Problem with rocket fuel pressure control solved quickly, efficiently, with MATLAB® and Simulink®

The Challenge
To design a control system for a rocket fuel tank that would ensure a continuous flow of liquid oxygen from the pressure tank to the turbine.

The Solution
Use MATLAB and Simulink to model, analyze, and implement a control system consisting of a series of flow-regulating valves and a modifiable opening.

The Results
- An efficient, cost-effective design
- A focus on finding solutions, not fixing code

The Challenge

GenCorp's Aerojet Division in Sacramento, California, needed to develop a control system that would provide a constant pressure in the fuel tanks of the Kistler Aerospace K-1 space launch vehicle.

When it is completed, the K-1 will be the first commercially available, fully reusable launch vehicle to provide low-cost access to space for low earth-orbiting satellites.

The K-1 is powered by a modified Russian rocket engine, provided by Aerojet, that burns LOX (liquid oxygen) and kerosene. The actual thrust is achieved when the appropriate mixture of LOX combines with the kerosene and explodes, causing the rocket to fire.

As LOX levels in the tank drop, greater pressure is required to force the LOX towards the combustion chamber. To restore pressure, the LOX consumed during firing is replaced with helium from external storage tanks. But the introduction of helium creates a new control engineering problem, because the two gases operate at different pressures (the LOX requires steady pressures, while the helium requires constantly increasing pressures).

The Solution

Perry Stout, controls engineer for the project, developed a solution in which flow between the high-pressure helium storage tanks and the low-pressure LOX tanks is controlled by a series of flow-regulating solenoid valves and an orifice that can vary in size according to ambient conditions.

He used MATLAB® and Simulink® to design a control system that regulates the operation of the valves and moderates the orifice size. He began by

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— Perry Stout, controls engineer, GenCorp Aerojet

deriving the physical equations and writing them out on a sheet of paper. It was fast and easy to move these core equations into Simulink. He could then develop a model based on the equations, test them, and add heat transfer equations and closed-loop control laws graphically, without writing additional code. He was then able to analyze the design, using MATLAB, and modify it quickly and easily in search of optimal conditions.

This project would have taken several months using a conventional engineering process. "I don't know how I would have solved this problem without [MATLAB and] Simulink," said Stout. "As a Fortran project, the control system design would have involved an entire team. A manager would have been required to divide the modeling, simulation, and control tasks among several people, closely monitor and coordinate all activity, and summarize the results."

The Results

- **An efficient, cost-effective design.** With MATLAB and Simulink, the crucial control system was designed, tested, and validated in a matter of weeks—and by a single engineer.
- **A focus on finding solutions, not fixing code.** "Simulink allowed me to concentrate on the physics of the modeling and control problem without becoming overwhelmed by programming details," Perry Stout stated.

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