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 Hay-
stack 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 rota-
tion should, of course, be combined in a single solution to obtain the most
definite estimate of the spin vector and its time dependence.

Further improvements in techniques that yield precise estimates of the in-
stantaneous spin angular velocity will also enable the difference in the prin-
cipal 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 reso-
nance with the relative orbital motions of Earth and Venus, the fractional dif-
ference in these equatorial moments [conventionally defined as (B-A)/C,
where A < B < C are the three principal moments] most probably ex-
cedes 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, ac-
curates within 0.01 day or better, with each involving data that span an in-
terval short compared to 60 days, will provide not only useful information on
the value of (B-A)/C and on the orien-
tation 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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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-137,
and strontium-90 in air filters collected between 1961 and 1966, the yield of
europium-155 from weapons was estimated at 1400 atoms per 10⁶ 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, hydro-
graphy, and ecology, debris from the testing of nuclear weapons has been
widely used. The long-lived nuclides Sr⁹⁰ and Cs¹³⁷ are most commonly
employed in these investigations, but radionuclides of medium-long life, such as
Ce¹⁴⁴, Ru¹⁰⁹, Sb¹²⁸, and Pm¹⁴⁷, 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 Eu¹⁵⁵ in this family of useful environ-
mental tracers (1).

Europium-155 is a fission product having a thermal neutron fission yield,
in U⁴²⁵, of 326:10⁸ (atoms:fission) (2). In debris from nuclear weapons,
Eu¹⁵⁵ 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 (7), plankton and sea water (6), and marine sediments (7). Our aim
has been to follow the concentration of Eu¹⁵⁵ in ground-level air for a longer period, and, from these measure-
ments and simultaneous determinations of Ce¹⁴⁴ and Sr⁹⁰, to estimate the
weapon yield of Eu¹⁵⁵.

Since 1961, air samples have been collected at ground level at Risø, Den-
mark, by means of a 7.5-hp centrifugal pump handling air at about 10⁶ m³/
month. The debris was collected on

Table 1. Europium-155 in air samples (pc/10⁸ m³). The relative S.D. of a single deter-
mination was 23 percent (10).

<table>
<thead>
<tr>
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<td></td>
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<td>17.2</td>
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<td>1.8</td>
<td>.44</td>
<td></td>
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<td>18.2</td>
<td>9.5</td>
<td>5.2</td>
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<td>25.2</td>
<td>10.5</td>
<td>1.3</td>
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<td>July</td>
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<td>9.4</td>
<td>15.5</td>
<td>3.7</td>
<td>1.3</td>
<td>.36</td>
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<td>0.83</td>
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<td>.24</td>
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<td>1.6</td>
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<td>.16</td>
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<td>5.7</td>
<td>3.6</td>
<td>1.2</td>
<td>1.2</td>
<td>.06</td>
</tr>
</tbody>
</table>

References and Notes
4. That is, as seen from Venus, the sun rises in the west and sets in the east.
6. M. Goldstein, ibid., p. 94.
8. M. Goldstein, personal communication.
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 m³ of air, was measured on a 2.3-cm³ lithium-drifted germanium detector (I) 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 Eu¹⁵⁵; the 134-kev peak, for Ce¹⁴⁴. All samples were corrected for decay back to the middle of the month of sampling.

The maximum of the Eu¹⁵⁵ determinations (Table 1) (10) occurred, as for other long-lived, bomb-produced nuclides (11), in June 1963 (Eu¹⁵⁵, 0.025 pc/m³). The Chinese nuclear tests, made since 1964, have resulted in transient increases in the atmospheric concentrations of Eu¹⁵⁵ during the first months after the explosions.

Along with the Eu¹⁵⁵ measurements, Ce¹⁴⁴ was determined; Fig. 1 shows the Ce¹⁴⁴:Eu¹⁵⁵ ratios and the decay curves for the mean ratios on 15 October 1961 and 15 November 1962. Strontium-90 was determined by radiocellometry from paper-filter samples from another air sampler at Risö (11); the Eu¹⁵⁵:Sr⁹⁰ 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).

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 Eu¹⁵⁵:Sr⁹⁰ mean ratios are greater than the errors of the Ce¹⁴⁴:Eu¹⁵⁵ ratios when one considers that Sr⁹⁰ and Eu¹⁵⁵ were determined from different samples taken by different samplers, whereas Ce¹⁴⁴ was determined simultaneously with Eu¹⁵⁵ 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 Ce¹⁴⁴:Eu¹⁵⁵ ratios on the two dates of formation are in good agreement, the difference between the Eu¹⁵⁵:Sr⁹⁰ ratios is obvious; it may merely result from the greater error of the Eu¹⁵⁵:Sr⁹⁰ 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 Ce¹⁴⁴:Eu¹⁵⁵ ratio, as the precursors of these nuclides may be less volatile than the precursors of Sr⁹⁰ (16).

The mean ratios in Table 2 are rather close to the ratios found for fast fission in U²³⁸ [Ce¹⁴⁴:Eu¹⁵⁵, 64.4; Eu¹⁵⁵: Sr⁹⁰, 0.78 (2)]. Kuroda et al. (4) found a Eu¹⁵⁵:Sr⁹⁰ ratio of 0.24 in precipita-

![Fig. 1. Ratios Ce¹⁴⁴:Eu¹⁵⁵ and Eu¹⁵⁵:Sr⁹⁰, with decay curves, in air-filter samples.](image-url)
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\(^8\) fissions, respectively. From these determinations and the mean ratios in Table 2, the weapon yield of Eu\(^{152}\) is calculated at 1400/100 (atoms/fissions). As 1 kton of fission corresponds to 1.45 \(\times 10^{21}\) fissions (17), production of Eu\(^{152}\) 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 Mt ons (18), so that the total production of Eu\(^{152}\) in these tests was 7.3 Mc.

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References and Notes

10. The amount of air in the Feb. 1963 sample is unknown, so that exact values of the Eu\(^{152}\) concentration and the Eu\(^{152}/\text{Sr}^{89}\) ratio for this month are not available. About one-third of the figures in Table 1 rely on double determination. Europium-155 was identified in the June 1963 sample by radiochemistry. The rare earths were isolated by ion exchange and europium was reduced by zinc-amalgam to Eu\(^{3+}\), thus preventing it from precipitating as the hydroxide with gaseous NH\(_3\) along with the other rare earths.
15. The contributions of Eu\(^{152}\) and Ce\(^{141}\) in 1963-64 from the 1961 series were corrected for decay and were thus less than the 20 percent taken as the Sr\(^{90}\) contribution from the 1961 tests.
19. We thank Miss Bodil Lassen for the Eu\(^{152}\) determinations.

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.

<table>
<thead>
<tr>
<th>Time</th>
<th>Zenith angle of field center</th>
<th>Mean location</th>
<th>Objective</th>
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<td>1120-1220</td>
<td>43°</td>
<td>27° N 124° W</td>
<td>L4 region</td>
</tr>
<tr>
<td>1130-1240</td>
<td>61°</td>
<td>26° 125°</td>
<td>L4 region</td>
</tr>
<tr>
<td>0240-0530</td>
<td>31°</td>
<td>23° 125°</td>
<td>L5 region</td>
</tr>
<tr>
<td>0515-0620</td>
<td>43°</td>
<td>24° 125°</td>
<td>L5 region</td>
</tr>
</tbody>
</table>

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.

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