ETLS 509 - Validation & Verification
University of St. Thomas

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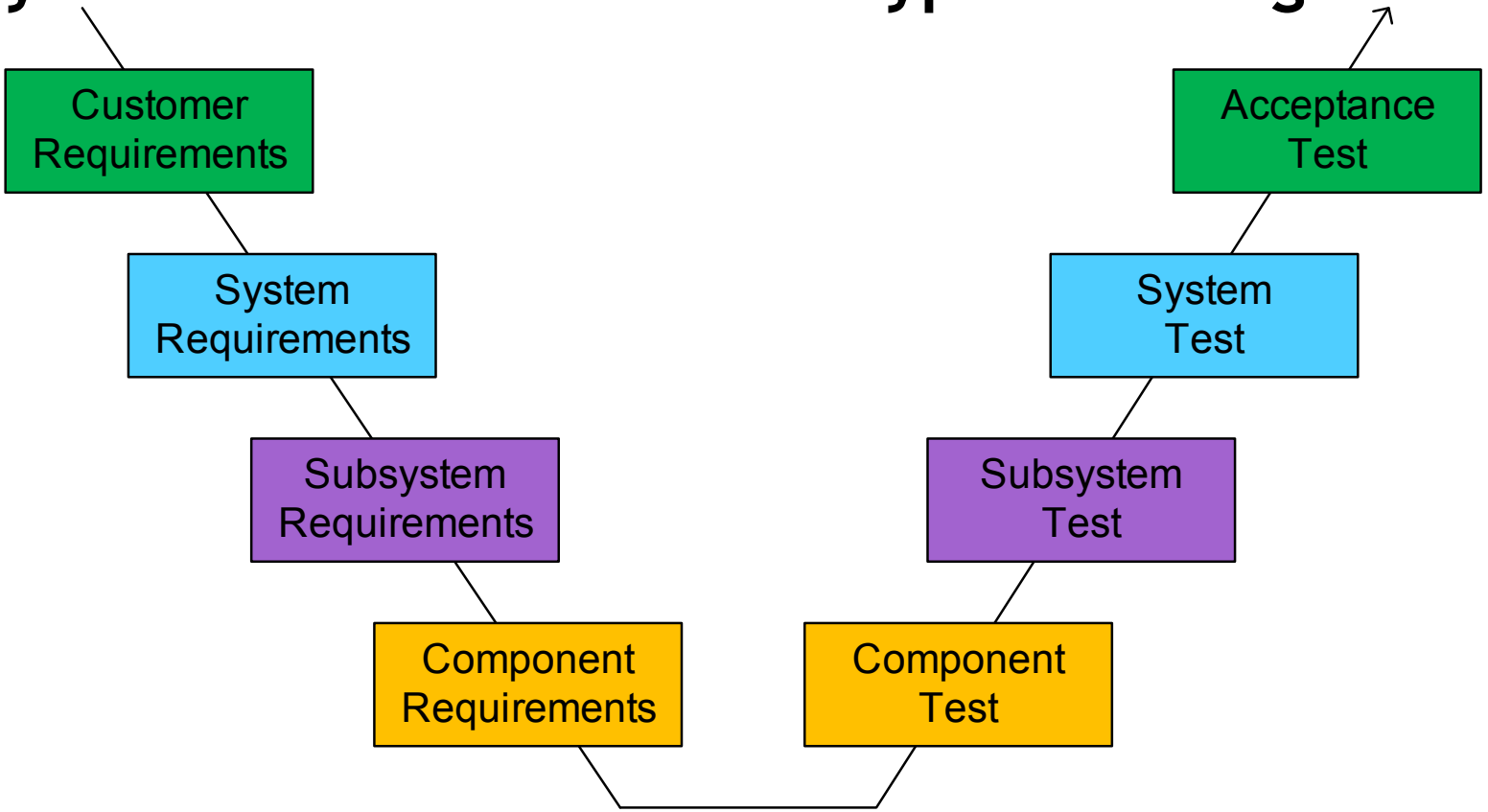
Outline

- Overall systems testing – verification/validation
- Technical measures
- Example
- Measure of effectiveness (MOE)
- Measure of performance (MOP)
- Technical Performance Measure (TPM)
- Key Performance Measure (KPP)
- Overview of system testing
- How TPMs, KPPs, MOPs, & MOEs fit into system testing
- Verification

ETLS 509 - Session 4

- System Test & Evaluation - Analytical & Simulation Testing / Type 1 testing / Verification
- System Test & Evaluation - Type 2 testing




Don't you people test your software before releasing it? This thing barely works.
Test?...
Nobody wants to test a fire fighting system, what if it doesn't work!
Brainstuck.com

Overall system testing

- **Technical Measures -**
  - Measures that provide information on the definition, development and acceptability of the system.
- **Types of Technical Measures**
  - **Measures of Effectiveness (MOEs)**
    - Measures how well a system in operation meets its intended goals
  - **Measures of Performance (MOPs)**
    - Measures of attributes of a system in an operational environment
  - **Technical Performance Measures (TPMs)**
    - Measures that determine how well as systems satisfies a technical requirement
  - **Key Performance Parameters (KPPs)**
    - A set of critical system performance parameters, typically if KPPs are not achieved the system will not meet its operational goals

Simplified example

- **The system (from the user's perspective) – an drone with a camera/video camera that is to be utilized for examining crop development**
- **What are possible performance measures (a small subset)**
  - Video
    - Image size (e.g., 1,920×1,080)
    - FOV (field of view) with a wide angle lens, 45^{o} x 25^{o} the ground space distance (GSD) at 400 feet above ground would be 2.1 in. x 2 in. (note GSD is also sometimes taken as the square root of the pixel area)
      - Is pixel size the same as resolution?
    - Image blur (in pixels)
      - Measurement conditions need to be defined, e.g., light level (determines exposure time), drone speed
    - Video frame rate
    - Storage capacity (in time)
    - Video capture format
  - Drone flight duration (in minutes)
    - While maneuvering
    - While hovering
  - Drone speed
  - Data link data rates
  - Drone maximum altitude
  - Maximum drone control distance
  - Maximum wind
  - System availability
  - Battery recharge time & number of cycles

Quadcopter

Measures of Effectiveness (MOE)

- **MOEs are related to the intended use of the system from the user's perspective**
  - User wants to use system to survey crop fields
  - Is this a good definition?
    - What are the operational conditions
      - Distance from control point to field being surveyed?
      - What are acceptable wind levels?
      - What level of detail is being sought?
        - » Is it expected that insect damage will be apparent from the imagery?
        - » Other?

MOEs continued

- **Define the measurement/test conditions**
  - MOEs are intended to represent the use of the system in an operational environment
  - Test conditions need to be either in a realistic environment or realistically simulate an operational environment
- **Our example –**
  - Size of plants, indications of adequate water, fertilizers (e.g., nitrogen)
  - Check their cattle, check their property
- **MOE example**
  - Check on cattle
- **What's in an MOE**
  - An overall objective that defines success of the system, e.g., the system provides the ability to check on cattle
  - Quantitative Measures (may be multiple per overall objective)
    - Time to survey one square kilometer of for cattle
    - Number of cattle in one square kilometer
    - Others?
  - For each quantitative measure, the measure method that will be utilized and the score associated with the quantitative measure

MOE Example continued

- **Notes system ground station capability**
  - Ground station software will mosaic imagery into one large image that is updated on-the-fly enabling operator to see and count the cattle in the region
- **Time to survey one square mile of for cattle - measurement method**
  - factors – data link data rate (effective) 700 Kbits/second
  - Measurement conditions & methods
    - Imagery will be downlinked as 1,920×1,080 images JPEG compressed at 30:1 - 1.6 second download per image, operating in 3840 x 2160 image mode, 6.3 second download
  - Drone will fly at an elevation of 400 feet (122 meters) above ground (why – FAA regulations)
  - Drone speed 44 feet/second (13.4 meters/second) – time to fly 1000 m is 75 seconds
  - Camera will point straight down (camera will be set to 45 degrees wide x 25 degrees long) foot print ~332 feet x 180 feet. (~101m x 55 m)
  - Overlap between passes will be 10% (~ 10 m)
    - 11 passes will cover the 1 km x 1 km area
  - Approximate time ~ 15 minutes (other considerations? Time to get to altitude? Commuting time to field?
  - How should the MOE be scored? What are the items being scored?
- **What is the system impact if FAA regulations are changed**
  - If the height above ground is changed allowing drones to fly 1000 feet above ground?
  - What are the system considerations?

MOE continued

MOE	Quantitative Measures	Measurement Method	Score
The system provides the capability to check on cattle			
	Time to survey on square kilometer	Time will start when drone is at the edge of field and stop when final image has been downlinked	A-F (see note 1)
	Number of cattle in one square kilometer	System will be tested over user's field with known number of cattle. The mosaic constructed by the system will be utilized by the operator to count the cattle using tools provided.	Pass/Fail – if system mosaic contains the correct number of cattle – Pass If not – Fail

1 A – time to survey 1 sq. km. test field is 15 min or less, B – time to survey < 17 min, C – time to survey < 20 min, F – incomplete survey or time >20 min

Measures of Performance (MOPs)

- **What's needed for an MOP**
  - Parameter of what's being measured
  - What are the units
  - Typically threshold and objective values (may be the same)
  - The measurement method
- **From our simplified example**
  - Mission duration
    - Units – minutes
    - Threshold – 15 min
    - Objective – 60 min
    - Measurement method – missions will be timed under flight profiles representing minimum, maximum and nominal conditions
  - Others?

Measures of Performance (MOP)

- **Measures that characterize attributes of the system under operational conditions**
- **Examples**
  - Camera field of view 45 x 25 degrees
  - Drone nominal speed 44 feet / second
  - Data link rate 700 kbits/sec

MOP continued

- **Measures that characterize attributes of the system under operational conditions**

Examples within an MOP table

MOP #	MOP Parameter	Threshold value	Objective Value	Measurement method	Score
MOP1	Drone speed	44 ft/s (13.4 m/s)	60 ft/s (18.2 m/s)	Measured in level flight at 400 feet above ground based on downlinked GPS data with aircraft flying into and with the wind.	
MOP2	Exposure time	10 ms	2 ms	Based on lighting at 10,000 lux Photo taken on ground	
MOP3	Camera pixel	1920 x 1080	3840 x 2060	Camera specification measured via manufacture, demonstrate operating in sill photo mode	
MOP4	Image compression	JPEG 1:1 to 100:1	JPEG 1:1 to 300:1	Ground based photos taken in uncompressed JPEG format. User selectable compression.	

Technical Performance Measures (TPMs)

- **Measures of attributes of system elements that will ultimately determine how the system will perform**
- **TPMs are used as a means of tracking the development of a system.**
  - It is common for TPMs to be time phased with the TPM improving as a function of time.
  - Example – TPM is the number of frames per second of video that can be H.264[1] encoded
    - Towards the beginning of a video encoding project the number of frames per second might be 10 with the end goal being 60 frames per second.
  - Measurement methods for TPM are not necessarily representative of an operational environment
  - Analysis is an acceptable evaluation method

H.264 is a video coding format

TPMs continued

- **TPM examples**
- **Exposure time**
  - Threshold 10 ms (lighting 10,000 lux)
  - Objective 2 ms (lighting 10,000 lux)
  - Measurement method – analysis of camera & camera lens
  - The TPM will be met/not met based on selection of camera/lens
- **Field of view (FOV)**
  - 45^{o} by 25^{o} (objective value)
  - FOV may vary by +/- 5^{o}
  - Measure method analysis of of camera & camera lens
- **Aircraft speed at 400 feet above ground**
  - Minimum speed 5 feet/sec (means that aircraft must be able to fly this slow) and maintain altitude – Threshold value
  - Nominal speed 44 feet/sec maintaining altitude – Threshold value

Examples of TPM Table

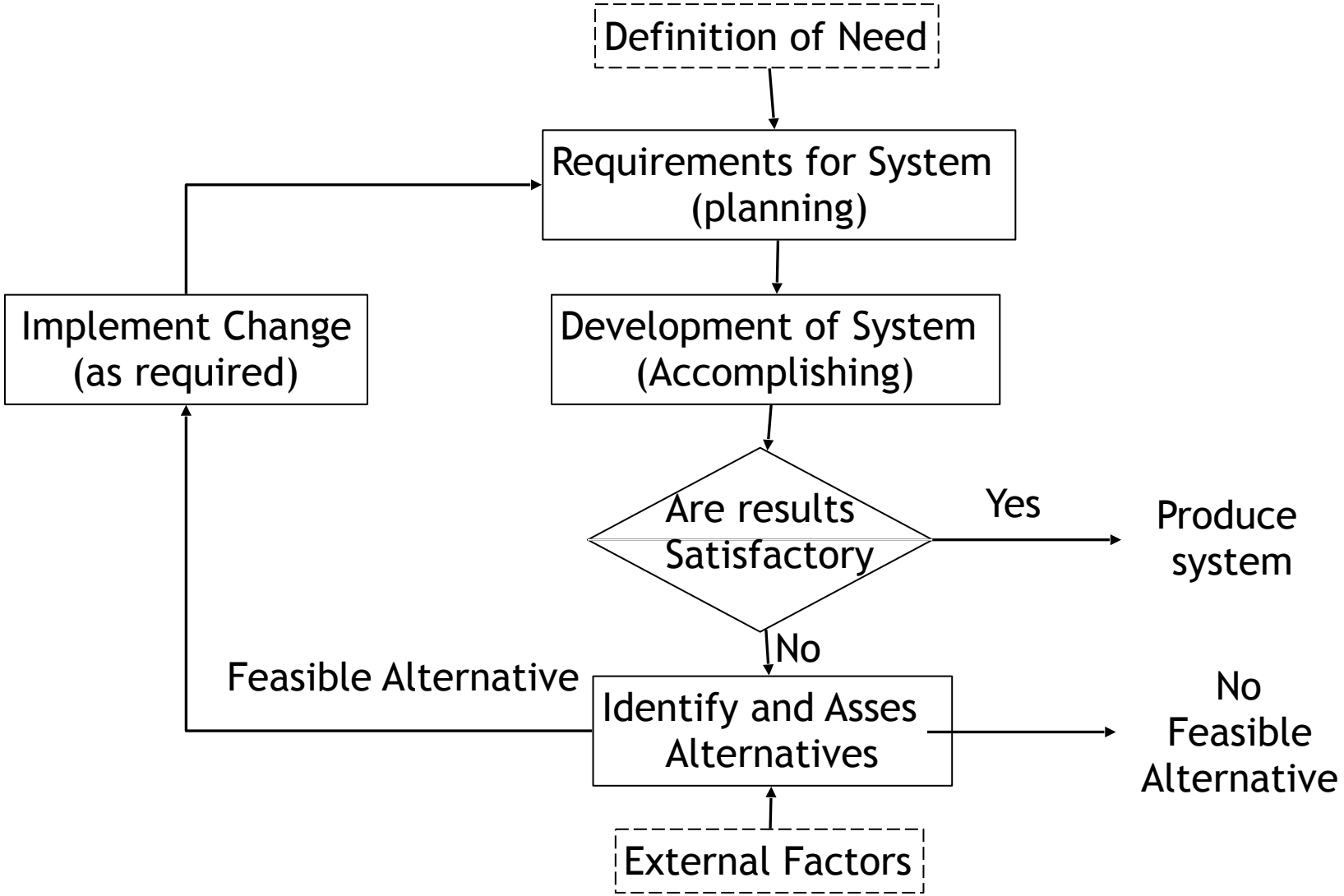
- **Multiple formats can be utilized for TMP tables depending on how the table is being utilized**

TPM #	TPM	Threshold value	Objective Value	Measurement method	Meas. Result
TPM 1	Drone Weight without payload	2200 gm	1800 gm	Weigh system (allocate weight to motors, batteries, structure, gyro, avionics – e.g., radios)	
TPM 2	Payload capacity	500 gm	1500 gm	Payload weight determined by maximum gross weight less empty weight. Measured at sea level.	
TPM 3	Gimbal	1 mradian	.5 mradian	Feedback performance of the gimbal, measured by pointing gimbal with camera at fixed point and moving drone in circles at maximum velocity	
TPM 4	Exposure time	10 ms	2 ms	Measured in lighting level of 10,000 lux (clear day outside), photos taken with camera at exposure times of .5 to 20 ms in 0.5 ms increments checking for values of each pixel	

Key Performance Parameters (KPPs)

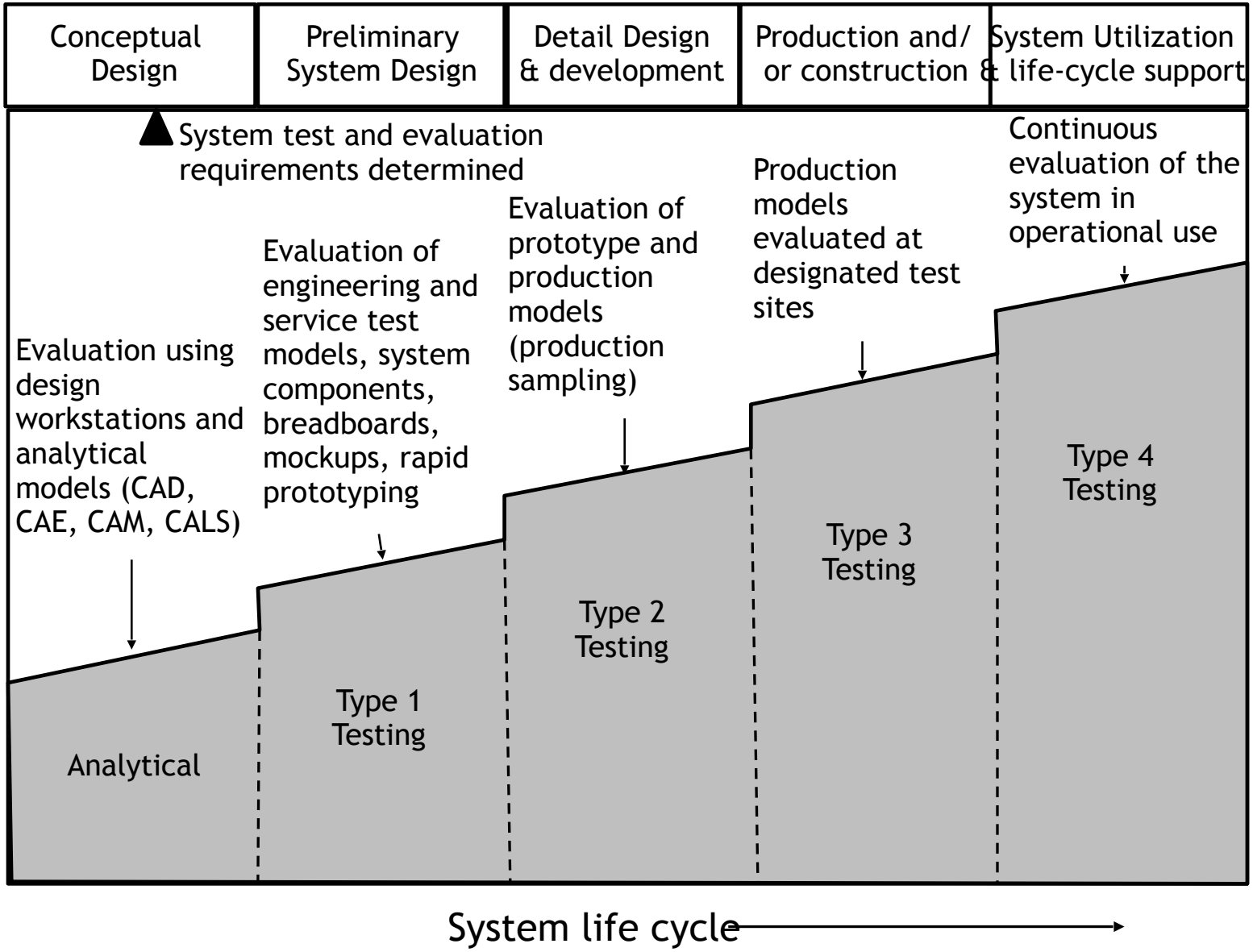
- **A subset of the TPMs that are critical to the overall performance of the system.**
  - Missing KPPs would result in the system not achieving its desired goals
- **Typically KPPs are reviewed on a development program more frequently than the full set of TPMs**
  - In this example exposure time might be a KPP
    - The exposure time is a function of the lens, a faster lens (lower f number) will reduce the exposure time at the expense of additional weight. A bona fide system trade as the additional weight will reduce mission duration

Overview of Testing



System requirements and evaluation relationships (from Blanchard)

Stages of Evaluation During the Life Cycle[1]



1 Blanchard fig. 6.2

How MOEs, MOPs, TPMs, KPPs, Fit into Testing

- **MOEs, MOPs, TPMs, KPPs are all measures of a system or portion of a system**
- **Typically these are the things that are being tested and measured**
- **MOEs are directly traceable to the intended function of the overall system**
  - MOPs, TPMs, KPPs are typically items that are in support of the overall system MOEs
- **When all of these are well defined and the list is comprehensive, what needs to be tested is defined**
  - Keep in mind that some of these items may be tested via analysis. For example, for a new system Mean Time Between Failures (MTBF) is typically done via analysis. MTBF is likely to be one of these measures.

How verification is performed

- **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.
- **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**
  - Written assurance that the product or article has been developed and can perform its assigned functions in accordance with legal or industrial standards.

Planning for testing

- **Identify all tests to be accomplished, items to be evaluated – know the Requirements Verification and Traceability Matrix**
- **How do we test a requirement – the central question**
  - Within limits
  - Outside limits
  - Engineering margins
  - Corner testing
- **Identify organizations responsible**
- **Where are the tests being held?**
- **Test preparation**
- **Description of the formal test phase – what people and equipment when and where?**
- **Plans for retesting if required**
- **Description of formal test report**
- **Question – can a requirement be tested at multiple levels?**

System Test & Evaluation – Analytical & Simulation Testing

- Statistical Models
- CAD models – i.e. Pro-E fly-thru's
- Simulations
- Mock-ups; i.e. to test human equipment interfaces, displays, repair procedures
- The idea is to find faults before they get farther, before bending metal – rule of 10

System Test & Evaluation – Type 1 testing / Verification –

- **Generally component level – may or not be formal tests**
  - Breadboards
  - Bench-test models
  - Engineering models
  - **Engineering software – be sure to throw it away after – avoid “oh, yea but”!!**
  - Service test models
  - Tests of logistic and support actions

System Test & Evaluation – Type 2 testing

- Formal tests & demonstrations conducted during latter part of detail design
- Performance tests of the system – the thing itself
- Environmental qualification – what test facilities required, and at what cost?
- Structural tests – MIL-STD 901D shock trials
- Reliability qualification
- Maintainability demonstration
- Support equipment compatibility tests
- Personnel test & qualification
- Technical data verification
- Software verification (can compute software MTBF – more on this when we cover reliability)
- Supply chain element compatibility tests
- Compatibility tests with other elements

777 Project

- What are the what Testing / Type 1 / 2 testing considerations for the 777?
- 21st Century Jet - Making the Boeing 777 1-4