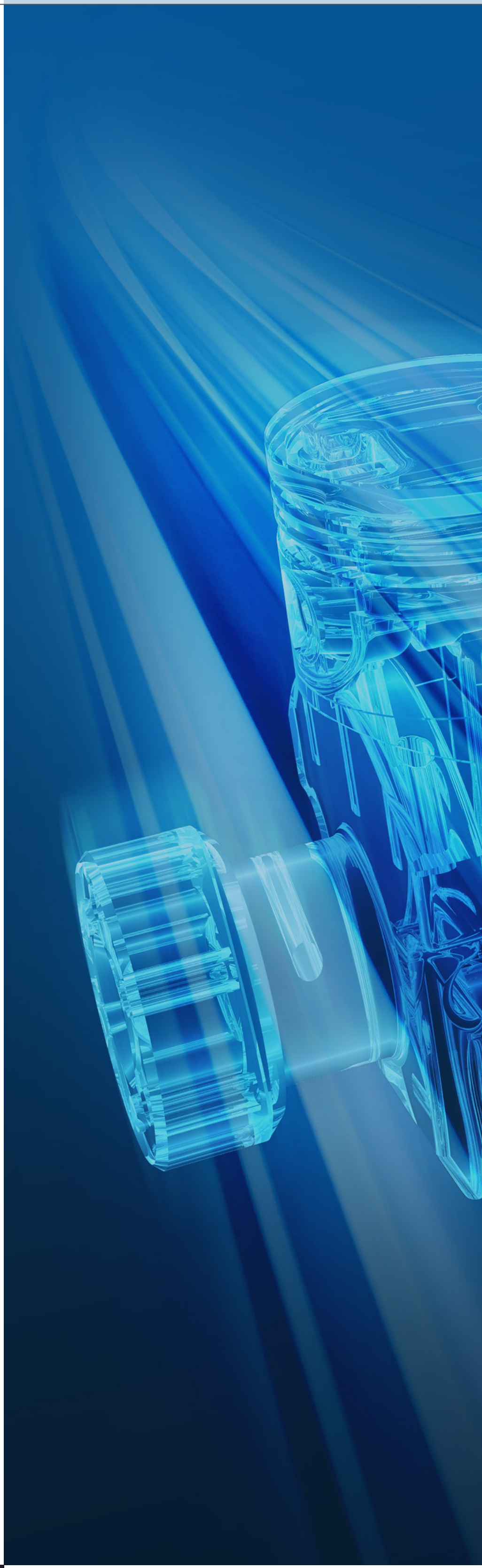


"There has to be a better way." – This is the mindset of Tula Technology, and this innovative engineering company has succeeded in solving an engine design challenge that the automotive industry has grappled with for decades. That issue is how to achieve individual engine cylinder deactivation. The creative minds at Tula have developed a software-based approach that combines advanced digital signal processing, algorithms, and sophisticated powertrain controls to automatically manage when a single engine cylinder should deactivate (skip) or activate (fire) to meet the torque requirements of the driver. Their solution is called Dynamic Skip Fire (DSF®) technology.

Dynamic Skip Fire

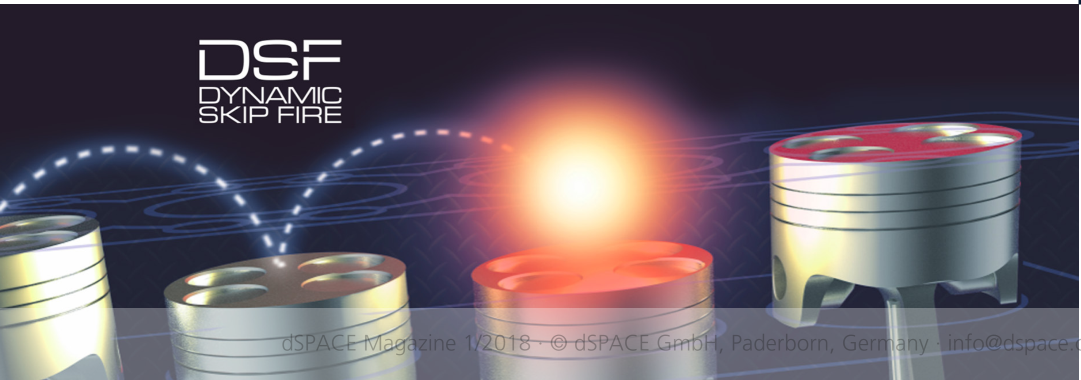
With DSF technology, the engine control system automatically turns individual fuel cylinders on or off to meet the vehicle's power requirements with the most efficiency. In contrast to conventional methods of cylinder deactivation, Tula's Dynamic Skip Fire algorithms fire between 0% and 100% of cylinders in a near continuum. This operation reduces fuel consumption through a substantial reduction in pumping losses, higher combustion efficiency, and an improvement in catalyst management during deceleration. DSF technology gives drivers the power they need, but keeps the engine running at optimal efficiency. This solution can reduce fuel consumption and CO_2 emissions by 10-15%. General Motors (GM) has taken notice of this fuel economy technology. The automaker has invested in Tula, as have other companies including Delphi, Sequoia Capital, Khosla Ventures, and Sigma Partners. Delphi is a strategic Tier 1 partner of Tula as well.

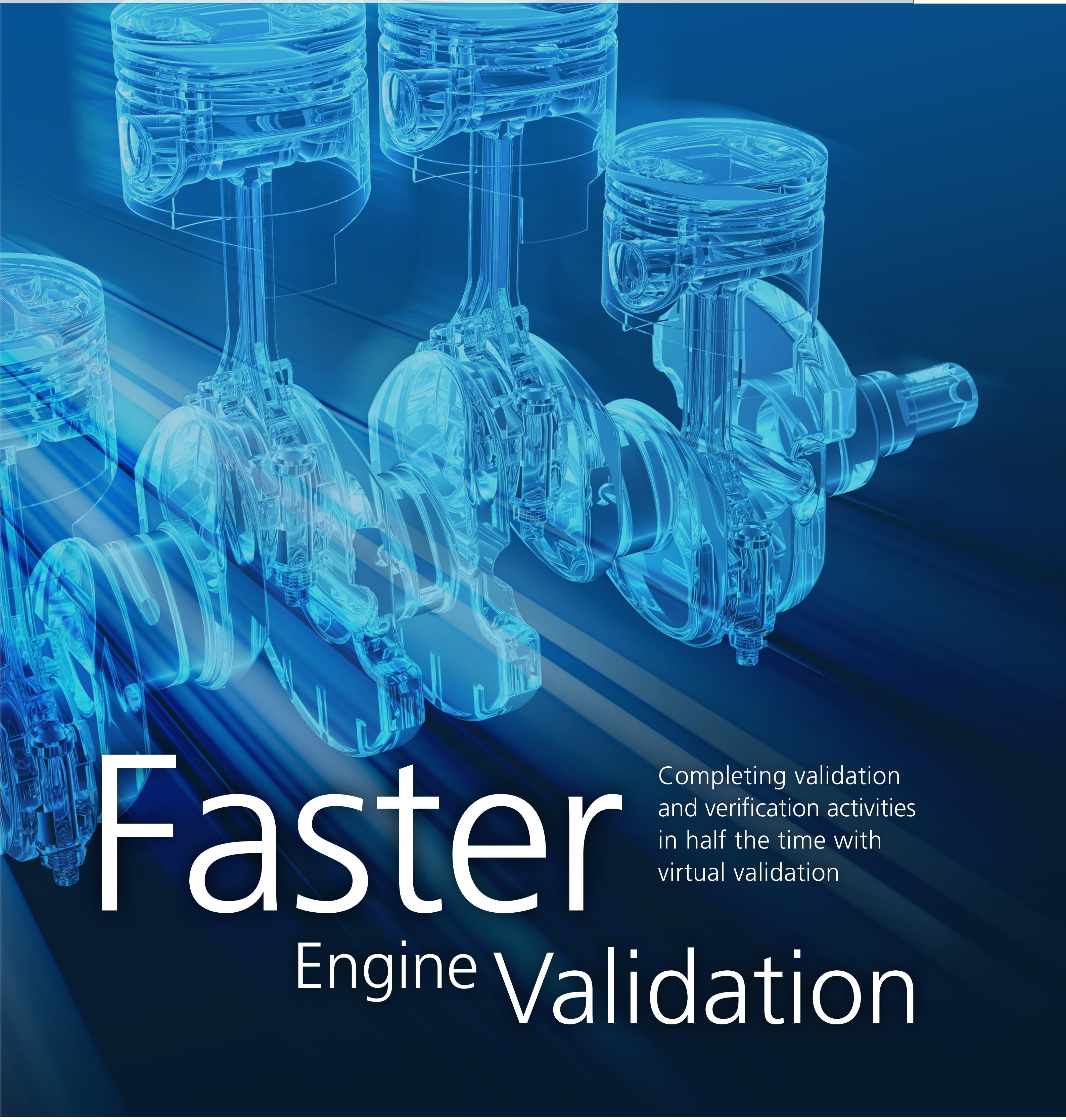
Pursuing Automated Testing

Tula has been fine-tuning its DSF solution since 2008, when the Silicon Valley technology company was established in San Jose, California. The company has since received 52 patents and currently has over 70 patents pending. Tula first contacted dSPACE in 2009, when the company set out to explore embedded software development and electronic control unit (ECU) testing options. Today, Tula has established an automated testing platform that incorporates several dSPACE tools, including MicroAutoBox II for rapid control prototyping, RapidPro for signal conditioning, a hardware-in-the-loop (HIL) system for simulating and testing engines, ControlDesk for controlling the experiment, SystemDesk for modeling architectures and systems, and AutomationDesk for writing and updating standardized tests and recording and sharing test data. To further expand on its automated testing capabilities, Tula has most recently adopted a virtual validation environment and added dSPACE VEOS, a simulation platform for virtual validation, to its laboratory.

Faster Validation and Earlier Bug Detection

The desire to complete validation tasks faster and find bugs earlier in the software life cycle are two of the main drivers that motivated Tula to pursue virtual validation in 2016. Alfred >>





Faster Engine Validation

Completing validation and verification activities in half the time with virtual validation

Can you execute testing activities faster without the physical hardware? Tula, a Silicon Valley technology company, has seen a 50% reduction in time required to complete validation and verification activities since establishing a virtual validation environment.

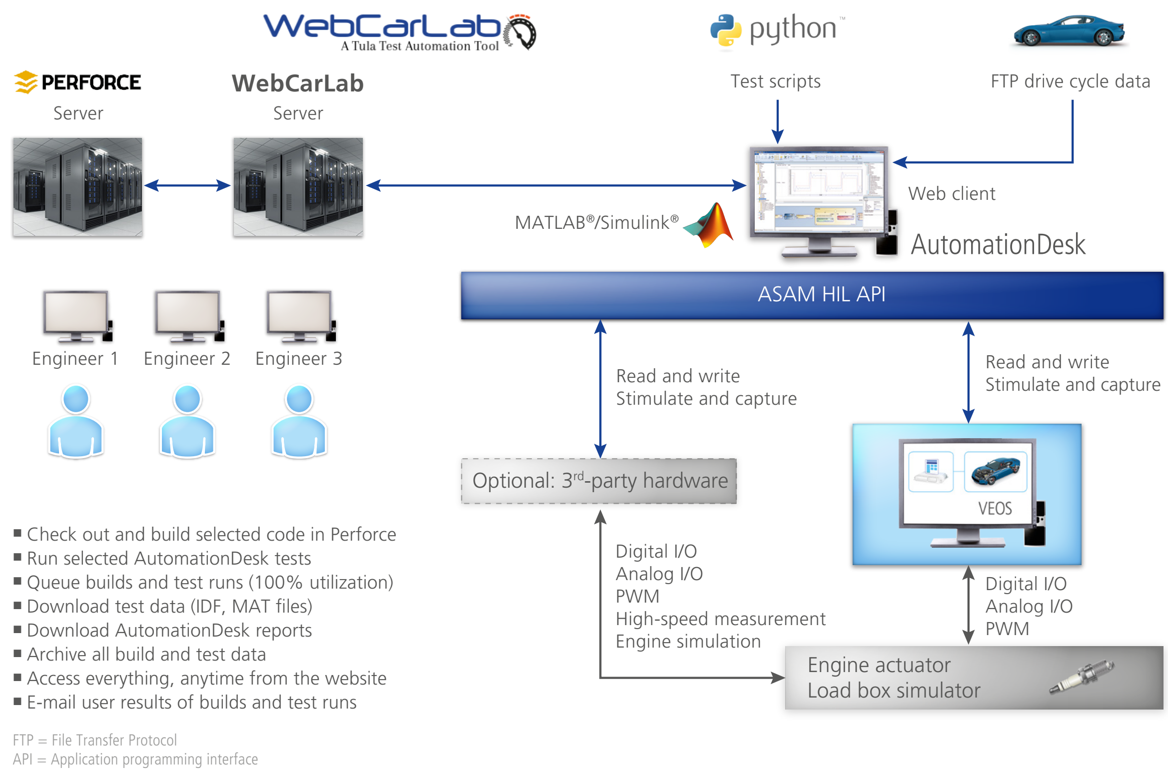
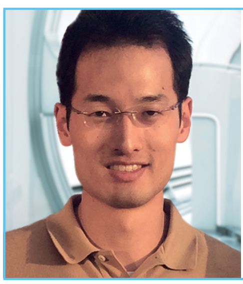


Figure 1: In Tula's new validation and verification infrastructure, all code and test scripts are organized in dSPACE AutomationDesk and executed using the PC-based simulation platform dSPACE VEOS.



> "We have found that it is generally faster to validate software early in the development process using just your PC and VEOS."
>
> *Alfred Wong, embedded software and systems engineer, Tula Technology, Inc.*

Wong, an embedded software and systems engineer for Tula, explained that their process for verifying and validating updates to software was time-consuming due to multiple dependencies. This issue, coupled with the challenge of managing multiple customers with different hardware and time limitations stemming from having to share the HIL bench among team members, prompted the company to seek a better alternative. Tula's main objectives in establishing a virtual validation environment were to:

- Reuse existing tests developed with AutomationDesk
- Execute validation and verification tasks in a virtual setting, without the physical hardware
- Reduce costs and maintenance time

Advantages of the dSPACE Tool Chain

Tula turned to the dSPACE virtual validation tool chain because it promised to fulfill all objectives. One of the main components of this solution is the simulation platform dSPACE VEOS. The software runs on a standard PC and gives engineers many new options for developing new functions and validating, verifying, and testing ECU software in a entirely virtual environment. Since implementing its virtual validation platform, Tula has met all of these goals and is seeing impressive results. The company reports that it has cut its validation and verification (V&V) process time by more than 50%. Tula credits much of these time savings to their newfound ability to execute tests in a virtual environment – without the physical hardware.

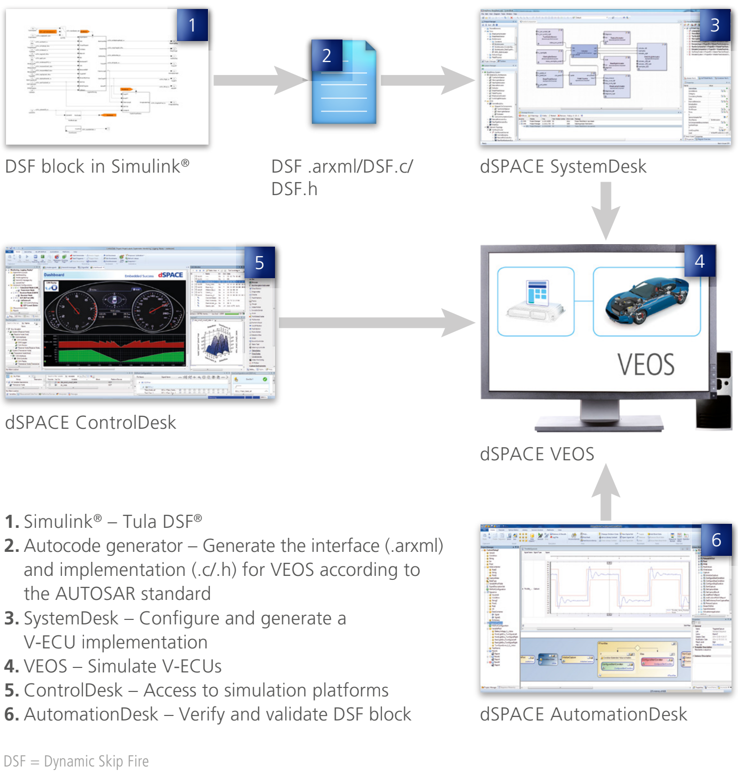


Figure 2: Typical workflow for generating V-ECUs with Tula's DSF functions and simulating them on VEOS for testing.

Tulas Virtual Validation Environment

Tula's virtual validation environment includes the following tools:

- SystemDesk for modeling architectures and systems, and generating virtual ECUs (V-ECUs)
- VEOS for simulating the V-ECUs
- MicroAutoBox II for rapid control prototyping
- RapidPro for signal conditioning
- A hardware-in-the-loop (HIL) system for simulating and testing engines
- ControlDesk for controlling the experiment
- AutomationDesk for writing and updating standardized tests and recording and sharing test data

Applying Virtual Validation to a Simulink® Block

Tula is using virtual validation for its Dynamic Skip Fire (DSF) technology. Specifically, Tula is applying virtual validation to its DSF algorithm Simulink® block. The generated DSF algorithm is running on a virtual ECU over an FTP cycle as input, and the outputs are recorded. Tula then compares the recorded outputs (software-in-the-loop) against the expected outputs (model-in-the-loop) to determine if requirements have been met. "Virtual validation saves us time, finds bugs early in the software life cycle, and frees up our HIL bench," said Wong. "It gives us confidence in our software, prior to deployment on the engine and vehicle."

Bending the Learning Curve

Tula had to face a learning curve in setting up its virtual validation platform. Some setup challenges they successfully managed included importing Tula software into the virtual environment, creating physical models for hardware components, and starting tests with the same initial default values. Tula used a signal generator to create input values that would otherwise be generated from the hardware components. They also set the initial values to default and waited for the software to reach a steady state before injecting stimuli.

Wong clarified that virtual validation does not replace their use of MicroAutoBox II for function prototyping, but it complements the process by allowing them to reduce their time spent in the HIL environment. "We are using virtual validation on our development PC to verify functional requirements early in the software life cycle," said Wong. "It is less expensive than physical hardware, and it frees up our physical hardware for other work." For its next customer project, Tula plans to utilize virtual validation as well. ■

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