echo delays, one could determine not only the average spin period with an accuracy increasing with the time span of the data, but also the differences in equatorial radii and the orientation of the elliptical equator. With the Haystack facility, differences of as little as 0.5 km should be detectable near inferior conjunction (*23*). Another independent estimate of average spin period might be made by accurately monitoring the variations in radar cross section as a function of aspect. All data affected significantly by Venus's rotation should, of course, be combined in a single solution to obtain the most definitive estimate of the spin vector and its time dependence.

Further improvements in techniques that yield precise estimates of the instantaneous spin angular velocity will also enable the difference in the principal equatorial moments of inertia to be inferred. Thus a theoretical analysis of the rotation of Venus (*21, 22*) indicates that, for the spin to be in resonance with the relative orbital motions of Earth and Venus, the fractional difference in these equatorial moments [conventionally defined as $(B-A)/C$, where $A < B < C$ are the three principal moments] most probably exceeds 10^{-4}. The torque exerted on Venus by the sun, which predominates on an instantaneous basis, will therefore introduce an oscillation in the spin period with an amplitude greater than 0.01 day and a period of about 58.5 days. Estimates of the spin period, accurate within 0.01 day or better, with each involving data that span an interval short compared to 60 days, will provide not only useful information on the value of $(B-A)/C$ and on the orientation of the inertia ellipsoid, but also an upper bound on the magnitude of the average tidal torque exerted on Venus by the sun (*24*).

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15. See, for example, M. E. Ash, I. I. Shapiro, W. B. Smith, *Astron. J.*, in press.
16. Although the operating frequency at Haystack was three times higher than at Goldstone, the accuracy obtainable from Goldstone data was degraded by the limited resolution available in the small-scale graphs included in the published report (*10*). The original data were not obtainable.
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23. The inference of the difference of the principal equatorial moments of inertia from the geometric shape is, of course, dependent on the assumed density distribution (*15, 22*).
24. For Earth to control the present spin of Venus, the average tidal torque exerted by the sun must be less than the average torque exerted by Earth on the permanent asymmetry of Venus's equatorial region (*21, 22*).
25. I thank A. Forni, K. McGrath, and A. Rasinski for the computer programming. Lincoln Laboratory is operated with support from the U.S. Air Force.

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Europium-155 in Debris from Nuclear Weapons

Abstract. *The lithium-drifted germanium detector enables determination of europium-155 on a routine basis in environmental samples contaminated with debris from nuclear weapons. From measurements of europium-155, cesium-144, and strontium-90 in air filters collected between 1961 and 1966, the yield of europium-155 from weapons was estimated at 1400 atoms per 10^6 fissions, which is close to the yield of europium-155 from fast fission of uranium-238.*

In studies of circulation processes in nature, such as in meteorology, hydrography, and ecology, debris from the testing of nuclear weapons has been widely used. The long-lived nuclides Sr^{90} and Cs^{137} are most commonly employed in these investigations, but radionuclides of medium-long life, such as Ce^{144}, Ru^{106}, Sb^{125}, and Pm^{147}, also have found some applications. The great spectral-resolving power of the lithium-drifted germanium detector has made it possible to include 1.7-year Eu^{155} in this family of useful environmental tracers (*1*).

Europium-155 is a fission product having a thermal neutron fission yield, in U^{235}, of $326:10^6$ (atoms:fission) (*2*). In debris from nuclear weapons, Eu^{155} was detected for the first time in 1957 in soil on Rongelap Atoll (*3*); later it was measured in global fallout in samples of rain water (*4, 5*), dust (*5*), lichens (*1*), plankton and sea water (*6*), and marine sediments (*7*). Our aim has been to follow the concentration of Eu^{155} in ground-level air for a longer period, and, from these measurements and simultaneous determinations of Ce^{144} and Sr^{90}, to estimate the weapon yield of Eu^{155}.

Since 1961, air samples have been collected at ground level at Risö, Denmark, by means of a 7.5-hp centrifugal pump handling air at about 10^6 m^3/month. The debris was collected on

Table 1. Europium-155 in air samples (pc/10^3 m^3). The relative S.D. of a single determination was 23 percent (*10*).

Month	1961	1962	1963	1964	1965	1966
January		3.6	10.0	4.9	1.1	0.27
February		4.6		5.6	1.0	.43
March		5.1	19.7	8.5	1.9	.36
April		4.2	17.2	12.1	1.8	.44
May		6.4	18.2	9.5	5.2	.59
June		11.8	25.2	10.5	1.3	.60
July	0.11	9.4	15.5	3.7	1.3	.36
August	.55	4.9	7.6	4.0	0.66	.28
September	1.1	3.7	7.1	2.8	1.3	.21
October	1.9	3.5	8.1	0.83	1.0	.22
November	3.1	4.7	4.1	1.6	0.41	.16
December	5.8	5.7	3.6	1.2	.24	.06

two Whatman-GF/A glass-fiber filters (each 56 × 48 cm) having a filter efficiency of about 100 percent (*8*); normally they were changed twice weekly. A monthly portion of 10 g of pressed filter, representing about 30,000 m^3 of air, was measured on a 2.3-cm^3 lithium-drifted germanium detector (*1*) in concert with a TMC-256 multichannel pulse-height analyzer; the counter was operated as a Compton-rejection spectrometer (*9*). Most of the samples were counted for 1000 minutes. The 105-kev photo peak was used for the calculations of Eu^{155}; the 134-kev peak, for Ce^{144}. All samples were corrected for decay back to the middle of the month of sampling.

The maximum of the Eu^{155} determinations (Table 1) (*10*) occurred, as for other long-lived, bomb-produced nuclides (*11*), in June 1963 (Eu^{155}, 0.025 pc/m^3). The Chinese nuclear tests, made since 1964, have resulted in transient increases in the atmospheric concentrations of Eu^{155} during the first months after the explosions.

Along with the Eu^{155} measurements, Ce^{144} was determined; Fig. 1 shows the Ce^{144}:Eu^{155} ratios and the decay curves for the mean ratios on 15 October 1961 and 15 November 1962. Strontium-90 was determined by radiochemistry from paper-filter samples from another air sampler at Risö (*11*); the Eu^{155}:Sr^{90} ratios calculated from these measurements appear in Fig. 1 (bottom).

For estimation of the mean ratios at formation, two periods (indicated by the solid decay curves in Fig. 1) were selected: (i) from November 1961 to August 1962—from the end of the 1961 series to the month when the fresh fallout from the 1962 series became important; and (ii) from after the 1962 series (from January 1963) until September 1964—the month before the resumption of atmospheric tests by China. The ratios from these two periods were referred to 15 October 1961 and 15 November 1962, respectively, the reference dates being the estimated mean dates for the 1961 and 1962 series (*12*).

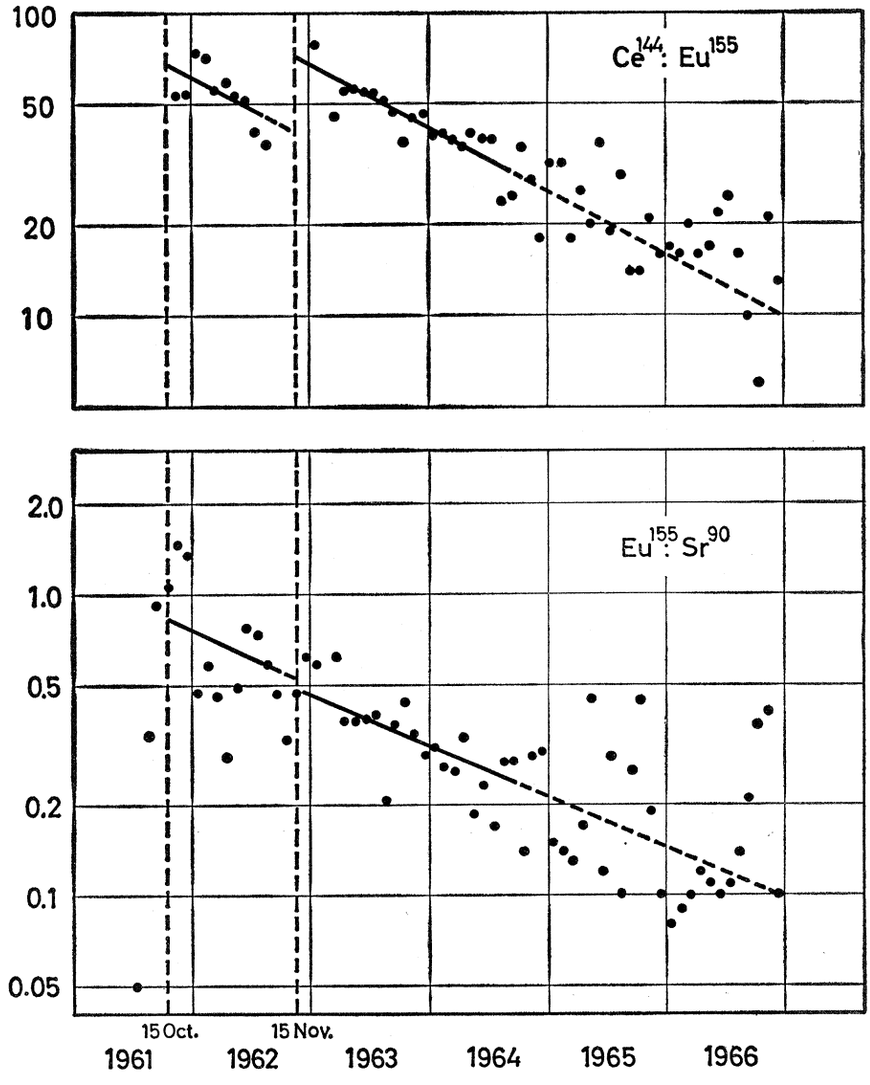

Fig. 1. Ratios Ce^{144}:Eu^{155} and Eu^{155}:Sr^{90}, with decay curves, in air-filter samples.

Table 2. Mean ratios of formation of Ce^{144} and Eu^{155} and of Eu^{155} and Sr^{90} in debris from nuclear weapons.

Date	Ce^{144} : Eu^{155}	Eu^{155} : Sr^{90}
15 Oct. 1961	68 (S.E., 3)	0.84 (S.E., 0.13)
15 Nov. 1962	71 (S.E., 2)	.48 (S.E., 0.02)
Corrected for 1961 debris		
15 Nov. 1962	74	0.47
Mean ratios for 1961 and 1962 debris		
	71 ± 3	0.66 ± 0.19

Table 2 shows the mean ratios, and the standard errors of the means, calculated for the two periods. It is not surprising that the relative errors of the Eu^{155}:Sr^{90} mean ratios are greater than the errors of the Ce^{144}:Eu^{155} ratios when one considers that Sr^{90} and Eu^{155} were determined from different samples taken by different samplers, whereas Ce^{144} was determined simultaneously with Eu^{155} from the same samples.

Pre-1961 debris was disregarded in the following calculations because the contribution in 1962 from this old debris was less than 10 percent; in 1963–64, less than 5 percent (*13*). It is estimated that about 80 percent of the debris in 1963–64 came from the 1962 series, the remainder coming from the 1961 tests (*13, 14*). Thus the ratios on 15 November 1962 were corrected (Table 2) by omitting the contributions of debris from the 1961 series (*15*).

While the Ce^{144}:Eu^{155} ratios on the two dates of formation are in good agreement, the difference between the Eu^{155}:Sr^{90} ratios is obvious; it may merely result from the greater error of the Eu^{155}:Sr^{90} ratios, but it may reflect a real difference between the ratios from the 1961 and 1962 test series —perhaps due to fractionation. This phenomenon is less likely to be important for the Ce^{144}:Eu^{155} ratio, as the precursors of these nuclides may be less volatile than the precursors of Sr^{90} (*16*).

The mean ratios in Table 2 are rather close to the ratios found for fast fission in U^{238} [Ce^{144}:Eu^{155}, 64.4; Eu^{155}:Sr^{90}, 0.78 (*2*)]. Kuroda *et al.* (*4*) found a Eu^{155}:Sr^{90} ratio of 0.24 in precipita-

tion on 16 October 1964; this ratio fits the decay curve in Fig. 1 excellently.

Harley *et al.* (*17*) have measured the weapon yields for Ce^{144} and Sr^{90} at 46,900 and 35,000 atoms per 10^6 fissions, respectively. From these determinations and the mean ratios in Table 2, the weapon yield of Eu^{155} is calculated at $1400/10^6$ (atoms/fissions). As 1 kton of fission corresponds to 1.45×10^{23} fissions (*17*), production of Eu^{155} by nuclear weapons is estimated at 72.6 kc per megaton of fission. The total fission yield of the 1961–62 test series was 101 Mtons (*18*), so that the total production of Eu^{155} in these tests was 7.3 Mc.

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6 March 1967

Photography of the Earth's Cloud Satellites from an Aircraft

Abstract. *Under astronomically favorable circumstances, photographs do not reveal excess light near the triangular libration points of the earth–moon system. We find that the visible surface brightness of anomalous dust populations, if these populations do exist, is less than 10^{-9} candela per square centimeter.*

Kordylewski (*1*) successfully recorded on film, on two different nights, cloud-like objects in the vicinity of the libration points, L4 and L5, of the earth-moon system. These points are also sometimes called the Lagrangian equilibrium points as a result of the early mathematical treatment of the restricted three-body problem by Lagrange. Recently Steg and DeVries (*2*) have reviewed the theory of the earth-moon libration regions and Simpson (*3*), the history of photographic attempts. As of late 1965, there had been no other available photographs in spite of several serious and lengthy observing efforts by others. For example E. Morris, U.S. Geological Survey, conducted a photographic investigation of the libration regions from Mt. Chacaltaya, Bolivia, in 1962–3 and was unable to obtain conclusive results. More recently R. G. Roosen (*4*) reported his attempts and concluded that in March 1966 the L5 position was empty to the limit of photographic detection. While visual observations are also important, photographs suitable for even crude photometry would be a more fruitful way of confirming the existence of these clouds and also of providing some potential data as to particle size distribution.

We here report an attempt to photograph these clouds from the NASA Convair-990 jet laboratory operating at an altitude of 12,000 meters over the

Table 1. Circumstances of observations. All observations were made in 1966; time is universal time.

Time	Zenith angle of field center	Mean location		Objective
1120–1220 1 March	43°	27°N	124°W	L4 region
1130–1240 2 March	61°	26°	125°	L4 region
0420–0530 10 March	31°	23°	125°	L5 region
0515–0620 12 March	43°	24°	125°	L5 region

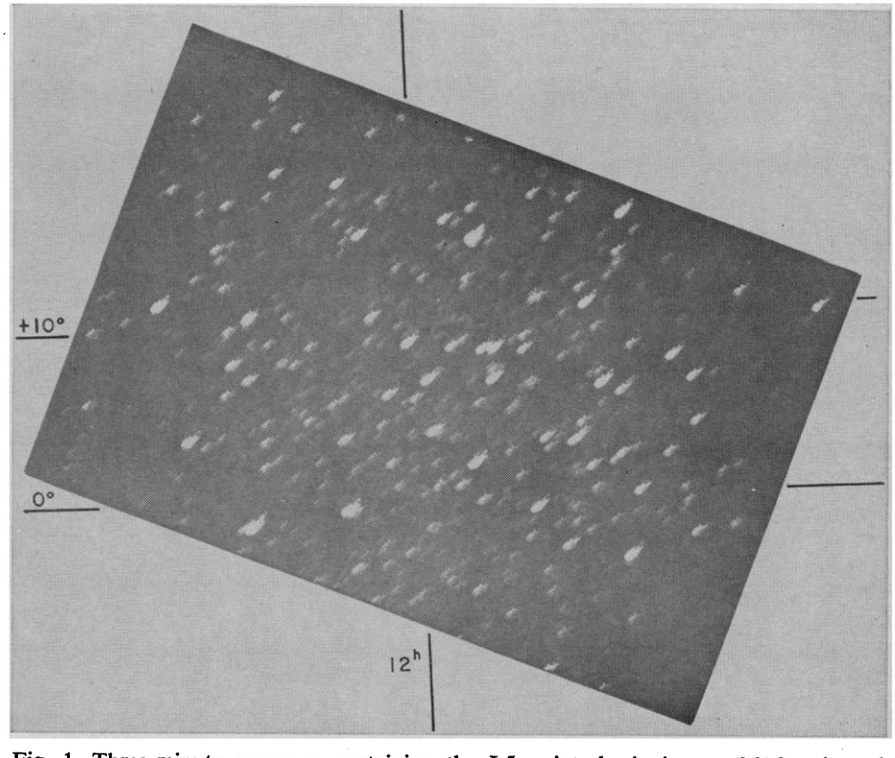

Fig. 1. Three-minute exposure containing the L5 point, beginning at 0616 universal time on 12 March 1966. The approximate right ascension, declination, and scale are indicated.