LETTERS

Base SI Units

I read with interest the article "Using time to measure length" by Arthur L. Robinson (Research News, 24 June, p. 1367). I would like to point out that the seven base units of the International System of Units specify standards for time, distance, mass, temperature, current, amount of substance, and luminous intensity; the last two quantities were replaced by voltage and resistance in the article.

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Floating Accelerator

Reading "Neutrino exploration of the earth" by M. Mitchell Waldrop (Research News, 10 June, p. 1142) brought to mind the original tongue-in-cheek suggestion of a floating accelerator by William A. Shurcliff in *Science* (Letters, 5 November 1965, p. 685). Shurcliff's letter predates by 7 years the suggestion by Alvaro De Rújula, Georges Charpak, Sheldon Glashow, and Robert Wilson of a floating accelerator mentioned by Waldrop. Shurcliff's letter is uproariously funny and, in my opinion, deserves republication in view of its prophetic nature.

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We reprint below the prophetic letter.—Eds.

Floating Accelerator: Progress at Last

It has been a pleasure to observe, during the last 6 weeks, increasing interest among policy makers in the proposal that the 200-Gev proton accelerator be located on a large, specially designed, floating platform. Long recognized as offering unique advantages of flexibility of use and economy of construction, the plan has been plagued by questions of safety. Happily, these have been solved, and, according to a report soon to be issued by the Conference of Eastern Coastal Universities (CECU), full-scale consideration of the plan is now warranted.

The report stresses two main design goals: (i) avoidance of extensive use on land and (ii) transferability of the accelerator from one harbor to another at approximately 6-month intervals. Preliminary engineering surveys show that the harbors of New York, Philadelphia, Baltimore, Boston, and Norfolk, Virginia, are almost ideal for the purpose, and West Coast harbors could be used after the widening of the Panama Canal is completed.

The accelerator, of strong focusing (alternating gradient) type, would be incorporated in four floating platforms, each about the length and width of a modern 100,000-ton oil tanker. Each would have the form of a quadrant of a circle, and the four units would be joined (by a precision key system and giant hydraulic clamps) to form a single rigid ring. Prior to the clamping operation, ballast tanks in each quadrant would be flooded with sea water to appropriate depth to bring the quadrants to the same level. Thanks to the slight elasticity in the integrated structure, fine-scale alignment of the quadrants of the synchrotron itself can be accomplished by fine adjustment of the water levels in these tanks.

The diameter of the accelerator is relatively small: 400 meters. Correspondingly more powerful magnetic guide fields are provided by 60-kilogauss superconducting magnets of low-inductance design in a multiple-pyramiding arrangement which provides especially tight control of betatron oscillations without significant increase in the period of the synchrotron oscillation (except at injection, when special pentapole magnets of diamagnetic ferrite are superimposed on interphased counterfields).

Plans for the linac injector are still tentative, but may call for a 1500-foot 1-Gev traveling-wave assembly mounted on two aligned concrete barges to be held by slender, prestressed-concrete equants in rigid tangential orientation.

The ring of 1024 magnets, located in a common circular tunnel running through all four platforms, will be situated 6 meters below the waterline, so that adequate shielding is provided, at no expense, by the surrounding water. A protective screen of nylon netting will probably be mounted some 10 or 20 meters from the quadrants to keep fish away and thus prevent radiation damage to them. The use of such a screen was suggested by the Izaak Walton League.

Although shielding, cooling, and electrical grounding present no problems (thanks to the unlimited amount of sea water available), the provision of adequate power poses problems. Because city electric power, supplied to the accelerator via submarine cables, may be in short supply during the daytime, the accelerator may have to be operated at night only. (If so, tourists could visit the accelerator during the day, and the entrance fees charged might pay a significant fraction of the operating cost.)

When repair work must be performed in the circular tunnel, which would soon become highly radioactive, accelerator engineers would fill the entire tunnel with sea water. Mechanics employing aqualungs or diving suits could then work in complete safety.

A separately constructed central area of the assembly would contain machine shops, special power supplies, a large control room, administrative headquarters, and also a kind of motel (with parking for helicopters rather than cars) for the crew of approximately 1000 engineers and technicians. Recreation facilities would include a movie theater, squash courts, swimming pools, and a specially stocked fishing pool.

The plan circumvents rivalry from groups in different parts of the country. (The possibil-

ity of building the quadrants in smaller units that could pass through the St. Lawrence Seaway and be assembled in Lake Erie or Lake Michigan has not been ruled out.) Also, four different parts of the country could be given contracts for building the four arc-shaped platforms. (Already, a bid has been received from a Japanese shipbuilding firm experienced in building supertankers.) Since these four quadrants—and the linac structure and the experimental hall structures—could be built simultaneously in different shipyards, as much as 2 years could be saved relative to the time needed to construct a fixed synchrotron.

Only in the last few weeks has the last and thorniest problem been solved: the problem of radiation beamed toward a particular part of the city adjacent to the harbor in question. If an emergent beam were aimed toward a certain portion of the city, persons living there would receive, during a typical month, five or ten times the permissible dose (from muons, which are fundamentally aquatic and can travel freely in water). The solution is to mount a 5-hp outboard motor tangentially at the outer edge of the platform and keep the motor running continuously, so as to rotate the entire accelerator at the rate of one revolution per week and thus distribute the radiation uniformly along the entire harbor-front. The direction of rotation will be the same as that of the protons in the accelerator, so as to add to their speed; even a slight increase is significant if the particles are already traveling at a speed almost equal to that of light.

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Carcinogenic Risk

Although G. M. Williams and J. H. Weisburger (Letters, 1 July, p. 6) refer to "safe" levels of carcinogens, their letter sheds no light on means by which these may be established. They assert that carcinogens can be divided into genotoxic and epigenetic agents but do not discuss the reality that the mechanism by which any carcinogen acts is unknown. That many carcinogens are genotoxic is known, although in those instances in which we can roughly quantify carcinogenicity and genotoxicity there is no quantitative relationship between the two, even within chemical families of known carcinogens. Nevertheless, it is not known that any carcinogen induces tumors through genotoxicity, and there is no known difference between tumors induced by, for example, "nongenotoxic" carcinogens, such as nitrosodiethanolamine or methapyrilene, and those induced by other carcinogens. Dose-response relationships in carcinogenesis are observed with these, as with other carcinogens.

Furthermore, whether or not there is one or more mechanisms by which carcinogens act is irrelevant to the assessment of risk in large populations, perhaps millions, of people to a substance shown to be carcinogenic in animals. Normally, we test a compound at high doses in small groups of animals and extrapolate the risk to the lower doses to which humans may be exposed. At these low doses errors in calculation can be enormous, particularly when the difference in length of exposure can be 60 years for man versus 2 years for a rat or mouse.

To calculate the "carcinogenic risk" at low doses that would be reliable to protect human health would require using huge numbers of animals (tens of thousands per group), which would be prohibitively expensive, even if practical. The safest course is to continue to treat any substance identified as a carcinogen as if it posed a reasonable risk to the human population and to regulate it accordingly.

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Williams and Weisburger are correct in their assertion that there are different kinds of carcinogens but not in concluding that there are "two distinct classes." The evidence for genotoxic or nongenotoxic mechanisms of carcinogenicity is not as available as they imply. The term "genotoxicity" covers a universe of events from single base changes, additions, or deletions in DNA to chromosome and chromatid deletions and rearrangements and to the gain or loss of chromosomes. More recently, the term has also been extended to include other effects on DNA or chromosomes, such as sister chromatid exchanges, induction of DNA strand breaks, or unscheduled incorporation of thymidine into the cell nucleus. The term "epigenetic" has been used as a catchall to categorize chemical carcinogens that do not appear to be genotoxic, but the term is not defined in the negative sense (lacking genotoxicity) and provides no information on mechanisms of action.

Since Ames and his colleagues (*1*) began demonstrating that the majority of carcinogens were mutagenic in *Salmonella typhimurium*, results from this test have been used as the basis for the identification of chemicals as "genotoxic carcinogens." Recently, however, additional studies have shown that many chemicals originally judged nonmutagenic based on their lack of mutagenicity in *Salmonella* can cause mutation, chromosome aberrations, aneuploidy, or sister chromatid exchanges in eukaryotic microorganisms, insects, or cultured mammalian cells (*2*). Additionally, some carcinogens that were not mutagenic in *Salmonella* when tested by the original protocol were mutagenic when modified protocols or different metabolic activation procedures were used (*3*). At this time, however, too few chemicals that are not mutagenic in *Salmonella* have been tested adequately in other genetic toxicity assays and for carcinogenesis to know the predictability of results from the other genetic toxicity tests for carcinogenicity. Furthermore, other modifications of DNA or chromatin that could result in heritable phenotypic changes in mammalian cells (*4*) are not commonly explored.

If a carcinogen has not been tested for a variety of genetic endpoints, including some from in vivo genetic toxicity tests, it is inappropriate to classify it as "nonmutagenic." A recent IARC Working Group (*5*) has also concluded that ". . . at present, no classification of carcinogens could be exhaustive or definitive." Mutagenicity and rodent cancer data are too sparse to support general statements on carcinogenic thresholds for chemicals that have not been shown to be mutagenic.

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References

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4. P. A. Jones and S. M. Taylor, *Cell* **20**, 85 (1980).
5. *Approaches to Classifying Chemical Carcinogens According to Mechanism of Action* (International Agency for Research on Cancer, Lyons, in press).

Erratum: In the article "Sulfur diagenesis in Everglades peat and origin of pyrite in coal" by Z. S. Altschuler *et al.* (15 July, p. 221) the equation at the bottom of the middle column on page 221 had a misprint; it should have read

$$Fe^{2+} + S_x^{2-} + HS^- \rightarrow FeS_2 + S_{x-1}^{2-} + H^+$$

Erratum: In the article "Yellow rain experts battle over corn mold" by Eliot Marshall (News and Comment, 5 August, p. 527), Pat Hamilton was incorrectly identified as a poultry scientist at the University of North Carolina. Hamilton is at North Carolina State University.