SYSTEMS ENGINEERING

ME 481 Senior Design
Fall 2019

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

System
(aka *plant* or *process*)

• mathematical models
• states

Inputs

Subsystem 1
Subsystem 2
Subsystem 3
Subsystem 4
Subsystem 5

Outputs

Component A
Component B
Component C
Component D
Component E
Component F
Component G
Component H
Component I

A Trimble, T. Sorensen, Z. Song

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Systems Engineering
Systems Engineering

• Systems engineering is the art and science of developing an operable system capable 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

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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
A Trimble, T. Sorensen, Z. Song

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What happens if you ignore systems engineering throughout the design life-cycle?
Perfect Airplane as Designed by Each Engineering Group

Source: Technical University of Delft
Systems Engineering Methodology
17 common technical processes
Systems Engineering Methodology

New Products or Upgrades Entering the SE Engine

Upgrades/Changes Reenter SE Engine at Stakeholder Expectations Definition

Source: NASA Systems Engineering Handbook
Systems Engineering Methodology

Source: DOD Systems Engineering Fundamentals
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`i Sat-1 Bus

Onboard Computer Subsystem (OBCS)

- Analog
- Temperature Readings

Electrical Power Subsystem (EPS)
- RS422
  - WDT Heartbeat
  - SoH Telemetry
  - Power Control
- USB
  - Ops Uplink
  - Telemetry Downlink
  - Beacon Updates
  - C&C
- RS422
  - SoH & Overrides

Telecom Subsystem
- Reset Inputs
- GPO

Attitude Determination and Control (ADCS)
- GPS
  - 2x RS232

Lightband Separation Connector
- Ethernet

TCS Temperature Sensors

EPS Latching Relay Control (Safety)

Deployment Detection (Open/Short)

Umbilical Power

Electrical Power Subsystem (EPS)

Temperature Sensors

Thermostat Controlled Thermofoils

EPS Latching Relay Control (Safety)

Deployment Detection (Open/Short)

Umbilical Power
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*. 
# LEO-1 Project WBS

## Systems Engineering Methodology

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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.
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

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### Real-Time String
- Anomaly detection and response: x x x x x x x x x x x
- Command verification: x x x x x x x x x
- Control input: x x x x x x x x x x
- Decommission: x x x x x x x x x
- Engineering data storage and retrieval: x x x x x x x
- EU conversion: x x x x x x x x x
- Frame synchronization: x x x x x x x x x
- Mnemonic to binary conversion: x x x x x x x
- Script processing: x x x x x x x
- Remote data display: x x x x x x
- S/C Telemetry display: x x x x x x x x x x
- Data Security: x x x x x x

### Mission Planning
- Activity planning: x x x x x x x x
- Activity scheduling: x x x x x x

### Flight Dynamics
- Attitude generation: x x x x
- Tracking data preprocessing: x
- Ephemeral generation: x
- Orbit determination: x
- Orbit centroid generation: x
- Orbit maneuver calculations: x
- Pointing angle determination: x

### Health and Safety Trending
- Data analysis: x x x x x
- Data trending: x x x x

### System Management
- Network monitoring: x x x x x x x x x x

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A Trimble, T. Sorensen, Z. Song

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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.
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).
• 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.
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.
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.
As design matures, re-examine basic assumptions.

Source: DOD Systems Engineering Fundamentals
• 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

- Prepare to conduct product integration
- Obtain lower level products for assembly and integration
- Confirm that received products have been validated
- Prepare the integration environment for assembly and integration
- Assemble and integrate the received products into the desired end product
- Prepare appropriate product support documentation
- Capture product integration work products

Source: NASA Systems Engineering Handbook
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

From user or program and system design processes:
- Interface Requirements

From project and Technical Assessment Process:
- Interface Changes

Prepare or update interface management procedures

Conduct interface management during system design activities for each WBS-like model in the system structure

Conduct interface management during product integration activities

Conduct interface control

Capture work products from interface management activities

To Configuration Management Process:
- Interface Control Documents
- Approved Interface Requirement Changes

To Technical Data Management Process:
- Interface Management Work Products

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

- From project:
  - Project Configuration Management Plan
  - Engineering Change Proposals

- From Requirements Management and Interface Management Processes:
  - Expectation, Requirements, and Interface Documents
  - Approved Requirements Baseline Changes

- From Stakeholder Expectation Definition, Logical Decomposition, and Technical Planning Processes:
  - Designated Configuration Items to Be Controlled

- To applicable technical processes:
  - List of Configuration Items Under Control
  - Current Baselines

- To project and Technical Data Management Process:
  - Configuration Management Reports

- To Technical Data Management Process:
  - Configuration Management Work Products

- Prepare a strategy to conduct configuration management
- Identify baseline to be under configuration control
- Manage configuration change control
- Maintain the status of configuration documentation
- Conduct configuration audits
- Capture work products from configuration management activities

Source: NASA Systems Engineering Handbook
Systems Engineering Processes

Typical Configuration Control Process

1. Originator
   - Prepares change request and sends to configuration management organization

2. Configuration Management Organization
   - Checks format and content
   - Assigns number and enters into CSA
   - Determines evaluators (with originator)
   - Schedules CCB date if required
   - Prepares CCB agenda

3. Evaluators
   - Evaluate change package

4. Responsible Office
   - Consolidates evaluations
   - Formulates recommended disposition
   - Presents to CCB

5. Configuration Control Board
   - Chair dispositions change request
   - Chair assigns action items if required

6. Actionees
   - Complete assigned actions

7. Configuration Control Board
   - Chair signs final directive

8. Actionees
   - Updates document, hardware, or software

9. Actionees
   - Performs final check on documents

10. Actionees
    - Releases document per directive
    - Stores and distributes as required

Source: NASA Systems Engineering Handbook
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.).
Technical Data Management Process

- Prepare for technical data management implementation
- Collect and store required technical data
- Maintain stored technical data
- Provide technical data to authorized parties

From all technical processes and contractors:
- Technical Data Products to Be Managed

From project and all technical processes:
- Technical Data Requests

To all technical processes and contractors:
- Form of Technical Data Products
- Technical Data Electronic Exchange Formats

To project and all technical processes:
- Delivered Technical Data

Source: NASA Systems Engineering Handbook
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

COSMOS Data Functional Flow Diagram

MOC

Front-end Processing
- Frame header removal
- Conversion to Eng. Units
- Telemetry page filter

Real-Time Operations

Mission Planning & Scheduling

Level 0 Processing
- Frame header removal
- Duplicates removal
- Time ordering
- Report generation

Level 1a,b,c Processing

Level 2 Processing

Level 3 Processing

Data Analysis
- S/C SOH Analysis
- FD (Orbit) Analysis
- Payload Analysis
- Mission (objectives) analysis
- Anomaly Identification
- Reports Generation
- Request/report mission changes

SOC

Ground Station

GS Archive

MPS Products & Command Uploads

R/T SOH Data

Stored SOH Data

Raw Science Data

All Received Data

MOC Data Archive

SOH Data

Analysis Reports

Tasking Requests

MPS Products

Stored SOH Data

MPS Products & Command Uploads

R/T SOH Data, Cmds, Logs

All Level 0 Data

Level 0 Science Data

Level 1a Science Data

Level 1 Science Data

Level 2 Science Data

Level 3 Science Data

Level 3 Science Data

Level 3 Science Data

Level 2 Science Data

Level 2 Science Data

Level 1 Science Data

Level 0 Science Data

Analyzed Engineering Data

Science Data & Reports

Science Data & Reports

Engineering Data Subset

Engineering Data Subset

Scientists

COSMOS Overview

ME 481 – Fall 2019

A Trimble, T. Sorensen, Z. Song

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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
Systems Engineering Tools
DR/CR Tracking System

HawaiSat-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 (NRC). A nonconformance is defined as any deviation of a product or process from applicable requirements, standards, or procedures. The required 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: ____________________________
## CR Log

### Standard Change Log Template:

<table>
<thead>
<tr>
<th>Project:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Change No.</strong></td>
<td><strong>Date</strong>, <strong>Status</strong>, <strong>Comments</strong></td>
</tr>
<tr>
<td><strong>Change Type</strong></td>
<td><strong>Description of Change</strong></td>
</tr>
<tr>
<td>Each change request is assigned a reference number.</td>
<td>This may be a design, scope, schedule or other type of change.</td>
</tr>
<tr>
<td>Change No.</td>
<td>Change Type</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------</td>
</tr>
<tr>
<td>CR001</td>
<td>Design/Scope</td>
</tr>
<tr>
<td>CR002</td>
<td>Schedule</td>
</tr>
</tbody>
</table>
# CR Log in the CM Process

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Done By</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Identify the need for a change</em> Requestor submits a completed change request (CR) form to the Systems Engineer (SE) or Systems Integrator</td>
<td>Any Stakeholder including team members</td>
</tr>
<tr>
<td>2</td>
<td><em>Log change in the CR register</em> The SE maintains a log of all change requests for the duration of the project</td>
<td>SE</td>
</tr>
<tr>
<td>3</td>
<td><em>Conduct an evaluation of the change</em> - 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</td>
<td>SE, Project Manager, Project Team, Requestor</td>
</tr>
<tr>
<td>4</td>
<td><em>Submit CR to Change Control Board (CCB)</em> The project manager submits the CR and analysis to the CCB for review</td>
<td>PM</td>
</tr>
<tr>
<td>5</td>
<td><em>Change Control Board decision</em> The CCB discusses the proposed change and decide whether or not it will be approved based on all submitted information</td>
<td>CCB</td>
</tr>
<tr>
<td>6</td>
<td><em>Implement change</em> 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</td>
<td>SE &amp; PM</td>
</tr>
</tbody>
</table>
Systems Engineering Management Plan
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
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?”
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.
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.
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.
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.
5. Systems Engineering Processes (cont.)

- The common technical processes according to NASA are:

<table>
<thead>
<tr>
<th>A. Requirements Definition Processes</th>
<th>E. Product Transition Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Stakeholders Expectations Definition</td>
<td>9) Product Transition</td>
</tr>
<tr>
<td>2) Technical Requirements Definition</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. Technical Solution Definition Processes</th>
<th>F. Technical Planning Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>3) Logical Decomposition</td>
<td>10) Technical Planning</td>
</tr>
<tr>
<td>4) Design Solution Definition</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. Design Realization Processes</th>
<th>G. Technical Control Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5) Product Implementation</td>
<td>11) Requirements Management</td>
</tr>
<tr>
<td>6) Product Integration</td>
<td>12) Interface Management</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D. Evaluation Processes</th>
<th>H. Technical Assessment Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>7) Product Verification</td>
<td>16) Technical Assessment</td>
</tr>
<tr>
<td>8) Product Validation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E. Product Transition Process</th>
<th>I. Technical Decision Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>9) Product Transition</td>
<td>17) Decision Analysis</td>
</tr>
</tbody>
</table>
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

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  NASA/SP-2007-6105 Rev1
  https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20080008301.pdf

• **DOD Systems Engineering Fundamentals**
References & Bibliography

- **Space Mission Engineering: The New SMAD**
  Microcosm Press, Hawthorne CA, 2011

- **System Engineering**, Goode and Machol

- [https://www.technologyuk.net/computing/project-management/managing-change.shtml](https://www.technologyuk.net/computing/project-management/managing-change.shtml)

- [http://www.projectmanagementdocs.com/#axzz4tNExCInG](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