Siemens Digital Industries Software

The simulation factory answers heavy equipment variability

Simcenter system simulation solutions more easily perform machine architectures trade-offs and optimization studies

Executive summary

As heavy equipment engineers face countless obstacles due to the many different machine usages and configurations, Simcenter™ System Analyst software allows manufacturers to leverage the value of existing models by providing an easy-to-use, deskilled simulation platform for performing trade-off and optimization studies. It also serves as a collaborative platform which capitalizes on the shared and validated simulation models and the knowledge that they contain.

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Abstract

Managing heavy equipment complexity is complicated. A single machine can be engineered for several different purposes and many variants are proposed. To address this complexity, system simulation has been instrumental for over 20 years, supporting the engineering of tractors, excavators, forklifts and hydraulic systems. To leverage the investments that have been made in system simulation, a simulation factory process is proposed, enabling more engineers to perform simulation analyses. Tractors represent a typical application where the number of variants and usages is high and a simulation factory approach is required.

Foreword by CNH Industrial

In the age of Agriculture 4.0, the modeling of complex physical systems, such as agricultural machines or off-road vehicles, plays a fundamental role in the study and understanding of physical phenomena. This can be difficult to understand while operating such vehicles in the field.

CNH Industrial, as a manufacturer of agricultural and construction equipment, among other machineries and vehicles, has always closely collaborated with its dealers and customers. The company tries to provide technical solutions that meet customer expectations for greater vehicle comfort and usability during field operations. CHN Industrial creates increasingly innovative products and cutting-edge technical solutions.

Considering the multiplicity of customer requirements, new technical regulations, increasingly stringent emissions regulations and new technological challenges (hybridization and electrification), the simulation of complex systems such as those found in off-road vehicles is fundamental in the evaluation, design and analysis of different new concepts compared to current production vehicles.

The study of innovative concepts is a process that requires time and specialized resources. This is true in both the knowledge of the product as well as in the relative modeling part, which cannot ignore the creation of a baseline system simulation model, considered the main reference and starting point of all studies.

Constantly updating baseline models representative of the current state of vehicles (current production) is a difficult challenge. CNH Industrial has a host of expert users in this field.

Starting from the baseline system simulation models, the further field of development in the digital age is to create variants of complex systems. These variants must be easily deployable within the current models. They also must be suitable for the evaluation of issues focused on the needs of customers and engineering to reduce development costs and increase the reliability of models and product knowledge.

This foreword from Dr. Pintore highlights the importance of system simulation as a solution to manage complexity. In this white paper, we will review how system simulation is used to support off-road vehicle engineering and how it will evolve in the coming years.

> *"In that way, the Simcenter system simulation solutions allow users to evaluate all critical aspects and give stakeholders a clear response to drive the project development and decision-making processes."*
>
> *Francesco Pintore, Ph.D.*
> *Design Analysis & Simulation,*
> *System modeling & System Performance*
> *CNH Industrial*

System simulation for heavy equipment: the maturity age

System simulation appeared in the industrial world in the late 1980s using in-house codes that relied on C or Fortran languages. These codes were developed and maintained by researchers in universities or directly by industrial companies.

In the mid-1990s, the need for a simpler modeling approach increased with the understanding of system simulation power and effectiveness. This marks the birth of model authoring tools based on drag and drop like Simcenter Amesim™ software. Simcenter is a part of the Xcelerator™ portfolio, a comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software. In the heavy equipment industry, Tamrok (now part of Sandvik Mining) was the first to use Simcenter Amesim to engineer its hydraulic hammer and drilling machines.

Heavy equipment suppliers and original equipment manufacturers (OEMs) understood the value of Simcenter Amesim and deployed it widely. Today, system simulation is an integral part of their process. In addition, pre- and postprocessing are tightly linked to other processes, methods and tools. System simulation value (frontloading, quick turnaround, design exploration, machine synthesis) has been demonstrated over time and is at its zenith. (From heavy equipment component design to system integration with Simcenter Amesim)

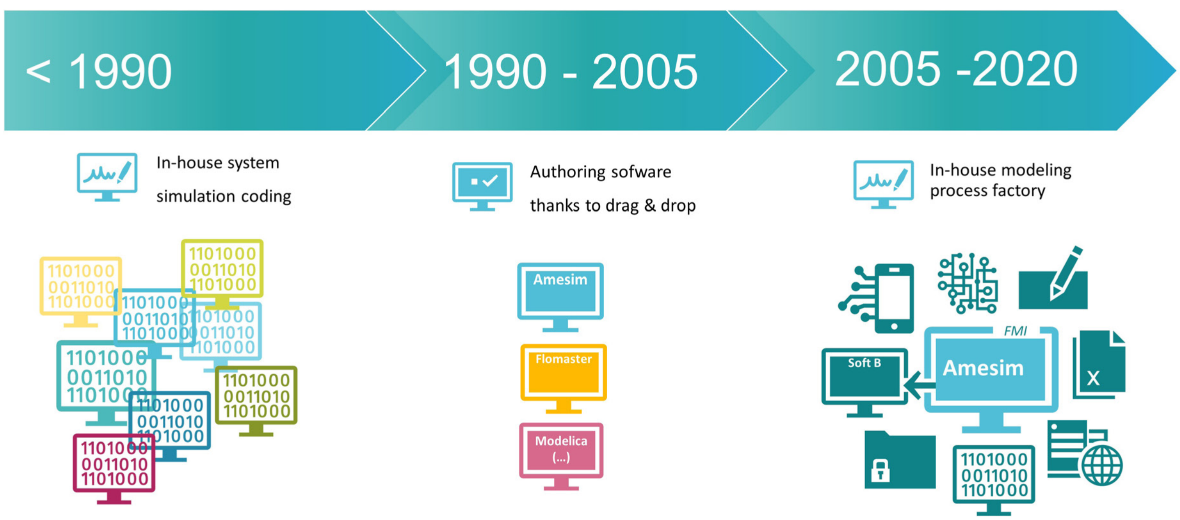

Figure 1: The system simulation history.

The other side of the coin is that since more and more system simulation analyses are required, the resources dedicated to running these analyses are under constant delivery pressure. Indeed, simulation engineers must deliver results for many different variants, through different projects, for different markets. On top of that, they need to gather data from many different stakeholders, suppliers and departments to feed into their models.

This creates a bottleneck for the simulation engineers, particularly in the heavy equipment industry, where the number of product lines and variants are high.

Starting from this observation, there are two solutions. The first and most straightforward one is to increase the system simulation workforce. But we live in a budget-constrained world and this may not always be possible for every company.

The other alternative is to make the models usable by people who are not system simulation engineers (for example, allowing other engineers to do engineering analyses). At Siemens Digital Industries Software, this concept has a name: the simulation factory.

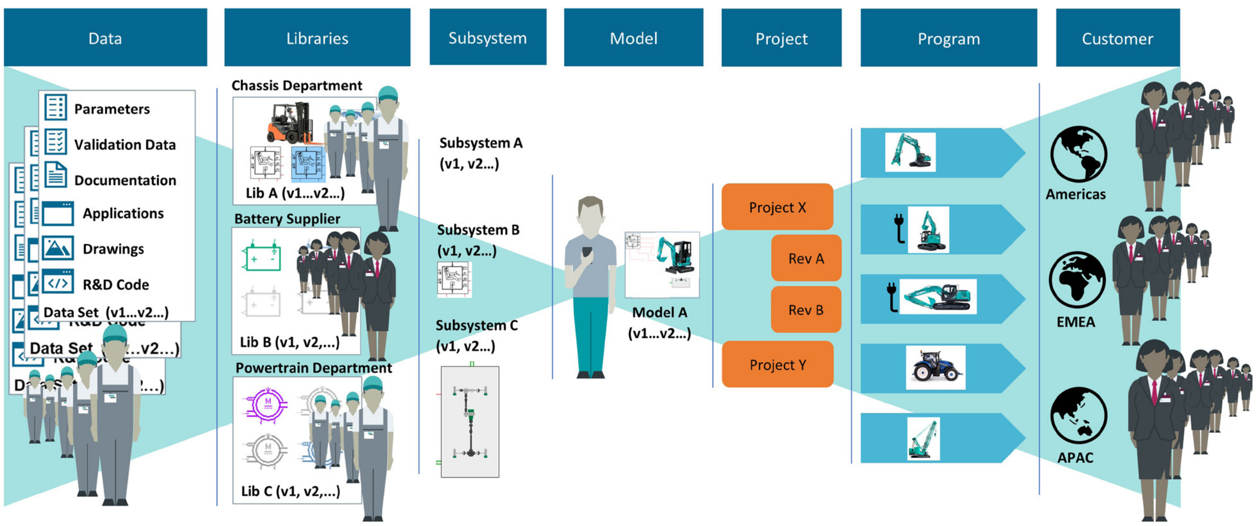

Figure 2: Simulation engineer inputs and outputs.

The simulation factory: enabling system simulation mass deployment

To describe the system simulation factory, let's first make an analogy with an off-road vehicle factory. To build a vehicle, we need raw materials (figure 3 and 4). These raw materials are processed using machine tooling and these machines are arranged around different product or assembly lines. Once the vehicle is built it is delivered to the different customers.

Now, let's replace the off-road vehicle with a system simulation model:

- The raw materials become the input data (test results, datasheet, parameters, submodels) that are stored and managed by a model lifecycle management solution such as Teamcenter™ Simulation Management software
- The machine tooling becomes the solver of Simcenter Amesim and its eco-system (reduced order models methodology, co-simulation, scripts)
- The assembly line where several architectures are defined and managed becomes the system simulation architecture modeling solution such as Simcenter System Architect
- Finally, the delivery is made through an easy-to-use capability to orchestrate the data, the solver and the architectures. This can be done by using either Simcenter System Analyst or Simcenter Webapp Server, depending on the customer

The strength of the system simulation factory, supported by the Simcenter System simulation solutions, is to run a massive number of analysis based on managed models, data and architectures without having to be a simulation engineer. This unclogs the bottleneck that appeared on the simulation engineering part of the product development process.

In the next section, a part of the simulation factory is demonstrated through an agricultural tractor simulator developed in Simcenter Amesim and explored in Simcenter System Analyst.

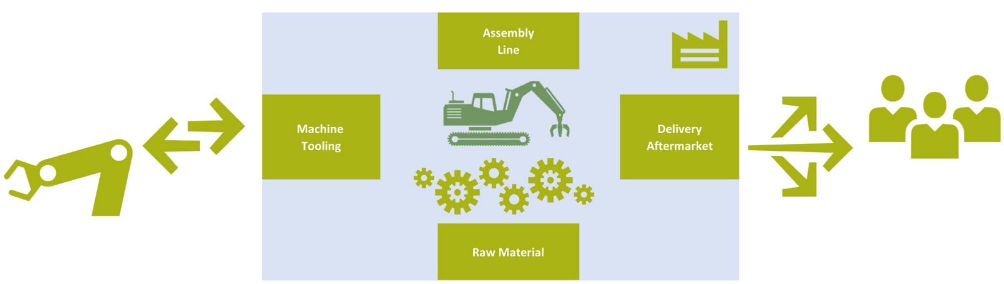

Figure 3: A simplified factory process.

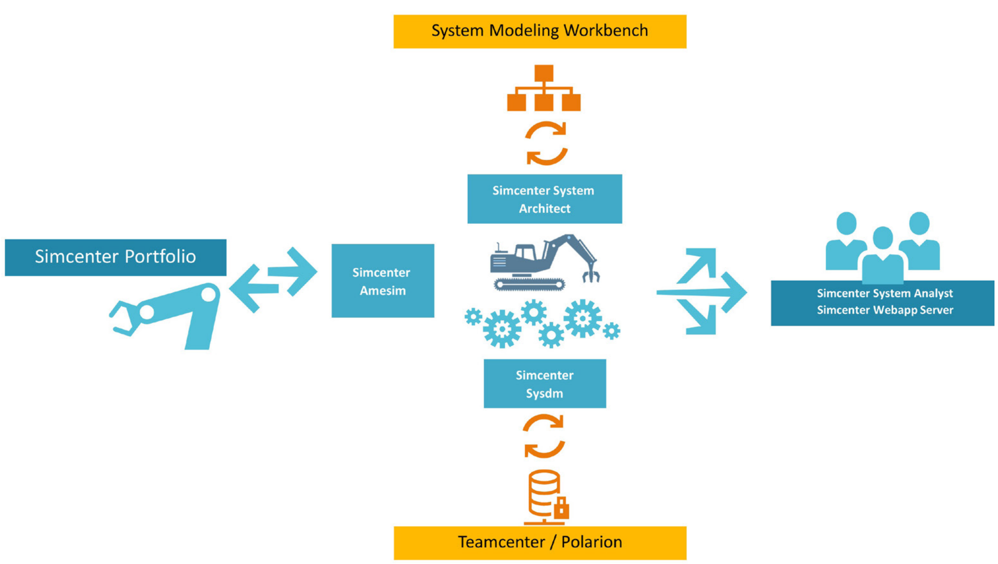

Figure 4: The Simcenter system simulation factory.

Managing the engineering complexity of a tractor with Simcenter System Analyst

Configurability is an important aspect of agricultural equipment. Tractor usage is quite versatile and usually performs a broad range of tasks such as trailing, loading, mowing, digging, seeding and tilling. As an example, in one year a tractor OEM received orders for 7,800 different tractor configurations from its customers (Source: Bloomberg). Managing these configurations, not only from a manufacturing perspective but also from a conception perspective, is critical (figure 5).

Additionally, according to a study from the Deutsche Landwirtschafts-Gesellschaft (DLG) organization, fuel economy is the second most important criteria when purchasing a tractor.

The DLG proposes a standardized test cycle that compares the fuel efficiency of several tractors, the so-called DLG PowerMix, which is truly influential in the agricultural industry. As a result, the DLG PowerMix assessment is a must when developing a new tractor.

In this use case, we will show how Simcenter Amesim and Simcenter System Analyst can answer these two challenges during the product development phase.

While Simcenter Amesim is a system simulation solution, Simcenter System Analyst is a collaborative solution that creates industry-specific applications to drive system simulation models. Model reuse by an increased number of people helps to maximize return on investments for the model development efforts.

The starting point is a Simcenter Amesim model arranged in supercomponents, which contain several submodels that are gathered in company libraries (figure 6).

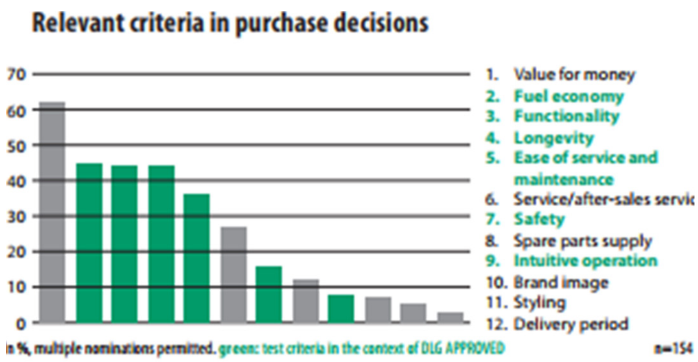

Figure 5: Relevant criteria in tractor purchase decisions according to DLG.

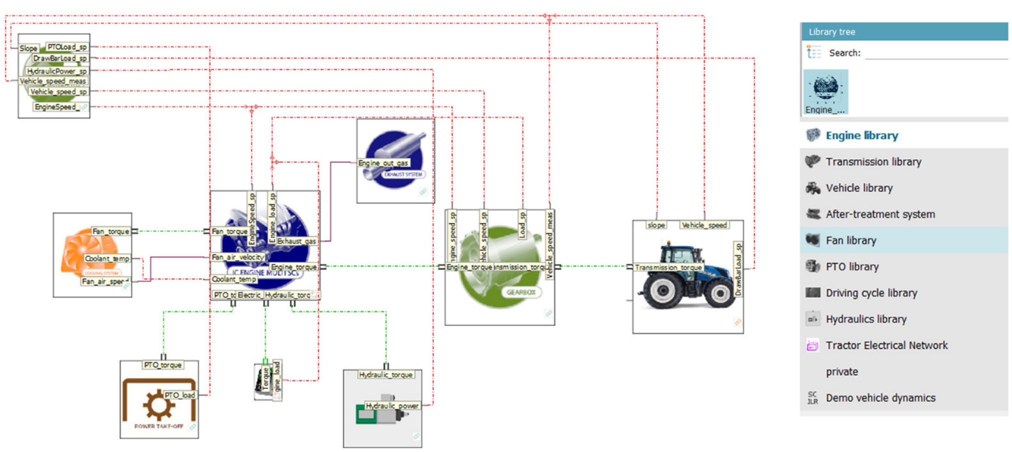

Figure 6: Simcenter Amesim tractor model.

The different submodels representing a system (like an aftertreatment system or internal combustion engine) can either represent the same variant with different modeling approaches or different configurations.

For each submodel, we defined the parameters and variables that are accessible by the Simcenter System Analyst user. These submodels can be shared across the company (and beyond) and facilitate complete tractor model assembly through standard interface contract definition.

Once the architectures and submodels are defined, they are shared through the model lifecycle management solution or locally for later use in Simcenter System Analyst.

One can customize the views, filters and scripts in Simcenter System Analyst using a “view editor” that ensures a smooth connection between Simcenter Amesim submodels and architectures and the Simcenter System Analyst user experience.

The first step in Simcenter System Analyst is to select the architecture or architectures to be simulated. This is done by selecting among existing technical definitions and modifying them if needed. In our case, there are three architectures (figure 7):

- One for assessing the DLG PowerMix and transport cycles
- One for assessing stability and vehicle dynamics
- One for the detailed analysis of hydraulic systems

Once the technical definition is selected, we can still modify it before doing any analysis.

Base	Parameter set
Aftertreatment_icon	EATS_STAGE_5
Electrical_Network_1	ELECTRICAL_NETWORK_SUB1
Hydraulic_circuit_1	HYDRAU_LS_PRIORITY
Fan_models_PN	HYDROSTATIC_TRANSMISSION_DMD_20192
Engine_map_based_V2	DEUTZ_9L_300KW_20192_V2_OK
Functional_model	IVT
Working_cycle_2	DLG_POWER_MIX
PTO_model	PTO_MODEL
Tractor_1Dmodel_Trailer_3Axles	MIDSIZE_TRACTOR_2
Cost_component_view	Costs

Component properties

Attributes

Component preview

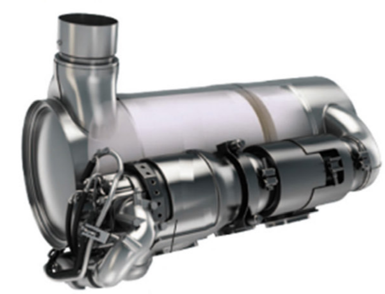

Figure 7: Simcenter System Analyst technical definition of a given tractor.

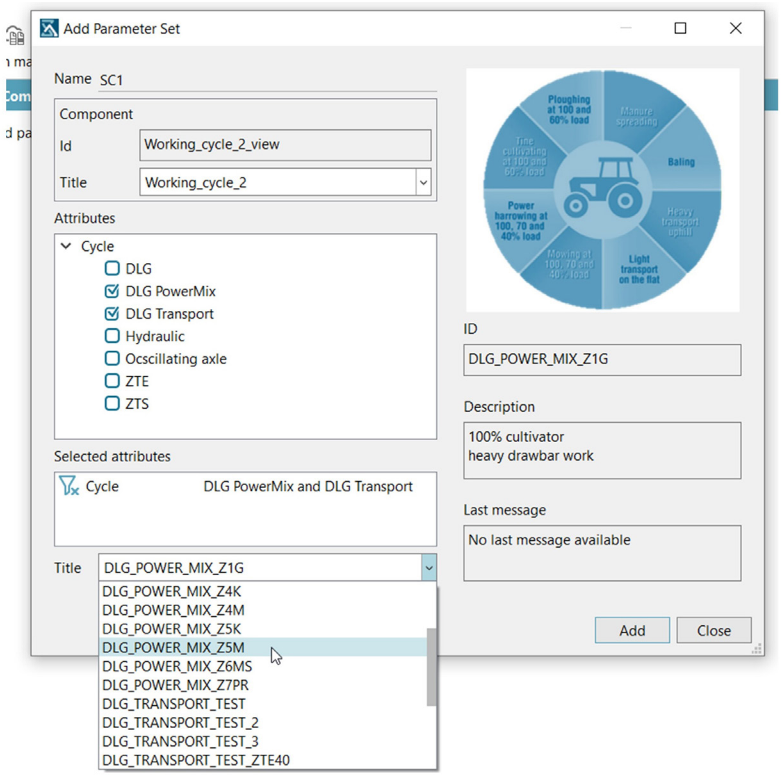

Figure 8: Selection of the mission profiles to study.

Once the technical definition is done, we can select the component and/or individual parameter set variations. In this case, we choose to modify:

- The mission profiles
- The transmission type (infinitely variable transmission or automatic transmission)
- The fan drive (hydrostatic fan transmission or visco-coupling fan)

This is done by using the filters to select among the different available submodels prepared in Simcenter Amesim.

The variability manager lets the user choose if they want to run a full factorial design of experiment or deselect any specific combination. When the variability is defined, the user can launch the simulations. Since the number of simulations to be run can be huge, parallel processing or high power computing (HPC) options are proposed to execute the simulations.

A synthesis of the results can be made in different ways. Spider charts, tables and bar charts are available and can be matched with the exact same kind of reporting the DLG PowerMix proposes, for example. The cost of fuel or other attributes that are not Simcenter Amesim variables can also be added in the study in order to assess, for example, the total cost of ownership of different variants under different operating profiles (figure 9).

In this case, the simulations allow us to understand that the infinitely variable transmission (IVT) with a fan hydrostatic transmission is the best in terms of brake-specific fuel consumption and brake-specific urea consumption over the DLG PowerMix and transport cycles. Meanwhile, the drawback in terms of top tank temperature (maximum coolant temperature) is very limited.

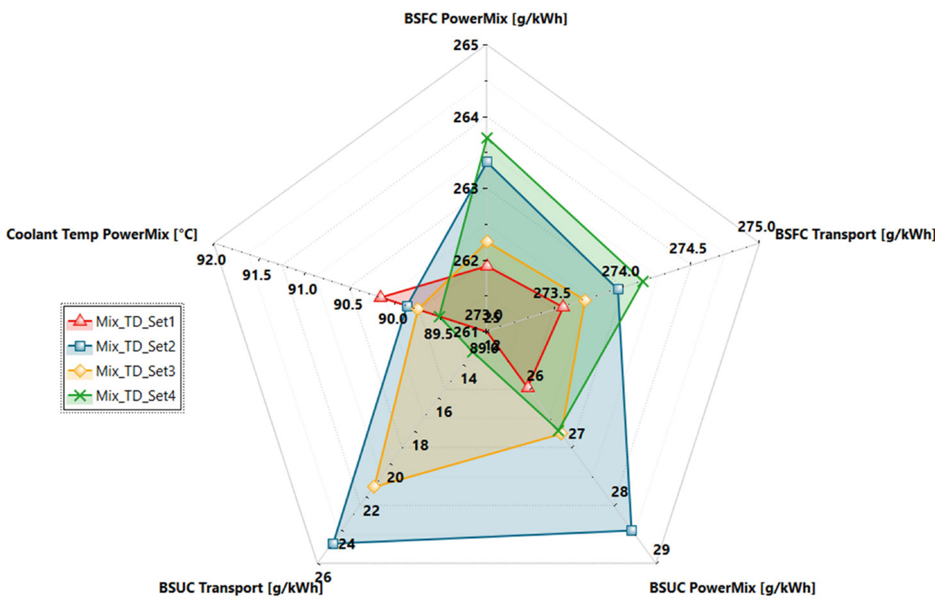

Figure 9: Simcenter System Analyst summary of the tractor variants analysis.

Conclusion

In the heavy equipment industry, the many different usages and configurations of a given machine quickly become an engineering hurdle. It is not reasonably possible to simulate every variant for every market for every product by only relying on simulation engineers. Simcenter System Analyst allows you to leverage the value of existing models by providing an easy-to-use, deskilled simulation platform for performing trade-off and optimization studies. This also behaves as a collaborative platform which capitalizes on the shared and validated simulation models and the knowledge that they contain.

Ultimately, the system and modeling simulation process is automated. Clear roles are defined to run the simulation factory. Most of the time and effort is spent on analysis simulation results rather than on creating and managing the models. This is where system simulation meets tomorrow.

Siemens Digital Industries Software has the experience required to deploy simulation factories. We already did it for several customers.

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