Design exploration process for aerospace industry

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Introduction

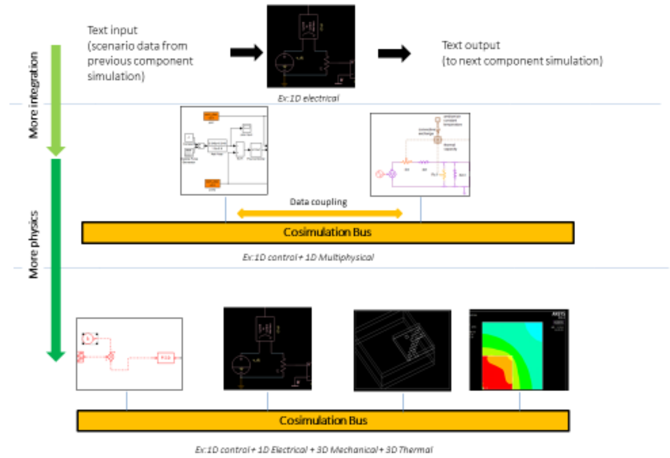
It is not really surprising that design optimization is a more commonly used simulation method than design exploration as an optimal design is in many cases good enough, or?
Even though the outcome of a new design is unknown to the design engineer in the beginning, optimization methods are more frequently used approaches within engineering. This needs a radical change as time to market, risky designs and overall costs are too much of a pain. To accomplish the best design for a new aerospace part, system or aircraft, design exploration beyond co-simulation within extended enterprise processes is one of the best and intuitive future proof method to evolve and investigate multi-disciplinary design-spaces and –discoveries. As it is a much wider and open approach, it better supports the decision making throughout all of the design phases.
As it is impossible to formulate and characterize all problems before hand, let us explore all of them (known and unknown) during the research process. Anyhow it is the necessary step to constantly improve engineering efficiency, which do addresses the pain points of our industry today!

Why is design exploration so important nowadays?

The simulation world has made progress in supporting increased complexity of products and processes. Even though there is still a long way to become true multi-domain & multi-physic co-simulation oriented.
The need to provide simulation environments for physical systems with interaction of all components and parts has significantly grown. By supporting a system made of multi-components and using multi-physics (mechanical, electrical, hydraulic, thermal, pneumatic) describes well what multi-domain & multi-physics is. To accomplish non monolithic solutions, which are required in a world of distributed components, electronics and networked software, sharing intellectual property (IP) with an interdisciplinary mindset needs to happen in research, design and engineering. The simulation strategy needs to change and adapt from:

1) simulation to co-simulation
2) mono-physics to multi-physics
3) design optimization to design exploration

Following these 3 steps will make simulation stay tuned with industry requirements and will help to add significant value to engineering. Picture 1 illustrates the required simulation progress.

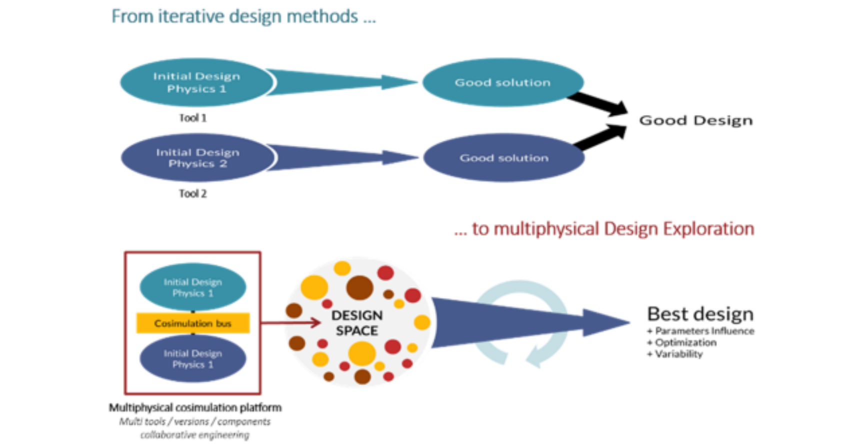


Picture 1, required simulation progress

Specifically in the aerospace industry, where development phases are longer than anywhere else, latest available technologies are out dated before a new airplane hits the clouds. In using optimization methods as the basis for research & design approaches are wrong as those rely on known technologies, known components and known rules only. Therefore any optimization approach will ultimately end up with a compromise in design, inadequately addressing development steps big enough to accomplish competitive edges of tasks like weight reduction, aerodynamic buoyancy and energy efficiency.

As in all industries of mobility, less combustion and more electrification as well as less manual and more autonomous functions are daily engineering challenges. Not only that engineering products are more and more complex, the pressure for time to market, better reliability and performance as well as optimized maintenance costs are engineering guidelines to follow. We need a choice of alternative designs to choose from and that is where design exploration helps with.

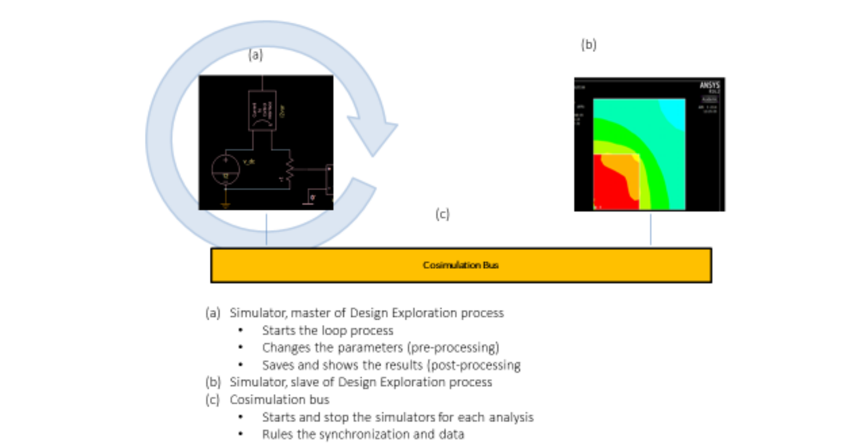
Today in research of new designs and under the engineering circumstances detailed above, the time is there to use design exploration within multi-physics co-simulation as it leads to more desirable solutions than design optimization does. The design exploration process shown in picture 2, as a formal or semi-formal method, is a gradual approaching method heading for the optimal best design. It is used to evolve and investigate multidisciplinary design space with the intent of design discovery. The strategies are based on the belief that the problem formulation evolves during the process of searching. A design space process creates parametric topologies followed by selecting varied parameters within associated ranges. A selection of new parameter configurations is used to explore the entire design space and the performance feedback to find the most promising areas.



Picture 2 process of design exploration

The need for the best design of parts, systems and aircrafts is essential for a successful aerospace business. In being able to explore all problems (known and unknown) during the research & design process will make the outcome of engineering far more future proof and therefore much longer competitive. The need for competitive edges and best designs are accomplished herewith.

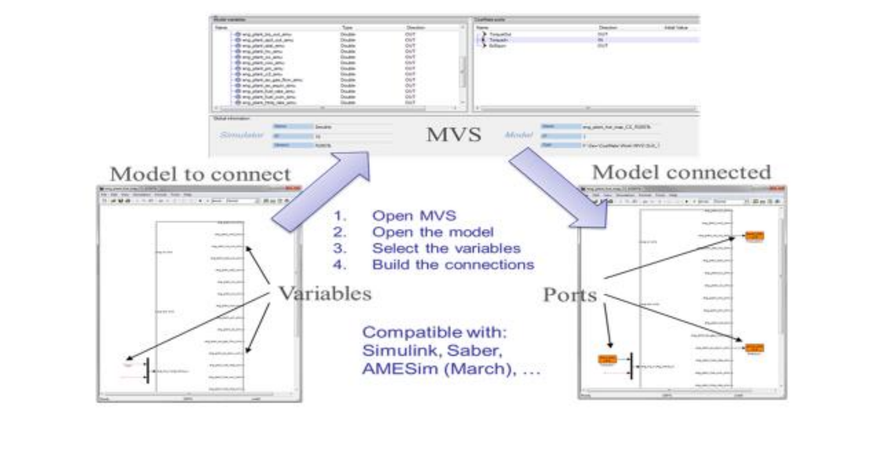
What is needed and how it can be accomplished within existing engineering environments?
It is a commonly known that simulation needs to be the first step in all kind of development activities. It is also understood that engineers do have a preference for simulation tools they have used or familiar with. Furthermore it is convenient to use existing simulation models, as they have been a good basis for perfecting accuracy over time. Last but not least dedicated simulation tools are optimized for very specific tasks, physics and domains. In being able to choose the best matching tool out of a wide range of available simulators (new & historical once) is advantageous as it enforces constant tool improvements satisfying customer requirements and stimulates competition.



Picture 3 support of existing simulation environments

Those existing engineering environment, picture 3, need to be supported and unchanged as much as possible even though constant enhancements are required to stay tuned with existing engineering requirements as well as upcoming new challenges. It is our understanding to support all simulation parties, to enrich their system application capabilities and to enable future-oriented tool utilization thanks to native coupling.

Coupling simulators can be accomplished in many ways. For a real benefit of enabling virtual integration to assess an assembly consistence before any prototype or even computer added design (CAD) is available, dynamic data- and signal-exchange as well as control through native coupling supports it. Processes like design exploration can be accomplished. The required co-simulation architecture in mind needs to be a native based & open bus architecture, allowing to manage all kind of activities such as communication speeds, timed or unsynchronized traffics, and so on.



Picture 4 coupling set-up ease of use

Required set-up of the bus communication exemplary drawn in picture 4 just means filling in parameter values into so called netlist template per simulator underlines ease of use. Once this is done, it manages everything fully automatically and acts as a background task. Adding more tools to the co-simulation bus is just repeating netlist value entrances accordingly. As soon as a netlist is completed, co-simulation is ready to use. At that point of time user can run more than one simulator at time to solve:

1) compatibility issues between outdated models and unsupported software versions
2) system-simulation across heterogeneous tools, teams and geographies
3) multi-physic simulation supporting design optimization
4) design exploration shooting for the best design

The common and heavily used method of traditional design optimization is easy to use as experts will concentrate on their area of expertise from a known solution. Needless to say that this is a widely used approach in all kind of design phases. It is an efficient approach even by taken into account multi-physical constrains through textual of static data, but does not take into account how other possible design variable combinations will impact the designed solution.

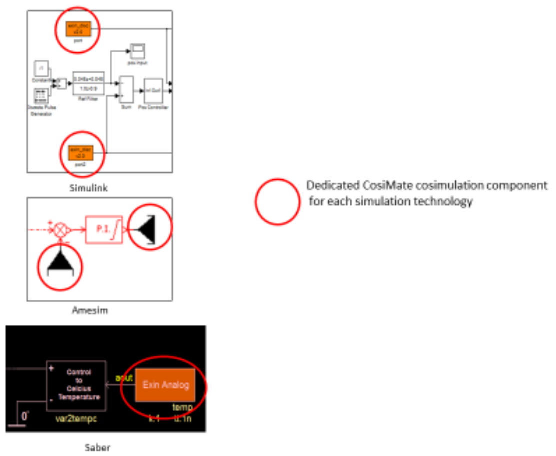
The real need to extend design of experiment has become so important due to the dramatic increase of networked electronics and coupled software driven by the fact of far more electrification and autonomy. This requires other simulation approaches and should therefore be based on multi-domain co-simulation. The simple example of fast current and slow heat in any power electronic design, requires at least 2 dedicated simulation tools natively coupled. Taking heat recovery, usage or dissipation additionally into consideration adds more simulation tools. This is not a conflict, it is a must for new designs. Optimization methods are inadequate addressing the complexity of networked hardware, software and applications. Furthermore they cannot quickly evaluate changes in design, reducing development costs and preventing late-stage design changes.

This is where design exploration goes far beyond and drives for perfection. It takes all combinations of parameters to evaluate the outcome on the design performance into real world scenarios.

How it supports engineering tools familiarity already in place?

The foundation to ensure support of engineering tool familiarity already in place is the co-simulation bus architecture (Picture 4). The unique part of data exchange and control is native tool coupling, where no translation of simulation data and/or control data can mislead to inaccuracy or latency issues impacting performance. This simplistic approach requires permanent adaption of tools already implemented, new tools coming available and simulation workflows supported. Due to native data exchange and control, this unique bus architecture does not require to be the master instance running multi-domain or multi-physics co-simulation; obviously it can be, but it doesn´t need to be.

It is structured to delegate master instances according the simulation workflow required. Therefore an engineer, who is per example an Amesim expert can run other simulation tools through his own application. The flexibility of master/slave operation can be even go beyond all of the simulation tools to management solutions such as product life cycle or any other very specific tool, which could run design exploration workflows automatically.



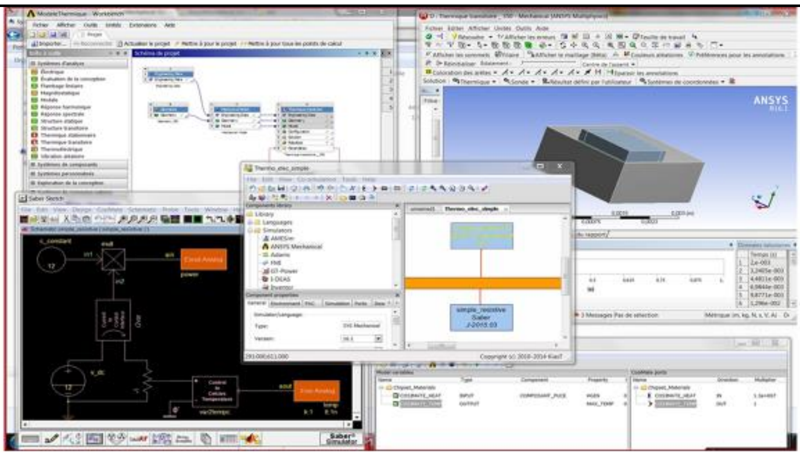
Picture 5 collaboration through co-simulation

Such an open & independent approach not only enriches any simulation tool available, it also enables needed collaboration between vendors, suppliers and all contributors involved in the process picture 4. Historically co-simulation has first taken place in aerospace industry, followed by early adaption of what if studies known as Monte Carlo analysis. With this background design exploration is the next logical step advancing simulation processes, unlocking knowledge and helping to support a next revolutionary step in aerospace design.

Conclusion

Establishing a design exploration process as part of multi-physics co-simulation helps the engineer to find alternative designs and to evaluate system integration. Furthermore he can collaborate with colleagues and stay with his favorite platform.

The advantageous usage of design exploration as part of the research & development workflow within aerospace industry, targeting best designs, is out of question. Next generation aircrafts, components and systems cannot longer rely on optimized designs. The aerospace industry needs revolutionary ideas to stay in sync with the fast pace of economic changes, business trends and environmental restrictions. In the world of simulation, the aerospace industry is leading and will greatly benefit from their system simulation know-how already in place as picture 6 example shows.



Picture 6 thermal-electrical system-simulation example

This industry is very familiar with design optimization processes and therefore well prepared for a wide usage of design exploration. To address existing industry technology challenges like

1) new hypersonic solution
2) high energy efficiency
3) full electrification
4) wide autonomous functions
5) connected aircrafts

The need to virtualize an all-in-one solution of a next generation component, system or aircraft is there. We are just in the beginning of adapting design exploration processes and published use cases are rare. As it is impossible to formulate and characterize all problems before hand, let us explore all of them (known and unknown) during the research process.