MIT xPRO

FROM MODULES TO MODELS: HOW FORD MOTOR COMPANY IS SHIFTING ITS SYSTEMS ENGINEERING STRATEGY

Ford Motor Company is undertaking a global effort to reinvent itself because its customers are demanding a higher pace of change, the most in the industry's history. Customers want more intelligent features, increased automation, and new forms of propulsion technologies, such as electric vehicles, and they want these new features implemented faster posing challenges for Ford and other automotive manufacturers.

To meet these challenges, Ford is embracing systems engineering (SE) practices across the organization to such an extent that the company is changing nearly every aspect of vehicle design, optimization, and production. And, over the last year, they have built a global SE organization to deliver it. It's singular mission: deliver cost, warranty, and quality improvements on a systems level within the engineering teams across its global product offerings.

Ford has been making significant shifts in its portfolio of cars and trucks and its engineering strategies. They will no longer sell sedans in North America; instead launching several new SUVs and crossovers to replace them. Launching a series of new variants will require the company to be on their game for systems engineering, because they will not have the bandwidth to engineer those vehicles individually.

"As part of the redesign of the company which we just completed in early summer, systems engineering is an all-new team that has been added to the larger Vehicle Components and Systems Engineering (VCSE) team," says Julie Rocco, co-director of the newly formed SE group along with co-director Julie Levine. She comments that systems engineering has been done well in pockets within Ford, largely by function– body engineering, chassis engineering, electric engineering has had SE in pockets–but this is an all-new team that works across body, chassis, and electrical to implement all of the SE methods and tools across the functions.

"Historically, we re-engineer multiple components of our vehicles," says Rocco. "When you do that you don't get economies of scale and you spend a ton of engineering dollars because people are focusing on their own piece but not focusing across the different functions."

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Instead, Ford is undertaking a modular strategy, which will need a strong systems engineering complement to work. Under a modular strategy, Ford will design building blocks according to interfaces and compatibility rules and will be reliant on excellent SE to ensure that those blocks fit together and work as a car when assembled. This contrasts with the "old" way of doing it, which was designing new parts for a new car from the ground up.

"Instead of designing custom parts and commodities for every single vehicle, there is a modular catalogue to choose from where you are effectively shopping out of a catalogue taking what module works best for you," explains Rocco, adding that the practice reduces complexity and engineering costs. "As we are modularizing it became more and more necessary to formalize and operationalize a systems engineering team. We are charged with connecting and managing the interface and performance between all of the modules within a vehicle." The team also includes a group using digital engineering tools, like modeling, simulations, and requirements analysis to form an 'end-to-end digital thread' of engineering tools from the very beginning of the product life cycle all the way through to the end.

As part of its commitment to implementing SE practices and successfully moving to its modular design strategy, Ford has partnered with MIT xPRO's online learning community. To date, over 400 Ford engineers have participated in the MIT program, "Architecture and Systems Engineering: Models and Methods to Manage Complex Systems," a four-course online course on model-based systems engineering.

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FROM EXECUTIVE SESSIONS TO ONLINE LEARNING AT SCALE

Rocco describes the new SE team at Ford as a "department of professionals from all different areas of the company with a huge need for training because we have people with different skills sets from across the globe." Along with its core in Dearborn, Michigan, the SE team also includes team members at multiple global centers.

Her team decided to focus on the MIT courses after she and others in senior leadership completed a face to face session by Bruce Cameron, Director of the Systems Architecture Group at MIT, who developed the online program in 2016. "What I valued is that the executive course did not teach us textbook material," she said, instead applying it directly to Ford and its issues at the time they were making a switch to the global systems engineering team. "The magic of having us all together in the group is that people started to open up; we talked to each other around Ford problems, not theoretical SE methods. It was directly applied to the executives in the room."

She also found value seeing how broad systems engineering is embedded in the aerospace and other industries. "We looked at those examples and were able to apply them to Ford executive training."

From that executive session, Ford made a commitment to recruiting its engineers across all its functions to enroll in the MIT online certificate program. The four-course online program spans 6 months, which requires about 4-6 hours of work/week. Each course combines videos, reading material, assessment and course work. At the end of each week, students are required to complete a project which is reviewed by peers. The flexibility of the format and delivery allows for Ford's organization to deploy it at scale, including participants from Ford USA, Canada, Mexico, England, Belgium, Germany, India, China, Thailand, and Australia.

"A lot of my team members are later in their career and

they are extremely busy," says Rocco. They were not interested in pursuing SE degrees through local organizations, many of which are 2-year programs in the evening. "They found the MIT online certificate program to be high value and very fresh information that they could more easily accommodate into their daily schedules."

DESCRIPTIVE MODELING HELPED IDENTIFY EFFICIENCIES

"Systems engineering is essential because you have to ensure that all of these parts and systems that might now exist in a new combination actually work," says Chris Allard, who reports to the Rocco/Levine team and leads Pack Systems Optimization, one of the core subgroups in the new SE team. His team is responsible for systems optimization across the 'skateboard' of the vehicle, including propulsion, body structure, and chassis; to integrate them into a successful product.

"I found the coursework to be very helpful," Allard says. "With something like approximately 130 modules on a car, and as many as 20+ variants to pick from out of the catalogue, it is not practical to model all possible combinations in advance." Instead, it will be essential to quickly assemble new models from a library to enable

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quick assessment of alternatives.
Allard, who completed the online certificate program in August 2019, used the program to learn more about the importance of descriptive modeling, which is a mathematical modeling practice describing real-world events and how factors interact to create them. "I saw how Model-Based Systems Engineering can quickly improve the efficiency of the product development cycle and how errors can be reduced in a very complex system" he says. He also valued the discipline around case studies; focusing on the customer, and how the customer is going to interface and use a product and how that translates all the way down the engineering process.

Given his role in optimization, he also valued the program's presentation of SE optimization techniques. "We are at a moment where we have to model more and more complex systems and consider more characteristics and do more in-depth analysis with parametric models," he says. "Now with a lot of software packages that are coming out for optimization we can perform 50,000 runs during a coffee break and find an area we hadn't conceived of."

"In our business, margins are razor-thin, so improving variable costs by a percent can be extremely impactful for the bottom line of the business," he says. "I found using models to look at all the factors you care about in a design, pulling them in one place using model-based systems engineering, and then assessing those designs was really powerful."

Along with its own products, Ford is undertaking new partnerships which will require even stronger SE to manage interfaces with its original equipment manufacturers. Examples include Ford's investment of $500 million in Rivian Automotive, a company founded by MIT alumnus RJ Scaringe (Ph.D. Mechanical Engineering 2012), to make electric trucks and SUVs and its partnership with Volkswagen to build midsize pickup trucks and commercial vans for each other. "With modularity you get very precise about what you're doing," says Allard. "The ability to communicate with a partner is really helped by following SE disciplines, particularly if your tools are interoperable and you've got one standard way of doing things."

COMBINING SE WITH COMPUTER-AIDED ENGINEERING

Ford is connecting its engineering requirements into model-based systems engineering that will be used with computer-assisted engineering (CAE). "Before this, all of the engineering to-dos that are scattered on various computers are not linked; now we are moving toward putting then in a systems engineering model that is linked and traceable," says Rocco.

As Global Chassis Virtual Engineering Manager, Narayana Venugopal (Venu) is responsible for CAE for chassis at Ford. A self-described "ambassador" for the MIT program, he has encouraged and motivated the global chassis team to participate in the program. More than 150 chassis engineers from US, Germany, Mexico, China and India have completed or are enrolled in the program. He completed it in February 2019.

Venu's team has long experience with many of the concepts of the MIT program. "But I wanted to see how other industries handled similar issues and it was very

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valuable to learn more about trade space analysis and optimization strategies across many industries," he says. "The more awareness we have of the methodology, tools, and how industries are applying these concepts the better."

MOVING CLOSER TO THE CUSTOMER

"Ford has existed for 116 years," says Rocco. "As we make the shift in our global organization, it is really important in the culture that the SE team is highly trained and adding value, and we have found the MIT coursework has a lot of relevant information."

"I think the information we are learning from the MIT program will get us closer to the customer," adds Allard. "The emphasis on use cases will always put in our minds, 'how does the customer fit in this?" And he believes Ford's modularity structure and emphasis on model-based systems engineering will quicken time to market for its products. "We do a good job engineering cars and trucks, but we don't go as fast as we want to. If you look at the digital world, the customer expectation is a product can change itself without it leaving their pocket. In some ways, the cycle time is zero. We need to be much faster."

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