19 AUGUST 1983 · VOL. 221 · NO. 4612 $2.50

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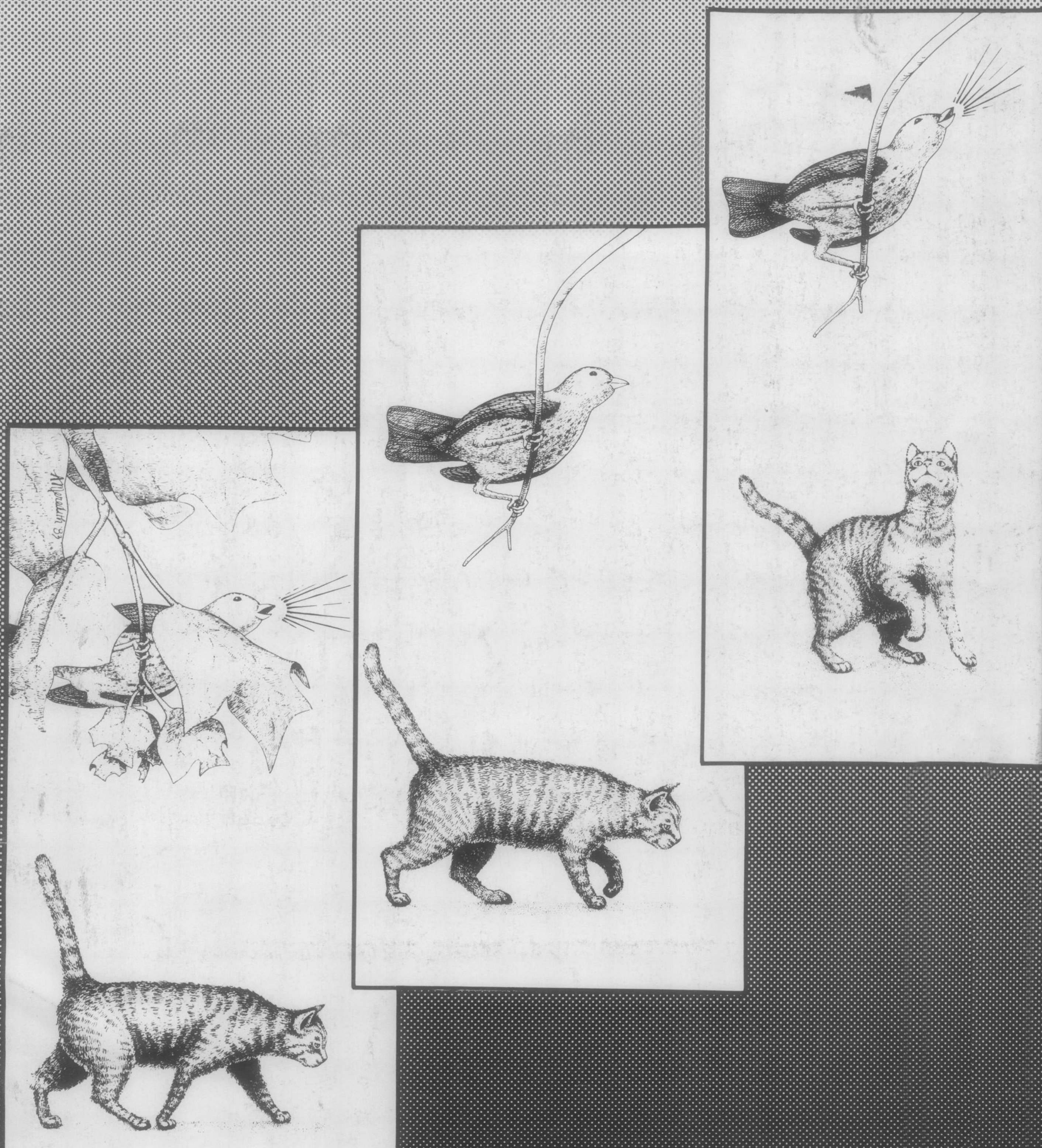

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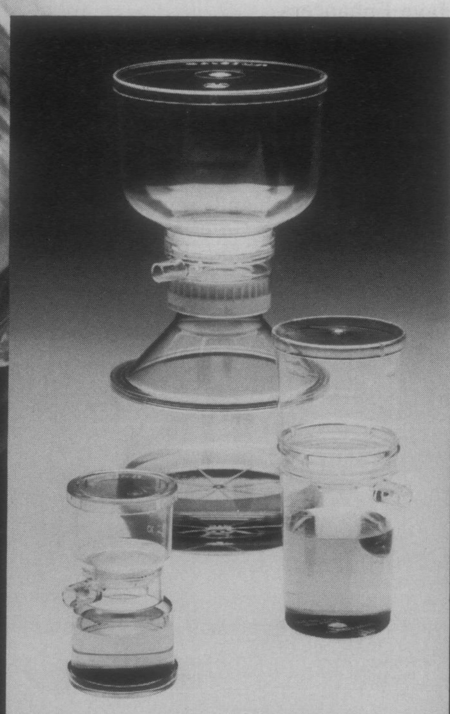

ISSN 0036-8075
19 August 1983
Volume 221, No. 4612

SCIENCE

SCIENCE is published weekly on Friday, except the last week in December, by the American Association for the Advancement of Science, 1515 Massachusetts Avenue, NW, Washington, D.C. 20005. Second-class postage (publication No. 484460) paid at Washington, D.C., and at an additional entry. Now combined with **The Scientific Monthly**® Domestic individual membership and subscription (51 issues): $53. Domestic institutional subscription (51 issues): $90. Foreign postage extra: Canada $24, other (surface mail) $27, air-surface via Amsterdam $65. First class, airmail, school-year, and student rates on request. Single copies $2.50 ($3 by mail); back issues $3 ($3.50 by mail); Biotechnology issue, $5 ($5.50 by mail); classroom rates on request. **Change of address:** allow 6 weeks, giving old and new addresses and seven-digit account number. **Postmaster:** Send Form 3579 to *Science*, 1515 Massachusetts Avenue, NW, Washington, D.C. 20005. *Science* is indexed in the *Reader's Guide to Periodical Literature* and in several specialized indexes.

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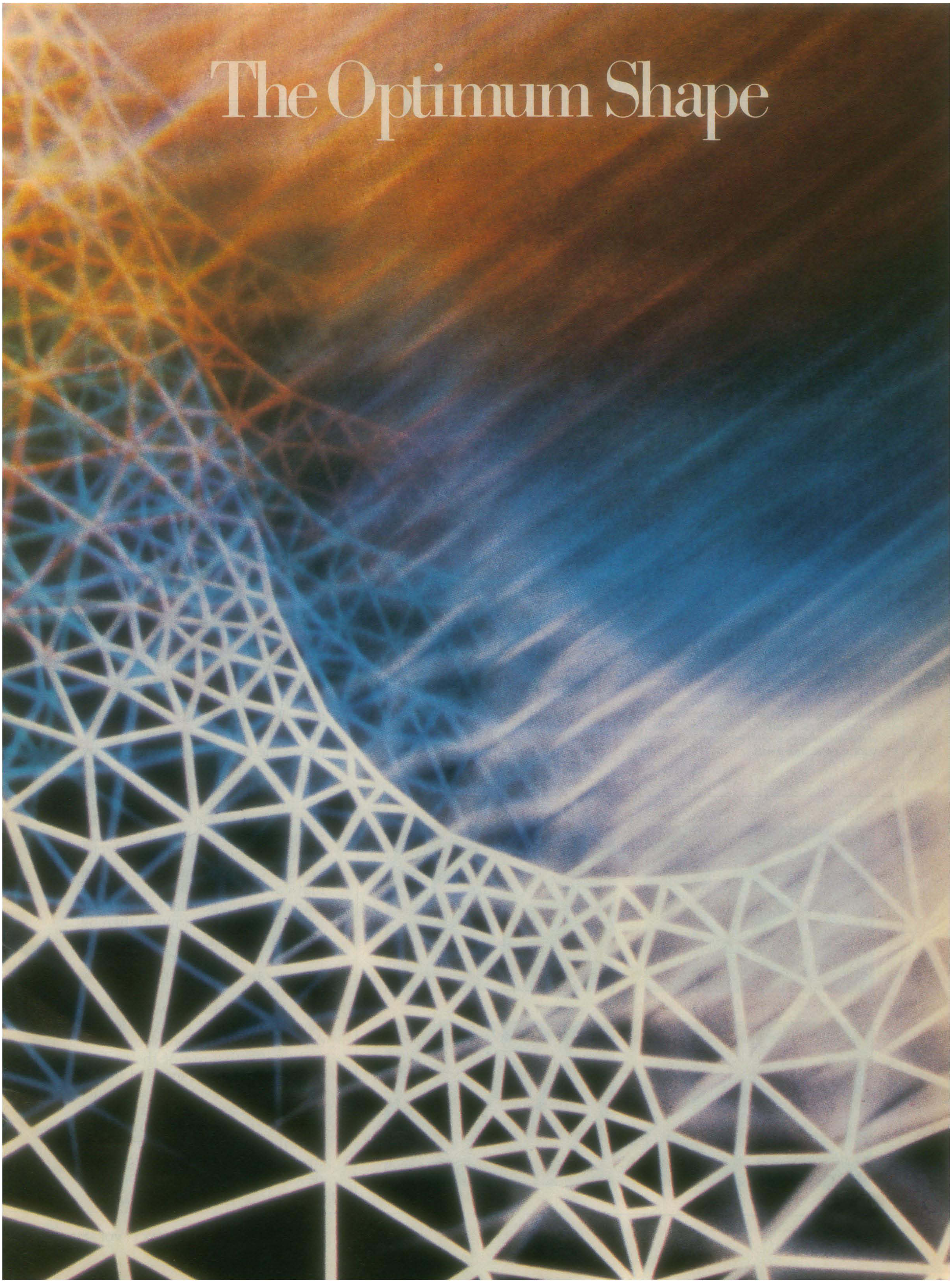
COVER

Inputs from two or more sensory modalities (for example, conveying information about the sight and sound of a bird) often interact multiplicatively in superior colliculus neurons, thereby facilitating orientation behavior (upper right panel). The presence of either of these cues alone (left and center panels) may be incapable of eliciting the necessary activity in these cells to evoke an orientation response. See *Science*, 22 July, page 389. [M. Alex Meredith, Medical College of Virginia, Virginia Commonwealth University, Richmond 23298]

The Optimum Shape



The Optimum Shape

Researchers at the General Motors Research Laboratories have developed the first integrated system for computer design of mechanical parts with minimum mass. Optimal Shape Generation automatically optimizes the component shape in a single computer run.

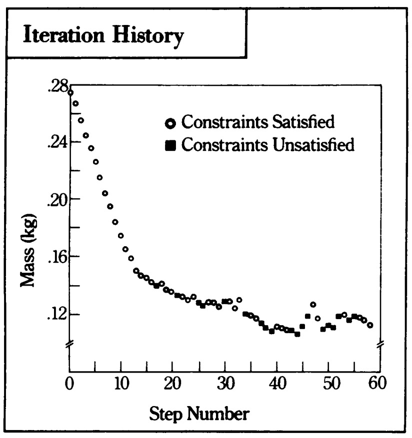
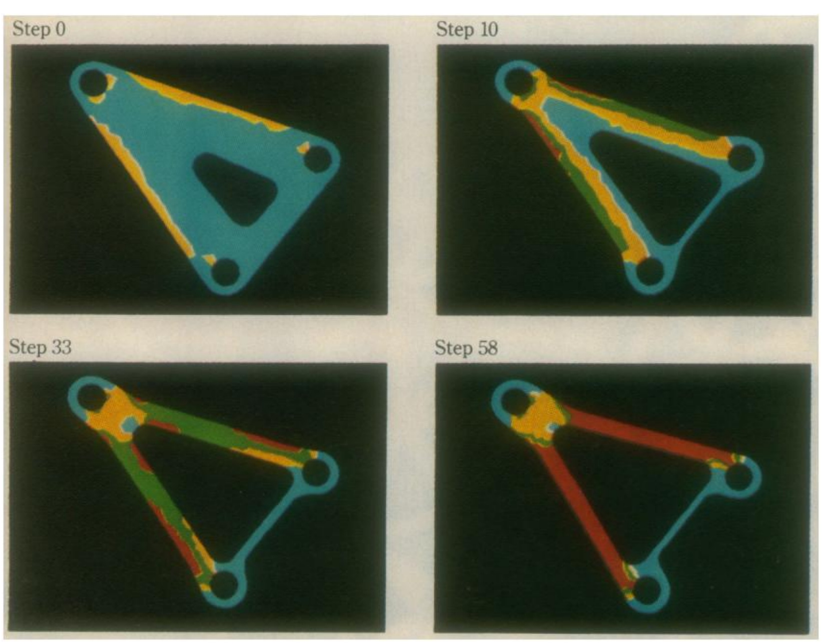


Figure 1: Decreasing mass plotted as a function of design iterations for the component shown in Figure 2.

Figure 2: Shapes as they appear on the CRT screen in the design of a minimum mass automotive component capable of performing under the structural loads. Color changes indicate (blue→yellow→green→red) increasing stress levels within the design limits.



COMPUTER-AIDED design systems automate the processes of generating geometric data and engineering drawings of parts, but they do not determine whether these parts meet structural performance requirements. In an ongoing research project at the General Motors Research Laboratories, a system has been developed that automatically ensures that the design meets structural performance constraints. More important, Optimal Shape Generation provides the component shape with the minimum mass capable of satisfying structural demands in a single computer run, without requiring human interaction with the machine.

In the last two decades, extensive research has been done in the area of computer design of structural components. Most of this work has focused on individual aspects of the process. Drs. Jim Bennett and Mark Botkin have succeeded in integrating the process from description of the model through convergence to the optimum solution.

Conventional systems continue distinctions characteristic of age-old "build and test" methods by separating the tasks of design generation and design analysis. Typically, a "designer" uses one computer system to produce engineering drawings of a given part. The task then shifts to an "evaluator" who creates a mathematical model with which to test the design on another computer system. The evaluator determines only whether or not the design meets the requirements. A lengthy interaction between the designer and the evaluator is required to optimize the design. Optimal Shape Generation integrates the process from design generation through design optimization. The system can generate the mathematical model from the design data as the shape changes without requiring additional input, thereby turning the process from a multiperson, multimachine operation into a one-person, one-machine operation.

Since there is no interaction beyond the initial input, a flexible description of the problem is crucial to effective use of the system. The researchers responded to this challenge by developing a geometric format based on a parametric description of the boundary. Defining the problem with geometric data is desirable because it describes the shape of the part in a form directly suitable for conceptual visualization.

Because the boundary geometric description must be transformed into an analysis model not once but several times, some type of automatic finite element mesh generation is required. The researchers adapted a mesh generation technique which divides a closed region into triangular elements based on a discrete description of the boundary. The sizes of the elements of the mesh are determined by a characteristic length selected for each problem and are related to the need for accurately describing the geometry. Automatic triangulation is used to create a set of connectivities for the discrete points placed uniformly throughout the part's interior with approximately the same density as the boundary points. The combination of boundary data description and automatic mesh generation permits the system to accommodate major changes in shape from the initial design.

ADEQUACY of the triangular meshes to calculate accurate stress levels was next addressed by the development of an adaptive mesh refinement scheme. By evaluating the solution for the uniform mesh created by the choice of characteristic length and identifying areas where the strain energy density changes rapidly, the system selects the areas of the mesh that require mesh refinement. These refinements can take the form of either adding elements in the area to be refined or increasing the order of the finite element polynomial interpolation. The former approach has been taken, because it can be implemented automatically and does not require the formulation of new finite elements.

The culmination of the process introduces an optimization routine which directs the design toward a minimum mass configuration. A mathematical optimization technique is used to change the design to that shape giving minimum mass within the structural constraints. This optimization technique is based upon a sequential first-order Taylor series approximation of the constraints and a feasible directions solution of the problem. Periodic mesh refinements are performed throughout the optimization, since the design is continually changing, and the system must predict the stresses and the behavior of the constraints as the design changes.

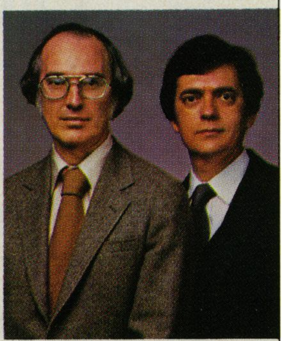
"By taking an integrated approach," says Dr. Bennett, "we're able to combine the objectives of reducing the mass of the material and meeting structural performance requirements in a single automatic system."

"We expect," adds Dr. Botkin, "that in the future this technique will become the standard way of designing structural components."

General Motors

GM
MARK OF EXCELLENCE

THE MEN BEHIND THE WORK



Drs. Jim Bennett and Mark Botkin are members of the Engineering Mechanics Department at the General Motors Research Laboratories.

Dr. Bennett holds the title of Assistant Department Head. He attended the University of Michigan as an undergraduate and received his graduate degrees from the same institution in the field of aerospace engineering. His Ph.D. thesis concerned non-linear vibrations. Before coming to General Motors in 1973, he taught aeronautical and astronautical engineering at the University of Illinois.

Dr. Botkin is a Staff Research Engineer. He received his undergraduate and graduate degrees from the University of Missouri at Rolla. His graduate work was in the field of civil engineering, and his doctoral thesis concerned structural optimization. Prior to joining General Motors in 1978, he worked for four years as a consultant to computer applications engineers.

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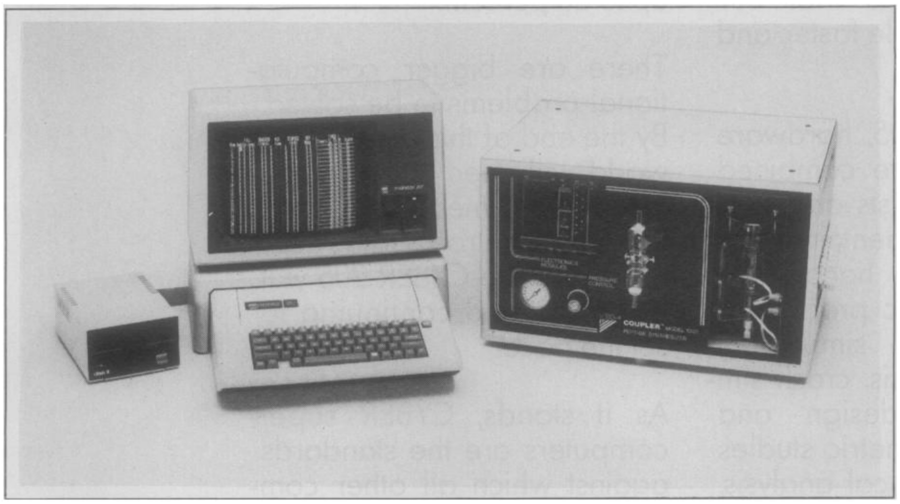

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19 August 1983, Volume 221, Number 4612

SCIENCE

Gordon Battelle

This month marks the hundredth anniversary of the birth of a little-known but great supporter of scientific research in the United States. A businessman with no credentials in science, he nonetheless added a new dimension to the nation's research structure. That person was Gordon Battelle, founder of Battelle Memorial Institute, who was born on 10 August 1883.

Battelle, son of a wealthy Ohio industrialist, might appear on the surface to have been most unlikely to found an organization dedicated to scientific research. He was not a scientist or engineer; he was not an inventor. He did not discover anything. Yet his conviction that research has practical value has had important consequences.

Battelle's brief life—40 years—spanned a period of great industrial expansion during which invention and applied research moved from the lone inventor's workshop to the company-built laboratory. His first interest in research was apparently sparked by a former university professor who was trying to develop a process to recover valuable chemicals from waste products of mining. Battelle set up a small laboratory for the research and eventually a commercial process was perfected.

When Battelle died in 1923, he left most of his sizable estate to found an institute that would be a place for "the making of discoveries and inventions" and that would be wholly independent of government, academic institutions, and industrial companies. He did not spell out the concept of contract research in his will. He did, however, create an institution ideally suited to employ that concept.

Thus the first independent, nonprofit, contract research institute came into being. It is indicative of the usefulness of this addition to the nation's research resources that Battelle Memorial Institute, during its 54-year history, has grown from an organization of some 30 people to one with a worldwide staff of some 7200. More important, the institute has served as a model for other independent contract research organizations throughout the world. Today there are at least eight other independent research institutes scattered across the United States. Each year they serve the research needs of thousands of companies and government agencies. Within Battelle alone, for example, in 1982, more than 3200 studies for about 2300 industrial and governmental sponsors in 47 countries were in progress.

The independent research institutes had combined research expenditures in 1982 of more than $900 million and they played a vital role in technological progress. They have been the catalyst for a long list of achievements, including the first practical tape recorder, the commercialization of xerography, the first video disc, special paint used to coat such space vehicles as Skylab and Columbia, anticancer drugs that are used worldwide, and one of the first uses of bacteria for industrial waste management.

These institutes have grown and flourished because they meet real needs of industry and government; they are eminently practical. By their nature, they offer scientists an alternative to research careers in either an academic institution, a government laboratory, or a captive research center of private industry. The independent institutes have their greatest appeal for the scientist who enjoys the challenge of being an entrepreneur—of identifying a real-world need, "selling" the idea to a company or government agency, and leading the research to fill that need. This is a kind of research that calls for alertness to change, sensitivity to market forces, and innovation. Some scientists find this environment exciting; others find it frightening. Nowhere else in the world of research is the value of the work so frequently weighed against its cost.

These, then, are some of the features that set the independent institutes apart and make them valuable. In view of the many contributions of the independent institutes, it is no exaggeration to say that Gordon Battelle was a man with a vision. We need many more people with his faith in the value of science and research.—SHERWOOD L. FAWCETT, *Chairman and Chief Executive Officer, Battelle Memorial Institute, Columbus, Ohio 43201*

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