Systems Engineering Weekly Summary

I. Week 1

A. Standish Chaos Report

The 1994 report surveyed IT executive managers from large, medium and small US companies with management information systems. They had 365 respondents that represented 8,380 software applications in the market. The report can be found here: Standish Chaos Report. It surveyed the managers on projects and found the following:

- successful projects (on time and on budget): **16.2%**
- challenged projects (completed, but not on time, on budget or with reduced functionality compared to specification): **52.7%**
- impaired projects (cancelled at some point): **31.1%**

1) Success factors: The project success factors were found to be:

- user involvement: **15.9%**
- executive management support: **13.9%**
- clear statement of requirements: **13.0%**
- proper planning: **9.6%**
- realistic expectations: **8.2%**
- smaller project milestones: **7.7%**
- competent staff: **7.2%**
- ownership: **5.3%**
- clear vision and objectives: **2.9%**
- hard-working, focused staff: **2.4%**
- other: **13.9%**

2) Challenged factors: The project challenged factors were found to be:

- lack of user input: **12.8%**
- incomplete requirements and specifications: **12.3%**
- changing requirements and specifications: **11.8%**
- lack of executive support: **7.5%**
- technology incompetence: **7.0%**
- lack of resources: **6.4%**
- unrealistic expectations: **5.9%**
- unclear objectives: **5.3%**
- unrealistic time frames: **4.3%**
- new technology: **3.7%**
- other: **23.0%**

3) Impaired factors: The project impaired factors were found to be:

- incomplete requirements: **13.1%**
- lack of user involvement: **12.4%**
- lack of resources: **10.6%**
- unrealistic expectations: **9.9%**
- lack of executive support: **9.3%**
- changing requirements and specifications: **8.7%**
- lack of planning: **8.1%**
- didn't need it any longer: **7.5%**
- lack of IT management: **6.2%**
- technology illiteracy: **4.3%**
- other: **9.9%**

The report also speaks at length about four case studies: the California DMV, American Airlines and CONFIRM Car Rental, Hyatt Hotels and Banco Itamarati.

B. Systems Engineering Job Ads

We were required to be able to list relevant skills required by companies when they recruit systems engineers. Some of these were:

- proficiency in company-relevant software
- ability to manage whole of life cycle of engineering projects
- ability to maintain technical documentation and conduct technical investigations
- have a developed professional network within the industry
- have teamwork, communication skills and professionalism
- previous experience
- ability to troubleshoot software problems
- have a customer focus
  - NV1 clearance
  - citizenship
  - experience on Defence projects

C. Lecture 0 - Course Overview

1) System Factors: Types of systems are defined on page 4 of the textbook. When a system is designed, there are a number of necessary factors to consider. Broadly, these can be grouped as the acronym, POSTED:

- people
- organisation
- support
- training
- equipment → specification → engineering → product
- doctrine

2) System Life Cycle: The system life cycle is broken down into four phases:

- pre-acquisition phase: idea for a system being generated as a result of business planning, including consideration of possible options, research and development
- acquisition phase: bringing the chosen system into service, including definition of business/stakeholder requirements and engagement of contractors
  - conceptual design phase: production of a set of clearly defined requirements in logical terms - this results in several key documents:
    - Business Needs and Requirements (BNR)
    - Stakeholder Needs and Requirements (SNR)
    - System Requirement Specification (SyRS)

    * System Design Review (SDR)
  –
- utilisation phase: the functional life of the system, including maintenance, modification and upgrades
- retirement phase: end of the life cycle of the system as it no longer meets operational requirements - the end of this life cycle could be the start of a new life cycle with a different business (service aircraft being used for scenic flights, for example)

D. *Lecture 1 - Intro to Systems Engineering*

1) Broad Description of Systems: This can be one of two ways:

- logical/functional - what the system will do, described with a narrative or scenarios in mind;
- physical - the technical specifications of system elements, how they look, dimensions etc.

2) Conceptual Design Overview: This marks a formal transition from the stakeholder requirements specification (which is business-y) to a complete logical, physical description of the system. It ensures proper definition of system technical requirements and integrates the appropriate stakeholders in decision making. In this phase, we transition from BNR and SNR to a full SyRS developed by requirements engineers and eventually to the functional baseline for the system. After this, we transition to the system design review to ensure that both engineers and stakeholders are satisfied with the logical and physical concept of the system and how it will be designed. The SDR confirms BNR, SNR and SyRS formally.

3) Preliminary Design Overview: This part of the design phase takes the functional baseline and allocates the development of each subsystem to specific configuration items through means of an allocated baseline (system requirements being allocated to subsystems). Finally, this phase has a preliminary design review; again, this formalises all decisions made during this phase.

4) Detailed Design and Development Overview: During this phase, each subsystem (and components thereof) is developed in accordance with the ABL, the SyRS and the StRS. This results in both the product baseline and a critical design review.

5) Construction and Production Overview: After design and detailed verification and validation of the entire system, components are produced in accordance with the PBL. This ends with a formal qualification review, which formalises the customer accepting the system in its current state from the contractor as designed to specification. This is informed by acceptance test and evaluation.

6) Utilisation/Retirement Overview: During this phase, the system undergoes operational use, maintenance programs, and modifications and upgrades as deemed necessary by the customer. Ultimately, the system is retired as it is no longer viable, necessary or redundant.

7) Types of Development Approach: These can be loosely grouped into a few categories, with the most common being the first one:

- waterfall
- incremental
- spiral
- evolutionary

These will be individually defined later. For now, we need to tailor our approach always to maximise value/viability and minimise risk.

8) System Need-To-Know: There are five things we need to know clearly about a system that is being designed:

- what the system will do;
- how it does its job and how well it does it;
- under what conditions it operates;
- what systems it needs to integrate with;
- how can we be absolutely sure that it succeeds in these tasks?

II. Week 2

A. *Lecture 2 - Conceptual Design*

1) Stakeholder Requirements Specification: This document should contain:

- likely applications for the system;
- major operational characteristics;
- operational or safety constraints;
- external systems/interfaces;
- operational and support environment;
- the support concept to be employed.

2) System Requirements Review: This may be conducted periodically through the conceptual design phase to verify and approve versions of system-level requirements. The goal of this review process is to monitor and approve requirements on the way to the initial FBL. It allows requirements analysis to continue to lower levels of the system hierarchy by validating higher levels, providing a firm baseline for lower level analysis to work from.

III. Week 3

A. *Lecture 3 - Preliminary Design*

*1) **Requirements Allocation**:* Requirements allocation refers to the allocation of specific design requirements to elements of the design. This requires expertise in the domain of the system in question to understand which subsystems can handle which requirements. It's important to remember at this point that we don't want scope creep and extra functionality that hasn't been requested. Both the contractor and customer need to be able to look horizontally and understand the impact that requirements of a subsystem may have on other subsystems. This is particularly relevant when changes are proposed. It's really important to remember that requirements need to inform design choices and not the other way around.

*2) **Configuration Items**:* Subsystems are broken into configuration items. These could be in the form of hardware vs software or in elements of a subsystem being bought by the subcontractor as COTS items. The configuration of each item is managed separately for design, development, documentation, construction, auditing and testing. Items can be identified as CIs due to:

- complexity;

- interfaces;
- use/function;
- commonality;
- single supplier ownership;
- criticality;
- maintenance and documentation needs.

The CI decision process belongs to the contractor but may be influenced by the customer, who may have particular constraints on suppliers, requirements for documentation and intellectual property rights (access to software under the hood etc).

3) Interface Selection: Interfaces between relevant subsystems are identified at this stage of design. These determine successful operation of the system once integrated, but also place limitations and requirements on individual subsystems/-CIs. These interfaces can be:

- physical: pipes, wires, fibre;
- electronic: wired/wireless;
- software: I/O, data format, protocols;
- human-machine: layouts, displays, seating, controls;
- electrical: voltage levels/types, frequency, tolerances;
- environmental: vibration, acoustic, thermal, magnetic, radiation;
- hydraulic/pneumatic: flow rates, temperatures, pressures.

4) Subsystem Design Choices: There are three broad choices available to subsystem developers:

- buy the subsystem from a supplier and integrate (COTS):
  - (+) readily available;
  - (+) cheaper;
  - (+) reduce technical risk and maintenance liability;
  - (-) may not be suitable/approaching outdated state;
  - (-) could be quite immature/unproven;
  - (-) may have less support/documentation;
  - (-) may have undesired functionality.
- buy a COTS subsystem and modify to meet needs (modified COTS):
  - (+) same advantages as COTS;
  - (-) maintenance/support may be void if modified;
  - (-) effort to modify could outweigh benefits of COTS in the first place.
- design and build specific to purpose:
  - (+) should meet exact needs;
  - (+) should be fully understood by own organisation;
  - (-) may not eventuate;
  - (-) significant effort;
  - (-) maintenance and support is wholly own responsibility.

5) The Design Space: The reason we conduct requirements analysis and develop particular subsystems (that may not be optimal) is to develop as close to an optimal system-level solution as possible. System-level requirements outweigh everything at the subsystem level and below. Design and selection of subsystems may be required to be evaluated a number of times before preliminary design is complete and this may be influenced significantly by the Standish Report reasons given above as well as long project times that can lead to technological developments that influence the system.

6) Preliminary Design Review: Once complete, preliminary design results in a description of the preliminary architecture of hardware, software, personnel and so on organised in such a way as to satisfy the series of applicable requirements. The main deliverable is a description of all of the subsystems and how they interface with each other. Once the design is mature enough, it is reviewed before releasing the Allocated Baseline (ABL). This is only after the customer is sufficiently satisfied with the system design. The review process investigates each CI, ensuring that requirements have been appropriately allocated.

IV. Week 4

A. *Lecture 4 - Detailed Design and Development*

*1) **Product Baseline**:* After preliminary design, detailed design and development finalises the design of specific components that make up each CI. The realisation and documentation of all of these individual components is the Product Baseline (PBL). The PBL is a detailed description of the products that meet the requirements allocated to them in the ABL.

*2) **Detailed Design Process**:* Sufficient detail is required in the PBL to facilitate construction/production. Once this has been completed (the 'what'), analysis on production methods must be done (the 'how'). The process:

- is iterative;
- features review/feedback;
- involves integration of assemblies/components;
- may result in prototypes;
- involves test and evaluation.

At each stage of integration (components, assemblies, subsystems), evaluation will take place to ensure that requirements are being met and that elements are integrating effectively.

*3) **Prototypes**:* Prototypes may be required to verify the design in a final state. These combine and integrate all lower-level components.

*4) **Critical Design Review**:* This is a major review of detailed design and development. It also marks the final stage before construction/production. Things reviewed include:

- software products;
- design drawings;
- materials and parts lists;
- analyses and other reports.

Aims include:

- design evaluation;
- determination of readiness for production;
- determination of maturity of software;
- determination of design compatibility;
- establishment of the PBL.

B. *Lecture 4 - Construction/Production*

This phase could be very large and require well-supported infrastructure ... or not. Compare a single flight simulator production and a fleet of armoured vehicles. The requirements of this phase need to be considered early in the design of the overall system.

*1) **Production Issues to Address**:* The following production issues must be addressed early in system development:

- material availability (lead time), ordering and handling;
- availability of skill sets and requirement to train production force;
- availability of tools, equipment and facilities;
- processing and process control;
- assembly, inspection and testing facilities/requirements;
- packaging, storage and handling.

*2) **Production Plan**:* The contents of the Production Plan include:

- resources:
  - plant size and type (need to consider lead time, expense and any specialised plant requirement);
  - personnel resources (need to consider number and specialisation of personnel, including training delta).
- production engineerng considerations:
  - scheduling;
  - manufacturing methods/processes;
  - tooling and test equipment;
  - facility requirements;
  - automation.
- materials and purchased parts:
  - Bill of Materials (BOM);
  - procurement of any COTS CIs;
  - identification and mitigation of long lead times;
  - inventory control.
- management and logistics;
- other activities such as test and evaluation;
- configuration audits.

*3) **Functional Configuration Audit**:* This is used to verify and certify that a CI meets performance requirements as specified in the Development and Product Specifications. This may not be a full review - it can be done incrementally throughout the development of the CI. Sometimes this audit cannot be done due to some CIs needing other CIs to be functional and integrated to work effectively. FCA will usually precede PCA so as to avoid failing the FCA and invalidating the PCA.

*4) **Physical Configuration Audit**:* This audit confirms that the as-built CI matches product specifications, design drawings and technical (simulation) data. A PCA is conducted on the first production version of each CI.

*5) **Test Readiness Review**:* Testing is expensive and time-consuming, involving highly trained personnel and special facilities/equipment. Sometimes, TRR is required to ensure a system is ready to undergo testing. The idea is to avoid T&E on CIs or a system that is not properly mature enough. The TRR usually reviews a range of documentation, including:

- verification plans;
- formal and informal test results;
- supporting documentation;
- support, test and equipment facilities.

*6) **Formal Qualification Review**:* FQR may be required to verify that all the CIs meet functional requirements once integrated. FQR verifies specifications in SyRS, development specifications and interface requirement specifications.

*7) **Configuration Management**:* CM is the act of keeping track of what is being designed, current versions of parts, requests for changes and results of audits.

V. Week 5

A. *Lecture 5 - Systems Engineering Management and Risk*

VI. Week 6

A. *Lecture 6 - Project Management Introduction*

1) Process Groups: The five process groups are:

- initiate;
- plan;
- execute;
- monitor and control;
- close.

2) Knowledge areas: The ten knowledge areas are:

- time;
- scope;
- cost;
- quality;
- risk;
- human resources;
- procurement;
- communications;
- stakeholders;
- integration.

3) Capability levels: The capability levels of an organisation are:

- level 0 - incomplete;
- level 1 - performed:
  - ad hoc processes;
  - variable outcomes;
  - inconsistency between projects;
  - depends on the quality of the individual project team;
  - project awareness permeates the organisation.
- level 2 - managed;
- level 3 - defined:
  - mature processes;
  - consistency between projects;
  - project oriented systems;
  - project awareness permeates the organisation.
- level 4 - quantitatively managed;
- level 5 - optimised:
  - continually improved processes;
  - measured performance;
  - agile and adaptive systems;
  - empowered people.

4) Project initiation stage: At this point, the project charter is written up by the company executive(s) or board and issued to the project manager. The project management plan (PMP) is also completed and gives the project team a document hierarchy to work to. At this point, the project team work to identify the scope of the project and collect requirements.

VII. Week 7

A. *Lecture 7 - Scope Management*

1) Steps of Scope Management: Scope management steps:

- plan scope management;
- collect requirements - identify scope;
- define scope;
- create work breakdown structure (WBS);
- validate scope;
- control scope.

2) Inputs to Scope Management: Inputs to this phase are:

- project charter;
- PMP;
- enterprise environmental factors;
- organisational process assets;
- project documents:
  - assumption log;
  - lessons learned register;
  - stakeholder register.
- business case;
- agreements.

3) Outputs from Scope Management: Outputs from this phase are:

- scope management plan;
- requirements management plan;
- requirements traceability matrix;
- create work breakdown structure (WBS);
- project scope statement;
- project documents updates:
  - assumptions log;
  - requirements traceability matrix;
  - stakeholder register.

4) Work Breakdown Structure: Each level of the WBS covers 100% of the project. Elements are outcome/deliverable focused, not action focused. Elements can be grouped according to things like phasing, performance groups or 'like' system elements.

5) Scope Management Processes:

- planning process group:
  - plan scope management;
  - collect requirements;
  - define scope;
  - create WBS.
- monitoring and controlling process group:
  - validate scope;
  - control scope.

VIII. Week 8

A. *Lecture 8 - Risk Management*

1) Risk: Risk = probability (0 to 1) * impact (+ or -). Negative impact is bad. Positive impact is good. Unlike a risk, a problem is something that **has** occurred.

Knowledge Areas	Project Management Process Groups				
	Initiating Process Group	Planning Process Group	Executing Process Group	Monitoring and Controlling Process Group	Closing Process Group
4. Project Integration Management	4.1 Develop Project Charter	4.2 Develop Project Management Plan	4.3 Direct and Manage Project Work 4.4 Manage Project Knowledge	4.5 Monitor and Control Project Work 4.6 Perform Integrated Change Control	4.7 Close Project or Phase
5. Project Scope Management		5.1 Plan Scope Management 5.2 Collect Requirements 5.3 Define Scope 5.4 Create WBS		5.5 Validate Scope 5.6 Control Scope	
6. Project Schedule Management		6.1 Plan Schedule Management 6.2 Define Activities 6.3 Sequence Activities 6.4 Estimate Activity Durations 6.5 Develop Schedule		6.6 Control Schedule	
7. Project Cost Management		7.1 Plan Cost Management 7.2 Estimate Costs 7.3 Determine Budget		7.4 Control Costs	
8. Project Quality Management		8.1 Plan Quality Management	8.2 Manage Quality	8.3 Control Quality	
9. Project Resource Management		9.1 Plan Resource Management 9.2 Estimate Activity Resources	9.3 Acquire Resources 9.4 Develop Team 9.5 Manage Team	9.6 Control Resources	
10. Project Communications Management		10.1 Plan Communications Management	10.2 Manage Communications	10.3 Monitor Communications	
11. Project Risk Management		11.1 Plan Risk Management 11.2 Identify Risks 11.3 Perform Qualitative Risk Analysis 11.4 Perform Quantitative Risk Analysis 11.5 Plan Risk Responses	11.6 Implement Risk Responses	11.7 Monitor Risks	
12. Project Procurement Management		12.1 Plan Procurement Management	12.2 Conduct Procurements	12.3 Control Procurements	
13. Project Stakeholder Management	13.1 Identify Stakeholders	13.2 Plan Stakeholder Engagement	13.3 Manage Stakeholder Engagement	13.4 Monitor Stakeholder Engagement	

2) Project Risk Management Processes: This process occurs after the propject charter has been written up. The project risk management processes are:

- plan risk management, considering:
  - nature/types of causes/consequences and how to measure them;
  - how likelihood will be defined;
  - timeframes of likelihoods/consequences;
  - how levels of risk will be determined;
  - tolerance thresholds.
- identify risks;
- qualitative risk analysis;
- quantitative risk analysis;
- plan risk response;
- implement risk response plan;
- monitor risks.

The key output of these processes is the risk register.

3) Risk Response: Risk response is the process of developing options, selecting strategies, and agreeing on actions to address project risk exposure (enhance opportunities and to reduce threats) as well as treat project risks. This should be:

- appropriate for the risk significance;
- cost effective;
- owned by a responsible agent;
- realistic.

A risk response plan documents how chosen treatment options will be implemented. Risk response can be broken into the following categories:

- avoid (scheduling, strategy changes, scope adjustment, consultation);
- transfer (insurance, warranties);
- mitigate/reduce (increase testing, safer supplier options);
- accept (only when other strategies are non-viable or have led to risk becoming acceptably low).

IX. Week 9

A. *Lecture 9 - Time, Schedule and Cost Management*

1) Analogous Estimating: This method of estimation uses historical data on similar projects/activities to make an estimate. Similarity is judged on type, size, complexity, physical characteristics etc. Expert judgement is needed to make the comparison. Take the Collins class submarines as an example of this being completely retarded.

2) Parametric/Stochastic Estimating: This method of estimation uses patterns that can be analysed statistically but not necessarily predicted accurately. Sometimes uses historical data and project parameters to estimate cost.

3) Bottom-up/Engineering Estimating: Here, estimates are done for each work package (lowest WBS level). The estimate and basis-of-estimate are recorded in the WBS dictionary. This is the only way to achieve a definitive estimate for the performance management baseline.

4) Project Budget: The budget is the amount allocated to the project to achieve its objectives (the funding requirement). It must cover the aggregated cost estimates but includes reserves:

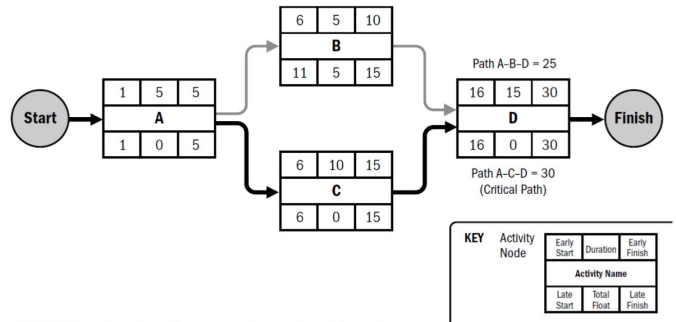
- contingency reserve:
  - inside the cost baseline (project manager responsibility);
  - to treat identified risks;
  - includes allocated (assigned to work packages) and unallocated (held by project manager).
- management reserve:
  - kept outside the cost baseline (sponsor responsibility);
  - for unforeseen changes in project scope;
  - a formal change to the cost baseline is recorded as the reserve is consumed.

5) Critical Path: This method estimates project duration and the flexibility of the schedule. Calculates early start, early finish, late start and late finish for each work package. **The critical path is the longest sequence of work packages**. Work packages on the critical path have no float.

6) Resource Levelling and Smoothing: This keeps the allocation of each resource type below a given constraint or used in the most efficient way.

7) Schedule Compression: Shortening the schedule without changing the scope of the project:

- crashing:
  - add resources to critical work packages to shorten duration;
  - often increases project costs;
  - often increases risks;



NOTE: This example uses the accepted convention of the project starting on day 1 for calculating start and finish dates. There are other accepted conventions that may be used.

  - for example, hiring three extra programmers for a 1-week work package.
- fast tracking:
  - start a work package ahead of schedule;
  - may increase risks and create rework;
  - for example, start flight testing before hovering has passed integration testing.

8) Earned Value Management: This approach shows deviations in project performance by combining measures of cost, schedule and resources. It uses three key metrics for each work package:

- planned value:
  - work packages carry costs into time space;
  - the aggregation of all work packages is the performance management baseline;
  - s-curve in the time-phase budget.
- actual costs:
  - captured as they occur and posted to work packages.
- earned value:
  - each work package is assigned a technique that best represents real progress;
  - periodic reporting of progress.

The three measures are then compared to measure variance (negative variance is bad).

X. Week 10

A. *Lecture 10 - Stakeholder and Communications Management*

1) Stakeholder Management Steps:

- identify stakeholders (roles, interests, level of knowledge/influence, expectations):
  - classify into levels of power/interest (potentially through salience model);
  - generate stakeholder register (identification, assessment, classification).
- plan stakeholder management:
  - engagement levels: unaware, resistant, neutral, supportive, leading;
  - identify strategies/actions to promote stakeholder involvement.

- manage stakeholder engagement:
  - meet needs, address issues, foster involvement;
  - keep communications open;
  - shift support towards project and meet expectations;
  - develop issue log to track stakeholder concerns.
- monitor stakeholder engagement (as best you can):
  - adjust plans for engagement;
  - apply communication and interpersonal skills.

2) Communication Management Steps:

- plan communication management:
  - develop an approach that meets stakeholder information needs;
  - apply relevant and available communications assets
  - develop communications management plan.
- manage communications:
  - collection, distribution, storage, retrieval, management, monitoring and disposition of information;
  - must receive response - not just broadcasting.
- control communications:
  - ensuring information needs are met at all times.

B. ***Lecture 11 - Development Models***

1) Waterfall Model: Top-down flow through systems engineering process. Business value is delivered in one hit. Suitable when:

- requirements are completely known;
- nature of requirement is stable;
- no unresolved, high-risk components;
- requirements are compatible with stakeholder expectations;
- implementation architecture is well understood;
- timeline allows for sequential development.

2) Incremental Model: Phased development of a known set of requirements (multi-waterfall). Business value is delivered in multiple hits. Suitable when:

- partial capability builds can be developed/maintained;
- partial core capability is desired as early as possible;
- funding is split into increments.

3) Evolutionary Model: Refinement and discovery of requirements through phases. Business value is delivered progressively, with backtracking possible. Suitable when:

- partial capability builds can be developed/maintained;
- usage of the system is expected to revise or discover requirements.

4) Spiral Model: Risk-driven process model generator for software projects. Iterates a set of elemental development processes to actively reduce risk, based on unique risk profile of a project. Spiral quadrants in order:

- determine objectives (requirements planning);
- identify and resolve risks (develop prototypes);
- development and testing (verification/validation, detailed design, integration and implementation)
- plan the next iteration (test/development planning and then release).

5) Spiral Model:

- approach:
  - working capability is the measure of progress;
  - deliver capability early and continuously;
  - welcome changing requirements;
  - reduce documentation - focus on conversations;
  - focus on architecture and technical excellence.
- team:
  - integrate business people with developers;
  - let the dev team identify requirements and develop architecture;
  - give the dev team authority;
  - sustain and retain the dev team;
  - adopt continuous team development.
- challenges:
  - active involvement from customer is mandatory;
  - requires continuous planning and updating;
  - formalised testing and acceptance criteria;
  - more difficult for large teams;
  - requires consistency across teams with respect to processes, skills and quality.

XI. Week 11

A. Lecture 12 - Sustainment Management 1

Operating and use costs always outweigh acquisition costs (totalling approximately 60 to 85%). These factors include:

- operations;
- human safety;
- reputation costs;
- professional responsibility and reputation;
- software and ICT systems;
- organisational change;
- organisation reputation;
- industry support;
- facilities;
- maintenance;
- spares;
- training;
- distribution;
- test and support equipment;
- technical data;
- environmental protection;
- retirement and disposal.

Sustainment includes:

- supply support (procurement, positioning, distribution, storage, salvage);
- maintenance (operational, preventative, repair, corrective, predictive);
- transportation (packaging, handling, storage, distribution);
- upgrades and modification;
- personnel and training;
- habitability;
- usability;
- supportability (the degree to which a system can be supported - standardisation, interchangeability, accessibility, commonality);

- survivability (to continue to operate in a hostile environment);
- environment;
- WHS;
- anti-tamper provisions;
- configuration management (the process of establishing and maintaining consistency of a product's performance, functional and physical attributes, with its requirements, design and operational information through its life);
- system data management;
- critical information protection;
- ICT including national security systems;
- interoperability functions (the ability to work with other products or systems without any restricted access or implementation).

Topics/aspects of sustainment:

- systems engineering;
- procurement project management;
- maintenance processes;
- ILS;
- product life cycle management;
- service management.

Major benefits arise from early integration of sustainment considerations:

- operating phase costs greatly outweigh initial capital costs;
- total lifecycle costs should be a prime consideration for system acquisition;
- non-monetary risks must be reduced – human death/injury, environmental damage, reputational risks and other legal risks;
- the sustainment system needs to be developed in parallel the mission system;
- this is difficult to achieve 360 degree processes because of ownership and procedural discontinuities.

XII. Week 12

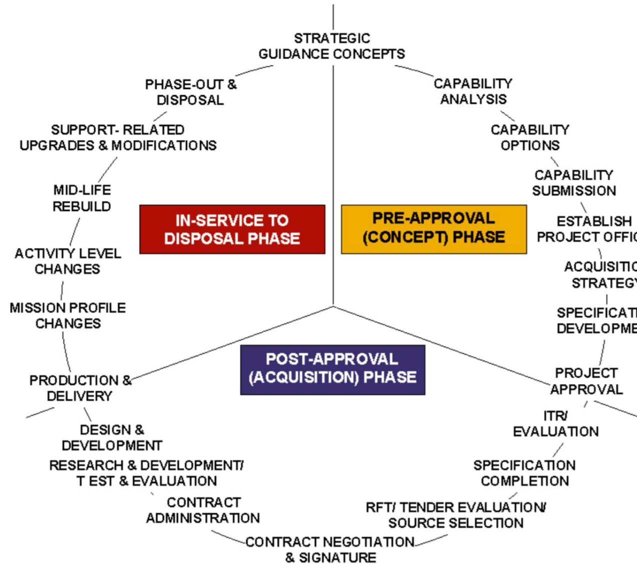
A. *Lecture 13 - Sustainment Management 2*

Life Cycle Cost Analysis is used as per the following picture: The typical method of LCCA is:

- develop the model/s:
  - usually a discounted cash flow model;
  - prompted by standardised lists and checklists.
- conduct cost estimates for each alternative;
- normalise data across alternatives;
- validate the data;
- conduct sensitivity analysis;
- conduct risk analysis;
- comparatively assess and rank alternatives;
- report and present;
- advocate the preferred alternative.

Typical life cycle cost elements for the pre-acquisition phase, acquisition phase, utilisation phase and retirement phase are included in the final lecture slides (13-16). LCCA tools often include (example is ACEIT):

- cost elements lists;



- standardised spreadsheets;
- statistical models;
- simulation tools;
- checklists;
- estimation techniques: analogy, parametric, engineering.

B. *Net Present Value Method*

This is a method of comparing the value of something in dollars compared to some possible future value:

$$NPV = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

where:

- N = number of periods modelled;
- t = time period index;
- R_t = net cash flow at time period t;
- i = discount rate = average cost of capital (long term government bod rate for government).

C. *Failure Rate*

The failure rate is given by:

$$\gamma = \frac{numberoffailures}{duration} = \frac{1}{MTBF}$$

Reliability of a system is 1 - γ.

D. *Types of failure*

The following are the possible types of failure:

- mission critical - cannot complete mission;
- safety critical - system safety is impacted;
- common mode - susceptible to a common cause;
- single point - failure of a single system element can cause system failure.

E. Availability

Availability is given by:

$$A = \frac{MTBF}{MTBF + MCMT}$$

where MCMT is mean corrective maintenance time.

F. TRF

The formal model used by an organisation to control the quality of its materiel and to enact regulations. Comprises of:

- governance - roles, responsibilities, authority, delegations, committees;
- processes;
- legislation;
- standards, regulation and other compliance requirements.

G. Ways to Conduct Engineering Precedence

The following are ways to conduct engineering precedence:

- design for minimum risk - eliminate hazards where possible;
- incorporate safety devices - protective features;
- provide warning devices - detect and annunciate;
- develop procedures and training - includes PPE;
- warnings and cautions.

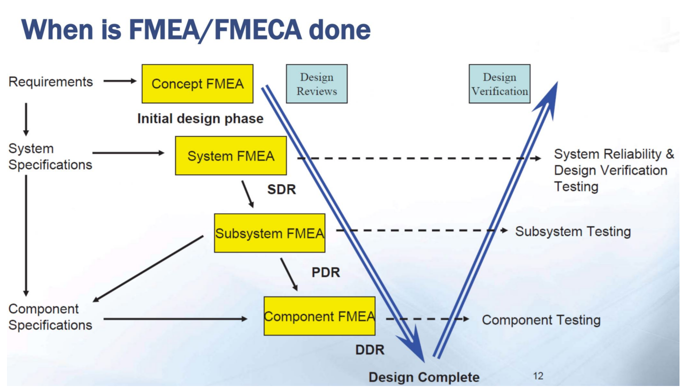
H. Failure Mode, Effects and Criticality Analysis

This is a bottom-up, inductive analytical method used to identify failure modes against the severity of their consequences. It is often mandated for certain industries and is often focussed on human safety.

I. FMECA Method

The following is the approach taken by the FMECA method:

- define the system;
- define ground rules and assumptions in order to help drive the design;
- construct system block diagrams- eg functional block diagram, fault trees;
- identify failure modes (piece, part level or functional level);
- analyse failure effects and causes;
- classify the failure effects by severity;
- perform criticality calculations;
- rank failure mode criticality;
- determine critical items;
- identify the means of failure detection, isolation and compensation;
- perform maintainability analysis;
- document the results and specify design corrections;
- document uncorrectable design areas and identify the necessary special controls;
- make recommendations;
- follow up on corrective action implementation/effectiveness.



XIII. Definitions

1) Approach - Evolutionary: Similar to the incremental approach; however this approach seeks to build upon previous builds and continue to evolve a system to satisfactory completion.

2) Approach - Incremental: For many reasons, it may be inadvisable to deliver a project in a single iteration (limited capability demand early, insufficient funds/time, incomplete understanding of system requirements, risk management). With a good understanding of the scope of the project, this approach allocates aspects to a series of increments to be delivered over time.

3) Approach - Spiral: Primarily a software model, this approach makes clear that a design development cannot be precisely determined prior to its full development and requires constant re-evaluation of the system at specific intervals. This allows for consideration given to changes in user perceptions, results of prototypes, technology advances, risk determinations, funding or other factors that may become relevant.

4) Approach - Waterfall: This approach relies on the development of a complete set of requirements at the system level, which influences and cascades into the subsystem requirements, which in turn, drive the requirements for the assemblies and components. At each transition, a baseline tends to be established.

5) Construction: The assembly and building of the system.

6) Costs - Burdened: Usually included with particular services/activities. Things like uniforms, employer-paid snacks, minor tools and equipment.

7) Costs - Direct: Costs that can be traced to a cost object (e.g. an output or process of the activity) with a high degree of accuracy.

8) Costs - Indirect: Costs that cannot be easily linked to a cost object, or where the costs of doing so outweigh the benefits. Indirect costs are apportioned to a cost object using an appropriate cost driver.

9) Failure Criticality: Likelihood of a critical failure ie mission failure including human safety.

10) Failure Effect: The consequence(s) a failure mode has on the operation, function, or status of an item.

11) Failure Mode: The way or manner in which an item fails - considered the ‘anti-function’.

12) Failure Reliability Centered Maintenance (RCM): The function of the equipment is considered. Possible failure modes and their consequences are identified. Cost effective maintenance techniques that minimise failures are identified and adopted.

13) Integrated Logistics Support (ILS): The functions that provides initial planning, funding and controls to ensure the user will receive a system that can be expeditiously and economically supported throughout its life cycle. Includes: maintenance, supply support, test and support equipment, personnel and training, facilities and equipment, packaging, handling, storage and transportation, technical data. ILS tasks: support concept, logistics support analysis, lifecycle cost analysis, inserting ILS considerations into system design and development.

14) Life Cycle Cost Analysis: Estimation and analysis techniques for the collection, analysis and presentation of Life Cycle Costing data to assist in decision making about required capabilities. Also called total cost of ownership.

15) Product Life Cycle Management: Also called asset management. Encompasses engineering change management. The system of strategic processes to:

- reduce the cost of getting a product to market;
- efficiently scale production to meet market demand;
- extend the duration of the effective life of a system;
- continue maximum effectiveness through obsolescence;
- collaborate among supply chain team members to design, build and manage the system;
- share data across disparate systems for design, quality, manufacturing and operational systems;
- collect system data for communication and management of system issues;
- ensuring the system meets and retains compliance standards.

16) Production: The manufacturing and procurement effort needed to support construction.

17) Project: A Project is a temporary endeavour undertaken to create a unique product, service, or result.

18) Project Charter: This is a document that is written at the initiation phase of the project. It authorises the project and gives the project manager authority to commit resources. Details found in the charter are such as:

- background and project purpose;
- objectives and success criteria;
- high-level requirements, scope, boundaries and constraints;
- key stakeholders;
- key deliverables;
- high-level risk assessment;
- high-level schedule requirements/deadlines;
- budget, authority and oversight processes;
- assignment of project manager;
- evidence of approval by sponsor.

19) Project Management: Project Management is the application of knowledge, skills, tools and techniques to project activities to meet the project requirements.

20) Project Management Plan: A living document that holds the current status of all PM processes. Defines how the project will executed, monitored, controlled and closed.

21) Risk: An uncertain event or condition that, if it occurs, has a positive or negative effects on one or more project objectives such as scope, schedule, cost, and quality.

22) Risk Management: The systematic process of identifying, analysing, responding, and monitoring project risk.

23) Scope Creep: Scope creep means changes, continuous or uncontrolled growth in the scope of a system’s functionality, including the addition of undesired functionality as a byproduct of COTS CIs.

24) Sustainment: To keep something going or extending its duration. The provision of personnel, logistic and other support required to maintain and prolong operations or combat until successful accomplishment or revision of the mission or of the national objective.

25) System: ISO/IEC/IEEE 15288 defines a system as a combination of interacting elements organised to achieve one or more stated purposes. A system comprises internal elements with interconnections (subsystems) and an external boundary. Anything inside the boundary is defined as the system of interest. The mission of a system is to provide a solution to a business problem.

26) Systems Engineering: An interdisciplinary collaborative approach to derive, evolve, and verify a life-cycle balanced system solution which satisfies customer expectations and meets public acceptability.

27) Traceability: Forward traceability allows design decisions to be traced from any requirement down to a lower level. Backward traceability means that any lower-level requirement is associated with at least one higher-level requirement.

28) Validation: This is the process of ensuring a system meets its operational purpose as dictated in the StRS.

29) Verification: This is the process of ensuring a system complies with the detailed specifications laid out in the SyRS, by meeting contractual requirements and performing adequately in an operational environment.

30) Work Breakdown Structure: A hierarchical decomposition of the total scope of work to be carried out by the project team to accomplish the project objectives and create the required deliverables.

31) Work Breakdown Structure Dictionary: Provides detailed information about each element of the WBS regarding scope, deliverables, scheduling, resources, costs etc.

32) Work Package: Deliverable or project work component at the lowest level of each branch of the work breakdown structure. Can be definitively estimated and associated with a deliverable that can be objectively verified and accepted.

XIV. Acronyms

ABL	Allocated Baseline
AT&E	Acceptance Test and Evaluation
BNR	Business Needs and Requirements
BOM	Bill of Materials
CDR	Critical Design Review
CI	Configuration Item/Critical Issue
CM	Configuration Management
CoC	Conditions of Contract
COI	Critical Operation Issue
COTS	Commercial Off The Shelf
DT&E	Development Test and Evaluation
FBL	Functional Baseline
FCA	Functional Configuration Audit
FFBL	Functional Flow Block Diagram
FHA	Functional Hazard Analysis
FIC	Fundamental Inputs to Capability
FQR	Formal Qualification Review
FRACAS	Failure Reporting and Corrective Action System
ILS	Integrated Logistics Support
LCC	Life-Cycle Cost
MOE	Measures of Effectiveness
MOP	Measures of Performance
OT&E	Operational Test and Evaluation
PBL	Product Baseline
PCA	Physical Configuration Audit
PDR	Preliminary Design Review
PM	Project Management
PMP	Project Management Plan
PRR	Product Readiness Review
RBS	Requirements Breakdown Structure
SDD	System Design Document
SDR	System Design Review
SE	Systems Engineering
SoR	Statement of Requirements
SoS	System of Systems
SoW	Statement of Work
SNR	Stakeholder Needs and Requirements
SRR	System Requirements Review
StRS	Stakeholder Requirement Specification
SyRS	System Requirement Specification
T&E	Testing and Evaluation
TEMP	Test and Evaluation Master Plan
TPM	Technical Performance Measures
TRR	Test Readiness Review
WBS	Work Breakdown Structure