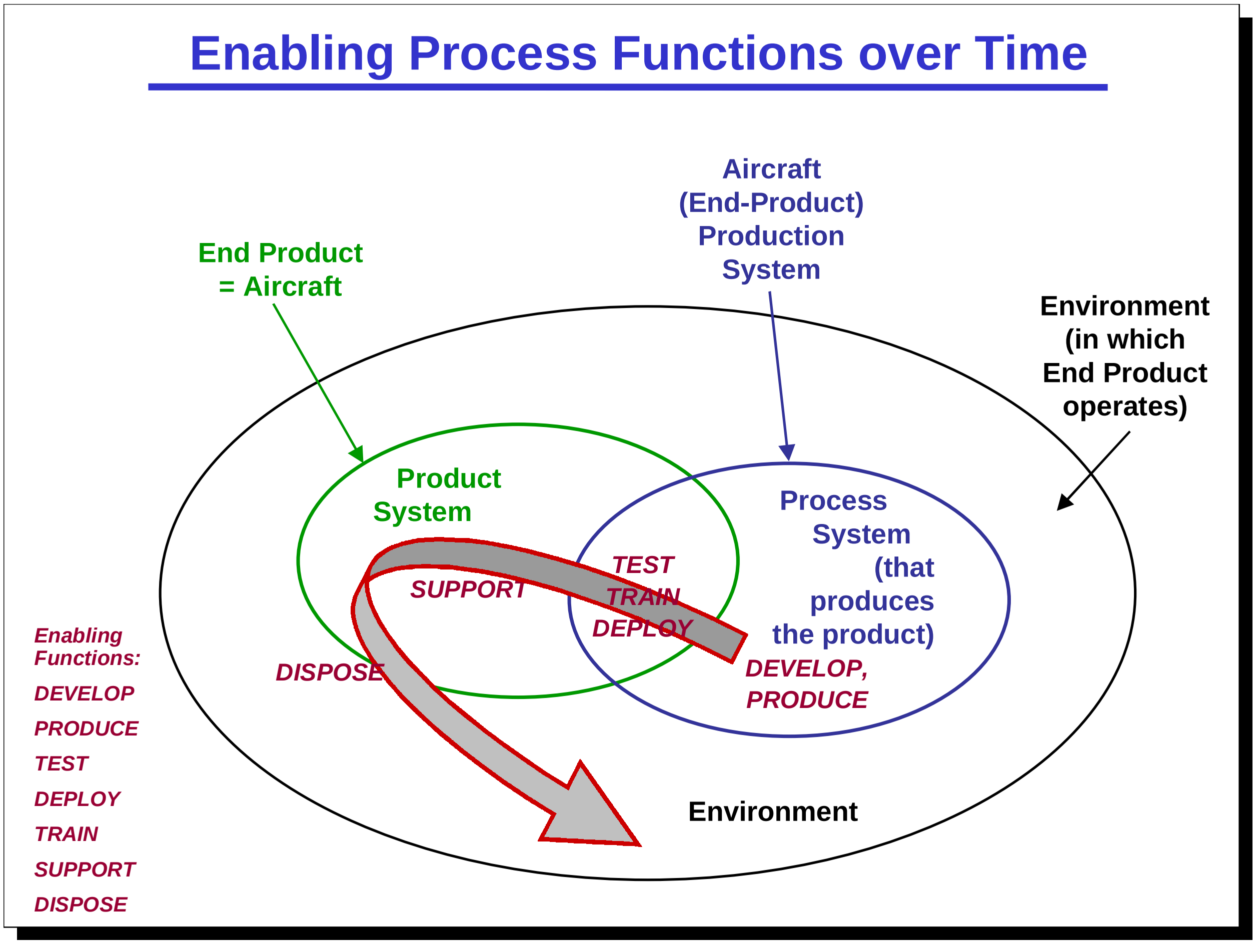


Figure 2.3-2 Enabling Process Functions over Time

Additional implications of non-engineered factors from the External Environment - and the engineered basic concepts - are found in the requirements and constraints identification of the Commercial Aircraft System. For example, sets of “Airline Operations Functions” that involve different phases in the operational movements of the aircraft are predominantly levied as **performance requirements** that the aircraft must successfully perform. ‘Airlines Operations’ Functions include such functions as:

- Airline Flight-Support Operations (Provide Airline Operations Certification, Perform A/C Flight Training, Maintain A/C Airworthiness, Plan/Schedule A/C Flights)
- Airline Flight-Phase Operations (Prepare for A/C Flight, Perform A/C Flight, Perform A/C Post-Flight)
- Airline ‘Non-Flight, Phase Dependent’ Operations (Perform Enroute Navigation, Manage/Communicate Flight Conditions, Perform Supplemental Normal Operations, Perform Non-Normal Operations, Provide Airline Passenger & Cargo Service)

Interestingly enough, some of these requirements and constraints have been assigned due to non-engineered factors.

The sets of certification that must be met are levied as Requirements from the Commercial Air Transport Level (where FAA, JAA, etc, reside) to the Commercial Passenger Aircraft Level.

Many important aspects of the system environments impact CAS requirements and constraints, the CAS structure that emerges, the number and complexity of CAS interfaces that must be managed to be successful, and the phases through which CAS evolves.

For CAS, the two primary external system interfaces are derived (reference Figure 2.1-3) from the Commercial Air Transport System: (1) the Airports (which includes the departure/landing surfaces and the airport facilities) and (2) the Commercial Air Traffic Control.

3.0 Life-cycle Framework

A product lifecycle (operational or enabling) is the period of time that begins when a product is conceived and ends when the product is no longer available for use. Systems are engineered, developed, produced, and deployed within the framework of three basic life-cycles. These life-cycles are: Enterprise, Project and Product. Each operation system; Commercial Air Transport System (CATS), aircraft and aircraft subsystem has these three life-cycles applied.

Life-cycle processes are discussed in Section 4.0.

3.1 Air Transport Life-cycles

From Figure 5.4-1, the Air Transport System is made up of the following operational systems:

- Commercial Air Transport
- Space Transport Systems
- Military A/C Systems

The life-cycle of Commercial Aircraft is the primary focus of this guideline. Life-cycles for Space Transport Systems and Military A/C Systems are beyond the scope of this guideline.

3.1.1 Commercial Aircraft Life-cycles

For the Commercial Aircraft System, the Operational/Enabling life-cycles of interest are grouped as follows:

- Aircraft manufacturer (Enterprise)
- Aircraft model (Project)
- Specific airplane or subsystem (Product)

Processes associated with each of these life-cycles are described in Section 4.

3.1.1.1 Aircraft Manufactures Enterprise-based Life-cycle

The Aircraft Manufactures Enterprise-based Life-cycle may be composed of:

- Opportunity Assessment Life-cycle - Aircraft Sales and Marketing
- Investment Management Life-cycle – Aircraft Plant and Equipment
- Resource Management Life-cycle – Workforce and Materials
- Aircraft Life-cycle – Project and Product

3.1.1.1.1 Opportunity Assessment Life-cycle

The Opportunity Assessment Life-cycle is the marketing and sales effort that continually assesses the business opportunities in the aircraft products. This activity is the beginning effort for the Aircraft Manufactures Enterprise based Life-cycle process. (Figure 3.2-1) The opportunities may arise due to changing market mix, (city pairs, passenger/cargo mix, passenger mix, etc) new and/or revised FAA/JAA regulations, new technology, or airline desires. This aspect of the Aircraft Manufactures Enterprise-based Life-cycle is beyond the scope of this guideline. This life-cycle usually is considered completed when “ Go-ahead” is authorized (See Figure 3.2-1).

The output from the Opportunity Assessment Life-cycle is:

- New or derivative A/C designs that offer improved range, payload, Total Airplane Related Operating Cost (TAROC), etc
- An assessment that the proposed new A/C meets the technical and business requirements
- New or derivative Baseline A/C
- Risk Assessment
- Preliminary A/C Requirements document

3.1.1.1.2 Investment Management Life-cycle

The Investment Management Life-cycle phase analyzes the data provided by the Opportunity Assessment Life-cycle. During this phase it is determined if the investment required (Aircraft Plant and Equipment) will provide the desired return, i.e. profit, market share, market position, flexibility, etc. This aspect of the Aircraft Manufactures Enterprise-based Life-cycle is also beyond the scope of this guideline. For further details please refer to section 6.1.2.

3.1.1.1.3 Resource Management Life-cycle

The Resource Management Life-cycle is the management task that insures that the right resources (labor, tools, processes, facilities, etc.) are available at the right time to assure success throughout the Aircraft Manufactures Enterprise-based life-cycle. This aspect of the Aircraft Manufactures Enterprise-based Life-cycle is beyond the scope of this guideline. For further details please refer to section 6.1.4 of Reference 15288.

3.1.1.2 Aircraft Life-cycle (Project and Product)

The Aircraft Life-cycle as shown in Figure 3.1-1, which includes both the Product (Aircraft Type) and Product (Specific Aircraft), is represented by the following phases.

- Aircraft Development Life-cycle
- Production
- Sustaining
- Disposal

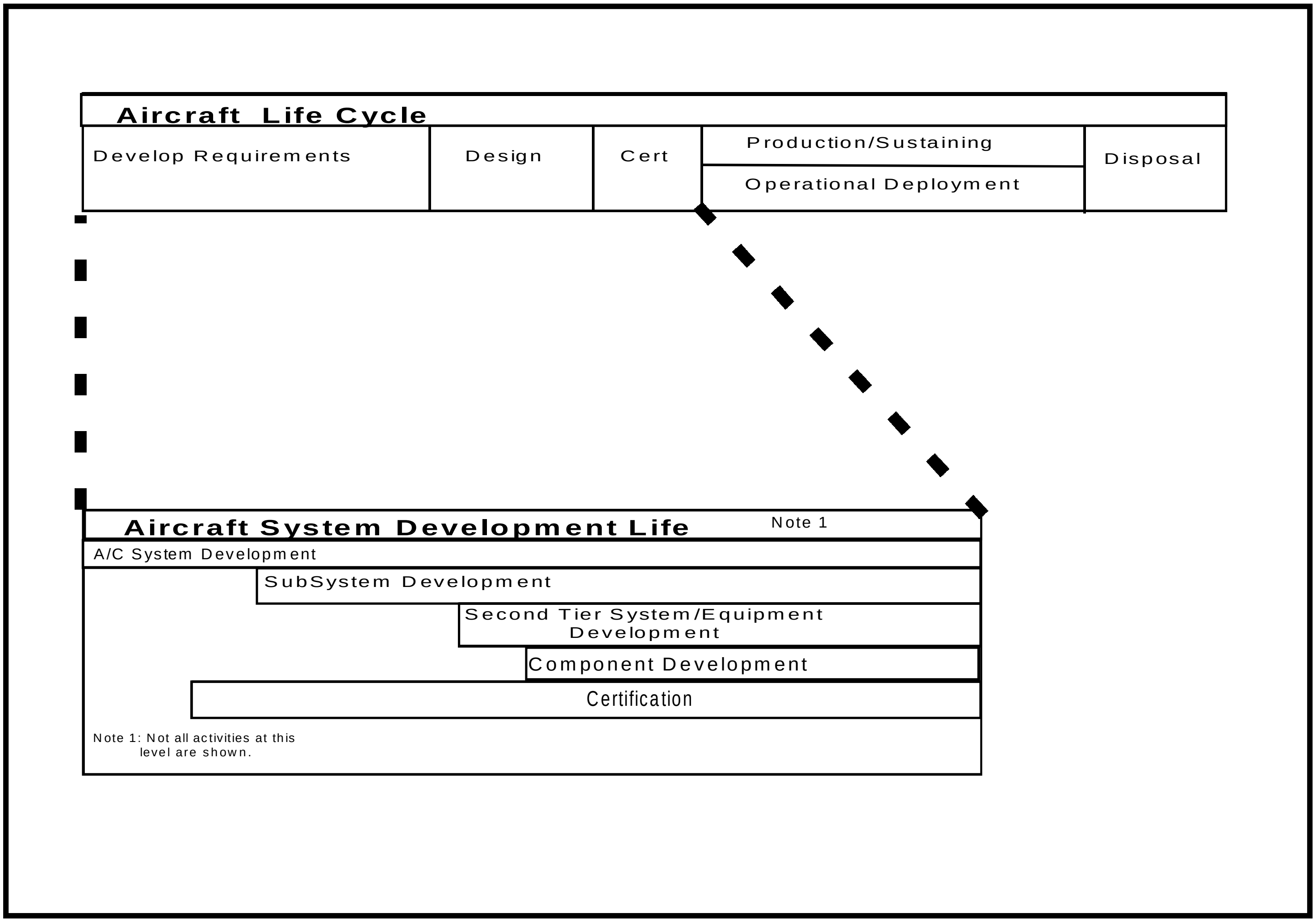


Figure 3.1-1 Aircraft Life Cycle

3.1.2.1 Aircraft Development Life-cycle

The A/C development Life-cycle begins with the authorization for A/C preliminary development and is considered complete with the certification of the aircraft.

The Aircraft Development Life-cycle, Figure 3.2-1, should consist of the following:

- A/C Level Design Development
- Subsystem Development
- Verification/Certification

The output from the Aircraft Development Life-cycle is:

- Budget and product schedule baseline
- Validated requirements
  (AR&O/DR&O Document)
- Verification that the product meets the requirements and is safe and certifiable.
- Technical data package
- Risk Management Assessment

3.1.2.1.1 Aircraft Level Design Development Life-cycle

The A/C Level Design Development Life-cycle should consist of, the following elements:

- Requirements Development
- Preliminary Development
- Prototype Development
- Go-ahead
- Firm Configuration
- A/C Level initial design review
- A/C Level final design review

The Aircraft Level Design Development Life Cycle ends with the aircraft transition to use in accordance with EIA 632 Requirement 21 - Transition to Use. Transition to Use include, for example:

- Documentation for Transition to the Airline Customer
- Agreement for Shipping and Storage
- Airline Customer Acceptance Tests
- Training for Airline Customer Employees
- Agreement for In-Service Support

A comparison of a typical A/C Development Life-Cycle with the Enterprise Life-Cycle is shown in Figure 3.1-1

3.1.2.1.2 Subsystem Development See Section 3.2

3.1.2.1.3 A/C Level Verification/Certification Life-cycle

In the CATS the primary emphasis for verification is:

- Safety
- Certification
- Functionality

Certification and safety activities are in accordance with FARs, JARs, and individual country requirements. . (Reference ARP 4754/4761). Functionality verification activities are in accordance with the A/C manufacturers requirements, Airline requirements, government and industry standards.

Processes for the above life-cycle elements are discussed in section 4 of this guideline.

The Verification/Certification Life-cycle begins with the functional analysis of components and subsystems continues with component and subsystem testing and is complete with the certification of the aircraft.

3.1.2.2 Production/Sustaining Lifecycle

The Sustaining Life-cycle includes:

- Production
- Block upgrades
- Service related Problems (SRP)

During the Sustaining Life-cycle the emphasis is on delivering production aircraft as new customer introductions (CI) and follow-on aircraft. Each customer introduction may result in significant upgrades in the A/C functionality and consequently it's systems. Many of these upgrades are usually grouped together into elements called blocks. Instituting block upgrades facilitates the development, certification and deployment of improved A/C functionality.

The changes instituted during CI and follow-on aircraft should address noted SRPs.

Development of new functionality for the A/C systems should follow the system design processes of chapter 4.

The sustaining life-cycle begins with the certification of the A/C and ends with the disposal of the aircraft.

3.2.2.3 Disposal

The Disposal Life-cycle for an existing operational aircraft, from the current user, should consider the feasibility of upgrading/life extension, conversion (Freighter, Combi, Military, Other) or Scrap.

3.1.2 Aircraft Subsystems Life-cycles

Similar to the Aircraft Development Life-cycle, the Aircraft Subsystem Life-cycle may consist of the following:

- Concept development
- Design Development
    - Requirements
    - Design
- Verification/Validation
- Certification
- Production
        - In Service
        - Maintenance
        - SRPs
        - Upgrades
- Disposal

These life-cycle elements should be addressed in a similar manner as the elements of the Aircraft Development Life-cycle, Section 3.2.3.

3.1.3 Aircraft Subsystem Development Life-cycles

Aircraft subsystems are provided by both internal and outside suppliers which should follow the outline for life-cycles of the Aircraft Subsystem Life-cycle, section 3.3.1.

3.2 Relationships Between Engineering Life-cycles and Enterprise Life-cycles.

Each facet of the product life cycle has intrinsic engineering life cycles associated with it. A typical mapping of engineering to the enterprise life cycle is represented in Figure 3.2-1.

During the preliminary development cycle, typical engineering activity may include simulation and requirements development. Prototype development may begin during this life cycle phase. Prototype development may include both functional and physical prototype development.

During the design development life-cycle the development prototypes are completed and first article/preproduction prototypes evolve.

During the production/operation/sustaining life-cycle the main engineering task is certification and product upgrade.

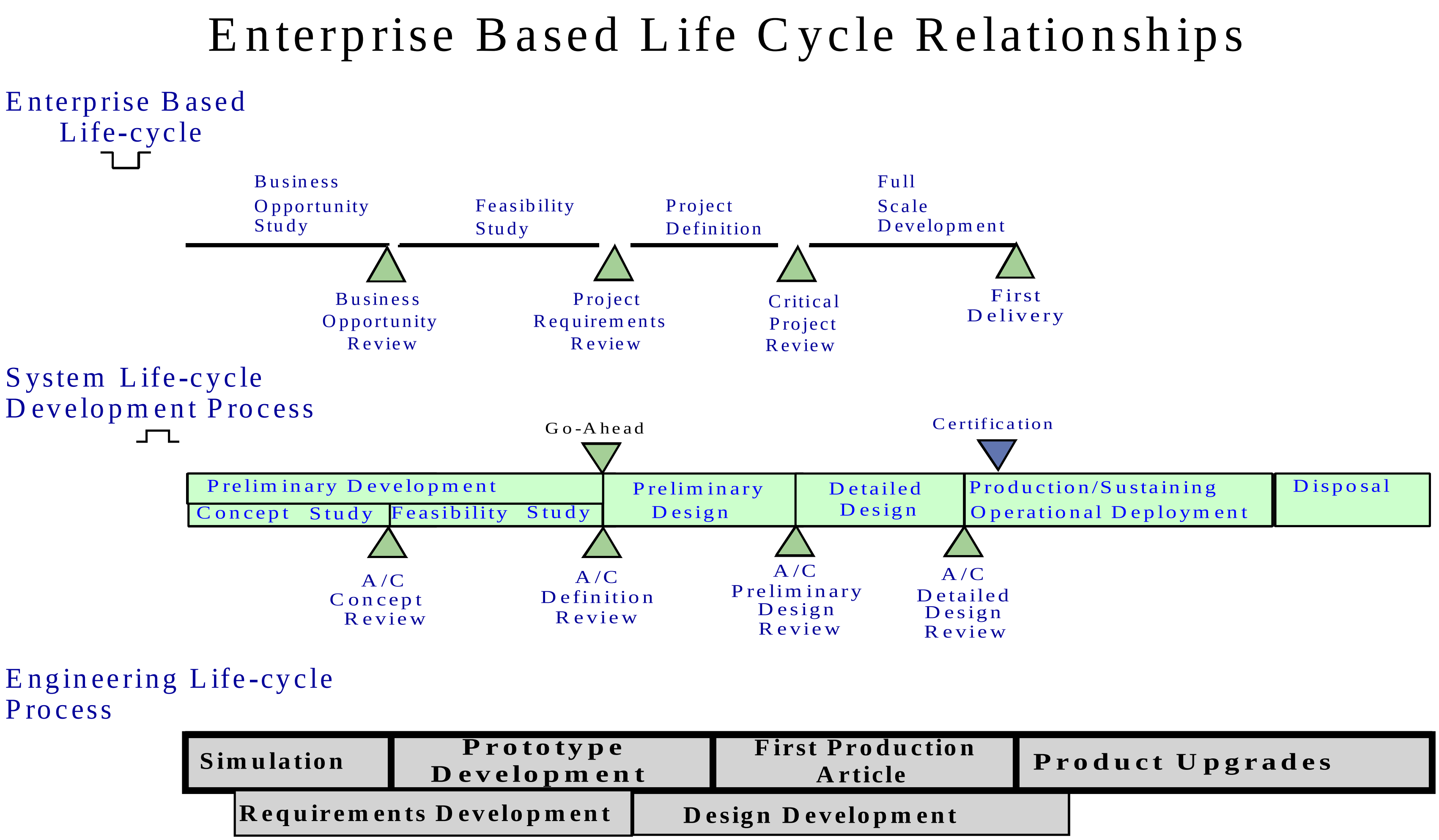


Figure 3.2-1 Enterprise Based Life Cycle Relationships

4.0 Commercial Aircraft Process Relationships

Commercial aircraft production is practiced by a small group of large companies on a global scale. A complicated network of cyclic processes covers the entire aircraft life cycle. In today's global economy environment, the aircraft creation process is a distributed activity that tends to flow from a single design area to a network of distributed suppliers and then back to one area for final product integration. There are many political, economic and technical forces that shape the way the interactions occurred. The tight, efficient integration of processes, methods and tools across this global network is considered a key success factor in modern commercial aircraft production.

This chapter defines the processes that need to be performed throughout the aircraft development life cycle from definition of the customer needs and domain-induced constraints via definition of the aircraft and its enabling products to the realization of certified aircraft that fit the airline operational environments. Also, this chapter explores typical methods, techniques and (software) tools that support the execution of the development processes.

The process framework for this Guideline document is presented in Figure 4.0-1.

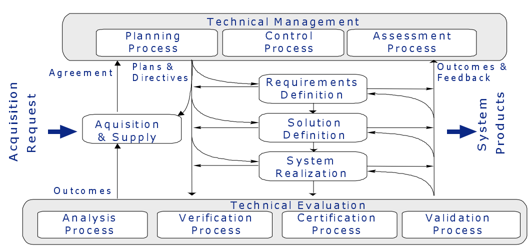


Figure 4.0-1 S.E. Process Framework for Commercial Aircraft

The process framework is directly derived from EIA-632 with the following modifications:

a) Verification process has been split into two processes:

1) a Certification Process that deals with the regulatory requirements only, as this involves activities that are most expensive, time consuming and complicated in a commercial aircraft development cycle,

2) a Verification Process that deals with all other stakeholder requirements.

b) System Design Process has been expanded to include its sub-processes: Requirements Definition, Solution Definition, and System realization. This is done to emphasize the requirement capture and analysis that is extremely volatile for a commercial aircraft development.

c) The Acquisition & Supply Process is moved to a parallel branch.

4.1 Requirements Definition

Requirement definition process for a commercial aircraft domain can be divided into four steps as depicted in Figure 4.1-1.

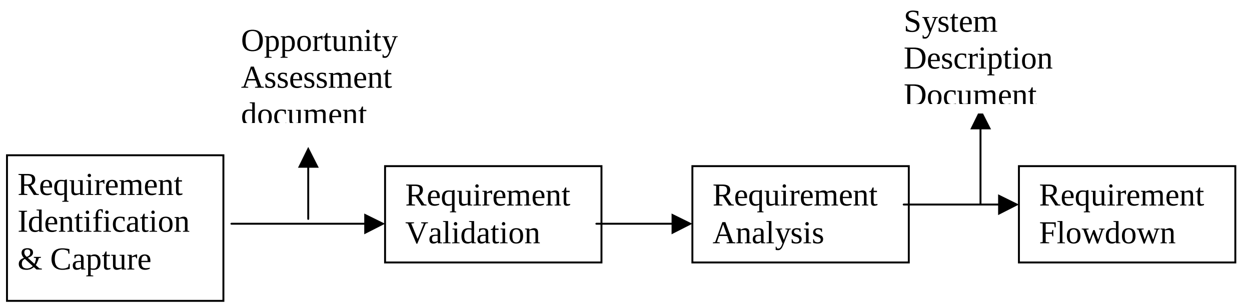


Figure 4.1-1 Commercial Aircraft Requirement Definition Process

4.1.1 Requirement identification & Capture

A clear definition of requirements is necessary as the requirements drive cost, schedule, skills required, resources required, verification plans and schedules and operational procedures. The consequence of poor requirements is that the customer does not get what they want, when they want it and for the price that is competitive.

First step in requirement definition is to identify what top-level requirements will be needed to develop a commercial aircraft. Requirements may be classified in accordance with their impact on the design. The types of requirements that are applicable to the aircraft domain are described below:

Stakeholders: Aircraft manufacturer, end users (airliners, passengers, freight operators), regulatory agencies (FAA/JAA/EPA), and suppliers & partners (subsystems)

Requirement types: Functional, Performance, Operational, Interface, Physical, Financial, Design and construction standards & "ilities"

4.1.2 Requirements Capture

Once requirements identification at the top level has been completed, than requirement capture process is implemented as shown in Figure 4.2-1. In this the process, the numbers are gathered against all identified requirements. Although, aircraft requirements are gathered from many sources; however, the primary requirements originate in the air transport systems operational profile, regulatory agencies, and aircraft customers. A database is created at this step of the process and a top-level set of system requirements are created. The resulting stakeholders needs are documented in 'Opportunity Assessment' document as primary requirements. At this stage, a quick feasibility analysis is accomplished to insure that the aircraft development program is feasible and that program meets most of the stakeholder top level requirements. . Each A/C is intended to have many customers, and different stakeholders will dictate diverse and often conflicting requirements. These conflicting requirements should be thoroughly analyzed in the requirement analysis step.

Diverse stakeholders will dictate conflicting requirements that are thoroughly analyzed in the requirement analysis step.

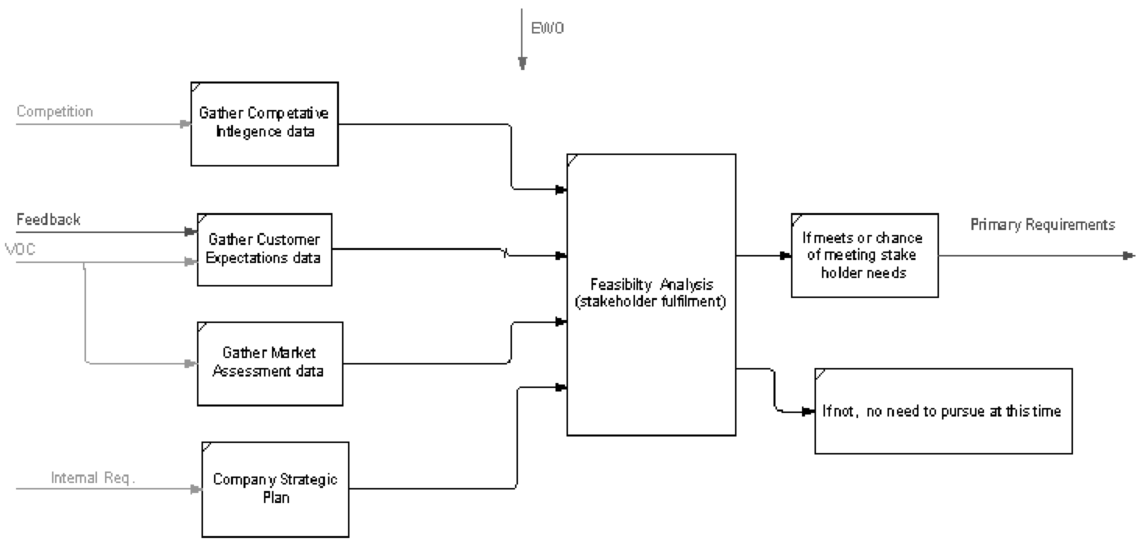


Figure 4.2-1 Commercial Aircraft Requirement Capture Process

The types of requirements that are applicable to the aircraft domain are described below

4.1.3 Functional Requirements

Aircraft functional requirements describe what the aircraft system must do and their desired behavior in terms of an effect produced, or an action or service to be performed in the commercial aircraft system. The following functions are those for which requirements must be identified:

Provide and distribute information and communications
Plan, Generate and control aircraft movement
Provide crew, passenger, and cargo environment & services
Detect and analyze aircraft conditions for flight

Generate and manage internal Power and manage systems materials
Provide airframe movement and attachment capability
Provide containment and internal support

The decomposition of the top-level functions to the third level can be found in Appendix D.

4.1.4 Performance requirements

Aircraft performance requirements delineate “how well” the system products are required to perform a function, along with the conditions under which the function is performed. The following performance requirements are applicable to commercial aircraft domain:

- Aircraft Transport Mission (Business, Regional or Commercial)
- Mission range (nautical miles at certain cruise Mach Number)
- Pay load to be carried (# of passengers & amount of cargo)

4.1.5 Interface requirements

Aircraft interface requirements are that defines the conditions (the activities that must be maintained at the aircraft physical and operational boundaries) of interaction between all elements in the aircraft system domain. External interfaces include fuel, power, and data interfaces.

External interfaces include fuel, power, and data interfaces

4.1.6 Constraints

4.1.5.1 Physical constraints

Aircraft physical requirements describe the activities that could impact weight, dimensional limits, coordinates system etc. Among these requirements, weight is one of the most critical in the commercial aircraft domain. This requirement imposes the need for a rigorous weight management program.

4.1.5.2 Financial constraints

Aircraft financial requirements describes the activities that could limited due to financial constraints like Non-recurring expenses, risk share partnerships etc.

4.1.6 Design & construction standards

Aircraft design & construction standard requirements describe what standard similar to ISO900.

4.1.7 Operational requirements

Aircraft operational requirements describes the activities that creates requirements at top level that may not be exclusively attributed to functional requirements (4.1.3) or constraints (4.1.6). These requirements relate to the transportation, facilitates, training, personnel, environment and logistics. An important operational requirement in the commercial aircraft domain is dispatch reliability. Dispatch reliability is the probability that the aircraft is available for takeoff within a specified time, usually 15 minutes, of a scheduled departure time. Dispatch reliability, like all reliability, can be allocated to the various aircraft elements in the product breakdown structure.

4.1.8 Specialties requirements

"Aircraft –ilities" requirements describes the activities that create requirements that may not be able to translate into functional requirements (4.1.3) or constraints(4.1.6). These specialties requirements in most part are qualitative and must be converted into quantitative verifiable requirements. For commercial aircraft domain, these "illities" requirements are applicable: maintainability, reliability, operability, availability, safety, and security.

4.1.9 Certification (Regulatory) Requirements

These requirements are imposed upon on the commercial aircraft and its sub-system developers by the government agencies like US Federal Airworthiness Authority, Europe's Joint Airworthiness Association, Environment Protection Agency, etc. Compliance to these requirements must be shown before the commercial aircraft is allowed to produced, sold, or operated. The commercial aircraft developers should be diligent in their assessment of certification requirements volatility. A thorough mutually agreeable (between Regulatory authorities and the manufacturer) certification basis must be reached before firm configuration is reached. In addition, a risk assessment for interpretation/verification of existing requirements should be accomplished prior a to reaching the certification basis. These requirements have to consider in the design solution.

4.2 Requirement validation

All top level collected requirements must be reviewed and checked if these requirements are necessary, clear, concise, expressed in simple language, physically possible and has an agreement with stakeholders. Any discrepancies during this process are resolved in consultation with stakeholders. At end on this process, a set of top-level system requirements should be finalized and published in a 'System Description Document.'

4.3 Requirement analysis

Aircraft requirement analysis is a process by which the aircraft requirements are developed from general statements of operational and functional need to specific detailed technical requirements. In general, requirements analysis is divided into two parts; analysis for what must be done (functions) and analysis of how well the functions have to be done (performance).

4.3.1 Functional Analysis

A function is a task, action or activity performed to achieve a given outcome. Functional analysis serves three purposes with respect to the synthesis of commercial aircraft systems:

1. Functions are the basis of performance requirements. Systems engineering principles require that there be at least one performance requirement associated with each function and that all performance requirements emanate from functions.
2. Functions enable the creation of system architecture. Each function may be performed by one or more architectural elements (see Section 3.0) or an architectural element may perform one or more functions. This assignment of functions to architectural elements is the beginning of the synthesis process.
3. Functions are essential to the analysis of aircraft safety. ARP 4754/4761 "discusses the certification aspects of highly-integrated or complex systems installed on aircraft, taking into account the overall operating environment and functions." These Guidelines complement ARP 4754/4761 by providing a recommended template for top-level aircraft functions.

4.3.1.1 Systems Engineering Concept of Functions

The concept of a function is an intrinsic part of the definition of a system. The INCOSE definition of a system is as follows: A "system" is an interacting combination of elements, viewed in relation to *function* (italics added). (Ref ?) Typical aircraft functions are: Provide Lift and Generate Power.

Two attributes of functions are that: (1) they begin with a verb, and (2) they do not specify the aircraft system, subsystem or component that satisfies the function. With respect to (2), for example, wings normally provide lift. However, other control surfaces and the fuselage can provide some degree of lift as well. Electrical, hydraulic and pneumatic systems can provide power. The function does not specify.

At the highest level, functions are entirely solution independent. As the aircraft solution is synthesized to lower levels of the system architecture, functions become solution dependent. At the highest level, for example, the function Provide Control is entirely solution independent. If aerodynamic surfaces are selected as the control solution, a lower level function would be Provide Control Surface Power. These Guidelines will provide solution-independent functions to the greatest extent possible.

4.3.1.2 Functional Templates

Appendix D provides a set of recommended top and second level aircraft functions and the typical aircraft subsystem allocations. These functions are intended to encompass the lower level functions performed by any aircraft component or components and used in the Functional Hazard Analyses (FHAs). These functions are intended to be mutually exclusive; however, more than one component may perform the sub functions of any given function. In addition, any given component may participate in the execution of more than one function. These functions are intended to be non-design specific. However, the assignments may differ with new design concepts. The designated allocated reflect only the principal allocations. Other aircraft systems may contribute to the execution of any given function. The functional breakdown, the architectural breakdown and the allocations may differ for specific designs.

4.4 Performance Analysis

The values must be associated for each function defined in the previous section, to show and 'how well' those functions must be performed. As evident form the section 4.4.1, the functional analysis creates complete description of aircraft and its subsystems as shown in Appendix D, but still don't associate performance requirement numbers to them. At the highest level, some of the functions may not even have the performance requirement associated with them. It is mandatory that each function has an associated performance requirement (numbers) assigned at the critical function level that is dictated by the aircraft mission requirements.

4.4.1 Detailed Technical Analysis

A detailed technical analysis is required to evaluate all requirements including:

a. Interface, operational and specialty requirements
b. Technical requirements development (Specifications)
   (used to link lower level requirements)
c. Verification of lower level requirements and product validation.

4.4.2 Functional Analysis in the Certification Process

ARP 4754/4761 recommends that a comprehensive top-down functional analysis be performed as part of the certification process. The top and second level aircraft functions of Appendix D provide the framework for this analysis. The functions of any system or subsystem being analyzed for certification can be traced to these top-level functions."

4.5 Requirement Flowdown

After requirement analysis has been completed, the top-level requirements (assigned to aircraft level) needs to flowdown to next level and subsequently to lower levels. In some instances, top-level requirements are allocated directly to the next level and other times, the top-level requirements are allocated (flowed down) using analytical relationships between the levels. Many times the top level requirements when allocated to lower level will change their characteristics. For example a top-level acoustic requirement may be translated in to vibration requirement at the engine system level. As a result, it is critical that all lower levels requirements be linked to top-level requirements to show completeness of requirements analyses. Figure 4.5-1 shows an example of requirement flow down.

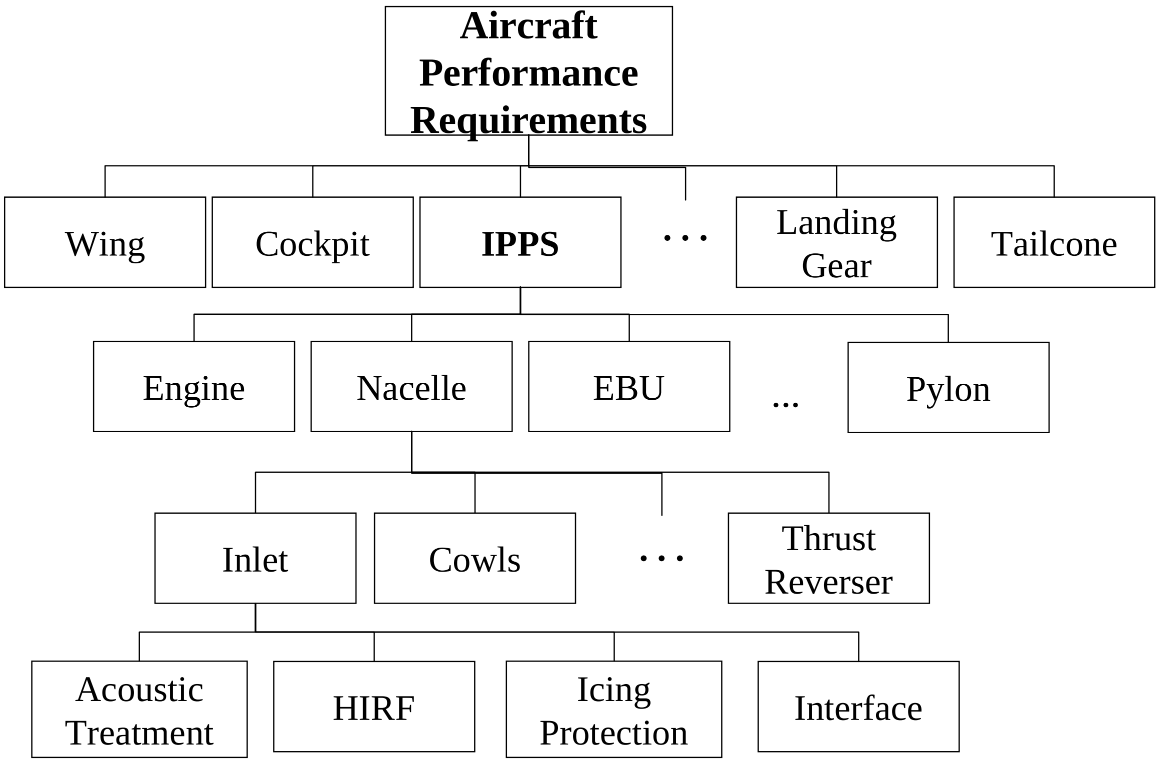


Figure 4.5-1 Requirement Flowdown Example in Commercial Aircraft domain

4.5.1 Multiple Levels of Suppliers

Multiple levels of suppliers are a part of the commercial aircraft domain. Therefore, it is often necessary to flow down requirements through several layers of a supplier hierarchy. In order to minimize risk it is necessary to maintain the accuracy and completeness of requirements through all the layers.

4.5.2 Derived Requirements

Subsystem solutions at each layer of the aircraft hierarchy will result in derived requirements. These subsystem requirements will be traceable to the top-level aircraft requirements.

4.6 Solution Definition

The solution definition process in commercial aircraft domain is used to define acceptable deign solution that will satisfy technical requirements derived in section 4.5 and derived requirements form the solution definition process. Solution definition begins with the transfer of a comprehensive set of requirements directly to the appropriate design organization.

4.6.1 Generate Alternative Designs

Because design solutions in most cases need to meet many requirements, sometimes conflicting, requirements simultaneously, more than one alternate design solutions are possible that meets the logical & physical solution.

EIA632 divides the design solutions into two categories: 1) Precedented- when the requirements that are to be used to meet technical requirements are already known 2) Unprecedented- when the requirements that are to be used to meet technical requirements are not known. Figure 4.6-1 shows the building block for EIA 632 solution definition approaches. Precedented designs are common in the commercial aircraft domain. Aircraft designs based on previous designs are normally called derivative designs.

RESERVED

Figure 4.6-1 Approaches for Design Solutions

4.6.2 Evaluate Alternative Designs

Evaluation of each alternate design needs to be accomplished based on the predetermined evaluation criterion. For the commercial aircraft domain, these evaluation criteria may be different for different subsystems. At the sub system level, the evaluation criteria may be: “the sub system design solutions meets the derived technical requirements at this level with out any adverse impact at the next level”. However, even at the subsystem level, the overarching criteria is to meet the overall technical requirements at the aircraft level Therefore, sub-system level designs must flow up to meet top-level technical requirements. At the end of evaluation criteria, all alternate design solutions should be ranked in the order they meet the technical requirements the best.

4.6.3 Select Preferred Design

After the evaluation of alternate designs solutions, the preferred design is selected based on the commercial aircraft objectives that are defined at the end of market analysis (section 6.0). The preferred design solutions must meet other requirements like cost, schedule, delivery, and customer acceptability etc. The agreement between all stakeholders for the final design solution can expedite the implementation of the design solution.

After the selection of preferred design solution, the actual design is committed to a baseline and is placed under configuration control. With the commitment of the design, verifications plans are produced, to analyze, test and certify the A/C for deployment.

4.6.4 Off-the-Shelf (OTS) Designs

Aircraft designs frequently employ OTS equipment. Sometimes the OTS equipment is buyer-furnished equipment (BFE). For example, an airline customer may specify specific equipment by manufacturer and serial number. This equipment will then be subject to end-product verification in the aircraft environment (See Section 4.7.2).

4.7 Relationship between Validation, Verification and Certification

The diagram in Figure 4.7-1 shows the relationship among validation, verification, and certification in the commercial aircraft domain.

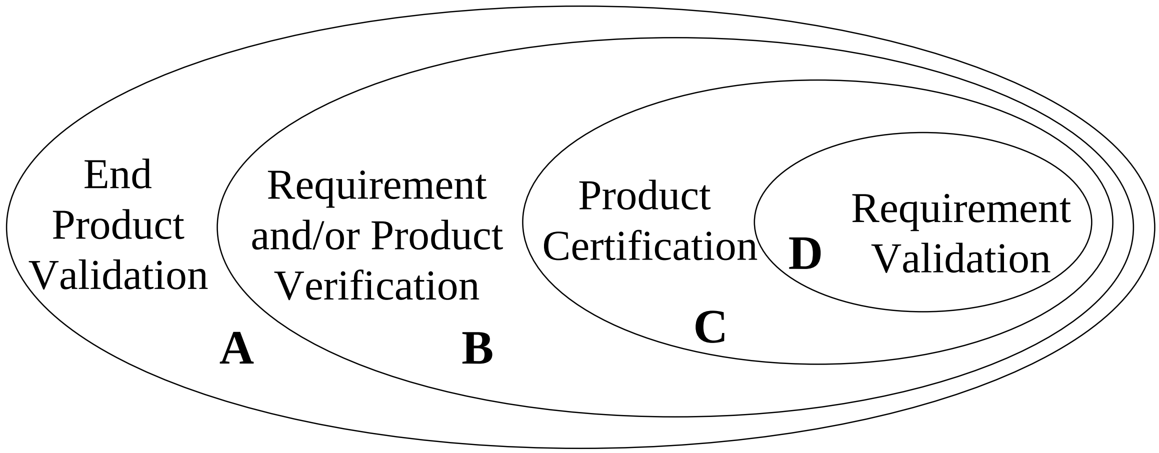


Figure 4.7-1 Relationships between Validation, Certification and Verification in the Commercial Aircraft Domain

The following paragraphs elaborate on the activities pertaining to validation, verification, and certification. Zones A through D of Figure 4.7-1 comprise all the End product validation, end-product & requirement verification, product certification and requirement validation activities on the aircraft.

4.7.1 End-product Validation

According to EIA 632, end-product validation (as opposed to requirements validation) pertains to the activities by the developer to ensure that the end product (or aggregation of end products) conforms to its validated acquirer (customer) requirements. In other words, end-product validation is act of determining if the product satisfies its stakeholders. The following paragraphs elaborate on validation in the commercial aircraft domain.

All activities within Zone A, including Zone B & C, represent the activities to confirm that the aircraft has met its customer and regulatory requirements as described in ARP 4754/4761. These types of activities are normally referred to as validation.

Typical methods used to perform non-regulatory validations include analysis, on-aircraft inspections and acceptance tests (ground and flight). Acceptance tests differ from qualification tests (part of verification) in that acceptance tests do not normally test the limits of the performance regime. Validation also includes the approval of supplier verifications in the integration of the entire aircraft.

Both validation and verification must be satisfied to have a successful aircraft in the market place. Even if the aircraft developer shows full compliance with the specification, but doesn't solve the problem (validation) of the users, the aircraft won't be successful.

4.7.2 Requirements and /or End-product Verification

End-product verification, as described by EIA-632, pertains to the activities performed by the aircraft manufacturer to verify that the aircraft conforms to its specified requirements. It can also pertain to the verification of products by suppliers that these products have met the developer's requirements. Enabling products, such as the aircraft manufacturing and support processes, are also included in the verification planning and execution activities.

Traditional verification activities include test, demonstration, inspection and analysis methods. In the commercial aircraft domain typical testing includes wind-tunnel testing, laboratory testing, and flight testing. Each test represents the verification of a specific requirement. Tests at the limit of the performance regime are called qualification tests. Demonstration refers to simple tests which do not require sophisticated equipment. Inspection refers to verification by visual means. Examples include the inspection of physical end product against drawings (2D or 3D) or against the specification. Analysis can refer to manual analyses, computer simulations or similarity analyses. Typical analyses in the commercial aircraft domain include structural analyses, thermodynamic analyses, computational fluid dynamics (CFD) analyses, and flight dynamics analyses. Similarity analyses are the comparisons of components against similar components that have met the performance requirements in similar operating environments.

The activities in zone Zones B and C, represent the verification of all requirements, that is, design solutions related to satisfying all requirements, whether internal component requirements or external airline requirements or regulatory requirements. These verifications are performed against the requirements found in contractual agreements between the aircraft enterprise and the aircraft customer, and also in procurement specifications between suppliers and the aircraft enterprise in the integration of the entire aircraft.

4.8 Certification

According to ARP 4754/4761, certification is "the legal recognition that a product, service, organization or person complies with the application requirements." It is not the intent of the guidelines to duplicate the certification requirements or methodology described in ARP 4754/4761. It is, however, the intent of this section to show how certification interacts with and overlaps with the general verification and validation activities for both regulatory authorities and non-regulatory.

Zone C in Figure 4.7-1 represents the activities to assure the regulatory agencies that the aircraft has met its intended requirements. This activity normally results in the approval of a type certificate.

While these guidelines do not intend to duplicate information in other references, the verification methods appropriate for certification is: a. inspection and review, b.

analysis, c. test, and d. service experience. These methods are described in ARP 4754/4761.

Zone C also represents the certification processes pertaining to the development of the aircraft as described in ARP 4754/4761. That is, zone C also includes the certification of the aircraft enterprise processes other than the aircraft itself. These activities are beyond the scope of these guidelines and are discussed in ARP 4754/4761.

4.9 Requirement Validation

This activity pertains to early phase of the aircraft development to check if the prescribed requirements are necessary, clear, concise, expressed in simple language, physically possible and has an agreement with stakeholders. Requirement validation in Zone D, process also checks for traceability, missing & extraneous requirements. Any new requirements that may be generated or changed during the aircraft development cycle must be validated before implementing that requirement.

5.0 commercial aircraft system architecture

This section describes the concept of the architecture of a commercial aircraft system within the context of the larger world aviation system. It also treats the concepts of operational and enabling products within the architecture, as described by EIA 632. The architectures described here are intended to provide templates for the development of the Commercial Air Transport System, its subordinate operational products, and its enabling products. It also provides a comprehensive view of external and internal interfaces (see Section 5.2.3) and traceability to aircraft level requirements.

5.1 The Systems Engineering Concept of a Product Architecture

A system architecture is a hierarchical framework for the structure of a system. Its elements are the building blocks described in EIA 632, p. 61. Early in development it can be seen as an evolving set of elements to which requirements can be allocated. The architecture is not unique or static. Its structure may vary as the system matures. The suggested architecture presented in this section can be considered typical. Elements can be added, deleted, or rearranged at the discretion of the system developer.

An architectural building block does not reflect ownership by any unique entity. A system may have elements owned by the aircraft manufacturer, the airline company, the airport, regulatory agencies, or other entities. All of these entities comprise the commercial aircraft domain.

5.2 The Concept of Enabling Products

Each architectural element consists of two parts: the operational product and the enabling system, in accordance with EIA 632, p. 61. The key operational product is the aircraft itself and any other products required to operate the aircraft, regardless of the level in the hierarchy the product appears.

Figure 5.2 -1 depicts the Aircraft System with both its operational and enabling products. The enabling system is the collection of items at any level which perform the enabling functions for the aircraft. There are seven enabling functions, namely, development, production, test, deployment, training, support, and disposal For each function there are four types of enabling items:

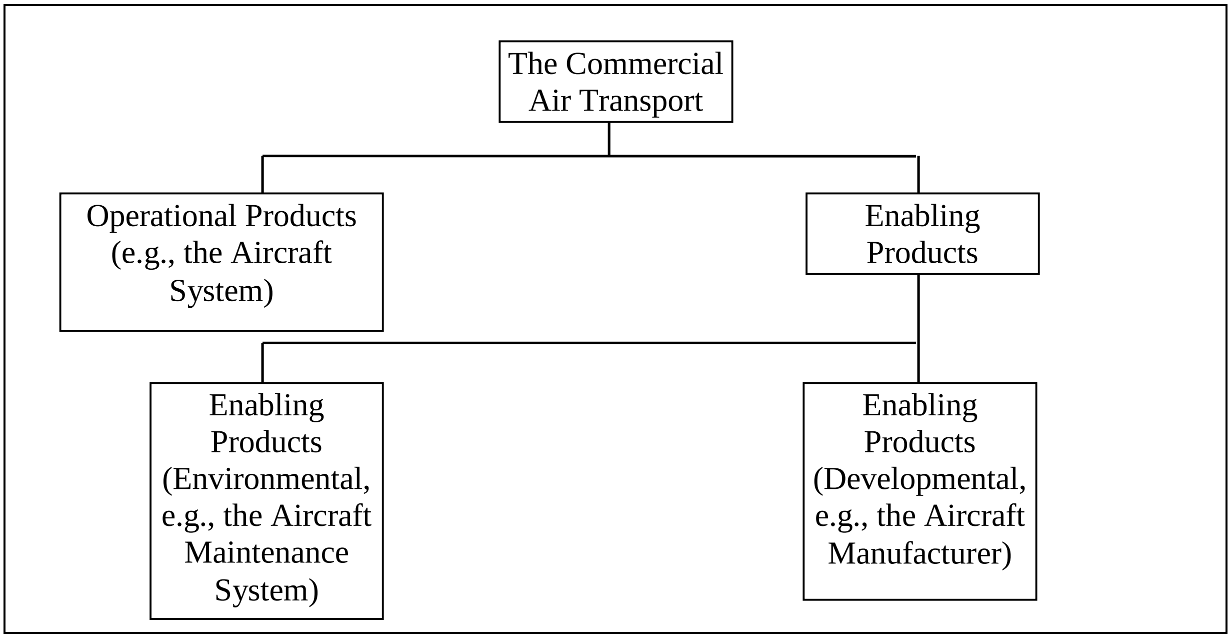


Figure 5.2-1. An Operational and Enabling View of the Commercial Air Transport System

1. Documentation. Typical products are plans, policies, reports, schedules, procedures, databases, and computer models.
2. Personnel. This element consists of personnel either in development of or support of the aircraft.

a. Equipment. This element may consist of computers, physical models, test equipment, and ground support equipment.
b. Facilities. This element consists of buildings, hangars, and other facilities required in the development and support of the aircraft.

To avoid repetition, the contents of each enabling system will not be listed unless there is some aspect unique to the air transport system. The above seven categories of enabling functions and four categories of enabling system items can be applied to the air transport system at any level. At each level the enabling functions and items will only apply to that level. For example, the production function at the aircraft level will pertain only to the assembly of the aircraft, which includes the mating of the wing to the fuselage. At the wing subsystem level, the production function will pertain to the fabrication of the wing. As shown in Figure 5.2-1, the enabling products consist of two types, developmental and environmental. Developmental enabling products are only necessary during the development of the aircraft system, such as the aircraft manufacturer. Environmental enabling products exist in the operational environment, that is, during the operational phase of the aircraft system, such as the maintenance system. Requirements may be allocated to both developmental and environmental enabling products.

5.3 The World Aviation System Architecture

The World Aviation System architecture shown in Figure 5.3-1 reflects five top-level functions, namely, air transport, passenger handling, cargo handling, the airport function, and air traffic management. These functions result in the five top-level systems shown in the diagram. These are the Transport System, the Passenger Handling System, the Cargo Handling System, the Airport System, and the Air Traffic Management System. It is the system which consists of all the elements required to perform all the functions required to transport passengers and cargo between two points by air. The Commercial Air Transport System is the primary system of these Guidelines. The other systems within the World Aviation System are described at the summary level in order to identify the interface with those systems.

This figure breaks down the subordinate systems by it their operational products. However, it also shows typical enabling products for each operational product *at its own level*.

5.3.1 Air Transport Systems

Although the Commercial Air Transport System is the focus system of these guidelines, there are two other air transport systems which occupy the same air space, namely, the military aircraft systems and spacecraft systems. The latter only pertains to those space systems which enter the atmosphere. Most of the principles described in these Guidelines will apply to those systems as well.

5.3.1.1 Commercial Air Transport System

The Commercial Air Transport System consists of the Aircraft System, the Flight Deck Crew, the Ground Power System, and any other operational elements. The Commercial Air Transport System is the primary system of these Guidelines and is the system which provides the function of delivering passengers and cargo between two points, and all the associated equipment to perform that function. Enabling systems include the Ground Maintenance System, the Spare Parts System, the Aircraft Servicing System (fuel, cleaning), and the Aircraft Design, Assembly and Test System. Business and general aviation aircraft are included in this category.

5.3.1.1.1 Aircraft System

The Aircraft System is the principal operational element of the Commercial Air Transport System. The Aircraft System is the flight vehicle and the aggregate of its subsystems. The subsystems are shown in Figure 5-3.
The enabling products for the Aircraft System consists of four subsystems: the Aircraft Development Subsystem, the Aircraft Production Subsystem, the Aircraft Test Subsystem, the Aircraft Deployment Subsystem, the Aircraft Training Subsystem, the Aircraft Support Subsystem, and the Aircraft Disposal Subsystem.

The Aircraft Development Subsystem consists of, but is not limited to, the aircraft development organization. The development documentation consists of engineering plans, policies, reports, schedules, procedures, databases, and computer models. Development equipment may include computers and mockups. The development personnel consist of the engineering and business personnel involved in the aircraft development. Development facilities consist of the engineering facilities. Key systems engineering documentation required for development includes the rigorous documentation of requirements at the aircraft level. It also includes the interface documentation required for the functional and physical integration of the aircraft's segments and subsystems. The aircraft development subsystem also includes collection of activities, equipment, and personnel required to select, acquire, deploy, and support a fleet of aircraft.

The Aircraft Production Subsystem consists of the documentation, equipment, personnel and facilities required for the assembly of the aircraft. Production documentation consists of production plans, schedules, policies, manuals, and procedures. Production equipment consists of production mockups, tooling, materials, measuring devices, computers, and vehicles. Production personnel consist of the fabrication, assembly, inspection, and management personnel in the production process. Production facilities consist of the facilities needed to assemble the aircraft plus any fabrication accomplished at the aircraft level.

The Aircraft Test Subsystem consists of test documentation, equipment, personnel, and facilities which may belong to the manufacturer or in the course of the development of the air transport system. It does not include operational ground test equipment. Test documentation consists of test work orders, plans, and reports. Test equipment may include measuring devices, simulation equipment, and any in-flight equipment used on test aircraft which will not be used in operation. Test personnel include laboratory and flight who conduct tests. Test facilities consist of laboratories and flight test facilities which may belong to the manufacturer or to the airport.

The Aircraft Deployment Subsystem contains all those elements required to deploy the aircraft. It does not contain any operational elements. Key aspects of this element are the airline customer buy-off and certification elements. The deployment documentation contains, but is not limited to, deployment plans and schedules, policies and procedures, instructions, and drawings. It would also include the contractual specification between the manufacturer and the airline customer. The deployment subsystem also contains any equipment, personnel, or facilities required to deploy the aircraft.

The Aircraft Training Subsystem consists of all training equipment, software, documentation, personnel, and facilities required to train any person involved in the aircraft operation, including pilots, flight attendants, maintenance personnel and service personnel.

The Aircraft Support Subsystem consists of all equipment, software, documentation, personnel, and facilities required to support the aircraft. Equipment and software would include the test equipment and its software used during aircraft operation. Personnel would include the airline or airport personnel involved in the aircraft support. Facilities can include either airline or airport facilities used for aircraft support. The establishment of a maintenance and parts acquisition system are a key part of this element.

The Aircraft Disposal Subsystem includes all the documentation, equipment, personnel, and facilities required to dispose of the aircraft. Disposal documentation would include forms and manuals needed to assure compliance with government regulations.

Figure 5-3 shows the Aircraft System broken out by its segment and subsystems. Since these elements mirror the operational and enabling elements at the aircraft level, no detailed description of these elements will be given. The principal differences of the subsystems from the Aircraft System are as follows:

(1) The primary organizational entity is the supplier rather than the aircraft developer.
(2) The primary customer is the aircraft developer (or higher level supplier) rather than the airline.
(3) Engineering and production pertain to a segment, subsystem, or component rather than the entire aircraft.

A common methodology for the numbering of the aircraft subsystems is the ATA (Air Transport Association) Index.

The aircraft system architecture shown in Figure 5-3 is, to a certain extent, solution-oriented. For advanced concepts for which this structure does not apply, the developer should tailor this architecture to fit the needs of the specific concept. For example, if the focus of the development is a flying-wing concept, the developer should ignore the Fuselage Subsystem in the Airframe Segment.

5.3.1.1.2 Flight Deck Crew

As essential elements to the operation of an aircraft the captain, first officer, and navigator, if necessary, are the operational elements of the flight deck personnel element. Enabling elements include the selection and training of these personnel.

5.3.1.1.3 Ground Power System

This element includes any equipment and associated personnel required for providing power to the aircraft on the ground, such as electrical, hydraulic, or pneumatic. Enabling elements include all the development and support items listed for these elements.

5.3.1.2 Spacecraft Systems

Spacecraft systems are those systems which leave the atmosphere, re-enter, and land. Since these systems occupy the same air space, their inclusion is important to commercial air transport systems.

5.3.1.3 Military Aircraft Systems

Like spacecraft systems, military aircraft occupy the same air space as commercial air transport systems. Also, like spacecraft systems, the standards and processes for their development differ from the commercial aircraft standards and processes.

5.3.2 Air Traffic Management Systems

The Air Traffic Management System consists of all those elements required to support the navigation and communications functions of the Aircraft System. These include radars, satellites, and communications equipment and personnel. Also included are the local air traffic control elements located at the local airport. Enabling systems include the towers at individual airports.

5.3.3 Passenger Handling System

The Passenger Handling System consists of three main subsystems, the Baggage Handling System (carousel and loading system), the Flight Attendants, and the Ticketing System. Enabling systems include the passenger functions of the airport terminal and flight attendant training. The Passenger Handling System will interface with the Aircraft System.

5.3.4 Cargo Handling System

The Cargo Handling System consists of the Cargo Transport System and the Cargo Loading System. Enabling systems consist of the cargo functions of the airport terminal. The Cargo Handling System will interface with the Aircraft System. The Cargo Handling System does not include the automatic loading systems on the aircraft, for example.

5.3.5 Airport System

The Airport System consists of those elements required to support the Aircraft System during landing and takeoff. These include the Runway System and the Lighting System. The Airport System does not include the elements of the Passenger Handling System and Baggage Handling System located at airports and described in Sections 5.3.3 and 5.3.4. Nor does it include the air traffic management elements and the tower described in Section 5.3.2. Enabling products include the airport security system and emergency systems. The Airport System will interface with the Aircraft System.

5.4 Summary of Commercial Air Transport Architecture

This section has presented a template of an architectural structure for the Commercial Air Transport System within the larger Worldwide Aviation System. This template will enable the developer to create a structure for the allocation of requirements following the functional and requirements analyses described in Sections 4. This structure will enable the developer to develop requirements for and synthesize the enabling systems *concurrently* with the air transport system itself. Finally, it is recommended that the developer maintain the architecture as a product which will evolve from the representation of early concepts to the final design.

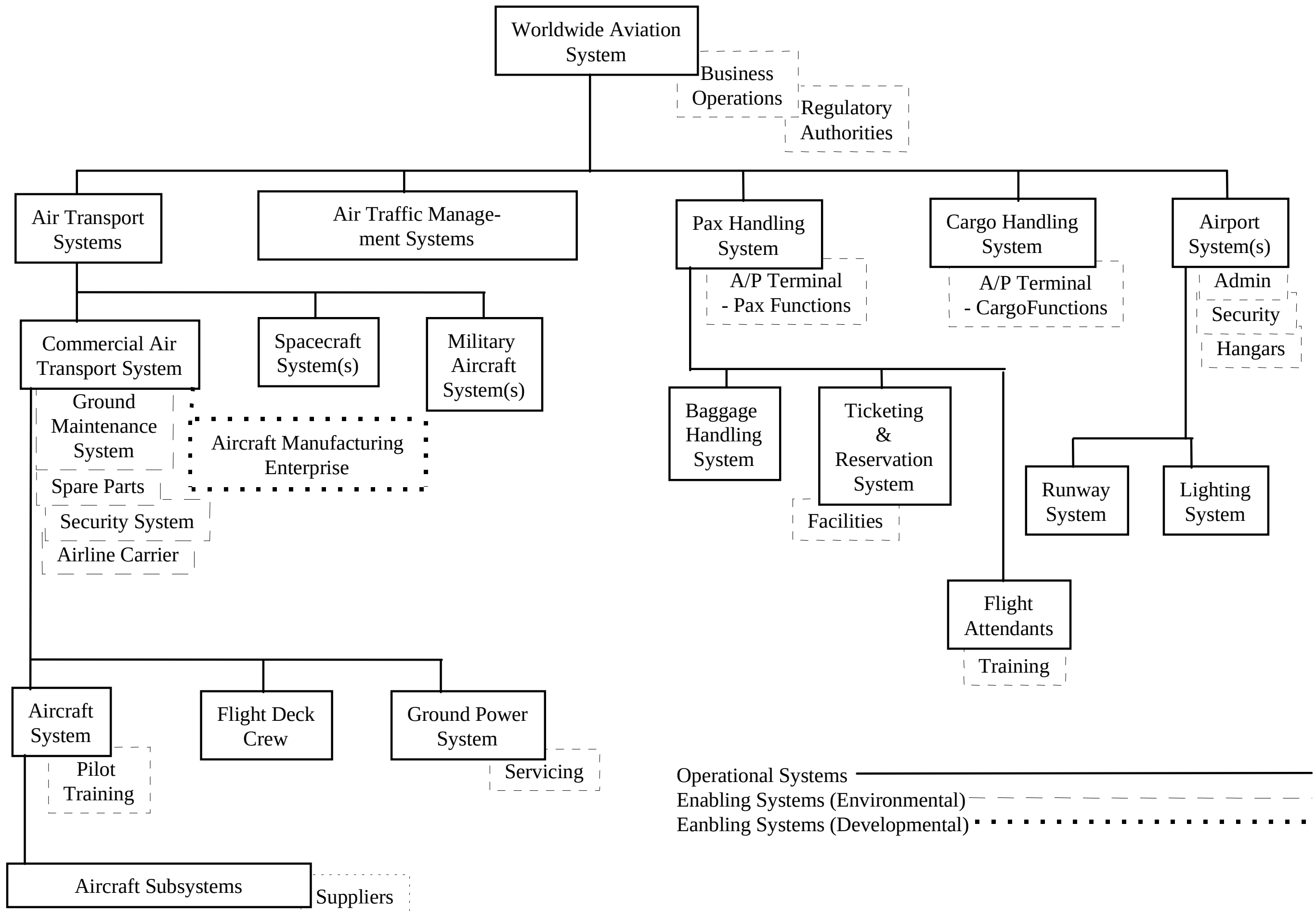


Figure 5.4-1. Worldwide Aviation System Architecture

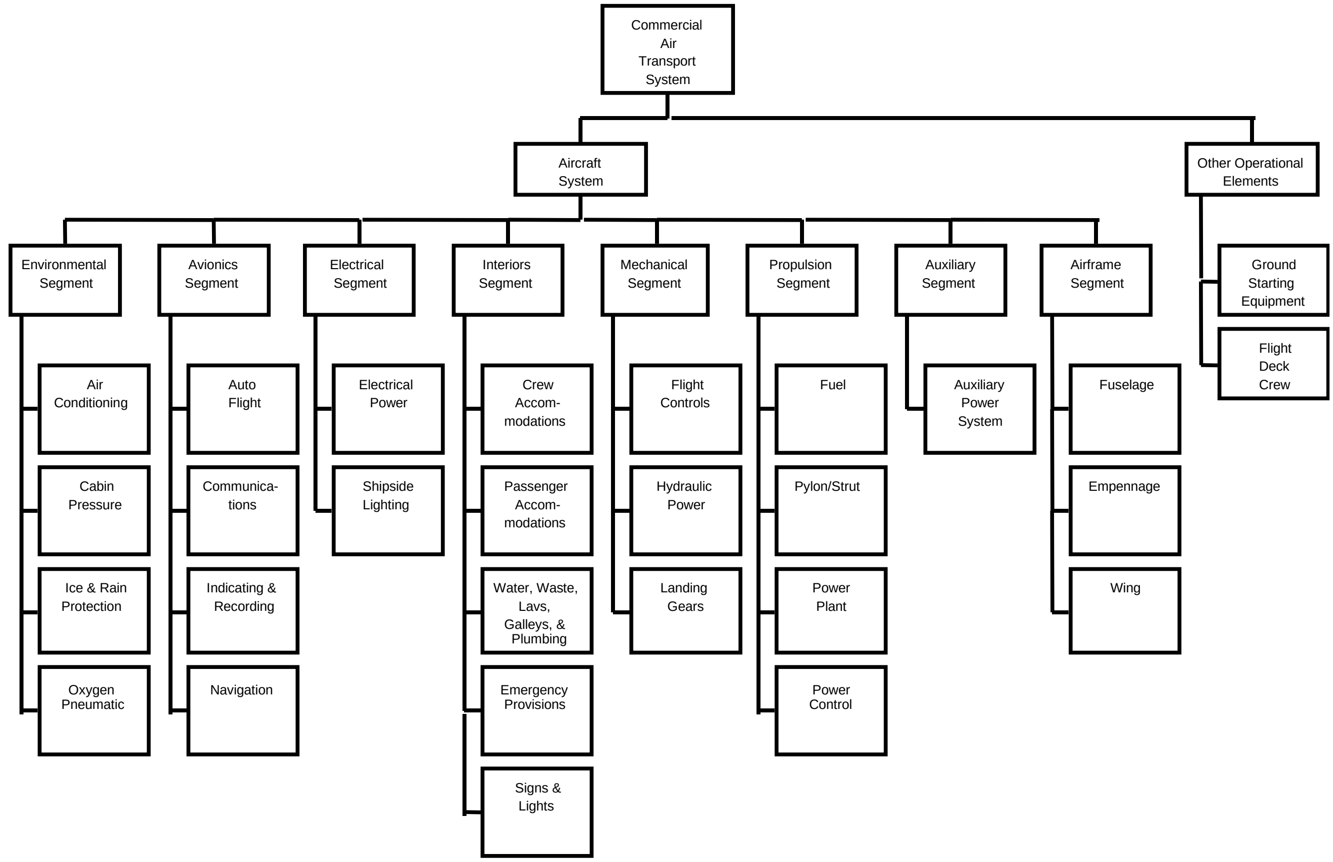


Figure 5.4-2. Commercial Air Transport System Architecture

6.0 Systems Engineering Management

Systems Engineering Management focuses on the control and management of technical efforts, activities and programmatic interfaces the systems engineering team typically completes to develop and deliver a completed and fully integrated system or product. Program Management and Systems Engineering Management activities are intertwined so deeply that distinction between the two disciplines often blur (See Figure 4.0-1), and change from program to program, project to project. Program Management addresses functions that pertain to the business or enterprise's financial ability to complete and deliver a system to a customer. Systems Engineering addresses functions that pertain to the business or enterprise's technical ability to complete and deliver a system to a customer. In many cases, the Systems Engineering customer is the business or enterprise's Program Management. Program Management, along with technical support from Systems Engineering, represents the business or enterprise to the outside world. From the above generalized distinction between Program Management and Systems Engineering Management, it is clear that one cannot fully function without the other. For a business or enterprise to sustain and expand its market, it is essential that communication between the Program Management and Systems Engineering Management be addressed in a repeatable, concise, and consistent format.

To this end, this section is divided into two additional sections. Section 6.1, addresses the development of a Systems Engineering Plan (SEP) for Commercial Aircraft Systems. Section 6.2 provides a brief description of other related Engineering Plans (EPs). Both the SEP and other related EPs are developed by and with Systems Engineering Management to facilitate technical and programmatic coordination and communication internally and externally to the business or enterprise. Internal to the business or enterprise refers to Program Management and specific Technical Discipline Management. External to the business or enterprise refers to customer, regulator, and scientific, legal, and political arenas.

6.1 Systems Engineering Plan (SEP)

Systems engineering plans are not necessarily a single plan, but perhaps a set of plans documented in company procedures or plans. A single systems engineering plan may appear as part of a proposal to executive management at the beginning of a new program.

The Systems Engineering Plan (SEP), as it relates to the Commercial Air Transport System, is the instantiation of the Systems Engineering process in aircraft and aircraft subsystem development. The SEP establishes the methodologies and guidance, and communicates the actions and activities required in managing and controlling the engineering development and product delivery. The SEP is the top-level of potentially many supporting, lower level plans that govern the systems engineering effort. The SEP is a "living" document in that it is further refined as the systems development progresses through a program's life cycle. It is essential for Systems Engineering Management to maintain the SEP as a guiding plan to remain effective in program or product development. It is the SEP that defines and manages the interface between Program Management, Technical and Specialty Management, and external influences. Generally the SEP will address and define the following:

Program Overview: This section describes the purpose, introduces the objectives and summarizes the development covered by the SEP. It contains any general information beneficial to Management or other team member in understanding the project or its background. It also contains any reference documents, which will be adhered to in the implementation of the design and project plans.

- Customer Description
- Current Market Description and Outlook
- Competition Analysis
- Most Important Requirements – Customer
- Most Important Requirements – Company
- Major Deliverables
- Issue Resolution Process Description
- Requirements Management Process
- Requirements Documentation Structure

6.1.1 Design Description:

This section provides a brief descriptive functional overview provided by the system and a brief descriptive operational overview of the modes and methods of control for the system.

- Overall Functional and Physical Requirements
- Environmental Requirements
- Critical Electrical or Mechanical Requirements
- Mission Profile Definition and Specification Tailoring
- Production Planning Quantities

6.1.2 Risk Mitigation Plan

- Technical Risks
- Schedule Risks
- Cost Risks

6.1.3 Certification Plan:

This section provides information on how the aircraft system and individual subsystems will be certified and indicates any special conditions. Identify all system level documentation and certification testing requirements. Any known or anticipated Technical Standing Order (TSO) deviations for the avionics subsystem to be certified should be identified.

6.1.4 Environmental Qualification:

This section lists the Environmental Categories (i.e. DO-160) the system and each subsystem will be designed to meet. Special testing such as extended testing, thermal testing, environmental stress screening, etc. should be addressed.

6.1.5 Software Qualification:

This section contains details on the level of software criticality (i.e. DO-178) assigned to functions of the system or subsystem as it will be designed and certified.

6.1.6 Design Plan:

This section provides the governing technical doctrine of the system development. Generally, it is a consolidation of plans from various technical disciplines that establish the development boundaries of a system. The listing is not fully inclusive and additions or deletions are expected depending on the scope of the system under development.

6.1.6.1 Design Considerations and Goals

6.1.6.1.1 Design Philosophies:
This section contains the philosophies of the design concerning consistency throughout the system, system to subsystem interface, and system to external system interface.

6.1.6.1.2 Design Environment
This section contains information on the software tools to be used in the system development.

6.1.6.1.3 Design for Manufacturability
This section provides detail on units design considerations, goals, and design deviations from standard practices. Addressing new development versus modification which will improve or reduce efficiencies or cost effectiveness of manufacturing of the design are accomplished.

6.1.6.1.4 Testability:

6.1.6.1.5 Maintainability

6.1.6.1.5.1 MTTR Requirements

6.1.6.1.5.2 Maintenance Philosophy

6.1.6.1.5.3 Built-In-Test Requirements

Maintenance Demonstration (M-Demo) Plan

6.1.6.1.5.4 Assessment of Proposed Concept

6.1.6.1.5.5 Testability Guidelines and Trade-off

6.1.6.1.6 Safety:

6.1.6.1.7 Human Factors:

6.1.6.1.8 EMI/RFI/HIRF and Lightning Protection

6.1.6.1.9 Reuse

6.1.6.1.10 Reliability

- Top Level Requirements
- Sublevel Allocations/Goals
- Analysis Requirements
- Assessment of Proposed Concept
- Designer Guidelines

6.2 Design Approach:

6.2.1 System Architecture Plan

6.2.2 Interface Plan

6.2.3 Electrical Design

- Electrical Design Approach
- Electrical Description – Overall Equipment Configuration
- Block Diagram – Top Level Partitioning
- Electrical Interfaces Plan

6.2.4 Mechanical Design

- Mechanical Design Approach
- Mechanical Description – Overall Equipment Configuration
- Top Level Physical Description
- Mechanical Construction Plan
- Family Tree
- Interconnect Plan
- Thermal Design/Cooling Plan
- Lighting/Display Plan
- Installation/Mounting Plan

6.2.5 Software Design Plan

- Software Design Approach
- Software Specifications, Documentation and Control
- Top Level Functional Description
- Sublevel Functional Description
- Software Design Considerations
- Software/Hardware Integration Approach

6.2.6 Parts/Materials/Processes Plan

- Standard/Non-Standard Parts Requirements
- Special Parts Considerations
- Standard/Unique Assembly Process Requirements

6.2.7 Installation Plan

- Installation Requirements
- Installation Design
- Installation Fabrication and Test

6.2.8 Engineering Support Plan

- Engineering Support Program Requirements
- Engineering Support Strategy and Approach
- Subsystem and Component Information
- Engineering Data Management
- Engineering Laboratories

6.2.9 Factory Transition Plan

- Factory Requirements
- Factory Design
- Factory Build Schedule

6.3 Other Related Engineering Plans

The SEP is used in conjunction with other program management standards to provide the necessary engineering management and project management controls for the system being produced. Typical associated plans are:

6.3.1 Statement of Work

6.3.2 Schedule Plan

- Design Reviews
- Customer and Internal Review Schedules
- Special Considerations
- Supplier Design Reviews

6.3.3 Staffing Plan

Program Team Training Plan

6.3.4 Resource Requirements

- Capital Test Equipment, Government Furnished Equipment, etc.
- CAD/CAE Tools

6.3.5 Intellectual Property Plan

6.3.6 Cost Plan with Cost Estimates

- Top Level Standard Costs/Goals
- Sublevel Allocations
- Performance Measurement Baseline
- Assessment of Proposed Concept
- Cost Avoidance Guideline

6.3.7 Build/Delivery Plan

6.3.8 Administrative Plan

- Program Team – Customer Communication Plan
- Shared Network/Communication Plan
- Program Conclusion Plan

6.3.9 Risk Management Plan

- Risk Assessment
- Risk Mitigation Plan

6.3.10 Configuration Management Plan

6.3.11 Data Management Plan

6.3.12 Quality Management Plan

6.3.13 Specialty Engineering Management Plans

6.3.14 Supplier Plans

6.3.15 Research and Development Plan

6.3.16 Security Plan

6.3.17 Aircraft Level and Subsystem Level Design Reviews.

Design reviews in the commercial aircraft domain are normally internal events conducted to assure that the development is on schedule, that designs comply with requirements, and that risks are being mitigated. In particular, aircraft-level design reviews assure that aircraft level requirements are being met, e.g., weight and performance, and that subsystem development supports the aircraft level development.

6.2.18 IPT Organizational Structure

7.0 Verification Plans

7.1 Verification by Test

7.1.1 Verification by Lab Test

7.1.2 Verification by Flight Test

7.1.3 On Aircraft Test Procedures (OATPs)

7.1.4 Acceptance Tests

7.2 Verification by Analysis

7.2.1 Simulation

7.2.2 Verification by Similarity Analysis

7.3 Verification by Demonstration

7.4 Verification by Inspection

8.0 Test Plan

8.3.1 Engineering Test

- Engineering Testing
- Engineering Test Equipment and Development Tools
- Engineering Test Procedures

8.3.2 Manufacturing Test

- Manufacturing Test Approach
- Manufacturing Test Equipment
- Manufacturing Test Procedures

8.3.3 Service Center Test

- Service Center Test Approach
- Service Center Test Equipment
- Service Center Test Procedures

8.3.4 Customer, Dealer, or Other Outside Testing

- Test Approach

- Test Equipment
- Test Procedures

8.3.5 Installation Test

- Installation Test Approach
- Installation Test Equipment
- Installation Test Procedures

Appendix A Linkage to Guidelines and Standards

RESERVED

Appendix B ACRONYMS

Acronym	Stands For:
A/C	Aircraft
ANSI	American National Standards Institute
ARP	Aerospace Recommended Practice
ATA	Air Transport Association
CAA	Civil Aviation Authority (U.K.)
EIA	Electronic Industries Alliance
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration (U.S.)
FAR	Federal Aviation Regulations
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers, Inc
ISO	International Organization for Standardization
JAA	Joint Aviation Authorities (European)
JAR	Joint Aviation Requirements
RTCA	Radio Technical Commission on Aviation
RTCA DO	RTCA Document
RTCA SC	RTCA Special Committee
SAE	Society of Automotive Engineers
SCD	System Control Document
OATPs	On Aircraft Test Procedures
IPT	Integrated Product Team
BFE	Buyer Furnished Equipment
SE	System Engineering
SEP	Systems Engineering Plan
IPPS	
EBU	
OTS	Off the Shelf
COTS	Commercial Off the Shelf

APPENDIX C - References

EIA 632
ARP 4754
ARP 4761
DO 178B
Airbus INCOSE paper
JCAWG paper

NEED DETAILS

APPENDIX D COMMERCIAL AIRCRAFT FUNCTIONS

Table 5.3-1 Aircraft Functions (1-2) and Subsystem Allocations

Top-Level Functions	
Second-Level Functions	
Third-Level Functions	
Provide and Distribute Communications	
Provide Communications Between the Aircraft and the Air Traffic Management System	
Present Identification. This function pertains to the display and transmission of the aircraft identification and emergency signals to other nodes.	Indicating and Recording, Communications
Communicate Position to Other Aircraft. This function pertains to the communication of the aircraft position for the purpose of collision avoidance.	Communications
Communicate Position to Air Traffic Control. This function pertains to the communication of the aircraft position during landing approach via signals or lighting.	Communications, Shipside Lighting
Receive Communication from Air Traffic Control and Other Aircraft. This function pertains to the receipt of identification, position, runway, and time signals.	Communications
Sense External Conditions. This function pertains to the sensing of weather, air, and ground data.	Navigation
Provide Communications Between Aircraft Systems and Airline Base Operations. This function pertains to the transmission of systems data the ground and the receipt of airline operational data.	Communications
Provide Communications From Aircraft Systems to Flight Crew	
Provide Communication of Aircraft External Conditions. This function pertains to the display and warning of external conditions and safety information to the flight crew.	Indicating and Recording and Flight Controls
Provide Aircraft Internal Conditions. This function pertains to the display of aircraft data to the flight crew.	Indicating and Recording
Provide Aircraft Relative Conditions. This function pertains to the display of aircraft flight state data to the flight crew.	Indicating and Recording
Provide Crew Alerting Inhibit. This function allows the crew to inhibit alerts.	Communications
Provide Communications of Instruction for Flight	Communications

Operations. This function enables the flight crew to read digital manuals.	
Provide Flight Crew Input and Control	
Provide for Flight Crew Control of Aircraft Maneuvering. This function allows tactile control and backdrive of aircraft movement.	Flight Controls
Provide for Flight Crew Control of Visibility. This function allows the flight crew to have control of exterior lighting and control of window conditions, such as icing, fogging, and rain.	Flight Controls
Provide for Flight Crew Control of Displays and Messages. This function allows the flight crew to have control and selection of displays.	Indicating and Recording
Provide for Flight Crew Control of Aircraft Systems. This function allows the flight crew to activate and control the configuration of aircraft systems.	Indicating and Recording
Provide Maintenance and Ground Crew Communications With Aircraft. This function allows the crew to view equipment failure and replacement data from the aircraft.	Communications
Provide Cabin Crew Communications With the Aircraft. This function allows the cabin crew control of on-board services, communications with Air Traffic Control, and exterior telephone services.	Communications
Provide Passenger Communications Via Exterior Telephone Nodes. This function allows the passengers to communicate through the exterior telephone system.	Communications
Provide Information to Passengers. This function provides prerecorded safety and emergency evacuation information to the passengers.	Communications
Plan, Generate and Control Aircraft Movement	
Plan and Analyze Flight Path	
Provide Navigational Guidance. This function provides and displays aircraft guidance commands and cues.	Navigation, Indicating and Recording
Provide Aerodynamic / Attitudinal Guidance. This function provides glide slope and stall avoidance cues.	Navigation
Monitor and Report Aircraft Performance and Progress. This function monitors fuel availability, time durations, and performs cost optimizations.	Fuel System and Navigation
Plan Flight. This function generates the route flight path and plans and updates the flight plan.	Navigation
Generate and Control Aircraft Movement	

Generate Thrust. This function starts the engines and provides the proper level of thrust through all phase of flight and controls noise and emissions.	Power Plant
Control Thrust and Thrust Reverse. This function provides the thrust and thrust reverse control through all phases of flight and maintains thrust and thrust reverse within established limits.	Power Control
Provide for Ground Steering. This function provides flight crew control of ground steering and provides the wheel steering capability.	Flight Control and Landing Gears
Control Ground Braking. This function release, braking, and skid avoidance capability.	Landing Gears
Control Aircraft Aerodynamic Configuration	
Control Lift. This function controls the degree of lift, lift stability, load relief, lift asymmetry, gust load, and stall.	Flight Controls
Control Speed Aerodynamically. This function provides, controls and protects speed aerodynamically.	Flight Controls
Control Direction Aerodynamically. This function controls the direction of the aircraft aerodynamically.	Flight Controls
Control Altitude Aerodynamically. This function controls the altitude of the aircraft aerodynamically.	Flight Controls
Control Attitude Aerodynamically. This function control the attitude of the aircraft aerodynamically in roll, pitch and yaw.	Flight Controls
Protect Aerodynamic Control. This function provides protection against wake turbulence, flight envelope penetration, excessive bank angles, stall, and any undesirable air flow pattern.	Flight Controls
Provide Aerodynamic Control Forces (moved from 7.4). This function provides and controls control forces, protects against aerodynamic noise, and maintains control flow through temperature and anti-ice control.	Wing, Empennage
Support Supplemental Flight Control. This function provides control of primary and secondary control forces and force feedback, stability augmentation, crew command damping, and flight envelope protection.	Flight Controls
Provide Thrust Asymmetry Compensation (TAC). This function controls asymmetric thrust and provides aerodynamic compensation for asymmetric thrust.	Power Control and Flight Controls
Control Landing Gear. This function controls the configuration and extends or retracts the landing gear.	Landing Gear

Provide Anti-Ice Capability. This function provides anti-ice pneumatic air or spray.	Ice and Rain Protection
Auto-Manage and Control Flight	
Auto-Fly the Aircraft During Flight (Climb and Cruise). This function automatically generate flight control commands for all phases of flight.	Auto Flight
Auto-Land the Aircraft. This function generates flight commands during the landing phase, announces aircraft position, and enables communications with the Air Traffic Control.	Auto Flight and Communications
Generate Lift (moved from 7.3). This function generates aircraft lift and maintains aerodynamic control through temperature control and anti-ice.	Wing and Anti-Ice
Provide Aerodynamic Stability. This function provides aerodynamic stability of the aircraft.	Empennage

Table 5.3-1 Aircraft Functions (3-4) and Subsystem Allocations

Top-Level Functions	
Second-Level Functions	
Third-Level Functions	
Fourth-Level Functions	Subsystem Allocations
Provide Crew, Passenger, and Cargo Environment and Services	
Provide Business Services and Entertainment Services	Passenger and Crew Accommodations
Provide, Control and Support Entertainment Services. This function pertains to television, music, and other entertainment services provided to the passengers.	
Provide Passenger Workstation Services. This function pertains to the delivery of the entertainment at the passenger seat.	
Provide Cabin Crew Workstation Services. This function pertains to accommodations for crew administrative duties.	
Provide Passenger and Crew Physiological Needs. This function pertains to the seating, lavatory, food, water, and workstation services that are required for passengers.	Passenger Accommodations; Water, Waste, Galley, Lavatories, and Plumbing
Control Cabin and Flight Deck Environment This function pertains to maintenance of air quality, pressure, and temperature and to all interior lighting, the suppression of interior noise, emergency oxygen, and emergency lighting.	Air Conditioning, Pressure System, Signs and Lights, Passenger Accommodations, Oxygen System
Protect Aircraft Internal Environment. This function pertains to the detection and suppression of fires both in the cabin as well as the cargo and equipment bays. It also pertains to the detection and ventilation of smoke and the protection of the lighting from damage.	Emergency Provisions, Signs and Lights
Control Cargo Environment. This function pertains to the quality, temperature and pressure of breathable air to the cargo. It also pertains to the space allocated to cargo and cargo lighting.	Air Conditioning, Pressure System, Fuselage, Signs and Lights
Provide Cargo Handling. This function pertains to the cargo handling, loading and unloading functions on the aircraft and to cargo restraints and protection from fire, temperature and pressure damage.	Fuselage
Detect and Analyze Aircraft Conditions for Flight	
Determine Aircraft External Conditions	

Determine and Report Time to Aircraft Systems. This function pertains to the flight relevant times, such as, reference time, elapsed time, estimated arrival time, etc.	Navigation
Determine Position Referenced to Runway. This function pertains to the determination of the position of the aircraft relative to the runway while the aircraft is in the air, on the ground and transitioning between air and ground. It also pertains to the detection of tail strike.	Navigation
Determine Aircraft Attitude. This function pertains to the determination of the attitude of the aircraft in a 3D coordinate system.	Navigation
Determine Aircraft Position. This function pertains to the determination of altitude, longitude, and latitude and relevant distances, terrain features, speed relative to the ground, acceleration and jerk.	Navigation
Determine Air Mass Reference State. This function pertains to air speed, pressure altitude, air temperature and density, and aircraft speed relative to wind speed.	Navigation
Determine External Conditions. This function receives information regarding weather and air conditions, wind shear, air traffic alert conditions, the position of other air vehicles, and ground proximity.	Communications, Navigation
Determine Internal Systems Conditions	
Support Checklist Execution. This function verifies systems per the checklist and verifies the checklist completion.	Navigation
Measure, Analyze, and Support Systems Conditions. This function measures aircraft volume, pressure, temperature, energy, signals, velocity, orientation, c.g., balance, and mass, and monitors and determines the proper configuration for systems.	Navigation
Monitor and Report Misconfigured Aircraft States. This function monitors thrust asymmetry, brake configuration, control surface and landing gear position for takeoff and descent, flight envelope compliance, ground proximity, stall conditions, and door positions.	Navigation

Detect, Isolate, and Report Faults and Failures. This functions detects and reports software and equipment faults, system diagnostics and monitoring, and analyzes systems conditions.	
Control Systems Re-Configuration. This function reconfigures systems and manages weight and balance.	Navigation

Aircraft Functions (5-6)

Distribute Information and Communications	
Distribute Communications	
Support Communications Among Aircraft Equipment. This function pertains to the conversion of signals and transmission of messages.	Communications
Provide Communications of Data to External Sources. This function pertains to the transmission and receipt of data from sources external to the aircraft.	Communications
Support Communications Between Crew and Ground Nodes. This function pertains to communication between the crew and Air Traffic Control, with external telephone services, and with airline base operations.	Communications
Support Communications Between People on Aircraft. This function pertains to communications among the crew and with passengers and for passenger signaling to the crew. It also pertains to crew workstation capability for passenger servicing.	Communications, Crew Accommodations
Support Passenger to Ground Communications. This function pertains to passenger communications through telephone services to the ground.	Communications
Distribute and Manage Aircraft Information and Data. This function pertains to the management of on-board data and to the transmission of software load data.	Communications
Provide for Systems Redefinition and Installation of Data. This function pertains to software loading, replacing software with new versions, and the acceptance and loading of maintenance data, airport characteristics, navigation data, performance envelope data, etc.	Communications
Record Flight Data. This function pertains to the capture and store of flight records and voice communications.	Indicating and Recording
Record and Manage Systems Conditions Data. This function pertains to the capture and store of aircraft condition data and tail strike indication.	Indicating and Recording
Record System Faults and Failures. This function pertains to the capture and recording of equipment faults and failure event data.	Indicating and Recording

Provide Visibility for Flight Crew. This function pertains to exterior lighting for flight and for ground maneuvers. It also pertains to the control of flight deck window visibility against icing, fogging and rain.	Shipside Lighting, Ice and Rain Protection
Generate and Manage Internal Power and Manage Systems Materials	
Provide Power and Materials Distribution	
Provide Power Distribution. This function pertains to the distribution of electrical, hydraulic, and pneumatic power.	Electrical Power, Pneumatic System, Hydraulic System
Provide Materials Distribution. This function pertains to the distribution of air, supply gases, fuel, potable and waste water, and oxygen. It also pertains to the ventilation of waste gases and liquids.	Air Conditioning; Emergency Provisions; Water, Waste, Lavs, Galleys and Plumbing; Fuel System
Provide Distribution to and Acceptance From External Sources. This function pertains to the loading and unloading of provisions, the loading and unloading of fuel, and the receipt of external electrical power, air conditioning, pneumatic air, and hydraulic power.	Crew and Passenger Accommodations, Fuel System, Electrical
Provide Power to Carryon Electrical Devices (moved from 1.6). This function pertains to the supply of power to carryon electrical devices, such as electric shavers.	Electrical
Generate and Manage Internal Power	
Provide and Control Power. This function pertains to the distribution of ground electrical power, the support of power needs, the supply and control of internal electrical power, hydraulic power, and pneumatic power, and the start and control of auxiliary power and ram air, and the mitigation of of HIRF, EMI, and lightning.	Electrical System, Hydraulic System, Pneumatic System, Auxiliary System
Manage Energy Transformation. This function pertains to the transformation of energy to electricity, heat, light, air pressure, and mechanical action. It also pertains to heat and noise dissipation.	Electrical Power, Air Conditioning, Pneumatic System, Power System
Transport and Control Systems Materials Internally	
Provide Fuel. This function pertains to the storage and distribution of fuel, the control of crossfeed, the balance of fuel weight, the control of fuel during a fire threat, and the management of fuel flow.	Fuel System

Manage and Control Hydraulic Fluids. This function pertains to the control of hydraulic fuel during normal operations and during fire threat.	Hydraulic Power, Auxiliary System
Manage and Control Engine Oil. This function pertains to the management and control of engine oil in the power plant.	Power Plant
Control Emissions to External Environment. This function pertains to the control of chemical gas and liquid emissions.	Power Plant
Manage and Control Pneumatic Air. This function pertains to the supply and control of pneumatic air from the air source through aircraft pneumatic ducts.	Pneumatic System, Auxiliary System, Power System
Detect and Suppress Systems Fire. This function pertains to engine, APU, fuel, and wheelwell fire protection and suppression.	Emergency Provisions

Aircraft Functions (7-8)

Provide Airframe Movement and Attachment Capability	
Provide Capability for Ground Support. This function pertains to the capability of providing ground mobility of the aircraft and for jacking and shoring. It also pertains to vibration and corrosion mitigation.	Fuselage, Landing Gear
Provide Airframe Connection Capability. This function pertains to the capability of the aircraft to accommodate the attachment of aerodynamic surfaces and engine mountings; to the accommodation of vibration and corrosion mitigators; to the transmission of thrust from the engine through the airframe structure; to the maintenance of surfaces temperatures and the absence of ice; and to protection against foreign object damage.	Wing, Empennage, Fuselage, Air Conditioning, Anti-Ice, Power Plant
Provide Capability for Service Equipment Attachment. This function pertains to the capability for external hookups and attachments and the support for aircraft jacking.	Fuselage, Wing
Provide Containment and Internal Support	
Provide Containment	
Provide Containment Against Aerodynamic Forces. This function pertains to the capability of containing the aircraft components within a volume protected from the external aerodynamic environment. It also pertains the control of entry and exit capabilities, to viewing the exterior, to providing space for payloads, and for the control of noise.	Fuselage, Wing, Empennage
Provide Structural Integrity and Loads Distribution. This function pertains to the capability of maintaining primary and internal structural load integrity and loads distribution throughout the airframe, the capability of the aircraft to absorb aft body contact, and for the capability of maintaining internal pressure loads.	Fuselage, Wing, Empennage
Provide Storage for and Protect Equipment. This function pertains to the protection of the internal equipment from the environment and from hazards; for the positioning of equipment, for the capability of corrosion inspection, for removal and access,	Fuselage
Provide Storage for Systems Provisioning. This function pertains to the storage of fuel, hydraulic fluid, oxygen, chemicals, water, and waste; to the mobile storage of food; and to the refrigeration of	Fuel System, Hydraulic System, Oxygen System, Emergency Provisioning; Water, Waste, Lavs,

galley items.	Galleys, and Plumbing
Provide for Interior Configuration Changes. This function pertains to the loading and unloading of interior equipment and galley and lavatory equipment.	Passenger and Crew Accommodations; Water, Waste, Lavs, Galleys, and Plumbing
Provide for Crew and Passenger Personal Items Storage	
Provide for Flight Crew Flight Materials Storage. This function pertains to storage space for flight crew materials both within the airframe and for access during flight.	Crew Accommodations
Provide for Cabin Crew Materials Storage. This function pertains to the storage of retail items.	Crew Accommodations
Provide for Cabin and Passenger Personal Items Storage. This function pertains to the storage of both passenger and crew personal items.	Passenger and Crew Accommodations
Provide Crew and Passenger Entries and Exits	
Provide Normal Egress for Passengers and Crew. This function pertains to the capability of supporting passenger and crew entries and exits; and to the passenger and crew loading and unloading.	Fuselage
Provide Emergency Egress for Passengers and Crew. This function pertains to passenger and crew emergency egress, survival in water, to emergency door opening, and to emergency ground evacuation/	Fuselage, Emergency Provisions
Provide for Cargo Storage. This function pertains to cargo storage, restraint, and positioning; to the protection of the structure from damage by the cargo, and to space for cargo.	Fuselage
Provide Cargo Entries and Exits. This function pertains to the support of cargo entries and exits and to cargo loading and unloading access.	Fuselage
Provide Equipment Access. This function pertains to doors and panels for equipment access.	Fuselage

Appendix E GLOSSARY

acquirer: an enterprise, organization, or individual hat obtains a product (good or service) from a supplier

aircraft: any vehicle, with or without an engine, which can fly, such as a plane or helicopter

airplane: A fixed wing aircraft capable of flight, generally heavier than air and driven by jet engines or propellers.

commercial aircraft: xxx

commercial enterprise: defined by the "holder" of the type certificate of the aircraft

constraint: (1) A restriction, limit, or regulation imposed on a product, project, or process (2) A type of requirement or design feature that cannot be traded off

cyclic: xxx

enabling product: item that provides the means for (a) getting an end product into service, (b) keeping it in service, or (c) ending its service (enabling products are related to the associated processes: development, production, test, deployment, training, support, and disposal)

end product: the portion of a system that performs the operational functions and is delivered to an acquirer

end product validation: confirmation by examination and provision of objective evidence that the specific intended use of an end product (developed or purchased), or an aggregation of end products, is accomplished in an intended usage environment; answers the question "Does the delivered end product conform to the validated input acquirer requirements, certification criteria, or acceptance criteria as applicable?"; used to demonstrate that the product developed or purchased satisfies the validated acquirer requirements in the context of its intended use

end product verification: confirmation by examination and provision of objective evidence that the specified requirements to which an end product is built, coded, or assembled have been fulfilled; answers the question "Does the output end product comply to the output specified requirements from which the end products were built, coded, procured, or assembled and integrated?"; used to demonstrate that the specified requirements (specifications) generated by the developer and used to build, code, or assemble the end product have been satisfied

engineering life cycle: a sequence of phases that evolves an instance of a system from a concept to a set of products consistent with the exit criteria established for an enterprise-based life cycle phase

enterprise: the entity that has governance over a set of projects, or over organizations in which project are carried out

enterprise-based life cycle: the incremental progress of a system from conception through disposal, marked by management-established milestones with assigned exit criteria

function: a task, action, or activity performed to achieve a desired outcome

functional requirement: a requirement that defines what system products must do and their desired behavior in terms of an effect produced, or an action or service to be performed

interface requirement: a requirement that defines the conditions of interaction between elements of the aircraft system

iterative: xxx

layer of development: (1) a level of abstraction as it relates to the system structure made up of building blocks; (2) a level of system decomposition

'other aircraft': includes private aircraft

performance requirement: a requirement that defines how well the system products are required to perform a function, along with the conditions under which the function is performed

process: a set of interrelated tasks that, together, transform inputs into outputs

subsystem: a grouping of items that perform a set of functions within a particular end product

sustaining: xxx

system: an aggregation of end products and enabling products to achieve a given purpose

Appendix F Comments Form

Enclosed is a copy of the **Framework for the Practice of Systems Engineering in the Commercial Aircraft Domain**, Version 1.2a, July 28, 2000 for your review . Please use the attached comment sheet to provide constructive comments. The latest version of the document is available at http://www.incose.org/seatc/ .

In order to make the next revision of the document (ECD Jan 2001), comments are requested by Oct 29 2000. Please send comments to: greg.mathers@boeing.com .

These Guidelines provide a framework within which the Commercial Aircraft Industry may determine **how** to improve the implementation of specific aircraft designs (end products), and tailor the development and production (enabling end products)of the aircraft to suit their individual enterprise needs. The framework also promotes a common understanding, of the concepts, dialog and processes that may be used across all interfaces in the Commercial Aircraft Domain to improve communication across the industry.

Greg Mathers
Chairman, JCAWG,
greg.mathers@boeing.com

JCAWG Comments Form

Comments may be either general in nature or suggest specific changes. Paragraph/word substitutions preferred. Rationale must be provided for each comment. Each comment should cite **category, page, paragraph**, and include **rationale**. Choose categories from the following:

CRITICAL - Critical comments will cause non-concurrence with the document if comment is not satisfactorily resolved.

SUBSTANTIVE - Substantive comments are provided because sections in the document appear to be or are potentially unnecessary, incorrect, incomplete, misleading, confusing, or inconsistent with other sections.

ADMINISTRATIVE - Administrative comments correct what appears to be a typographical or grammatical error.

THE FOLLOWING COMMENTS ARE PROVIDED BY:

NAME	Representing (Office)	PHONE	E-MAIL

DOCUMENT NAME
Framework for the Practice of Systems Engineering in the Commercial Aircraft Domain **Version 1.2a** **July 28, 2000**

No	PAGE	PARA	LINE	COMMENT	RESOLTION
1.				**CRITICAL, SUBSTANTIVE or ADMINISTRATIVE** **RATIONALE:**	
2.				**CRITICAL, SUBSTANTIVE or ADMINISTRATIVE** **RATIONALE:**	