

The Systems Engineering Process

Richard Morgan

Definition – What is 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 systems-level results.

The results include system level qualities, properties, characteristics, functions, behaviour and performance.

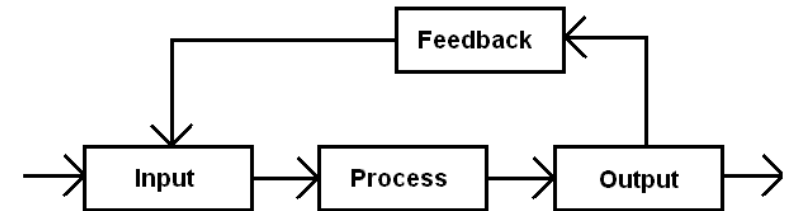
The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected

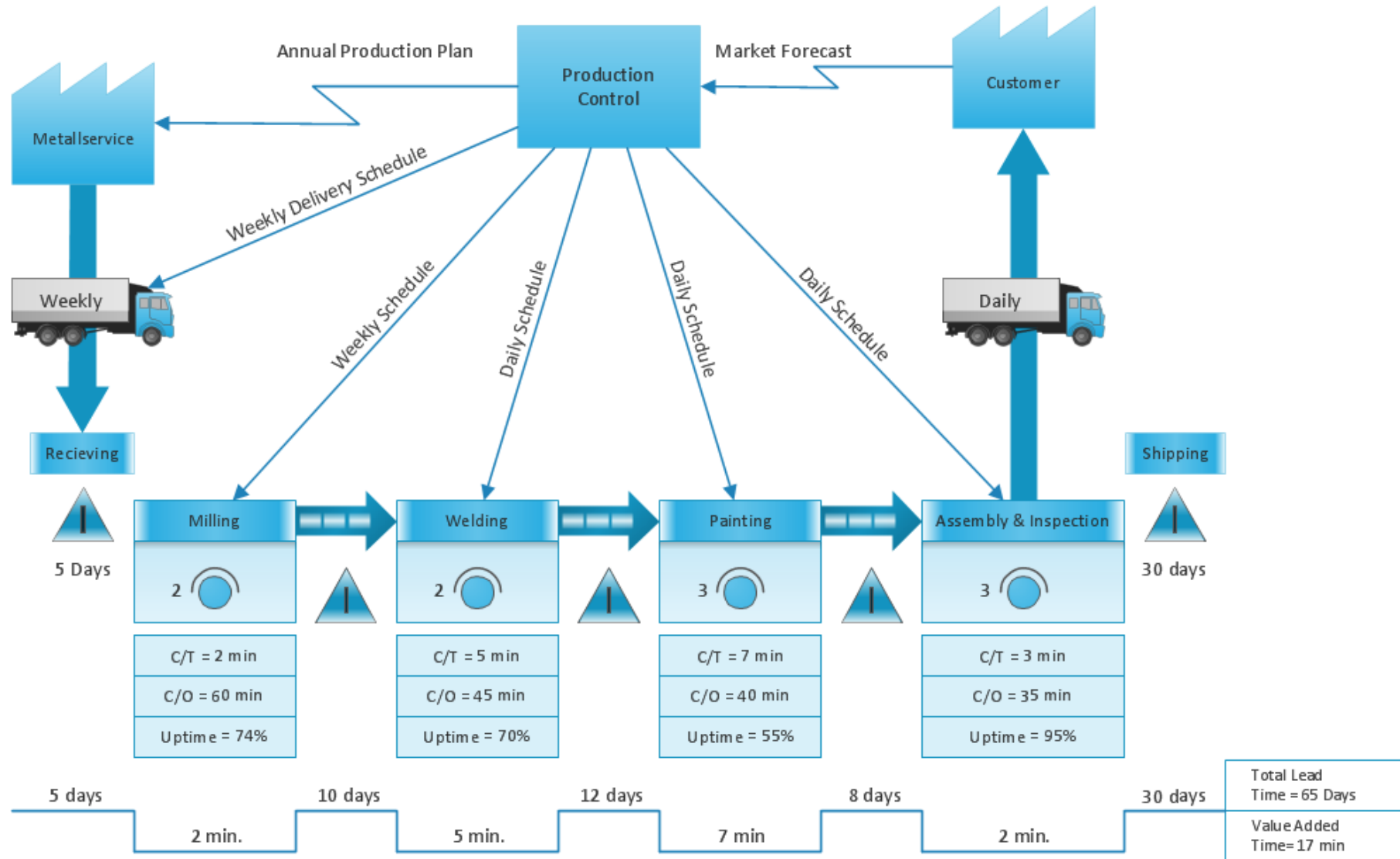
(Rechtin, E., Maier, M., The Art of Systems Architecting, 2nd Edition, CRC Press LLC, 2000, extract taken from: <http://www.incose.org/AboutSE/WhatIsSE>)



Significance of the System Concept in Management

- Systems exist in concrete form, not only as a concept
- System implies purposeful design
 - Rational approach to specific goals
 - Logical coordination of parts and sub-systems
 - Smooth flow of operations
 - Design as a “system of systems”
- Guides thinking towards optimised and effective goal delivery
- Rational control of resources in a competitive, changing environment
- Derivation and continuous update of specific and general objectives





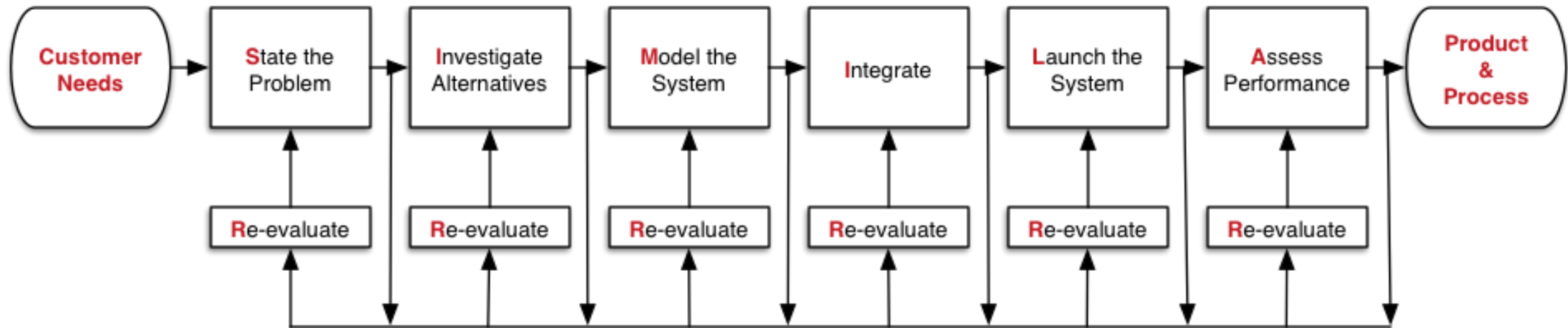
Which Gives Us?



- Managers problem orientated towards organisation benefits as well as local specifics
 - Better holistic decisions, emphasis against short-termism
- Chance of end-to-end optimised solutions
- Helps managers to understand and master responsibilities, particularly managing complexity
- Predetermined decisions or rules, procedures and operations
- Objectivity and evidence-based decision making
- Visibility of risk, if done correctly

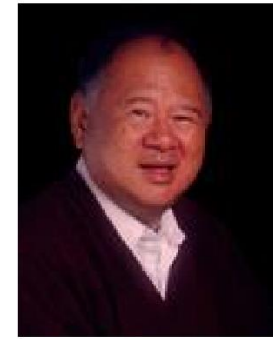
Systems Engineering Process - SIMILAR

Seven tasks:



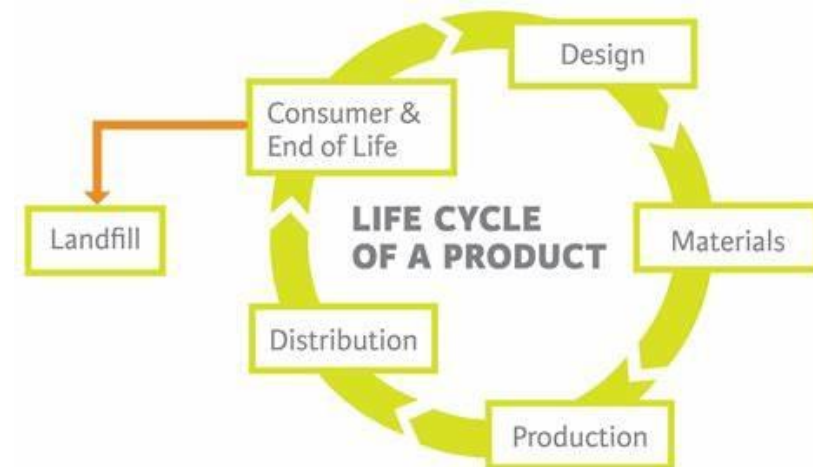
Systems Engineering functions are parallel and iterative

Commentary by Brian Mar (INCOSE)



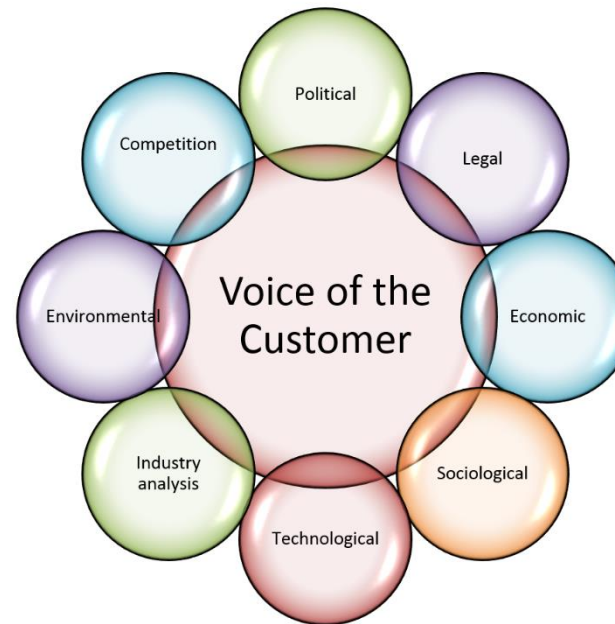
Most systems engineers accept the following basic core concepts:

- Understand the whole problem before you try to solve it
- Translate the problem into measurable requirements
- Examine all feasible alternatives before selecting a solution
- Make sure you consider the total system life cycle. The birth to death concept extends to maintenance, replacement and decommission. If these are not considered in the other tasks, major life cycle costs can be ignored
- Make sure to test the total system before delivering it
- Document everything



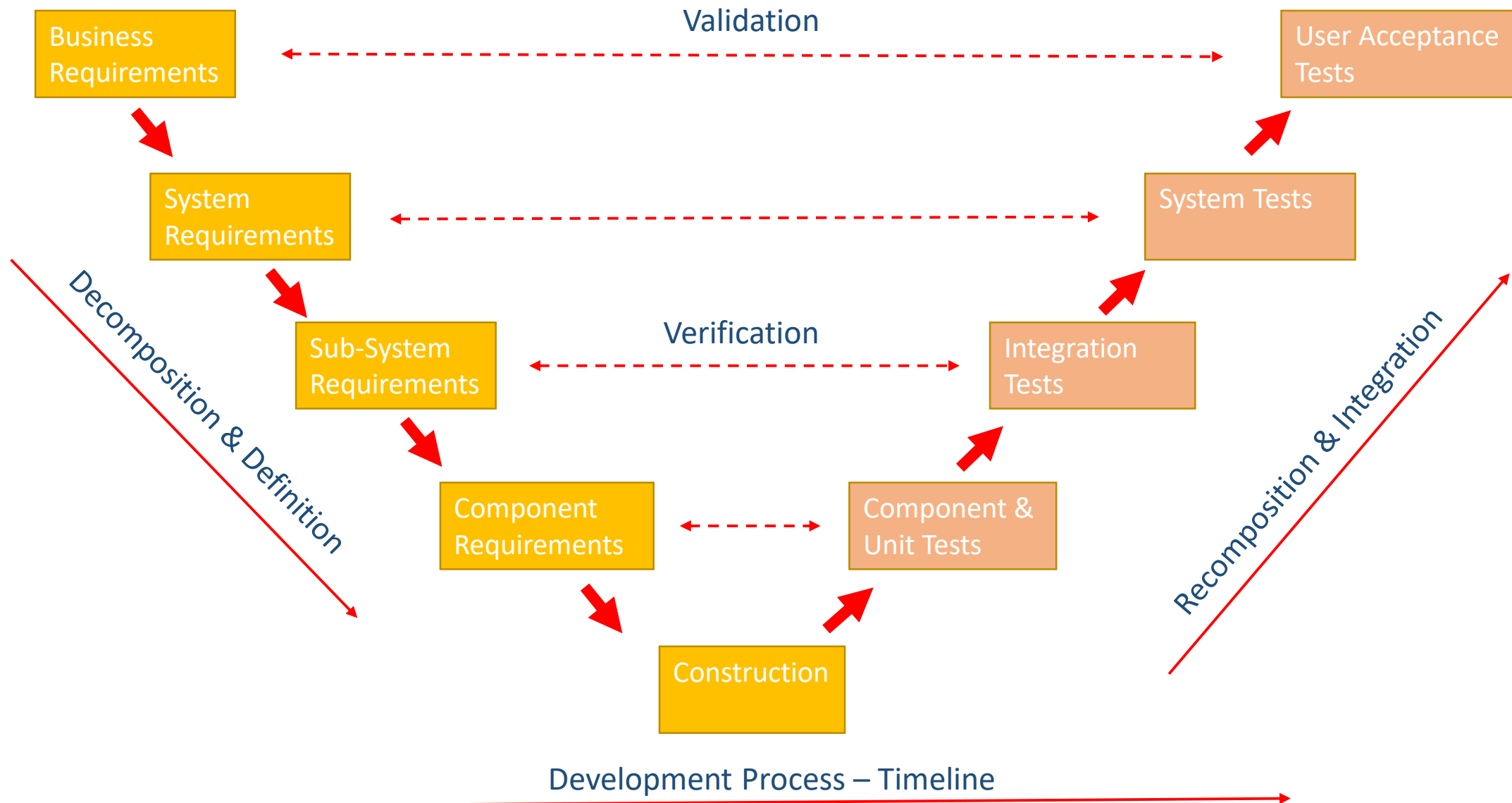
Fine – But What Do We Want to Achieve?

- Our goals are customer satisfaction and good performance
- The various stakeholders in the project have their needs fulfilled
- How?

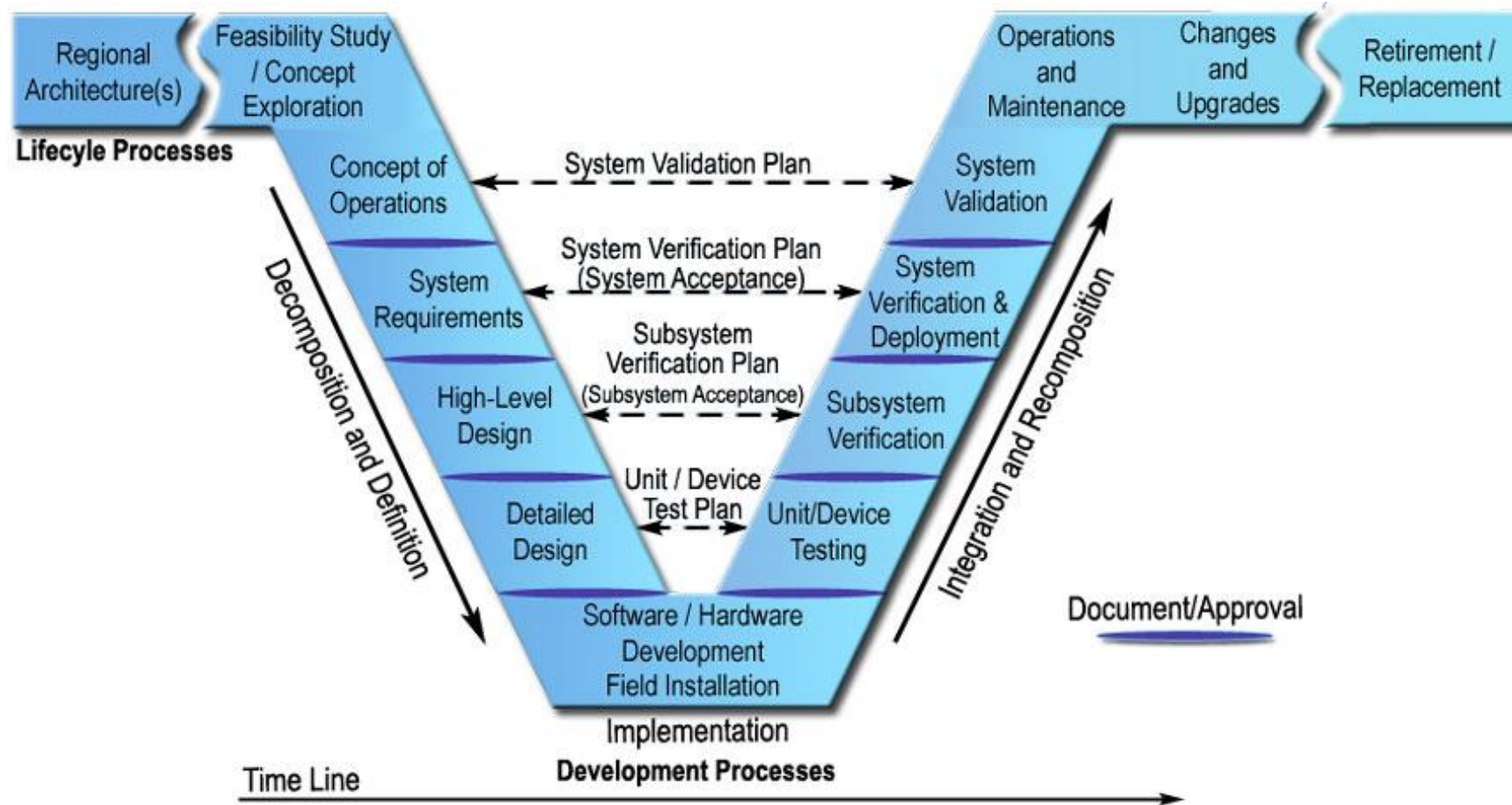


- High quality product/service
- Cost effective solution
- Reliable in the field
- Delivered on time/to budget
- Safe, maintainable and cost controlled through the system's lifecycle
- Cost managed and safely disposable at cycle end

The Systems Engineering V Model

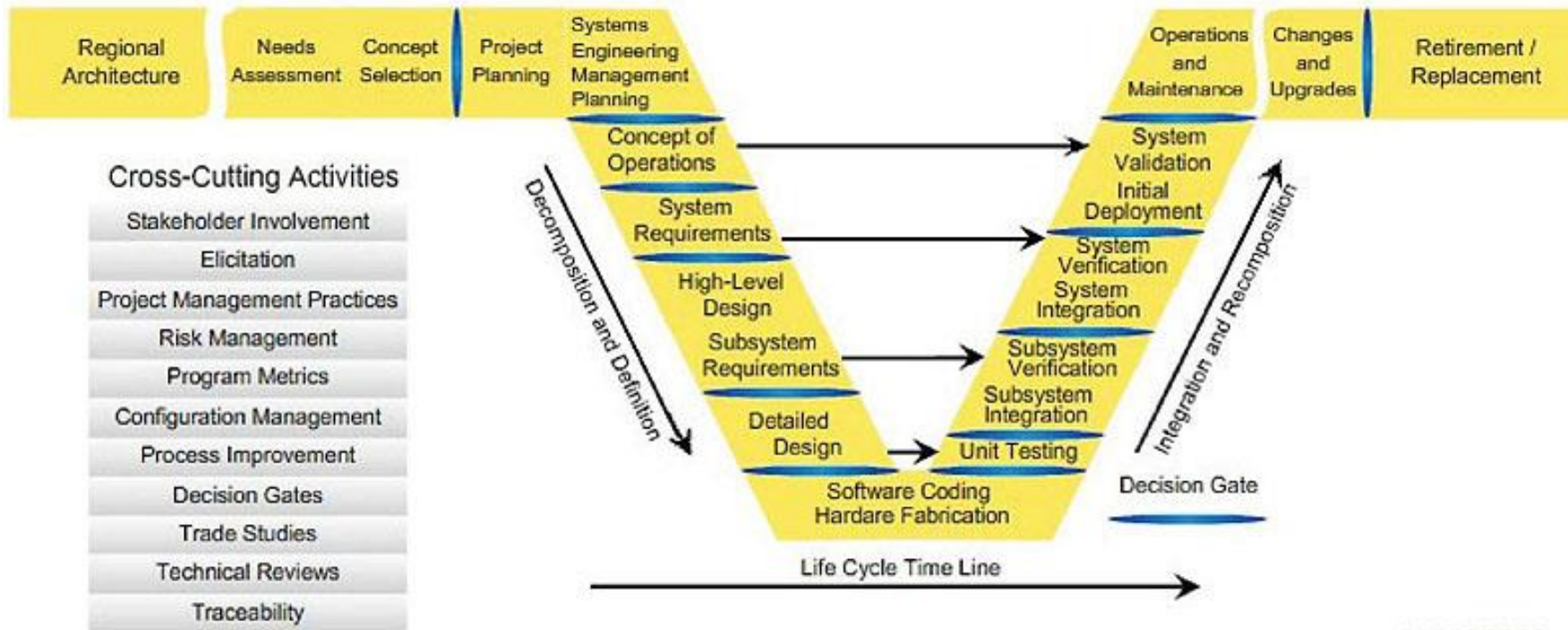


V-Diagram (US Federal Highways Agency)



V-Diagram (RITA)

Phase -1	Phase 0	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Interfacing with Planning and the Regional Architecture	Concept Exploration and Benefits Analysis	Project Planning and Concept of Operations Development	System Definition and Design	System Development and Implementation	Validation, Operations and Maintenance, Changes & Upgrades	System Retirement / Replacement

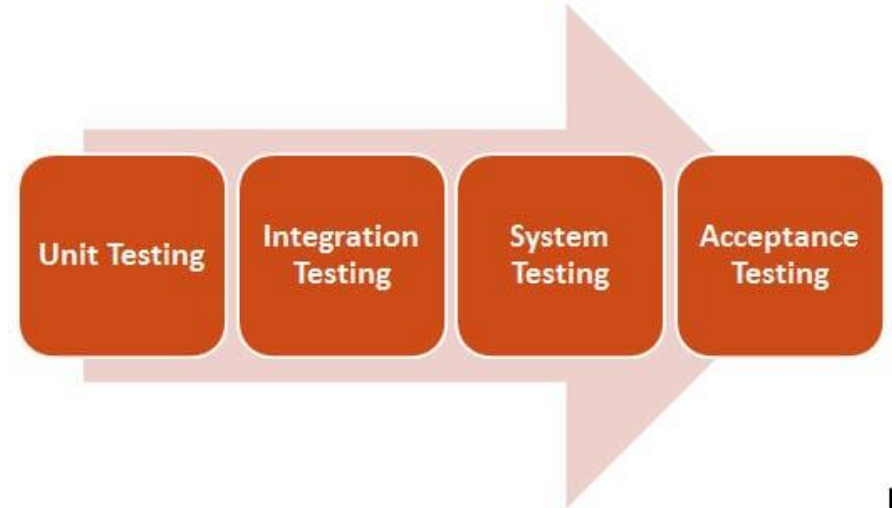


Considerations

- Vision - complex systems are not simple to envisage/conceptualise
- Complex systems have complex drivers for their existence
- Communication – stakeholder engagement, team communication, inter-team (sub-system) communication
- Control of complexity – modular design, validation and verification, integration
- Standards
 - Data, communications, parts and services, operations
- Manage the systems engineering to manage complexity and risk
- Disposal and replacement are part of the systems lifecycle

Final Stages – System Test

- Testing is critical to success
 - Verify subsystems
 - Meet standardised interface
 - Against requirements and specification
 - Verify system works
 - Integrates all components together
 - *Validate* system meets user needs
 - Against specifications, usability, performance characteristics
- Document all testing (including test equipment):
 - Allows reproducible results
 - Validation against calibration standards
 - Document activities and work undertaken
- Budget and schedule for multiple rounds
 - Problems will occur during initial tests
 - Give scope for fix and retest



Standards in Systems Engineering

- **ISO/IEC TR 24748-1:2010 – Guide for Life Cycle Management**
 - http://standards.iso.org/ittf/PubliclyAvailableStandards/c050502_ISO_IEC_TR_24748-1_2010.zip
- **ISO/IEC 15288: 2015 – System Life Cycle Processes**
- **IEEE 15288.1-2014 – IEEE Standard for Application of Systems Engineering on Defense Programs**
- **IEEE 15288.2-2014 – IEEE Standard for Technical Reviews and Audits of Defense Programs**

System Lifecycle Costs

- Everyone focuses on design, manufacture, implementation costs
- Considered at one level, these are intrinsic, one-off costs
- There are other basic cost elements of any *system*
 - Operation costs
 - Inspection costs
 - Testing and verifying compliance, legal or otherwise, and initiating corrective actions
 - Prevention costs
 - Resources deployed in avoiding failures and defects – including training, QA and audits
 - Failure or defect costs
 - Avoidable losses during design, production and performance
 - Costs escalate as external (field) rather than internal (test) failures/defects
- Costs relate to risk (financial and reputational)

