SysML 2 Analysis WG Updates

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Goal

Our goal is to develop the workflows for the 3 challenge problems related to HSUV. We will then derive the services required in the System Modeling Environment (SME) to support that workflow. From there, we will derive the analysis concept models and capabilities required in the SME. To summarize, our progression will be as follows:

Analysis Workflows (HSUV Challenge Problem) → SME Services → Concept models and capabilities

Scenario # 1: Govt. regulation to improve fuel efficiency

#Aerospace - For spacecraft, this could be a need to gather more data per time period, which pushes on efficiencies of downlink, power use, or tasking of instruments.

(1) Locating and gathering the baseline model package — Total System Model

a. Checkout the latest version (baseline) of the Total System Model package. This includes the architecture model (SysML), connected design models (CAD/PLM/ALM), connected analysis models (simulation/FEA/CFD), and connected requirement models of the vehicle (system of interest) and the environment. The Total System Model is a consistent set of connected models that represent the vehicle.
b. Get the latest versions of analysis models used for computing fuel efficiency, the results of the last analyses, and the decisions taken thereof.
c. Where are the latest on-field test results for fuel efficiency?
d. What is the discrepancy between the analysis model results and on-field results?
e. Have we identified factors that contribute to this discrepancy? Are they formalized so that we can account for those in the next set of analyses?

(2) Reviewing the architecture, create new design alternatives, and analyze

a. Understanding factors that influence fuel efficiency at the system level, such as mass, size, engine, powertrain efficiency, driving environment, driver behavior, and other factors.
b. Identify the parametric changes versus the topological changes that can be made to improve fuel efficiency.

i. Parametric changes (can affect topology beyond a certain range)
ii. Topological changes
iii. Combination

c. **Parametric changes** and related analyses
   i. Examples - Engine maps, Torque/speed correlation to fuel economy, Gear ratios, and Controls calibration. These could be available as: (1) multivariate functions that need to be evaluated simultaneously, and/or (2) tables from handbook, such as fuel rate = *f* (torque load, requested speed).
   i. Need to perform a trade study of torque, speed and fuel economy
   ii. Multiple control algorithms have to be in sync for the fuel efficiency to be optimum. Loss of synchronization between a shift control algorithm and the engine control algorithm would lead to a fuel efficiency loss. I think this is true for a lot of big system-level optimizations … lots of components and subsystems need to be coordinated.

#Issue - Analysis models from the suppliers are usually black box models, not parameterized or you do not have control over the knobs that control them.

b. **Architectural / Topology changes** - Identify if the current architecture is capable of meeting fuel efficiency goals, if not, perform an architectural exploration study to find an architectural solution that would meet the fuel efficiency goal.
   i. Example of architectural changes -- Turbocharged engine Vs naturally aspirated Vs Hybrid; Controls Architecture (instead of controlling speed at the wheel, you control torque at the drive shaft)
   ii. What architectural changes will require rebuilding models (beyond the scope of existing analysis models) versus reusing?

#Issue – How do you know that the changes (parametric or topological) will not break existing analysis models? How do you capture the analysis intent, when model is built, so that we can verify if the assumptions in the model still hold true for the new scenarios? Capture the analysis intent describing the assumptions and goals of the analysis. For example, a particular analysis used a fixed step solver with 2 msec interval and if this is not communicated to domain experts, they may build analysis models that run with a different configuration, leading to issues while integrating**.** Similarly, if a domain expert makes an engine model and does not specify that it is not to be used for cold cycle simulation, could lead to errors. In Simulink, assumptions by the modeler are either not made explicit, or are specified sometimes twelve levels down. ***We need a property-based / math-based description of the assumption and not text-based, e.g. all analysis models in the chain of analyses to compute fuel efficiency are valid from -10C to 45C operating temperature range.***

c. **Analysis planning** – Planning the analyses to compute fuel efficiency for parametric and topological changes.
   i. What is the order in which we will explore the parametric and topological changes?
   ii. What is the level at which changes will be affected – single component, sub-assembly, whole system, hardware-only, software-only, etc.
   iii. What is the order in which we will run the analyses for each change? For example, running analysis at different scales – isolated component versus sub-assembly versus vehicle,

iv. What additional analyses would we run to check that we don't fail other requirements while we try to analyze the impact of changes to fuel economy.
v. When are you done?

It would be helpful we had an "**Architectural Distance**" model to give a sense of degree of changes, such as how extensive are they in terms of number of element affected, disciplines affected, and the range of analyses that we have to be re-run. This is similar to what is called platform or program or technology scale based on degree of change to underbody, upper-body, etc. elements of the vehicle. Maybe if computed this could help confirm or alert when changes have been made beyond the intended scale of change allowed, etc.

d. **Executing the analysis models based on the the analysis plan**
   i. Parametric analyses - Perform a sensitivity study to figure out which parameters effect the fuel efficiency, based on a given architecture description, e.g. given a hybrid-electrical vehicles architecture, find the parameters that affect fuel efficiency.
   ii. Trade studies – Perform parametric and architectural trade studies per the analysis plan to compute fuel economy for various scenarios.

e. **Visualization and review of analysis results**
   i. Stack analysis results against each other to view the "analyzed" impact of parametric and topological changes to the fuel economy.
   ii. Compare the gains in fuel economy to the estimated cost and completion time of the vehicle program.

f. **When do you stop the analysis?**
   i. Regulatory requirements vs vehicle program attributes, dictate when the analysis is stopped. A regulatory requirement must be met, vs a market demand, fo which we can be in the nearby/ballpark figure. In short, the analysis is stopped when it is no longer valuable to further continue based on the cost/benefit tradeoff.

(2) Perform field tests

a. Order and install new parts in the test vehicle
b. Perform field tests under same operating conditions as analysis
c. Compare on-field results versus as-analyzed results, and recheck the factor
d. If on-field results agree with as-analyzed results, plan a broader test, and eventual rollout
e. Setup formal test cases, e.g. a specific parameter is within a specific percentage, validated through a particular test case.
f. Comparing test data with the parameters in the analysis, e.g. transient signals.
g. Query a test repository for a test case data, pull down data, but sometimes certain signals that are required to compare the analysis are not in the data. Need to estimate those signals from the ones that are measurable.

Scenario # 2 -- I&T provides data stating that vehicle fails to meet its fuel efficiency requirement

(1) Locating the baseline results and models

a. Get I&T results, and identify as-built test vehicle, fuel efficiency measurement approach, and test environment (driving conditions, driver behavior,....)
b. Gather as-designed information (BOM / architecture), analysis models and as-analyed fuel efficiency results

(2) Review the results and planning out next steps

a. Do the fuel efficiency measurement approaches on-field and as-analyzed match?
b. What is the different margin between on-field and as-analyzed results? Is this margin normal based on past vehicle designs? If yes, did the design team not account for this?

(3) Updating the design

a. Follow step 2 in Scenario 1

(4) Perform new on-field tests

a. Follow step 3 in Scenario 1