Table 1. Gamma-ray emitting radioactivity in the ground, and the dose therefrom, at Argonne National Laboratory as of May 1957 (sample series S_{II}).

Isotope	Radioactivity		
	mc/mi²	μr/hr	mr/yr†
U + daughters		4.02	35.21
Th + daughters		1.45	12.70
K^{40}		3.32	29.08
Zr^{95}-Nb^{95}	180	1.57*	3.45
Cs^{137}	35	0.12	1.08
Rh^{106}	175	0.23	1.47
Ru^{103}	175	0.50	0.70
Ce^{144}-Pr^{144}	240	0.09	0.37
Total		11.30	84.06‡

* Assuming Zr^{95}-Nb^{95} to be in equilibrium. † May 1957 to May 1958. ‡ In this total, 77 mr are due to natural activity, the remainder arising from fission products.

pared with that obtained from 1 kg of KCl, serving as a source of K^{40}; normalization showed 2.27×10^{-2} g of potassium per gram of soil. The peeling off of this spectrum leaves a spectrum due to fission products alone; this, in turn, may be broken down into the components due to individual fission products, as indicated in the figure.

Soil activity profiles were taken both where grassy cover existed and where the top soil was bare. Typical findings expressed as percentages of total fission activity, indicated that 62 percent occurred in grass and other vegetation growing or lying on the surface; 27 percent in the top 1½ in. of soil; 8 percent in the layer at a depth of 1½ to 3 in.; and the remaining 3 percent at 3 to 4½ in. Similar distribution was found in soil bare of vegetation. This profile study enabled us to take samples of sufficient depth to include essentially all fallout that had accrued up to the spring of 1957.

The individual fission product activities found in a 12 by 12 in. sector of soil, 4½ in. in depth, are summarized in Table 1; these data pertain to soil collected at the Argonne site in late May 1957. The Cs^{137} value is in rather good agreement with prevailing Sr^{90} values for this geographic area (*3*) and leads one to ponder the usefulness of this technique in assaying indirectly for Sr^{90} in the soil.

When the concentration of activity in the soil is known, it is then possible to calculate the dose rates. The values indicated in Table 1 pertain to a height of 3 ft above the ground. Those for uranium, thorium, and K^{40} were determined by means of the method of Hultqvist (*4*). The dose rate of 77 mr per year, due to natural radioactivity only, agrees well with results obtained by other methods (*5*) and offers evidence of the essential correctness of our nondestructive tests.

In the case of the dose due to fission activities, the approach of Dunning (*6*) was followed—namely, the assumption was made that fallout is limited to a thin, non-self-absorbing surface layer. These are, therefore, maximum values. The dose rates in microroentgens per hour shown in the second column of Table 1, will decrease markedly with time in the case of some of the fission products. In the absence of nuclear detonations, the fallout dose accumulated from May 1957 to May 1958 will be 7 mr at 3 feet above the ground. It is of interest to note that this value agrees remarkably well with the average yearly dose estimated by Eisenbud and Harley (*7*) for Chicago during the period Oct. 1952 to Sept. 1955, although they used entirely different methodology. This agreement, however, does not constitute rigorous proof of the correctness of either method, for it cannot be assumed that fission debris on the ground has remained constant in that period and equal to that obtained in May 1957.

In order to rule out any question concerning radioactivity produced locally, a group of soil samples was gathered 45 miles southwest of Argonne National Laboratory in July 1957. These showed comparable fission product activities. We concluded, therefore, that the values listed in Table 1 may be considered representative for this part of the country during the spring and early summer of 1957 (*8*).

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13 January 1958

Visual Thresholds for Detecting an Earth Satellite

The visibility of an earth satellite of known stellar magnitude can be predicted from visual thresholds for point sources of light as measured by Blackwell (*1*) and by Knoll, Tousey, and Hulburt (*2*). The results of such calculations, together with a discussion of some problems encountered in searching for satellites, have been published by Tousey (*3*). This calculation was based on visual thresholds for a stationary point source of light seen against starless fields of different brightnesses. Real satellites, however, are in motion, and are often seen under full night conditions when the sky is filled with stars. For greater accuracy, it was necessary to determine visual thresholds under the latter conditions.

A satellite simulator was constructed for this purpose. Satellites of stellar magnitude 2 to 10 were produced by an illuminated pin hole and collimator. The beam from the collimator was reflected into a viewing telescope by means of a rotating plane mirror driven by a cam and variable-speed drive. In this way the satellite could be made to move horizontally at any position across the field at angular rates characteristic of earth satellites at altitudes between 200 and 1500 or more miles. Stars and a uniform sky background were introduced by reflection.

The results of the experiment are shown in Fig. 1, where the threshold magnitude of the satellite is plotted as a function of the background sky brightness. Threshold values are for a probability of detection of approximately 98 percent. The observations were made through an 8-power elbow telescope of 50 mm aperture and 53 percent transmittance. Curve *A* is the visual threshold relation for a stationary point source of light whose position in the field of view is known, calculated for this telescope from the data of Knoll, Tousey, and Hulburt (*2*). The simple theory, given by Tousey and Hulburt (*4*), indicates that this telescope increases the unaided eye threshold by 3.8 magnitudes, in proportion to the increased light entering the eye. The correctness of the theory and curve *A* were verified by using the satellite simulator to produce a stationary satellite which was viewed with and without the telescope against a field containing no stars.

Curve *B* is for a satellite moving in a star field. The altitude, magnitude, and angular velocity of a satellite crossing the meridian near zenith are related and are plotted on the ordinate scales of the figure for a specularly reflecting spherical satellite 20 inches in diameter. The subjects did not know where in the field of view the satellite would appear. How-

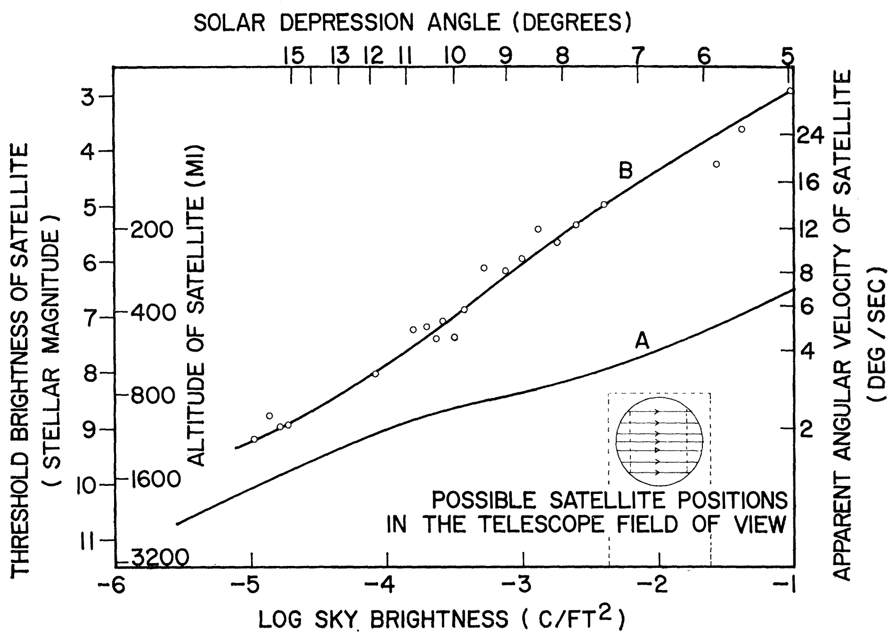

Fig. 1. Threshold magnitude of a satellite as a function of the background sky brightness.

ever, the satellite always traversed horizontally from left to right within the vertical limits set by an inscribed square.

It can be seen that the moving satellite, to be detected against a dark night sky with stars, must be approximately 1 magnitude brighter than for the stationary case with no stars in the background. This difference in threshold magnitudes begins to increase rapidly for skies brighter than 0.0002 ca/ft^2, where the changeover from rod to cone vision takes place. For 0.1 ca/ft^2, the highest sky brightness investigated, the difference reaches nearly 4 magnitudes.

The nature of these results can be explained qualitatively. At low field brightnesses, rod vision is used, and a satellite at threshold and at an unknown position can be detected almost equally well at any point in the visual field unless it lies on the fovea or the blind spot. Its presence is detected by its motion in the star field and it needs to be only 1 magnitude brighter than a stationary point of known position in a starless field. At high brightnesses, cone vision is used, and the threshold rises rapidly as the distance between the point of light and the point of fixation increases. Therefore, in effect, the satellite can be seen over only a small area surrounding the point of fixation. To have a reasonably high probability of detecting the satellite as it moves through a bright field, its brightness must be increased enough so that the area over which it can be seen at a single glance is fairly large.

Figure 1 can be used to obtain information of use in searching for spherical, specular satellites 20 inches in diameter. The scale of solar depression angle refers to the stage of twilight for which the sky within about 45° of the zenith has roughly the brightness shown by the scale at the bottom. For more details see Koomen *et al.* (*5*). The solar depression can be obtained with sufficient accuracy by linear interpolation between the times of sunset and the end of astronomical twilight, which are tabulated in the *Nautical Almanac*. The scale of altitude can be used without excessive error as a scale of slant distance for satellites seen as much as 45° from zenith.

As an example of the information given in Fig. 1, curve *B* indicates that a satellite at 200 miles altitude can be seen crossing the zenith, starting when the sun is 7.5° below the horizon and ending when the sun has set at the altitude of the satellite, in this case, 17° depression. For a satellite at 800 miles altitude and zenith, or at 400 miles altitude and zenith angle 60°, the sun must be depressed at least to 11°; however, sunset on a satellite at 800 miles altitude will not occur until the solar depression reaches 34°. Thus, high satellites can be seen well into full night, especially when they pass somewhat away from the zenith in the direction of the set sun.

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Effect of Length of Observing Time on the Visual Threshold for Detecting a Faint Satellite

It is well known that the human observer performs at reduced efficiency when required to perform a difficult and uncertain visual task which extends over a considerable length of time. At a typical Moonwatch (*1*) station, to detect earth satellites, each observer looks through a low-power telescope fixed in position as part of an optical fence. He may be required to man the telescope for 2 hours or more during the entire twilight period favorable to seeing the satellite. Described in this report (*2*) is an investigation of the reduction of an observer's ability to detect a faint satellite after protracted observation periods.

Viewing conditions were simulated in the laboratory by use of the equipment described in a separate report (*3*). Looking through an 8-power elbow telescope, the observer saw a night-sky background with stars, across which the satellite traveled in 10 seconds, the speed appropriate to a 400-mile altitude.

Eight Naval enlisted men, well trained in observing with the simulator, served as subjects. Visual threshold measurements were made at the beginning and end of seven different observing periods ranging in length from 5 to 120 minutes. An additional watch period of 120 minutes during which the satellite did not appear was included early in the observing sessions to produce an uncertainty in the mind of the observer as to whether he would see the satellite at all.

For the initial, or "prewatch," threshold measurements, the position and time of appearance of the satellite were made known to the observer. For the watch periods, however, the observer was uncertain when and where the satellite would appear, if at all. His task was to observe continuously and, when he detected the satellite, to close a switch at the instant it crossed the eyepiece reticle.

The decrement in observer performance during watch was measured in terms of the difference between the prewatch and the watch thresholds. These differences for each observer are plotted in Fig. 1 against the duration of each watch. The mean curve is also shown. An ordinate value of + 1 indicates that in order for the satellite to be detected, it was necessary to increase its brightness by one stellar magnitude, or a factor of 2.5 in luminosity, over that detected during prewatch observation.

It can be seen from Fig. 1 that the threshold after 5 and 15 minutes of watch was increased by 0.3 magnitude, on the average, over the prewatch value. From the absence of change between 5 and 15 minutes, it was concluded that the initial decrement was largely a result of