Synthesis

1 Definition

Design synthesis is the process of defining the product or items in terms of the physical and software elements which together make up and define the item.

Design loop is the process of revisiting the functional architecture to verify that the physical design synthesized can perform the required functions at the required levels of performance.

System synthesis translates the system functional architecture into a physical architecture. It is an iterative process, functional or performance allocation may be changed to create a 'balanced' solution. The products of system synthesis include a physical architecture baseline and the subsystem trade study results.

2 Steps

1. Begin with the functional architecture, its performance requirements and constraints (from functional analysis).
2. Allocate (flow-down, or derive) subsystem performance and resource requirements.
3. Define physical subsystem alternatives
4. Assess technology alternatives and their maturity.
5. Define physical interfaces and incompatibilities.
6. Estimate subsystem and system performance of each combination of alternatives.
7. Use utility curves (or trade studies)
8. Determine the driving requirements and consider reallocation.
9. Select a preferred system design. i.e., the physical architecture with subsystem implementation plans and functional and performance allocations and system performance estimates.

2.1 Step 1,2: Functional Architecture and Allocation

2.1.1 Architecture

Architecture is the fundamental and unifying system structure defined in terms of system elements, interfaces, processes, constraints and behaviors. It is the structure of components, their relationships, and the principles and guidelines governing their design and evolution over time.

Difference between system architecture and system design:

System Architecture is used:

1. To establish the framework for subsequent system design
2. To support make-buy decisions
3. To discriminate between alternative solutions
4. To 'discover' the true requirements or the 'true' priorities

System Design is used:

1. To develop system components that meet functional and performance requirements and constraints
2. To build the system
3. To understand the system-wide ripple effects of configuration changes

2.1.2 Allocation of Functional to Physical

1. Functional architecture generally determines physical architecture.

2.2 Step 3: Define Physical Subsystem Alternatives

2.2.1 Methods

1. Start with an existing system/subsystem - at least for comparison - and an understanding of the current state-of-the-art (SOTA) and the merits of heritage solutions.
2. Use morphological matrices to keep track of options for each physical implementation.
3. Decompose the problem functionally or physically to help generate alternatives.

2.2.2 Morphological Matrix

Morphological Matrix is used to identify possible new technological combinations for a system. The procedures include:

1. Functionally decompose the existing system
2. For each function, list all the possible ways in which it might be satisfied.
3. Examine the matrix for possible new permutations.

	Characteristics \ Alternatives	1	2	3	4
Config	Vehicle	Wing & Tail	Wing & Canard	Wing, Tail & Canard	Wing
	Fuselage	Cylindrical	Area Ruled	Oval	
	Pilot Visibility	Synthetic Vision	Conventional	Conventional & Nose Droop	
Mission	Range (nmi)	5000	6000	6500	
	Passengers	250	300	320	
	Mach Number	2	2.2	2.4	2.7
Propulsion	Type	MFTF	Turbine Bypass	Mid Tandem Fan	Flade
	Fan	None	1 Stage	2 Stage	3 Stage
	Combustor	Conventional	RQL	LPP	
	Nozzle	Conventional	Conventional & Acoustic Liner	Mixed Ejector	Mixer Ejector & Acoustic Liner
Aero	Low Speed	Conventional Flaps	Conventional Flaps & Slots	C C	
	High Speed	Conventional	LFC	NLFC	HLFC
Struct	Materials	Aluminum	Titanium	High Temp. Composite	
	Process	Chordwise Stiffened	Spanwise Stiffened	Monocoque	Hybrid

Figure 1: Morphological Matrix.

2.3 Step 4: Technology Alternatives Assessment

2.3.1 Technology Maturity

Technology maturity is a measure of the flight readiness of a considered technical approach, also a measure of the risk associated with a particular approach in the specified application and environment. **Technology Readiness Level (TRL)** is a commonly used measure of technical maturity.

2.3.2 Methods for Readiness Assessments

1. Individual estimation
2. Group discussion estimation
3. Individual-group estimation
4. Calculator Based approaches (AFRL TRL Calculator)

2.3.3 Measures of Difficulty

1. **Research Development Degree of Difficulty** ($R\&D^3$): Measure of how much difficulty is expected to be encountered in the maturation of a particular technology.
2. **Advancement Degree of Difficulty** (AD^2): What is required to advance the immature technologies from their current TRL to a level that permits infusion into the program/project within cost, schedule, and risk constraints.

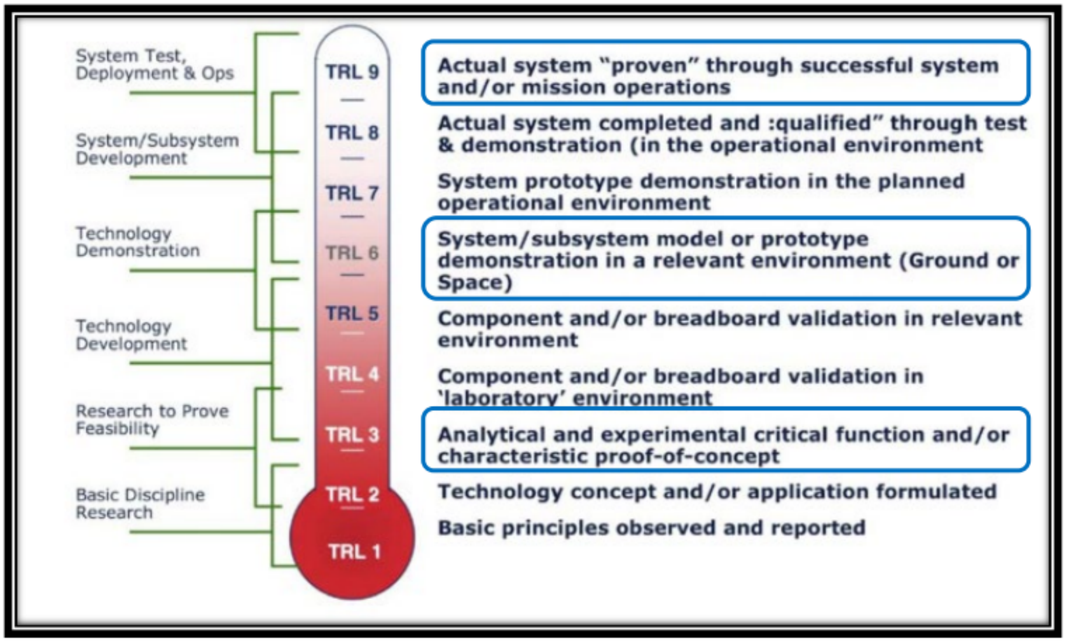

Figure 2: Technology Readiness Level (TRL).

2.3.4 Manufacturing Readiness Level (MRL)

Manufacturability is the characteristics in the design cycle that focus on process capabilities, machine or facility flexibility, and the overall ability to consistency produce at the required level of cost and quality.

MRL is designed to be measures used to assess the maturity of a given technology from a manufacturing perspective. It provides the ability to harness the manufacturing, production, quality assurance, and industrial functions to achieve an operational capability that satisfies mission needs.

2.3.5 Integration Readiness Level (IRL)

IRL is the systematic measurement of the interface of compatible interactions for various technologies and the consistent comparison of the maturity between integration points. Index must consider physical properties, interaction, compatibility, reliability, quality, performance, and consistent ontology when two pieces are being integrated.

2.3.6 Systems Readiness Level (SRL)

SRL is designed to be a function of the individual TRLs in a system and their subsequent integration points with other technologies, IRL.

2.4 Step 5: Physical Interfaces Definition

Normally we use N-squared diagram helps define and record where interfaces exist. Incompatibilities are considered among architecture options to reduce the combinatorial space.

IRL	Definition [9]
7	The integration of technologies has been ***verified and validated*** with sufficient detail to be actionable.
6	The integrating technologies can ***accept, translate, and structure information*** for its intended application.
5	There is sufficient ***control*** between technologies necessary to establish, manage, and terminate the integration.
4	There is sufficient detail in the ***quality and assurance*** of the integration between technologies.
3	There is ***compatibility*** (i.e. common language) between technologies to orderly and efficiently integrate and interact.
2	There is some level of specificity to characterize the ***interaction*** (i.e. ability to influence) between technologies through their interface.
1	An ***interface*** (i.e. physical connection) between technologies has been identified with sufficient detail to allow characterization of the relationship.

Figure 3: Integration Readiness Level (IRL).

- **Level 1: Operations and Support, 0.9-1.0**
  - Execute a support program that meets operational support performance requirements and sustains the system in the most cost-effective manor over its total life cycle
- **Level 2:Production and Development, 0.8-0.9**
  - Achieve operational capability that satisfies mission needs
- **Level 3: Engineering and Manufacturing Development, 0.5-0.8**
  - Develop a system or increment of capability; reduce integration and manufacturing risk; ensure operational supportability; reduce logistics footprint; implement human systems integration; design for producibility; ensure affordability and protection of critical information; and demonstrate system integration, interoperability, safety, and utility
- **Level 4: Technology Development, 0.2-0.5**
  - Reduce technology risks and determine appropriate set of technologies to integrate into full system
- **Level 5: Concept Refinement, 0.1-0.2**
  - Refine initial concept. Develop a system/technology development strategy

Figure 4: System Readiness Level (SRL).

2.4.1 External Versus Internal Interfaces

External interface requirements are established with other system level requirements. **Internal interface requirements** are different because they are created as part of system decomposition.

2.4.2 Internal Interfaces Management

System decomposition creates a set of subsystems and the interfaces between them. Ownerships of the subsystem interfaces are usually not obvious, which will let the project run the risk of future interface incompatibility. Therefore, we need to explicitly identify the owner of every interface. Good ways for interface design:

1. **Low Coupling:** Coupling is a measure of the relative dependence or information

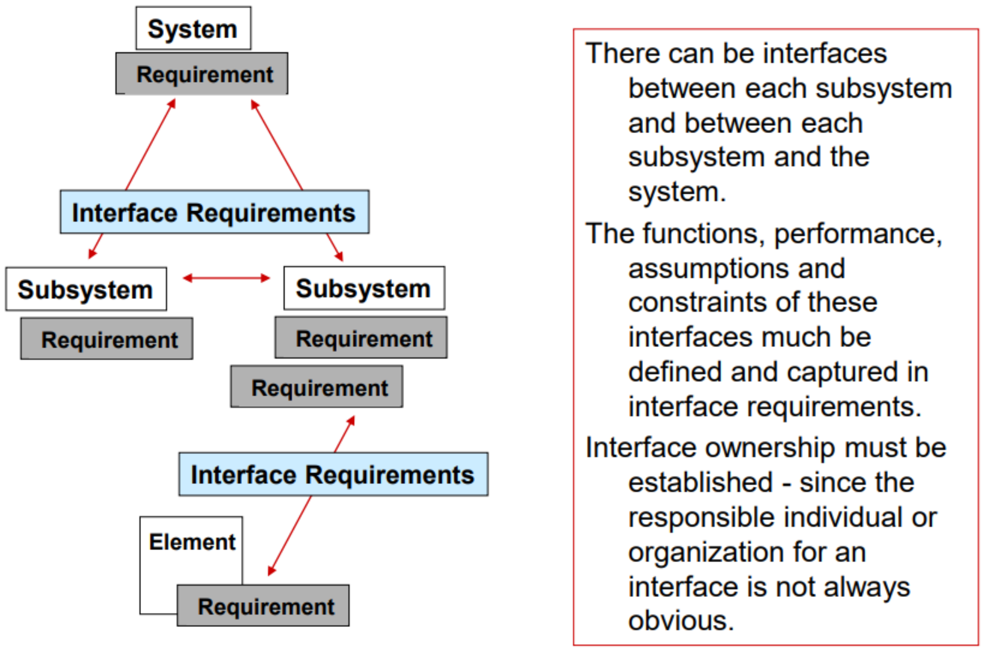

Figure 5: Interface Requirements.

shared between subsystems. Low coupling results in a system that is less prone to 'ripple effects' when errors or changes occur within a subsystem.

2. **High Cohesion:** Cohesion is a measure of the similarity of tasks performed within a subsystem. High cohesion allows for use of identical or similar parts, or for use of a single component to perform multiple functions.

3. **Low Connectivity:** 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.

2.5 Step 6,7,8,9: Decision Making

2.5.1 Definition

Decision making is the process of sufficiently reducing uncertainty and doubt about alternatives to allow a reasonable choice to be made from the alternatives.

2.5.2 Decision Making Methods

1. **Squeaking Wheel:** cut resources from every area and then wait and see which area complains the most. Based on the loudest and most insistent, then restore budget until ceiling is hit.

2. **Level Funding:** budget perturbations minimized and status quo maintained; if this approach continues within a rapidly changing technology field, the company, group, or agency will end up in serious trouble.

3. **Glorious Past:** once successful, always successful". Assign resources solely on past record of achievement.

4. **White Charger:** best speaker or last person to brief the boss wins the money or whichever department has the best presentation.

5. **Committee Approach:** a committee tells the manager or decision maker how to allocate resources.

2.5.3 Heuristic vs Analytic Decision Making

Heuristic Decision Making	Analytic Decision Making
Reach decisions by acting	Reach decisions by analyzing
Uses trial and error	Uses step-by-step procedure
Values experience	Values quantitative information and models
Relies on common sense	Builds mathematical models and algorithms
Seeks completely satisfying solution	Seeks optimal solution

Figure 6: Heuristic vs Analytic Decision Making.

2.5.4 Decision Making Process

1. **Intelligence Phase:** Sensing, finding, identifying, and defining problem/opportunity.

2. **Design Phase:** Generating alternatives.

3. **Choice Phase:** Choosing the best alternative.

4. **Implementation Phase:** Implementing the selected solutions and getting feedback.

2.5.5 Components of Decision

1. **Alternatives:** Specific Courses of action or options, being considered

2. **Criteria:** The standards by which decision makers (DM) evaluate alternatives

3. **Preference:** A real or imagined "choice" between alternatives and the possibility of rank ordering of these alternatives

4. **Cause and Effect:** The linkages between the alternatives and specific criteria

2.5.6 Decision Making Strategies

1. **Optimizing:** selecting the one as the best alternative if it has the maximum/ minimum value of a predefined utility index function

2. **Satisficing:** selecting the alternative solution which achieves at least a minimum level of each criteria