CHAPTER 6

DESIGN SYNTHESIS

6.1 DESIGN DEVELOPMENT

Design Synthesis is the process by which concepts or designs are developed based on the functional descriptions that are the products of Functional Analysis and Allocation. Design synthesis is a creative activity that develops a physical architecture (a set of product, system, and/or software elements) capable of performing the required functions within the limits of the performance parameters prescribed. Since there may be several hardware and/or software architectures developed to satisfy a given set of functional and performance requirements, synthesis sets the stage for trade studies to select the best among the candidate architectures. The objective of design synthesis is to combine and restructure hardware and software components in such a way as to achieve a design solution capable of satisfying the stated requirements. During concept development, synthesis produces system concepts and establishes basic relationships among the subsystems. During preliminary and detailed design, subsystem and component descriptions are elaborated, and detailed interfaces between all system components are defined.

The physical architecture forms the basis for design definition documentation, such as, specifications, baselines, and work breakdown structures (WBS). Figure 6-1 gives an overview of the basic parameters of the synthesis process.

- **Outputs:**
  - Physical Architecture (Product Elements and Software Code)
  - Decision Database
- **Inputs:**
  - Functional Architecture
- **Enablers:**
  - IPTs, Decision Database, Automated Tools, Models
- **Controls:**
  - Constraints; GFE, COTS, & Reusable S/W; System concept & subsystem choices; organizational procedures
- **Activities:**
  - Allocate functions and constraints to system elements
  - Synthesize system element alternatives
  - Assess technology alternatives
  - Define physical interfaces
  - Define system product WBS
  - Develop life cycle techniques and procedures
  - Integrate system elements
  - Select preferred concept/design

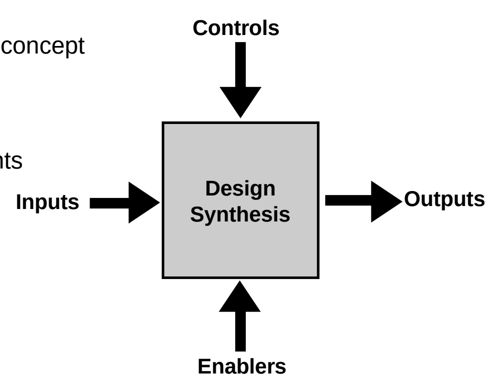


Figure 6-1. Design Synthesis

Characteristics

Physical architecture is a traditional term. Despite the name, it includes software elements as well as hardware elements. Among the characteristics of the physical architecture (the primary output of Design Synthesis) are the following:

- The correlation with functional analysis requires that each physical or software component meets at least one (or part of one) functional requirement, though any component can meet more than one requirement,
- The architecture is justified by trade studies and effectiveness analyses,
- A product WBS is developed from the physical architecture,
- Metrics are developed to track progress among KPPs, and
- All supporting information is documented in a database.

Modular Designs

Modular designs are formed by grouping components that perform a single independent function or single logical task; have single entry and exit points; and are separately testable. Grouping related functions facilitates the search for modular design solutions and furthermore increases the possibility that open-systems approaches can be used in the product architecture.

Desirable attributes of the modular units include low coupling, high cohesion, and low connectivity. Coupling between modules is a measure of their interdependence, or the amount of information shared between two modules. Decoupling modules eases development risks and makes later modifications easier to implement. Cohesion (also called binding) is the similarity of tasks performed within the module. High cohesion is desirable because it allows for use of identical or like (family or series) components, or for use of a single component to perform multiple functions. Connectivity refers to the relationship of internal elements within one module to internal elements within another module. High connectivity is undesirable in that it creates complex interfaces that may impede design, development, and testing.

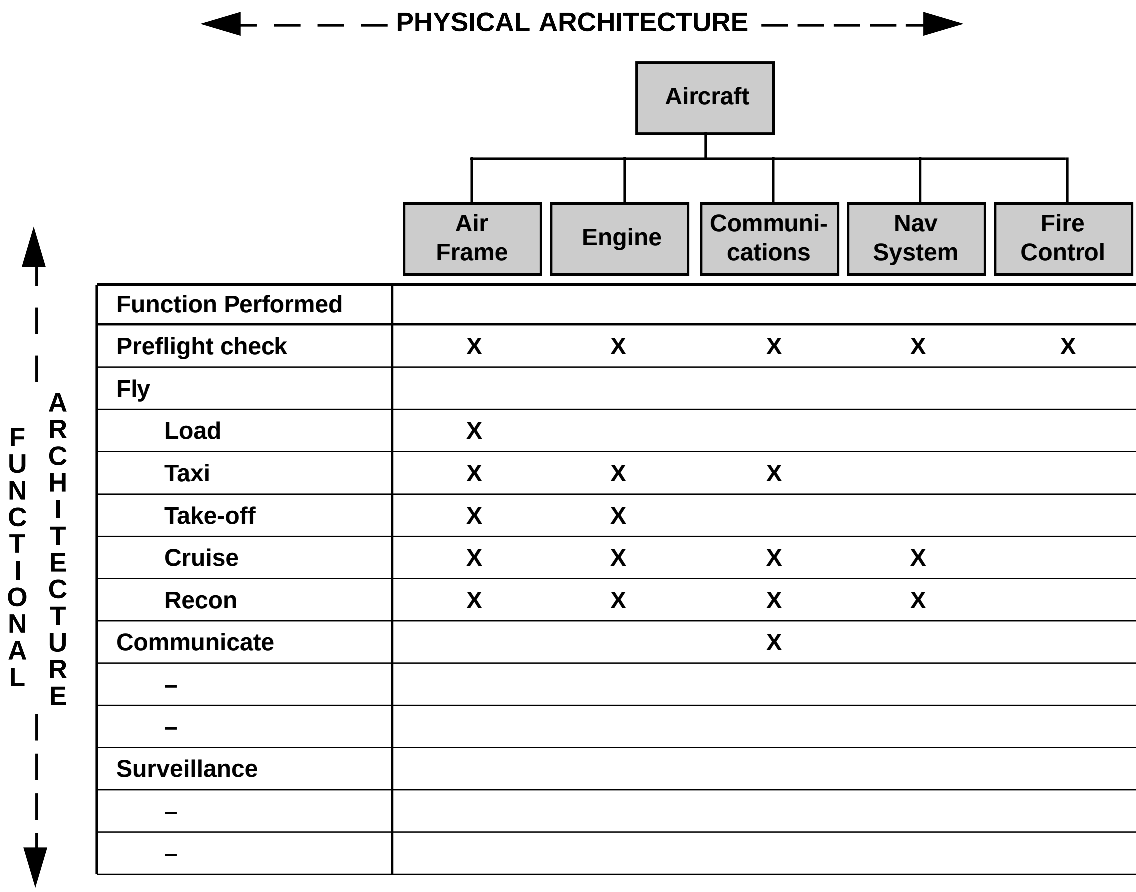
Design Loop

The design loop involves revisiting the functional architecture to verify that the physical architecture developed is consistent with the functional and performance requirements. It is a mapping between the functional and physical architectures. Figure 6-2 shows an example of a simple physical architecture and how it relates to the functional architecture. During design synthesis, re-evaluation of the functional analysis may be caused by the discovery of design issues that require re-examination of the initial decomposition, performance allocation, or even the higher-level requirements. These issues might include identification of a promising physical solution or open-system opportunities that have different functional characteristics than those foreseen by the initial functional architecture requirements.

6.2 SYNTHESIS TOOLS

During synthesis, various analytical, engineering, and modeling tools are used to support and document the design effort. Analytical devices such as trade studies support decisions to optimize physical solutions. Requirements Allocation Sheets (RAS) provide traceability to the functional and performance requirements. Simple descriptions like the Concept Decription Sheet (CDS) help visualize and communicate the system concept. Logic models, such as the Schematic Block Diagram (SBD), establish the design and the interrelationships within the system.

Automated engineering management tools such as Computer-Aided Design (CAD), Computer-Aided-Systems Engineering (CASE), and the Computer-Aided-Engineering (CAE) can help organize, coordinate and document the design effort. CAD generates detailed documentation describing the product design including SBDs, detailed



Function Performed	Air Frame	Engine	Communi-cations	Nav System	Fire Control
Preflight check	X	X	X	X	X
Fly					
Load	X				
Taxi	X	X	X		
Take-off	X	X			
Cruise	X	X	X	X	
Recon	X	X	X	X	
Communicate			X		
–					
–					
Surveillance					
–					
–					

Figure 6–2. Functional/Physical Matrix

drawings, three dimensional and solid drawings, and it tracks some technical performance measurements. CAD can provide significant input for virtual modeling and simulations. It also provides a common design database for integrated design developments. Computer-Aided Engineering can provide system requirements and performance analysis in support of trade studies, analysis related to the eight primary functions, and cost analyses. Computer-Aided Systems Engineering can provide automation of technical management analyses and documentation.

Modeling

Modeling techniques allow the physical product to be visualized and evaluated prior to design decisions. Models allow optimization of hardware and software parameters, permit performance predictions to be made, allow operational sequences to be derived, and permit optimum allocation of functional and performance requirements among the system elements. The traditional logical prototyping used in Design Synthesis is the Schematic Block Diagram.

6.3 SUMMARY POINTS

- Synthesis begins with the output of Functional Analysis and Allocation (the functional architecture). The functional architecture is transformed into a physical architecture by defining physical components needed to perform the functions identified in Functional Analysis and Allocation.

- Many tools are available to support the development of a physical architecture:
  - Define and depict the system concept (CDS),
  - Define and depict components and their relationships (SBD), and
  - Establish traceability of performance requirements to components (RAS).
- Specifications and the product WBS are derived from the physical architecture.

SUPPLEMENT 6-A

CONCEPT DESCRIPTION SHEET

The Concept Description Sheet describes (in textual or graphical form) the technical approach or the design concept, and shows how the system will be integrated to meet the performance and functional requirements. It is generally used in early concept design to show system concepts.

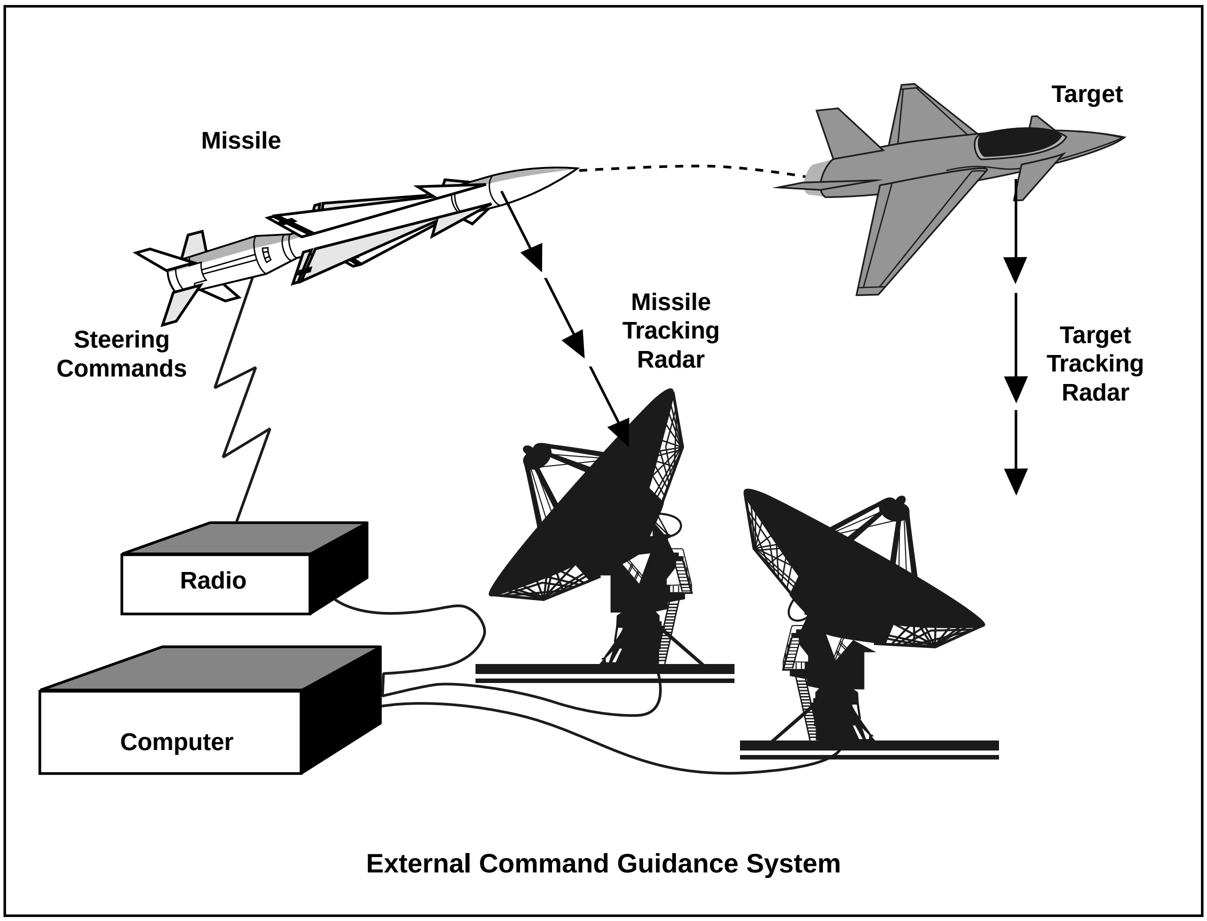


Figure 6-3. Concept Description Sheet Example

SUPPLEMENT 6-B

SCHEMATIC BLOCK DIAGRAMS

The Schematic Block Diagram (SBD) depicts hardware and software components and their interrelationships. They are developed at successively lower levels as analysis proceeds to define lower-level functions within higher-level requirements. These requirements are further subdivided and allocated using the Requirements Allocation Sheet (RAS). SBDs provide visibility of related system elements, and traceability to the RAS, FFBD, and other system engineering documentation. They describe a solution to the functional and performance requirements established by the functional architecture; show interfaces between the system components and between the system components and other systems or subsystems; support traceability between components and their functional origin; and provide a valuable tool to enhance configuration control. The SBD is also used to develop Interface Control Documents (ICDs) and provides an overall understanding of system operations.

A simplified SBD, Figure 6-4, shows how components and the connection between them are presented on the diagram. An expanded version is usually developed which displays the detailed functions performed within each component and a detailed depiction of their interrelationships. Expanded SBDs will also identify the WBS numbers associated with the components.

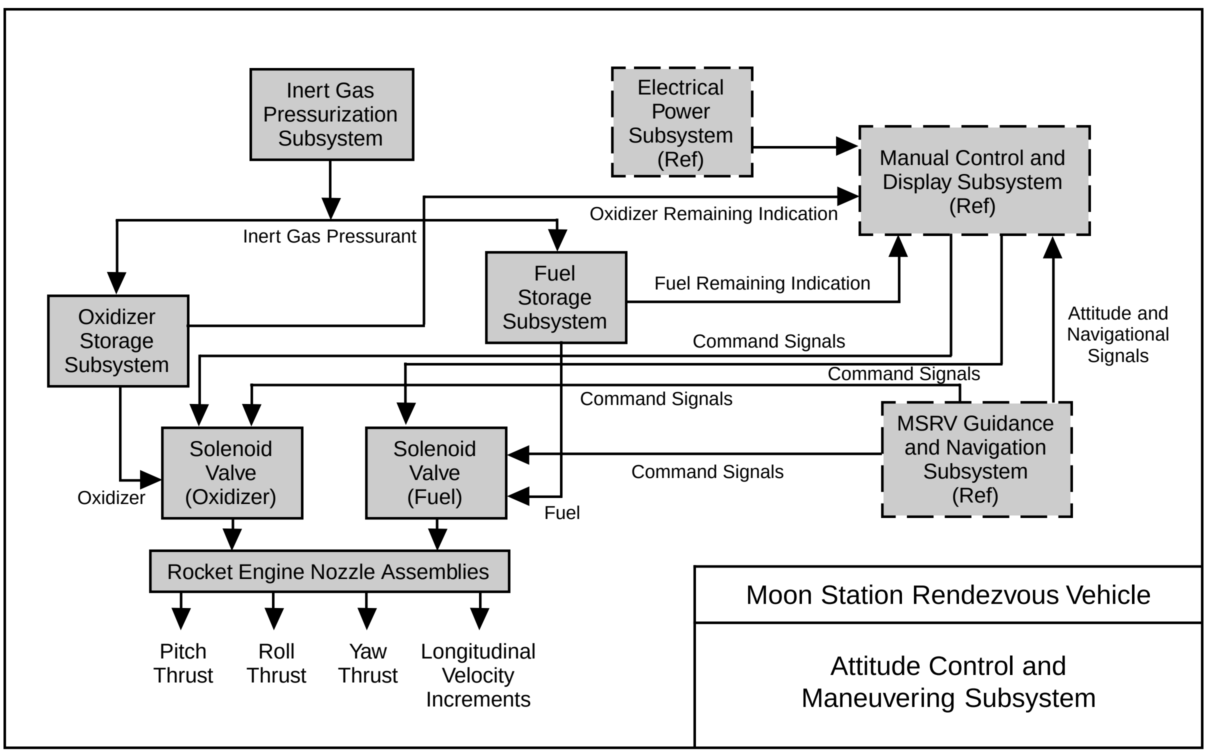


Figure 6-4. Schematic Block Diagram Example

SUPPLEMENT 6-C

REQUIREMENTS ALLOCATION SHEET

The RAS initiated in Functional Analysis and Allocation is expanded in Design Synthesis to document the connection between functional requirements and the physical system. It provides traceability between the Functional Analysis and Allocation and Synthesis activities. It is a major tool in maintaining consistency between functional architectures and the designs that are based on them. (Configuration Item (CI) numbers match the WBS.)

Requirements Allocation Sheet	Functional Flow Diagram Title and No. 2.58.4 Provide Guidance Compartment Cooling		Equipment Identification	
Function Name and No.	**Functional Performance and Design Requirements**	**Facility Rqmnts**	**Nomenclature**	**CI or Detail Spec No.**
2.58.4 Provide Guidance Compartment Cooling	The temperature in the guidance compartment must be maintained at the initial calibration temperature of +0.2 Deg F. The initial calibration temperature of the compartment will be between 66.5 and 68.5 Deg F.		Guidance Compartment Cooling System	3.54.5
2.58.4.1 Provide Chilled Coolant (Primary)	A storage capacity for 65 gal of chilled liquid coolant (deionized water) is required. The temperature of the stored coolant must be monitored continuously. The stored coolant must be maintained within a temperature range of 40–50 Deg F. for an indefinite period of time. The coolant supplied must be free of obstructive particles 0.5 micron at all times.		Guidance Compartment Coolant Storage Subsystem	3.54.5.1

Figure 6-5. Requirements Allocation Sheet (Example)