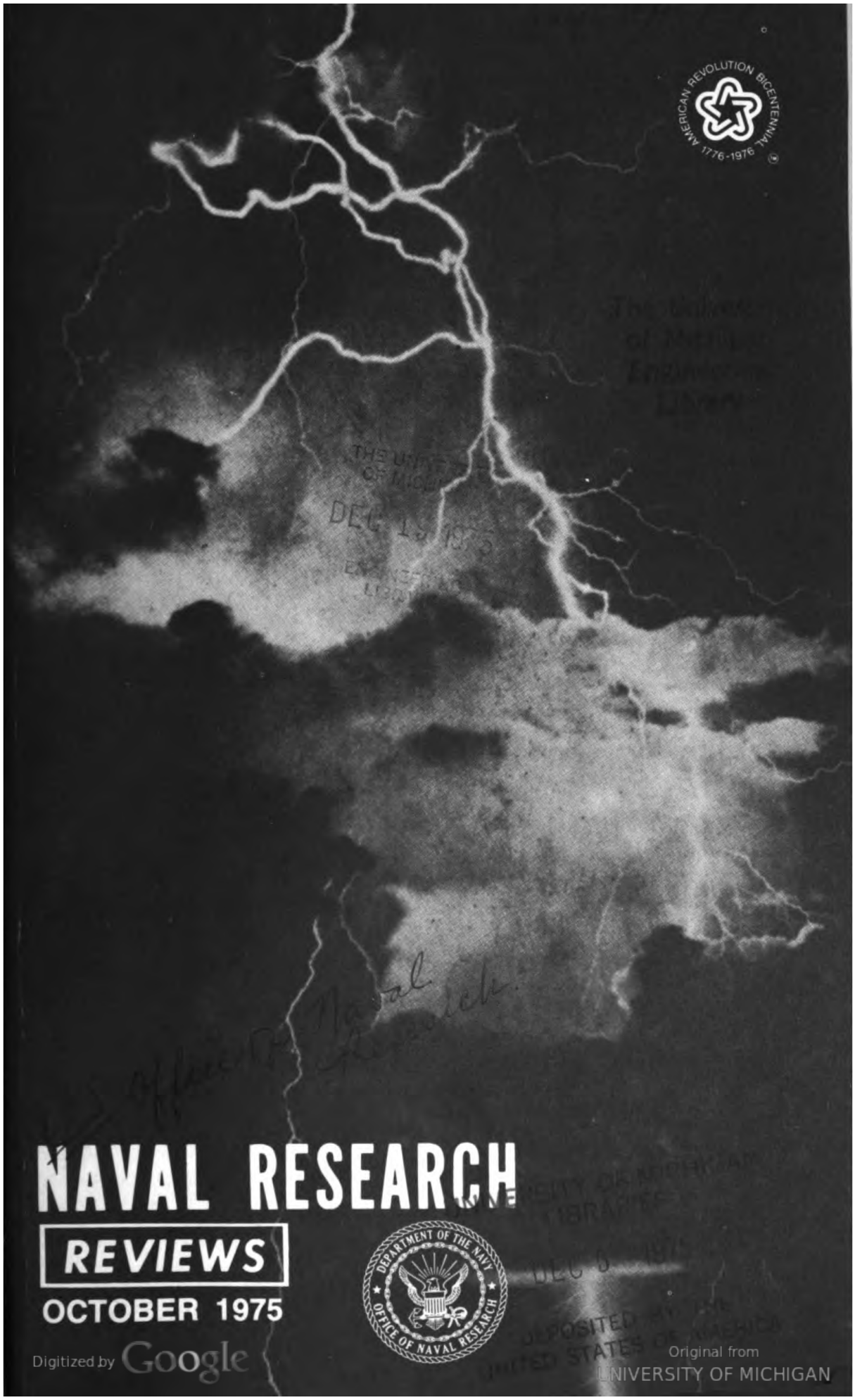

PROFILES IN SCIENCE

Dr. Edward T. Pierce

Dr. Edward T. Pierce is a Staff Scientist at Stanford Research Institute where his work has been supported by ONR for many years.

Dr. Pierce was born in Wales and received his doctorate from the University of Cambridge. He has a wide scientific background and has published extensively. The areas covered by his papers include astrophysics, gas discharge phenomena, meteorology, radio wave propagation and radio noise, and the geophysical effects of nuclear explosions; his research in this last area led to extensive testimony before Congressional Committees prior to the signing of the limited Test Ban Treaty.

Dr. Pierce has a special interest in atmospheric electricity and, in recognition of his significant contributions to this subject, was recently elected Honorary President of the International Commission on Atmospheric Electricity. Presently, he is particularly concerned with the hazards accompanying natural electrification processes; these hazards include lightning strikes to rockets and aircraft, and supertanker explosions.

From January through April 1975, Dr. Pierce – on leave-of-absence from SRI – served as the first scientist attached to the newly established ONR Scientific Liaison Group at the U.S. Embassy in Tokyo.

Lightning Research

R. D. Hill*

Introduction

Research into the nature of lightning has interacted with many other areas of science and technology. Many questions have been raised which still remain unanswered.

In the early 1930's, Brasch and Lange (1) stretched an insulated wire between two peaks in the Alps and from this wire suspended an outlet terminal by a conducting wire reaching almost to the ground of the valley below. During thunderstorms, high potentials would develop between the terminal and ground, and on occasions sparks of hundreds of feet would occur. Their plan was to harness the high potential for the acceleration of charged particles to be used in nuclear research. Unfortunately, the potentials derived from thunderclouds were sporadic and uncontrollable, and their experiments were abandoned when Lange was killed.

With the world energy shortage deepening in the present 1970's, we should possibly ask again whether energy from the clouds should not be tapped. In the classical text on "Physics of the Air," W. J. Humphreys estimated in 1940 that just one lightning flash "would be the equivalent of 14,000 horse power operating continuously for 24 hours, at a rate of working equivalent to 60 horse power for every man, woman and child on the face of the earth." We should perhaps look at this estimate again today for two reasons: (a) world population has doubled between 1940 and 1975, and (b) more reliable lightning information is available today.

Based on ONR sponsored research, one of the best estimates for the energy dissipated per unit length of channel in a single lightning stroke is 10^5 joule per meter, obtained by Krider, Dawson and Uman (2) in 1968. As the average length of a lightning stroke might be considered to be about 3 km, the average total energy per stroke is therefore 3×10^8 joules.

The duration of a lightning stroke, though highly variable from stroke to stroke, might be considered for the purpose of these estimates, to be on the average about 30 microseconds, so that the average power per stroke becomes approximately 10^{13} watts or $(4/3) \times 10^{10}$ horsepower. For a total world population of approximately 4 billion, the number of horsepower available per person per single lightning stroke is therefore estimated today to be about 3 h.p.

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*Dr. Hill, a consultant physicist, has a contract with ONR to work in the Atmospheric Sciences Program. He was formerly Professor of Physics at the University of Illinois.

As E. T. Pierce, who is an expert on global data pertaining to atmospheric electricity and who has just returned from Tokyo as the first ONR scientific officer in Japan, has estimated (3) there are approximately 100 lightning flashes per second continuously occurring around the world. Since there are, on the average, four strokes per lightning flash, the total global electrical energy dissipated by lightning per year is approximately 1 billion KWH, or the equivalent of approximately one fifth of the total world electric energy production (including nuclear power) in the early 1970's.

Although it is inconceivable that even a small part of the global lightning energy could be tapped, it must also be appreciated that lightning represents only a fraction of the electrical activity known to occur in clouds. If some technique could be developed for tapping the mechanism of charge separation in clouds it is conceivable that a new electrical energy resource would become available.

The Navy is investigating many aspects of lightning research for their immediate impact on technology. Such problems as: the protection of personnel and equipment from injury and damage by lightning, the prediction, location and modification of severe storms, the interference with communications and direction finding by lightning-generated noise and effects, are a few of the areas of interest to the Navy. There are also many research investigations bearing on the fundamental nature of lightning such as: the generation of charge centers in storm clouds, the nature of the breakdown mechanism in air of the lightning discharge, the generation of electromagnetic disturbances by lightning, etc., which will ultimately have important applications in the control of weather, the detection of storms, and possibly even on the harnessing of electrical energy in clouds. In the following review, we wish to address merely one aspect of lightning, viz; the nature of the lightning channel itself and the interaction of this knowledge with other areas of technology.

Destructive Power of Lightning

The destructive power of lightning arises from the high pressure generated in the lightning channel. In the open air, as already mentioned, the energy deposited by a single stroke of lightning is of the order of 10^5 joules per meter. This energy is the equivalent of approximately 22 gm of TNT per meter or approximately one-tenth of a ton of TNT for the whole channel. This amount of explosive, while significant, is usually not considered to be sufficient to catastrophically disable a hardened object. However, with such an intense explosive capability, it is of interest to understand why many objects struck by lightning are not more severely damaged than the actual statistics indicate. According to Robb (4), every commercial airliner in the U.S. experiences, once a

year, such a sufficiently severe lightning-stroke contact that it requires repair of damage before continuing in service.

An aircraft flying underneath a storm cloud is usually struck at one of its extremities such as: the pitot boom, the nose, empennage, or wing tip, *etc.* The reason for the lightning flash locating on the aircraft in this way is discussed in an earlier *Naval Research Review* by Brook, Holmes and Moore (5). In the present review, we will focus more on the damage aspect of the lightning channel.

As shown in Figure 1, the base of a storm cloud is normally negatively charged, and lightning current, largely negative electrons in the plasma channel, flows towards the positive induced charge on the surface of the sea. The lightning generating mechanism is of course located in the body of the storm cloud and is essentially an electromotive force. In some manner largely unknown, or if not unknown it is largely undecided (since there are at least four competing theories vying for acceptance) the lightning generator manages to continually separate positive and negative charges in the cloud. At some stage the potential between cloud and sea builds up to such an extent that breakdown of the intervening air occurs. We do not discuss the breakdown mechanism here, but focus on questions of the intense lightning-channel current, referred to usually as the return stroke.

It is found that in all flashes of any significance the aircraft acts only as an intermediary in the passage of the discharge between natural points. Moreover, the lightning track through, or rather over the skin of the aircraft generally occurs from one highly curved extremity to another, *e.g.* from empennage to wing tip. Other types of lightning than the cloud-to-ground stroke shown in Figure 1 do occur. In fact, flashes between neighboring clouds, and flashes intra-cloud, occur even more frequently and aircraft may be involved in these discharges also.

When an aircraft is a part of the lightning channel, the resistance of the electrical path along the metal fuselage is so low compared to the resistance of the path through the air that the total lightning current is essentially unaffected. In fact, the lightning current may be even slightly enhanced because the total resistance of path between cloud and sea is reduced. Since the total current in any section of the circuit is conserved, clearly the energy expended per unit length of path in the fuselage is related, at the most, to the current in the absence of the aircraft as the ratio of the resistivity of the fuselage material to the resistivity of the air. Since the resistivity of high temperature air in the plasma channel is, at a minimum, only of the order of 10^{-3} ohm-cm and the resistivity of aluminum is of the order of 3×10^{-6} ohm-cm over the range of temperatures encountered, it follows that the energy dissipated per unit length in the fuselage is only about 300 joules per meter, *i.e.* considerably less than 0.1 gm of TNT per meter. Actually, since the cross-sectional

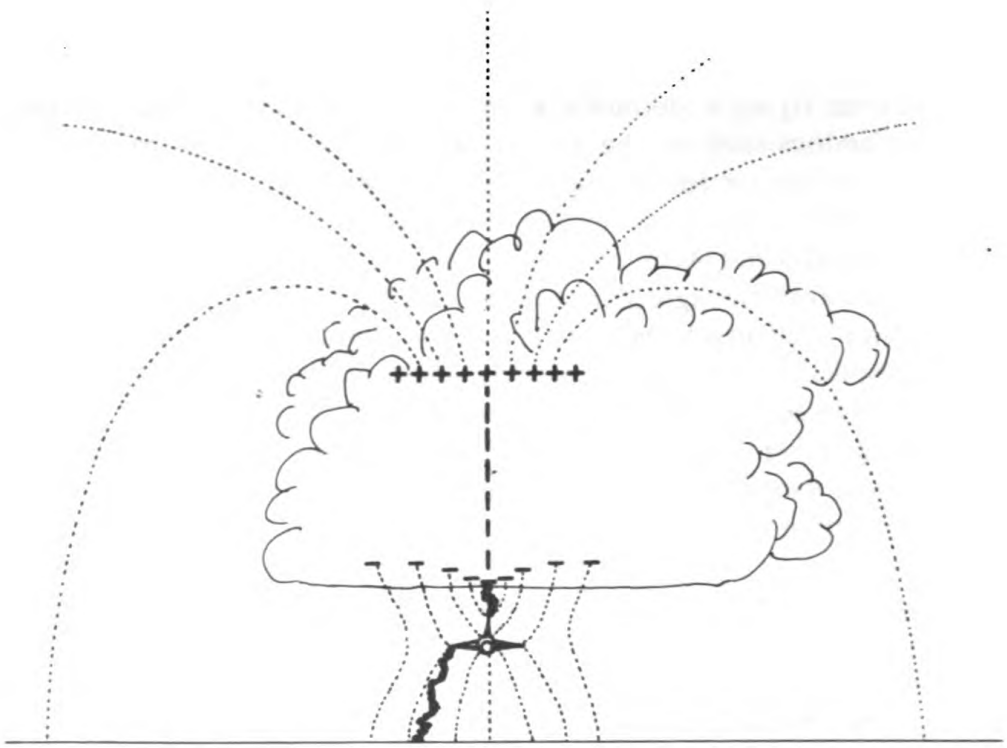


Figure 1 — Schematic drawing of electrical circuit when aircraft is struck by a lightning stroke. The lightning stroke is seen emerging from base of cloud to the tail of aircraft and emerging from wing tip in its passage to ground.

area of the conductor through which the current travels in the fuselage is undoubtedly much larger than the cross section of the lightning channel in the air, it is certain that the energy dissipation will be even considerably less than 0.1 gm TNT per meter.

Despite this low estimate of the explosive power of lightning in an aircraft fuselage, many instances of severe and catastrophic damage to aircraft are known. Damage has been attributed to the following types of interactions: (i) Direct stroke to radome and explosive rupture or complete removal. (ii) Direct stroke to pitot boom, explosion of pitot heater and possible removal of radome. (iii) Stroke to wing tip or to wing-tip light with subsequent explosion of wiring to light and possible removal of wing-tip section of fuselage. (iv) Stroke to flight control vane with consequent erratic aircraft motion. (v) Generation of high surface charge on dielectric windshield with subsequent shattering. (vi) Generation of surface charges and streamering on dielectric canopy with subsequent shocks to flight crew. (vii) Stroke to UHF antenna explodes wiring and causes transmission of high voltage disturbances to electronics. (viii) Stroke to engine inlet explodes de-icing circuits. (ix) Intense magnetic fields generated by currents, either internally or externally on the fuselage, causing disruption of magnetic compass and sensitive solid state

devices. (x) Sparking generated in the proximity of cavities containing fuel vapors. [The aircraft accident of a Pan Am Boeing 707 near Elkton, MD on Dec. 8, 1963 was attributed (6) to the ignition of combustible fumes at the fuel tank vent outlet by a lightning strike.] (xi) Trailing wire antennas are a prime lightning strike point. High voltage bushings allow ready access of high voltage transients to enter the aircraft, unless adequate protective measures are taken, following even low-current lightning activity.

An example of the damage to an aircraft of type (i) is shown in Figure 2 taken from a McDonnell-Douglas Aircraft Corporation report given by Amason *et al* (7) before the Lightning and Static Electricity Conference at Air Force Avionics Lab., Dec. 1972. The damage to a radome is clearly caused, in the first place, by a direct strike to the region of the dielectric material where a high concentration of charge has been induced by the lightning fields, and in the second place, by the explosive pressures built up by the passage of lightning current through a highly resistive dielectric material. Since it is essential that radomes should transmit electromagnetic radiations, it is necessary to design a shield which, although being a hydrodynamic barrier, is largely transparent to radar

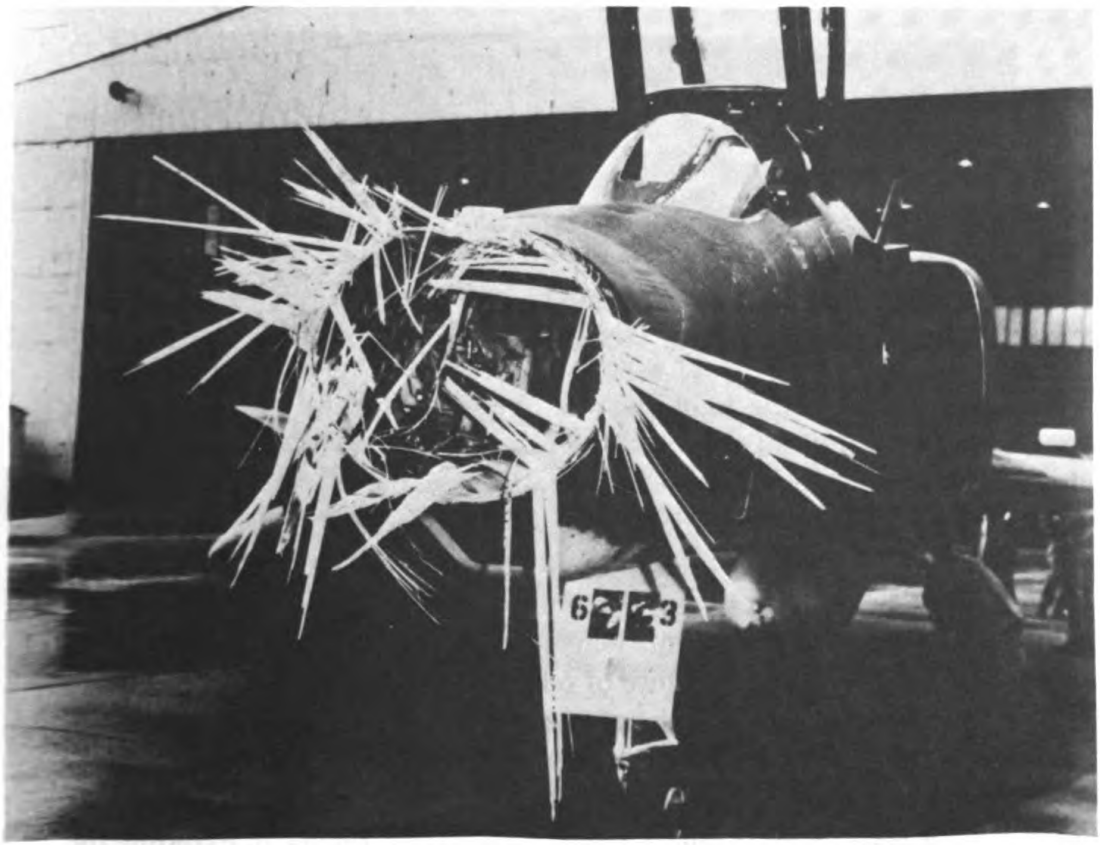


Figure 2 — Lightning damage to unprotected nose radome

wavelengths. A design of a pitot tube and radome for the Concorde, British-French aircraft is shown in Figure 3. This figure is taken from U. S. Patent No. 3,428,270 by J. R. Knight and J. Leworthy (8), assigned to the British Aircraft Corp.

A second example of aircraft damage of type (iii) is shown in Figure 4. This figure was taken from a report on the coordination of lightning and EMP protection by J. D. Robb (4) of the Lightning and Transients Research Institute. The explanation of the damage in this case is that a lightning stroke penetrated the wing-tip structure through a wing light. The current was conducted initially by the light wiring, before exploding the wires. The plasma channel created by the exploding wires still continued to conduct the lightning current and added to the explosive power of the high pressure lightning channel.

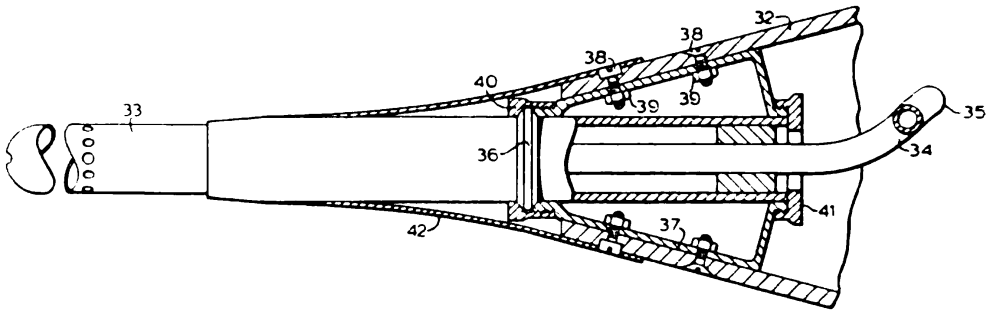
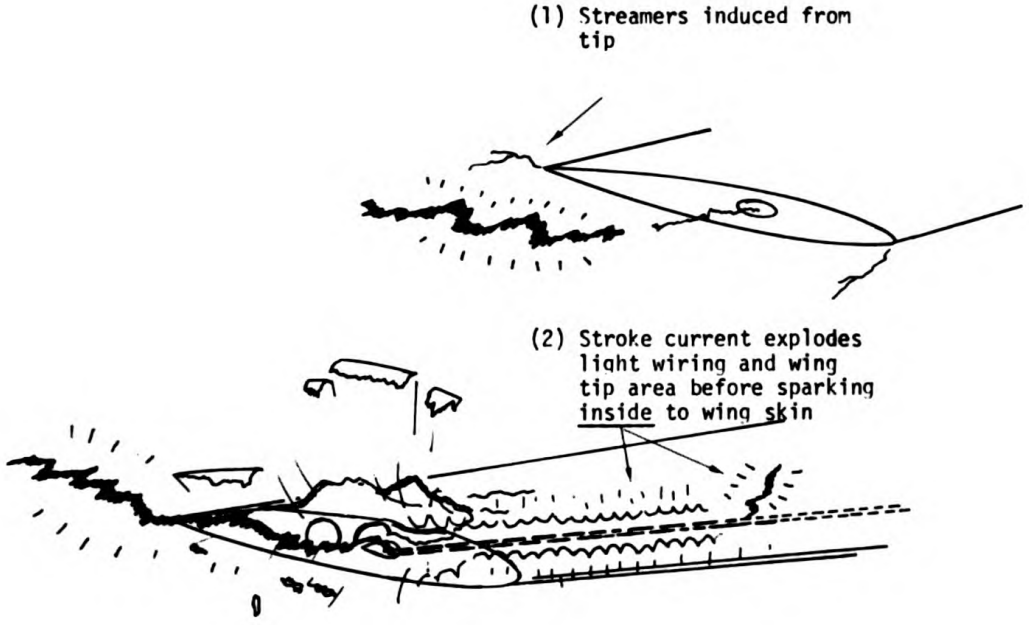


Figure 3 — Lightning conductor for Concorde Aircraft

Mention should also be made of the strikes that occurred to the Apollo 12 space vehicle on Nov. 14, 1969. Although no lightning had been observed in the vicinity of Cape Kennedy prior to launch, high electric potential gradients had been measured in the surrounding region. Subsequent analyses of the atmospheric electrical conditions by a number of research groups, several of which were associated with Navy programs (9-11), showed that the lightning was triggered by the presence of the long electrical length of the space vehicle and its exhaust plume. Breakdown of the electrical field, which would not otherwise have produced lightning, occurred through both the air and the vehicle.

Although a number of photographs of the lightning near the Apollo vehicle were taken, because of the obscuration by clouds, none actually recorded lightning striking the vehicle. However, Figure 5 shows an interesting all-sky camera picture of one of the lightning flashes emerging from the clouds in the vicinity of the vehicle plume which shows as a darker circular region towards the right of the field. By one of the strange vagaries of nature, often encountered in lightning phenomenology, the flash is also seen, in an ordinary camera picture in Figure 6, avoiding the 445 foot launch umbilical tower and striking the ground 100 feet away.



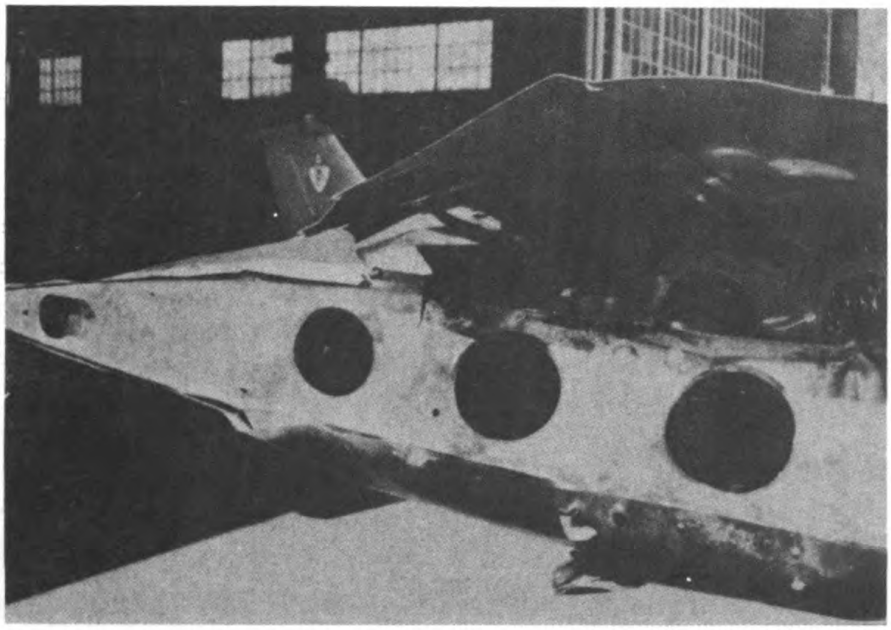


Figure 4 – Illustration of wing light explosion mechanism. Stroke punctures bulb and explodes light wiring to open up wing and blow off tip.

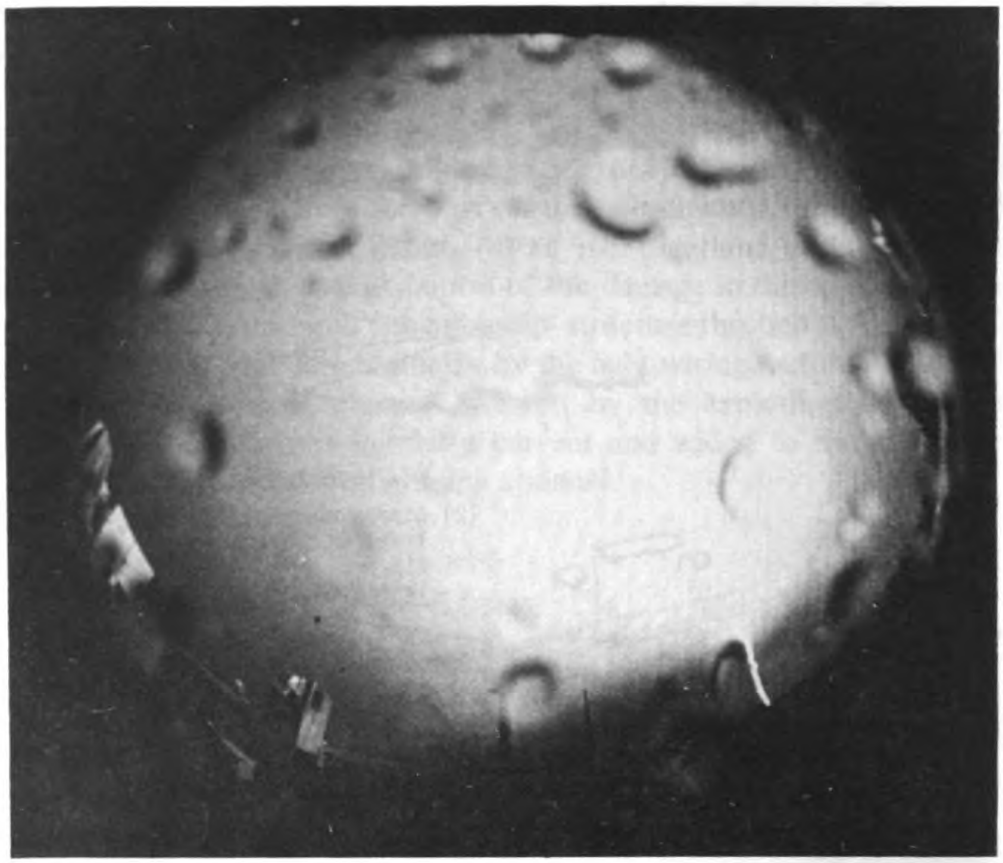


Figure 5 — All-sky camera shot of lightning stroke emerging from Apollo 12 plume below clouds. Base of plume can be seen as a bright circular region on right hand edge of picture from which lightning stroke is emerging. Small round circles on picture are rain drops on the lens.

Figure 6 — Photograph of same lightning stroke as in Figure 5. The structure to the left is the 445 foot launch unbilical tower. At this point 36 seconds after launch, the Apollo vehicle has an altitude of several thousand feet.

Lightning Pinch Forces

A curious effect is observed when lightning strikes a metal surface. A mound, or pip, of metal which has been melted by the lightning current is raised above the surface where the channel terminated. If the metal layer is thin and the heating is intense, such as in a very strong current discharge or alternatively in a protracted discharge called continuing-current lightning, the metal layer may be burned completely through. These effects are shown in Figures 7 and 8. When there is a strong aerodynamic flow over the surface, as when an aircraft skin is struck in flight, the molten pip is swept away and the surface may appear to be merely pitted. The fact that metal is raised from the surface into a very narrow conducting tube has been interpreted (12) as indicating that the plasma has been pinched into a channel, at least in the short region where it contacts the conducting metal surface.

The effect of magnetic pinch forces on metal objects struck by lightning has been known for at least 70 years. It had already been observed by this time that hollow metal conductors that carried intense lightning currents were collapsed. This phenomenon was first explained by two Australians, Pollock and Barraclough (13) in 1905 as due to the magnetic pressure from the parallel conducting linear elements in the cylindrical

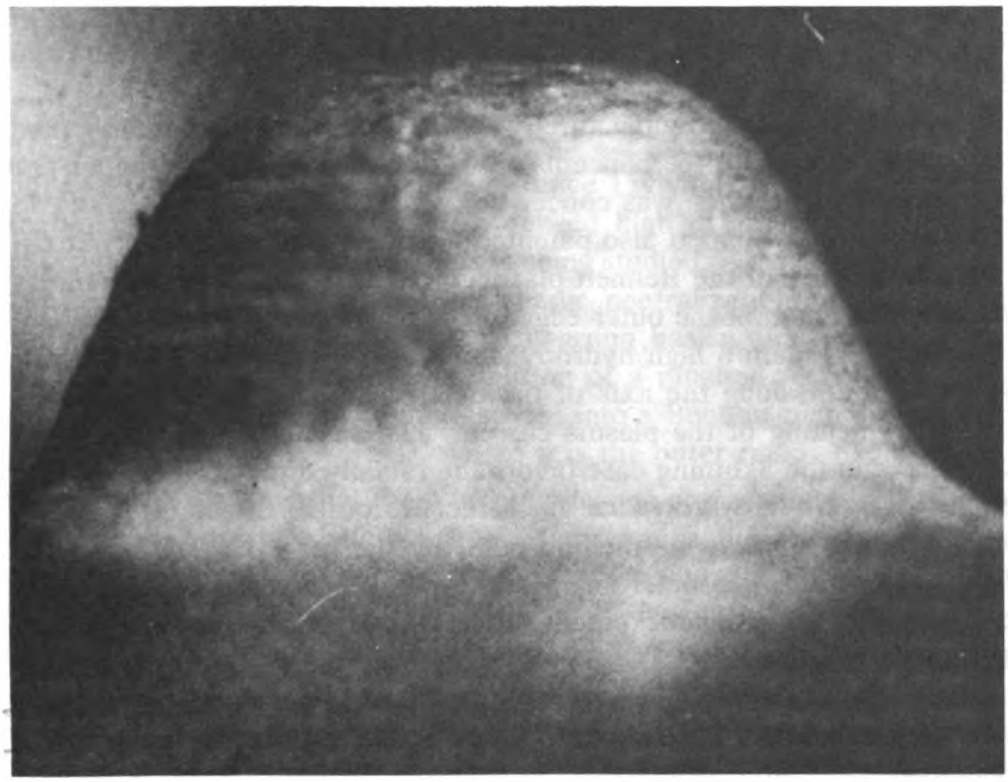


Figure 7 — Mound raised on copper surface by stroke of lightning. Base of mound is 2 mm across. Height is 1.5mm.

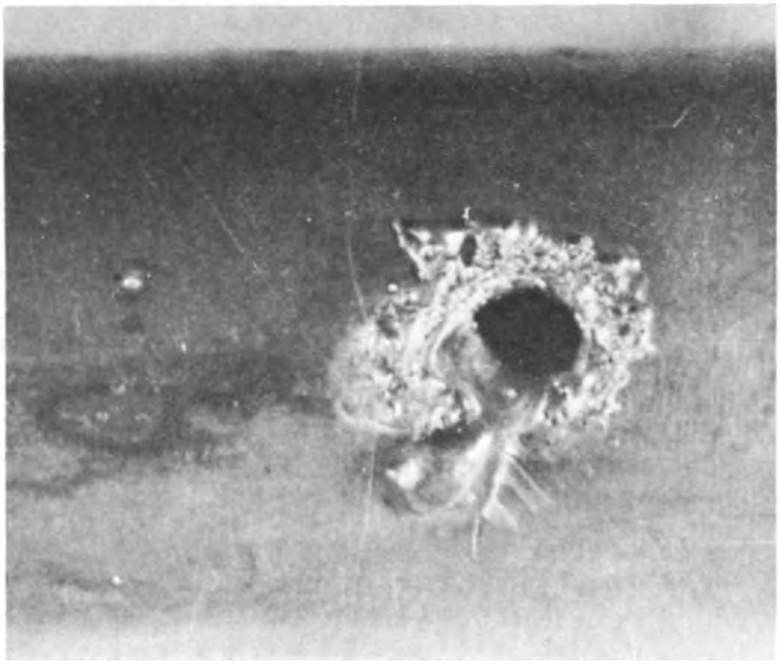


Figure 8 — Hole burned in copper plate 1/16 inch thickness by lightning stroke. Estimated lightning charge transferred to copper plate was 14 coulombs. The melted blob that was raised to a mound similar to the one shown in Figure 7 is seen collapsed at side of hole.

wall. A reproduction of the photograph of an example taken from Humphrey's book (13) is shown in Figure 9.

It is interesting to conjecture whether the pinch in lightning had any subtle impact on the concept of the pinch in plasmas. Although the so-called Bennett pinch was conceived before 1934, it is perhaps not so well known that Bennett also patented electrical dischargers for aircraft (14). In the case of the Bennett plasma pinch, the magnetic pinch forces reach a maximum at the outer edge of the plasma cylinder, but they are required to contain a high hydrodynamic pressure of the plasma which is a maximum along the axis of the cylinder and which is continually raised by heating of the plasma current. The case of the tubular metal conductor in the lightning case favors the radially directed inward pinch forces over the outward radial mechanical forces. If the metal temperature is raised close to its melting point by the resistive heating of the lightning current, the metal loses its mechanical strength and is readily collapsed by the magnetic pinch forces. These effects are discussed in Humphreys' book (13).

Although, as Uman (15) points out, there is no evidence that the lightning channel in air is pinched, as in a Bennett plasma pinch, there is considerable interest today in the way that very strong currents pinch in dense plasmas and gases. This interest is prompted by possible applications in thermo-nuclear energy reactions. The Navy is currently

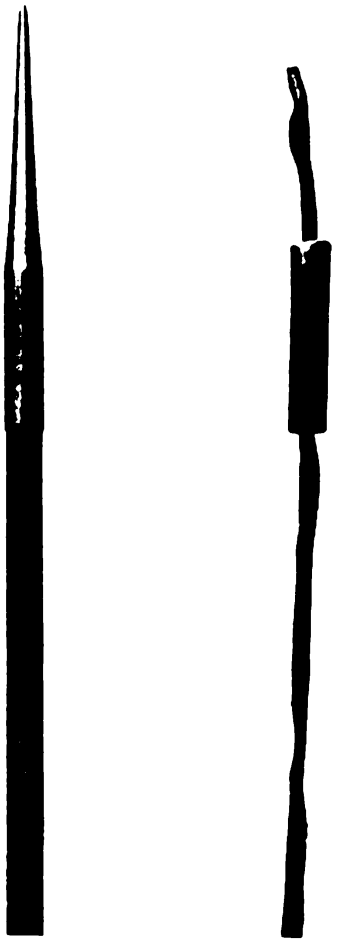


Figure 9 — At the left is an unused hollow cooper lightning rod, and at the right is an identical one pinched by lightning stroke.

supporting research (16) at the Lawrence Livemore Laboratory (LLL) in which the pinch effect in self-focused high energy electron beams propagating in high pressure gases is being studied. It has been found that the beam produces its own space-charge neutralization and is pinched by its own magnetic fields. The LLL group has in fact found that the radial beam-current density distribution of a pinched relativistic beam as a function of radius r quickly settles into a Bennett-type distribution proportional to $1/[1 + r^2a^2]^2$, where a is the outer radius of the beam.

It is not suggested that there is a one-to-one correspondence between the pinches in relativistic electron beams and lightning, but there are certain similarities in the development of channel temperatures and densities. The differences arise, of course, from the fact that in the electron beam case, the high currents derive from a low beam-particle density ($\lesssim 10^{10}$ electrons per cm^3) and a high velocity (of order c, the velocity of light), and in the lightning case the currents arise from the transport of a high density plasma ($\simeq 10^{18}$ electrons per cm^3) at a relatively low velocity corresponding to a plasma temperature of a few electron volts.

It is an old, related question in lightning research whether there are any high (relativistic) energy electrons produced by the many hundred million volt potentials generated in the thundercloud. A much respected thinker and experimenter in the field of atmospheric electricity in modern times, C. T. R. Wilson, argued in 1920 that electrons in the lightning channel would run away. A number of experiments, mainly in the 1920's and 30's, were performed in attempts to detect high energy, run away electrons.

While some of these experiments detected million volt electrons correlated with lightning, others were entirely negative, and the issue of whether there are run away electrons remains still rather unresolved. For example, Leona M. Libby and H. R. Lukens (17) have recently suggested that secular anomalies in the intensities of the carbon isotope, mass 14, which is used for radiocarbon dating, could be due to enhanced neutron production by lightning in the earth's atmosphere at certain anomalous periods. Libby and Lukens based their suggestion on the fact that neutrons have been produced by passing intense electric currents through polymeric fibers containing deuterium. This work on exploding wire discharges was performed at Naval Research Lab. (18). Direct observations of the production of neutrons by lightning has proved negative (19), however, and early experiments to observe high energy electrons directly in lightning were also negative (20).

Lightning Plasma Channel

There is considerable technological interest in the development of the lightning plasma channel, mainly for its application to two areas: (a) generation of thunder, and (b) emission of light radiations.

The work on thunder at Tucson (21) and Houston (22), which has been carried out under Navy support, has determined for the first time reliable spectral distributions of the power radiated in thunder. Because of the extended nature of the thunder source and the tortuosity of its radiating channel, the power spectrum observed is very complex, but details of the radiating channel can be resolved to good accuracy by an array of microphones and cross correlation between the detected signals. The work at Rice University, Houston, has laid the ground work for an important technique that can be employed to trace the paths of lightning channels in cloud where otherwise they cannot be determined by optical methods. Except for certain radar techniques, the only information on lightning within thunderclouds has previously been inferred by measurements of external electric field changes.

The second interesting study of the lightning channel arose from the need to discriminate between the light emitted from a high altitude nuclear burst in air and the predominant natural background of light flashes due

to lightning. A program to determine the characteristics of the light emitted by lightning was setup in connection with the Vela projects in 1965 by ARPA. Much of the lightning spectroscopy carried out at the University of Arizona, Tucson, originally directed by L. Salanave, and also the spectroscopy at Los Alamos performed by Connor and Barasch, was initiated for the Vela study. On the basis of this work, the Los Alamos group concluded that the N II multiplets at 5000 Å and the long persistent H_α line of 6563 Å were very intense in lightning spectra and that these emissions could be used for distinguishing the natural lightning background from nuclear flashes.

Ball Lightning

No report on the plasma aspects of lightning would be complete without at least a mention of the enigmatical topic of ball lightning. Many new reports of the phenomenon and of its interpretation continue to be given. Barry (23), of Air Force Avionics Laboratory, has recently published the most comprehensive bibliography of 1130 references on ball lightning to date.

One of the most interesting reports to appear on the subject of ball lightning in recent years is by J. L. Tuck (24), of Los Alamos Laboratory. Even by writing this objective report Tuck has added a certain respectability to ball lightning. However, he says categorically that there are to date absolutely no reliable scientific photographs or scientific measurements of ball lightning.

Ball lightning is a persistent sphere of luminosity of about 30 cm diameter, has a 5 seconds mean duration, and is mainly reported during thunderstorm and lightning conditions, although not necessarily. The balls, which are of a not-very-intense luminosity, have been reported to be of mainly a yellow-orange glow, and they have been seen in the open air, in houses, in metal buildings, in metal aircraft, and as Tuck points out, they may have been produced artifically in submarines. In fact, the Navy's contributions to the information on ball lightning is probably the most tangible to date. According to a study by Silberg (25), in 1965, a fireball was generated in the engine room of the USS Cutlass during a reconversion program at the Philadelphia Naval Shipyard in 1947. Silberg reported that at times a highly charged submarine battery, supplying 260 volts and 156,000 Amps, would be accidently connected across a dead generator. A reverse current relay would then be actuated to disconnect the circuit, and an arc would usually form across the relay electrodes. Although the arc was usually blown out, sometimes a green fireball would be blown off the contacts into the engine room and would persist in this air space for a time of the order of a second. The diameter of the fireball was between 10 and 15 cm. Silberg estimated that the

excess energy contained in the ball was between 400 and 20 Kilojoules, which corresponds approximately with the energy density in a lightning channel.

One of the most intriguing comments of Tuck's report is that he has been producing (with a 30 KV, 75 Kilojoule condenser battery). "Some enormous.... arcs far exceeding anything imaginable on a submarine." However, none of these afterglows resembles ball lightning in duration or coherence, *i.e.* in the power to "bounce" as observed in ball lightning. Tuck's plan in 1971 was reported to be that the U.S. Navy had been approached to provide an opportunity for observation on a submarine! How are we to interpret the silence since 1971: does it mean success or failure?

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Toward Hepatitis Vaccines

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The non-malignant diseases which affect persons of military age in large numbers and for which effective methods of treatment and prophylaxis are lacking are relatively few in number, but pre-eminent among them is hepatitis. Included in this category of diseases are hepatitis A and B (often called "infectious" and "serum" hepatitis, respectively) with their chronic sequellae; chronic active hepatitis, which leads to post necrotic cirrhosis; chronic unresolved hepatitis; and chronic persistent hepatitis; as well as one acute and usually fatal complication, fulminant fatal hepatitis. These conditions are common in persons of military age, and are increasing in frequency. A recent outbreak of hepatitis at a Naval facility in San Diego affected large numbers of persons not only by virtue of the fact that many required hospitalization or removal from duty but also because the contacts of patients needed to be carefully followed for signs of hepatitis, and gamma globulin had to be administered to all base personnel. In spite of the many technical difficulties which are associated with the development of vaccines, it is of the utmost importance that efforts be made to overcome the problems in order to provide a safe and effective viral vaccine for each form of hepatitis.

Only recently has it become apparent that the reservoir of hepatitis virus is being expanded, not only by the growing number of intravenous drug users especially among people of military age, but also by a significant number of persons who have previously recovered from hepatitis and have become asymptomatic carriers of hepatitis B antigen. It has recently been established that hepatitis A and hepatitis B may be transmitted not only by parenteral routes but also by fecal-oral contamination (1). Furthermore, hepatitis B antigen may be found in saliva, urine and even in droplets after sneezing. Venereal transmission of hepatitis occurs but with a frequency yet unknown. As the attack rate of acute hepatitis has increased in the past months, so too has the incidence of chronic sequellae of acute hepatitis (2).

Investigations in many laboratories have shown that there are at least two forms of acute viral hepatitis. Results of recent studies also indicate that the differentiation of "serum hepatitis" from "infectious

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hepatitis" is no longer tenable. Differentiation of the forms of hepatitis on the basis of incubation period or route of inoculation is, likewise, no longer valid. Studies in man have now made it clear that each of the two or more forms of hepatitis that do exist may be transmitted either by blood products or by the fecal-oral route. Although there may be a more common association of a long incubation period with one form, and only a short incubation period with another, there is a considerable overlap in incubation periods, so this may not be a reliable means of differentiation. Far more reliable for difining the type of hepatitis developing in a community are the highly sensitive serologic markers now available.

Under a study sponsored by the Office of Naval Research, new techniques for growing liver tissue in the laboratory have been developed. Aimed at providing an appropriate midium in which to cultivate hepatitis-causing viruses, these techniques represent an important step toward the eventual development of a vaccine against hepatitus. Presently there is no practical means of significantly reducing the frequency of hepatitis, and its eradication may not be possible until a vaccine is developed.

The ONR funded research is aimed at finding leads toward the development of a safe, live vaccine using less virulent strains of hepatitis viruses. Toward this end, the author has been attempting to grow the appropriate hepatocytes types of liver cells, on which to cultivate the hepatitis-causing virus. Until recently, however, these efforts have been frustrated by the fact that although hepatocytes would grow, other cells would soon develop in the culture to inhibit the further growth of hepatocytes. The hepatitis virus may only grow on hepatocytes. New methods have been developed which keep the hepatocytes growing for extended periods of time without overgrowth by other cells.

Hepatitis A

Hepatitis A is commonly associated with a short incubation period ranging from 2 to 6 weeks. This condition is often transmitted by contaminatied food or water, but may also be transmitted by systemic routes. The initial serologic means of detection involved the use of immuno-electronmicroscopy whereby hepatitis A viral particles were demonstrated in the stools of patients with active hepatitis while specific antibody would cause agglutination of the viral particles. Thus, this system could be used either to detect specific antigen in stool or antibody in serum. More recently a complement fixation test (3), and an apparently highly sensitive immune adherence test for hepatitis A have been developed (3). The agent of human hepatitis A has been successfully transferred to marmosets in several laboratories and these animals have developed a mild form of hepatitis. However, the agent of hepatitis A

has not yet been successfully cultivated in tissue culture. The studies described below document our recent attempts at achieving this goal.

Hepatitis B

Hepatitis B is commonly associated with a long incubation period, frequently 6 to 26 weeks. Clinically, patients may be more symptomatic and may often develop joint and skin symptoms in association with their hepatitis. The course of the disease may be longer and the risk of development of the chronic sequellae of hepatitis is thought to be more common after hepatitis B. The virus may be transmitted through blood products as well as by the fecal-oral route and frequently is transmitted through contaminated needles. The development of highly sensitive serologic techniques has resulted in a better understanding of the course of hepatitis B.

Australia antigen, recently re-named hepatitis B surface antigen (HB_sAg) and previously called hepatitis associated antigen (HAA), is often detected in the serum during the course of type B hepatitis. This antigen represents a particle from the surface of the hepatitis B virus. Each viral particle contains hundreds of hepatitis B surface antigens. In addition, the central portion of the virus, the core, contains DNA, which also can be detected by specific serologic techniques. Thus, the core particle is abbreviated hepatitis B core antigen (HB_cAg). A variety of serologic techniques are available for detection of HB_sAg but the most sensitive are the radioimmunoassay (RIA) and the reverse passive hemagglutination assay (RPHA). Hepatitis B core antigen may be detected by complement fixation or by radioimmunoassay. Surface antigen particles are easily detected by electron microscopy in the serum of patients with hepatitis B antigen. Whole virus particles, also called Dane Particles (14), are less commonly seen in hepatitis B sera. Using these serologic markers, important insights into the pathogenesis of hepatitis B have developed in recent years.

In 1963, Dr. Baruch Blumberg, a geneticist, was in the midst of a systematic study exploring inherited variations in serum proteins. He postulated that patients receiving multiple blood transfusions, such as hemophilia patients, would develop phenotypically different antibodies to the proteins to which they were exposed during transfusion. In the course of these studies, an unusual antibody was found in the serum of a patient with hemophilia. This antibody was found to react with the serum of an Australian aborigine but not with other sera in the panel. Because the antigen was present in the sera of the aborigine, it was designated "Australia antigen" (5,6). Dr. Blumberg and his colleagues then undertook to characterize the antigen and to define its significance. It was present in only 0.1% of the general population in the United States;

however, it was present in 5% of apparently normal people living in several Asian and oceanic countries (5). Equally confusing was the detection of the antigen in 7 of 38 patients with acute granulocytic leukemia and in 4 of 30 patients with chronic lymphocytic leukemia. Later studies (8) revealed that these patients had received multiple transfusions and indeed were found to have liver disease. The antigen was detected in 28% of 310 patients with Down's Syndrome but predominantly among patients with this illness who lived in institutions. The antigen was rarely present among patients with Down's Syndrome living outside of institutions (8,9). Follow-up studies demonstrated the association of the antigen with elevations in the SGPT (Serum Glutamic Pyruvic Transaminase) levels in these patients and subsequently liver biopsies documented the presence of chronic liver disease among the institutionalized patients with Down's Syndrome. Eventually, HB_sAg was detected in 58% of patients with post-transfusion hepatitis (8,10).

These early studies employed the insensitive immunodiffusion assay. The association of HB_sAg with acute hepatitis was confirmed by Okochi and Murakami (11). In time, new assay techniques were developed and by 1967 studies revealed that by testing serial sera, HB_sAg could be detected in up to 98% of 130 patients with post-transfusion hepatitis when the complement fixation assay was employed (12). The ability to detect the antigen varied with the population studied, the assay system used, and the time at which blood was drawn. Nevertheless, it became readily apparent that HB_sAg was intimately associated with the development of acute hepatitis. The value of screening blood products for HB_sAg was established in this and other laboratories (13,14). The association of HB_sAg with chronic liver disease gave new insight into the pathogenesis of chronic active hepatitis (10).

In 1969, Krugman and his colleagues demonstrated that the agent of "serum hepatitis" could be transmitted by the fecal-oral route as well as by the systemic route and that the agent of "infectious hepatitis" could similarly be transmitted by the systemic route as well as by the fecal-oral route (1). Accordingly, it became inappropriate to designate the form of hepatitis by the route of inoculation. Thus the terms "infectious" and "serum" hepatitis gave way to the terms "hepatitis A" and "hepatitis B". In this manner, reference to the route of inoculation and to the length of incubation period could be avoided. Australia antigen was invariabley associated with hepatitis B. This form of hepatitis was commonly transmitted by blood products and by the systemic route but on occasion could be transmitted by other routes. Hepatitis B tended to have a longer incubation period than hepatitis A. Depending upon the viral dose and the route of inoculation, however, a shorter incubation period could also be demonstrated. In an effort to avoid

further confusion, Australia antigen was recently renamed hepatitis B surface antigen (HB_sAg).

Subtypes of Hepatitis B Surface Antigen

Over the past three years, evidence has accumulated to indicate that HB_sAg particles have surfaces with multiple antigenic sites (11,17). In two dimentional double immunodiffusion assays, certain combinations of hepatitis B antigen and antibody reflect this antigenic complexity by the production of "spurs" in precipitin tests. Analysis of these reactions has resulted in the differentiation of 6 antigenic determinants (See Table 1). Common to all antigenic groups is determinant "a." Subtypes of the "a" specificity include "d" "x" and "y." Subtypes of the "d" specificity are "w" and "r." Of the antigenic subspecificities outlined, the de- the group specificity "a" have been divided into three antigenic sets, "d", "y" and "a" depending respectively on their possession of small "d" or "y" or neither of these determinants (16). It has been postulated that "d" and "y" reflect two different genotypes of the hepatitis virus which have been subtyped D and Y or may be described by their characteristic antigens as "a," "d" or "d positive" or "ay" or "y positive" (16). Initial studies indicate a greater prevalence of type "d" among asymptomatic chronic carriers of HB_sAg and a prevalence of type "y" in acute hepatitis among drug users (17). The degree of cross immunity between the viral subtypes has not been well defined. The relative degree of virulence of

TABLE 1
HB_sAg Subtypes

Group Specificity	Subtypes	Sub-Determinants	Common Subtype Groups
	(Mutually exclusive)	w	adw
	d		
a		r	adr
	y	w	ayw
		r	
			ayr
	x (Present in most HB_sAg positive sera)		

the subtypes or a tendency of either subtype to more commonly produce chronic or fulminant disease have not been delineated.

Prevention of Post-Transfusion Hepatitis

Hepatitis B surface antigen is commonly associated with post-transfusion hepatitis. Accordingly, efforts were undertaken over 3 years ago to screen all blood products for hepatitis B surface antigen prior to transfusion in order to remove from blood banks potential sources of hepatitis transmission. At that time, the most readily available and indeed the least expensive assay system available was the counterelectrophoresis system. By employing this rapid and specific assay system, it has been estimated that the frequency of post-transfusion hepatitis in the United States may have been reduced by approximately 25%. This assay system became readily available to all blood banks and provided inexpensive and reliable means of rapidly screening blood products for hepatitis B antigen. Subsequently, other more sensitive assay systems have become available.

A variant of a hemagglutination inhibition assay, reverse passive hemagglutination, is highly sensitive and exceeds the sensitivity of counterelectrophoresis, complement fixation and hemagglutination inhibition (23). It is rapid, requiring only 2 hours, and appears to be inexpensive and very reliable (18). It approaches the sensitivity of the radioimmunoassay for hepatitis B surface antigen. The latter test is probably the most sensitive assay system available (19). Recently, it has been reported that where blood found to be negative by counterelectrophoresis was rescreened by reverse passive hemagglutination and by radioimmunoassay, 23% of post-transfusion hepatitis at our institution may have been prevented (23).

Physical and Chemical Properties of HB_sAg

Electron microscopic studies were performed on HB_sAg preparations. partially purified by surcrose density gradient ultracentrifugation. HB_sAg was found to be composed of 200 angstrom particles with subunits 30 angstroms in diameter (20,21). These small particles were found to be the most common units in HB_sAg positive sera; however, tubular particles were demonstrated as well as large spherical particles 400 angstroms in diameter. The latter contain a dense core which contains nucleic acid. These particles have been called "Dane Particles." The surface consists of symmetrical polyhedral subunits 30 angstrom in diameter. The particles may be agglutinated by specific antibodies. Immunofluorescent studies have demonstrated HB_sAg in and around the nuclei of liver cells of patients with viral hepatitis but not in other forms of acute liver disease. The internal nucleoprotein or core has been found to be DNA; whereas the core of hepatitis A is RNA.

Hyperimmune Gamma Globulin

Initial studies have suggested that gamma globulin made from plasma containing antibody to HB_sAg may effectively reduce the risk of needlestick hepatitis (22). Small scale studies have indicated that such gamma globulin may have a prophylactic effect if given within a short time after exposure to HB_sAg. Prior studies have demonstrated the value of gamma globulin in the prophylaxis of hepatitis A (27-30). Thus, it is hoped that a single gamma globulin inoculation may be protective both against hepatitis A and hepatitis B. To test this, a national collaborative study sponsored by the National Heart and Lung Institute has been undertaken to evaluate the effect of hyperimmune gamma globulin in the prophylaxis of needlestick hepatitis.

Tissue Culture for Vaccine Development

Krugman has recently shown that the infectious moiety of HB_sAg may be inactivated by heat and this heat inactivated serum may be inoculated into children and will confer relative immunity to subsequent challenge with hepatitis inocula (26). The experimental vaccine appeared sufficiently immunogenic to provide hope that a vaccine would be feasible. Heat inactivated vaccines have not been previously licensed in this country because of the fallibility of this process for the complete inactivation of live virus. Nevertheless, it does seem possible that if an appropriate means of inactivation could be attained, an immunogenic vaccine would be possible. Recently Hilleman (31) reported the successful completion of studies in amimals demonstrating the immunogenicity of an experimental formalin treated HB_sAg preparation.

Extensive work was undertaken aimed at cultivation of hepatitis virus in tissue culture. These early studies have suggested that HB_sAg may proliferate for a short period in explant cultures of liver cells, but only to a limited degree as demonstrated by electron microscopy and not sufficiently for demonstration by standard biologic techniques. If sufficient viral replication could be obtained in tissue culture, it is possible that either a live attenuated viral vaccine or an inactivated vaccine could be developed.

Techniques for the establishment of substrates likely to sustain the replication of hepatitis A and B viruses and possibly of other hepatitis viruses, have been devised in this laboratory to the extent that monolayer cultures can now be maintained for periods of several months. If the hepatitis viruses, especially those with long incubation periods, do act as slow viruses, it is likely that they attach to and infect cells and then remain latent for prolonged periods of time before viral release and cell destruction occur. It is thus of the utmost importance that studies aimed at the cultivation of hepatitis viruses be performed carefully and patiently

and that cultures be maintained for prolonged periods of time before they are discarded. It is likely that in tissue cultures, as in man, the virus remains latent and intracellular for periods of weeks or even months before it becomes apparent. Our use of "slow viruse techniques," such as long-term monolayer cultures, co-cultivation and feeder layer cultures, would seem to be desirable methods of approach for eventually achieving successful cultivation of hepatitis A and B viruses.

Reproducible and reliable techniques have been developed both for the short and long-term maintenance of hepatocytes in monolayer tissue cultures. These cultures are free of fibroblastic cells and retain epithelial characteristics. They can be maintained for periods in excess of 10 weeks and are a likely substrate for the cultivation of hepatitis viruses. The development of this substrate constituted the initial phase of a program in which the goal is to develop viral vaccines for hepatitis A and hepatitis B. The second phase of this program now underway undertook to cultivate hepatitis viruses in hepatocyte tissue cultures. Initial studies have demonstrated electron microscopic evidence of HB_sAg within tissue culture cells during the first week after inoculation. Serologic studies have demonstrated evidence of HB_sAg in pour-off fluids for periods ranging from 4 to 7 days after inoculation. These encouraging findings led to studies aimed at long-term maintenance of infected cultures with the eventual goal of demonstrating viral replication in the hepatocytes after a period of intracellular viral latency. Continuation of these avenues of research may lead to the development of both an inactivated and a live attenuated viral vaccine for each of the important forms of hepatitis.

It seems reasonable to expect that with hepatitis virus, both a killed inactivated viral vaccine and a live attenuated vaccine will one day become available. It is, however, most likely that, as with other viral vaccines, long-term protection, as well as safety, will be better assured by the development of a live attenuated viral vaccine. Fortunately, acceptable and well characterized animal hosts (the marmoset and chimpanzee, respectively) are now available both for hepatitis A and hepatitis B, and serologic techniques are available for evaluation of exposed or treated animals. It is not likely that the reservoir of hepatitis in the general population will significantly decline in coming years, unless young people are provided with sufficient protection by means of a vaccine. The hepatitis B carrier state cannot be eradicated by the infusion of hyperimmune globulin as was once hoped. It is more likely that the carrier rate of hepatitis B virus and the frequency of hepatitis A and B will increase in coming years, unless vaccines are successfully developed. The high frequency of each of the forms of hepatitis and of their many sequellae in persons of military age continues to make their eradication especially desirable.

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New Technique Improves Air Filtration

Naval Research Laboratory scientists have taken an industrial-grade, fiberglass air filter, applied an electric voltage to it, and wound up with a filter ten times more effective than it was.

George H. Fielding, the principal investigator for this Environmental Protection Agency funded program, says, "Unlike electrostatic precipitators, with which it is occasionally confused, the NRL 'dielectrophoretic' filter requires only very low current and power. Also the system requires no more voltage than the power supply of a small portable TV set."

The new technique uses high voltage to establish an electric field across the fiberglass filter. This increases the efficiency of the filter for a 0.3 micron (0.0003 millimeter) aerosol from a normal 68 percent to 98 percent. Cigarette smoke falls in the 0.3 to 0.7-micron range. For larger aerosols of one micron, the filtration efficiency increases from 78 to 99 percent.

In the NRL technique, the power supply is connected to the metal screens on either side of the fiberglass filter. The electric field thus set up between the screens polarizes the aerosols, while the glass fibers distort the electric field. This accelerates the particles toward the fibers, where they are retained.

The method has many potential applications, especially for shipboard use. Cigarette smoke, for example, an aerosol that has been particularly difficult to filter, is especially troublesome in submarines and other closed spaces. This makes the future of dielectrophoretic filters in such environments quite promising.

Research Notes

The Besonar System of Whales and Porpoises

Large amounts of unique lipids (fats) in the foreheads of porpoises constitute a lens, enabling these mammals to focus sound waves in the ocean.

Cooperative research conducted by scientists at National Oceanic and Atmospheric Administration's Northwest Fisheries Center, Seattle University, and the Applied Physics Laboratory of the University of Washington shows that the ocean mammals use unusual lipids in their heads to modify sound properties, much as the lens of a camera is used for focusing light waves. The work is funded by Office of Naval Research.

The chemical basis for this biosonar process was described in the recent issue of the science journal, *Nature*, published in England (May 22, 1975).

Dr. Usha Varanasi and Dr. Donald C. Malins, both Research Professors of Chemistry at Seattle University, are the principal investigators. These scientists along with senior physicist Dr. Henry Feldman of the Applied Physics Laboratory have traced the molecular basis for the formation of the highly sophisticated biosonar system used by porpoises and whales in the pursuit and capture of prey.

The mixtures of highly unusual lipid molecules having a very simple composition are used by these animals for the transmission and the reception of high frequency sounds. These marine mammals possess a remarkably sophisticated biosonar capability for depth measurement, locating underwater objects, and for underwater communication with each other.

The clicks and beeps emitted by the echo-locating porpoises and small whales (odontocete) come from a fatty protrusion on the forehead (melon). The sound bouncing back from objects in the water enters a peculiarly formed lower jar (mandible) which flares into a posterior flange. The region of fatty tissue overlying this flange has been termed an "acoustic window." The mandible and melon are believed to be associated with sound transmission.

It is the melon that functions as the "sound lens" in focusing ultrasonic waves beamed into the water. This concept is consistent with the view that it is heterogeneous (different) in its component parts in terms of sound velocity and refraction.

The study has revealed that the lipids of acoustic tissues are different from those of the surrounding tissues. That is the crux of the matter, according to Dr. Varanasi. These lipids, which possess branched chains, behave differently from normal fats in other animal tissues. The short- and medium-chain lipid molecules constitute the lens that focuses the sound waves.

Different combinations of branched molecules fit together in different ways changing the sound properties of the melon which results in focusing. The peculiar "synthesis in the head" of the lipids provides the suitable chemistry for sound processing in aquatic environments.

Such information may be valuable in the further development of man-made sonar systems for use in the marine environment.

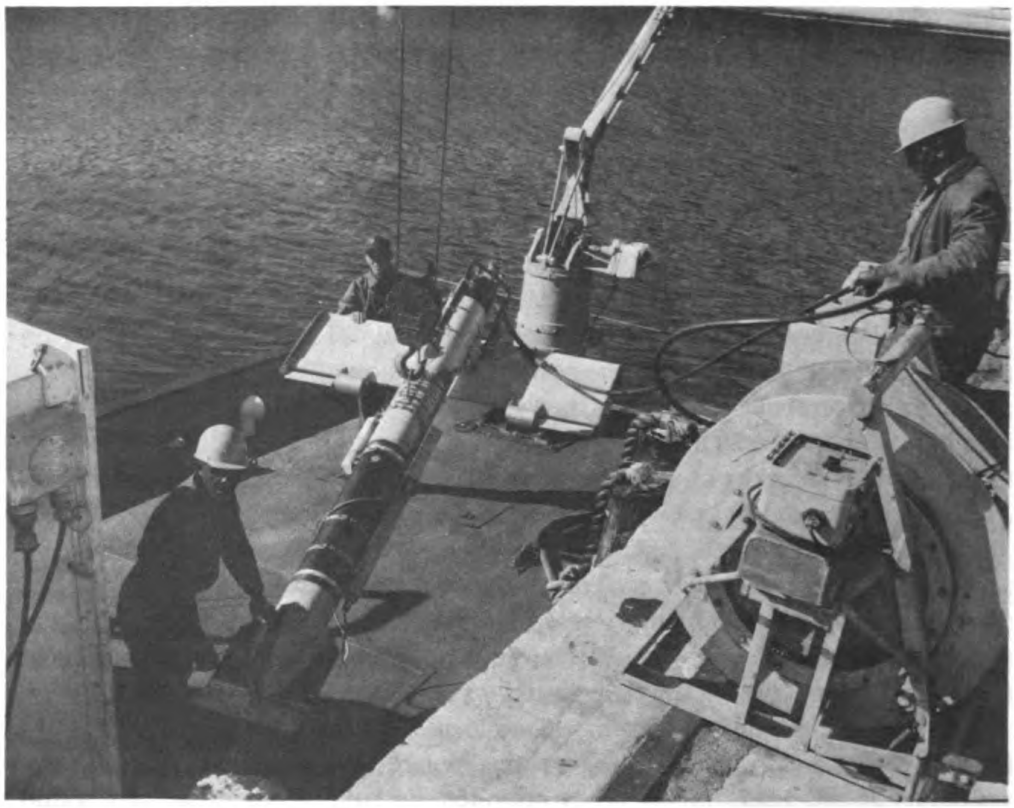
Synthetic Aperture Sonar

Development of a synthetic aperture sonar was developed by scientists at the Naval Coastal Systems Laboratory; it is the first time synthetic aperture processing in sonar has been accomplished.

Synthetic aperture processing was developed originally for airborne radar to solve the problem of antenna arrays which were larger than the airplane carrying the array.

In sonar, the ability to discern small underwater objects is determined by the length of the hydrophone array which a sonar system uses. To detect small objects at long ranges requires an array many feet long. Such physical apertures are unwieldy to handle, expensive to construct, and result in large towing platforms with inherent launch and recovery problems.

Scientists, by using a small physical aperture, or array, to synthesize the required large aperture, overcame these limitations of physical aperture sonar. Synthesizing of the large aperture in the water is accomplished by moving the small aperture along a line that would represent the length of the synthesized aperture if it were a real aperture. Sonar signals received during the time the small aperture is moving are stored in a memory so that all of the signals that would have been received by an imaginary large aperture become available for processing by a beamformer.



Naval Coastal Systems Laboratory employees are shown here using the C Mark 1 vehicle as a test platform for synthetic aperture sonar system data gathering in the Gulf of Mexico The stabilized vehicle containing the sonar system will be towed behind the craft.

In addition to its small physical size, other advantages of the system include: (1) no increase in complexity compared to physical array which is synthesized; (2) flexibility—can change sonar system parameters with just software changes; (3) drastic reduction in number of hydrophones or sensors and related processing electronics, permitting the data to be telemetered to the ship from the towed vehicle for processing in a central computer. For example, the several hundred sensors and receiver channels of the large physical aperture are replaced by the half dozen or so of the synthetic aperture equivalent; and (4) constant linear resolution which is independent of range. Most physical apertures have a beam pattern that is described by a constant angle of resolution, therefore the linear resolution increases with range.

Environmental Sensor Package

More current and up-to-date data on environmental parameters necessary in planning and execution of an amphibious assault will be provided by an environmental sensor package being developed at the Naval Coastal Systems Laboratory.

Under development for the Navy's Inshore Warfare Group II, based at Little Creek, Va., the remote sensor unit will provide, on command, real-time information on water current, water depth, and surface wave height and wave period.

Development of the sensor package will be a valuable asset in planning and conducting a beach assault. It will provide for the first time up-to-the-minute information which is invaluable just prior to landing troops and equipment. Currently, survey teams are dispatched to the scene to gather environmental information. To update the data, however, these survey teams must return to the beaches time and again, exposing the men and material to danger. Also, the frequent visit to the target shore may tip off the opposing forces that an assault is being considered. With the new system, the original data collected by the survey team may be correlated and kept up to date.

The remote environmental sensor package (RESP) is designed to measure wave heights and periods, water current velocity and direction, and water depth in the near-shore environment lying just beyond the surf zone. This first equipment development will demonstrate the feasibility and usefulness of collecting the environmental data. The first package is not intended for combat usage.

The package is self-contained and consists of an underwater sensor unit secured in position on the ocean bottom with an auger-type anchor installed by divers, a surface buoy containing radio equipment, and a receiver display unit which displays the received data in easily readable form.

The battery-powered underwater sensor receives a signal from a command transmitter located on board ship or on shore via the radio receiver equipment in the surface buoy. After receiving the "on" command, the sensor unit transmits approximately 50 seconds of wave, water current and depth information to the surface buoy unit via an interconnecting cable. The radio transmitter in the buoy telemeters the data to the command receiver for display on the receiver display unit.

Displaying the components that make up the environmental sensor package being developed at NCSL. The remote sensor will provide on command real-time data on water current, water depth, and surface wave height and wave period.

In the reciever display unit, data are processed and displayed on a direct-writing strip chart recorder which produces a permanent record of wave heights and periods during each 50-second data sampling interval. The receiver display also provides digital display of water depth in feet, water current direction in degrees magnetic, and water current velocity in knots.

In addition to its military and strategic applications, the remote environmental sensor has great potential for many other uses. For example, with internal recording of the data, the sensor package can aid in measurement of tidal flushing capabilities of the bays and harbors, or in assessing the spreading rate and area coverage of oil spills, or even waste outfall. Application also can be made to determine wave energy climates for design of beach erosion control projects such as sea walls, breakwaters, and groins.

Assistant Chief for Technology

The Office of Naval Research (ONR) has formed a new organizational segment under an Assistant Chief for Technology (Code 200). The mission of this group is to strengthen relationships with the fleet and shore commands, to provide new technological capabilities, and to solve specific operational problems.

The manpower for Code 200 was transferred from divisions under the Assistant Chief for Research (Code 400). The personnel involved were primarily from the Operational Applications Division (Code 410), which was disestablished, and from the Naval Analysis Program (Code 431) of the Mathematics and Information Sciences Division. Most of the contract research programs being pursued by the personnel involved were also transferred to Code 200 at the same time; these programs are primarily in the categories of exploratory development, and studies and analysis. Implementation of projects as part of a contract research program is one function of Code 200. Since most of the scientific and technical expertise at ONR is in the seven research divisions of Code 400, the success of Code 200 depends on its ability to steer the results of Code 400 research into useful benefits to the Navy and Marine Corps.

Code 200 personnel are assigned to three divisions for administrative purposes. Divisional titles are:

Code	Division
210	Technology Projects
220	Naval Systems
230	Fleet Analysis and Support

In Technology Projects the emphasis is on fundamental investigations for expanding technological capabilities while the focus in Naval Systems is on more immediate and direct support to existing or planned systems. There will be close liaison with the Naval Material Command and its laboratories in order to identify fruitful areas for applied research.

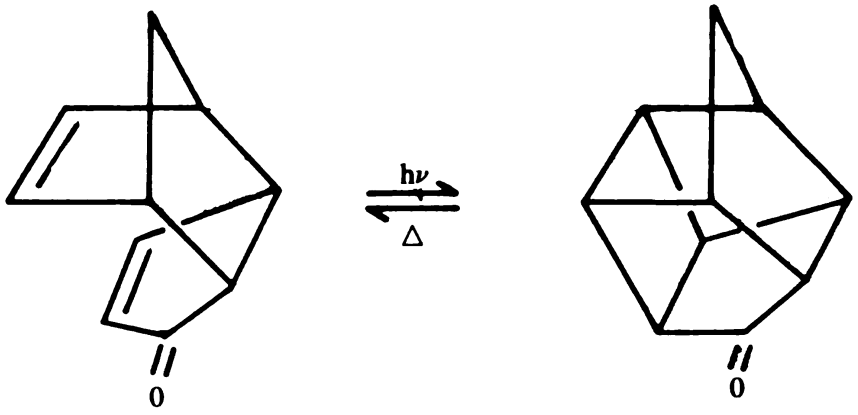
A major function of the Fleet Analysis and Support Division is to play a leading role in the development of effective tactics in response to ever-changing threat assessments. This effort involves detailed participation in the fleets' Tactical Development and Evaluation program. The knowledge gained from fleet operations combined with familiarity with characteristics of material systems, personnel, and logistics matters is important in formulating responsive research requirements to help guide ONR. Such requirements are prepared in formal statements, but more effective influence will hopefully be exerted by a continuing interchange on research matters between personnel of Codes 200 and 400.

The goal of Code 200 is to bridge the gap between research and the more advanced stages of development. Code 200 will aid in the transition from research results to operational applications.

The Assistant Chief for Technology is Captain John N. Green, USN, who is assisted by the Director of Technology, Dr. Lewis E. Larmore.

Solar Energy Storage

Professor Guilford Jones, II, Department of Chemistry, Boston Univesity, is studying the valence isomerization of organic molecules as a means of storing solar energy. The type of reaction is detailed in the accompanying figures, where the structure on the left, containing two double bonds, is transformed by solar energy (near UV light) into the cage compound



on the right, which contains a strained cyclobutane ring. To recover the stored energy, the cage compound is heated to initiate the reverse reaction, which gives off more heat. There are a number of problems involved in selecting a material which will undergo these reactions efficiently, cheaply, and reversibly, In order to be useful, the system must be able to compete with sensible heat storage systems which involve raising the temperature of water or of rocks. These systems are in current use, for example, solar heating of buildings: during solar irradiation, heat is stored in a mass of matter; on demand, the heat is transferred to the desired environment. Storage of light energy as chemical potential energy is, in principle, "permanent" or long term (no insulation required). In addition, the higher operating temperatures of reversion reactions may be advantageous.

Regarding the selection of an organic material for solar energy storage by valence isomerization, Professor Jones feels that there are five conditions that must be met to make the organic material competitive. If all five conditions are met, then a sufficient condition exists. The five conditions are summarized by the unpronounceable acronym PΦHT$ which stands for Photochromism-absorption, quantum yield (Φ), Heat of transformation, Temperature required for initiating the back reaction, and $ for cost.

The compound must absorb solar energy in the region of 300-700 nm; that is, from the near ultraviolet to the end of the visible wavelength. This region contains 49% of incident solar energy. The remaining 51% is largely low-energy infrared radiation which provides heat. The process of absorbing light must transform the compound into a species with different absorption characteristics, a process called photochromism. The materials of main interest are those which lose their absorption characteristics upon transformation and produce a stable product. The quantum yield is a measure of the efficiency of transformation; candidate materials must have a Φ value between 0.5 and 1.0. To be effective, the material must release a large amount of heat on reversion, roughly 10-50 kcal/mole; this restriction eliminates (except perhaps in special cases) a number of materials which have received considerable attention in the past, such as the synanti transformation in azo compounds and the nitrone-oxaziridine transformation:

where only small amounts of energy are recovered. The material in the high energy state must be stable and remain that way until the energy is called for. Therefore, it should not revert until its temperature is raised sufficiently above operating temperatures; somewhere between 50 and 200 C appears reasonable. The lower temperature is limited by the maximum theoretical efficiency of a heat engine $(T_2-T_1)/T_1$, whereas the upper temperature must be below the point where degradation reactions tend to occur. Finally, the material must be readily available or easily synthesized by simple one- or two-step reactions from readily available sources to put it in the \$0.50 – \$1.00/lb. range.

Professor Jones is currently examining a number of compounds and determing the PΦHT$ of each. The illustrated system exhibits good photochroism, $\Phi - 0.4$, $H = 16$ kcal/mole, and \$ is low because cyclopentadiene dimer is readily available on an industrial scale. Although T is quite high (290 C), it can be reduced to about 140 C with the aid of a $[Rh(CO)_2C1]_2$ catalyst, but the latter material is expensive (for use in large scale reversions) and tends to degrade on recycling. Other catalysts for opening the cyclobutane ring are being sought. Technical reports presently available concern studies of the illustrated dicyclopentadiene derivative and an azepine, a cyclic organic material which undergoes endoergic photochemical intramolecular ring closure. Work in progress involves evaluation of systems in which anthracene molecules are tied together in various arrangements and upon photolysis give energy-rich "cage" products.

Scientific City Sets Up Satellite Suburbs on Ice

Since its establishment on March 13, 1975, the Arctic Ice Dynamics Joint Experiment (AIDJEX) main camp has grown from six men and several tents to over fifty scientists, technicians and support personnel and thirty-six flourescent orange buildings, several Parcoll tents and a mess hall. "Big Bear," as the AIDJEX main camp is called, is located on the pack ice approximately 450 miles north of the Naval Arctic Research Laboratory at Barrow, Alaska. Camp electricity is available from a main generator, and heat for the buildings and tents is provided by diesel oil stoves. Fresh water is obtained by melting aged ice. Mr. Rolf Bjornert, one of the original six inhabitants, is the AIDJEX camp manager.

Working out of the Naval Arctic Research Laboratory (NARL), an Alaska International Air C-130 began transporting nearly two million pounds of supplies, equipment and personnel to Big Bear on March 16. During two major airlifts a total of 44 flights were made to the station. NARL loading crews and AIA personnel rotated on twelve hour shifts around-the-clock to provide the station with supplies to last through the summer. The ice runway will soon be too soft to support a C-130 landing. Resupply flights by lighter NARL aircraft will occur on a weekly basis, in addition to transporting personnel to and from the camp.

Why is the United States supporting a major scientific effort on the Arctic ice pack? The primary objective of the AIDJEX program is to develop a predictive model of sea ice movement in the arctic. At a time when resources in arctic regions are being developed, transportation in the Arctic Ocean is increasing and ice movement predictions would be invaluable. During the course of the

study many different factors will be examined, including wind and air stress, ocean tilt, seismology, stress and strain on ice, and ice thickness distribution. Such data can only be collected on the pack ice over an extended period of time.

In addition to the main camp, three satellite camps have been established in a 100 kilometer radius around Big Bear. Dubbed Snowbird, Blue Fox, and Caribou, each will eventually consist of three prefabricated buildings, a Parcoll tent for sleeping quarters, and a generator hut. After being secured in a sling, each prefabricated building is airlifted to the satellite site via a helicopter. The research conducted there will attempt to determine stress-strain relationships in ice. Working with the Navy Navigation Satellite System (NAVSAT), each camp will transmit positioning data to the main camp, and collect meteorological and oceanographic data as well.

Ten data buoys deployed in a 300 kilometer radius around Big Bear will also use the NAVSAT system and will feed data into the complex computer system at the main camp. Called the Arctic Environmental Buoy (AEB), these instruments will be used to verify predictions of the ice movement model. They are designed to record complex telemetry, barometric, and temperature sensing data, and to accurately determine their positions. According to Mr. Robert Darby, an Arctic Systems Consultant involved in the design of the AEB, "Such buoys permit an accuracy in measurement that is the most finite ever possible in the arctic." Once installed, they will begin recording data in their memory banks simultaneously each day. Nearby a 35 foot antenna has been installed outside for testing before deployment to the sites. Each buoy measures about 24 feet in diameter and has an instrument-battery tube that penetrates the ice to a depth of nearly 18 feet. The main camp buoy instrument tube extends down through the nine foot thick ice and into the ocean water below. Its batteries are designed to operate for approximately one year.

In-Water Contrast Measuring Device

Robert B. Patterson and Frank W. Heemstra, ocean scientists at the Naval Research Laboratory have come up with a unique in-water contrast measuring device.

While most attempts at measuring in-water visibility start by measuring a number of parameters, such as water turbidity (cloudiness), object size and light reflection/emission, *etc.*, this instrument, measures the apparent contrast of a known target at a fixed range in a single reading.

This single reading combines the effects of all the parameters that affect contrast, and can be related directly to visible range by subjective calibration. Most other contrast measuring devices use a model and parameters' effects to predict contrast as a function of range.

The NRL insturment readily permits divers preparing for search missions to get some idea of what kind of visibility they can expect prior to making their dives. This can result in sizeable savings of time and money.

The problem of in-water visibility has been studied for over 100 years, during which time there have been numerous attempts to provide usable measurement systems.

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Probably the first instrument designed to measure in-water visibility was a white disc proposed by Secchi in 1866. The Secchi disc was lowered into the water until it disappeared. This disappearance depth was a rather unrepresentative measure of visibility range, since in addition to water transparency, it also depended upon a number of unrelated factors, including the size and reflectance of the disc, the viewing and lighting geometry, and the water surface conditions. Other devices developed over the years presented similar functional problems affecting their practicability.

The instrument, however, not only measures the apparent contrast of a known target at a fixed distance but target characteristics, path length, and lightning geometry can be modified to approximate the situation of interest so that the range of extrapolation is minimized. The device has an added advantage of lending itself to remote sensing and can be adapted for measuring contrast loss in other turbid mediums.

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Cover Caption

Photograph of lightning flash taken from an aircraft. This shows the tremendous activity above and within clouds not seen by the observer on the ground. See page 1.