TISYE1 – Systems Engineering – (Winter/Spring 2014)

Integration Validation and Verification

TISYE1 – Lecture 6

Doc. no. TISYE1-15-010 R1.1

AARHUS SCHOOL OF ENGINEERING

Finally we can implement?

TABLE 12.1. Status of System Materialization at the Engineering Design Phase

Phase		*Concept development*			*Engineering development*	
Level	Needs analysis	Concept exploration	Concept definition	Advanced development	Engineering design	Integration and evaluation
System	Define system capabilities and effectiveness	Identify, explore, and synthesize concepts	Define selected concept with specifications	Validate concept		Test and evaluate
Subsystem		Define requirements and ensure feasibility	Define functional and physical architecture	Validate subsystems		Integrate and test
Component			Allocate functions to components	Define specifications	Design and test	Integrate and test
Subcomponent		Visualize		Allocate functions to subcomponents	Design	
Part					Make or buy	

- But what? How do we know?
- Do not forget the requirements!

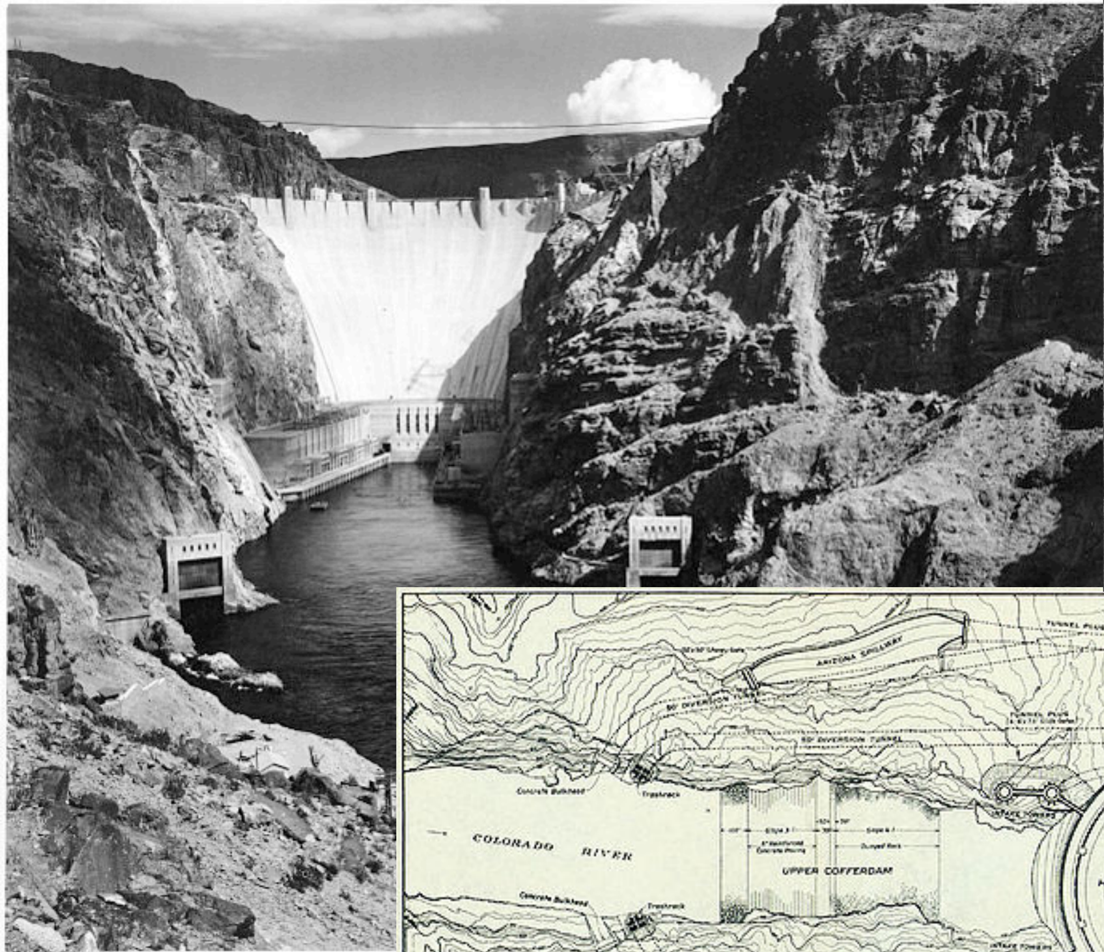
Finally we can implement?

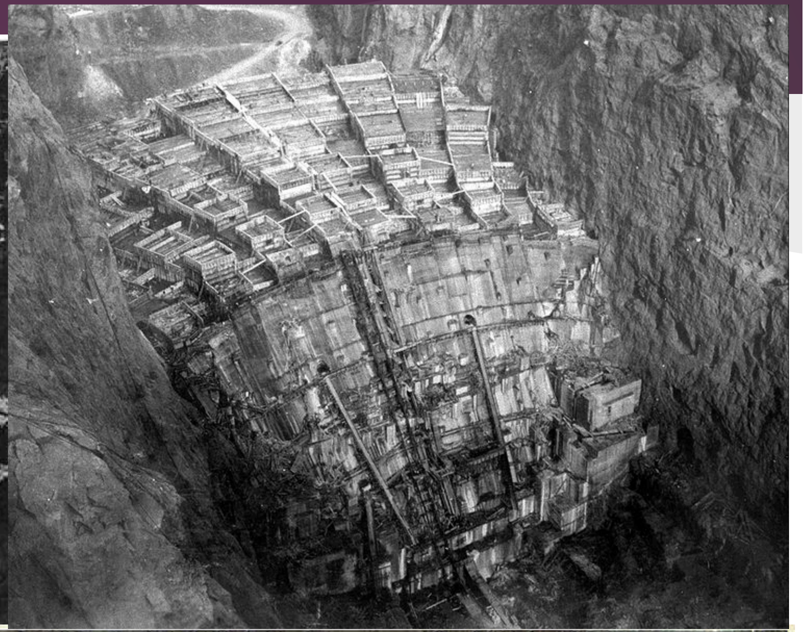
TABLE 13.3. Parallels between System Development and Test and Evaluation (T&E) Planning

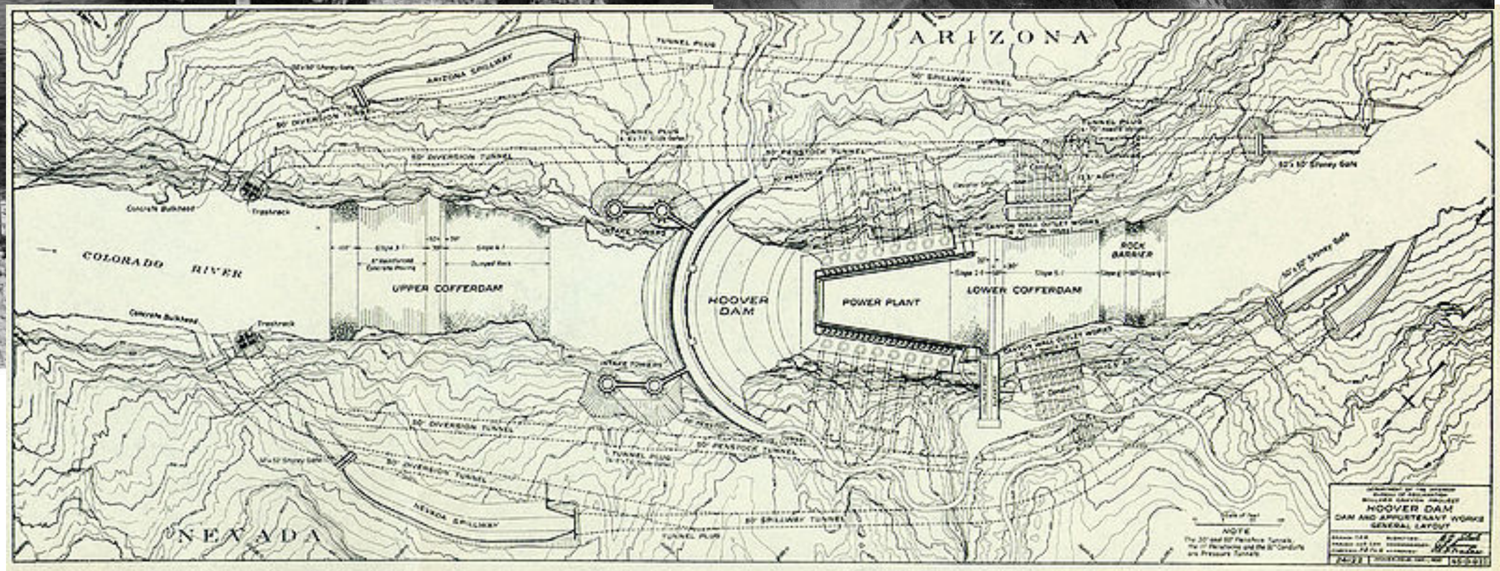
System development	T&E planning
Need:	Objective:
Define the capability to be fielded.	Determine the degree of sophistication required of the test program.
System concept:	Test concept:
Analyze trade-offs between performance, schedule, and cost to develop a system concept.	Evaluate trade-offs between test approaches, schedule, and cost to develop a test concept.
Functional design:	Test plan:
Translate functional requirements into two level specification for the (sub)system(s).	Translate test requirements into a description of each test event and the resources required.
Detailed design:	Test procedures:
Design the various components that comprise the system.	Develop detailed test procedures and test tools for each event.

- Testing is important at all stages (V-Model!)

How do you test this:







Which requirements?

- System design requirements
  - We have looked at these along the way
- External system interface requirements
  - User interfaces become clearer now
  - Review environmental interfaces
    - seals
    - insulators

How can we use requirements?

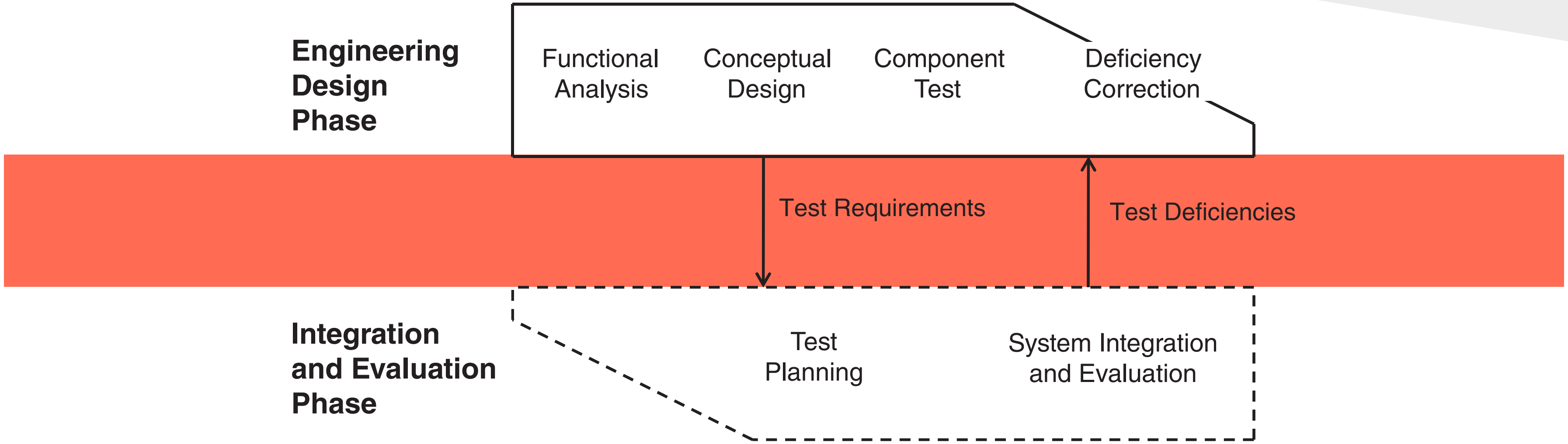


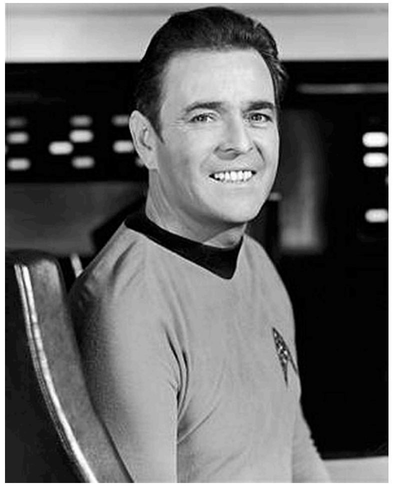
Figure 12.2. Engineering design phase in relation to integration and evaluation.

- Test and evaluate (continually)!

Overview of tasks

Advanced Development Phase

Lt. Commander Geordi La Forge:
Look, Mr. Scott, I'd love to explain everything to you, but the Captain wants this spectrographic analysis done by 1300 hours.
[La Forge goes back to work; Scotty follows slowly]
Scotty:
Do you mind a little advice? Starfleet captains are like children. They want everything right now and they want it their way. But the secret is to give them only what they ***need***, not what they ***want***.
Lt. Commander Geordi La Forge:
Yeah, well, I told the Captain I'd have this analysis done in an hour.
Scotty:
How long will it really take?
Lt. Commander Geordi La Forge:
An hour!
Scotty:
Oh, you didn't tell him how long it would *really* take, did ya?
Lt. Commander Geordi La Forge:
Well, of course I did.
Scotty:
Oh, laddie. You've got a lot to learn if you want people to think of you as a miracle worker.



Validated Design

Integration and Evaluation Phase

Figure 12.3. Engineering design phase flow diagram.

Functional analysis and design

- Modular configuration
  - each component can be developed separately
  - easy assembly of components
  - replacement and upgrading of components
- Functional elements
  - Significance:
    - distinct and significant function of each component
  - Singularity:
    - One engineering discipline drives each component
  - Commonality:
    - Components can be used in other systems too

Kinds of components

- Mechanical components
- Electronic components
- Hydraulic components
- Software components
- …

Component Design

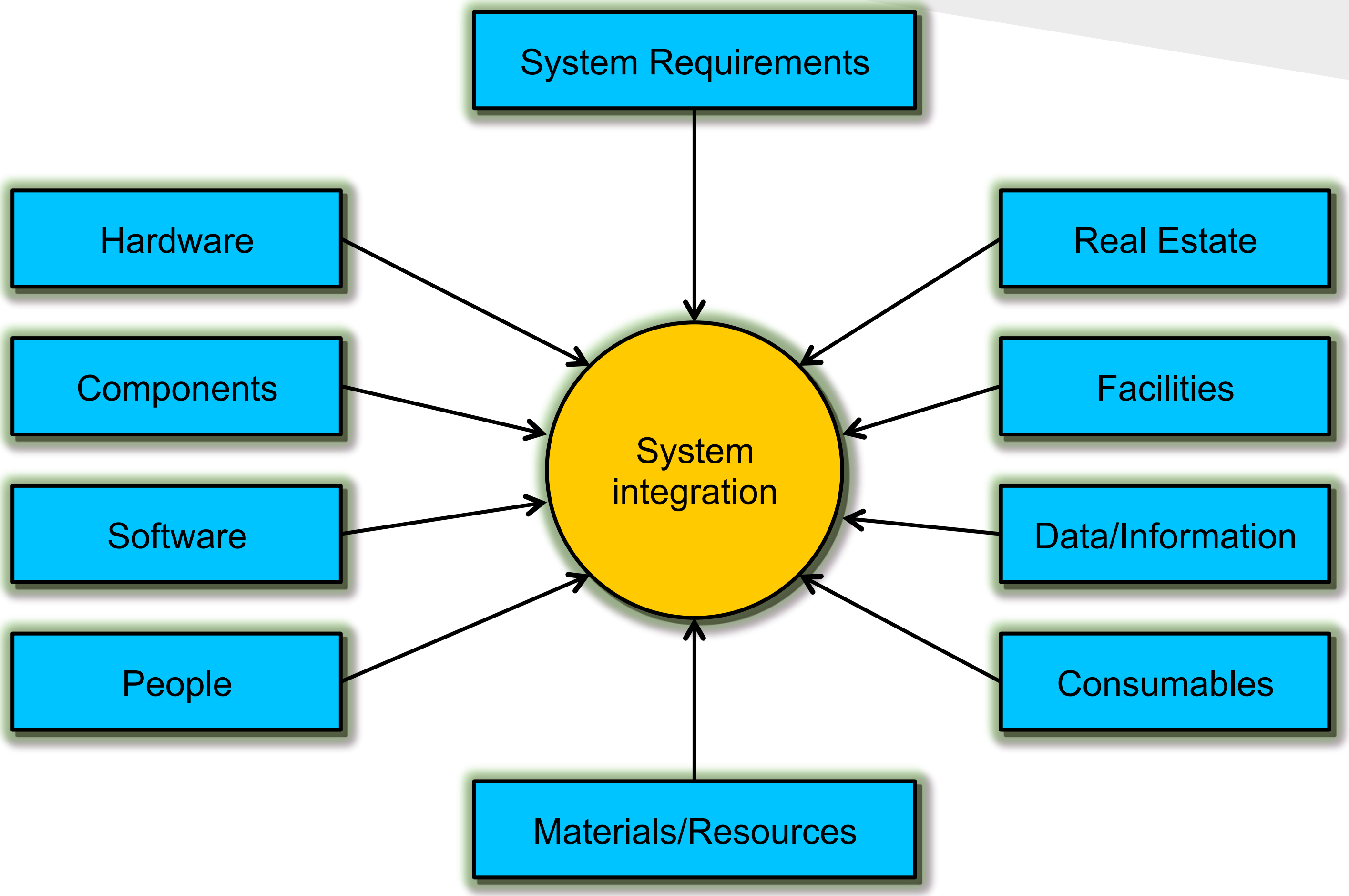
- Preliminary design
  - specifications
  - interfaces
  - mock-ups and models
  - development, integration and test plans
  - RMA
  - producibility
  - logistics
- Detailed design
- Design **reviews**

Product realization

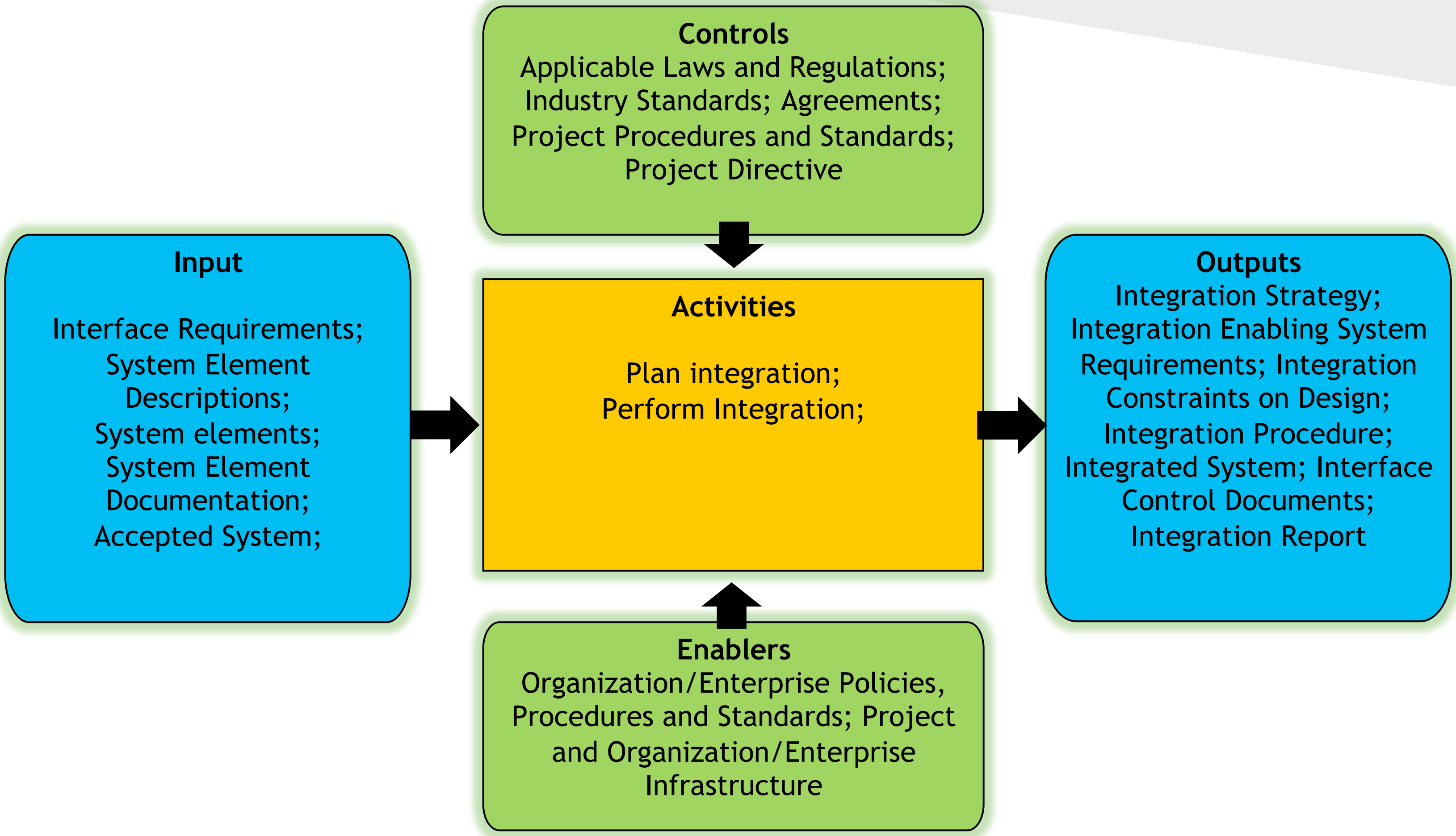
Design realization → **Evaluation process** → **Product transition process**

Product implementation	Product Integration	Product Verification	Product Validation	Product Transition
• Acquire • Make/code • Reuse	• Assembly • Functional evaluation	• Functional • Environment al • Operational testing in integration & test environment	• Operational testing in mission environment	• Delivery to next higher level in PBS • Delivery to operational system

The integration of system elements

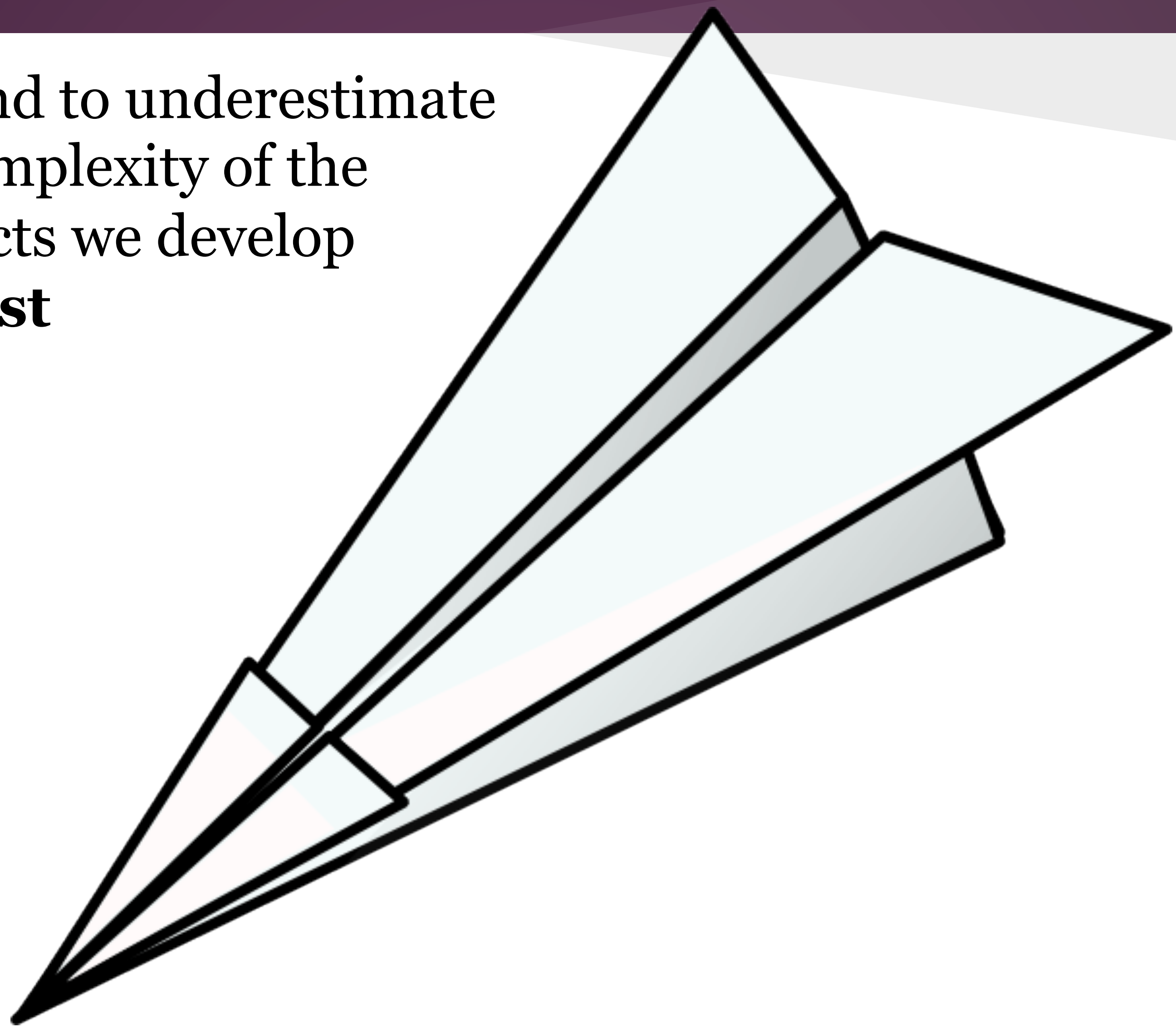


Integration Process (INT)

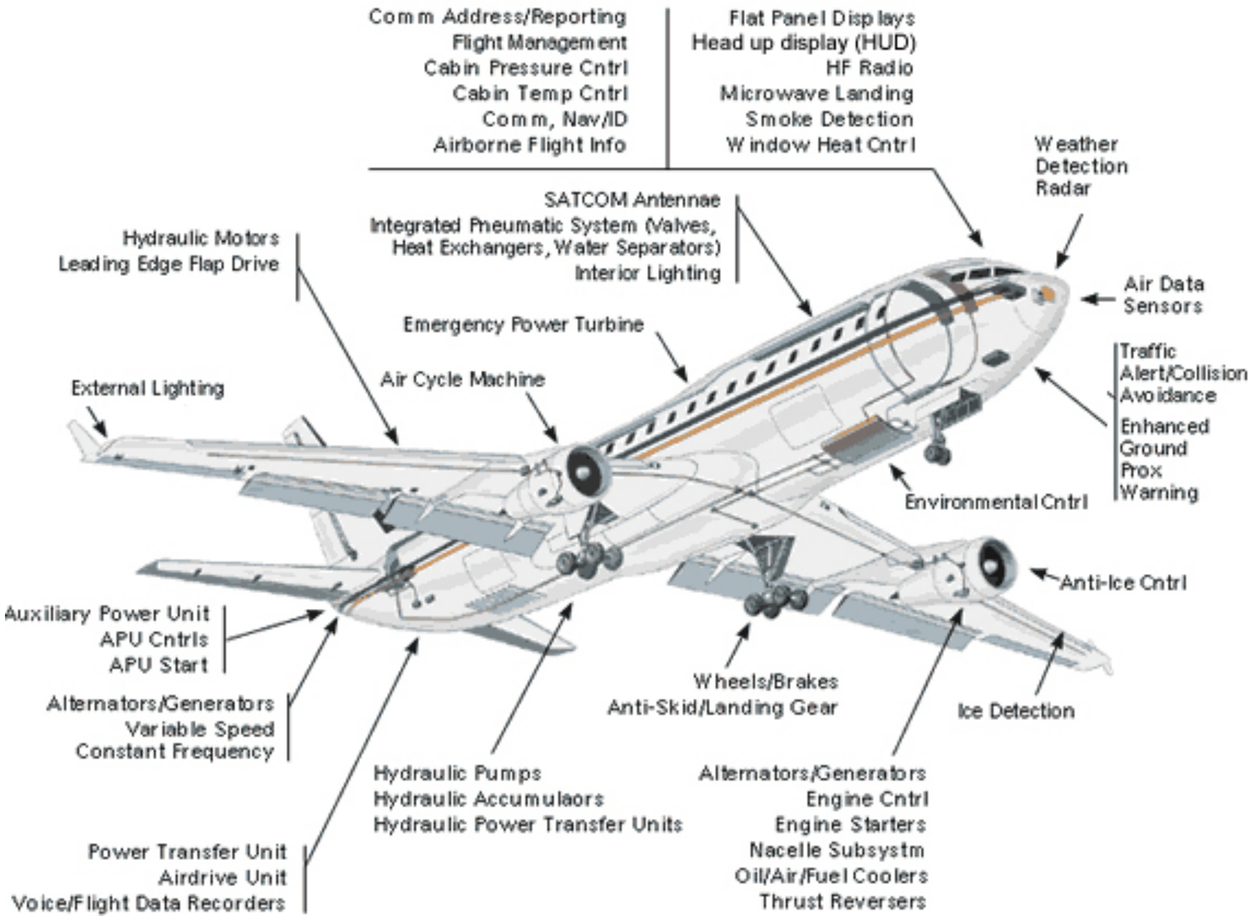


Imagination

- We tend to underestimate the complexity of the products we develop and **test**



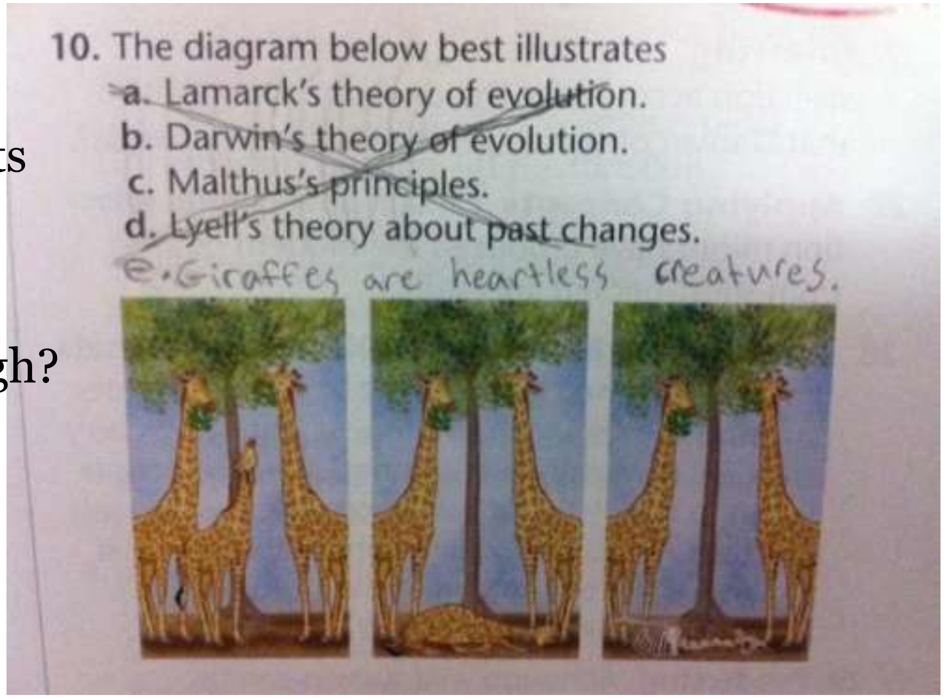
Reality



Comm Address/Reporting
Flight Management
Cabin Pressure Cntrl
Cabin Temp Cntrl
Comm, Nav/ID
Airborne Flight Info
Flat Panel Displays
Head up display (HUD)
HF Radio
Microwave Landing
Smoke Detection
Window Heat Cntrl
Weather Detection Radar
SATCOM Antennae
Integrated Pneumatic System (Valves, Heat Exchangers, Water Separators)
Interior Lighting
Hydraulic Motors
Leading Edge Flap Drive
Air Data Sensors
Emergency Power Turbine
Traffic Alert/Collision Avoidance
Air Cycle Machine
External Lighting
Enhanced Ground Prox Warning
Environmental Cntrl
Anti-Ice Cntrl
Auxiliary Power Unit
APU Cntrls
APU Start
Alternators/Generators
Variable Speed
Constant Frequency
Wheels/Brakes
Anti-Skid/Landing Gear
Ice Detection
Hydraulic Pumps
Hydraulic Accumulaors
Hydraulic Power Transfer Units
Alternators/Generators
Engine Cntrl
Engine Starters
Nacelle Subsystm
Oil/Air/Fuel Coolers
Thrust Reversers
Power Transfer Unit
Airdrive Unit
Voice/Flight Data Recorders

Design validation

- You are working on a large and complex product!
- Test planning
  - when should it be done? as early as possible
  - what should be tested? the implementation against the specification
- Testing
  - Development testing
    - before delivery of components
  - Qualification testing
    - on delivery
    - is the component good enough?



- Problems at many places
  - if not taken serious

Testing teams

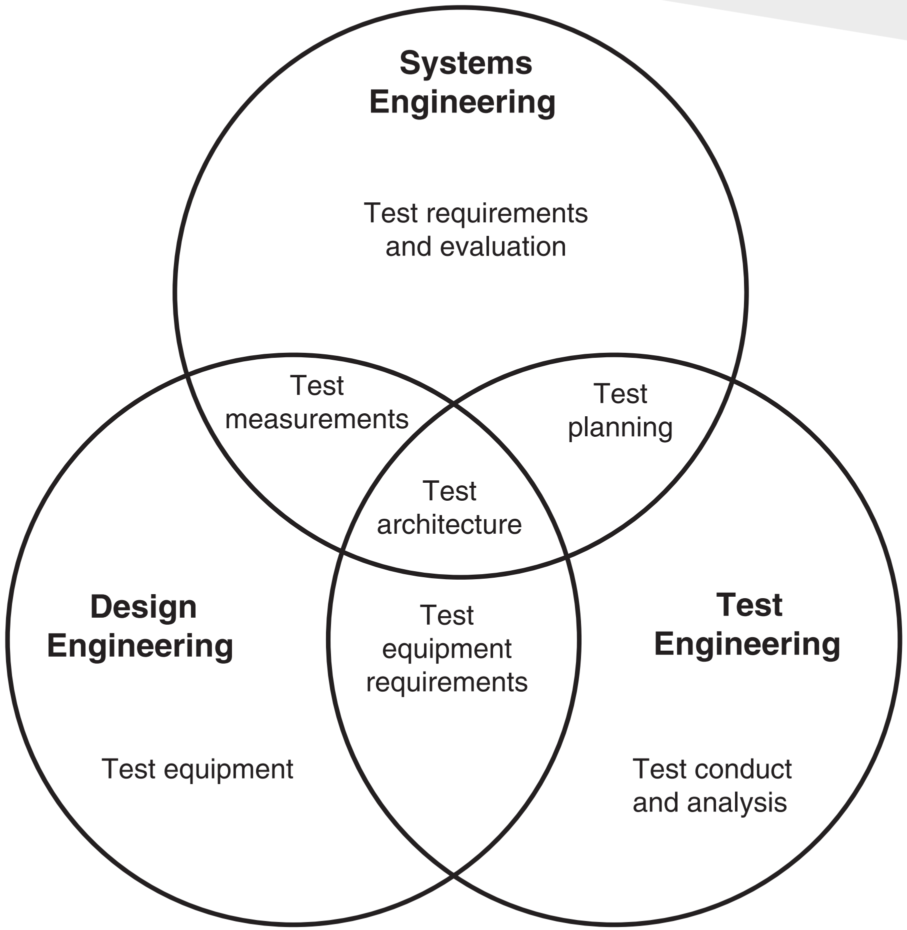


Figure 13.3. System test and evaluation team.

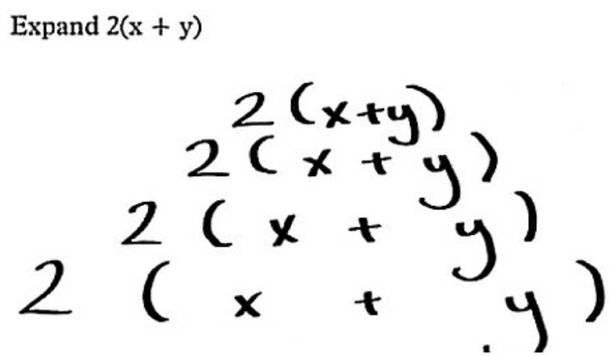
What is tested?

- Performance tests
- Environmental qualification
- Structural testing (Stress, material fatigue)
- Reliability qualification
- Maintainability demonstration
- Supportability test (Support equipment and compatibility)
- Personnel test and evaluation
- Technical data verification (Operational and maintenance procedures)
- Software verification
- Compatibility with other systems (in systems of systems)

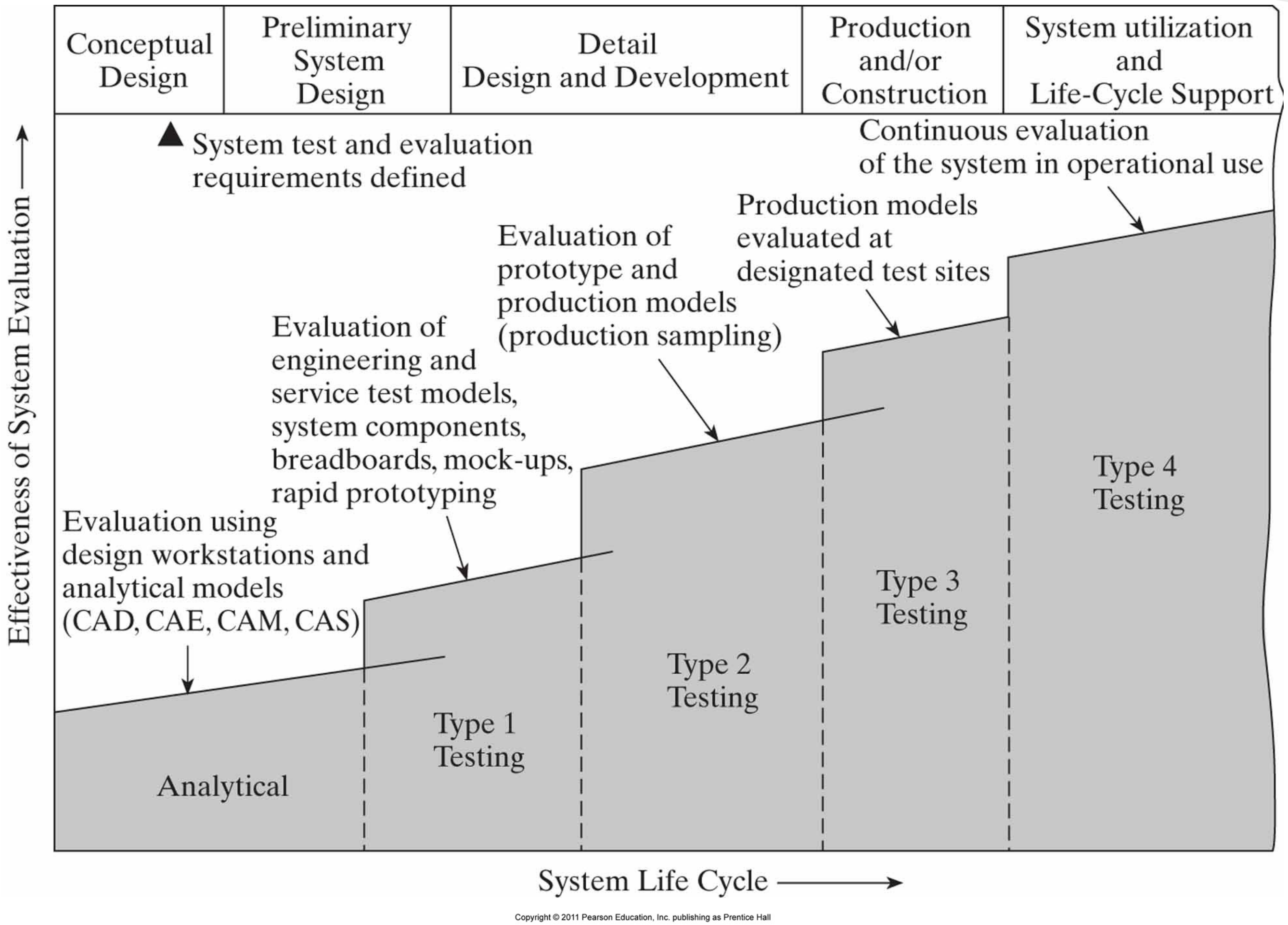
Development V&V stages

TABLE 13.2. System Integration and Evaluation Process

Integration level	Environment	Objective	Process
System	Real operational environment	Demonstrated operational performance	Operational test and evaluation
System	Simulated operational environment	Demonstrated compliance with all requirements	Developmental test and evaluation
System	Integration facility	Fully integrated system	System integration and test
Subsystem	Integration facility	Fully integrated subsystems	Subsystem integration and test
Component	Component test equipment	Verified component performance	Component test



Life-cycle V&V stages



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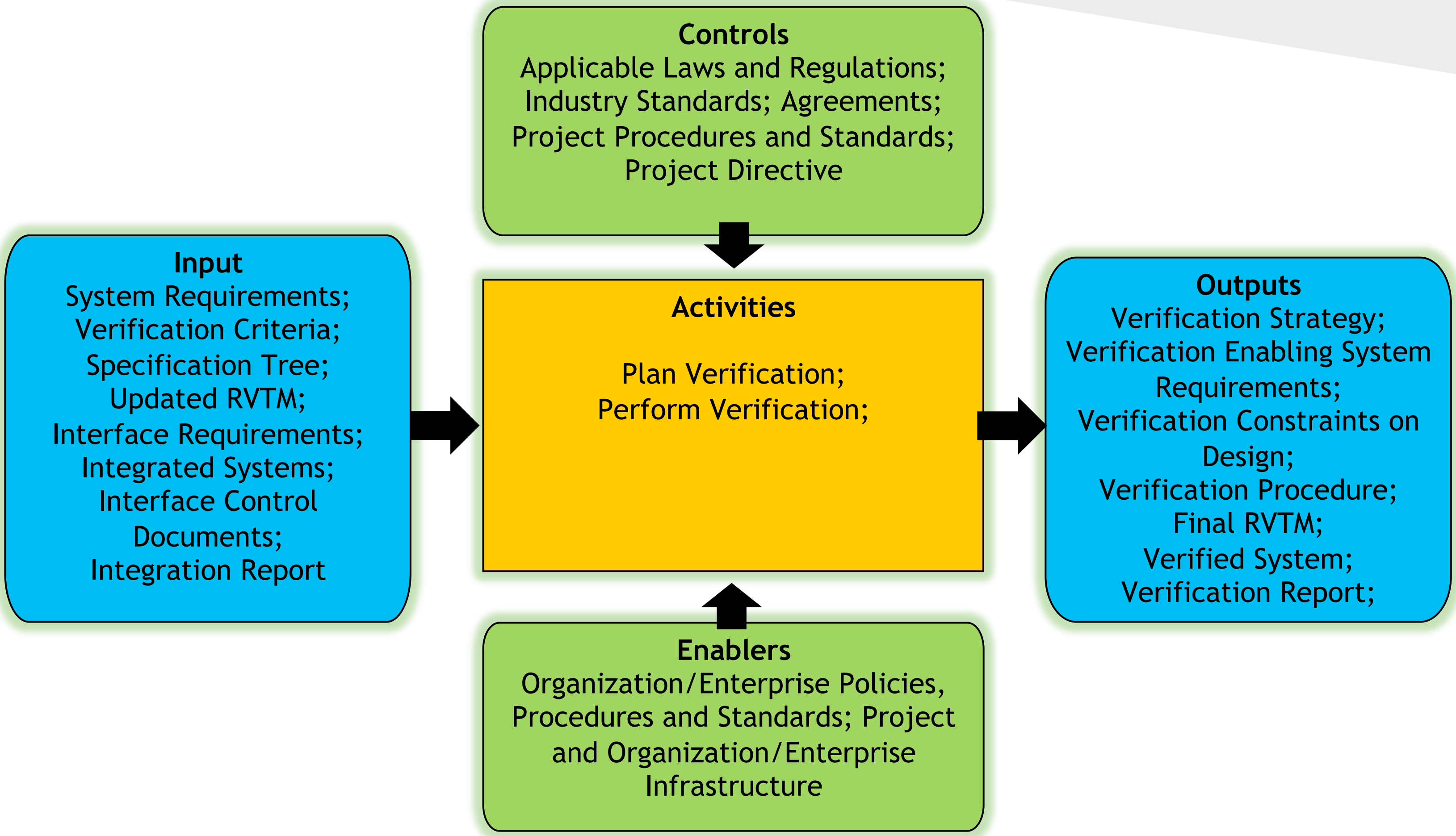
Verification Process (VER)



Test Readiness Review (TRR)

- Activity of the Technical Assessment Process.
- Purpose: assess readiness for verification and validation
  - availability of test ranges;
  - test facilities;
  - trained testers;
  - instrumentation;
  - integration labs;
  - support equipment;
  - and other enabling products; etc.
- Uses defined entrance/success criteria

Types of Verification

- Inspection: an examination of the item against applicable documentation to confirm compliance with requirements.
- Analysis: use of analytical data or simulations under defined conditions to show theoretical compliance.
- Demonstration: a qualitative exhibition of functional performance, usually accomplished with no or minimal instrumentation. A set of test activities with system stimuli selected by the system developer.
- Test: an action by which the operability, supportability, or performance capability of an item is verified when subjected to controlled conditions that are real or simulated.
- Certification: verification against legal or industrial standards by an outside authority without direction to that authority as to how the requirements are to be verified.

Test categories

- Development test: Conducted on new items to demonstrate proof of concept or feasibility.
- Qualification test: Tests are conducted to prove the design on the first article produced, has a predetermined margin above expected operating conditions, for instance by using elevated environmental conditions for hardware.
- Acceptance test: Conducted prior to transition such that the customer can decide that the system is ready to change ownership status from supplier to acquirer.
- Operational test: Conducted to verify that the item meets its specification requirements when subjected to the actual operational environment.

A Good Test Process

Test must be

- timely. Any system without a tight feedback loop is a fatally flawed system. Testing is that feedback loop for the (software) development process. Therefore, it must begin in the initial phase of the project: when objectives are being defined and the scope of the requirements are first drafted.
- effective. The approach to test-case design must have rigor to it. Testing should be based on a repeatable test process that produces the same test cases for a given situation, regardless of the tester (skill and experience) involved. The test-case design approach must provide high functional coverage of the requirements.
- efficient. Testing activities must be heavily automated to allow them to be executed quickly. The test-case design approach should produce the minimum number of test cases to reduce the amount of time needed to execute tests, and to reduce the amount of time needed to manage the tests.
- manageable. The test process must provide sufficient metrics to quantitatively identify the status of testing at any time. The results of the test effort must be predictable (i.e., the outcome each time a test is successfully executed must be the same).

Transition Process (TRAN)

Controls

Applicable Laws and Regulations; Industry Standards; Agreements; Project Procedures and Standards; Project Directive

Input

Concept Documents;
Operator/Maintainer Training;
Interface Control Documents;
Final RVTM;
Verified System;
Verification Report;

Activities

Plan the Transition;
Perform the Transition;

Outputs

Transition Strategy;
Transition Enabling System Requirements;
Transition Constraints on Design;
Installation Procedure;
Installed System;
Transition Report

Enablers

Organization/Enterprise Policies, Procedures and Standards; Project and Organization/Enterprise Infrastructure

System integration test facility

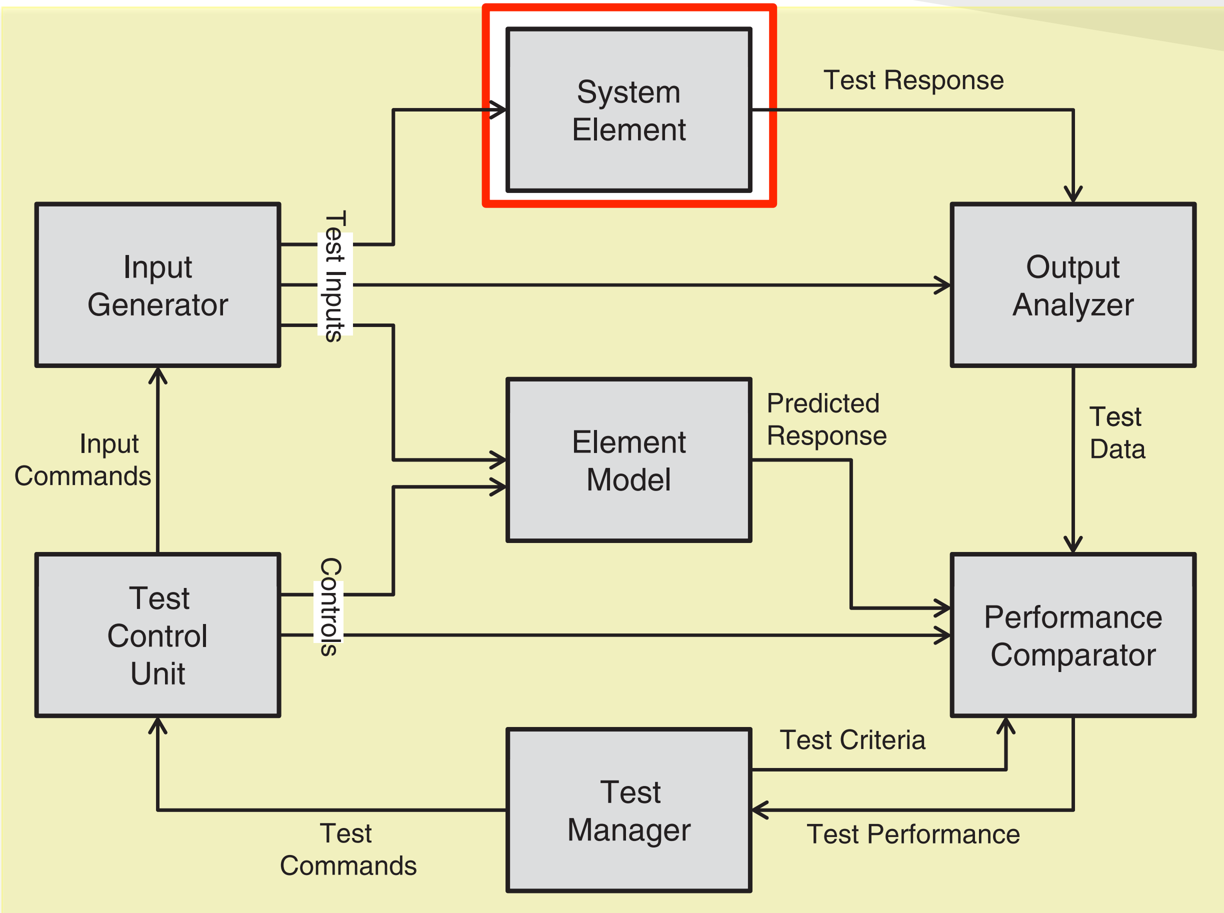


Figure 13.4. System element test configuration.

Subsystem integration test facility

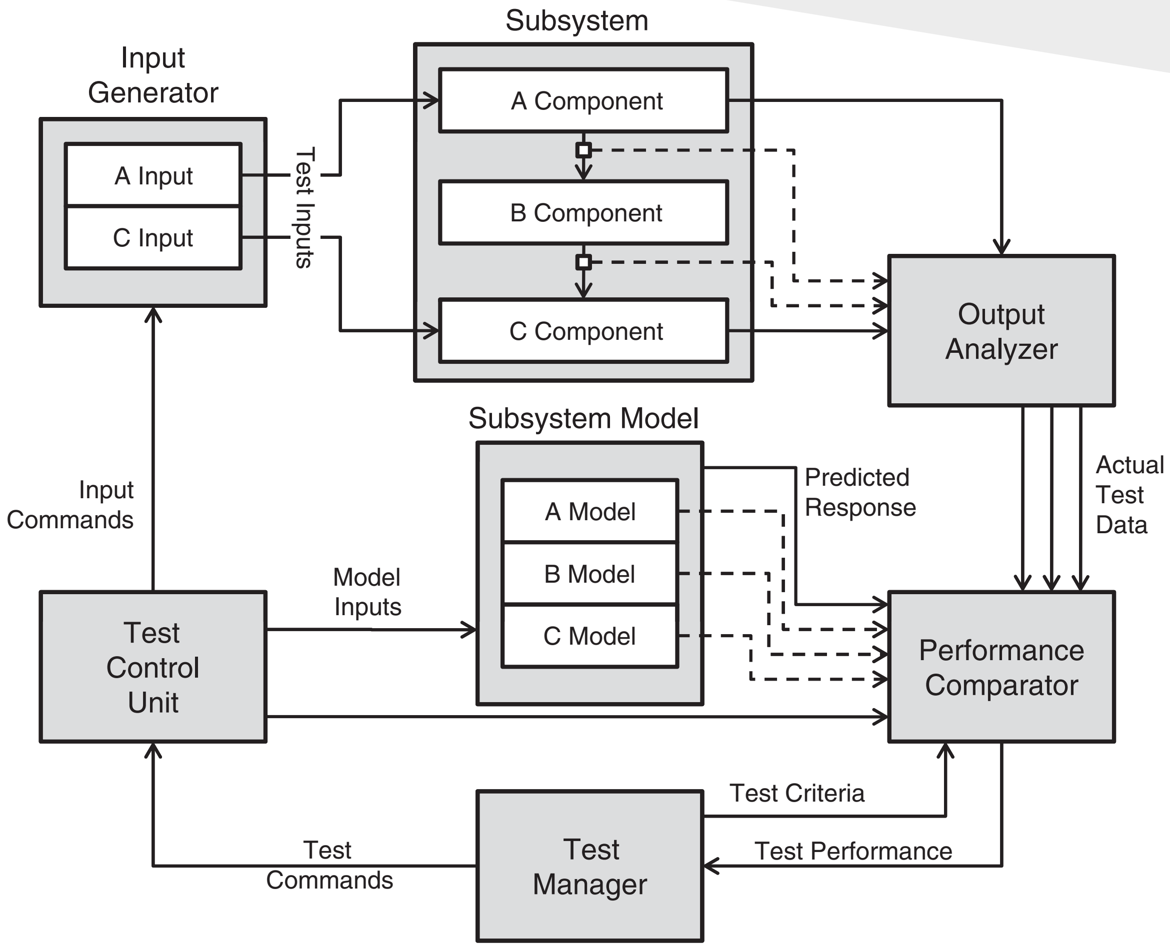


Figure 13.5. Subsystem test configuration.

Operational testing

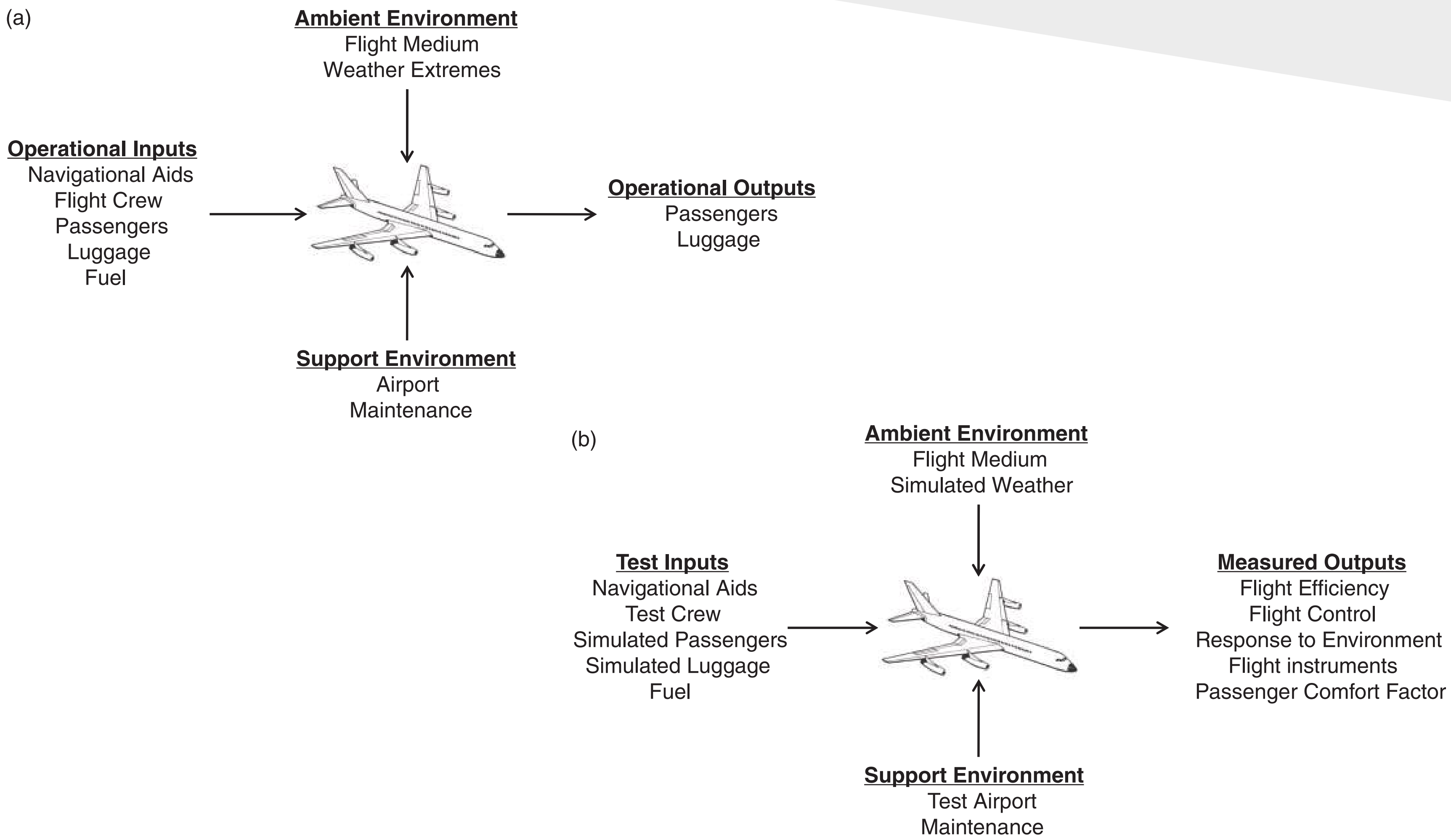
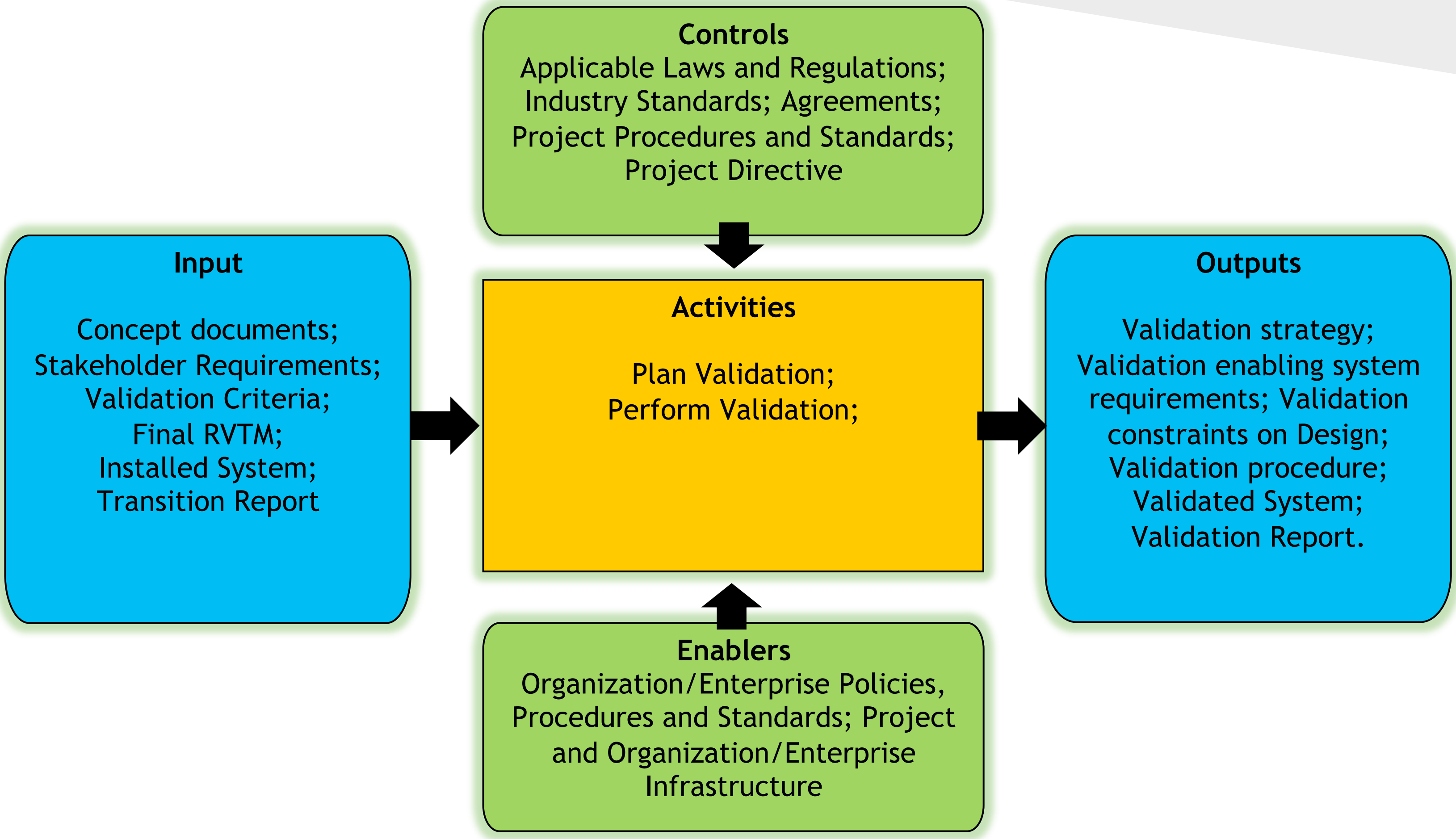


Figure 13.6. (a) Operation of a passenger airliner. (b) Operational testing of an airliner.

Validation Process (VAL)



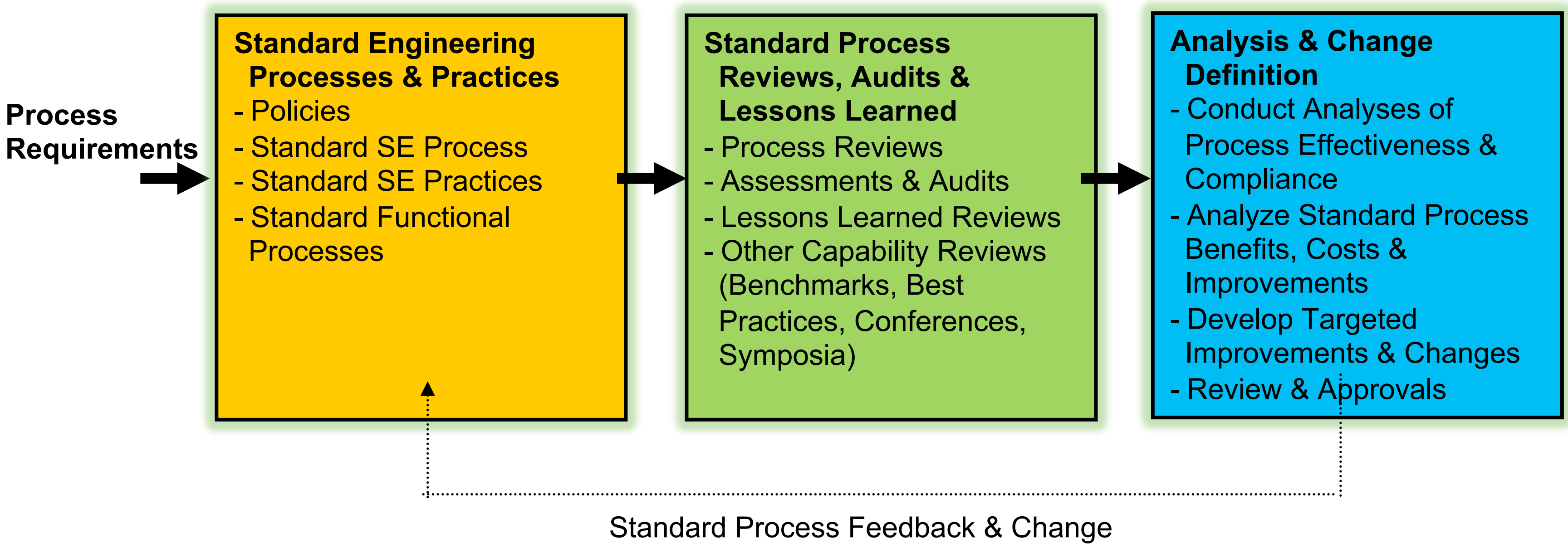
Requirements change

- Late requirements changes can be prohibitively costly
- Continual involvement of stakeholders necessary
- Agreed milestones
- Needs analysis is essential

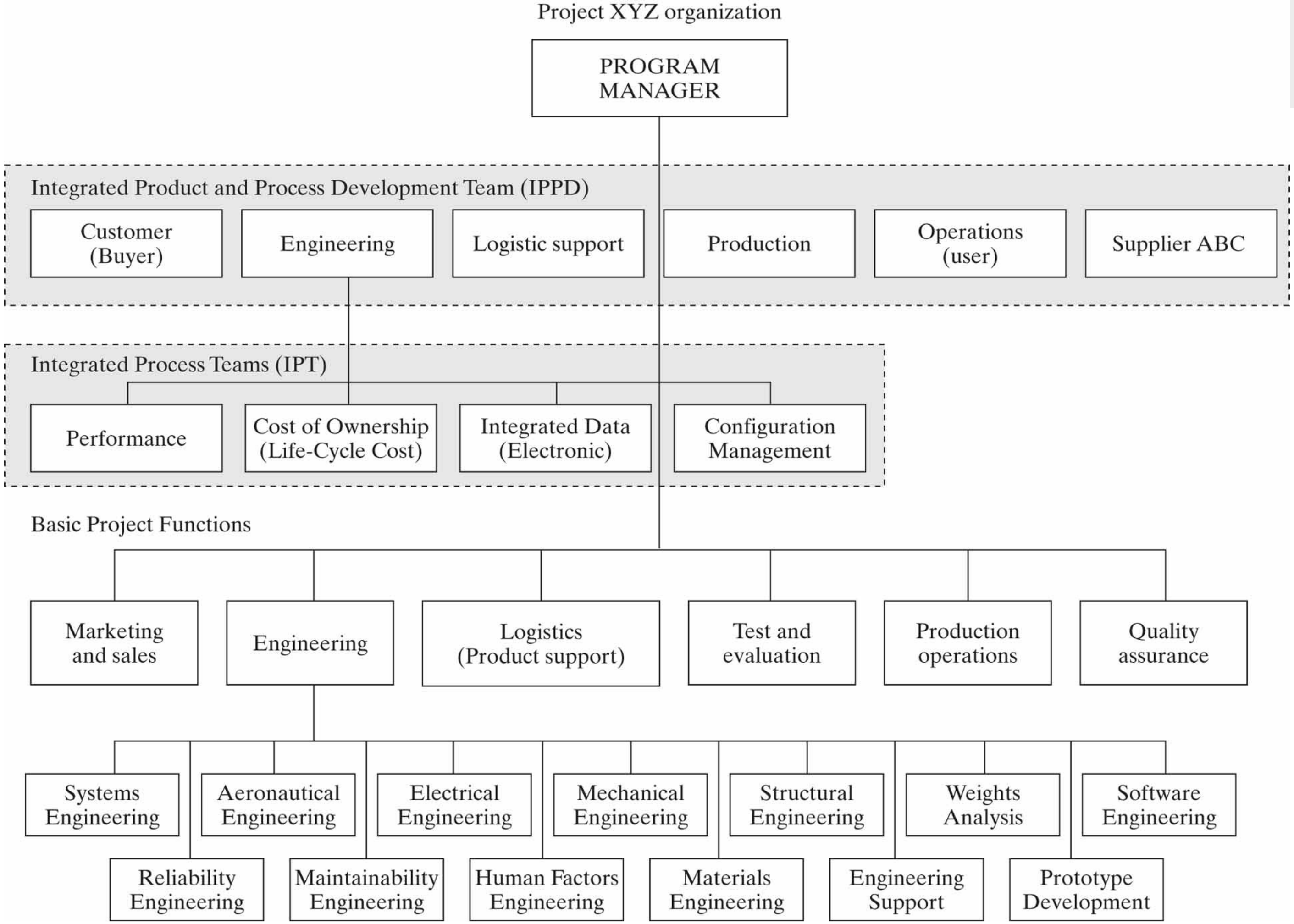
- However, modular design can make change of lower-level requirements (usually not derived from needs) easier

- Product variability should be planned, too

Context of System Engineering



System Engineering Organisation



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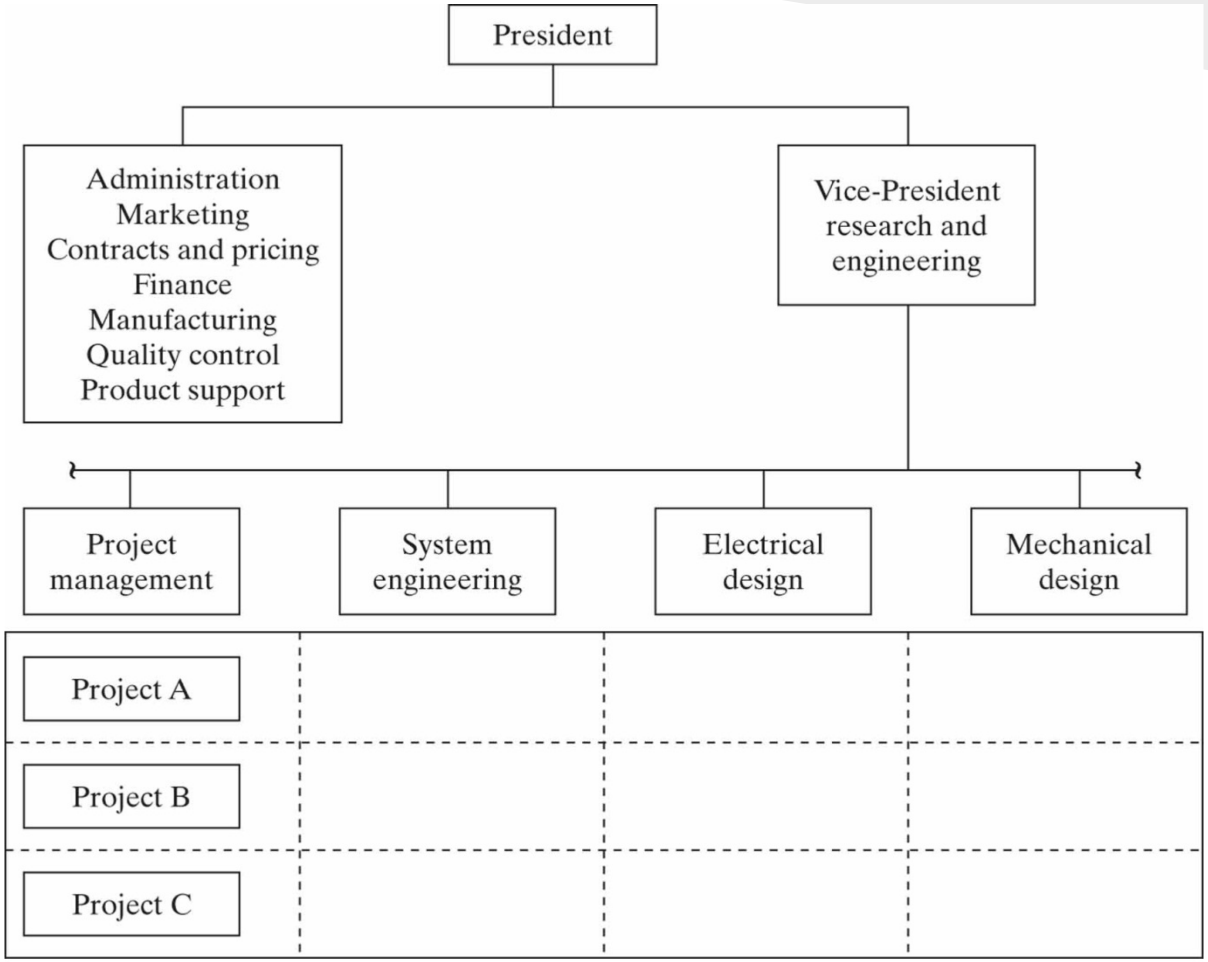
System Engineering Involvement



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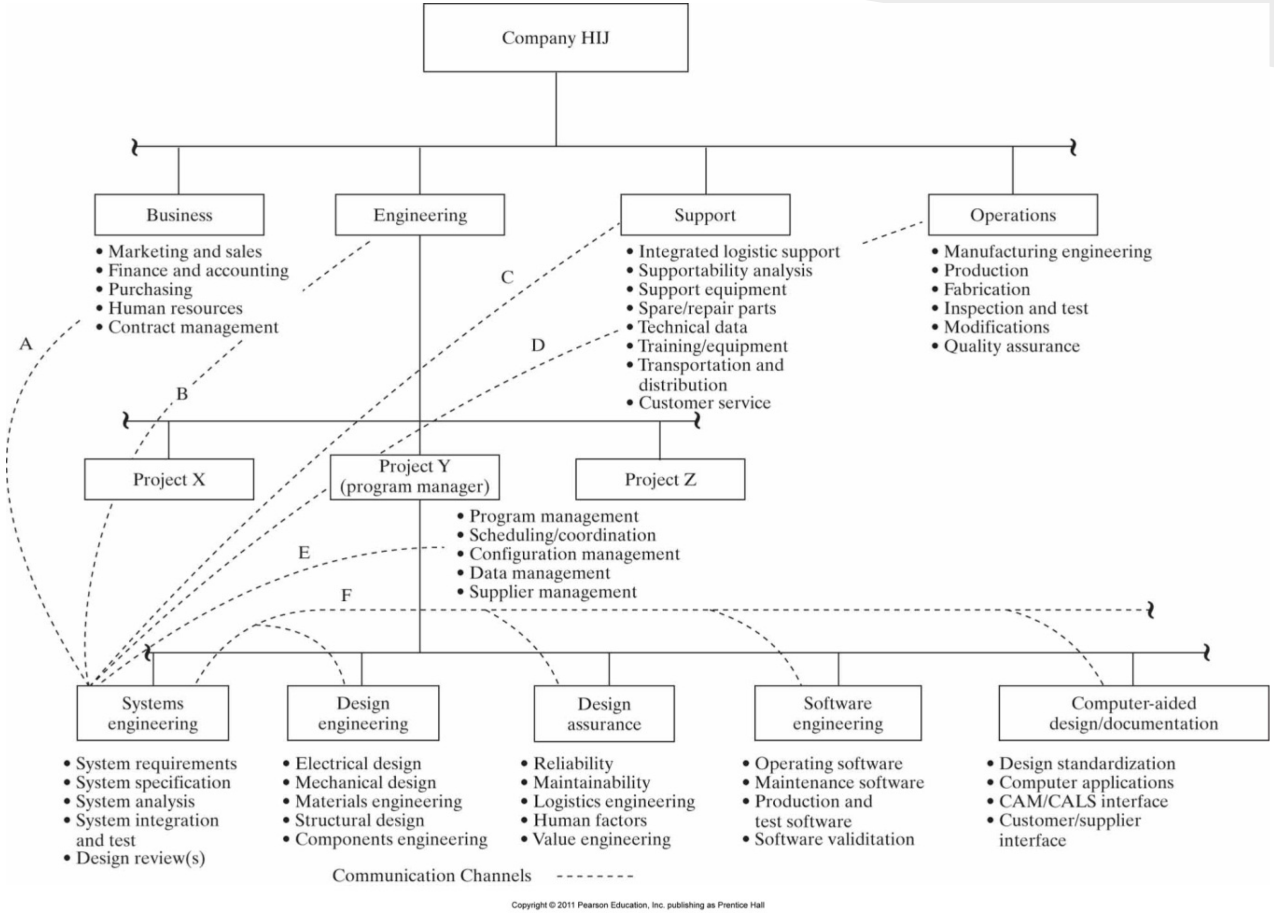
System Engineering Division Communication



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End of lecture