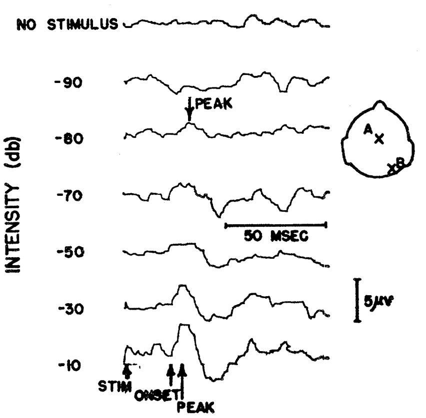

Fig. 1. Computed average responses to monaural, periodic clicks obtained from scalp electrodes for several stimulus intensities. Each trace represents the waveform of the average response to 400 individual presentations of identical click stimuli; the stimuli were presented at a rate of 1.5 per second. Upward deflection indicates that electrode A is positive with respect to electrode B. (Subject W.P., awake, eyes open, 10 Sept. 1957.)

the ongoing activity and are usually too small to be seen by direct inspection of the electroencephalogram (EEG). However, by use of different optical and electronic techniques, "average responses" to somatosensory (*1*), visual (*2, 3*), and auditory stimuli (*4*) have been obtained.

By the use of two different electronic averaging devices (*5, 6*) we have obtained responses to acoustic clicks from ordinary scalp electrodes in man. These average responses (see Fig. 1) are characterized by onset latencies of approximately 20 msec and peak latencies of approximately 30 msec and by response amplitudes and latencies that depend upon the intensity and the rate of presentation of the stimulus. The threshold for the appearance of a detectable average response agrees closely with the minimum intensity at which the subject reports that he hears clicks. Other response components with much longer latency [which may be identical with the so-called K-complex (*7*)] have been observed but are not described in this report (*8*).

Average responses with the latencies that we have given have been obtained from many of our experimental subjects. A given subject, under comparable conditions, yields similar average responses when he is tested repeatedly. The experiments were all performed in a soundproof room, and the clicks were introduced to the subject through an earphone. Controls have been run that rule out eyeblinks as a source of artefactual responses. Responses are obtained from locations that are widely distributed over the scalp. The response to monaural clicks is bilateral: electrodes placed symmetrically about the midline record virtually the same response. Our onset latencies are comparable to those measured by Dawson (*1*) for evoked responses to somatosensory stimuli and to those determined by Brazier (*3, 5*) for the visual system. These data, and the latency of the surface-negative component of evoked responses to clicks, in cats and monkeys, suggest that the responses which we obtain are cortical in origin. The fact that these responses can be obtained from many places on the scalp may reflect the deep location of the auditory cortex in man.

Figure 1 illustrates that, as the click intensity is increased, the peak amplitude of the response increases, while the peak latency tends to decrease. In other experiments we have varied the rate of presentation of the stimulus. Responses have been obtained for click rates as high as 10 per second, although the peak-to-peak amplitude of the most prominent component of the response tends to decrease with increasing rate.

It is interesting to compare, for a given subject, the psychophysical threshold with the stimulus intensity at which an extracranial response can first be detected with the aid of our averaging device. In subject W.P., the response is present, first, at − 80 db (Fig. 1). Subject W.P.'s psychophysical threshold, as determined during the same experiment, is approximately − 85 db. Other subjects have exhibited a similar correspondence between psychophysical thresholds and extracranially detectable responses.

C. D. GEISLER
L. S. FRISHKOPF*
W. A. ROSENBLITH

Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge

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* Present address: Rockefeller Institute for Medical Research, New York, N.Y.

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Ephemeral Natural Satellites of the Earth

Abstract. A discussion is presented of transient or short-lived natural satellites of the earth, which result from meteorites that only graze our atmosphere. Preliminary calculations show that only about 0.2 percent of the total number of the porous, stony meteorites which strike the earth will result in natural satellites. It is noted that such satellites also would be difficult to detect observationally.

In 1957 and 1958, the United States and the Soviet Union, in conjunction with the International Geophysical Year, have established several small artificial terrestrial satellites. The fascinating question arises as to whether these objects may be accompanied in their journey through space by certain "natural" satellites—that is, satellites that nature itself is continually contributing to the earth.

These natural satellites, if they do in fact exist, would originate from "near-miss" meteoritic trajectories that only graze the atmosphere of the earth, the meteorites being slowed sufficiently to enter onto a geocentric elliptical orbit. The natural satellite will not, of course, remain in its orbit indefinitely but, under the dissipative effects of drag, will spiral down to the surface of the earth or be consumed in flight. It is noted that there are other mechanisms for capture of natural satellites involving the attraction of the moon, the Poynting-Robertson effect, and so on; these processes are not analyzed in this report.

When first confronted by the suggestion of the existence of natural meteoritic satellites, one might hastily compute that the energy per gram that must be dissipated in order to slow a meteorite of any mass from escape speed to surface circular-satellite speed would be 31.2×10^{10} erg/g; moreover, reference to tables of heats of vaporization indicates that at most 10×10^{10} erg/g could be removed by vaporizing meteoritic material. How, then, could a meteorite become slowed sufficiently to assume a satellite orbit without becoming annihilated by aerodynamic heating?

In order to answer this question, one must recognize the fallacy of accounting for only the initial and the final energy of the meteorite. Actually, the whole meteoritic system, including the vaporized material, must be analyzed, and the conservation of energy must be applied in greater generality. In this connection the question can be clarified most directly by recourse to a simplified meteoritic model.

Let us assume that the meteorite loses no energy by radiation, conduction, sputtering, or any process other than direct vaporization, and that it moves in transitional flow. In order to account for the energy input to the meteorite, let us employ the interpretation that in transitional flow Λ represents the fraction of the oncoming molecules that effectively succeed in hitting the meteorite with full energy. Thus, the energy input to the meteorite is

$$\frac{1}{2} m_a V^2 \Lambda \frac{dn_o}{dt}$$

with

$$\frac{dn_o}{dt} = AVN \qquad (1)$$

where m_a is the mass of a typical atmospheric constituent; V is the speed of the meteorite (usually measured in units of surface circular-satellite speed); dn_0/dt is the rate at which molecules would strike the meteorite if none were shielded; A is the projected frontal-area of the meteorite; and N is the molecular number-density of the atmosphere. Let us introduce the drag-deceleration equation—that is:

$$\frac{dV}{dt} = -\frac{C_D}{2m} \rho A V^2 \qquad (2)$$

where C_D is the drag coefficient; m is the mass of the meteorite; and $\rho = m_a N$ is the density of the atmosphere. Combining these relations, we find that the total energy input to the meteorite is

$$m \frac{\Lambda}{C_D} V \frac{dV}{dt} \qquad (3)$$

The energy loss occasioned by vaporization only is simply

$$\phi_v \frac{dm}{dt}$$

where ϕ_v is the heat of vaporization of the meteoritic material. Hence

$$\frac{\Lambda}{C_D} V dV = \phi_v \frac{dm}{m} \qquad (4)$$

and integration immediately yields

$$m = m_o \exp \frac{1}{2\phi_v} \frac{\Lambda}{C_D} (V^2 - V_o^2) \qquad (5)$$

where m_0 denotes the initial mass of the meteorite. This is the classical equation of the physics of meteorites, and it indicates that the meteorite will only *approach* complete annihilation.

In order to assess qualitatively the plausibility of natural satellites, let us consider, as an illustrative example, a meteorite approaching the earth with $V_0 = 3$ (that is, about 24 km/sec) and ascertain the decrease in its diameter d resulting from its deceleration to geocentric parabolic speed (11 km/sec) near the earth's surface. First, we must assign numerical values to Λ, C_D, and ϕ_v. As can be shown (*1*), Λ/C_D is a function of atmospheric density, meteoritic diameter, temperature, and speed; nevertheless, Λ/C_D can be expected to exhibit an average value of roughly 0.35. A reasonable value for ϕ_v is 8×10^{10} erg/g. Hence, assuming a spherical meteorite, we find that if V is expressed in units of surface circular-satellite speed, V_{co}, ($V_{co} \cong 7.905 \times 10^5$ cm/sec), then

$$d = d_o \exp V_{co}^2 \Lambda (V^2 - V_o^2)/6\phi_v C_D$$
$$= d_o \exp (0.45)(V^2 - V_o^2) \qquad (6)$$

If $V_0 = 3$ and $V = 2$, then $d = 0.045\ d_0$, and, although it is significantly diminished in size, the meteorite is certainly not annihilated (*2*). Furthermore, the significant energy loss by radiation has been entirely neglected; therefore, larger meteorites could, in fact, be expected to survive and to take up short-lived geocentric elliptical orbits.

In order to determine the plausibility of natural meteoritic satellites in a more quantitative manner, we shall employ a perturbational scheme to compute a few typical examples. It should be noted that the transitional variation of the drag and the heat-transfer coefficient is crucial to the entire analysis.

Figure 1 shows a plot of meteoritic speed versus altitude for a typical porous meteorite, integrated according to the techniques previously discussed (*1*). The curves are drawn for different values of the gravity-free-trajectory altitude of perigee (*3*); in the 106-km case, the "wiggle" represents only an instability in the numerical integration. The preliminary computations indicated that even at perigee of the porous meteorites, the dynamic pressure is at most 500 dyne/cm²; hence, fragmentation is not expected to occur; furthermore, the surface temperatures remain below the temperature of fluidity, and, hence, without ablation these porous objects are invisible. One can account for these features of the meteoritic descent by noting that the mass/area quotient is about 1/100 g/cm². Consequently, the drag deceleration is large at altitudes where the heat transfer is still rather small, and the heat energy can be "drained-away" by radiation. A similar circumstance arises for micrometeorites, for which the mass/area quotient is about 1/15,000 g/cm²; consequently, as F. L. Whipple points out, micrometeorites will decelerate completely without melting or vaporizing.

Examples involving solid stony meteorites (aerolites) at various initial speeds have also been computed, and have been found to produce luminosities visible from the earth's surface (and, consequently, decrease in diameter as a result of ablation). In general, the gravity-free-trajectory altitudes at perigee must lie within a range of only 5 to 7 km in order that ephemeral natural satellites may be produced; hence, only about 0.2 percent of the total number of the porous, stony meteorites that strike the earth result in short-lived satellites; furthermore, the average brightness of the resulting meteors is of the sixth magnitude (some meteors reached the first magnitude for $V > 4$), and, hence, they also would be difficult to detect observationally. The number of partial penetrations of the atmosphere that such meteorites can survive is now being investigated.

As yet only the foregoing preliminary results have been obtained. The prob-

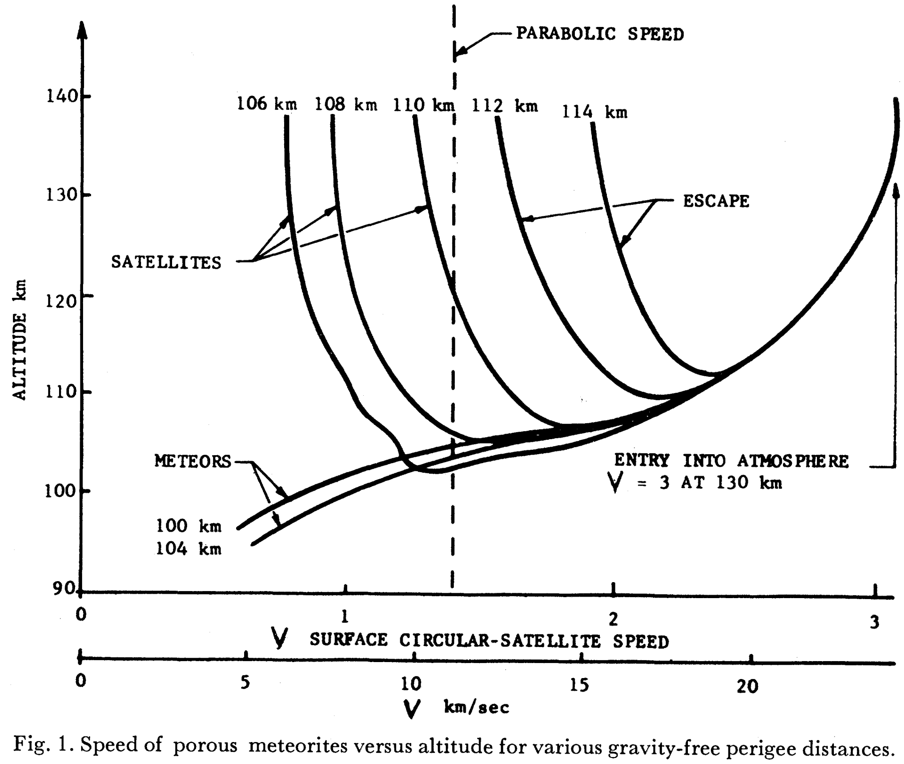

Fig. 1. Speed of porous meteorites versus altitude for various gravity-free perigee distances.

ability of occurrence of such natural satellites is quite dependent upon the magnitude of the drag coefficient. Thus, the inclusion of the transitional-flow correction in the analysis becomes extremely significant. Investigation of the Canadian fireball procession of 9 February 1913 (*4*) is now under way in order to determine whether or not those fireballs were natural, ephemeral, meteoritic satellites of the earth (*5*).

ROBERT M. L. BAKER, JR.
Aeronutronic Systems, Glendale, California

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2. A meteoritic "dust-ball" or "stone-flake" might, however, be fragmented during such a deceleration.
3. The curves, in other words, are drawn for different distances of closest meteoritic approach to the earth's surface.
4. A. D. Mebane, "Observations of the great fireball procession of 1913, February 9, made in the United States," *Meteoritics* 1, No. 4, 405 (1956).
5. It is noteworthy that F. L. Whipple, in a personal communication (8 Mar. 1957), mentioned the possible observational evidence of an ephemeral, natural, meteoritic satellite. I wish to acknowledge the many helpful criticisms and suggestions of Professors Frederick C. Leonard and Samuel Herrick, of the department of astronomy, University of California, in connection with this report.

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Semiquantitative Evaluation of the Gram Reaction

The Gram reaction is a special staining procedure applied especially to bacteria and certain other microorganisms. Essentially the technique consists of applying the dye, crystal violet, to a smear or tissue section, and then applying an aqueous iodine-potassium iodide solution. Subsequent washing with ethanol removes the dye-iodine complex from some species of bacteria (called Gram-negative) but does not remove it from others (called Gram-positive) during the customary time of application, 30 to 60 seconds. A counterstain of a contrasting dye, usually safranin, is then applied to color the Gram-negative cells and make them visible under the microscope. Since this procedure results in a dichotomous separation, it is one of the first and most important steps in the identification of bacteria and in diagnosis of bacterial diseases. The Gram reaction is also correlated with numerous physiological characteristics of the bacteria, particularly their sensitivity to various chemotherapeutic agents.

The advantages of a quantitative determination of the Gram reaction would be substantial and could possibly eliminate other more tedious steps in identification. Bartholomew and Mittwer (*1*) have discussed early methods for obtaining quantitative data which were based chiefly on microscopic examination of many hundreds of individual bacterial cells after various periods of time in the alcohol decolorization step. More recently, Barbaro and Kennedy (*2*) have described a different technique based on micro-Kjeldahl analysis of reagents and cells, but various difficulties in the interpretation of results have been pointed out by Bartholomew and Finkelstein (*3*). The quantitative Gram reaction techniques presented to date have been useful for research purposes and have yielded valuable data; however they are so time-consuming that they have never been adopted for routine use. The data do show that Gram-stained bacteria are all decolorized by alcohol if the latter is applied for a sufficiently long time. Thus Gram positivity can be measured as an inverse function of decolorization time, and all bacteria lie somewhere on a scale between the most Gram-negative and the most Gram-positive.

The present investigation uses the techniques of filter-paper chromatography to determine directly the relative Gram positivity of various species of bacteria (*4*). Bacteria were harvested, suspended in distilled water, and stained 1 minute with 0.1 percent crystal violet while in suspension. The stained cells were centrifuged, washed with distilled water, and recentrifuged (*5*). Lugol's iodine was applied to the cells for 1 minute, and they were again centrifuged and washed with distilled water. Small amounts of stained cell suspensions were applied as spots to Whatman No. 1 filter paper as in standard paper chromatographic techniques. The paper was then placed in a chromatography jar, dipping into 95 percent ethanol. The alcohol was permitted to ascend by capillarity, passing over the spots of stained bacteria. The dye was extracted from the stained cells in proportion to the time of contact with the continually fresh alcohol passing over the cells. This time was usually 6 to 8 hours, but sometimes overnight in the case of exceptionally Gram-positive cells.

This procedure resulted in streaks of dye which varied in length depending upon the Gram positivity of the strain of bacteria, the most Gram-positive species showing the longest streaks, as is shown in Fig. 1. Gram-negative bacteria which are very close to each other with respect to length of streaks could be compared by use of a slower-acting solvent such as propanol for 2 or 3 hours. Similarly, acetone or other fast-acting solvents could decrease the time required to obtain a comparison of a group of exceptionally Gram-positive bacteria. In any case, a direct, simultaneous comparison of several species or strains can be obtained. The filter papers can be dried and kept as permanent records. A typical series of results showed the following species to be arranged in an ascending order of Gram positivity: *Serratia marcescens, Pseudomonas aeruginosa, Escherichia coli, Neisseria catarrhalis, Bacillus subtilis, Saccharomyces cerevisiae, Staphylococcus aureus.*

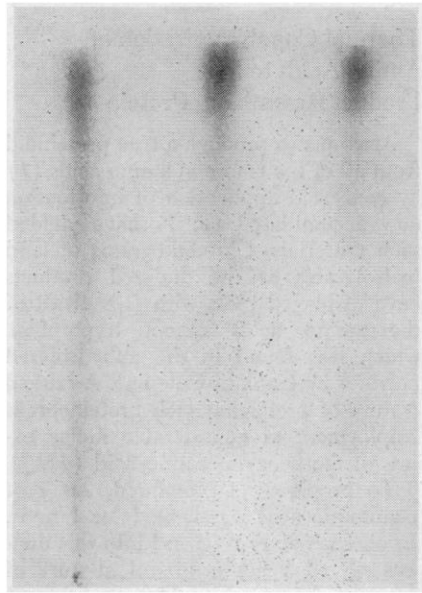

Fig. 1. Comparison of three species (left to right, *Staphylococcus aureus, Escherichia coli, Serratia marcescens*) of bacteria by the method described in the text. The top edge of the streaks represents the solvent front. Note that *Escherichia coli* and *Serratia marcescens,* although both are de-can be dried and kept as permanent scribed as Gram-negative, are not of equal Gram positivity.

Absolute numerical parameters based upon Gram positivity cannot yet be assigned to bacteria. The streaks on filter paper can be measured as to length, dye content, and in other ways; but numerous factors affecting the Gram reaction (*1*), such as age of culture, culture medium, fixation methods, and temperature, have not yet been evaluated with this new technique. It is expected that complete standardization of all necessary details will require additional time.

TOD MITTWER
Bacteriology Department, University of Southern California, Los Angeles

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4. This investigation was supported by research grant E-1329 from the National Institute of Allergy and Infectious Diseases, U.S. Public Health Service.
5. This washing step must be standardized and kept as brief as possible, since it exerts a strong influence on the results of the Gram reaction [J. W. Bartholomew and H. Finkelstein, *J. Bacteriol* 75, 77 (1958)].

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