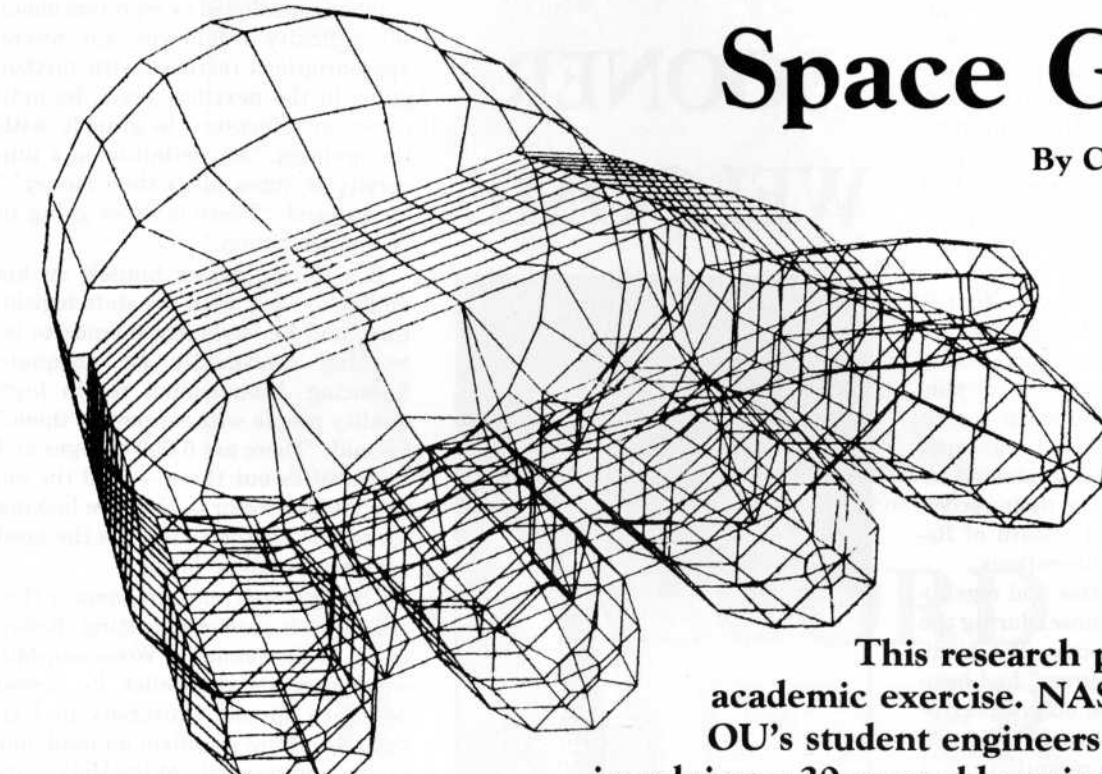
To Build a Better Space Glove



By CAROL J. BURR

This research project was no academic exercise. NASA was asking OU's student engineers for new ideas in solving a 20-year-old equipment problem.

Seldom do student research projects attract much attention from the general campus population. Science and engineering majors routinely go about their business ensconced in their mysterious laboratories, communicating in a language known only to other scientists and engineers. Last year, however, a group of OU students succeeded in capturing both the attention and imagination of their fellows with a project that had all the right stuff. The Sooners were invited by the National Aeronautics and Space Administration to design a space glove for the astronauts.

The space glove project was no artificial academic exercise. The problems involved are real, hampering the ability of astronauts to effectively perform their jobs in space. Simply put, for an astronaut wearing pressurized gloves to carry out even the simplest manual task in the vacuum of space is the equivalent of trying to grasp a small object with a tennis ball in the palm of your hand.

The University became involved in this phase of space research through a national competition financed by $180,000 from NASA and sponsored by the American Society for Engineering Education. In May 1984 universities throughout the country were asked to submit proposals to ASEE from which four — Massachusetts Institute of Technology, Worcester Polytechnic Institute, Kansas State University and the University of Oklahoma — were chosen to receive $30,000 each for a year of study and development. The competition was to be decided on May 31, 1985, with formal presentations in Washington, D.C., before a panel of engineering deans, an astronaut, NASA scientists and professional design engineers.

The author of OU's initial proposal was an associate professor of industrial engineering, Brian Peacock, a dynamic British import who became coordinator of the project. But Peacock quickly determined that he needed skills in addition to his own, some of which he found in Alfred Striz, an assistant professor of aerospace, mechanical and nuclear engineering and an expert in computer modeling.

When Robert Shambaugh arrived at the University as an associate professor of chemical engineering and materials science from the DuPont research and development department, his expertise in materials and fibers was an invaluable addition to the instructional team. Peacock also enlisted the services of the director of research at the Federal Aviation Administration in Oklahoma City, Jerry Hordinsky, who had worked for 10 years as a flight surgeon on the Skylab program at the Johnson Space Center in Houston and in Germany.

From the beginning, the OU team adopted an approach to the space glove project different from that of the other universities; they decided not to construct an actual prototype of a space glove but to attack the basic technological problems which had been baffling NASA for 20 years. The engineers realized that this direction might cost them the competition — and it did. Nevertheless they felt that the contributions they could make in new ideas for NASA and in design experience for a broad range of OU students would be worth the price. Even after the Sooners finished second to Kansas State, they were convinced they had chosen the right course — and had won much more than they had lost.

The research group began the project from ground zero with the admission that they knew very little about space or the problems associated with designing a space glove. As Peacock says, "We had a lot of finding out to do that first semester."

Six graduate students were employed quarter-time to research materials, manufacturing, testing methods, the anatomy and function of the hand. A series of Friday afternoon seminars were organized for anyone interested in space-related problems — faculty, students or staff. The first half of the session featured a faculty lecture on an issue pertaining to glove design, such as space environment, hand anatomy, finite element modeling, testing methods, alternative materials, etc. The 20 or more who attended each of the seminars would then brainstorm possible solutions to the problems presented.

At the same time, students in the College of Engineering were encouraged to enter their own space glove ideas in a local design competition. Some of the 15 entries, which were similar to term papers or projects, produced hardware while others were entirely conceptual. The winner, Doug Engebretson, and the runner-up, Margarita Beneke, each received plaques.

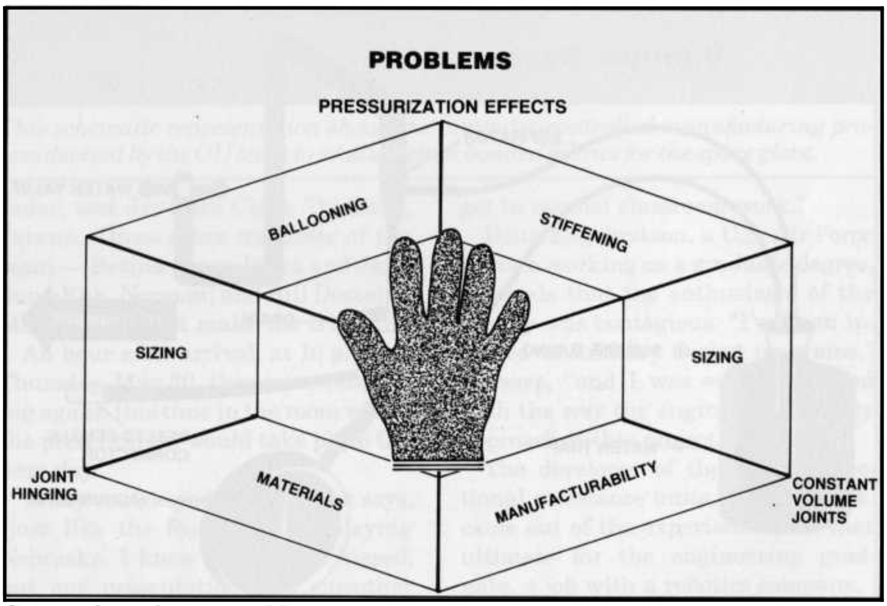
By Christmas break, a group of 15 students was far enough into the project to profit from a trip to the space center in Houston, where they met with NASA glove designer Mike Rouen, who briefed them on the problems which had been identified and the solutions that had already been tried.

"He tried not to guide us too much," Peacock says. "NASA wanted new ideas, and the ASEE wanted maximum student involvement, so they wanted to give us as much leeway as possible."

While in Houston, the OU group

Robert Cole

Touring Houston's Johnson Space Center (from left) Mark Wenner, Gandhi Chinnadurai, Jerry Hordinsky, Robert Shambaugh, Brian Peacock, Allan MacArthur.



Space glove design problems resulting from the effects of pressurization were broken into special areas of concentration assigned to separate research teams.

met Jim Claugherty, a representative of International Latex Corporation of Dover, Delaware, the manufacturer of the space suits, who later came to Norman for a seminar, bringing with him prototypes of several generations of space gloves.

With all this background, the team decided to concentrate its available resources — time, effort and money — on a few of the principal unanswered questions in glove design, even though the end product would not be a glove model they could place in the hands of the judges. To build such a model would be an expensive proposition — a pair of gloves currently worn by astronauts costs approximately $30,000 — and would require spending considerable time on issues NASA had already mastered.

"The principles involved in finger joints, for instance, were fairly well established," Peacock says. "The need for pleats in the fingers, issues involving the fingertips and many kinds of suitable materials were already known. However, problems with the

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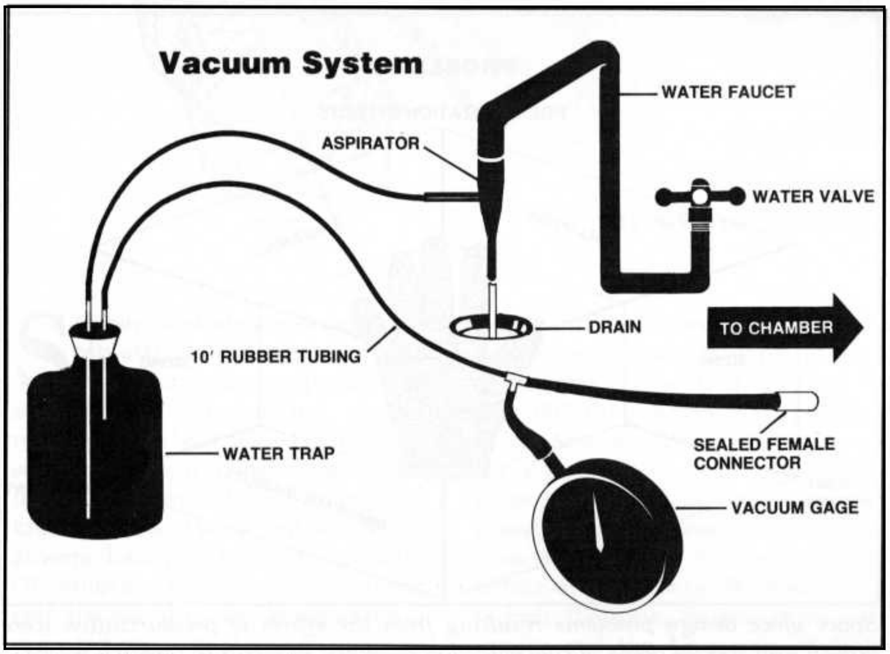
Robert Cote

On the second trip to Houston, Brian Peacock tests problems remaining in a NASA glove prototype as Jerry Hordinsky (left), Mike Swatek and Shawn Smith observe.



Designed by the OU engineers to test the effects of pressurization, the simple, inexpensive, portable vacuum chamber was proved easy to administer and reliable.

palm joint and the thumb joint had not been solved."

Work on the space glove, which was voluntary during the fall semester, was tied to a 3-hour credit course in the spring. Five problem areas were identified, and five separate groups of students were organized for the spring semester to work on them, the entire team getting together every Friday to compare notes and discuss difficulties. A second trip to Houston was scheduled to try out the students' ideas on NASA's glove design experts, and by mid-May the final report was ready.

The first phase of the OU study dealt with computer modeling, which, strangely enough in this age of computer-aided design, had never been applied to space glove development. By devising a computer simulation of the glove through the use of a conventional mechanical engineering model system, the rigid body model, and a system called finite element analysis, the engineers were able to answer questions such as the proper stiffness, placement of the finger pleats, placement of strengthening, etc.

Next the OU researchers tackled the labor intensive manufacturing problems which result in the high cost of the gloves, principally the tremendous amount of sewing required to bond together a great many components, made of many different materials. They settled on a process called spun bonding, which involves laying down a very strong material called Kevlar by use of an air jet and a suction mechanism, then bonding rather than weaving the material together by a heat process.

Spun bonding had been done before, but no one — not even DuPont where Bob Shambaugh had worked — had used computer control to vary the characteristics of the material, such as stiffness, thickness and strength, by utilizing a series of robots. Even the size and shape of the gloves could be changed to fit different astronauts just by altering a number in the computer.

The third issue addressed by the OU team was the all-important palm joint, with which the winning Kansas State model dealt almost exclusively. The astronauts' gloves, like the rest of their space suits, must be inflated to compensate for the absence of atmospheric pressure when they venture outside the space vehicle. Squeezing the fingers forces all the air into the palm, causing a ballooning effect against which the astronauts must work to perform any task in space. By the end of the day their fingers are not only fatigued but black and blue from bruises and abrasions.

Previous glove designs had tried both hard palms, which almost completely restricted finger dexterity, and soft palms, which ballooned. So a couple of the OU students, Jay Estes and Allan MacArthur, compromised by devising multiple rigid bands for the palm, which paralleled the skin creases, allowing for finger movement but holding down the ballooning.

The fourth OU contribution to glove design was in the area of functional assistance in the form of an overglove which astronauts could slip on during periods of intensive manual work to ease the strain on their hands. Student Mike Swatek developed miniature power assist units — much like little robots — to be placed on the back of each finger of the gloves to provide a little extra push, the effect being the same as power steering on a car. The astronauts could be trained to obtain the right amount of push by the amount of pressure they applied to the fingers, just as turning the steering wheel harder results in greater assistance from power steering.

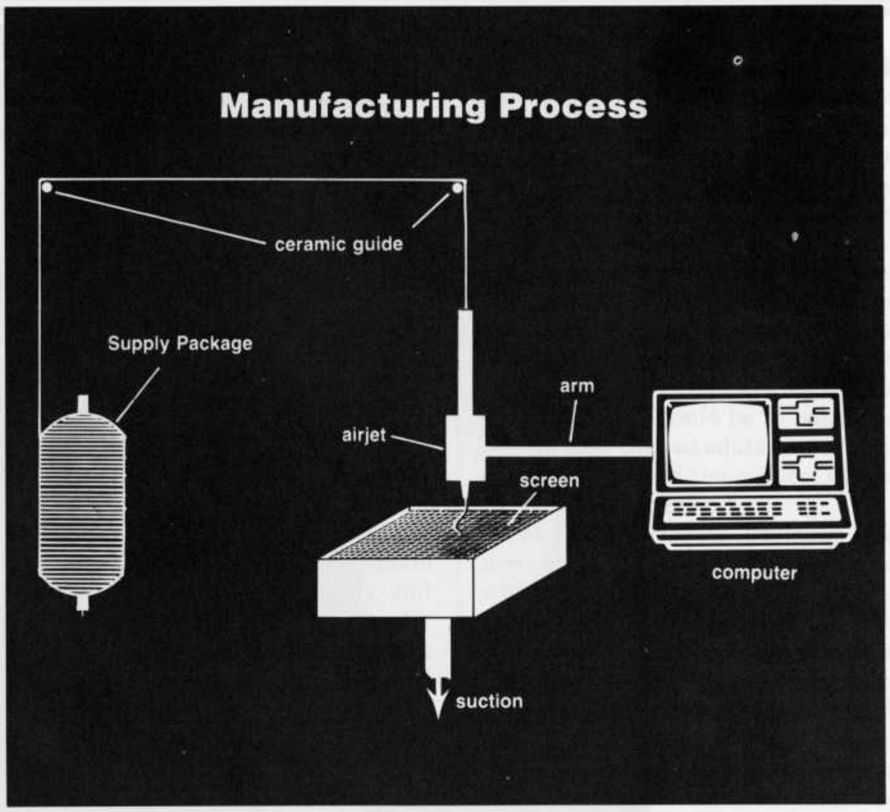
Finally the engineers developed a program of standardized, systematic testing for the various aspects of glove design.

"They were not really testing the gloves in a sophisticated way," Peacock explains. "They had given the gloves to an astronaut and said, 'How do they feel? How do you like them?' Or they tried them out physically in the water tank where they do most of their training.

"We built a vacuum chamber, then standardized the testing routines for the gloves by measuring strength, mobility, touch, and so on, and comparing those results to tests of ungloved hands."

By mid-May the final report had been completed, a major professional learning experience in itself for the students who carried it all the way through to proofreading, preparation of graphics and slides, etc. Then the 14 students who would accompany the four faculty sponsors to Washington began preparation of the oral presentation to the judges. Numerous rehearsals were staged, several in public for anyone Peacock could recruit to hear them out.

At one time or another throughout the year-long project, from 30 to 40 engineering students had been involved with space gloves. When the plane to Washington left Oklahoma City, the following were aboard: Sharon Cheatwood and Robert Cote Jr., Lawton; Daryl Bitting, Muskogee; Allan MacArthur, Noble; Jay Estes, Oklahoma City; Tuan Dang, Mike Swatek, Stuart Tison and Mark Wenner, Norman; Doug Engebretson, Council Bluffs, Iowa; Shawn Smith, Buhler, Kansas; Gandhi S. Chinnadurai, Coimbatore, India; Margarita Beneke, San Salvador, El Salvador; and Jen-Gwo Chen, Taichung, Taiwan. Three other members of the team — Betina Jones-Parra and Jang Sung Kuk, Norman; and Bill Dostalik, Miami — did not make the trip.



This schematic representation shows the computer-controlled manufacturing process devised by the OU team to produce spun bonded fabrics for the space glove.

An hour after arrival, at 10 p.m. on Thursday, May 30, they were rehearsing again, this time in the room where the presentation would take place the next day.

"They were keyed up," Peacock says, "just like the football team playing Nebraska. I know I'm a little biased, but our presentation was smoother than any other school, and the depth of the analysis, the technical content, was light years beyond any of the others. We all knew we had done a good job; the other schools knew it; and NASA knew it. We hadn't won; we had done something different, but we had accomplished our purposes. We had developed new ideas for NASA, and we had involved our students in a major design project."

"We couldn't really make a space glove in a couple of semesters," one of the participants, Robert Cote, insists. "We couldn't solve all the problems, but in the process of trying, we had the kind of experience that you don't get in normal classroom work."

Doug Engebretson, a U.S. Air Force captain working on a graduate degree, contends that the enthusiasm of the faculty was contagious. "I've been involved in military design programs," he says, "and I was very impressed with the way the engineering faculty approached this project."

The developer of the robotic functional assistance units, Mike Swatek, came out of the experience with that ultimate for the engineering graduate, a job with a robotics company.

But if the students at OU and the other participating institutions profited, so did NASA. For its $180,000 investment, NASA drew into the space program dozens of young engineers and their professors all across the country, hopefully developing sources of new ideas as well as future personnel.

And who knows, perhaps someday an astronaut, rocketed aloft at the cost of millions, will successfully repair a multi-million-dollar satellite, never knowing that he can flex his fingers with ease because a group of college students found a way to build a better space glove.