tragic exceptions), these lightning discharges do very little damage to conventional aircraft. It is doubtful that the new aircraft will be as "safe" with respect to this hazard, because of their extensive use of more sophisticated hardware, which is more susceptible to damage from lightning.

The consequences of lightning strikes to aircraft, the increased danger presented by the new, larger aircraft, and the meteorological situations in which lightning might be triggered are all matters which should receive thorough investigation.

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Reference

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One-Way Radar Range to the Moon

It is perhaps rash to comment on a communication (*1*) signed by no less than 14 authors with names ranging from Alley to Wampler. However, I do so with regard to the conversion of radar travel times to distances in meters. The point in question is found in the paragraph beginning "The basic uncertainty in measuring the approximately 2.5 second round-trip travel time. . . ." The paragraph ends with the remark that an error of 0.5 nsec in travel time would lead to the conclusion that "an overall uncertainty of $\pm$ 15 cm in one-way range seems achievable." In spite of a second remark made by Alley *et al.* regarding the use of the light-second as unit of distance, the paragraph in question can be read to mean that the distance to the moon could be known to an accuracy of $\pm$ 15 cm because of the fact that the radar travel times were measurable to an accuracy better than one part in 10^9. For the benefit of those who are not experts in radar, it is perhaps useful to point out why such an interpretation is untenable. The demonstration is this. Suppose, for the sake of argument, that the one-way travel time is assumed to have the value $(1.25 \pm 0.5 \times 10^{-9})$ second, and that there are no errors, other than the one shown, in this time interval. The speed of light adopted by Cohen and DuMond (*2*) is

$$c = (299792.5 \pm 0.4) \text{ km sec}^{-1}$$

and they also quote one value of higher accuracy due to Froome (*3*), namely,

$$c = (299792.5 \pm 0.1) \text{ km sec}^{-1}$$

If the Cohen-DuMond value is employed, the one-way range to the moon is

$$(299792.5 \pm 0.4) \times 10^3 \times (1.25 \pm 0.5 \times 10^{-9}) \text{ m}$$

The error in this range is therefore

$$\pm (400 \times 1.25) \pm (0.5 \times 299792 \times 10^{-6}) \text{ m} = \pm 500 \text{ m} \pm 15 \text{ cm}$$

whereas, if the Froome value is used, it becomes

$$\pm 125 \text{ m} \pm 15 \text{ cm}$$

In both cases, the error in the range depends on that inherent in the value of c, the $\pm$ 15 cm due to the error in the travel time being entirely negligible in comparison. In my example, the one-way range would be known to $\pm$ 15 cm only if a value of c were available correct to 1 part in 10^{10}, which is at least three orders of magnitude better than has so far been achieved.

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References

1. C. O. Alley *et al.*, *Science* **167**, 458 (1970).
2. E. R. Cohen and J. W. M. DuMond, *Rev. Mod. Phys.* **37**, 537 (1965).
3. K. D. Froome, *Proc. Roy. Soc. London Ser. A* **247**, 109 (1958).

5 February 1970

A value of 299,792.5 km/sec for the speed of light has been adopted for use in astronomical and geophysical work by the International Astronomical Union, International Union of Geodesy and Geophysics, and the International Scientific Radio Union. Essentially all current measurements of astronomical distance within the solar system are based on this value. Most geodetic measurements of the highest accuracy over long base lines are also made in terms of the speed of light. Thus we have, in effect, two distance scales at present. One is based on an adopted value for the wavelength of the orange line of krypton and is used mainly in laboratory measurements. The other is based on the adopted value for the speed of light and is widely used in astronomical and geophysical measurements. While this situation is not ideal, it is also not unusual in metrology. There are no important scientific experiments which we are prevented from doing because of our not yet knowing the conversion factor between the two scales with sufficient accuracy.

McVittie is correct in saying that an accuracy of 0.5 nsec in the one-way travel time of light does not permit one to deduce the range to high accuracy in terms of the meter as defined by the General Conference on Weights and Measures. However, as stated in our article: "The present uncertainty of three parts of 10^7 in the knowledge of the velocity of light will not affect the scientific aims of the experiment, since it is the practice to measure astronomical distances in light travel time." Which distance scale we use for finding the scale factor for the lunar orbit is not important, since we are mainly interested in whether the form of the motion can be reproduced by the theory. The only other distances that we expect to measure with accuracies greater than that of the present value of the speed of light are the coordinates of the ground stations with respect to each other and to the axis of rotation and center of mass of the earth. Here it is the changes in the coordinates which are of major interest, and in any case more accurate measurements of the speed of light in the near future are likely to make the question academic.

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