Towards More Effective Design of Space-Borne EO Sensors
Integrated STOP analyses in hours rather than weeks!

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Space-Borne EO sensors are highly sensitive instruments that must survive the harsh environments of launch and of space. Product teams design and deliver the hardware, *ensuring success the first time around.* As failures are costly and often highly visible, a great deal of care and effort goes into the design, analysis and T-VAC testing of these instruments before launch.

As physical testing is extremely expensive and limited, design teams use simulation to help explore the design space and provide a first level of validation, testing the evolving designs under a large number of environmental conditions and what-if trades. These simulations require teams of subject matter experts (SMEs) – experts in space systems engineering, CAD, controls, and optical, thermal, structural and electromagnetic analysis. Working in today's hierarchical/"silo'ed" organizations, and using a number of highly-fragmented analysis tools, each iteration takes an unacceptably long time to complete - it is not unusual that an integrated STOP (structural, thermal, optics performance) analysis can take 3-6 weeks of wall-clock time to complete! These simulations, which assess the performance of the sensor in the field, generate large amounts of fragmented data, forcing the SMEs to manually transmit data between them and to manually collate key results required to make design decisions. Managing the rapidly evolving design and the associated analysis data is at best difficult and often may not happen. This approach does not foster collaborative systems thinking and significantly reduces the impact that simulation could have on creating a working design, on time and within budget. Fewer scenarios than desired get analyzed and, often, projects are over budget and schedule by factors of 2-5, and worse, result in on-orbit failures[1].

One application domain of the Comet Performance Engineering Workspace is STOP analysis[2]. Using this integrated simulation environment, engineers at The Aerospace Corp[3-4], NASA Langley, NASA Goddard (a first project with Comet has recently begun), Air Force Research Labs (AFRL)[5], and other optical institutes/orgs outside the US are seeing significant improvement to their design process and simulation throughput.

Figure 1 is a Process Schematic that captures the data flow and execution flow of a typical STOP analysis process. The Process takes a CAD model and the associated optical prescription as inputs. Each rectangular box represents a Task in the simulation Process. For example, there are Tasks that perform meshing operations (the thermal and structural meshes are often quite different), thermal analysis, structural analysis and optics analysis. The data flow between these Tasks is quite complex, but is handled seamlessly, automatically dealing with unit and coordinate system transformations, often a source of errors and inefficiency. Within each Task, the SMEs codify the appropriate set of rules for running the associated underlying analysis tool - these rules are encoded graphically, largely eliminating the need for scripting and programming when creating the templates.

Once the templates have been set up, the various analyses are automated, *allowing any of the engineers, regardless of their expertise, to run the entire STOP process from start to finish in a few* *hours.* Changes can be made to the design geometry and any other aspect of the design, and also to the environment, and the updated design can be reanalyzed rapidly without further user input. The Comet workspace fosters "systems thinking" and collaboration amongst the engineers, in stark contrast to the rigidly "silo'ed" approach in current simulation environments, and, most importantly, facilitates concurrent engineering of the optical system[3-4]. A flier on a case study related to how the Comet STOP template works, is available via the Web[5].

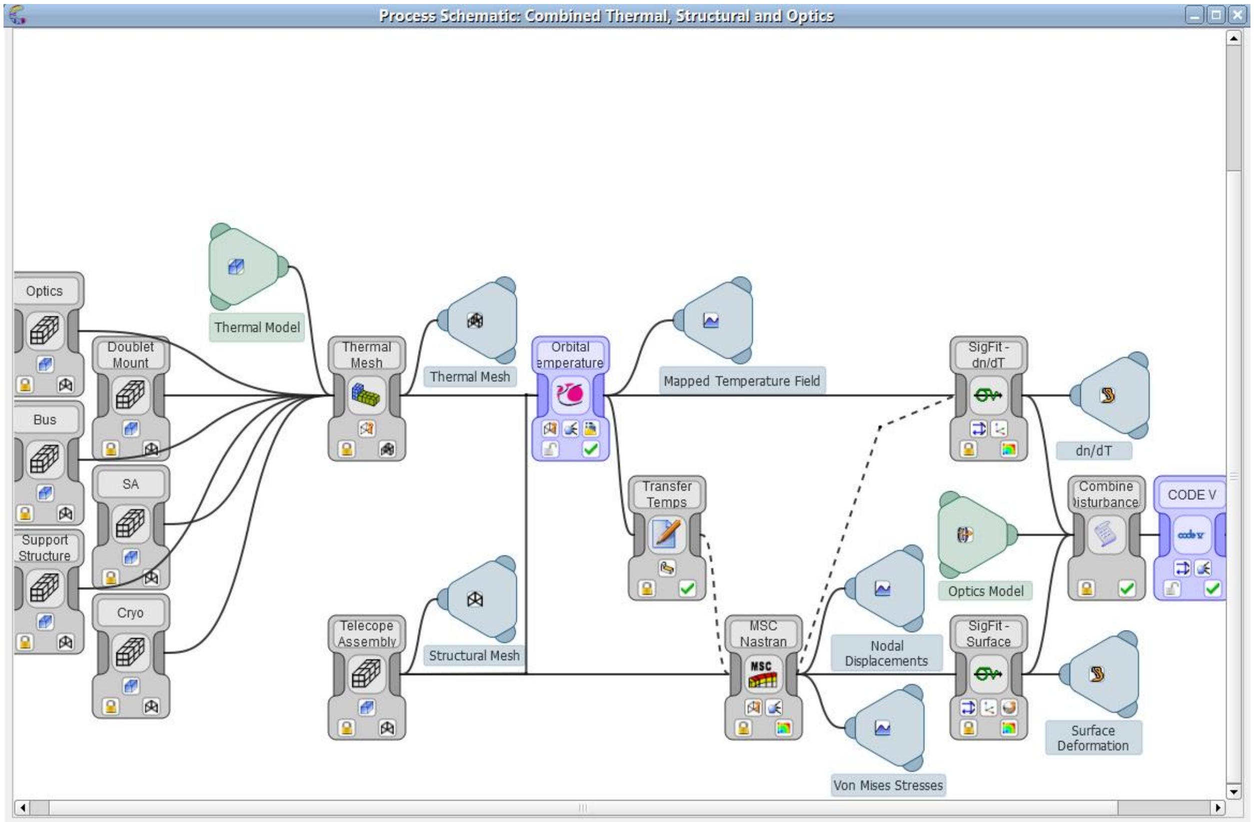

Figure 1: Typical STOP Process in Comet – meshing, thermal, structural, and optics Tasks.

Customer Use Cases

The Aerospace Corp

A multidisciplinary EO Sensor Payload Team at the Aerospace Corp, led by Dr. David Thomas, has been using Comet as the integrated workspace that facilitates their concurrent engineering process, for a number of years[3-4,7]. The projects have ranged from early conceptual design to final design validation. Dr. Thomas has concluded that the concurrent engineering process, anchored by the Comet workspace, has provided numerous benefits over the prior process – significant efficiency gains and improvements in simulation throughput, enhanced "systems thinking" amongst the SMEs, and the ability to introduce higher-fidelity simulation in the earliest conceptual design stages resulting in higher quality designs faster.

NASA Langley

At NASA Langley, the Comet workspace has been used by a thermal engineer to run the entire STOP process for validating the design of an HSRL (Lidar) optical system. Using the expertise of structural and optics experts, he was able to create the STOP template and then execute the entire process by himself. The template allowed him to rapidly explore various what-if trades over a short period of time. This use case demonstrates how SMEs and systems engineers, who traditionally only run calculations in their physics domain, can now *safely* run simulations using tools outside their domain, enhancing the ability of all the engineers in a team to consider the system as a whole. This reverses the current trend which has been creating experts with a very narrow tool-centric focus, to the detriment of designing and delivering complex systems.

AFRL Directed Energy Program

At the AFRL, teams of engineers have been designing and testing complex, cutting edge technologies for laser weapons. Recently, the Comet simulation workspace has been used to demonstrate the ability to perform mixed-fidelity systems evaluations of complex laser systems[6]. Comet's integrated data model can capture and manage multiple representations of components, each utilized by different analysis programs, across multiple physics domains and multiple levels of model fidelity[7]. This capability allowed the engineers to "zoom in" on certain subsystems, from a fidelity perspective – the subsystems were suspected of causing beam-spread issues. Hence, the engineers were able to retain a low-fidelity systems representation for the vast majority of the system, while performing high fidelity thermal and structural calculations on selected subsystems. This mixed-fidelity approach provided higher fidelity results that matched the system anomalies that were detected in physical tests, without the human and computational expense that would be incurred if the entire system were analyzed using high fidelity representations.

Conclusion

The current STOP workflow is sequentially-executed, fragmented and inefficient, executed by teams of SMEs in multiple, "silo'ed" organizations. In the AFRL example, and in many other use cases at the Aerospace Corp., NASA and elsewhere, the Comet approach to analysis knowledge capture and reuse has demonstrated significant improvements. Comet templates have allowed product teams to deal rapidly with design variations, while ensuring analysis accuracy and collaborating effectively across multidisciplinary groups to make design decisions. Product teams deliver better designs in time and on budget, when each full design iteration is completed in a few days rather than in 4-6 weeks. Currently, Comet Solutions is working with AFRL to enhance Comet's ability to manage systems-level and mixed-fidelity models, and with Aerospace Corp and others to enhance its ability to deal with dynamics (jitter analysis) and composite materials.

References:

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The Performance Engineering Workspace