chairman of the Aeronautical and Space Sciences Committee.

The Atomic Energy Commission included design funds for the machine in its submission to the Bureau of the Budget last year, but following consultations involving the Bureau, the Atomic Energy Commission, the Office of Science and Technology, and President Johnson, it was decided to remove the item from the budget.

In defense of the Los Alamos site, the JCAE included in its annual hearings* an analysis which stated that the meson factory would contribute to the scientific strength and morale of the Los Alamos nuclear weapons laboratories.

"The weapon research and development program at Los Alamos," it stated, "is in an extremely effective and vigorous state at the present time. It is essential for national security to keep it so. Even if nuclear weapon testing is continued at its present basis indefinitely, it will be necessary to provide the Laboratory with means to attract new generations of scientists to provide new ideas and new stimulus. The meson factory will not be an isolated part of the laboratory; it will be an integral part of our scientific work as are all our research activities. If, on the other hand, the nuclear weapon testing is stopped—and even when there are rumors that it might be stopped—it is equally essential that we maintain Laboratory morale and viability. The Laboratory and the country would have to plan for the possible resumption of testing on the basis that the USSR or some other nation might resume testing. We would have to put devices on the shelf for possible further testing. . . . This would have to go on for 2, 5, perhaps 10 years. It can go on if the Laboratory staff believes that Los Alamos has a future with or without weapon testing. Construction of the proposed meson factory will provide tangible evidence that Los Alamos is here to stay."

This argument, along with the accelerator's scientific and political support, is potent stuff, and it therefore appears that this is one case where a multimillion-dollar research facility may go through without stirring a nasty pork-barrel fight.—D.S.G.

Daniel S. Greenberg is contributing to Science *on an every-other-week basis while working on a book about science and politics, to be published by McGraw-Hill.*

Tornadoes: Weather Bureau Office in Kansas City Is Nerve Center for Severe Storm Warning Network

A modern Montesquieu might well surmise that the strain of violence in the American character is related to the random violence of nature in the United States. The climates of the 50 states range from subtropical heat, to arctic cold, to the temperature extremes of the desert. Indigenous also are a rich variety of natural disasters —hurricanes, floods on the great rivers, droughts, earthquakes, and tornadoes.

As the spring floods on the upper Mississippi attest, Americans have not yet succeeded in preventing these disasters, though we have made considerable progress—with hurricanes, floods, and tornadoes, at least—in predicting them.

In the case of tornadoes, which can be terribly destructive in a relatively limited area and which have a frightening capriciousness, a workable warning system with wide coverage is little more than a decade old.

The Weather Bureau's national tornado warning system is centralized in the Severe Local Storm (SELS) forecasting center in Kansas City, which is located about in the middle of the echelon of states, running roughly northwest from the Gulf of Mexico, which the weathermen, on good statistical grounds, call "Tornado Alley."

The forecasting center is interested not only in tornadoes but in severe thunderstorms, particularly those which are accompanied by high surface winds, which produce hail, and which cause serious turbulence aloft. "Extreme turbulence," in the weathermen's parlance, is the sort that will cause severe damage or failures in aircraft. But tornadoes are a chief concern of the center staff, as they are of the public in a number of states when the thunder clouds of spring and summer begin to roll.

Tornadoes have been reported in every state of the Union and in every month of the year, but there are striking patterns in the distribution of tornadoes, and also in tornado "seasons," which vary from area to area. In the cold months, tornado activity is concentrated in the Gulf states and states of the Southeast. From the end of February through the end of August, the arena of greater activity shifts to the central and northern plain states. Lowest tornado activity occurs west of the Rockies, a fact which long ago led observers to the pragmatic conclusion that the mountain barrier played a significant role in this freedom from tornado weather.

Empirical observations indicated that the frequency of severe storms is greatest during the time of year when thermal contrasts in the atmosphere are most pronounced. In the plains states this period is May and June. It was also observed that, particularly in the plains states, afternoon and early evening, especially, is tornado time.

Severe-storm forecasting was lent sharp impetus during World War II when intensified weather research yielded increased knowledge of the characteristics of thunderstorms and the turbulent eddies associated with them.

By the early 1950's the rise in commercial air traffic had created strong pressure for better severe-storm forecasting. The Weather Bureau historically reacts to such economic demands, and in 1953 a severe-storm warning center was set up in Washington; a year later it was moved to Kansas City on orders of Weather Bureau chief Francis W. Reichelderfer, who thought the unit should be closer to the center of action.

Starting from Scratch

A cadre of younger meteorologists was assigned to the project, and many of them are still working at the center. There was no need to reeducate old-line forecasters, since everyone was young and, so to speak, starting from scratch. Donald C. House, who was one of the early members of the group and now is meteorologist in charge of the forecast center, says this long experience on the part of the center's forecasters has been an important factor in achieving a more than respectable record of accuracy in a new and difficult genre of forecasting.

The state of the art is still far from perfection. While there appears to be a definite correlation between the intensity of thunderstorms and the occurrence of tornadoes, says House, the exact nature of the linkage between the two remains unknown.

Forecasting depends on a network of radar stations, upper-air soundings, and conventional weather observation. In the early days of the center, hand-processing of data fitted in with the rule-of-thumb methods which had to be used. But as knowledge and the flow of data from around the country in-

creased, improved techniques became necessary. Two years ago a computer was installed and put into use; this is about to be replaced by one that is 20 to 30 times faster.

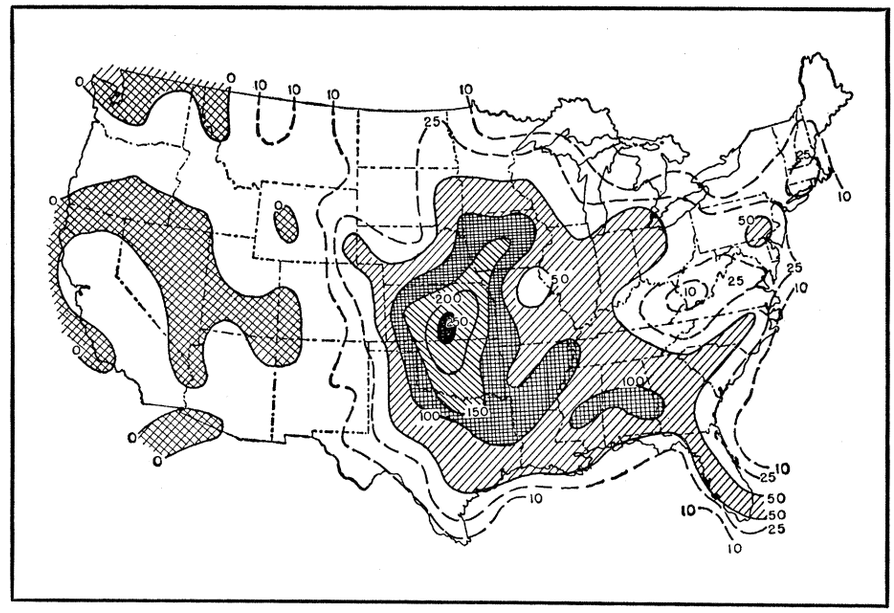
The SELS Center is located in the Kansas City office of the Weather Bureau, which is one of five regional offices. In addition to 11 forecasters assigned to the severe-storm forecasting unit, the center draws on perhaps 20 additional people from the regional office for supporting services, primarily communications and computer operations.

In the matter of accuracy, forecast verification statistics show a pattern of steady improvement leading up to a sharp setback, followed, in turn, by a steady recovery. In 1953 forecasts of severe-storm activity proved correct in 22 percent of the areas considered in verification studies. By 1957 the percentage had risen to 65 percent. The next year the percentage plummeted to 34 percent. This drop is ascribed to limitations of data caused by a budget cut, notably to the discontinuance of the routine taking of four upper-air soundings daily at a number of observation stations in the central Middle West. By 1961 the percentage of correct forecasts had climbed back again to 60 percent.

The Weather Bureau's success in calling the shots has been somewhat higher in the East than in the Middle West. The explanation for this is that there are more observation stations in the East than in the Middle West. And there are more observation stations where there are more people.

The airlines have a particularly keen interest in the correct forecasting of severe storms. Delays, detours, and groundings can play havoc with airline schedules and public relations, and flying into extreme turbulence, of course, can have a much worse result. The heavily traveled air corridors connecting New York, Washington, and Chicago form what is called the "golden triangle" in tribute to the richness of the airline business there. And the Weather Bureau is consequently under a rather special kind of pressure to make accurate forecasts of severe storms for that area.

The SELS Center uses the teletype network which ties the bureau's weather stations together. Radar reports come in hourly, and these and other data are analyzed at the center and severe-storm warnings go out speedily to local stations for transmission to news media. In the Palm Sunday storms which raked Illinois, Indiana, Michigan, and Ohio, 33 of the 37 reported tornadoes occurred within forecast areas, but the word, in several cases, did not beat the funnels to many of the people threatened.



From *Weather Bureau Technical Paper No. 20*, 1960

Total number of reported tornadoes per 2-deg latitude-longitude square over the United States, 1916–1955.

A report on the Palm Sunday tornadoes by a special Weather Bureau survey team was addressed in part to the question of why, if forecasting was accurate, more than 270 people died—the highest toll in 40 years. Recommendations were made by the team "from the standpoint of importance as factors in connection with heavy loss of life in the Palm Sunday tornadoes." These recommendations stressed the development of local emergency plans for alerting the public; provision of better background information on tornadoes and tornado warnings for the public during the tornado season; improvement of communications in the weather-warning network in general, and, in particular, the installation of alerting devices in the news outlets, and the extension of advanced weather radar coverage to all areas east of the Rockies.

As a killer, the tornado has been limited primarily by accidents of geography and by population patterns. The areas of highest tornado frequency are for the most part rural and lightly populated. Cities and towns have been struck in Texas, Oklahoma, and Kansas, with devastating effect, but twisters' targets are much more thinly spaced on the plains than they would be between Washington and Boston. The potential effect of tornadoes in areas where population is concentrated and where dwellings are vulnerably constructed was demonstrated by the Palm Sunday storms, which struck subdivisions and trailer parks with tragic results.

Prospects for improvement in the forecasting of severe local storms, according to House, depend primarily on two things: (i) the amount and quality of observational data, and (ii) a better understanding of the physical processes that combine to form severe local storms. A good deal of federally financed research has been devoted to the investigation, for example, of the thermodynamics of air masses, but theoretical knowledge of the conditions which trigger the tornado has so far eluded the researchers.

The SELS Center itself has an R & D offshoot, the National Severe Storm Laboratory at Norman, Oklahoma. The NSSL laboratory developed over a period of years, with first one and then a few permanent researchers attached to the operational center in Kansas City. The lab was formally set up in Norman in 1964, but a WSR 57 radar had been acquired for the research group the year before and installed in Norman. The breakaway really began in 1960 when a data-gathering center for a new National Severe Storm Project was located in Oklahoma City.

The laboratory has close ties with the Weather Bureau's Research Flight Facility. The Weather Bureau's small but doughty air force has headquarters in Miami, convenient to the hurricanes which its planes also probe, but operates out of Tinker Field, Oklahoma, during the tornado season, which trails off just as the hurricane season begins in earnest in the Caribbean.

The laboratory in its relatively brief history has contributed several refinements to operational radar, which is regarded now as the primary data-gathering tool in the forecasting of severe local storms.

The lab staff is interested in other aspects of tornado research—upper-air sounding, for example—but the staff of 23, with its mix of meteorologists, radar operators, electronics engineers, and technicians, seems to be concentrating on improving weather radar. Especially needed are ways to increase radar's useful range and to reduce the importance of the state of maintenance of a particular radar set and the skill and experience of a particular radar operator—now rather large factors.

In the realm of forecasting, experience seems still to be the great teacher. As House wrote in a journal article in 1962, "The forecast itself will, for some time, continue to be based largely upon empirical relationships and objective techniques devised and developed from experience gained as a consequence of completely objective analyses."

As to the possibility of learning to forestall or dissipate tornadoes, a fairly typical statement came from one meteorologist, who said, "If we find out more about energies in storms, we might be able to apply opposite energies." But that possibility, at this point at least, like the form of the statement, is highly hypothetical.—JOHN WALSH

Announcements

The University of North Carolina at Chapel Hill has established a department of **information science**. The department will offer graduate degree programs and will undertake research in the design and application of automatic information processing systems. Frederick P. Brooks, Jr., is chairman. Information on the instructional and research programs and on opportunities for graduate fellowships and assistantships is available from the department.

The Thomas Alva Edison Foundation last month presented its tenth annual awards for contributions by the mass media to education and service for youth. The **science education awards** were given to the following:

Mutual of Omaha, "Wild Kingdom," best science television program for youth.

University of Michigan Television Center, special citation for educational television.

Columbia Pictures, *World Without Sun*, best science film for youth.

William Bixby, *The Universe of Galileo and Newton*, published by American Heritage, best children's science book.

Kirtley F. Mather, *The Earth Beneath Us*, published by Random House; best science book for youth. [This was reviewed in *Science* **147**, 852 (1965)]

A report entitled "The Integrity of Science" is to appear in the June 1965 issue of *American Scientist*. The report was prepared by the Committee on Science in the Promotion of Human Welfare of the American Association for the Advancement of Science. Membership of the committee during the preparation of the report included Robert B. Brode, T. C. Byerly, Ansley J. Coale, John T. Edsall, Lawrence K. Frank, Margaret Mead, Walter Modell, and Barry Commoner, Chairman (Department of Botany, Washington University, St. Louis, Mo. 63130).

The Humble Oil and Refining Company announced last month that it plans to give its **earth sciences observatory** to the University of Oklahoma. The installation was built in 1961 at Leonard, Okla. (about 27 miles southeast of Tulsa), and includes facilities for simultaneous measurements of local and distant earthquakes, earth tides, earth tilts, geomagnetic field variations, magnetic micro-pulsations, earth current fluctuations, and micro-barometric pulsations. The gift includes all the observatory's sensitive instruments, and all the records compiled there since its opening. The observatory and its facilities are valued at more than $600,000. It will be turned over to the university 1 July.

A cooperative study of the **Gulf Stream**, coordinated by the Coast and Geodetic Survey, will begin in July. Work will be concentrated on a large area of the Gulf Stream from the Florida straits past Cape Hatteras, North Carolina into the North Atlantic. The study, estimated to need a least a year to complete, aims at increasing ability to evaluate the role of the Gulf Stream in weather modification, fisheries utilization, and commerce. Besides the C&GS, participants will include the Weather Bureau, M.I.T., Woods Hole Oceanographic Institution, the University of Rhode Island, Lamont Geological Laboratory of Columbia University, and the University of Miami. Harris B. Stewart, Jr., chief oceanographer of the C&GS, will be the project director.

Meeting Notes

The call for papers has been issued for the 12th **nuclear science** symposium, sponsored by the group on nuclear science of the Institute of Electrical and Electronics Engineers. The meeting, scheduled 18–20 October in San Francisco, will be concerned with nuclear detectors, instruments, and on-line computers for application in high-energy physics research, space power and propulsion development, and power and research reactors operation. Abstracts of 100 to 300 words are required. Deadline: *1 July*. (J. M. Harrer, Argonne National Laboratory, Argonne, Illinois)

The University of Michigan division of biological sciences will hold its 16th annual **biological** symposium, 12–14 July. The title of the meeting is Biological Excitability and Membrane Phenomena. The program will present a discussion on the general problems of tissue excitability and membrane events which play a role in the initiation, maintenance, and propagation of excitation. (L. B. Mellett, Department of Pharmacology, University of Michigan Medical School, Ann Arbor)

The 18th annual conference on **engineering in medicine and biology** is scheduled 10–12 November in Philadelphia. It will be sponsored by the Institute of Electrical and Electronics Engineers, Instrument Society of America, and the American Society of Mechanical Engineers. Papers on all phases of engineering in medicine and biology are invited. Persons who wish to submit a paper should request an "author packet" by 1 July. Deadline for receipt of abstracts: *15 July*. (H. P. Schwan, Electromedical Division, Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia 19104)