

# SYSTEMS ENGINEERING

**ME 481 Senior Design**

**Fall 2021**

**Dr. Trevor C. Sorensen**

---

# Definition of a System

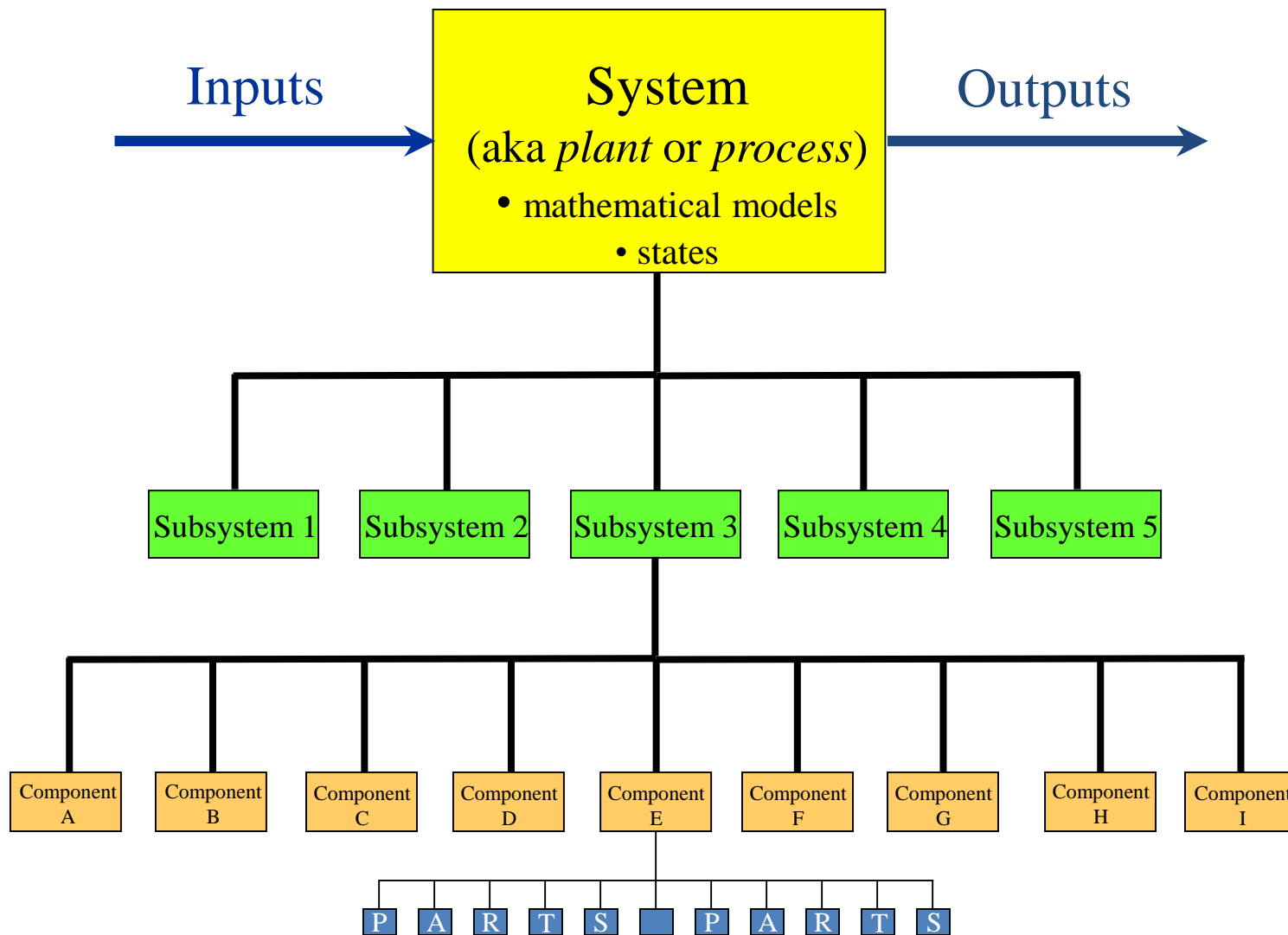
# Definition of a System

---

- A “system” is a construct or collection of different elements that together produce results not obtainable by the elements alone.
- The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce system-level results.

Source: NASA Systems Engineering Handbook

# Definition of a System



---

# Systems Engineering

# Systems Engineering

- Systems engineering is the *art and science* of *Holism* is the idea that systems and their properties should be viewed as wholes, not just as a collection of parts. of meeting requirements within often opposed constraints including *performance, cost, risk, and schedule*.
- Systems engineering is the application of *holistic* *technical* and *management* efforts to transform mission requirements into a description of system performance parameters and system configuration through an iterative process of *definition, synthesis, analysis, design, test, and evaluation*.
- Systems engineering should emphasize good engineering judgment as well as technical capabilities.

# Systems Engineering

- Technical issues should be resolved in context of the full system and mission objectives.
- Systems engineering requires a *team effort* for maximum effectiveness (the synergistic approach) and usually includes experienced multi-discipline engineers capable of understanding the technical and programmatic areas sufficiently to comprehend the issues and information available, while performing the technical analyses and modeling required.

# Systems Engineering

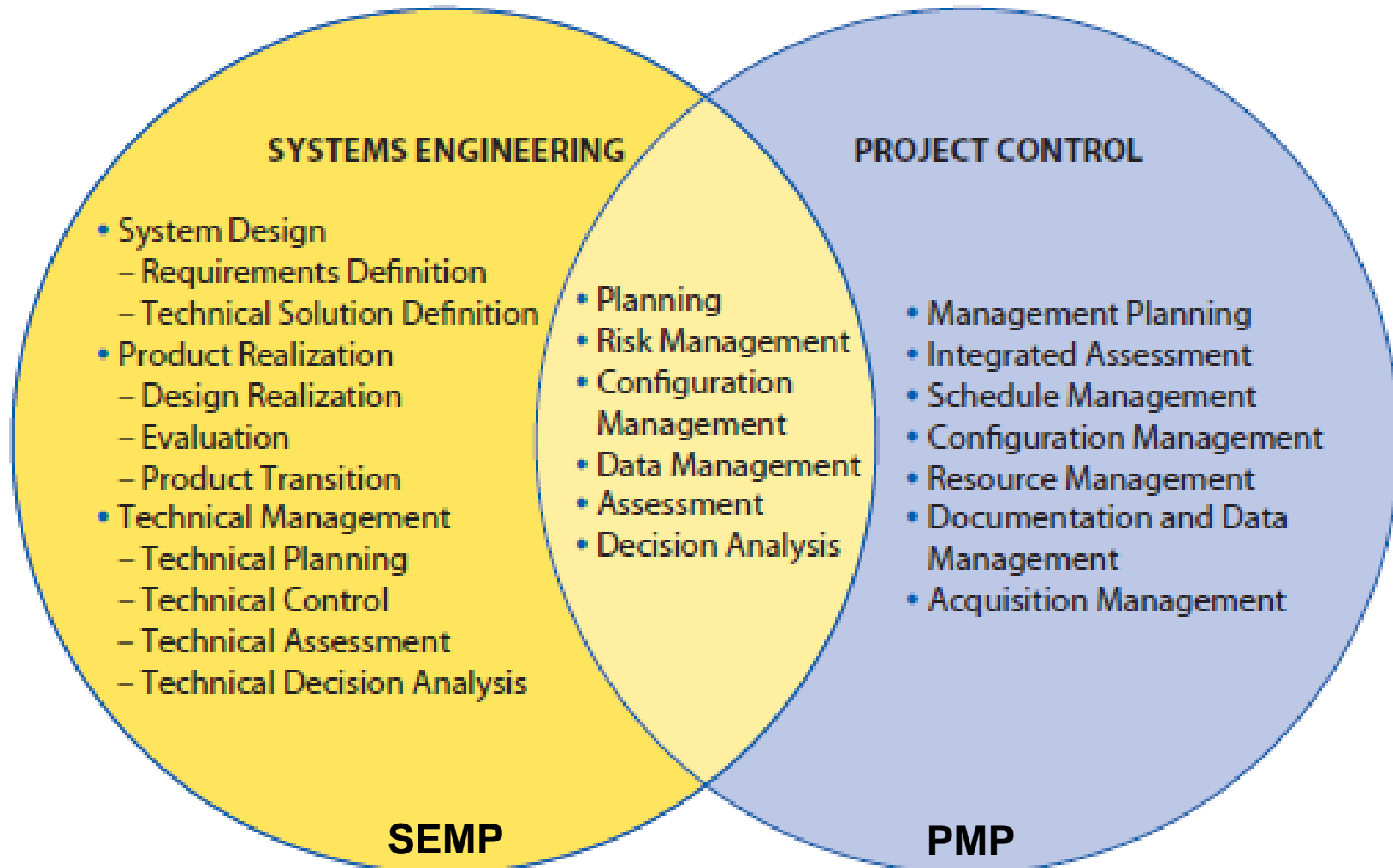
## Systems Engineering Management Plan

- Any systems engineering effort should be preceded with the development of a *Systems Engineering Plan (SEP)* or *Systems Engineering Management Plan (SEMP)*.
- The SEMP is a plan for doing the project technical effort by a technical team for a given WBS model in the system structure and to help meet life-cycle phase success criteria.
- The SEMP is the rule book that describes to all participants how the project will be technically managed. It is subordinate to the Project Management Plan (PMP).
- The project SEMP is the senior technical management document for the project: all other technical plans must comply with it. *The SEMP must be regularly updated.*
- The SEMP should be comprehensive and describe how a fully integrated engineering effort will be managed and conducted.



# Systems Engineering

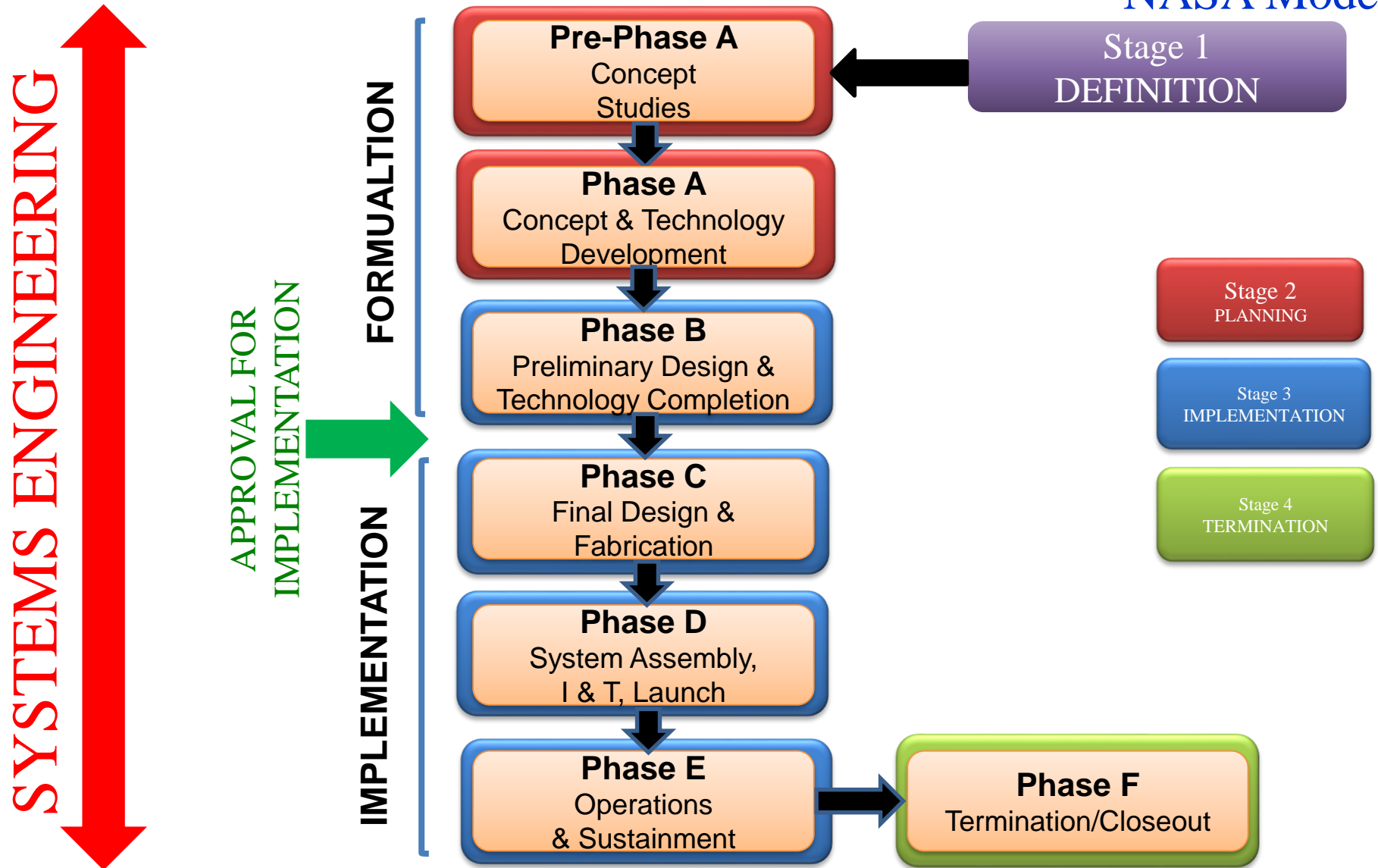
## SE in Context of Overall Project Management



Source: NASA Systems Engineering Handbook

# Systems Engineering

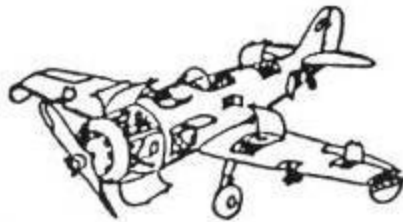
## NASA Model



---

What happens if you  
ignore systems  
engineering throughout  
the design life-cycle?

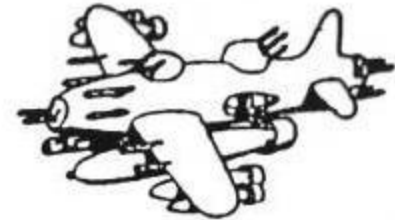
# Perfect Airplane as Designed by Each Engineering Group



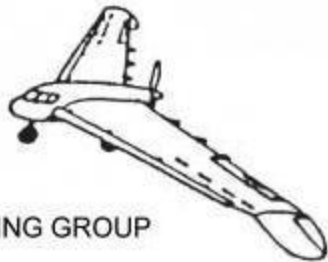
SERVICE GROUP



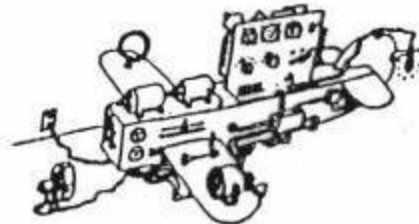
EQUIPMENT GROUP



ARMAMENT GROUP



WING GROUP



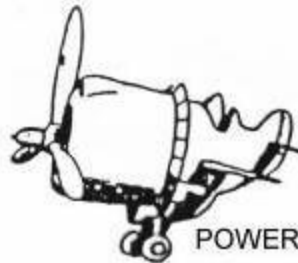
ELECTRICAL GROUP



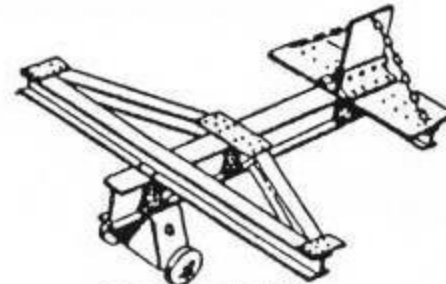
AERODYNAMICS GROUP



EMPENNAGE GROUP



POWER PLANT GROUP



STRESS GROUP

Source: Technical University of Delft

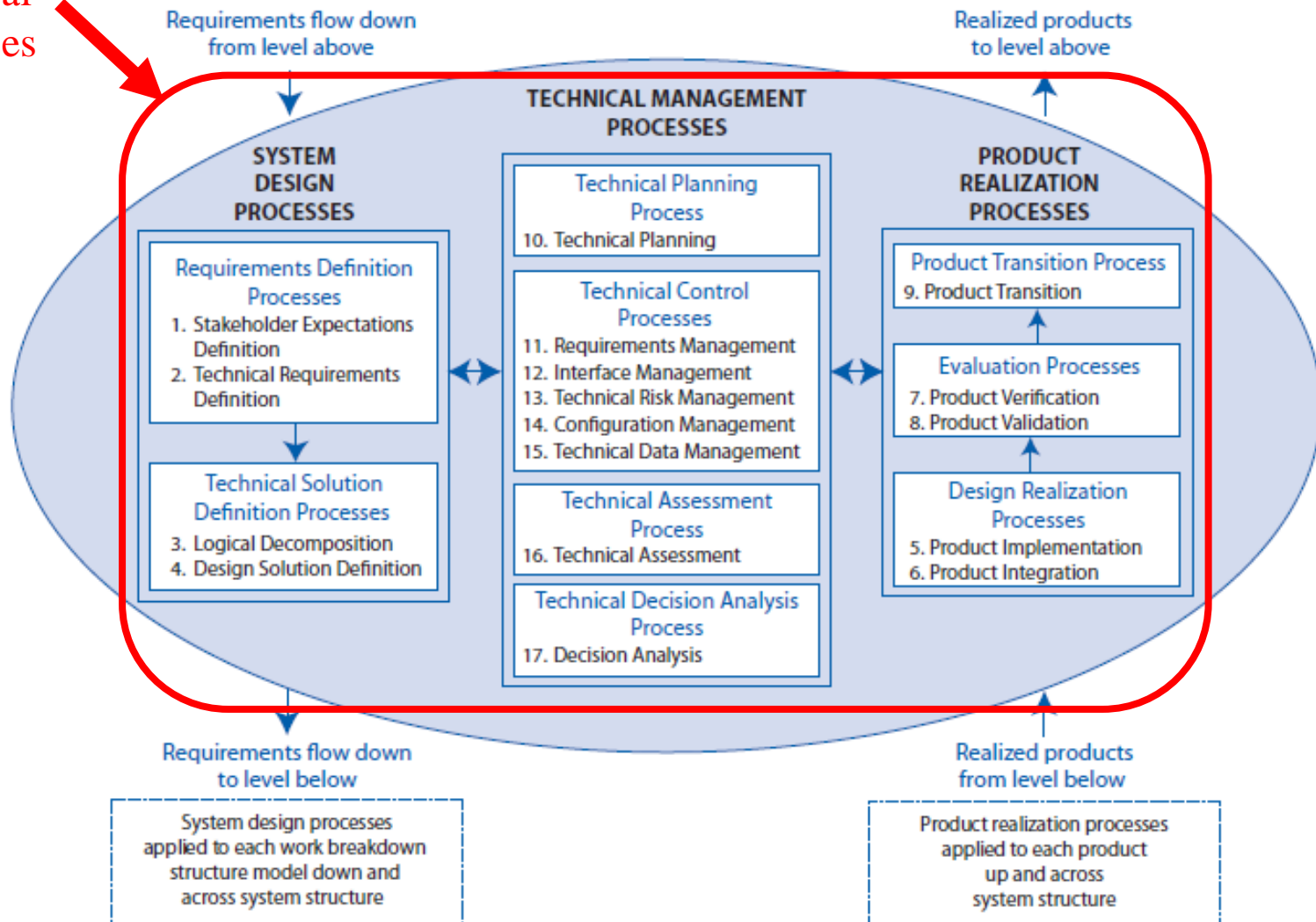
---

# Systems Engineering Methodology

# Systems Engineering Methodology

## Systems Engineering Engine

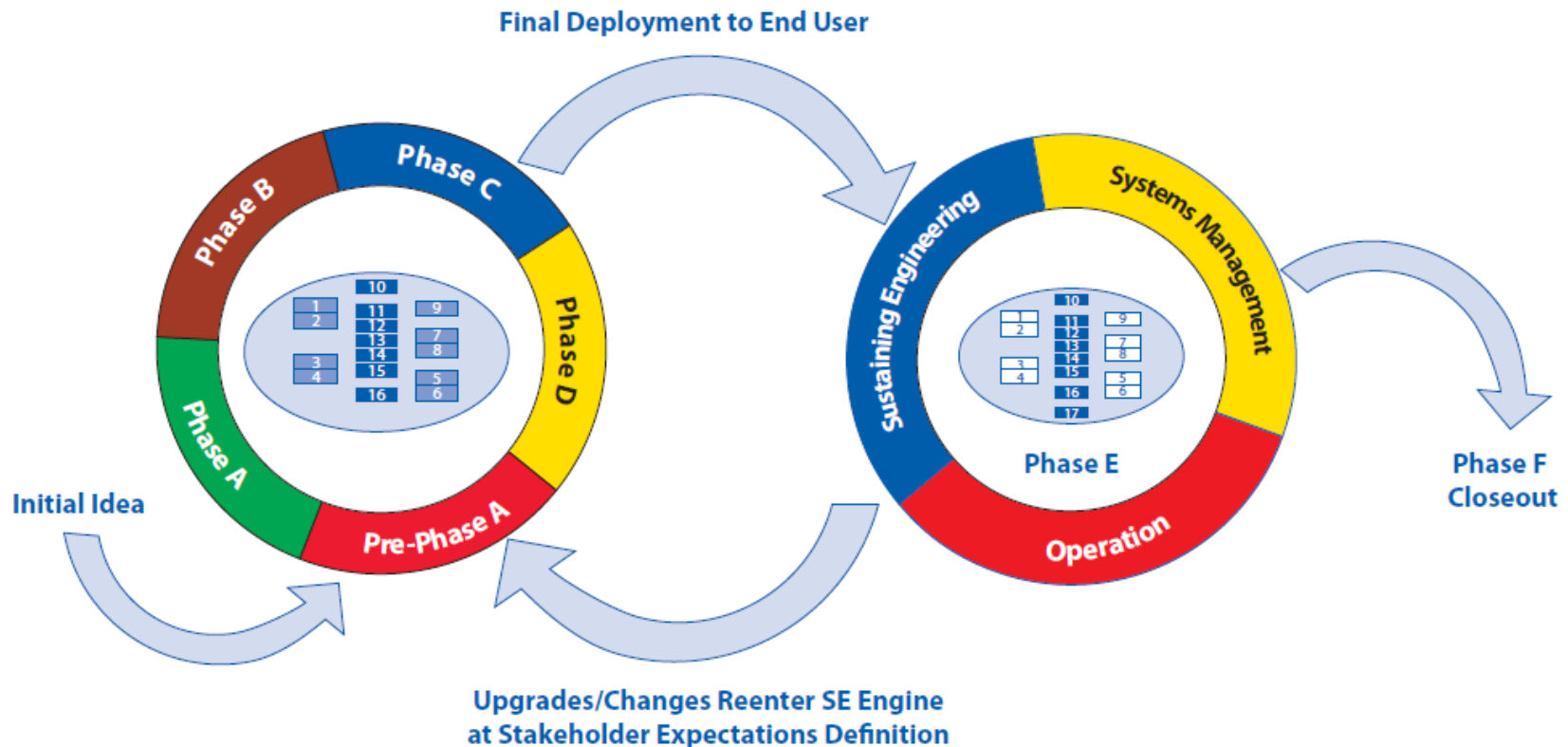
17 common  
technical  
processes



Source: NASA Systems Engineering Handbook

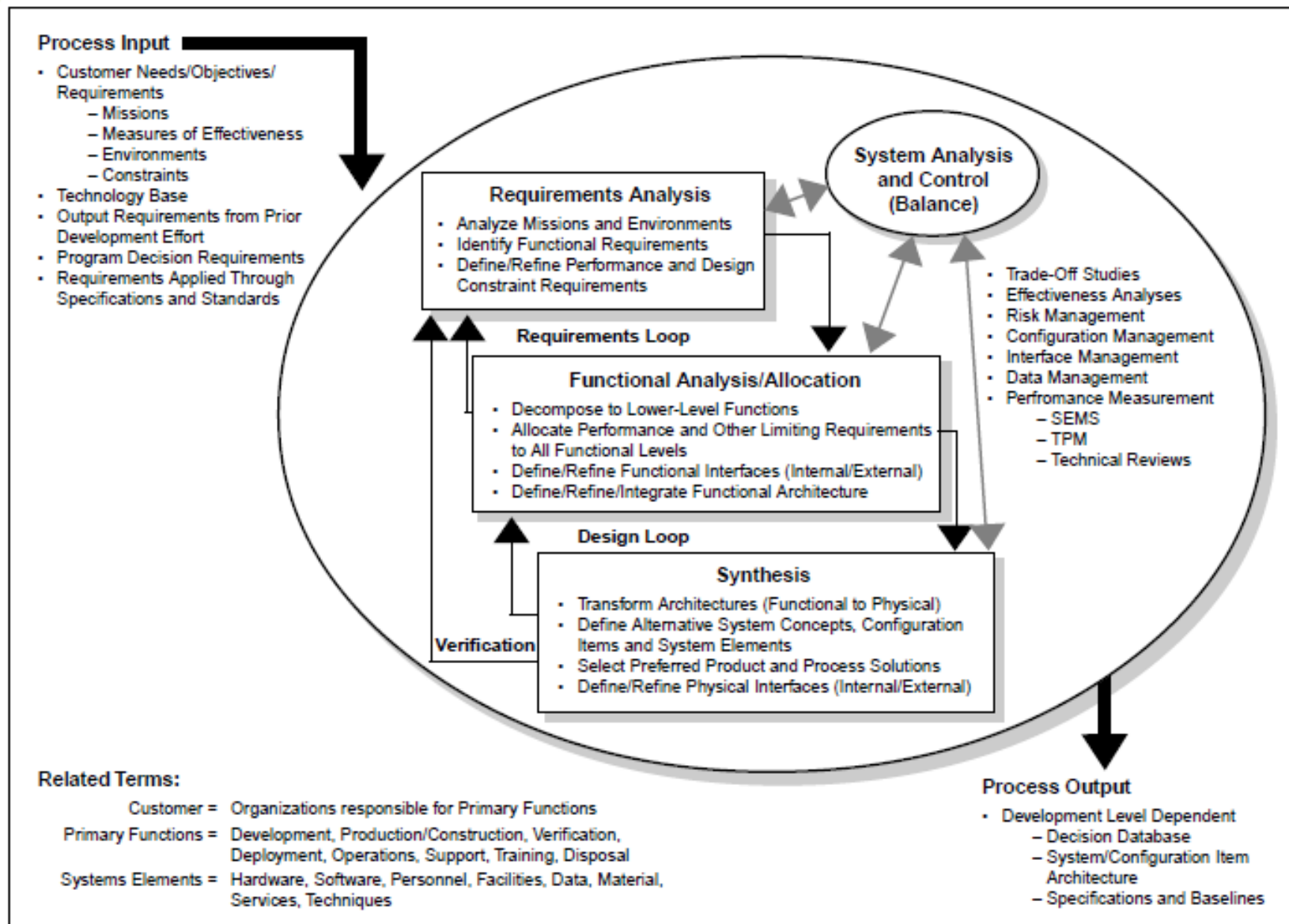
# Systems Engineering Methodology

## New Products or Upgrades Entering the SE Engine



Source: NASA Systems Engineering Handbook

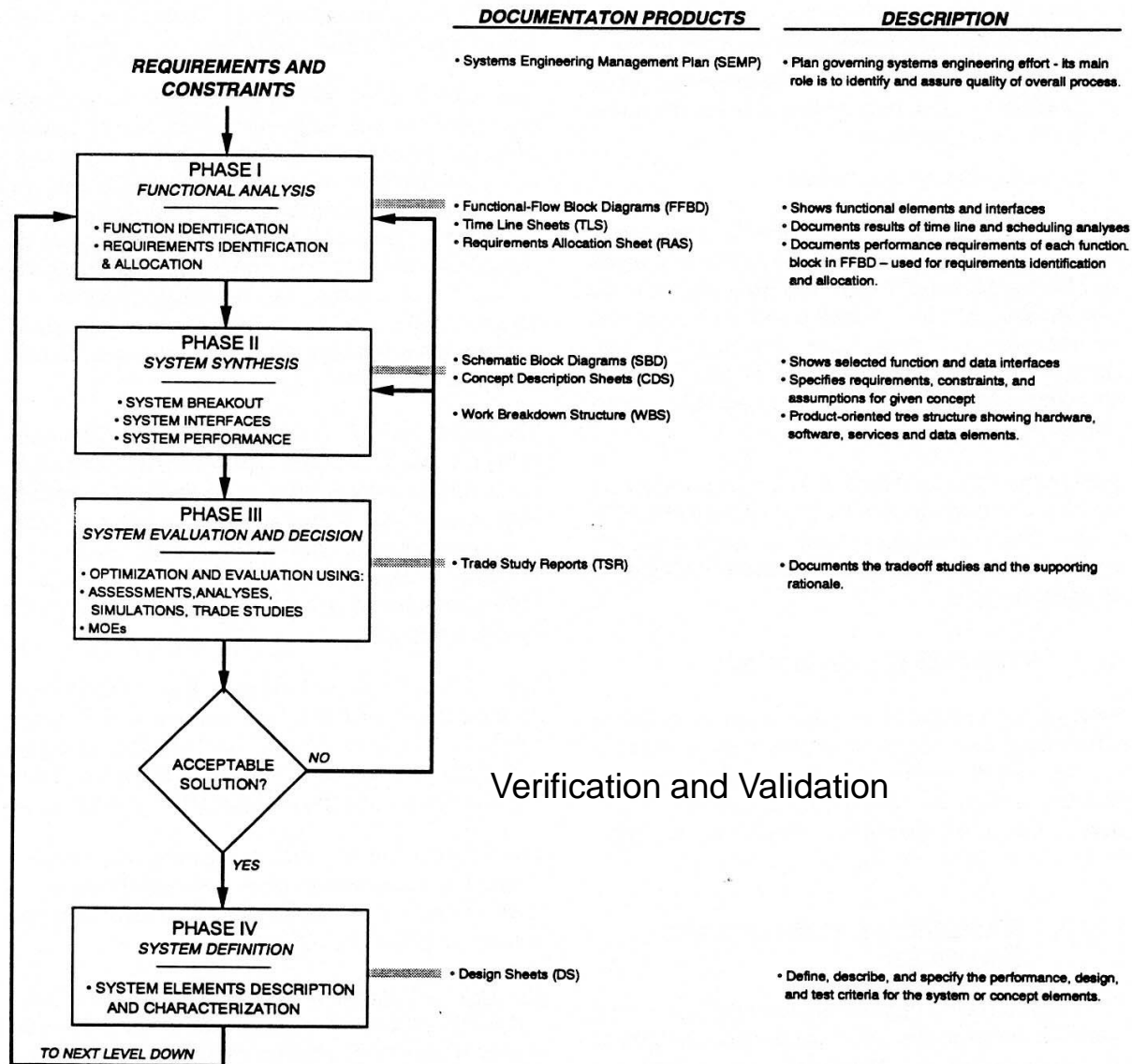
# Systems Engineering Methodology



Source: DOD Systems Engineering Fundamentals



# Systems Engineering Methodology



A91-0873 1/18 R1

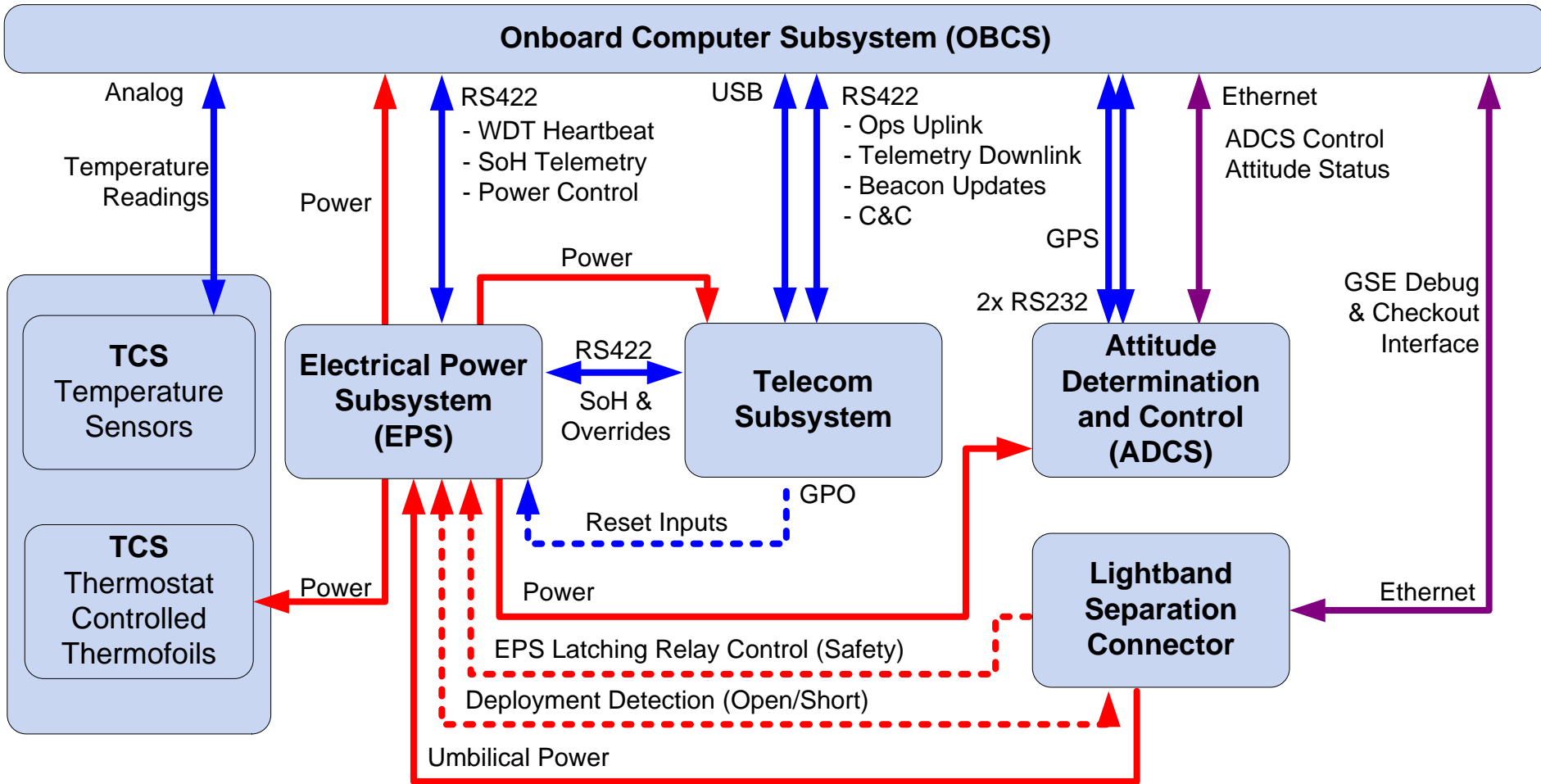
# Systems Engineering Methodology

## Phase I – Functional Analysis

- The systems engineering process translates the defined mission/system requirements into engineering criteria and definitions by performing the following phases:
  - PHASE I - Functional Analysis
    - The initial functional analysis effort expresses the specified performance requirements in functional and engineering terms. This involves the creation of mathematical models for the various system functions or components.
    - Interaction between various subsystems and technology area is essential for understanding the impact of requirements on the complete system.
    - ***Functional-flow block diagrams (FFBD)*** are developed to demonstrate the relationships of major mission/system elements within a system.

# Systems Engineering Methodology

## Functional Flow Block Diagram for Hawai'iSat-1 Bus



# Systems Engineering Methodology

## Phase II – System Synthesis

- Data established during functional analysis is expanded by a system breakout effort. Interfaces that are required to provide compatibility and system flow amongst the various subsystems and modules are identified and described. Data generated includes *schematic block diagrams (SBD)* and more detailed functional description or mathematical models of the system components. During this phase the *Work Breakdown Structure (WBS)* for this level is developed.
- The WBS is a key product. It is the foundation for program planning, cost estimation, schedule and budget formulation, specifications, progress status reporting, and problem analysis.
- To quantify system performance, three main techniques are used: *system algorithms*, *analogies* with existing or previous systems, and *simulations*.

# Systems Engineering Methodology

## LEO-1 Project WBS

<div>▣ 1.0 Project Management &amp; Systems Engineering</div> <div>1.1 Management &amp; Administration</div> <div>1.2 Systems Engineering</div> <div>1.3 Quality &amp; Safety Assurance</div> <div>1.4 Configuration Management</div> <div>1.5 Documentation</div> <div>1.6 Technical Reviews</div> <div>1.7 Conferences &amp; Presentations</div> <div>1.8 Outreach</div> <div>▣ 2.0 Spacecraft Bus</div> <div>▣ 2.1 Avionics</div> <div>2.1.1 Segment Management</div> <div>2.1.2 Requirements Analysis</div> <div>▣ 2.1.3 Command &amp; Data Handling Subsystem (C&amp;DH)</div> <div>2.1.3.1 Task Management</div> <div>2.1.3.2 Requirements Analysis</div> <div>2.1.3.3 Subsystem Design</div> <div>2.1.3.4 Procurement/Vendor Monitoring</div> <div>2.1.3.5 Fabrication</div> <div>2.1.3.6 Testing (SS Level)</div> <div>2.1.3.7 Integration &amp; Testing (System Level)</div> <div>▣ 2.1.4 Electrical Power Subsystem (EPS)</div> <div>2.1.4.1 Task Management</div> <div>2.1.4.2 Requirements Analysis</div> <div>2.1.4.3 Subsystem Design</div> <div>2.1.4.4 Procurement/Vendor Monitoring</div> <div>2.1.4.5 Fabrication</div> <div>2.1.4.6 Testing (SS Level)</div> <div>2.1.4.7 Integration &amp; Testing (System Level)</div> <div>▣ 2.1.5 Telecommunications Subsystem (Telecom)</div> <div>2.1.5.1 Task Management</div> <div>2.1.5.2 Requirements Analysis</div> <div>2.1.5.3 Subsystem Design</div> <div>2.1.5.4 Procurement/Vendor Monitoring</div> <div>2.1.5.5 Fabrication</div> <div>2.1.5.6 Testing (SS Level)</div> <div>2.1.5.7 Integration &amp; Testing (System Level)</div> <div>▣ 2.1.6 Flight Software (FSW)</div> <div>2.1.6.1 Task Management</div> <div>2.1.6.2 Requirements Analysis</div> <div>2.1.6.3 Design</div> <div>2.1.6.4 Implementation</div> <div>2.1.6.5 Integration &amp; Testing (System Level)</div> <div>2.1.7 Integration &amp; Testing (System Level)</div>	<div>2.1.7 Integration &amp; Testing (System Level)</div> <div>▣ 2.2 Mechanical Systems</div> <div>2.2.1 Segment Management</div> <div>2.2.2 Requirements Analysis</div> <div>▣ 2.2.3 Structures &amp; Mechanisms (S&amp;M)</div> <div>2.2.3.1 Task Management</div> <div>2.2.3.2 Requirements Analysis</div> <div>2.2.3.3 Subsystem Design</div> <div>2.2.3.4 Procurement/Vendor Monitoring</div> <div>2.2.3.5 Fabrication</div> <div>2.2.3.6 Testing (SS Level)</div> <div>2.2.3.7 Integration &amp; Testing (System Level)</div> <div>▣ 2.2.4 Attitude Determination &amp; Control Subsystem (ADCS)</div> <div>2.2.4.1 Task Management</div> <div>2.2.4.2 Requirements Analysis</div> <div>2.2.4.3 Subsystem Design</div> <div>2.2.4.4 Procurement/Vendor Monitoring</div> <div>2.2.4.5 Fabrication</div> <div>2.2.4.6 Testing (SS Level)</div> <div>2.2.4.7 Integration &amp; Testing (System Level)</div> <div>▣ 2.2.5 Thermal Control Subsystem (TCS)</div> <div>2.2.5.1 Task Management</div> <div>2.2.5.2 Requirements Analysis</div> <div>2.2.5.3 Subsystem Design</div> <div>2.2.5.4 Procurement/Vendor Monitoring</div> <div>2.2.5.5 Fabrication</div> <div>2.2.5.6 Testing (SS Level)</div> <div>2.2.5.7 Integration &amp; Testing (System Level)</div> <div>2.2.6 Integration &amp; Testing (System Level)</div> <div>▣ 2.3 Payload Systems</div> <div>2.3.1 Segment Management</div> <div>2.3.2 HSFL Imager</div> <div>2.3.3 RADCAL II</div> <div>2.3.4 CERTO Beacon</div> <div>2.3.5 GPSRO</div> <div>2.3.6 Integration &amp; Testing (System Level)</div>
--	---

# Systems Engineering Methodology

## Phase III – System Evaluation and Decision

- Evaluation, optimization, and selection of promising system concepts are done using trade studies, technical analyses, and simulations. Risk, life cycle, and effectiveness assessments are also factored into the evaluation.

### *1. Trade Studies*

- System trades consist of selecting and analyzing system drivers which determine mission performance. These parameters can then be used for performance analysis and utility analysis.

# Systems Engineering Methodology

## Phase III – Steps for System Trades

1. Select trade parameter (typically system driver)
2. Identify factors which affect the trade parameter or are affected by it
3. Assess impact of each factor
4. Summarize and document results
5. Select parameter value and possible range (margin)

*Be aware of parameters with multiple effects on system*



# Systems Engineering Methodology

## COTS Software Trade Study for DataLynx

		Company	Science Systems	Altair Aerospace	JPL	SpectrumAstro	STI	Cisco	DataViews Corp.	Predict/IDU	Integral Systems Inc.	Microsoft	AI Solutions Inc.	Genzym	Pacific-Sierra Research	Research Systems	ILOG	ILOG	Storm Control Systems	National Instruments Inc.	L3	ADC Metrics	Monico, Inc.	GSFC	UDP Consulting	Optimal Networks	Integral Systems Inc.	Veda Systems Inc.	HP	Genzym	Matra Marconi	Matra Marconi	Science Systems	STI	GSFC	Polyhedra PLC	Visual Numerics	Talarian	Kinesix	Interface Control Systems	Lockheed Martin	Cabletron	Analytical Graphics Inc.	Sun Microsystems	Tivoli					
	Function	Product	Advanced SLICK (UNIT)	Altair AMCS	ASPEN	AstroDACS	CC/ObjBase	CiscoWorks	DataViews	EAV	Epoch 2000	Excel	FreeFlyer	G2	GREAS	IDL	ILOG Solver/Scheduler	ILOG Views	IMT	LabViews	L3 System 500 Model 550	Metrics	Monitor	MOPSS	NetLayer7	OAE & OAI	OASYS	Omega Toolkit	OpenView	Operations Expert	OpsCenter	OPSWARE	ORATOS	OS Comet	PARR	Polyhedra	PV-WAVE	RT Works	SAMMI	SCL	SCS 21	Spectrum	STK	Sun Solstice	TME 10					
Real-Time String																																																		
	Anomaly detection and response		x	x		x					x			x					x																															
	Command verification		x	x							x		x						x									x																						
	Constraint checking		x	x		x					x			x					x																															
	Control input		x	x		x			x		x			x				x	x		x																													
	Decommutation			x		x					x																																							
	Engineering data storage and retrieval		x	x		x	x				x																																							
	EU conversion		x	x		x					x																																							
	Frame synchronization			x		x					x																																							
	Mnemonic to binary conversion		x	x							x				x																																			
	Script processing		x	x							x				x																																			
	Remote data display																																																	
	S/C Telemetry display		x	x		x			x		x			x						x	x	x	x																											
	Data Security																																																	
Mission Planning																																																		
	Activity planning		x		x																																													
	Activity scheduling		x		x	x																																												
Flight Dynamics																																																		
	Attitude ephemeris generation																																																	
	Tracking data preprocessing																																																	
	Ephemeris generation																																																	
	Orbit determination																																																	



# Systems Engineering Methodology

## Phase III - Performance Assessment

- Three main methods are used to compute system performance:
  - *System Algorithms* - the basic physical or geometric formulas associated with a particular system or process (e.g., link budget). They provide best method for computing performance and provide clear traceability and establish relationship between design parameters and performance characteristics.
  - *Analogy with Existing Systems* - compares design with existing systems. Modifications are made based on differences between the systems.
  - *Simulation* - allows complex modeling and determination of multiple effects of various parameters. Because of time and resources required, this is usually only done for key performance parameters where more detail is required. Commercial tools (e.g., STK, SolidWorks Simulation) can make this option more readily and easily available at earlier phases of mission analysis.

# Systems Engineering Methodology

## Phase III – Evaluate System Utility

- System utility analysis quantifies system performance as a function of design, cost, risk, and schedule. It is used to:
  - Provide quantitative information for decision-making, and
  - Provide feedback on the system design.
- Two different types of quantities are generated and used in the mission utility analysis:
  - *Performance Parameters* - quantify how well the system works without measuring how well it meets mission objectives (e.g., coverage statistics, power efficiency, slew rate). They can usually be determined unambiguously by analysis or simulation.
  - *Measures of Effectiveness (MoEs)* or *Figures of Merit (FoMs)* - these quantify directly how well the system meets the mission objectives, usually expressed as a probability or degree of meeting the objective. It is often expressed as a percentage or a unitary value (between 0 and 1 where 0 means no merit or effectiveness and 1 means full merit or complete effectiveness).

# Systems Engineering Methodology

## Measures of Effectiveness

- Good MoEs must be:
  - Clearly related to the mission objectives
  - Understandable by decision makers
  - Quantifiable
  - Sensitive to system design (if used as a design criterion)
- MoEs can be related to discrete events (e.g., solar flare), coverage of a continuous activity, or timeliness of the information or other indicators of quality.

# Systems Engineering Methodology

## System Utility Simulation

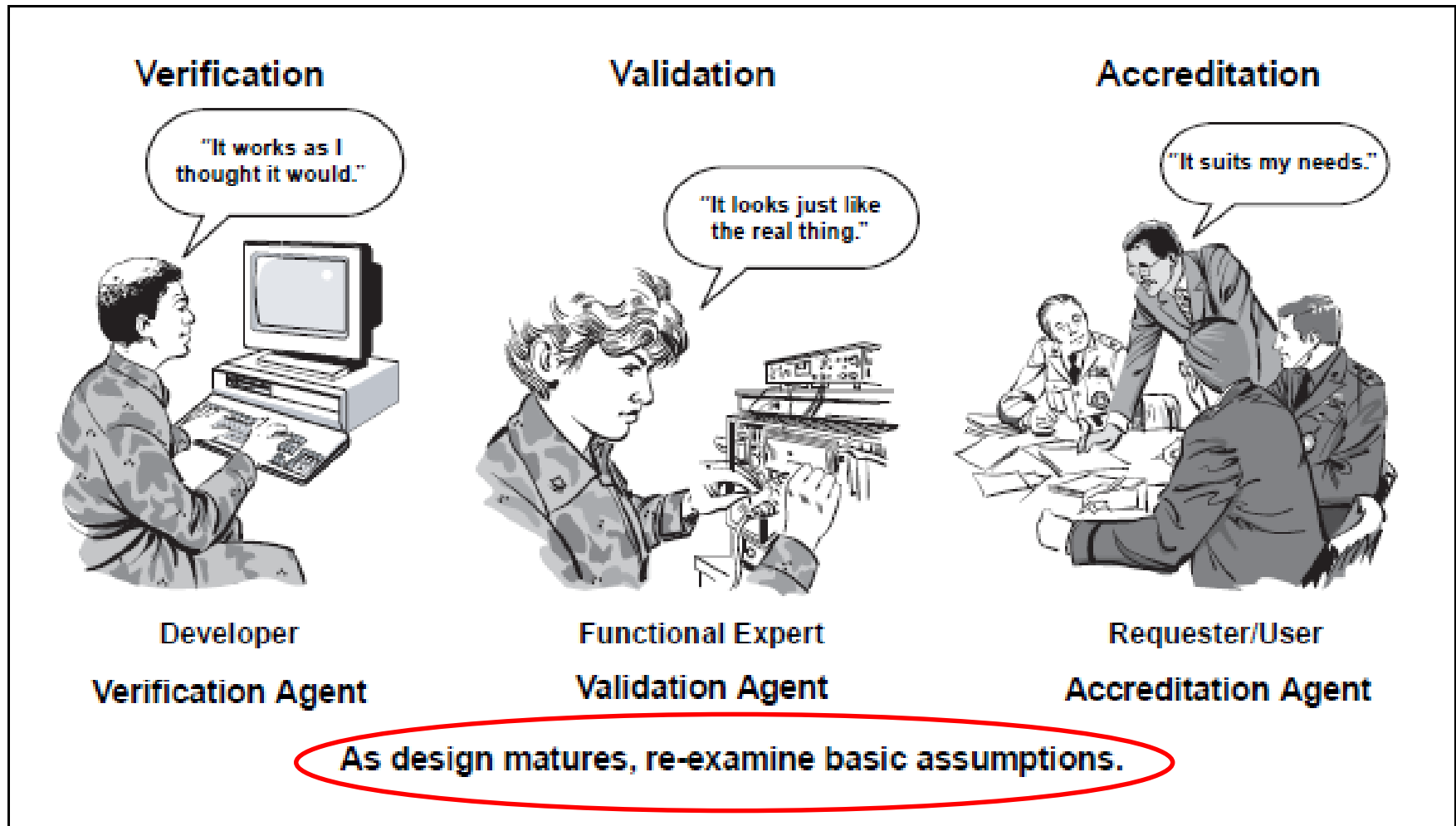
- System/mission utility analysis is used by top-level decision makers to make informed decisions based on solid technical grounds (in the perfect world!).
- Most effective way to evaluate the system utility is to use a *system/mission utility simulation* designed specifically for this purpose. The system simulator is separate from the payload simulator.
- The system simulator assumes a certain performance and by the payload and assesses its ability to meet system objectives.
- The goal of system utility simulation is to estimate MoEs as a function of the key system parameters.
- Collecting statistics on multiple simulation runs with varying conditions is called a *Monte Carlo simulation*. This usually provides a more viable set of evaluation data.
- KISS principle! Results must be usable and understandable.

# Systems Engineering Methodology

## Verification and Validation

- *Verification* of a product shows proof of compliance with requirements— that the product can meet each “shall” statement as proven through performance of a test, analysis, inspection, or demonstration.
- *Validation* of a product shows that the product accomplishes the intended purpose in the intended environment—that it meets the expectations of the customer and other stakeholders as shown through performance of a test, analysis, inspection, or demonstration.

# Systems Engineering Methodology



Source: DOD Systems Engineering Fundamentals

# Systems Engineering Methodology

## Phase IV – System Definition

- During system definition, the systems elements are described, and previously established data are numerically defined and expanded.

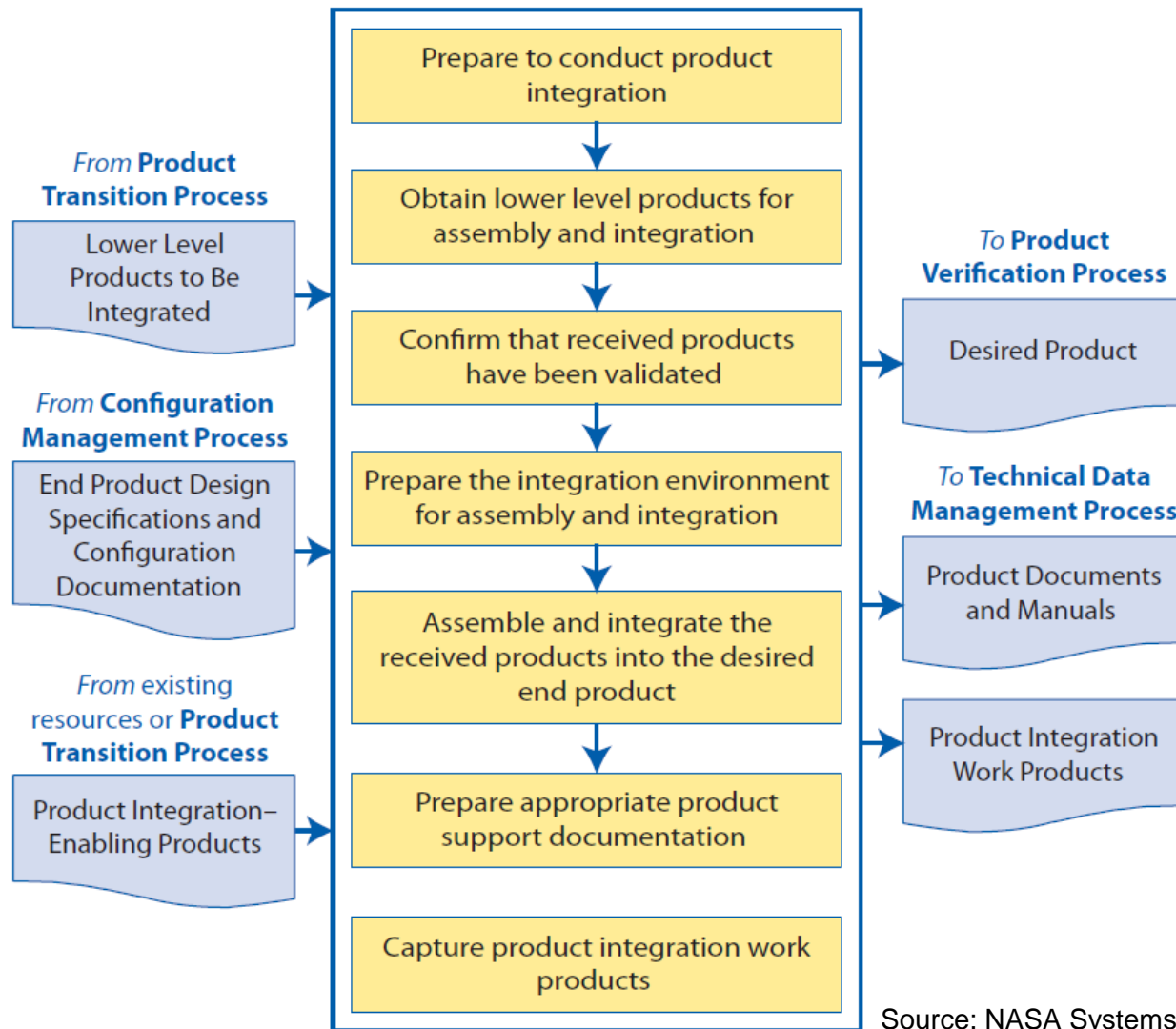
---

# Systems Engineering Processes



# Systems Engineering Processes

## Product Integration Process



Source: NASA Systems Engineering Handbook

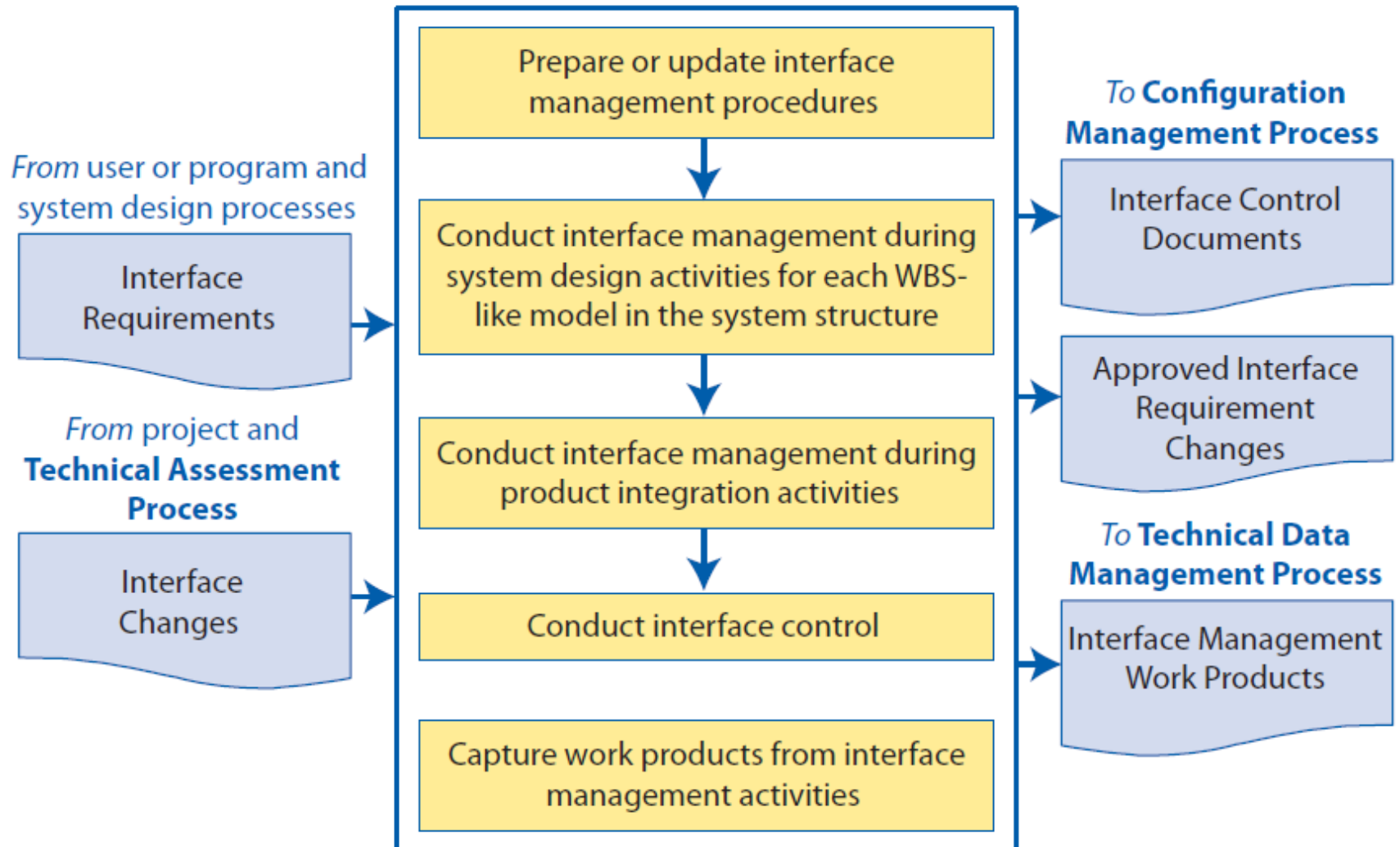
# Systems Engineering Processes

## Interface Management

- Objective of the interface management is to achieve functional and physical compatibility among all interrelated system elements.
- Documenting interfaces between system elements, segments or subsystems is done in the ***Interface Control Document (ICD)***.
  - The system-level ICD may be included in the system specification.
  - Each ICD usually covers the interface between only two different segments, otherwise it will become too complex (e.g., Space-to-Ground ICD)
  - ICDs always address physical and data or signal interfaces and interactions. They should be very specific to avoid ambiguity or misinterpretation (e.g., pin connection allocation, data formats). ICDs should be under configuration control and each ICD should have an identified owner (HABE example).

# Systems Engineering Processes

## Interface Management Process



Source: NASA Systems Engineering Handbook

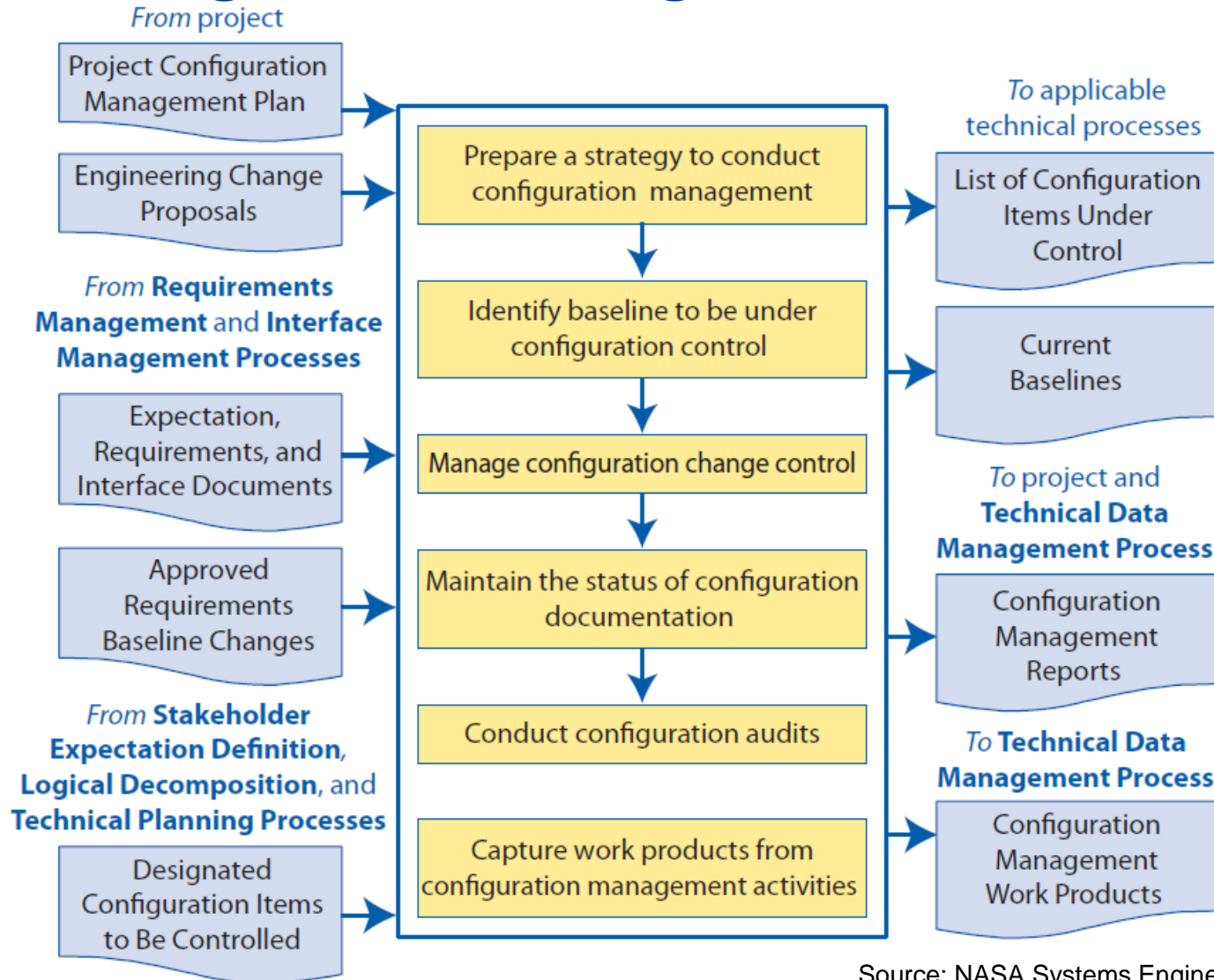
# Systems Engineering Processes

## Configuration Management (CM)

- CM is a management discipline applied over the product's life cycle to provide visibility into and to control changes to performance and functional and physical characteristics and ensures that:
  - the configuration of a product is known and reflected in product information
  - any product change is beneficial and is effected without adverse consequences
  - changes are managed
  - technical risks are reduced by ensuring correct product configurations distinguishes among product versions
  - there is consistency between the product and information about the product
  - the embarrassment of stakeholder dissatisfaction and complaint is avoided
- The first step is to establish a robust and well-disciplined internal Configuration Control Board (CCB) system, which is chaired by someone with project change authority.

# Systems Engineering Processes

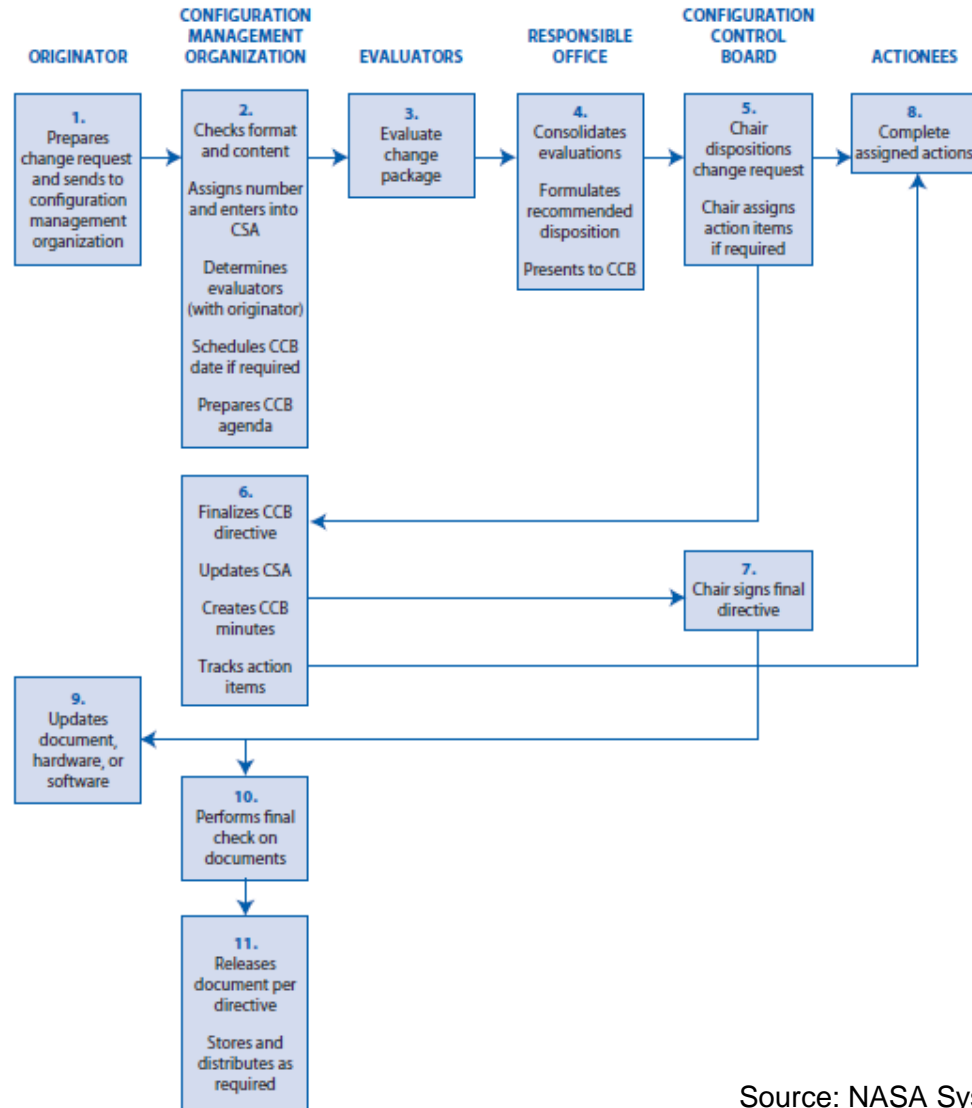
## Configuration Management Process



Source: NASA Systems Engineering Handbook

# Systems Engineering Processes

## Typical Configuration Control Process



Source: NASA Systems Engineering Handbook

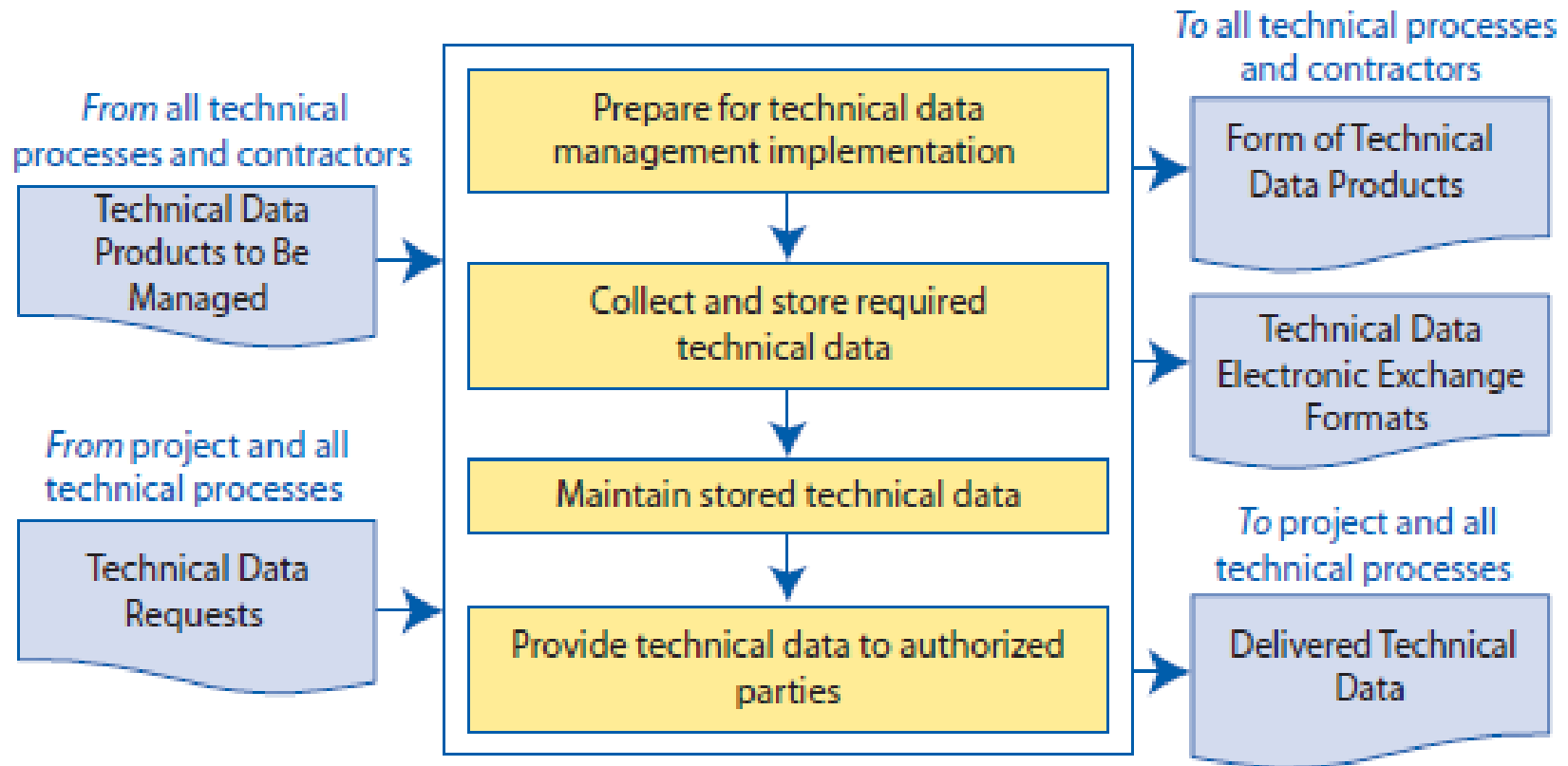
# Systems Engineering Processes

## Data Management

- *Data* is defined as recorded information, regardless of form or characteristic, and includes all the administrative, management, financial, scientific, engineering, and logistics information and documentation required for delivery from the contractor.
- Contractually required data are classified as one of three types:
  - Type I: Technical data
  - Type II: Non-technical data
  - Type III: One-time use data (technical or nontechnical)
- Data are acquired for two basic purposes:
  - Information feedback from the contractor for program management control, and
  - Decision making information needed to manage, operate, and support the system (e.g., specifications, technical manuals, engineering drawings, etc.).

# Systems Engineering Processes

## Technical Data Management Process



Source: NASA Systems Engineering Handbook



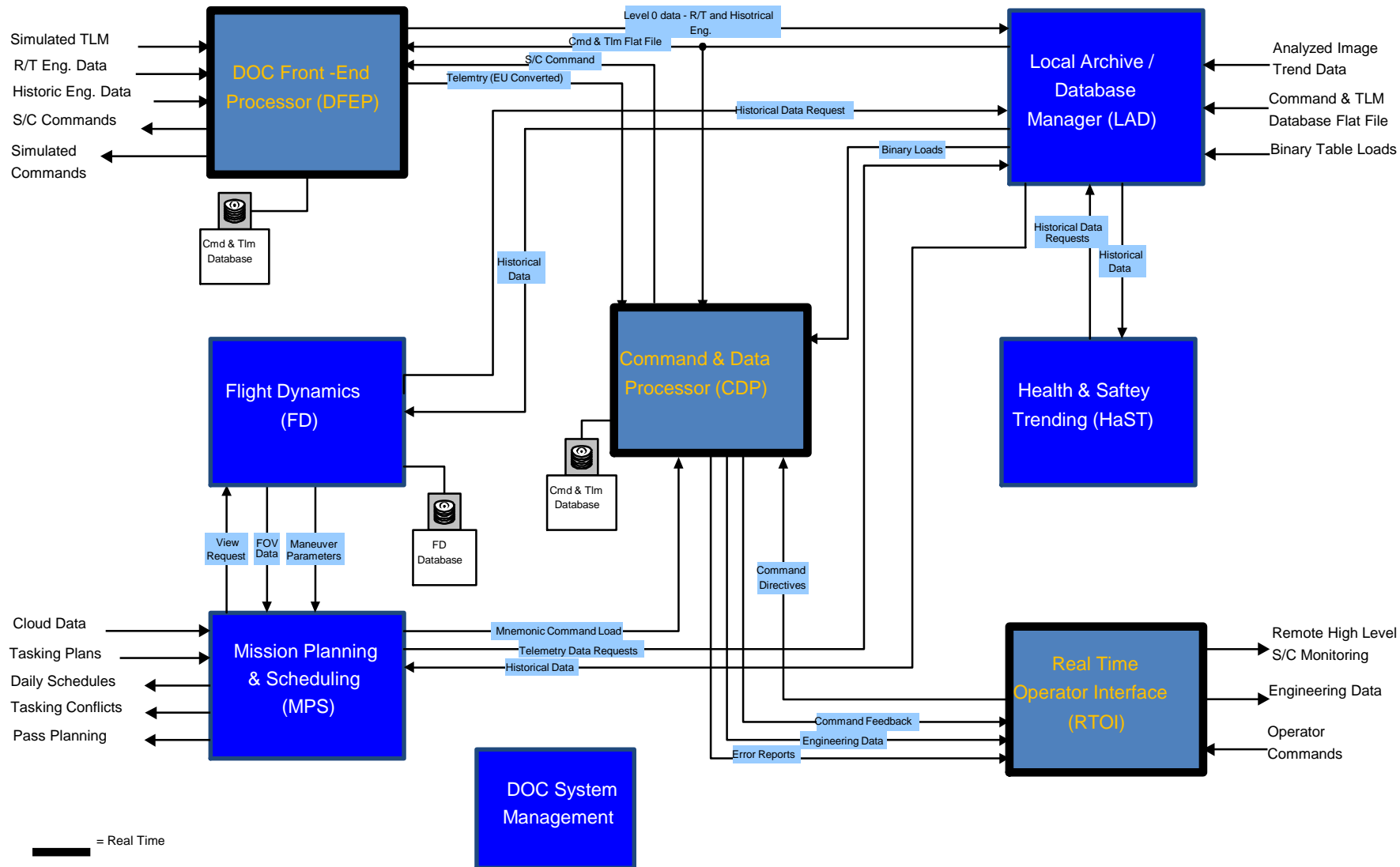
# Systems Engineering Processes

## Data Management Process

- First step after identifying the data to be handled is to perform a *data-flow analysis*
  - This defines where the data originate and what happens to the data until they reach the final end-user
- To examine the data flow draw a data-flow diagram which can either be a *block diagram* or a *bubble diagram* (*see DataLynx example*)
  - The data-flow diagram identifies the tasks involved in data management and the input and output data flows
  - In early concept development, although the tasks might be identified, how to accomplish them is not

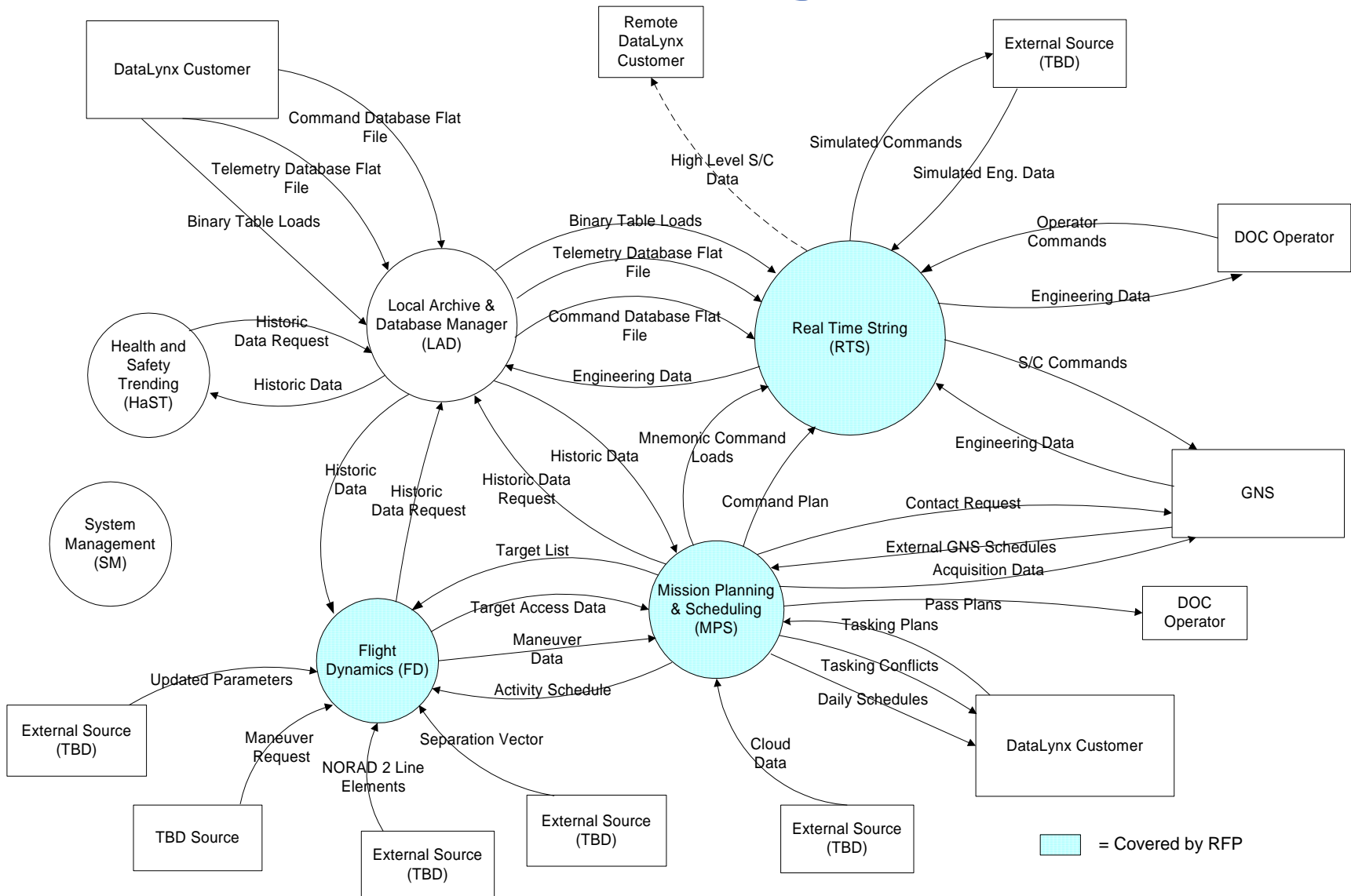
# Systems Engineering Processes

## DataLynx DOC Functional Flow Block Diagram



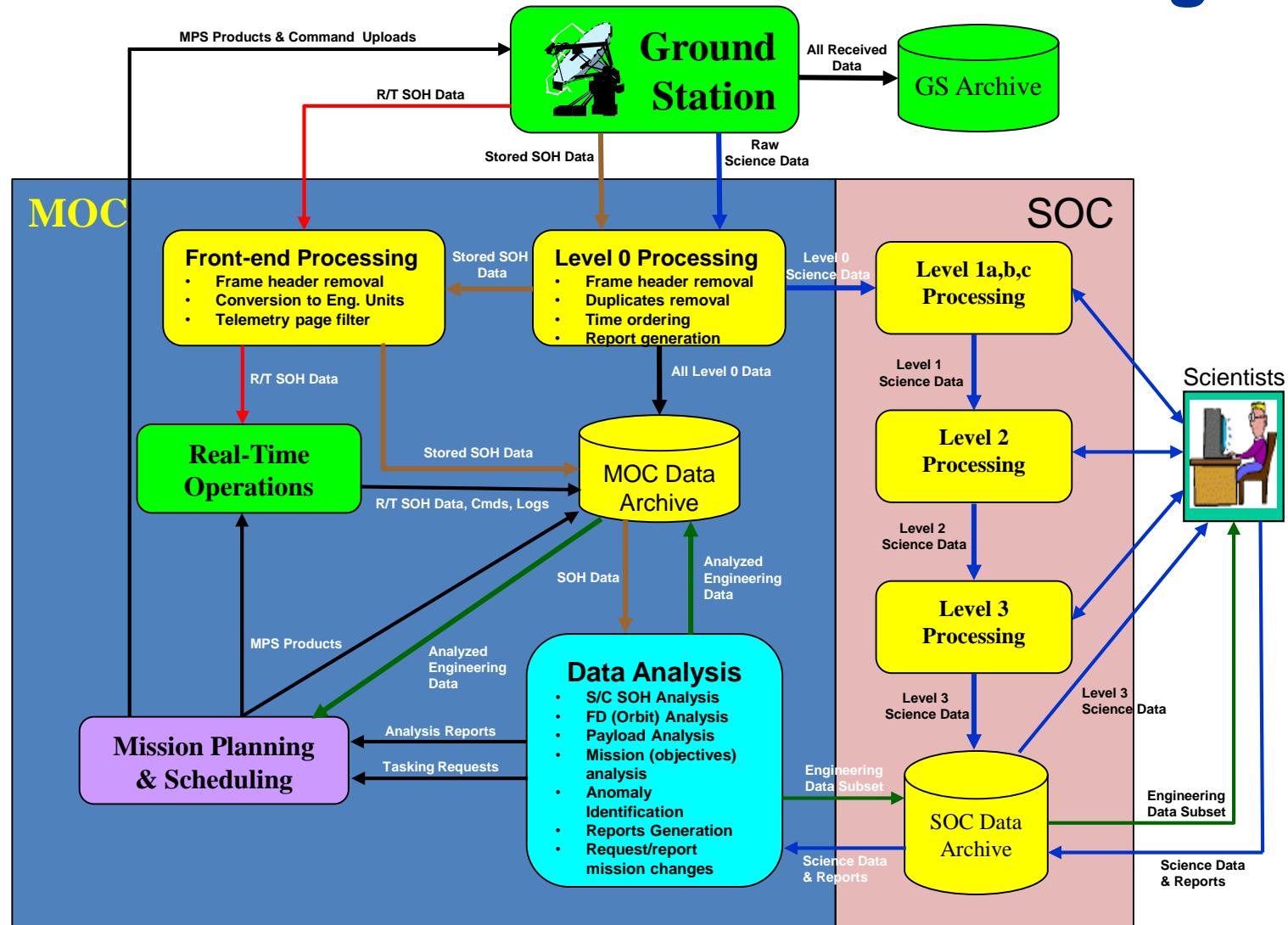
# Systems Engineering Processes

## Bubble Diagram



# Systems Engineering Processes

## COSMOS Data Functional Flow Diagram

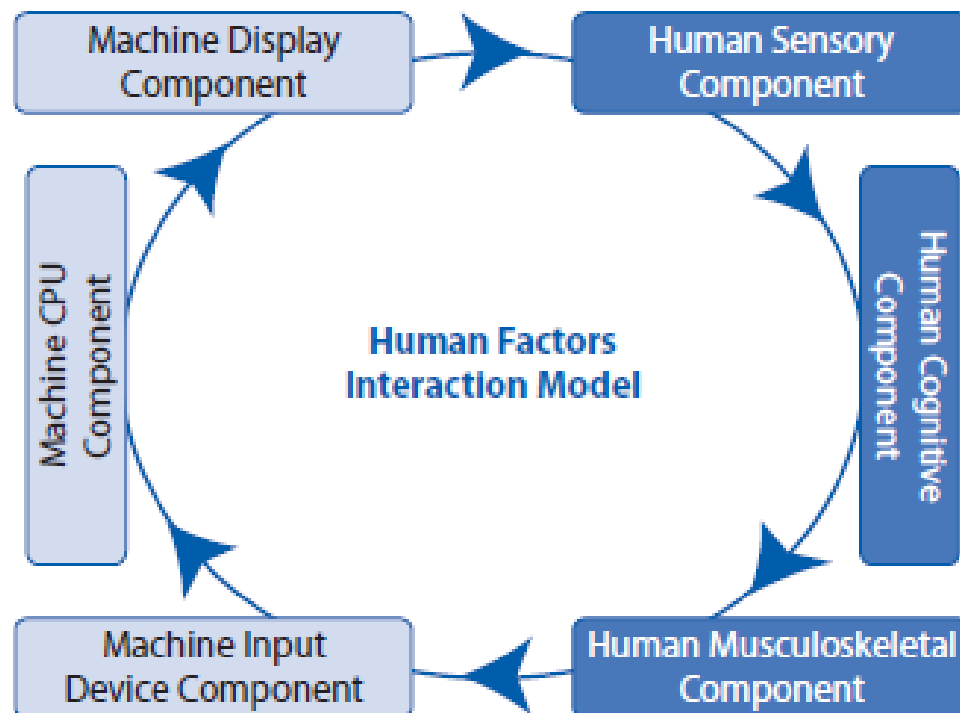


---

# Human Factors

# Human Factors

- The discipline of *Human Factors (HF)* is devoted to the study, analysis, design, and evaluation of human-system interfaces and human organizations, with an emphasis on human capabilities and limitations as they impact system operation.
- HF engineering issues relate to all aspects of the system life, including design, build, test, operate, and maintain, across the spectrum of operating conditions (nominal, contingency, and emergency).



Source: NASA Systems Engineering Handbook

# Human Factors



Source: NASA



# Human Factors




Source: NASA



---

# Systems Engineering Tools

# DR/CR Tracking System



## HawaiiSat-1 Discrepancy Report Form

Name of Submitter

Current Date

**Purpose of the DR**

The purpose of the DR is to state a discrepancy to a product or product specification. The process of filing a DR may be referred to as a nonconformance reporting and corrective action (NRCA). A nonconformance is defined as any deviation of a product or process from applicable requirements, standards, or procedures. The requirement for reports of this type and the process for analysis and disposition is specified in the Management Plan.

**Discrepancy Type**   ☐ Hardware   ☐ Software   ☐ Ops/procedures   ☐ Other/unknown

Product/Software/Process Name

Serial/Version Number

Environment Information (e.g., location, hardware and operating system, etc.)

Description of Discrepancy

Recommendation for Resolution

DR Input Ends Here

Current Date

DR Title

DR Number: DR-HS1-

Criticality

Assigned By:

To:

Due Date

Resolution Plan

Date Tested

Date Closure

Authorized Signature

Project Change Request Form					
Change request number:	Requested by:	Date requested:			
Change Request Description					
Change description:					
Business or technical justification for change request:					
Priority:					
<input type="checkbox"/> Top <input type="checkbox"/> High <input type="checkbox"/> Medium <input type="checkbox"/> Low					
Impact of not making the change:					
Change Impact Analysis					
Impact on project requirements:					
Impact on project risk:					
Impact on project schedule:					
Impact on project budget projection:					
Impact on project configuration:					
Alternatives:					
Recommendation:					
Change Request Resolution					
Change request decision:					Decision date:
<input type="checkbox"/> Approved <input type="checkbox"/> On hold <input type="checkbox"/> Denied					
Decision made by:					
<input type="checkbox"/> Project manager <input type="checkbox"/> Project sponsor <input type="checkbox"/> Executive sponsor <input type="checkbox"/> Other					
Reason for decision:					
Change Request Tracking (updates to project baseline)					
Requirements document	Yes	N/A	By:	Date:	Comments:
Schedule (WBS)	Yes	N/A	By:	Date:	Comments:
Risk management plan	Yes	N/A	By:	Date:	Comments:
Configuration management plan	Yes	N/A	By:	Date:	Comments:
Communication plan	Yes	N/A	By:	Date:	Comments:

# CR Log

## Standard Change Log Template:

Change Log							
Project:						Date:	
Change No.	Change Type	Description of Change	Requestor	Date Submitted	Date Approved	Status	Comments
Each change request is assigned a reference number.	This may be a design, scope, schedule or other type of change.	The change request should be described in detail.	Who initiated the change request?	When was the request submitted?	When was the request approved?	Is the change request open, closed or pending? Has it been approved, denied or deferred?	This section may describe why the change request was rejected, deferred or provide any other useful information.

# CR Log

## Example with Sample Data:

Change Log							
<b>Project:</b> Network Upgrade Project						<b>Date:</b> 04/01/20xx	
Change No.	Change Type	Description of Change	Requestor	Date Submitted	Date Approved	Status	Comments
CR001	Design/Scope	This change request calls for replacing existing ABC network routers with NextGen 3000 routers.	J. Doe	03/25/xx	N/A	Denied	This request was denied by the change control board because there is not adequate funding available for the purchase of new routers and because the request is outside of the project's scope.
CR002	Schedule	This change request calls for delaying the existing schedule by one week to ensure all applications are backed up which was not considered in the original project plan.	A. White	03/26/xx	4/10/xx	Approved	This request was approved to ensure the security and continuity of all applications. One week will be added to the project schedule and the project manager will communicate the impact of this change to all stakeholders.

# CR Log in the CM Process

Step	Description	Done By
1	<i>Identify the need for a change</i> Requestor submits a completed change request (CR) form to the Systems Engineer (SE) or Systems Integrator	Any Stakeholder including team members
2	<i>Log change in the CR register</i> The SE maintains a log of all change requests for the duration of the project	SE
3	<i>Conduct an evaluation of the change</i> - the project manager (PM) conducts an evaluation of the impact of the change to cost, risk, schedule, and scope, while the SE conducts an evaluation of the technical merits of the change	SE, Project Manager, Project Team, Requestor
4	<i>Submit CR to Change Control Board (CCB)</i> The project manager submits the CR and analysis to the CCB for review	PM
5	<i>Change Control Board decision</i> The CCB discusses the proposed change and decide whether or not it will be approved based on all submitted information	CCB
6	<i>Implement change</i> If a change is approved by the CCB, the SE updates and re-baselines project documentation as necessary as well as with the PM ensures any changes are communicated to the team and stakeholders	SE & PM

---

# Systems Engineering Management Plan

# Systems Engineering Management Plan

## SEMP Outline

### 1. Introduction

- *Scope*: encompasses SE technical effort required to generate the work products necessary to meet the success criteria for the product-line life-cycle phases.
- *Purpose*: of the engineering effort should be described in general terms of the outputs, both end products and life-cycle enabling products that are required. The stated purpose should answer the question, “What does the engineering effort have to produce?”
- *Focus*: for the effort should be provided to clarify the management vision for the development approach, e.g., *lowest cost to obtain threshold requirements, superior performance within budget, or superior standardization for reduced logistics, etc.*

### 2. Applicable Documents

- List documents applicable to project
- Describes major standards and procedures that project needs to follow

# Systems Engineering Management Plan

## SEMP Outline

### 3. System Description

- Executive summary describing the problem to be solved by this technical effort and the purpose, context, and products of the WBS model to be developed and integrated with other interfacing systems identified.
- Includes a general discussion of the system's operational function
- Contains a definition of the purpose/mission/objective of the system being developed, a brief description of the expected scenarios for the system.
- The description should include any interfacing systems and system products, including humans, with which the WBS model system products will interact physically, functionally, or electronically.
- Identify and document system constraints, including cost, schedule, and technical (for example, environmental, design).
- Answers the question “What is it and what will it do?”



# Systems Engineering Management Plan

## SEMP Outline

### 3. System Structure

- Shows the system architecture and a description of the boundary of the system including definition of internal and external elements involved in realizing the system purpose. The boundaries can be defined in terms of space, time, physical, and operational terms.
- System structure should:
  - include general and functional descriptions of subsystems,
  - document current and established subsystem performance characteristics,
  - identify and document current interfaces and characteristics,
  - develop functional interface descriptions and functional flow diagrams,
  - identify key performance interface characteristics, and
  - identify current integration strategies.

# Systems Engineering Management Plan

## SEMP Outline

### 5. Technical Strategy

- Describes how the overall system structure will be developed and identifies the phasing and technical milestones.
- *Project Technical Requirements*: Contains a description of the relationship of the specification tree and the drawing tree with the products of the system structure and how the relationship and interfaces of the system end products and their life-cycle-enabling products will be managed throughout the planned technical effort.
- All conditions or constraints that impact the strategy should be identified and impact assessed.
- Critical technologies should be identified with determination of the risk associated with their development and impact on the technical strategy and overall development effort.
- Cost As an Independent Variable (CAIV) needs to be considered and if implemented, how will it impact the strategy.
- Identifies associated parallel developments or product improvement considerations.

# Systems Engineering Management Plan

## SEMP Outline

### 5. Systems Engineering Processes

- Describes how the system engineering processes will be designed to support the strategy. This section should include:
  - Specific methods and techniques used to perform the steps and loops of the systems engineering process,
  - Specific system analysis and control tools and how they will be used to support step and loop activities, and
  - Special design considerations that must be integrated into the engineering effort.
- *Steps and Loops*: The systems engineering process should show the specific procedures and products that will ensure:
  - Requirements are understood prior to the flowdown and allocation of requirements,
  - Functional descriptions are established before designs are formulated,
  - Designs are formulated that are traceable to requirements,
  - Methods exist to reconsider previous steps, and
  - Verification processes are in place to ensure that design solutions meet needs and requirements.

# Systems Engineering Management Plan

## SEMP Outline

### 5. Systems Engineering Processes (cont.)

- *Analysis and Control*: identify those analysis tools that will be used to evaluate alternative approaches, analyze or assess effectiveness, and provide a rigorous quantitative basis for selecting performance, functional, and design requirements.
- Planning must identify the method by which control and feedback will be established and maintained. The key to control is performance-based measurement guided by an event-based schedule.
- Entrance and exit criteria for the event-driven milestones should be established sufficient to demonstrate proper development progress has been completed.
- Each of the common technical processes should have its own separate subsection, as applicable, that contains a plan for performing the required process activities as appropriate based on the information provided in this section.

# Systems Engineering Management Plan

## SEMP Outline

### 5. Systems Engineering Processes (cont.)

– The common technical processes according to NASA are:

**A. *Requirements Definition Processes***

- 1) Stakeholders Expectations Definition
- 2) Technical Requirements Definition

**B. *Technical Solution Definition Processes***

- 3) Logical Decomposition
- 4) Design Solution Definition

**C. *Design Realization Processes***

- 5) Product Implementation
- 6) Product Integration

**D. *Evaluation Processes***

- 7) Product Verification
- 8) Product Validation

**E. *Product Transition Process***

- 9) Product Transition

**F. *Technical Planning Process***

- 10) Technical Planning

**G. *Technical Control Processes***

- 11) Requirements Management
- 12) Interface Management
- 13) Technical Risk Management
- 14) Configuration Management
- 15) Technical Data Management

**H. *Technical Assessment Process***

- 16) Technical Assessment

**I. *Technical Decision Process***

- 17) Decision Analysis

# Systems Engineering Management Plan

## SEMP Outline

### 6. Technical Effort Integration

- This section contains a description of how the various inputs to the technical effort will be integrated into a coordinated effort that meets cost, schedule, and performance objectives during each iteration of the processes.
- It should contain, as needed, the project's approach to the following:
  - Concurrent engineering
  - Verification and validation
  - Reliability
  - Maintainability
  - Quality assurance
  - Integrated logistics
  - Human factors engineering
  - Safety
  - Producibility
  - Survivability/vulnerability
  - Environmental compliance
  - Flight/operations readiness
- *Technical Staffing and Organization Planning*: This sections shows how the organizing structure for the technical teams assigned to this technical effort and includes how the teams will be staffed and managed, and definition of roles and responsibilities.
- Provide an organization chart and denote who on the team is responsible for each activity. Indicate the lines of authority and responsibility
- The policy of using Integrated Product Teams should be defined here.

# Systems Engineering Management Plan

## SEMP Outline

### 7. Waivers

- This section contains all approved waivers to the SEMP.

### Appendices

- Appendices are included, as necessary, to provide a glossary, acronyms and abbreviations, and information published separately for convenience in document maintenance.
- Included should be a summary of technical plans associated with the project (e.g., CM Plan, Verification and Validation Plan, Test Plan).
- Any templates for forms, plans, or reports the technical team will need to fill out, like the format for the verification and validation plan, should be included in the appendices.

### References

# References & Bibliography

- *NASA Systems Engineering Handbook*

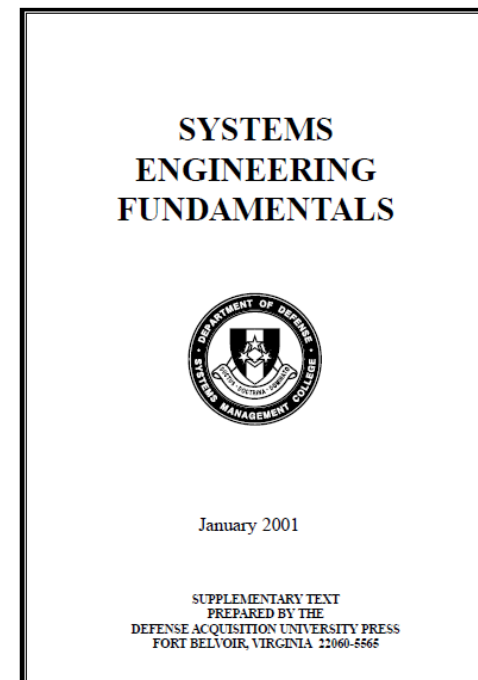
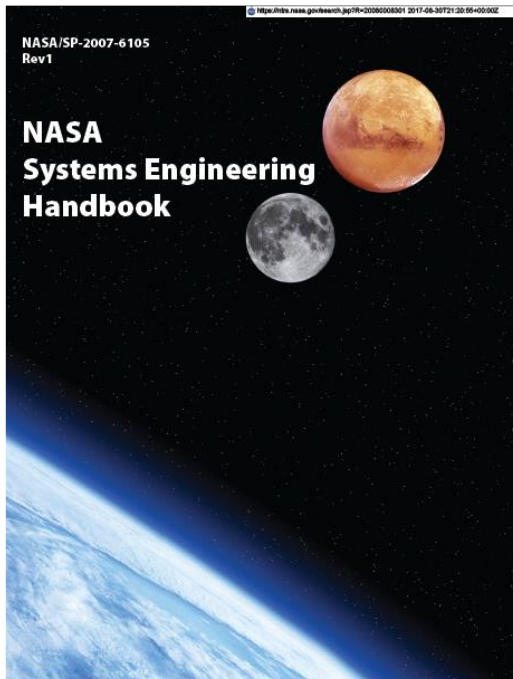
NASA/SP-2007-6105 Rev1

<https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20080008301.pdf>

- *DOD Systems Engineering Fundamentals*

Defense Acquisition University (2001) Systems engineering fundamentals. Defense Acquisition University Press, Fort Belvoir, Virginia.

[http://ocw.mit.edu/courses/aeronautics-and-astronautics/16-885j-aircraft-systems-engineering-fall-2005/readings/sefguide\\_01\\_01.pdf](http://ocw.mit.edu/courses/aeronautics-and-astronautics/16-885j-aircraft-systems-engineering-fall-2005/readings/sefguide_01_01.pdf)





# References & Bibliography

---

- *Space Mission Engineering: The New SMAD*

Microcosm Press, Hawthorne CA, 2011

- *System Engineering*, Goode and Machol

McGraw-Hill Book Company, New York, 1957

- <https://www.technologyuk.net/computing/project-management/managing-change.shtml>

- <http://www.projectmanagementdocs.com/#axzz4tNExCInG>

# Space Spectaculars!



**STS-98 Launch**  
**2/7/2001**



**MMIII Launch**  
**VAFB 9/19/02**

**Clementine's View of  
Earth Over Lunar North  
Pole Mar. 1994**

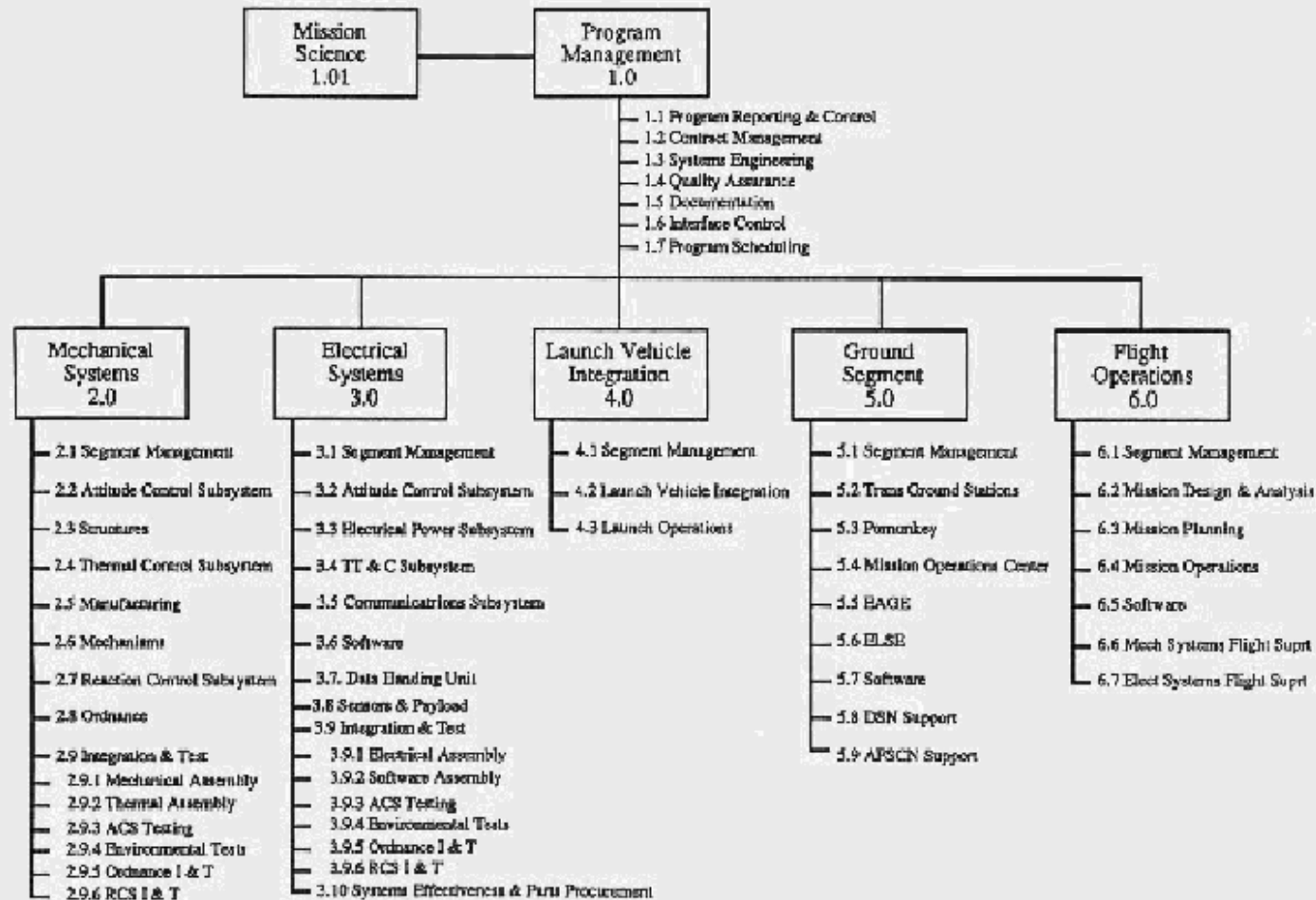


---

# BACKUP SLIDES

# Systems Engineering Methodology

## DSPSE Work Breakdown Structure



Revised  
3/11/92