Massachusetts Institute of Technology

Models in Engineering

Week 4: Models in Verification and Validation

Project

Name

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Week 4 Project

Overview

In the fourth and final project activity of this course, you will choose a product/system/sub-system you have worked on. You will then develop the V&V framework and determine the V&V techniques and V&V plan of those models.

Before proceeding with this project, review the table of 32 Verification and Validation types in the course unit titled "When Are Models the Right V&V Strategy?"

Note that some Scratch Pages are included at the end of this document for you to capture any ideas, sketches, etc. that you have as you work through the project. These will not be assessed and you are not required to submit them with your project (but you may do so if you think they offer any additional insight into your thinking process!).

REQUIRED STEPS:

Step 1: Develop the V&V framework

Step 2: Develop the V&V options

Step 3: Elaborate on one model

Step 4: Review and submit your project

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Step 1: Develop the Verification and Validation Framework

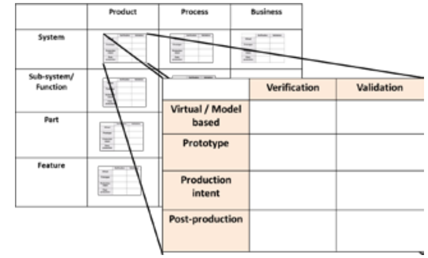
Dr. Anna Thornton talked about determining the V&V framework of your system from a product, process, and business perspective. Here you will focus on just product and process.

A. Choose a scope -- for example, bicycle models 1,2,3 built at the Charleston, SC assembly plant, or software product A.
B. For the grey boxes (the framework labels), decide whether these are appropriate names in your industry. If they are not appropriate, please change the names.
C. For the blue boxes, customize the generic questions to your industry. You don't need to answer the questions here; just write an example question in each box.

Scope :	*Determine the V&V of the crankshaft of a reciprocating engine (https://en.wikipedia.org/wiki/Crankshaft).*

	Product	Process
System (including environment)	*Does the crankshaft assembly work as expected?*	*Can the production assemble the whole assembly as expected?*
Sub-system/Function	*Does the crankshaft work as expected?*	*How efficient is the production system (work in process, rate, labor, etc....)?*
Part	*Does the crankshaft meet design requirements?*	*Can rates be maintained for part production?*
Feature	*Do the features (geometry, finishes etc.) meet requirements?*	*Does the process reliably create features (i.e. surface finish, radii etc. required for fatigue life)?*

Step 2: Develop the Verification and Validation Options



A. *If you changed the grey boxes in Step 1, please change them in the table below as well.*
B. *For each empty box in the framework below, describe a potential V&V method you could employ. You may employ the same method in multiple boxes. In reality you may not need all 32 types of V&V – you might choose to use a model only for subsystem function V&V.*

	Product		Process	
System	Models	3D Assembly Simulations, Design Failure Mode and Effect Analysis	Models	Discrete Event Simulation
	Prototype	On-Engine Functional Tests	Prototype	Early soft pre-production
	Production Intent	On-Engine 1500 hour Endurance test	Production Intent	Process capability from initial production batch and then process monitoring
	Post-production	Field Failure Rate Analysis	Post-production	Key Performance Indicators
Sub-system/ Function	Models	3-D Tolerance Stack up, Assembly finite element analysis studies, Design Failure Mode and Effect Analysis	Models	Virtual assembly, Digital mockups
	Prototype	Bench assembly Fatigue test, Bending Test	Prototype	Design for assembly analysis, design for ergonomics simulation
	Production Intent	Bench endurance testing >10^6 cycles	Production Intent	Early soft pre-production/3D manufacturing
	Post-production	Failure Report Analysis	Post-production	Defect Analysis
Part	Models	Tolerance Stack up, Assembly simulation, finite element analysis, Design Failure Mode and Effect Analysis	Models	Process simulation
	Prototype	Fatigue test, 3 point bending test	Prototype	Design for manufacturability analysis
	Production Intent	First article inspection	Production Intent	Piot trials
	Post-production	Deviation Report Analysis	Post-production	Defect analysis
Feature	Models	Process Capability Analysis	Models	Process simulation
	Prototype	Supplier adherence analysis	Prototype	Prototype mfg process
	Production Intent	Geometric Dimensioning and Tolerancing/Sample analysis	Production Intent	standard operating procedure/Pilot
	Post-production	Statistical Process Control	Post-production	Statistical Process Control /Process Auditing

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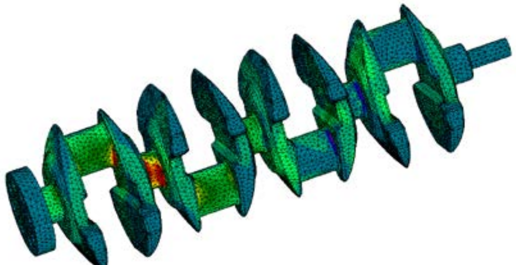
Step 3: Elaborate on One Model



http://www.ampsolutions.it/wp-content/uploads/2015/01/Crankshaft_2-e1421335114537.png

For one of the eight potential models you identified in Step 2, do the following:
A. State the name of the product on which it would be used, and give a brief explanation of the product.
B. Highlight one or two critical issues that this model would help you verify and/or validate. For example, a critical issue could be, "Will the software crash under any operating conditions?"
C. Provide a potential name of the model, and a brief description of how the model does or should work.
D. On a scale of 1 (low) – 10 (high), describe how well you think the model will accomplish the V&V task.

SAMPLE ENTRY:
A: Crankshaft: I am going to elaborate on the Finite Element model of Crankshaft. A crankshaft is a mechanical part in internal combustion engine to perform a conversion between reciprocating motion and rotational motion. This is the backbone of the engine and one of the highly stressed parts.

B: Critical issues which this model validates:
1) Will the design sustain the static/dynamic loads during operation? In a structural simulation, FEM helps tremendously in producing stiffness and strength visualizations and also in minimizing weight, materials, and costs.
2) Will the design stay away from the resonant natural frequencies of the engine? -- FEM allows detailed visualization of where structures bend or twist, and indicates the distribution of stresses and displacements at different modal frequencies.

C: Crankshaft finite element analysis Model: Finite Element model is extensively used to analyze the design for stresses and create stiffness and strength visualizations and also to minimize weight, materials, and costs. The finite element method (FEM) is the dominant discretization technique in structural mechanics. The basic concept in the physical interpretation of the FEM is the subdivision of the mathematical model into disjoint (non-overlapping) components of simple geometry called finite elements. The response of each element is expressed in terms of a finite number of degrees of freedom characterized as the value of an unknown function at a set of nodal points. FEA provides engineering information(Stress/strain, deformation, natural frequencies, etc.) about a structure/component which cannot be obtained by using traditional analysis methods. It is possible to generate a simulation of any design concept and to determine its real-world behavior under almost any imaginable environments, therefore allowing the concept to be refined prior to the creation of drawings. However, the results depend on the correct imposition of the boundary conditions.

D. If the boundary conditions are correct, finite element model behaves as a high fidelity approximation of the system and accurately simulates the static/dynamic response of the system. I would rate it 8 out of 10.