

## Mind Games

*Drawing on his consulting experiences, Prof. Jack Muckstadt creates simulation games that bring real-world engineering to the classroom.*

By Mark Rader

TROUBLE is brewing at the Mammoth Motors parts distribution center. Dealer #5, otherwise known as Oguzhan Vicil, a third-year Ph.D. student in operations research, has requested an unusually large number of auto parts for his dealership and now Gavin Hurley, a fourth-year Ph.D., also in operations research, and three of his classmates—the gatekeepers of the parts distribution center (PDC)—have to figure out how to cope with it. What’s worse? To leave the customers hanging high and dry or to go way over budget on transportation and overtime costs?



Grad student Retsev Levi and Muckstadt

The four graduate students blink at the five columns of numbers that stripe the sleek black computer monitor in front of them. “What’s a good fill rate?” asks Kabeh Vaziri, a third-year Ph.D. student in civil and environmental engineering. The question is discussed, but, with the information provided, it’s hard to tell. Finally, they decide to send all the trucks needed.

“This is all pretty random,” Hurley says. “We’re pretty sure we’ll screw this up.”

He clicks the mouse a few times. The trucks are now filled, as far as the computer is concerned. But the creator of this game, Professor Jack Muckstadt, who is joking with Dealer #1 near the front of the room, has stipulated that the transaction is not actually complete until the PDC team fills five envelopes with Monopoly money-sized slips of paper representing the requested auto parts and hands them over to the dealers. Then, the dealers have to count out the parts by hand and type the numbers on the bill of sale into their own computers.

Muckstadt decided to include these kinds of menial tasks because his goal in designing the game was to give his students, many of whom have never had more than a summer job, an authentic real-world experience. And one of the many truths Muckstadt wants his students to understand is that, in the real world, people sometimes do the difficult things well but mess up the easiest tasks, like putting parts in the wrong place or typing a number incorrectly into a spreadsheet. This is why he believes it’s crucial to always be on the ball, to take even the smallest of responsibilities seriously. And better to make your mistakes in the classroom, rather than in the boardroom, where your mistakes can potentially lose people money, cost people their jobs.

“Here,” Muckstadt says, “failure is costless.”

Muckstadt, a member of the faculty in the School of Operations Research and Industrial Engineering at Cornell since 1974, was first introduced to operations research–related experiential learning games in 1981, by John Jenner '57, B.M.E. '58, M.B.A. '59. At that time, Jenner worked at the IBM Manufacturing Technology Institute in Manhattan, devising educational materials for IBM employees. The two of them met when Muckstadt, then the director of the Cornell Manufacturing Engineering and Productivity Program (COMEPP), came to Manhattan with the hopes of receiving some of the fifty million dollars in grant money IBM had set aside to induce universities to focus more on manufacturing issues. Cornell's proposal was rejected but Jenner did take the time to show Muckstadt something he called "The Operations Game." Its purpose was to illustrate the complex dynamics of managing a manufacturing line. Students read numerical data about a particular production system off a computer screen and were then asked to figure out how to optimize the system's production based on what they saw. Occasionally problems arose—a bake oven's temperature went berserk, for example—and the students were asked to resolve the problem as best they could.

Muckstadt wasn't much impressed. "Frankly, at first I thought it was all fluff and no stuff," he says. But by the time he was ready to leave, he had reconsidered. He asked Jenner if he could use the game in his classroom, reprogrammed for Cornell's microcomputers. Student response was so positive that Muckstadt soon found himself reconsidering the way he taught. "I came to the unfortunate conclusion that most people don't learn very well using the traditional model," he says. It wasn't long before he was designing games of his own.

Today, the games Muckstadt and his colleagues have designed are being used in business and operations research courses at universities all over the country. The games' widespread use is partly due to a number of National Science Foundation–funded seminars Muckstadt and his collaborator in ORIE, associate professor Peter Jackson, ran at Cornell in the late 80s, during which they shared the games, the teaching methods, and the software with academics from around the country. Not surprisingly, many former graduate students who are now professors also use Muckstadt's games as teaching tools.

"What's great is that they introduce an element of competition," says David Murray, assistant dean for information technology in the business school of the College of William and Mary. "And business students love to compete. They just think [the games are] wonderful." Jim Rappold, an assistant professor in the business school at the University of Wisconsin, Madison agrees: "I've propagated Jack's beliefs in all my classes. The reaction to this stuff is extraordinarily positive. They're always hungry for more."

Muckstadt says that a big reason for his success as a teacher—he's won numerous national teaching prizes and four college teaching awards in the past sixteen years—is the other fundamental change he made to his teaching approach, back in the early nineties. Inspired by Dennis Severance, a professor in the business school at University of Michigan and a teacher of executive education classes, Muckstadt decided he could engage his students better by utilizing the Socratic method to a much greater extent. "If you just tell people something they're not going to comprehend it," Muckstadt explains. "But if you ask some questions, and they have to go off and think about it as a group, they're going to understand what they don't understand."

Muckstadt's ability to ask the tough but necessary questions has served him well in his other career as a part-time consultant. For the past thirty years, he has given advice to some of most powerful companies in America—such as General Electric, IBM, General Motors, and Xerox Corporation—as well as the U.S. Navy and Air Force. Says Murray: "He's an absolute giant. There are probably two or three people in the industry who are in the same league, and even that's a stretch." He has, says Rappold, created systems changes that have saved the military and public companies "billions of dollars—that's billions with a 'B.'" He's also worked wonders with smaller companies,

most notably the Aeroquip Group, a maker of industrial metal connectors, fittings, adapters, and rubber hoses in Van Wert, Ohio.

Before Muckstadt and Severance were hired on in the late 1980s, Aeroquip was experiencing financial difficulties. The company was burdened with an outdated inventory system and saddled with a reputation for making late deliveries. Muckstadt and Severance, along with the company's management team, decided that the revitalization process would only work if every level of employee were involved, so they eventually put the office and plant managers, as well as the top management team, through a weeklong course. During that time they laid out their ideas for overhauling the company's operations and subsequently spent hundreds of hours walking the floor of the company's plants sharing their thoughts about efficiency and customer service with employees and, more important, listening to suggestions. The turnaround has been astounding. As a Fortune magazine article entitled "America's Elite Factories" reported in 2000, on-time delivery over the last decade has jumped from 63 percent to 96 percent, inventories have been reduced from a costly 135-day supply to a 46-day supply, and the company's operating income has increased by 855 percent.

The employees of Aeroquip haven't been the only ones to benefit from Muckstadt's innovations. Using Aeroquip as a model, Muckstadt created the "Velocity Manufacturing Game," for his undergraduate course, Design of Manufacturing Systems 416/515, a game that confronts the students with the same challenges Muckstadt and Severance faced when they signed on with Aeroquip. One of the great bene-fits of doing so much consulting work, Muckstadt says, is that his exposure to actual workplace dilemmas helps him create compelling simulations for the classroom. "This whole thing works in a circle," he says. "You see the problems, you try to abstract the problems in general, and then you create micro worlds."

Mark Eisner, director of ORIE's master of engineering program, says that in a department that is one of the most theoretical in the country, Muckstadt is a grounding force. "Jack has maintained that contact with real problems that many academics don't have." Janis Chang, a third-year Ph.D. student and one of Muckstadt's advisees, says that Muckstadt reminds students, specifically Ph.D.s with an eye for teaching, that there's more to operations research than writing proofs of theorems. "He has his feet planted in both worlds, and fairly firmly planted too," she says. "He has a lot of credibility with students. He can say, 'if you say this, they'll think you're crazy,' and they take it seriously. I think that excites them a great deal."

Muckstadt was an undergraduate at the University of Rochester when he first started making suggestions to companies. In the summers, Muckstadt worked at the Kodak manufacturing plant in Rochester where his father was an hourly employee. The younger Muckstadt supplemented his weekly earnings by filling out suggestion cards during his lunch breaks—usually about 20 a week. For every suggestion deemed useful, Kodak paid out a small fee. It was a habit that paid dividends. "I was making about \$75 a week and proba-bly making maybe another 40 bucks a week on the suggestions," he says, laughing.

After going on to get a master's degree in mathematics and a doctorate in industrial engineering from the University of Michigan, Muckstadt, already an active duty officer in the U. S. Air Force, joined the faculty at the Air Force Institute of Technology. It was here that he first confronted the types of real-world problems he has been tackling ever since. The Air Force needed someone to design mathematical models that would dictate when and how often to buy parts for its F-15 airplanes. A weighty task, considering that individual airplane parts often cost hundreds of thousands—sometimes millions—of dollars. But Muckstadt felt up to the challenge. "In the military, they say you should never volunteer," Muckstadt explains, "but I stuck up my hand and said, yeah, I can do that. I've been basically working on these types of problems ever since."

Muckstadt's experience with the Air Force gave him his first exposure to supply-chain management, but, more important, he says, it shaped his values. He learned "a lot of simple things," for example, that a manager has to understand the operations of his or her outfit. "I learned very early," Muckstadt says, "that people who are very good wing commanders went out on the flight line. They were finding out what was going on. They kept very close tabs on everything." He learned that, usually, individuals depend on others for their success, which is one of the reasons he so often collaborates with others, in his teaching, research, and consulting. He also learned the importance of personal integrity. It's a principle he brings up with his students on the first day of class. "I tell my students that they are very fortunate not only to be here but to be who they are," Muckstadt says. "And their responsibility when they leave here is to use those talents not only for their personal gain but for society in general. It's a necessity that they do that."

In spring 2000, Muckstadt was named the Acheson/Laibe Professor of Business Management and Leadership Studies. The endowed chair was established in memory of Howard Acheson Jr. '50 by his business partner, John W. Laibe '50, his widow, Margaret Acheson Allesee, and the Acheson family. Their intent was that the holder of the position would look for ways to integrate business concepts into the engineering curriculum, encourage collaborations between engineering and management studies, and foster a greater understanding of business among engineering students.

That charge syncs perfectly with Muckstadt's goals. "We are helping students develop, through our classroom experiences, the critical reasoning skills and the team leadership skills that are needed today to lead both small and large organizations." Muckstadt also does his homework, visiting frequently with industry leaders. "This keeps me up-to-date on what they are thinking," he says, "and how they are attempting to deal with the pressing issues of our time." He uses what he learns to keep classroom exercises relevant to decision making in today's business environment.

Two days after playing the Mammoth Motors Service Parts game, the students in Special Topics in Operations Research are back in room 253 of Rhodes Hall, to see how their decisions panned out.

The student who played Dealer #5, the dealer programmed to be the most erratic and problematic, isn't in attendance today. "He knew what was going to happen to him so he didn't show up!" Muckstadt jokes. Retsef Levi, a student in the class, has compiled all the data from Tuesday's activity, and Muckstadt asks him to start the PowerPoint presentation, which is projected on a large white screen at the front of the classroom.

As Levi clicks between financial summaries and line graphs, Muckstadt moves about the room, perching for a while on a table, walking over to students as they raise their hands and make their points, moving occasionally to the lit screen to point something out. All the while he asks questions, lots of questions.

Some of the questions are meant to help the students clarify what actually transpired on Tuesday. After data appear on the screen showing that the PDC spent almost double what was budgeted for overtime, he asks, "What caused all that to happen? Why?" He turns to the students who ran the PDC and asks, "Could you tell if you were providing good customer service? What measures are relevant? How do we know we've been giving them the best service? If you were in charge what would you keep in stock?"

By the end of the class, the four major factors affecting each dealer's performance are made clear: the inventory policy of each dealership, the variability of demand, re-supply lead times, and communications between the different links in the supply chain. This insight prompts another question, the kind of question that has driven Muckstadt for more than thirty years: What can be done to make the system better?

The answer to this question will not come easily. This simulation is merely the catalyst to get these graduate students invested in the complexities of supply-chain management. The hard work—the reconceptualizing, the problem solving, and the attendant mathematical theorem-writing—is still to come. And if this class is like most of his past classes, Muckstadt expects that things will get messy before they become clear. Students will argue, they will become frustrated, they will spend countless hours in his office, trying to work things out.

“They struggle and when they come back after getting lost in the wilderness, they start telling you things, and you go at ‘em,” Muckstadt says. “They all feel embarrassed and they think they’ve failed. But then you have to give them a pep talk and say, Look it’s the whole point of this course. If you could do all this stuff easily, there’d be no reason to study it.”

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