plied both to the Ising model and to the more realistic Heisenberg model, to ferromagnetic, antiferromagnetic, and spiral spin structures, and to transitions between these structures.

A regular feature of these conferences is the exhibits, in which manufacturers of materials and apparatus display and explain their offerings. Another feature is the distribution of the *Magnetic Materials Digest*; the current issue summarizes, in connected and organized sequence, the publications in magnetism—1777 in all—for 1963 (M. W. Lads Co., 46 South 40 Street, Philadelphia, $6). The proceedings of the conference itself will be published in a separate issue of the *Journal of Applied Physics* in the spring of 1965 (American Institute of Physics, $5). The A.I.P. and the Institute of Electrical and Electronics Engineers are the joint sponsors of these conferences.

The number of registrants was 747, with at least six foreign countries represented—despite the recency of the International Conference on Magnetism at Nottingham in September. Having been abroad during the preparations for this conference, I can without immodesty commend the excellent work of the local committee, headed by R. J. Prosen. This was a very successful decennial. The first conference of the second decade is scheduled for 15–18 November 1965, in San Francisco.

WILLIAM FULLER BROWN, JR.
University of Minnesota, Minneapolis

Space Vehicles in an Ionized Medium

An exciting set of problems which do not usually receive much public attention were discussed at a symposium on the interaction of space vehicles in an ionized medium which was organized as part of the 15th International Astronautical Congress held in Warsaw during the week of 6 September 1964.

In his introduction, S. F. Singer, chairman of the symposium, considered the interactions between bodies and ionized gases. On the one hand, the body itself will acquire an electric charge by the accretion of ions and electrons from the plasma. This phenomenon is further complicated by the presence of a magnetic field and by the environment of solar ultraviolet photons and high-energy charged particles. Because of its electric charge, the body will undergo momentum exchanges with the plasma particles, the summation of which produces a drag force which may be termed a coulomb drag. Such drag forces may have important dynamical effects on the trajectories of small bodies, such as cosmic dust particles.

On the other hand, the plasma is disturbed by the passage of the body, which produces wakes whose character depends on the characteristics of the plasma and the presence of the magnetic field; magnetohydrodynamic effects may occur with wave propagation initiated by the interaction. Such effects are of great interest, as is their detection by direct measurements or by indirect radio propagation studies.

The phenomena involved in the interaction between a charged body and the plasma are of interest both for pure science and for engineering. The local disturbance of the plasma affects the usefulness of a satellite for making measurements on the ambient plasma; it affects the operation of various types of plasma probes, langmuir probes, and impedance probes, the operation of antennas at certain frequencies, and the propagation of radio waves generally. The coulomb drag may affect the orbit and the lifetime of a satellite, and the coulomb interaction can also give rise to torques which can change the orientation of a body operating in the space environment. As another application of electric charging, in the operation of ion propulsion engines, great care must be taken that the potential of the body does not rise to too high a level. Finally, Singer mentioned a whole range of effects which relate to the production of plasma clouds by a charged body moving through the outer ionosphere.

The first paper, presented by Marcel Nicolet (Space Research Center, Belgium), reviewed the ionized gas environment of the earth. The problem is closely linked to the problem of neutral particles in the upper atmosphere. The ion production depends, in normal conditions, upon the solar ultraviolet radiation. The photoelectrons produced have energies clearly greater than those of the atmospheric surroundings, and the distribution of ions with altitude depends at the same time upon the ionic temperature and the electronic temperature.

It must be pointed out that it is not possible to consider only one model of ionospheric distribution, because the solar conditions are extremely variable in the course of an 11-year cycle. Solar activity considerably modifies the distribution of ions, of oxygen, helium, and hydrogen; temperature variations from 2500°K to 750°K occur in the outer ionosphere. At the lowest temperature hydrogen becomes almost immediately the most important constituent in the exosphere, while at the highest temperature oxygen prevails up to considerable altitudes. Because of these variations it is not always possible to consider conditions of equilibrium. This is particularly true during rapid changes of temperature which are associated with perturbations of the earth's magnetic field.

A paper closely related but restricted more narrowly to the topic of the distribution of neutral hydrogen in the exosphere was presented by W. G. Kurt (Sternberg Astronomical Observatory, Moscow). Kurt described a new set of observations taken from a Soviet space probe by means of a Lyman alpha scattering experiment with a photometer. He has been able to deduce the altitude variation of neutral hydrogen. This paper, which showed a rather slow fall-off of the hydrogen density at a distance of four to five earth radii, provoked a great deal of discussion relating to the experiment itself and to the model calculations which were carried out to explain the observed results. No final determination was reached, however, and full publication of the results must be awaited.

A detailed account of the electric charging process which determines the potential of a body moving in a space environment was presented by K. P. Chopra (Melpar, Falls Church, Va.). Chopra also was concerned with the thermionic and photoelectric screening of electric charge on a metallic object moving in an ionized medium. He described (i) the estimate of the electric charge established on the object's surface through the processes of accretion of electrons and ions from the ionized medium and emission of electrons (thermionic and photoelectric) from the object's surface; (ii) the determination of the resulting screening electron density distribution; and (iii) the electric field distribution in the vicinity of the object. The analysis was based on the dynamical laws of the motion of electrons and ions in the electric field of the object. Analytical expressions were presented for the case of a spherical object of any radius R for the steady-state conditions established through the balance of the electron- and ion-accretion currents (electron emission being neglected), the plasma accretion current and the thermoelectron escape current (photoelectron emission being neglected), and the plasma accretion current and the photoelectron escape current (thermionic emission being neglected). Both the situations of stationary and moving objects were considered; but the effects attributable to the magnetic field are neglected.

Discussion of the paper centered mainly about the assumptions concerning the physical parameters of the surface, the work function, the photoelectric yield, and so on, and the sensitivity of the conclusions to the assumed values of these parameters. Discussion was also concerned with which portions of the solar spectrum would then be most effective in determining the final charge of the body. It turns out that this depends in a crucial way not only upon the parameters but also upon the electron density of the plasma in which the body moves.

The rest of the papers were concerned with the effects of the bodies on the plasma itself.

I. Shkarofsky (RCA, Montreal) described some of his laboratory experiments to simulate the kinds of disturbances which bodies moving through a plasma might set up and also other geophysical interactions. He described his experimental set-up and discussed the scaling laws which are pertinent. An example of a simulation which is in the range of his equipment is that of the earth as a magnetized dipole body in the plasma of the solar wind; the interplanetary magnetic field here is assumed to be zero. In the case of satellites, he would like to be able to simulate the conditions existing in the front sheath and in the wake structure, both with and without an external magnetic field parallel to the direction of motion.

Laboratory simulation was also discussed by R. N. Cox (Royal Armament Research and Development Establishment, Fort Halstead, England). He pointed out that these studies are of practical importance because the redistribution of plasma particles about a body moving through the ionosphere can have a large influence on radiowave propagation near the body and on the interpretation of experiments from probes mounted on the body. He discussed the three different flow regions which depend upon the relative sizes of the charged-particle and neutral-particle mean free path, and a typical body dimension. For each of the three regions, the qualitative nature of the flow can be discussed and, to a certain extent, simulated in the laboratory. The velocities of bodies considered are those in which a satellite's velocity is greater than the ion velocity but considerably smaller than the plasma electron velocity.

Cox was particularly interested in observing ion shock waves ahead of the body, but the langmuir probes used to measure the densities showed no positive evidence of them ahead of the body. (The ion Mach number in these experiments was 1.4.) No ready explanation has yet been found for these results, and work is continuing with a view toward achieving larger values of the Mach number.

The next papers dealt with theoretical investigations of supersonic motion of a body in a plasma. A detailed account of the problem was presented by A. V. Gurevich of the Lebedev Institute of Physics in Moscow and L. P. Pitaevsky of the (Kapitza) Institute for Physical Problems, Moscow, They presented the special case of a large body, that is, a body whose linear dimensions are many times greater than the Debye length. They were able to reduce the system of equations to a single nondimensional equation which did not contain either linear dimensions or velocity of the body and thus expressed a similarity law for the interactions discussed. They tried to describe the complete distribution of electrons and ions both near the body and at large distances from the body. They found that they could not neglect the thermal velocities of the ions; otherwise, they would obtain infinite concentrations near the Mach cone. Taking into account the ion thermal velocities gave finite values.

Particular cases have to be investigated by numerical methods. Pitaevsky presented a paper by Maslennikov and Sigov of the Mathematical Institute of the Academy of Sciences of the U.S.S.R., who have treated the case in which the size of the body is of the order of a Debye length. In these investigations, they assume that the electron density follows a Boltzmann distribution with respect to local values of the potential and investigate the distribution of ions in the vicinity of the body.

The density of plasma particles in the vicinity of a cylindrical body has been treated by A. M. Moskalenko of the Academy of Sciences of the U.S.S.R. with the help of the Boltzmann and Poisson equations. The cylinder is stationary with respect to the plasma but may have any size, much larger or much smaller than the Debye length. Both the density and the flux of the particles were calculated. This work was applied in establishing probe characteristics in rarified plasmas.

Another paper by Moskalenko discussed probe characteristics in the case of artificial satellites. Here the probe is moving with respect to the plasma. He considered the case of a probe which is much smaller than the Debye length. Expressions are obtained for the total particle current and for the concentration of particles in the vicinity of the probe.

Workers from the different laboratories expressed some differences of opinion about the theoretical approaches and methods of calculations. The problem appears to center on whether one can ascribe to the Debye length a physical reality as an actual screening length or whether the screening has to be calculated in a self-consistent manner from the trajectories of the ions and electrons.

Nonlinear effects at high frequencies were considered in a paper by Gurevich and Pitaevsky which was entitled "Resonant ionospheric disturbances near the surface of satellite antennas." From previous work it was possible to obtain a distribution of the a-c electric field around an antenna as a function of frequency. If nonlinear effects are neglected, then with a given electric field E_0 on the surface, the electric field in the plasma will increase indefinitely as the frequency approaches the plasma frequency (resonance). Consideration of nonlinear effects limits the magnitude of this electric field but also introduces a kind of hysteresis; that is, more than one value of E may be possible for a given frequency. It is found that the width of the resonance curve depends on E_0, the amplitude of the field at the surface. It is also found that the amplitude of the electric field in the plasma undergoes spatial oscillations. When the frequency is very close to the plasma frequency, the period of these oscillations is proportional to $E_0^{-1/3}$.

This work represents an application of the linear effects of Landau damping. It is of obvious importance in analyzing the performance of the so-called resonance probes for measuring electron densities as well as for observing ionospheric plasma radiation.

The final paper, by S. F. Singer, was concerned almost entirely with dynamical effects caused by the electric charge of a body which moves through an ionized plasma. He first described methods for calculating the coulomb drag and gave a simple formula which applies to particles very much smaller than the Debye length. For large bodies, the coulomb drag is usually a small effect; however, for large bodies made out of screens, the coulomb drag can become very important in relation to radiation pressure drag and aerodynamic drag. For example, it can produce measurable torques on space vehicles with complicated antenna configurations. Conversely, the coulomb drag effect can be utilized to orient vehicles in a direction parallel to the direction of motion.

For very small bodies, whether they are natural dust particles or artificial particles, such as the dipoles used in the West Ford project, the coulomb drag can produce important dynamical effects on the trajectory and orbits. Some of the applications are related to the capture of very small particles as they traverse the earth's magnetosphere; their hyperbolic orbits are changed into elliptic orbits which eventually contract into the earth's atmosphere. Other applications are related to the behavior of dust particles on the surface of the moon under the influence of the lunar electric field. A particularly interesting application establishes the maximum lifetime of dust particles in the earth's magnetosphere. It can be shown in this way that particles ejected from the surface of the moon cannot form an appreciable component of gravitationally trapped material in the earth's vicinity.

The symposium was sponsored jointly by the International Academy of Astronautics, the International Astronautical Federation, and UNESCO. It was regrettable that many workers from the Soviet Union and the United States who are interested in this field were unable to attend. Nevertheless, this first international symposium was indicative of the great interest which exists among scientists everywhere in discussing a subject which has both fundamentally interesting aspects and widely ranging applications. The proceedings will be published by Springer Verlag, Vienna.

S. FRED SINGER

University of Miami, Coral Gables, Florida 33124

Radio Meteorology

A conference covering radio meteorology and weather radar was held at the National Bureau of Standards Boulder (Colorado) Laboratories 14–18 September 1964. It was organized somewhat differently from the usual conference; a proceedings volume containing all accepted papers was printed in advance, and the papers were not presented orally at the conference. Instead, it was expected that the papers would be studied before the meeting so that they could be discussed during their scheduled session. By this method the Conference Committee sought to encourage the free presentation of ideas and more effective communication between scientists, leading to constructive discussions of radio meteorological problems. Lead speakers at each of the sessions presented review papers and introduced the discussion of new developments reported in the contributed papers. In this way, the new ideas contained in the papers were digested and presented in a short period of time, leaving most of the session for the discussion of the topics under consideration. This method of operation for the most part worked extremely well and, except for a few instances in which the conference participants had not done their homework, resulted in participation in the discussions of almost the entire assembly of over 300 scientists and engineers, 32 of whom were from outside the western hemisphere.

Discussions on anomalous echoes and angels centered on the controversy which has raged for some years as to whether unidentifiable radar targets (angels) may arise from inhomogeneities in the atmosphere or from birds or insects. It is suggested that certain atmospheric regions associated with angels are attractive to birds or attractive to insects which in turn can attract birds. At the same time much of the evidence for the absence of wildlife from angel targets has been weak. J. S. Marshall (McGill University) suspects that a great majority of the debated targets are biological. Only a minority of the meeting appeared to hold that extreme view; most would agree that some measure of confusion exists. The majority found merit in David Atlas's thesis picturing an angel as a marked refractive index gradient across an extensive near-spherical surface.

Quite apart from arguments about angels, bird watching by radar was discussed as an important item for scientific observation which can be reasonably undertaken by radio meteorologists. Bird migration is related to the weather and a great and important opportunity offers itself to learn more about that relation. The importance to aviation of a knowledge of where and when the birds fly can provide practical justification for studies in this area. This was pointed up during the regular session and additionally by William W. H. Gunn, Canadian ornithologist, who provided the commentary for the showing of the Marconi Company's time lapse film of birds on a PPI radar display. This information was greatly extended by E. W. Houghton (Royal Radar Establishment, United Kingdom) in his paper in the *Proceedings*.

Discussions on radio climatology and meteorological effects on propagation were concerned with attempts to establish quantitative correlations of radio signal strengths and fading frequencies over a variety of paths with meteorological conditions as observed by radiosonde and refractometer. No new principles were disclosed, but some hope appeared that a useful degree of forecasting of transmission conditions could be achieved with easily observed meteorological parameters. The importance of performing radio meteorological experiments in well understood radio meteorological conditions and the inadequacy of simple meteorological models on a great majority of occasions were pointed out.

Reports on the relative merits of various systems for locating sferics positions dealt with the later stages of thunderstorms and, in particular, the existence of lightning in the decaying stage of a thunderstorm. The interrelation of source, propagation, and frequency factors in the radio noise observed from a thunderstorm was also discussed. It was pointed out that the observed distribution with frequency of radio noise did not necessarily imply a corresponding distribution at the source.

Certain physical facts, which impose limitations on the measurement by radar of rainfall and drop-size distribution, include the presence of a bright band, beam filling factors, and, particularly, the uncertainty of the radar reflectivity of rainfall. The last, the Z/R relationship, continues to be studied as described in some of the papers. Much of the uncertainty in current attempts to relate rainfall to radar