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Virtual is Real With Electronic Systems Prototyping

"Time to market" is the key metric for every commercial product development effort. Unless your product is truly "crazy great," being second to market is never good. Commercial product developers leverage leading-edge tools and technologies to try to win the race to get their product to market the fastest.

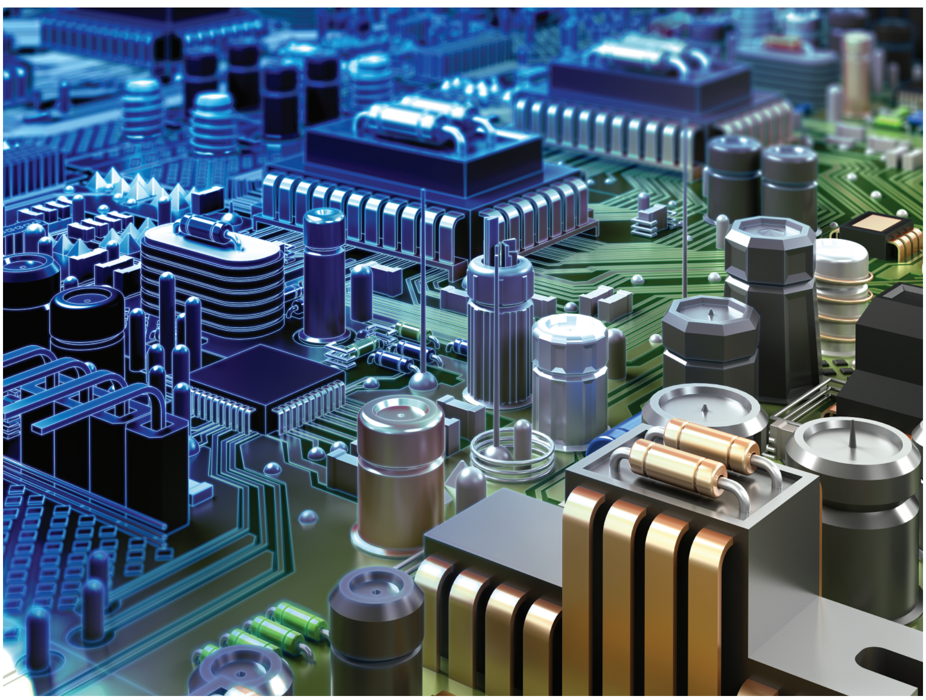
When faced with reducing product development time, the Defense Department and defense industrial base revive tactics from the past "Total Quality Management" initiative. This initiative focuses on efficiencies in current processes. Each step within these processes is thoroughly examined. Self-defined "non-value added" efforts are eliminated, usually replaced with self-defined "better" efforts. The new and improved process is then implemented, during which self-defined success criteria are created and, oddly enough, met.

This technique has proven to be quite ineffective. The process improvements are, at best, marginal and are never permanent. The reason for this failure is simple: the problem is not the process steps — the problem is the process. And the biggest contributor to schedule delays and costs overruns to the defense product development process is the overdependence on prototypes of the actual system, creating a "build–test–repair" flow.

When one takes time to ponder the paradox of system prototyping, the schedule delay and cost overrun contributions of this single step become obvious and ominous.

Consider this: Developing the prototype system takes time and costs money. Because the design is dependent on the results of the prototype testing, all major design work stops. It should be no surprise that the costs of the prototype system are generally quite high.

Developing and executing the test plan for the prototypes requires a separate and large engineering staff and test facilities. This large group must work hand in hand with the design team to develop the test plan and ensure that their test instrumentation does not affect the performance of the subject system.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Assessment of the testing results and determining the impact of the design takes time. Designs are "locked" following the appropriate series of testing and results interpretation. But because of the current long defense industry and department design cycles, the moment the designs are locked they immediately have diminishing manufacturing source issues.

Because prototype testing is performed individually first on all subsystems, then major subsystems, then finally as an integrated platform, issues with subsystem and system integration, interfaces, operation and maintenance are not discovered until platform integration and testing. At this point, uncovering the prototype platform operation issues are expensive and quite hazardous. And fixing those issues is quite expensive and takes lots of time.

Experience has shown that once software development is factored into this process, the cost overruns and schedule delays are easily doubled.

It should be of no surprise that for today's Defense Department acquisition programs, close to 50 percent of the costs are for test and evaluation. While the T&E portion would appear to be the major driver of program cost overruns and schedule delays, we must acknowledge that the current design processes and practices drive the need for expensive test and evaluation.

Until this is properly examined, dissected and commercial best practices are transitioned, costs will continue to rise while schedules extend out further and further.

Commercial electronic systems have become systems of systems, and if each of these had to be physically prototyped first, then put together into larger systems, the development window would be way too long. Therefore, for several years commercial designers have refined the process of using pre-silicon virtual, not real, prototypes for testing throughout the design cycle.

What is a pre-silicon virtual prototype? It's an electronic version of the subsystem or system that can be used to model, simulate and visualize its behavior under real-world operating conditions. Done at the right development stages, virtual prototyping can speed up the design process by providing certainty that the design is correct.

Once a robust virtual model is created, it's much faster to probe the design for potential failures, then tweak the design to make sure it has been improved. Considering that for chip development assessments need to be made pre-silicon, prototypes here can sometimes be not purely virtual — if for example, executed on a host workstation — but can utilize techniques called "emulation" and "field-programmable gate array-based prototyping" that actually utilize specific hardware. It is just not the actual hardware that later will be included into the system.

Pre-silicon virtual prototypes are used for two main purposes: as a functional prototype used for early software development and for architectural exploration to make key decisions about the hardware and its performance.

While the architectural prototype is essential at the beginning of the design cycle, the functional prototype is much more widely used as each major system element is designed and refined. The classic dilemma of architectural prototypes is, however, that they are to be available as early as possible and architectural decisions require the full accuracy of the subsystem to be looked at, like an interconnect. As a result, purely software-based virtual prototypes are augmented with architecture decisions that are done using more detailed representations like emulation.

Today's electronic systems are a combination of complex hardware and software that must work together. Traditionally, hardware and software were developed separately, and most of the software was developed and verified after the hardware design was complete. The software development process became a huge bottleneck.

Now, with pre-silicon virtual prototypes, software developers can start months before the hardware design is complete, significantly speeding the overall design cycle so that, when the hardware is complete, the fully functional software can be brought up within days.

Software-based virtual prototyping is essential and is used with two other steps in the electronic design process.

One is emulation, which provides much faster software run times on the virtual prototypes. (See the article "Preventing Expensive Electronic Hardware Mistakes" in the April 2018 issue of *National Defense*.)

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As for field-programmable gate array prototyping, the hardware design is loaded onto field-programmable gate arrays to further test the hardware design and run software before actual silicon is created. While they run slower than "real" silicon and use more power and area, they provide a great test case to double check the virtual prototype designs after emulation. These prototypes can run in the performance range of 20s of MHz and can give important debug insights to the hardware and software running on it. The speed allows designers to boot operating systems like Android, better simulating the final product.

The guardians of the status quo who dominate both the acquisition process and defense industrial base product development process will definitively state that virtual prototypes cannot be used for their projects. They will point to the past failure of using computation fluid dynamics models in place of wind tunnels. They will cite some past where modeling and simulation was partially used, only for some unforeseen event or circumstance to cause failure.

And they will ignore that in the commercial world, the use of modeling and simulation to develop on-schedule, on-budget "first-pass success, future-proofed" products is common, and has been for some time.

During the early 1990s, Chrysler used modeling and simulation to "virtually" design and test the engines for their "savior" LH vehicles. Its product clinic results revealed a consumer preference for quiet, responsive and powerful engines. The resulting 3.5-liter V-6 was not only critically acclaimed, but was the first "paperless" engine. Incidentally, the development time and costs met the rather aggressive targets.

Because of significant dependence on electronics, the defense world can immediately benefit from the commercial electronic design and development best practices in application domains like automotive, consumer electronics and networking.

The use of virtual prototypes speeds design cycles and cuts costs because that "virtual" prototype is actually the real product design. The technology is well established and ready for Defense Department project adoption. ND

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