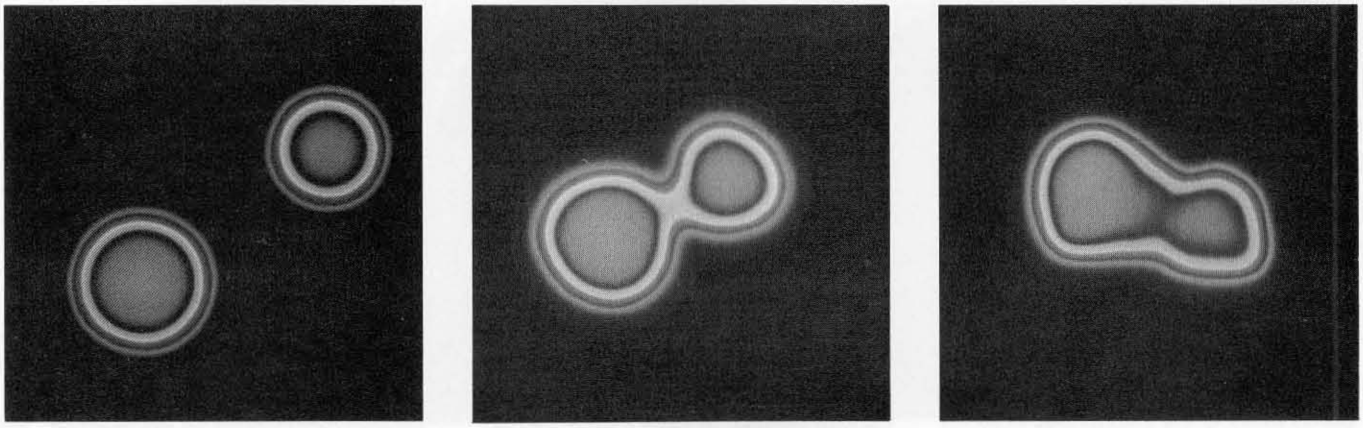
# Research in Progress



## Nuclear Bumps

When two large *nuclei* (heavy ions), each carrying its collection of *nucleons* (neutrons and protons) collide in a particle accelerator, classical and quantum mechanics also meet. The motion of the *nucleons* within each nucleus is governed by quantum mechanical nuclear forces, but the trajectories of the *nuclei*, whether head-on or just grazing, can be viewed as governed by classical physics. Steven Koonin, professor of theoretical physics, studies what happens at this interface of physical laws in low-energy, heavy ion collisions, calculating models of the "semi-classical" phenomena that result.

These collisions, and how the resulting system shares its excitation energy and reaches equilibrium, can be investigated in the laboratory under various conditions involving nuclei of different sizes bombarding each other at various speeds and colliding at different angles. When the nuclei collide more or less head-on, they fuse briefly, for about $10^{-17}$ seconds, forming a single "compound" nucleus before decaying, often into two large pieces. (This is not the same as thermonuclear fusion of light nuclei.)

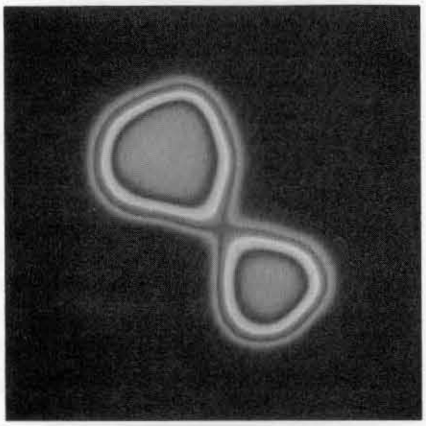
When the nuclei merely sideswipe each other, however, instead of meeting in a direct hit, an entirely different set of phenomena results. In these events, called deep-inelastic collisions, the combined nucleus appears to lose most of its energy but still retains a memory of its original components, breaking up into two fragments closely resembling them, give or take a few nucleons. Because of these interesting, contradictory phenomena (the energy loss is indicative of a violent collision while the memory suggests the opposite), deep-inelastic collisions are of particular interest to Koonin and his colleagues.

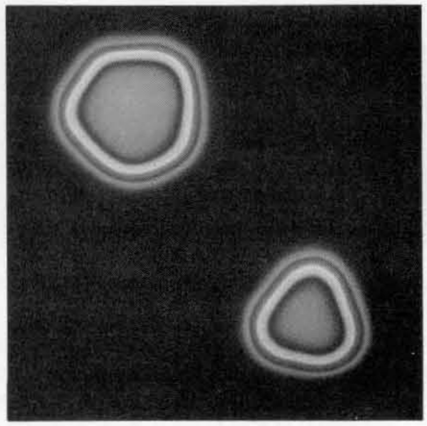
Koonin performed the massive calculations modeling these collisions on a Cray-1 computer. The model is derived from the independent particle model (also called the shell model) of the nucleus, which holds that, under weakly excited conditions, all the nucleons move in orbits affected by the average force generated by other particles. In other words, the interior of the nucleus can be considered roughly homogeneous, with the nucleons moving freely about and not hitting each other. This theoretical picture correlates closely with experimental observations. The computer calculations can follow the development of the wave function (or, essentially, the motion) of each nucleon from the beginning of the collision to its final state and so can predict the average properties of the products of the collision — numbers of neutrons and protons, spin, and degree of excitation.

Since the mechanisms that change these different properties operate at different rates, Koonin applied a time-dependent generalization of the shell model (time-dependent Hartree-Fock method) to track the average properties experienced by each nucleon as the system moves toward a new equilibrium. The project has been under way for six years and is now largely finished. Koonin's models describe heavy ion collisions with surprising accuracy and have become a standard tool in the field; researchers can apply a computer program to predict what will result from a particular collision reaction. He and his colleagues have also made heavy ion collisions visible by converting their theoretical models into computer-animated "movies," which show the nuclei merging on contact, bobbling around in a single distorting shape, and, depending on the original angle of impact, oozing apart like a droplet of honey into separate fragments.

Now, says Koonin, he and his students are "cleaning up the corners" and pursuing various sidelines. One of the clean-up operations is to extend the calculations to account for fluctuations; the models agree with the average properties of the fragments but not with the observed fluctuations. J. Bradley Marston, BS '84, elaborated these calculations in his senior thesis and is continuing work on the problem.

Another direction of extension is to develop a description of collisions at higher energies. The independent particle model holds only for weakly and moderately excited conditions. Under more highly excited conditions collisions between the nucleons inside the nucleus become more important and must be considered in the model. This creates a much more complicated problem — but an interesting one, as new accelerators capable of higher energies make experimental observations of such nuclear collisions possible. □ — *JD*





*These frames from a computer-graphic movie show a peripheral collision between two heavy nuclei, $^{86}Kr$ and $^{139}La$, at a total energy of 505 MeV. In the first frame they are moving toward each other. They fuse temporarily into a single, rapidly rotating system and then break apart again almost immediately.*

# Hispanic Politics

By official count California's Hispanic community currently represents 19.2 percent of the state population and is probably larger. This percentage has been increasing and will likely continue to do so — a demographic shift that will have long-term effects on the politics and policies of the state. To try to define and anticipate some of these effects, a group of faculty and students in political science are undertaking a comparative study of the Hispanic and other minority populations in California.

Bruce Cain, associate professor of political science, is principal investigator on the two-year project. He and his team will be collecting both published statistics and survey data on community leaders (in businesses and unions as well as in politics) and will conduct an extensive poll of the larger public. They will try to determine from what kinds of backgrounds these leaders emerge, what their attitudes are about specific issues, and how they may differ from other minority leaders and within the Latino national groups. They will look into voting patterns — who sponsored and who lobbied for what bills. And they're interested in how representative the political elites are of the attitudes of their constituents — for example, whether political leaders feel the same way about bilingualism as the Hispanic community at large.

On the economic side they want to know what areas of business Latinos have entered, how active they are in unions, and how the business community has adapted to the growth of the Latino population. Questions on the surveys of business and political leaders will be coordinated with questions on the statewide attitude survey of the larger Latino public.

Associate Professor Rod Kiewiet and Douglas Rivers, assistant professor of political science, will design and supervise the statewide poll — an extremely ambitious attempt to examine minority attitudes on a broad range of issues. Unique and difficult sampling procedures will be necessary to capture the characteristics of urban and rural populations, as well as regional, national, and generational variations.

In additional to learning about what Latinos *think* about particular issues, the Caltech group wants to know how they participate in and influence the political process; for example, what issues they organize around (such as the Simpson-Mazzoli bill, bilingualism, agricultural labor, social services), what kind of political action committees and grass roots organizations arise, and where political funds come from.

While the study concentrates on Hispanics, it will also be a comparative study of California's other large ethnic groups — Asians and blacks. Other studies have concentrated on a single group and have been conducted from "inside." Cain believes his comparative approach from a disinterested perspective will make a significant contribution to understanding the political dynamics of California's minorities — not only how they differ or are similar to each other, but also what their attitudes are toward each other and what the possibilities of tension and coalition are.

For example, Cain expects to find that the Asian community is less concerned than Hispanics about mass public issues, such as social services, and more likely to organize around local problems, such as zoning, local

*Senior Michael Chwe (right, foreground) presents his report taken from census data on Asian Americans to a meeting of the political science group involved in the comparative study of Hispanic and other minority populations in California. Associate Professors Bruce Cain (left), principal investigator on the project, and Rod Kiewiet sit across the table.*

taxes, and education. Asian political candidates also often do not come from specifically Asian communities, while Hispanic politicians almost invariably represent Hispanic areas. The researchers hope to be able to explain some of these differences. They also want to compare the strength of ethnic identification and the perception of discrimination among California's major ethnic groups.

Cain has already begun interviewing Latino leaders. Students will conduct interviews for the mass survey in September; the researchers intend to avoid the national election with their poll so as not to get caught up in polarized or uncharacteristic results. Students working under the grant for the study (from the Seaver Institute) and on SURF (Summer Undergraduate Research Fellowships) have spent the past summer compiling statistics and will also eventually be involved in coding and computer processing all the data. Cain, Kiewiet, and Rivers plan to hold a conference at the conclusion of the study and invite national leaders to react to the position papers that emerge from the research.□ --*JD*

# Give It a Whirl

THE CIVIL ENGINEERING profession as a whole is paying increasing attention to the use of centrifuges for modeling studies. At Caltech, for example, Ronald F. Scott, professor of civil engineering, has been operating an unusual and versatile centrifuge for soil studies for a number of years. It is one of the first in the United States to be used for geotechnical research.

Because of the size of full-scale civil engineering structures, it is almost impossible to conduct full-size tests. The available alternatives are theoretically based computer solutions and the centrifuge, which affords the opportunity of checking computer calculations. The Caltech machine has an acceleration range of from 1 to 175g at the 40-inch radius of the basket, with a payload capacity of 10,000g per pound. A variety of computer-driven accessories supply engineering information and store it in a digital data acquisition system.

Examination of the qualities and behavior of the surface soils of the moon and Mars between 1960 and 1980 prompted Scott's proposal to the National Science Foundation in 1974 to obtain a centrifuge for scientific experimentation. He wanted to study granular materials at increased gravitational acceleration under a variety of conditions, and with a range of tools.

Since it was obtained and installed, the centrifuge has had diverse uses, most of which have been aimed at establishing model-to-prototype relationships in engineering research and design. One of the important engineering problems, particularly for offshore structures, concerns the load-bearing and deflection performance of piles. Exact correspondence of model with prototype is difficult, however, because of the size of the prototype projects involved, the inability to obtain the exact soil profile in the field, and possible scaling inconsistencies. Nevertheless, model pile studies are beginning to bridge the computational gap in studies of offshore structures. Though early testing was done by static loading of the pile, research at Caltech, funded by the American Petroleum Institute, initiated the first dynamic studies — application of an electromagnetic shaking device to a pile. Subsequent tests employed a variety of apparatus designed to shake different models.

Other tests made use of a special bucket constructed and donated by Chevron Oil Field Company for mounting on the arm of the centrifuge in order to model a prototype of up to 175 feet in length and 50 inches in diameter. In 1977-78, Scott conducted large-scale pile tests using the Chevron bucket in the centrifuge to study pile behavior in a fine-grained silt soil from an offshore location. The results were interesting enough to prompt further study — this time on a model of a large offshore concrete platform — in the same clayey silt. The model platform (10 cm in diameter, representing a 10-meter diameter prototype) was subjected to vertical and inclined concentric and eccentric cyclic loads. These experiments were accompanied by a computational study using the finite element method, which transforms the governing differential equations to a matrix equation that is solved on the computer.

Then, in 1981 a consulting firm, Earth Technology, Inc., of Long Beach, John Ting (now of the University of Toronto), and Scott, with NSF funding, cooperated on the most extensive pile study to date. Full-scale piles were driven and tested at Seal Beach, California, with Caltech structural shaking machines. Model pile tests were performed on the same soil in the centrifuge. The researchers achieved good correspondence between the two tests.

The variety of uses of the Caltech centrifuge is underlined by a review of some of the experiments conducted. In 1975, K. Tagaya of Mitsubishi used it to begin the first systematic study of anchors embedded in sand or clay at various depths and in different configurations. These anchors were to be applied as possible support systems for offshore guyed oil towers.

In 1976 Hsi-ping Liu, a postdoctoral fellow in the Division of Geological and Planetary Sciences, became interested in the use of the centrifuge for geophysical modeling. He experimented in the centrifuge by fracturing a simulated rock block at high acceleration and recorded the vibrations, later continuing the work on the Boeing Company centrifuge in Seattle with an artificial block of sandstone. This block was tested at 400g until a precut plane displaced, simulating a geological fault rupture that produces an earthquake. Small transducers recorded the seismic waves the rupture generated. A little later, in 1979, the Southern California Gas Company became interested in a site for liquefied natural gas tanks and wanted to examine the mechanism of fault rupture in soil overlying a fault in bedrock. After a soil layer was placed in the Caltech centrifuge, a fault was generated by a hydraulic mechanism with the centrifuge in flight and a high-speed movie camera recording the motion of marked layers of soil. At the same time accelerometers recorded accelerations in the container and soil. This testing was done with a variety of soils, thicknesses, and speeds of fault initiation. The work was done in cooperation with Dames and Moore, a geotechnical consulting firm.

Another application of the centrifuge in engineering studies has involved dynamic earth pressures on retaining walls during seismic shaking through a study completed in 1982 by Alexander Ortiz. The focus was on reinforced cantilever concrete walls like those along freeway construction. By simulating a Richter magnitude 5.5 earthquake through a hydraulically operated apparatus, a corresponding prototype earthquake of several seconds duration and 0.5g peak acceleration was developed.

Behnam Hushmand (PhD 1983) made studies of the behavior of footings and foundations under seismic and other dynamic loading. Model footings and rigid structures on soil were rotated in the centrifuge at elevated g's. Impulsive loading was accomplished by means of small explosions generated by toy pistol caps exploded electrically. In addition, an air-driven shaking machine using two counter-rotating unbalanced disks, which generated a vibrating force at speeds to 40,000 rpm, was applied to the model structures.

A last example of recent centrifuge application is in the developing area of plate tectonics. H. Nataf, a visiting associate in geophysics, undertook geophysical research in the Caltech centrifuge on the motions of the hot viscous mantle underlying the crustal plates. This study of the stability of convection patterns used a custom-built, thermally controlled, fluid-filled cell, in which the illumination of the convecting unstable fluid by a split beam of light reveals the patterns of fluid motion. By filming these occurrences at elevated g's in the centrifuge, Nataf has been able to note convection patterns, material property interactions, temperature gradients, and associated shear stresses.

A key element in all the research conducted since 1977 has been John R. Lee, research engineer with the centrifuge. He makes the equipment, keeps the electronics working, and assists the students in running the machine.

The future holds many challenges for new applications of the centrifuge. Likewise, the addition of more centrifuges in this country and throughout the world may result in the formation of an international body specializing in the compilation of centrifuge studies. Such an organization could serve as the focal point for worldwide information on progress in the field. A journal published by such a group could give scientists access to the information on the subject more directly.

Government funding has proved invaluable in centrifuge studies, as has industry support. Future cooperation with a given industry, such as the oil industry, or by joint government/industry studies, will promote the solution of engineering problems common to an increasingly industrialized world. □ *--Sylvia McBride*

*Ronald Scott adjusts the earthquake basket of the centrifuge. A model of, say, a dam, set into the basket, can be shaken like a model earthquake (compressed into .2 seconds), reflected in the mirror angled above the basket, and filmed by a high-speed movie camera that uses 100 feet of film in 3 to 4 seconds.*