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5 March 1976, Volume 191, No. 4230

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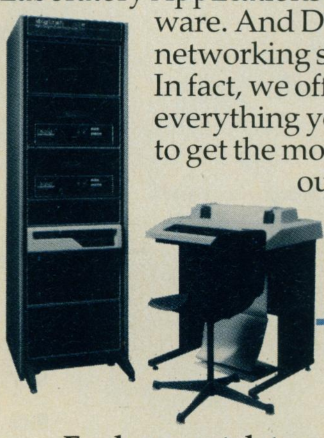

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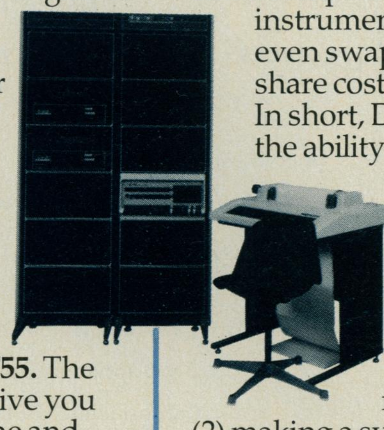

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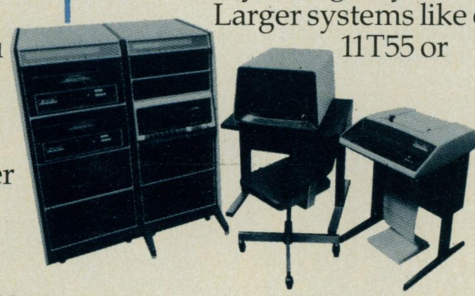

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The American Association for the Advancement of Science was founded in 1848 and incorporated in 1874. Its objects are to further the work of scientists, to facilitate cooperation among them, to improve the effectiveness of science in the promotion of human welfare, and to increase public understanding and appreciation of the importance and promise of the methods of science in human progress. Postmaster: Send Form 3579 to SCIENCE, 1515 Massachusetts Avenue, NW, Washington, D.C. 20005.

COVER

Dancer in an origin myth ceremony representing a mythical ancestral wind rearranging islands of floating grass which are the land. Iatmul, Tabunanam Village, East Sepik District, Papua New Guinea. Photograph by Gregory Bateson, 1938. See page 903. [Source for 3(a) Plate XIX(A) from *Naven*, second edition, by Gregory Bateson (Stanford University Press, Stanford, 1958)] as in birds or the uropotagium (tail membrane) in bats. The Late Cretaceous reptiles appear to have been highly efficient and uniquely structured slow, but maneuverable, flapping animals—the product of 150 million years of reptilian adaptation to flight.

ROSS S. STEIN

Department of Geology,
Stanford University,
Stanford, California 94305

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4. J. Gray, *Animal Locomotion* (Weidenfield & Nicolson, London, 1968).
5. C. H. Greenewalt, *Smithson. Misc. Collect.* **144** (No. 2), 1 (1962).

I read with interest the exchange between Greenewalt and Lawson regarding the wing design of the "Texas pterosaur" (*Quetzalcoatlus northropi*). Lawson is quite correct in pointing out the structural dissimilarity between the wings of birds, bats, and pterosaurs. The structure of the latter for the specific case of *Pteranodon ingens* and the corresponding aerodynamic and operational consequences have been fully discussed by Bramwell and Whitfield (*1*). No bird or bat appears to be an adequate paradigm for deducing pterosaur structure or performance.

What I find surprising in these discussions is that no one seems to have noticed that the wings of large pterosaurs appear to be direct natural counterparts of the National Aeronautics and Space Agency's high aspect ratio *cylindrically cambered* Rogallo wing, examples of which have been extensively flown as hang gliders for several years (*2*). The largest man-carrying hang glider of this type is presently the "Cronk V" with a span of 11.8 meters and loaded mass of 100 to 120 kilograms.

I have great respect for Greenewalt's earlier work (*3*) and have made extensive use of it in my own research (*4*) related to clarifying the interface between natural and low-speed, man-made flying devices (for example, hang gliders, man-powered aircraft, and sailplanes). On the basis of Greenewalt's data and mine, it appears that there is a remarkably good "square-cube law" relation between wing area (S, in meters) and loaded mass (M, in kilograms) for devices covering 12 orders of magnitude in mass (that is, small insects through large transport aircraft). The general trend for "conventional" flying devices is approximately

$$M = 15\,S^{3/2}$$

However, for low-wing loading "ultralight" types (for example, butterflies, the zinonia seed, *Pteranodon*, and hang gliders) the corresponding relation is

$$M = (1.2 \pm 0.6)\,S^{3/2}$$

For soaring birds and sailplanes the relation is about

$$M = (10 \pm 2)\,S^{3/2}$$

The relation between mass and wing area is directly related to flying speed [$V \propto (M/S)^{1/2}$], and is thus somewhat more significant in evaluating flight characteristics than the relation between mass and wingspan, which has mainly to do with vehicle drag and lateral (roll) control characteristics. The point is that, based on the laws of applied aerodynamics, it seems the bird is a poor model on which to base pterosaur flight characteristics, while the hang glider appears to be a direct counterpart. It should be noted, however, that no current hang glider has gliding performance approaching that estimated for *Pteranodon* (*2*) (and presumably *Quetzalcoatlus*).

Provided their estimates of meteorological conditions during the Cretaceous are correct, the flight modes of the large pterosaurs deduced by Bramwell and Whitfield are well verified by 5 years of operational experience with several thousand Rogallo wing hang gliders. Two major questions require further clarification, however. (i) How did the large pterosaurs take off if no hill or cliff was available to "leap" from? (ii) What is the maximum feasible size (specifically wingspan and mass) of a device of pterosaur configuration?

Both questions can probably be resolved rather economically by construction of full-sized models, perhaps rigged as a hang glider. On the question of maximum feasible size, it should be noted that the 12-m span Cronk V has poor lateral control characteristics, although it uses a spoiler system for control rather than the pterosaur system of differential sail billow. On the basis of this consideration and the general problem of making very low speed banked turns with "large"-span wings, I tend to favor Lawson's alternative estimate of an 11-m span for *Quetzalcoatlus*.

JOHN H. MCMASTERS

School of Aeronautics and
Astronautics, Purdue University,
West Lafayette, Indiana 47907

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A Global Rush Toward Nuclear Energy

Perhaps the most important sequel to the Arab oil embargo has been movement toward widespread adoption of nuclear energy. Some 38 countries outside the United States have a total of 260 power reactors either operating, under construction, or on order. Although the United States still has a major role in nuclear matters, it is rapidly losing its technological and political supremacy.

The situation is complex; one approach toward insight is to concentrate on a single country—France. This nation has little indigenous coal and oil. In 1950 its energy consumption was the equivalent of 87.5 million metric tons of coal (MTec), 65.3 million coming from coal and 15.5 million from oil. By 1973 energy use had tripled, but consumption of coal had fallen by a third while use of petroleum had increased more than 11-fold to 175.6 MTec. Thus, France had become dependent on oil imports for about two-thirds of its energy. In contrast, the United States obtains about 14 percent of its energy from foreign sources. If there is need for the United States to attain energy independence, there is desperate need for France to do so.

The French, who have abundant domestic reserves of uranium, have chosen to place emphasis on nuclear energy, in which they have developed considerable expertise. Their first research reactor went critical in 1948 and the first power reactor in 1958. (Later they obtained extensive know-how from Westinghouse and General Electric.) They have in operation a small gaseous diffusion plant for separation of uranium isotopes and nuclear fuel processing plants to produce plutonium, and they are well along with techniques for handling radioactive waste. They have now had nearly two years' successful experience with a 250 Mwe breeder reactor and in this respect are far ahead of their U.S. counterparts.

Before the embargo, France was obtaining 8.5 percent of its electricity from nuclear reactors. The plan for 1985 calls for 72 percent nuclear, 14 percent hydroelectric, and 14 percent thermal power, with almost all of the latter coming from domestic coal. France is likely to reach these goals. The time required for planning and constructing a power reactor there is about half that in the United States.

France is also a major participant in an international consortium which is building a very large isotope separation plant to produce enriched uranium for power reactors. The partners include groups from Belgium, Italy, Spain, and Iran. The plant is scheduled to begin operation in 1979 and reach full production in 1981. It will have an annual production capacity of 10.8 million separative work units (SWU), or 2670 metric tons of enriched uranium having an assay of 3.15 percent ^{235}U. A second large plant is in the planning stages with construction dependent on obtaining orders for nuclear fuel. Present U.S. capacity, which is being upgraded, is 16.6 million SWU.

In addition to the consortium, others, including an English-Dutch-German combine and the Russians, are producing and selling enriched uranium for reactors. The virtual monopoly of the United States is about to end. There has been talk on Capitol Hill of shutting off exports of enriched uranium, but this would merely lead to expediting the construction of separation plants elsewhere and to a further loss of U.S. influence.

The oil embargo forcefully reminded many nations that oil reserves are limited and oil supplies are vulnerable to other interruptions. The quadrupling of the price of oil made nuclear energy look very attractive from the viewpoints of cost and balance of payments. The embargo also came at a time when a number of industrialized countries had accumulated some experience in the design, construction, and operation of nuclear power reactors.

A country possessing power reactors is a step along the way toward nuclear weapons. However, irradiated fuel that contains plutonium also contains tremendous quantities of fission-product radioactivity. To obtain weapons-grade plutonium requires a complex processing plant. The best hope for holding down weapons proliferation is to bring spent-fuel processing plants under international control. Attaining such an objective should be a major and urgent goal of U.S. foreign policy.—PHILIP H. ABELSON