Research and Prelim. Engineering
Space Vehicle Program

General Objectives:

In the following outlines of fundamental research, specific details have been referred to for the purpose of imparting a clear understanding of the nature of the proposed investigations. These preliminary outlines should not be construed as limiting the scope or delineating special interest. The goal of the project is a carefully integrated and adequately financed study of gravitation, embracing every relationship between gravitation and electrodynamics.

It is to be remarked that the problem of relating gravitation to electrodynamics and the quantum theory is one which has taxed the ingenuity of some of the best mathematical brains for the last 30 years. So for, no very complete or satisfactory resolution of the matter has been found. Yet we are not completely in the dark with regard to it and the situation today is far from discouraging.

The so-called "red-shift" produced by gravitation, and even the deviation of light by stars, are phenomena which are concerned with a relationship between gravitation and electrodynamics. Even though they are cosmological in extent, the magnitudes of these phenomena are small.

Effects recently discovered in massive dielectrics point to the existence of hitherto unsuspected gravitational relationships and appear to have brought the matter for the first time into the realm of terrestrial experimentation.

No one can deny the possibility that, as a result of this and other discoveries, a concept may result which so revolutionizes all our previous thoughts on gravity, electrodynamics and quantum theory as to render the story of the inter-relations of these fields one of consistency and satisfaction. No one can deny that such inter-relationships would have very profound significance.

Such a program as herein outlined is necessarily of long-range. Unquestionably, there will be found many productive avenues of exploration which cannot be described in detail or even foreseen at the present time.

Policy:

The project must adopt a policy of inviting assistance from able physicists interested in the special problems involved. It must not fail to take into account and investigate any phenomena which bears even remotely upon the subject.

For example, in the study of physical properties of dielectrics, low-temperature research may be highly fruitful. Electrodynamic phenomena occur at low-temperatures which are completely unknown at room temperature. The possibilities of discovering wholly unsuspected gravitational effects below the superconductivity threshold, at temperatures approaching absolute zero, appear to be worth the costs involved.

Library:

The establishment of an adequate reference library on gravitation and related subjects, for the accumulation of technical information and to serve as liaison with academic institutions throughout the world, is a requirement of utmost importance particularly at the beginning of the program.

Highest Priority:

No one can guarantee results in research. No one can predict the direction the research will take. It is the express purpose of this project to obtain the technical answers as rapidly as possible by forming a coordinated program in which the best minds and all necessary laboratory facilities are brought together. It is the sincere hope that, in this way, a century of normal evolution in science, especially toward a better understanding of the nature of gravitation, may be compressed into from 5 to 10 years.

Such a program is expensive but, as it was with the atomic bomb project in America, money was traded to gain a far more valuable commodity - time. So it may also be with man's ultimate conquest of space. As a necessary and inevitable prerequisite, a concerted study of gravitation is clearly indicated. We are forced to the conclusion that a research program organized specifically for this purpose can no longer be neglected.

The Trouton-Noble Experiment (with massive dielectrics):

The experiment concerns itself with an electromagnetic torque operating on a charged condenser which moves with uniform velocity in a direction inclined to the normal of its surface. According to the theory of relativity, compensating effects, in this case having to do with the effect of the dielectric materials in the condenser on the torque aforesaid.

In the days before universal acceptance of the theory of relativity, there was a reason to believe that measurements of the rotation of such a condenser as the above, when supported by some suspension, would serve to determine the velocity of the earth's motion through space.

If, for a moment, we put ourselves in the mind of one who does not accept the theory of relativity in its entirety or wishes to test its validity further, the torque described above and possible rotation resulting from it becomes matters of experimental interest. A situation of great interest centers around the effect of the dielectric materials in the condenser on the torque.

Now it appears that the original calculation of the torque is completely erroneous; and it appears that if the torque had been calculated correctly, invoking the same fundamental principles as were invoked in the earlier calculations, it would have been found to depend only upon the potential difference between the plates of the condenser and to be independent of the dielectric constant.

However, a more refined analysis of the situation, which does not simply average the properties of the polarized molecules into a representation in terms of a dielectric constant, reveals that there may be a contribution to the torque which depends on the nature of the molecular dipoles, and in a manner which is not expressible in terms of the dielectric constant.

The above conclusions were reached by Kennard and Swann independently by different processes of mathematical analysis. They have rendered the Trouton-Noble experiment one of considerable interest to a person who had any doubts about the theory of relativity, and the interest would be enhanced by the bearing of the nature of the dielectric material upon the outcome of the experiment.

Mass of the Electrons in Metals:

This experiment has to do with the observations of momentum in a ring of conducting material carrying a current at the instant when the material is carried from the super-conducting to the non-superconducting state.

Briefly, the above experiment envisages a metal ring in which a current of electricity has been produced by the creation of a magnetic field passing through the ring when all is at a temperature such that the super-conducting state prevails. Under such conditions, the current will continue practically indefinitely.

If we now raise the temperature, the super-conductivity will disappear at a certain critical temperature, and the annular momentum of the electric current will be shared with the ordinary material of the ring in such a way as to give an angular rotation to the latter. The ring is, of course, to be envisaged as supported by a suspension and the angular rotation observed will depend upon the stiffness of this suspension. An interesting feature of the experiment lies in the fact that the sensitivity is greatest when the cross-section of the wire of the ring is smallest. The limiting conditions which determine the ultimate sensitivity are based upon the requirement that when the energy of the current is dissipated and the metal of the ring passes through the super-conducting state, the heat evolved shall not be sufficient to burn up the apparatus.

The fundamental theoretical interest of the experiment lies in the fact that the angular rotation obtained depends upon the electronic mass, and theoretical considerations have been presented to support the belief that this electronic mass may be different for the electrons in a metal than for the electrons in a free state.

Most authorities on quantum theory are of the opinion that the effective mass of the electron in a metal is the same as that for an electron in a free state. However, even those who support this view are in favor of performing the experiment because of the complexity of the theoretical considerations involved.

The most fundamental requirement is, of course, a means of producing liquid helium, and this implies a cryostat. If a cryostat were obtained, the potentialities of an enormous amount of other work in solid state physics would be provided for.

Investigation of High-K Dielectrics at Low Temperatures:

Research in solid state phenomena with special relation to dielectrics of high-K is of great current interest. Investigation of the properties of substances of high-K should be made in the realms of breakdown resistance, ferro-electrets, hysteresis, and allied phenomena. Special interest attaches also to the characteristics of electrets as such and to the conditions necessary to secure high activity of such electrets over long periods of time.

In all the foregoing work, low temperature researches involving the cryostat would be of fundamental importance; for although the dielectrics are not usually used at low temperatures, many of the characteristics which determine their behavior at ordinary temperatures can be examined more readily by experiments performed at low temperatures.

A survey of the literature on low temperature phenomena shows a large amount of work which has been carried out on the properties of paramagnetic salts, whereas the properties of dielectric materials have hardly been investigated at all. The reasons for this difference in emphasis are essentially understood. At liquid helium temperatures, the system of magnetic moments in most of the common paramagnetic salts is still in a thermally disordered state so that its magnetic properties are still varying with temperature in an interesting fashion.

In addition, since the technique of adiabatic demagnetization of a paramagnetic salt is the sole means, at the present time, of producing temperatures well below 1^{o}K, it is only natural that a great amount of effort has been spent in the elucidation of the properties of these materials.

Most normal dielectric materials show a negligible variation of their dielectric properties with temperature, especially in the liquid helium region. This may be seen by looking at the main sources of polarization in a dielectric, namely:

1. The electric polarizability, which arises from the fact that the outer electrons of an atom can be displaced with respect to the nucleus by an external electric filed thereby creating a dipole moment. This is a property of the particular atom under consideration and is independent of temperature.

2. The ionic polarizability, arising from the displacement of positive ions with respect to negative ions in an ionic crystal. In most materials, this type of polarizability varies only very slowly with temperature, leading to a slight variation of dielectric constant with temperature. That this is not always the case is the reason for the present proposal.

3. Polarization due to the alignment of molecules with permanent dipole moments. In solids where the molecule is not free to rotate, this effect is absent.

In recent years, a number of ferroelectric compounds have been discovered which are practically completely analogous in their dielectric behavior to ferromagnetic materials. Thus they show a Curie temperature, above which the dielectric constant follows a Curie-Weiss law and below which they exhibit spontaneous electrical polarization and hysteresis properties. Barium titanate

($BaTiO_3$) is the best known of these compounds. Most of these compounds have Curies temperatures which are fairly high. Two compounds are known which have very low Curie temperatures. These are Potassium Tartrate ($KTiO_3$) and Lithium Thallium Tartrate ($LiTiC_4H_40_6.H_20$ with Curie temperatures at 13.2^{o}K and 10^{o}K respectively. The existence of these very low Curie temperatures has created an additional interest in the study of dielectrics at the low temperatures obtainable with a Collins Helium cryostat.

In addition to the intrinsic value of a program on the properties of dielectrics at low temperatures, it is conceivable that it might be possible to provide another means of producing temperatures lower than 1^{o}K other than adiabatic demagnetization. If one had a ferroelectricmaterial with a Curie temperature well below 1^{o}K, then by the adiabatic, reversible depolarization of the material, it should be possible to produce a cooling effect (electro-caloric effect). since the equipment involved in this process is somewhat simpler than in the corresponding magnetic case, it would be of considerable interest to investigate its feasibility. This method is not applicable below the Curie temperature since the presence of hysteresis and spontaneous polarization introduces irreversible heating effects upon applying or removing an external electric field.

The Curie temperature of $BaTiO_3$ can be decreased by reducing the lattice parameter either by the addition of strontium or by application of external pressure. Presumably, this technique can be used to decrease the Curie temperature of $KTiO_3$ or $LiTiC_4H_40_6.H_20$. An understanding of the factors which influence the Curie temperature and of the range of Curie temperatures in different crystals is important for the development of a basic theory of ferroelectricity.

In summary, it appears that a program on the properties of dielectrics at low temperatures can contribute substantially to an understanding of solids. The starting point for this program should logically be an investigation of $KTiO_3$ and $LiTiC_4H_40_6.H_20$ as well as structurally similar crystals and their solid solutions with each other.

<u>Electromagnetic Equations for the Super-Conductive State</u>:

Among the many interesting phenomena which occur at low temperatures, superconductivity has long held the attention of experimentalist and theoretician alike since its discovery by H. Kammerlingh Onnes in 1911. With the discovery of the Meissner effect in 1933, the basic experimental behavior necessary for the development of an electrodynamic theory of super-conductivity has been established.

F. and H. London, in 1935, developed a set of equations which describe the macroscopic electrodynamic behavior of super-conductors in a quantitative manner to the present time. One experiment which would shed considerable light on the correctness of these equations has been suggested by F. London. This experiment involves a study of the magnetic properties of a rotating sphere. The theory of this experiment is worked out in complete detail by F. London. The following is a physical description of the nature of this experiment.

Consider a sphere of radius R. If we start with the sphere at rest below its super-conducting transition temperature and bring it into motion with uniform angular velocity (w), then by considering the super-conducting electrons are perfectly free it can be deduced that the sphere should become magnetized upon rotation. The reason for this is as follows:

> When the sphere is initially set into motion, the electrons - being perfectly free from interaction with the crystal lattice - will not move with the sphere, and a current is set up due to their relative motion. This changing current in turn induces an electric field within the sphere which acts on the electrons in such a manner as to accelerate them in the direction of rotation of the sphere. The final result is that when the sphere has reached a constant angular velocity the super-conducting electrons everywhere move with the sphere except for a narrow layer at the surface, where they lag behind slightly to produce a small current. This result was predicted on the basis of a free electron theory before the development of the theory of F. and H. London.

The London theory predicts the same result for the rotating sphere, except that it makes and additional prediction. F. London states that the rotating sphere will have a magnetic moment independent of the prehistory the sphere. In particular, if a rotating sphere is cooled below its transition temperature while rotating, the sphere will acquire the same magnetic moment as it would upon starting from rest below its transition temperature and being brought to the same angular velocity. On the basis of a free electron theory of super-conductivity, it is difficult to understand how a sphere which is already rotating will suddenly acquire a magnetic moment upon being cooled below its transition temperature. In this case, the electrons move with the sphere above the transition temperature due to their finite interaction with the lattice (finite resistance). That they should suddenly lag behind to produce a magnetic moment on cooing below the transition temperature seems surprising.

The magnetic moment predicted for the rotating sphere is small, but should be measurable with sufficiently careful experimental technique. This experiment would constitute a fundamental method of testing the basic assumptions of the London theory.