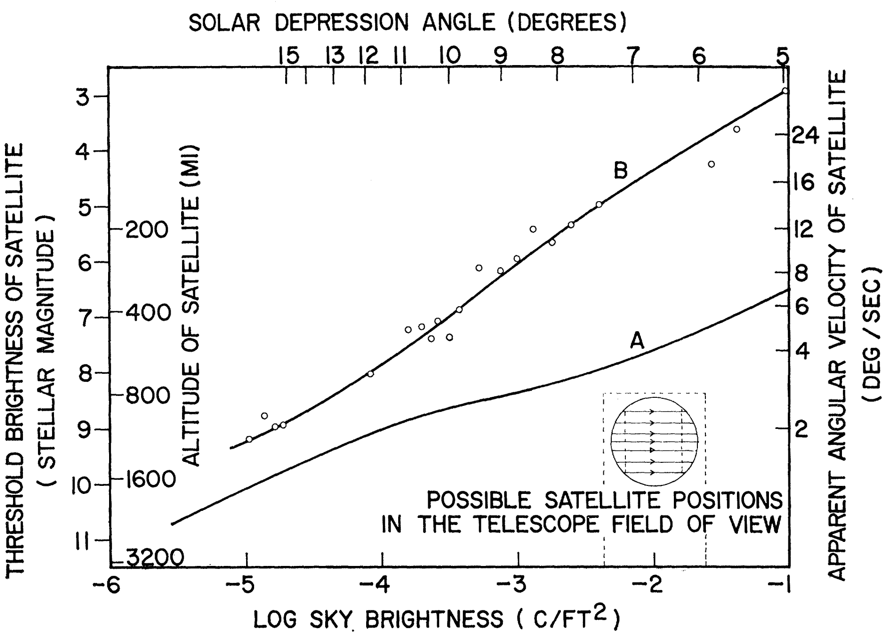

Fig. 1. Threshold magnitude of a satellite as a function of the background sky brightness.

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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References and Notes

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3. R. Tousey, *ibid.* 47, 261 (1957).
4. R. Tousey and E. O. Hulburt, *ibid.* 38, 886 (1948).
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25 February 1958

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 the fact that the subjects did not know exactly when and where the satellite was to appear.

For watch intervals beyond 15 minutes the decrement increased, reaching a maximum mean difference of 1.1 magnitude at 60 minutes. Observations at 90 and 120 minutes showed reduced mean decrements compared with the value at 60 minutes. The individual subjects, however, varied greatly in this respect, the greatest decrement occurring with S_4, and reaching 1.8 magnitudes at 60 minutes. Subjects S_5 and S_8, at the other extreme, showed very little decrement.

The group of points lying within the box labeled "observers warned that the satellite would appear" are data obtained after the observers had watched for 60 minutes as in other watch periods, but were then suddenly warned that the satellite would appear. These measurements were made to try to separate the decrement due to true fatigue from that caused by other factors. The small decrement was found not to be statistically reliable.

The conclusion reached from these results is that sometime between 15 and 30 minutes watch an additional decremental process sets in. This is distinct from the decrement due to space and time uncertainty and is caused by other factors which are associated with decreasing vigilance. The results obtained at 60 minutes with the observers warned show that this decrement was not caused by a true fatigue of the visual system.

A plausible explanation for the improvement in observer efficiency for watch periods longer than 60 minutes is that the observers knew that the longer they observed, the more probable it became that the satellite would appear.

It was found that training of the observers prior to the experiment resulted in an improvement in detection threshold, in some cases by as much as a magnitude. Training also reduced the number of false reports and the variability of individual thresholds.

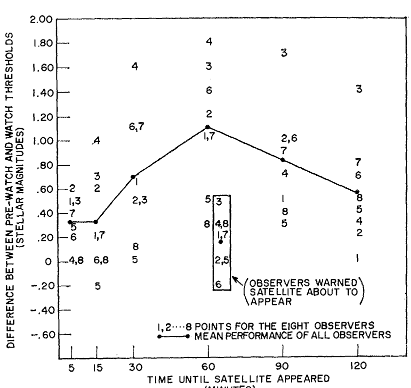

Fig. 1. Decrement in detection threshold as a function of the observing times before the satellite appeared.

The practical conclusion is that satellite observers should be rotated every 30 minutes when possible. However, if no relief is available, it is worth while for an observer to watch continuously for 1 to 2 hours, because the satellite will often be bright enough to be seen in spite of the increase of 1 to 2 magnitudes in his threshold.

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References and Notes

1. Individuals who may be interested in taking part in this program should write to S. A. O., 60 Garden St., Cambridge 28, Mass.
2. This report has been published in greater detail as NRL Report No. 5094 (Feb. 1958).
3. I. S. Gulledge *et al.*, *Science*, this issue.

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Inhibition of HeLa Growth by Intranuclear Tritium

Tritium-labeled thymidine (H^3TDR) of high specific activity is proving to be a useful label for deoxyribonucleic acid (DNA). In conjunction with autoradiography, it has revealed the mechanism of duplication of genetic material (*1, 2*) and the dynamics of cell renewal (*3*). As Robertson and Hughes have pointed out (*4*), such localization of tritium within the cell nucleus should result in almost exclusive irradiation of this radio-sensitive volume because of the very short range (average 1 μ, maximum 6 μ) of the resulting β-radiation. However, to date no evidence of radiation effects has been reported. This report demonstrates that high levels of incorporation of H^3TDR do cause radiation damage as predicted.

HeLa cells were grown in Eagle's basal medium (hereafter referred to as "standard medium") prepared in Hank's balanced salt solution, 20 percent horse serum and 15,000 units of penicillin, 1000 μg of Terramycin, and 5000 units of Mycostatin per 100 ml. The cells were inoculated into 1 ml of standard medium in Leighton tubes. Duplicate cell counts were made with hemacytometer chambers, observed at low (×100) power.

Tritium-labeled thymidine was prepared by catalytic exchange with CH_3COOH^3 and purified by column chromatography. It was homogeneous as judged by recrystallization with carrier thymidine and had a specific activity of approximately 500 mc/mole or about 2 mc/mg.

Incubation of HeLa cells for 24 hours with 2.5 μc/ml (about 1.25 μg/ml) of H^3TDR results in excellent labeling of the nucleus, as shown by autoradiography. Under these conditions, more than 100 silver grains appear over each nucleus after exposure of the film for 24 hours.

In early experiments testing the efficiency of uptake of H^3TDR, an apparent inhibition of growth of cells containing the labeled material was noted. To test the validity of this observation, several subsequent experiments were performed. Although alterations in design of the experiment were made in order to test other parameters, each included a test of the effect of H^3TDR, in various concentrations, in the medium on the growth of the HeLa cells. In all experiments the cells were allowed to attach to the glass for 3 days in the standard medium, which was then removed and replaced by the same medium containing the H^3TDR. After 24 hours at 37°C, this medium was removed and replaced again by standard medium, and growth was allowed to continue for 48 more hours. The cells were then removed from the glass by incubating with trypsin, and total cell counts were made on triplicate samples (with the exception of experiment 2, in which six replications per treatment were used). Finally, an experiment was also performed to test the effect of chronic irradiation from tritium oxide ($H^3{}_2O$) in the medium. The results are summarized in Table 1.

The most important point to be noted is that, in all cases, the inclusion of H^3TDR in the medium resulted in inhibition of growth, except where carrier thymidine was added. The fact that the latter material reversed the action of H^3TDR demonstrates that the inhibition was a result of the intracellular incorporation of tritium and not some toxic contaminant. It is also of interest that each of the three levels of H^3TDR resulted in approximately the same extent of inhibition (the difference between the means of experiments 2A and 2B is not significant). These results indicate that thymidine concentration in the medium, at the levels used, exceeds the amount which the cells can accumulate and that the effect is a function of specific activity, not concentration. This is consistent with autoradiographic observations where it appears that, in concentrations between 0.5 and 5 μc/ml, the amount of H^3TDR incorporated per cell is roughly the same.

The results of the last experiment illustrate that growth inhibition by $H^3{}_2O$ is accomplished only by concentrations in the medium of 5 mc/ml or the order of 1000 times that at which H^3TDR exhibits its effects. However, if the difference in volumes which are under actual irradiation is considered, the dose to the nucleus is probably of about the same magnitude in both cases. To illustrate, in the experiment with 5 μc of H^3TDR per milliliter, only about 20 percent (1