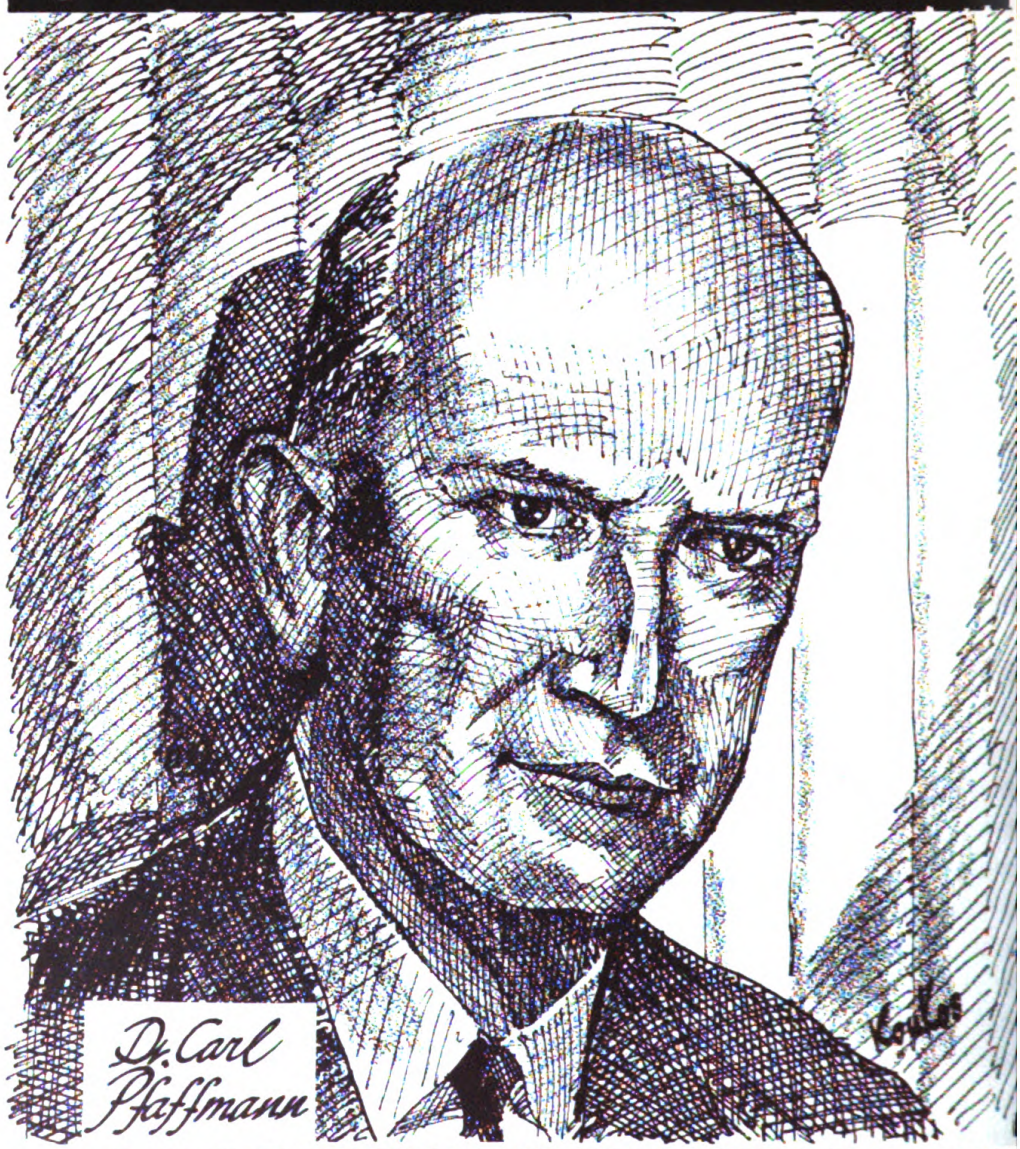
NAVAL RESEARCH

REVIEWS

NOVEMBER 1969

Portraits in Science



DR. CARL PFAFFMAN'S INTEREST IN PHYSIOLOGICAL PSYCHOLOGY WAS FOCUSED EARLY IN HIS CAREER ON THE SENSE OF TASTE AS WELL AS SMELL AND TODAY IS A RENOWNED AUTHORITY IN THESE FIELDS. HE PIONEERED IN THE APPLICATION OF ELECTROPHYSIOLOGICAL METHODS TO THE STUDY OF SINGLE NERVE FIBERS ARISING FROM TASTE BUDS IN DIFFERENT MAMMALS. DR. PFAFFMAN GRADUATED FROM BROWN UNIVERSITY IN 1933 AND WENT ON TO OXFORD TO RECEIVE HIS PH. D. IN 1940 DR. PFAFFMAN RETURNED TO BROWN AS PROFESSOR OF PSYCHOLOGY, WHICH POST HE HELD UNTIL 1965 WHEN HE BECAME VICE-PRESIDENT AND PROFESSOR AT ROCKEFELLER UNIVERSITY. DR. PFAFFMAN, WHO IS A MEMBER OF THE NATIONAL ACADEMY OF SCIENCES, HAS HAD CLOSE CONTACT WITH ONR AS A MEMBER OF THE PANEL ON PHYSIOLOGICAL PSYCHOLOGY AND THE NAVAL RESEARCH ADVISORY COMMITTEE

Spectroscopy in the Space Science Division of the Naval Research Laboratory*

W. R. Hunter and T. C. Winter, Jr.
E. O. Hulburt Center for Space Research
Naval Research Laboratory

The goal of the Space Science Division is to measure the intensity and spectral distribution of radiation reaching the earth from celestial sources. Such measurements have been made in the visible region of the spectrum since the time of Newton, when astrophysics may be said to have had its inception. It is only recently, however, that similar measurements outside of the visible region have become possible. The rapid growth of radio astronomy over the last two decades has permitted observations in the millimeter- and centimeter-wavelength region through the atmosphere.

With the advent of rockets and satellites which provide observatories above the atmosphere, scientists have extended their spectroscopic observations from the visible region to wavelengths shorter than one angstrom unit (1 Å) and can observe regions of the infrared normally absorbed by the atmosphere. We wish to study this radiation; first, because laboratory studies of the unseen portions of the total spectral range augured the existence of much important information on the constitution of stellar atmospheres and the interstellar medium. The stars themselves are natural laboratories for high energy physics, and the nearest star, the sun, may be considered a vast high temperature laboratory in which phenomena can be observed that cannot be reproduced on earth. Second, since the unseen radiation from the sun is absorbed in the earth's atmosphere it might be that the effect of this radiation has a significant part to play in the complicated solar-terrestrial relationship. In fact the first experiments showed how absorption of ultraviolet radiation in the upper atmosphere formed the ozone layer which effectively shields us from the harmful solar actinic rays. This complicated solar-terrestrial relationship provides the environment for life as we know it and it is important that we gain an understanding of it.

Radio astronomy was an outgrowth of the World War II development of radar, and is the result of work at many laboratories, mainly in England and America. On the other hand, rocket spectroscopy originated at

*Presented at the NRL Sponsor's Day Program; 13-15 May 1969

the Naval Research Laboratory as did many of the subsequent technological developments in this field. The initial vehicles were the captured V2 rockets intended for use in ballistic and propulsion studies by the U.S. Army. When they first became available in 1946, E. H. Krause, then of NRL, conceived the idea of using scientific equipment as ballast in place of the warhead. At his suggestion, E. O. Hulburt proposed a solar ultraviolet spectrograph as part of the instrument package, and rocket spectroscopy was born. The first successful results showed the solar spectrum extending to wavelengths less than 3000 Å as the rocket rose through the atmosphere. They are shown in Figure 1 (1). For low altitudes the solar spectrum appears to end at about 3000 Å. At an altitude of 34 kilometer (km) the first appreciable extension of the spectrum to wavelengths shorter than 3000 Å is seen while at 55 (km) the spectrum extends as far as 2300 Å. The wavelengths shorter than 3000 Å are absorbed by an ozone layer in the upper atmosphere and hence are never seen from the ground. Since these pioneering efforts, the technology of both rocketry and spectroscopy has made tremendous advances so that both the solar and stellar spectra are now being measured routinely to wavelengths as short as 0.5 Å. Infrared spectroscopy from rockets was started in 1968. The results so far show that this area of the spectrum yields data which, among other things, promises to have quite a large influence on cosmological theory.

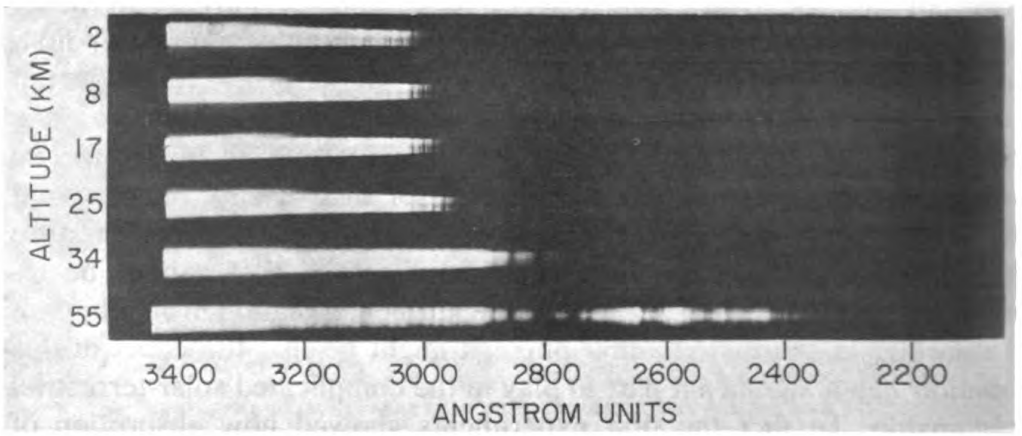


Figure 1 — The first photographs of the ultraviolet spectrum of the sun beyond the limit reached from the ground. Several exposures are reproduced from a sequence made by the Naval Research Laboratory with a spectrograph flown in a V-2 rocket on October 10, 1946.

Some idea of the technological developments necessary for the study of extra-terrestrial radiation from above the atmosphere can be gained from a study of Figure 2. Across the center of the figure is the electromagnetic spectrum spanning approximately nine decades with both wavelength and frequency indicated. The shaded areas in the spectrum are the regions where the radiation penetrates to the earth's surface.

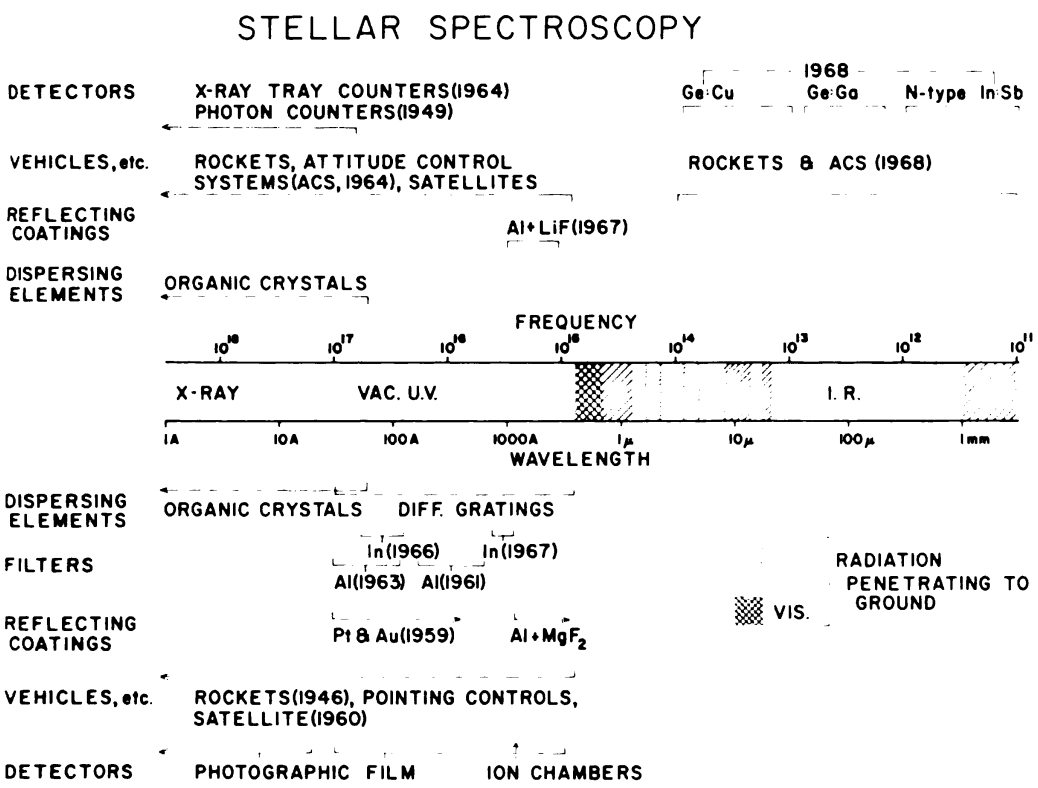


Figure 2 — Summary of some of the important technological developments which enabled solar and stellar spectroscopy results to be obtained from above the earth's atmosphere.

Below the spectrum are shown some of the various technological developments useful in solar spectroscopy, while above the spectrum are some of those which proved fruitful in the development of stellar spectroscopy. The dates indicate when the particular development was first successfully used by NRL to obtain meaningful data.

Almost concurrently with the advent of rockets, the development of pointing systems was begun to insure that the spectroscope always looked at the correct target during the 5 minutes or so that the rocket was above the atmosphere. The attitude control system for stellar spectroscopy was more difficult to develop than the solar biaxial (and more recently the triaxial) pointing system since the former does not have such a large energy source for guidance and must rely on inertial systems to point at a fixed position on the celestial sphere. Satellites were still another development and provided much longer observing periods than rockets. However, because of the inability to recover data from the satellities, all information had to be telemetered to earth. When manned satellites are in use, this requirement may be relaxed. Satellities do not replace rockets as research vehicles; in fact most

research is done from rockets because of the flexibility of their instrumentation and the relatively short preparation time required.

On the ultraviolet side of the visible region, dispersion has been obtained by diffraction gratings and, in the x-ray region, by organic crystals used in Bragg Spectrometers (2). The efficiency of reflecting and diffracting surfaces was improved with evaporated coatings of gold (3), platinum (4,5), and combinations of aluminum overcoated with MgF_2 (5) and lithium fluoride (6). Scattered radiation was eliminated by using thin unbacked metal films (7). Special Schumann emulsions have been developed for photographic techniques (8), while proportional and geiger counters, photon counters and image converters (9) have been used for photo-electric detection. In the infrared region, the semiconductors, Ge:Cu, Ge:Ga and N-type In:Sb are used as detectors in liquid helium cooled telescopes (10).

The remainder of this paper discusses the results obtained using these techniques beginning at the short wavelength end of the spectrum and working toward the longer wavelengths.

Recent measurements by NRL using proportional counters on board an Aerobee rocket have yielded the most accurate spectra to date from several x-ray sources. Figure 3 shows some results from Scorpius XR-1 (11), the brightest x-ray source discovered in the northern hemisphere. Its radiation has a measurable effect on the earth's ionospheric D-region. The data, shown by the plus signs, have not been corrected for instrumental effects. At the low energy end, the window of the x-ray detector absorbs the radiation while at the high energy end the argon gas used in the detector becomes transparent. The dip at about 3.8 KeV is an x-ray absorption edge of argon. The solid curves in the figure are

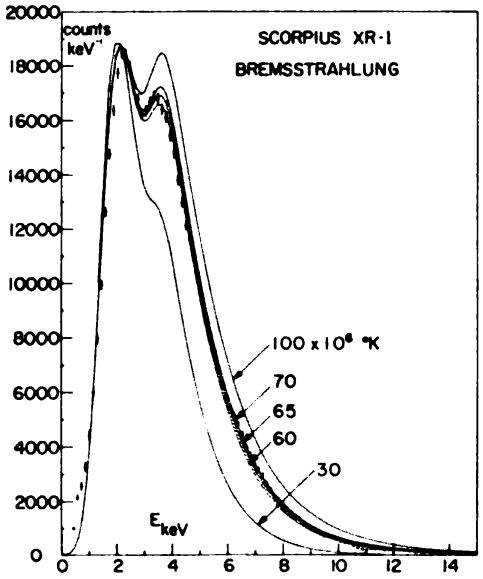


Figure 3 — X-ray data from Scorpius XR-I (plus signs), as limited by instrumental effects, plotted with calculated curves from several thermal bremsstrahlung models on which are imposed the same instrumental effects.

calculated to show the natural x-ray radiation of a thin gas at different temperatures, assuming a thermal Bremsstrahlung* model. Included in these calculations are the instrumental effects of the x-ray detector so that a direct comparison can be made with the observations. The close fit of the 6.5×10^{6}°K curve indicates that this is the temperature of Scorpius XR-1 according to this model.

However, the entire observed range of the Scorpius XR-1 spectrum from radio to x-rays will not fit a single thermal model. Equally plausible models explain the spectrum by synchrotron radiation, the radiation emitted by charged particles being accelerated in magnetic fields and moving at speeds near that of light. Existing observations do not permit choosing between these two models.

In the spring of 1969 an NRL rocket x-ray experiment revealed that a small (about 5%), but significant part of the x-radiation from the Crab Nebula, shown in Figure 4, is emitted in pulses with a period of about 33 milliseconds (12). Earlier NRL data had shown that most of the x-rays come from a large diffuse region of the nebula, about one light year across, rather than from a point source (11). However, the pulsating nature of part of the x-rays, coupled with the discovery in the past year of a pulsating object in optical and radio frequencies near the center of the Crab, tend to lend credence to the theory that the pulsating star is a neutron star that originated in the supernova explosion which formed the Crab. This explosion was observed in daylight and recorded by the Chinese astronomers in 1054 A.D.

The experiment which showed the spatial distribution of the Crab x-rays involved launching the rocket at a particular time so as to show the Crab being occulted by the moon—an event which occurs about once every nine years! The dashed arcs on Figure 4 show the position of the lunar limb at successive times as it moved across the nebula. The x-ray signal intensity decreased gradually, rather than ending abruptly, which would have occurred if all the x-radiation came from a point source. Launching rockets at precise times to observe time dependent extra-terrestrial phenomena, such as occultations, solar eclipses and flares, is a rather difficult maneuver, but has been accomplished successfully on several occasions by NRL to obtain important, and otherwise unobtainable information.

Satellites are ideally suited for monitoring stations because of their long observing time as compared to rockets. The Solrad program was developed for this purpose. It is a small satellite program which currently provides about 70% of the monitoring of the solar x-ray emission in those wavelengths that most directly affect the earth's ionosphere as a communication medium (13). The present vehicle, Solrad IX, was

*Bremsstrahlung is radiation from electrons which gain or loss energy while being accelerated in the field of an atomic nucleus or ion.

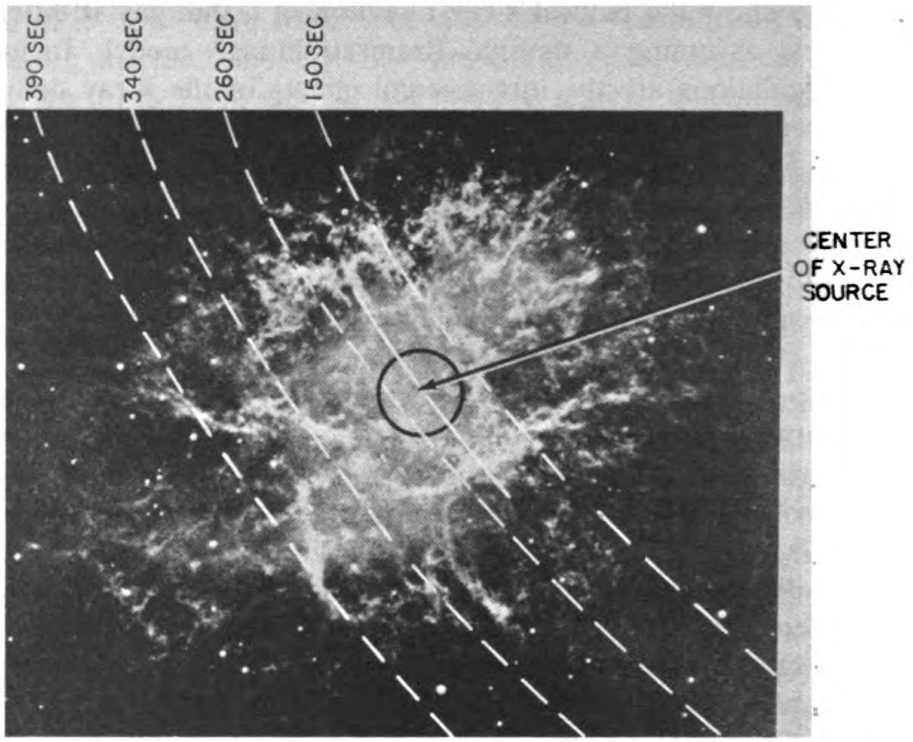


Figure 4 — The Crab Nebula; an extended source of x-rays found to be about one light year across. The dimensions were determined by the change in x-ray intensity as the Moon crossed in front of the Crab on July 7, 1964. The dashed arcs indicate the progress of the occultation.

constructed by NRL and launched by NASA in March 1968. It provides data transmitted in real time to United States and foreign observers who monitor the satellite transmission independently. Statistical analysis has now begun to yield x-ray flux criteria predictions of solar activity. Thus, data taken over a period of fourteen months show that solar flares are three times more likely to occur when the criteria are met than when they are not.

Figure 5 illustrates the solar x-ray data obtained from Solrad IX. Three separate x-ray bands are monitored, 0–3Å, 1–8Å, 8–20Å. Normal solar flux, with a few minor disturbances, was recorded until 2100 hours when an x-ray flare suddenly occurred. Note that the flux increase is greatest in the shorter x-ray bands. The flux peaked in minutes and then took several hours to return to normal. This is typical of flares.

The Solrad program also includes a prediction service for communication disturbances based on the x-ray data. The data processing has been streamlined to the point that when the satellite is over a ground station the data is received and evaluated, predictions are made and the information is sent out over communication links to interested military and other agencies within 15 minutes. This Solrad x-ray data appears to provide the most sensitive indication of ensuing solar disturbances

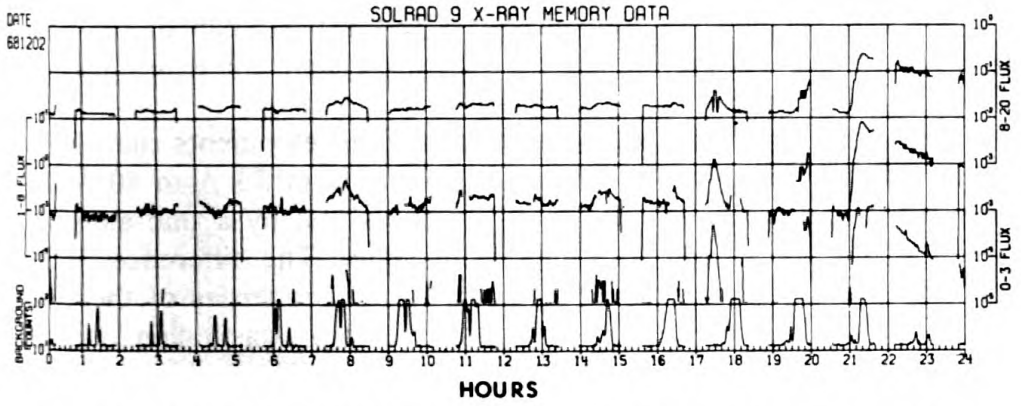


Figure 5 — SOLRAD IX data for December 2, 1968 showing three wavelength bands and background flux. Peaks on latter indicate exposure to Van Allen radiation belt where it dips closer to earth's surface over South Atlantic Ocean.

that can cause sudden ionospheric disturbances and shortwave radio communication fade-outs. Warnings of communication disturbances resulting from increased solar activity were announced some fourteen times in the past year, and have been proven reliable. Hence, radio operators can now get some warning of the possibility of communication interruptions.

By using platinum coatings on gratings and mirrors (4,5), and by going to grazing incidence spectrographs, the solar spectrum was extended to the soft x-rays, about 30 Å. Such spectra would have been impossible without another NRL technical development, namely the use of thin

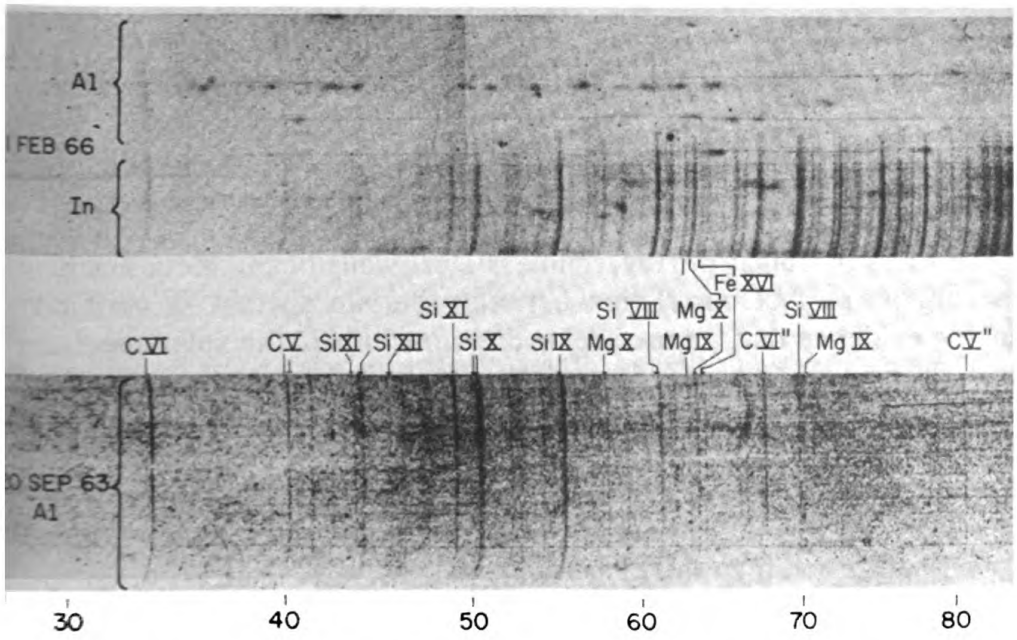


Figure 6 — The soft x-ray spectrum of the sun, photographed by NRL on September 20, 1963 with an active sun and on February 1, 1966 when the sun was quiet.

unbacked metal films as transmission filters (7) to keep the scattered light from the one-million-times-more-intense visible and near-ultraviolet solar radiation from reaching the photographic film.

Figure 6 illustrates the results of these two developments and shows a portion of the soft x-ray spectrum extending from 30 Å to 80 Å (14). In the top spectrum, half of the slit was covered by a thin aluminum filter and the other half by a thin indium filter. The differences in line intensities show the difference in transmission properties of these two metals at these wavelengths. The top spectrum was taken during a period of quiet sun and the bottom spectrum, which used an aluminum filter, was taken on an active sun. The differences in line intensities caused by these two conditions are easily seen. These differences indicate that lines such as Si IX arise from the mechanisms associated with the active regions.

A number of these solar x-ray lines have been identified as arising from highly excited states of metal atoms. The lines are identified by the chemical symbol of the element plus a Roman numeral which is larger by unity than the number of electrons removed from the atom. From such spectra over two hundred coronal emission lines have been measured with a wavelength accuracy of about 0.03 Å. Analysis of the intensities of approximately 70 identified lines indicated that approximately equal amounts of iron and silicon are present in the corona and that the quiet corona has a temperature of about 1,700,000 Kelvin (1.7×10°K).

Not all observed lines have been identified because of the paucity of experimental and theoretical spectroscopy for highly ionized atoms. It is heartening to know, however, that laboratory astrophysics is making its contribution as illustrated in Figure 7. Here we see part of the solar spectrum from 150 Å to 220 Å compared with the spectrum obtained from a Zeta machine, a type of Θ pinch or plasma apparatus, at Culham Laboratories, U. K. (15). The lines in the laboratory spectrum are of highly ionized Fe VIII to XIV, and Ni X to XIV arising from atoms literally boiled off the stainless steel walls of the Zeta machine. The almost perfect correlation between the two spectra is very convincing evidence that we are seeing the same lines in the solar spectrum. Note the sudden decrease in intensity of the solar spectrum at 170 Å going from the long to the short wavelengths. This is not a feature of the spectrum but is caused by a thin unbacked Al film used to shield the photographic film as previously mentioned. The $L_{2,3}$ absorption of Al occurs at 170 Å so that radiation of shorter wavelength is more strongly absorbed than the longer wavelengths.

Now that some of the lines have identities, the question arises: where do they originate on the sun? Are they coronal or chromospheric in origin? In other words, there is now a need for spatial as well as spectral resolution. This question of the origin of the lines is partially answered

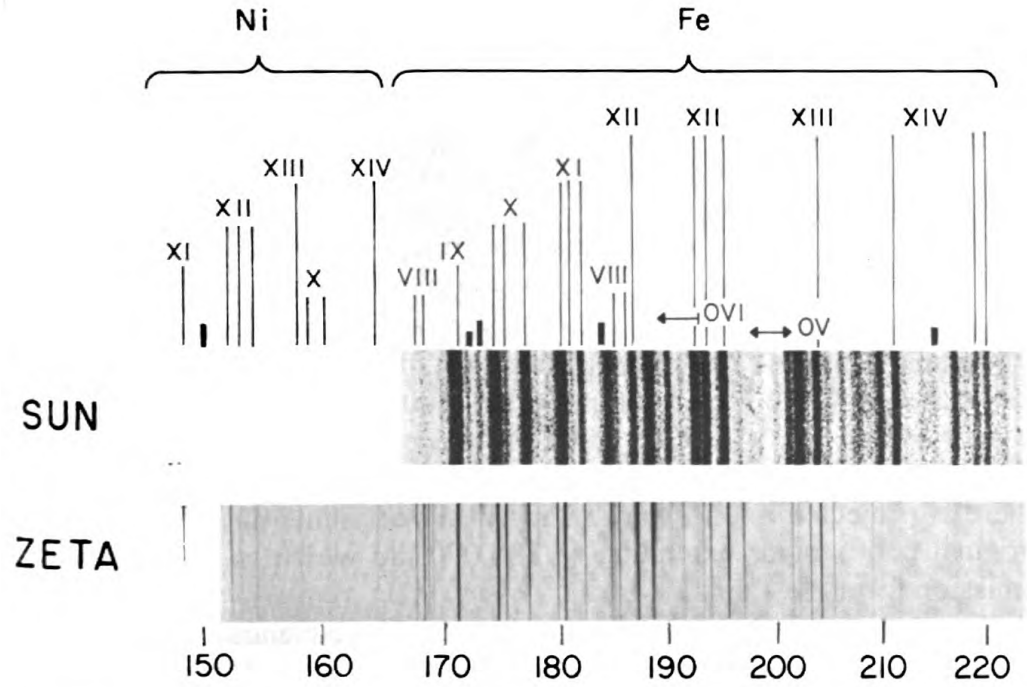


Figure 7 — The solar spectrum (above) as photographed by NRL on May 10, 1963 compared with the spectrum of the high temperature plasma produced by the zeta discharge (below) at Harwell, England. The identifications show the lines from the 3p-3d transitions of the Fe and Ni sequences as classified largely by the Culham Laboratory.

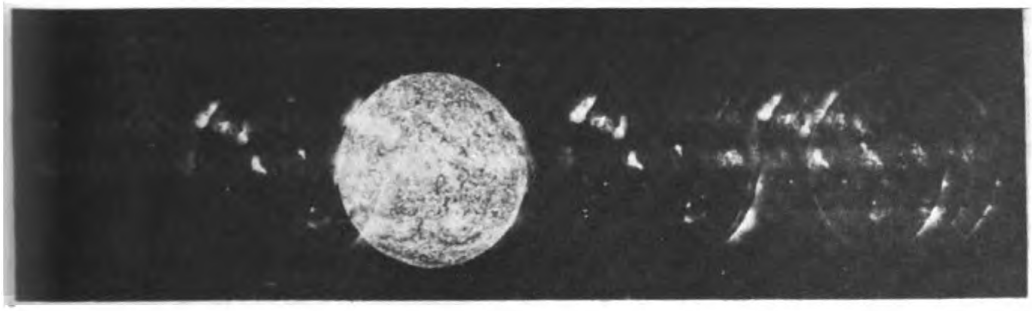


Figure 8 — Spectroheliograms photographed on NRL rocket experiment, September 22, 1968

in Figure 8. This is one of our latest spectroheliograms obtained with a slitless spectrograph (16). If a slit had been used, spectral lines would have been photographed; but elimination of the slit allows images of the sun's disc to be photographed. Since the spacing of the wavelengths is much smaller than the disc diameter, the disc images overlap. The pointing accuracy for this rocket flight was 10 sec. of arc, an accuracy

never before achieved. This permitted recording quite small details. He II (304 Å), the central feature, is a chromospheric line. It is intense over the disc and shows considerable detail; several large prominences were recorded in He II. On the other hand, the Fe XV and XVI lines originate in the corona, mainly above centers of activity since emission above the limb, or edge, of the disc is conspicuous and over the disc faint. The Mg IX emission is just above the limb and indicates that it has a uniform distribution in the lower corona. Intense coronal emission from a plage located on the limb, in the upper left-hand quadrant, of each solar image was extended to an altitude of 70,000 km. This feature, associated with the He II 304 image, is thought to be from Si IX which has a wavelength 0.4 Å short of He II; hence the small dark line between the disc and the coronal emission. Out of the center of this feature there is projected a long, thin, strongly curved plume discernible on the original photograph, extending to 300,000 km which is believed to be emission from He II.

Figure 9 shows a set of heliograms in 5 wavelengths which were obtained from an NRL experiment in the OSO V satellite launched in January, 1969 (17). In addition, an x-ray scan of the solar disc, from an instrument prepared by the University College, London and obtained from the same satellite, is shown. These heliograms are recorded photoelectrically whereas the previous rocket spectroheliograms were recorded photographically.

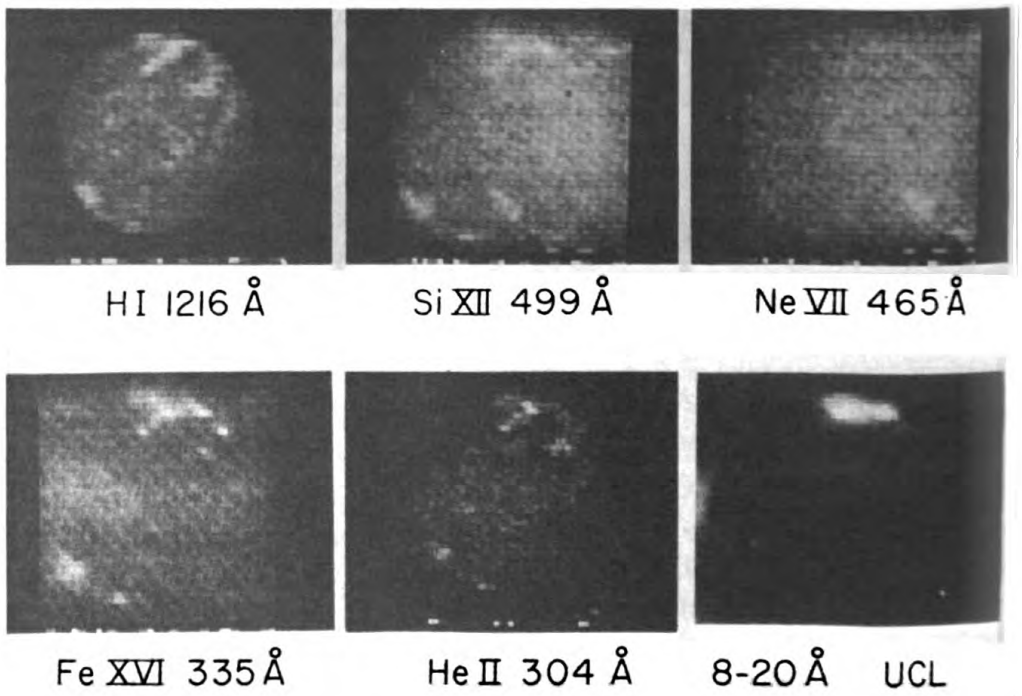


Figure 9 — Spectroheliograms recorded from OSO V on February 12, 1969

At 1216 Å (HI) and 304 Å (He II) the disc is clearly seen because these lines are chromospheric in origin. The other lines originate either in the upper chromosphere or lower corona where the temperature is higher. Because of the higher temperature, the density of the atoms and, consequently, the radiation intensity, is lower and no disc can be seen. Features associated with the hotter, active regions are common to all images. The bright spot in the picture labelled Ne VII is actually the 499 Å line of Si XII, shown in the upper central picture, which has overlapped the Ne image. The Si XII picture also contains part of an overlapping image, approximately at the center of the picture, that is the 522 Å line of Si XII.

Undoubtedly the more distant stars exhibit the same type of phenomena as the sun. However, their great distance makes such spatial

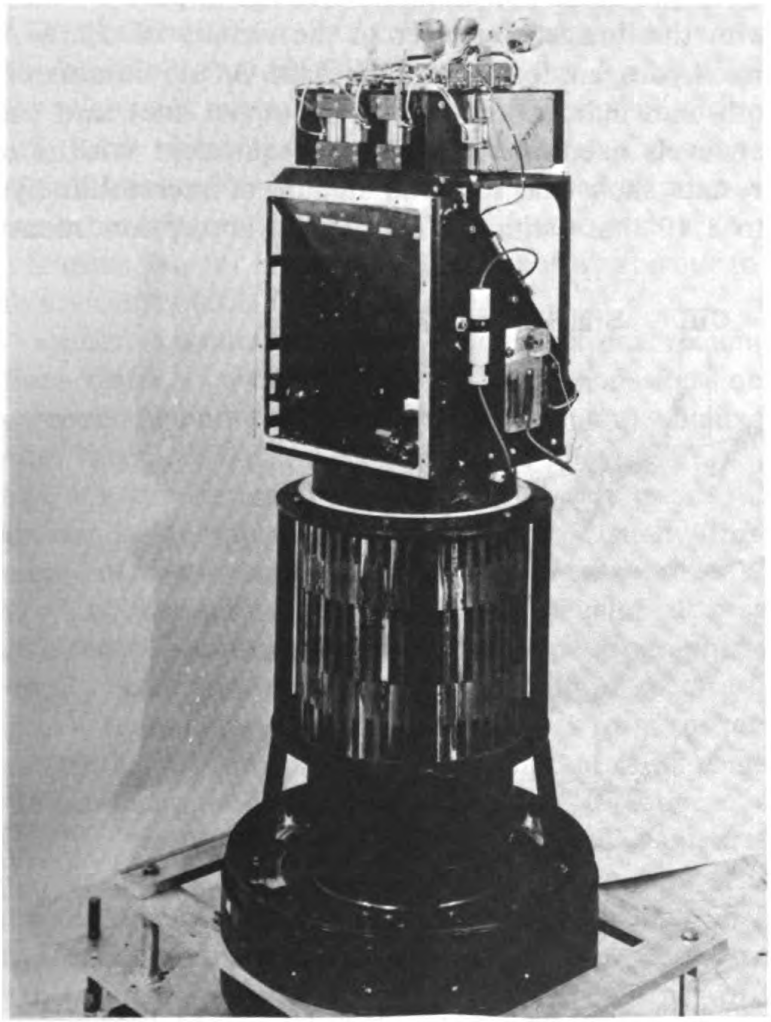


Figure 10 – Photograph of image converter spectrograph showing collimators mounted above grating mosaic, focussing coil, and primary mirror at the bottom. First used successfully to record stellar XUV spectra in 1967.

resolution impossible and all information must be deduced from spectra. The method of obtaining the spectrum of such distant and, compared to the sun, faint objects is a technology in itself and merits a short description. An extreme ultraviolet image converter was used which is shown in Figure 10 (18). A flat, objective grating, not shown in the figure, is used from which the diffracted wavelengths enter the instrument. They are focussed by the collecting mirror, which is coated with Al + LiF, onto a photocathode which has been sensitized with a coating of KBr. The photoelectrons are accelerated toward the emulsion and focussed on it by the magnetic field of the solenoid. Thus images of the stars are obtained in different wavelengths on the film. Early stellar spectra showed a short wavelength limit of about 1030 Å that was mostly instrumental but was extended to almost 1000 Å in the latest flight.

Figure 11 shows some densitometer tracings of part of the spectrum obtained with this image converter in the vicinity of 1216 Å, the HI line of atomic hydrogen, for three stars of the Θ Orionis cluster of Orion (18). Smooth lines indicate the continuum (upper line) and background (lower line) levels used in estimating the equivalent widths of the HI line. The results show that the total amount of interstellar hydrogen is only 1/5 to 1/10 that estimated from radio absorption measurements

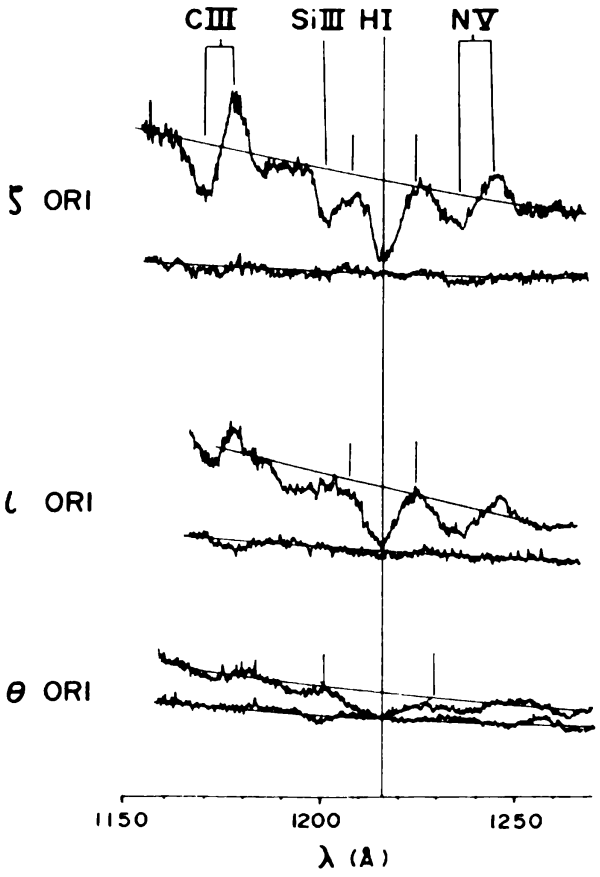


Figure 11 – Densitometer traces of spectra from three stars of the Θ Orionis cluster of Orion.

using the 21 centimeters (cm) line of hydrogen. They also include confirmation that the hot stars are less bright than predicted by model atmosphere theory at wavelengths shorter than HI and that early-type super-giant and bright Orion stars are ejecting gas at high velocity. This latter result is deduced by the absorption (dip at left) and emission (peak at right) feature of the C III line. The emission is thought to come from radiation from the star's central core. The absorption, which is shifted toward shorter wavelength, is believed to occur in an expanding shell of gas around this core.

The solar spectrum in this wavelength region is relatively uncomplicated by large concentrations of intervening material or rapidly expanding gas shells and consists mostly of emission lines with some continua. One example of the latter is the hydrogen recombination continuum beginning at 912 Å and extending, with ever decreasing intensity, to shorter wavelengths. However, even though the earth-sun distance is small compared to interstellar distances, there is still enough hydrogen to cause absorption of the Ly-alpha and Ly-beta lines at 1216 Å and 1026 Å respectively. The profiles of these lines have been recorded with high dispersion spectrographs and show broad wings with partial self absorption of the line center caused by atomic hydrogen in the solar atmosphere (19). In addition, in the center of the broad absorption feature is a quite narrow "telluric" absorption due to hydrogen in the earth's vicinity (20).

Toward longer wavelengths, the solar spectrum remains one of emission lines until, at about 1900-2100 Å, the emission lines become too faint to record against the photospheric continuum, with its thousands of absorption lines. In the wavelength region above 2000 Å, the near ultraviolet (UV), the absorption lines are so closely packed that rather high resolution is necessary to resolve them. Usually this involves an instrument of fairly large size which is incompatible with space limitations of rockets. However, NRL has developed a small, high resolution rocket spectrograph: the echelle spectrograph, which has been extremely useful in obtaining high resolution spectra of the sun in the near UV and also in observing line profiles from rockets.

The name of this instrument is derived from that of its coarse grating. This echelle grating is used in the high orders. Its direction of dispersion is at right angles with that of a prism or grating of comparatively low dispersion. The low dispersion separates the high orders of the echelle grating into separate, almost horizontal, bands, as shown in Figure 12, while within each band is a part of the highly dispersed solar spectrum. By using this scheme, the dispersion equivalent to that of a 21 foot radius of curvature, concave grating was obtained with an instrument about 3 feet long.

The spectral region covered in the echelle spectrogram of Figure 12 is from about 2100 Å to 4000 Å and has a resolution equivalent to that

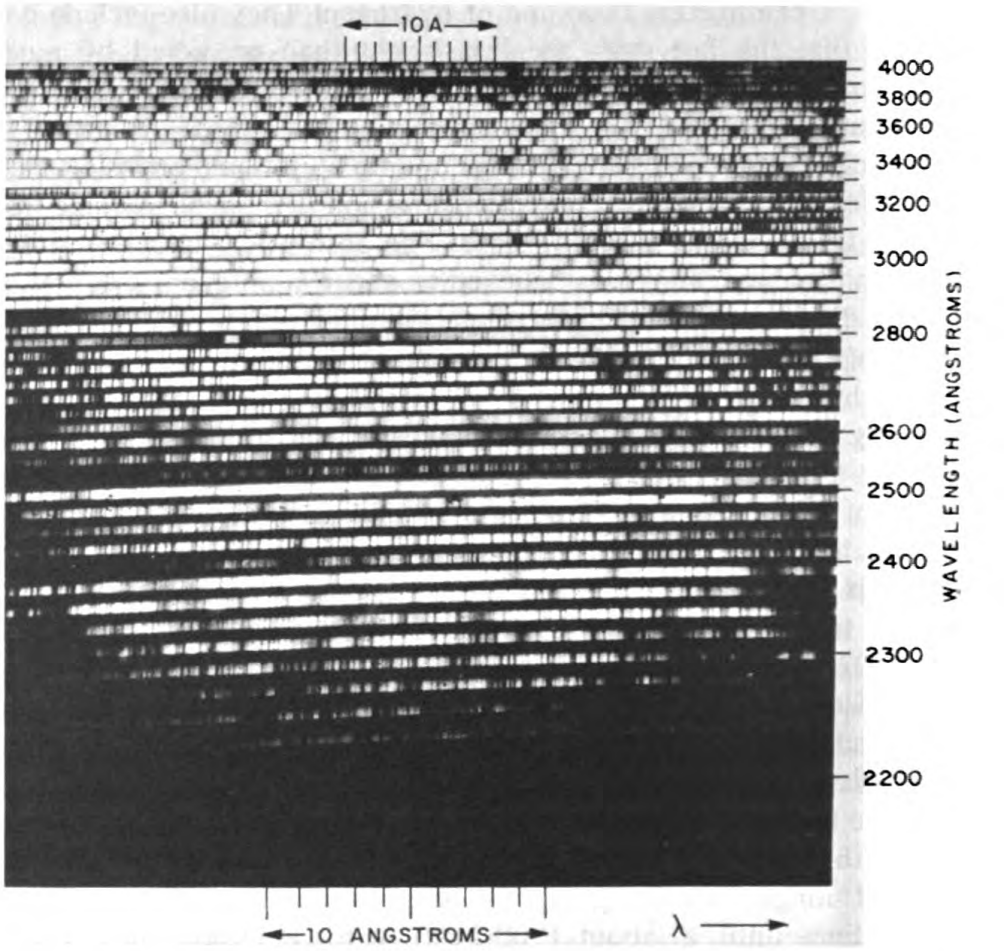


Figure 12 — The near ultraviolet spectrum of the sun, photographed with an echelle grating spectrograph by NRL on August 29, 1961. The resolution is about 0.03 Å.

of some of the best ground based instruments (21). With two exceptions, these lines are all seen in absorption (dark lines against the bright photospheric continuum as a background); they are called Fraunhofer lines. The two exceptions are the Mg II lines at 2795 Å and 2803 Å (in row labeled 2800) which are D lines in the Na isoelectronic sequence. They are strongly self-absorbed so that only the wings of the broadened line are seen in emission. From this spectrum a total of 7146 lines have been observed of which 3929 have been identified.

On the other side of the visible spectrum, considerable interest has developed in far infrared astronomy which also requires observations from above the atmosphere. The technical problems in such an experiment are very difficult and include cooling a telescope with liquid helium in a zero gravitational field. Despite formidable problems, a rocket flight in March 1968 showed several celestial sources in the 10-30 μ range (22). The sources could be associated with late-type spiral galaxies

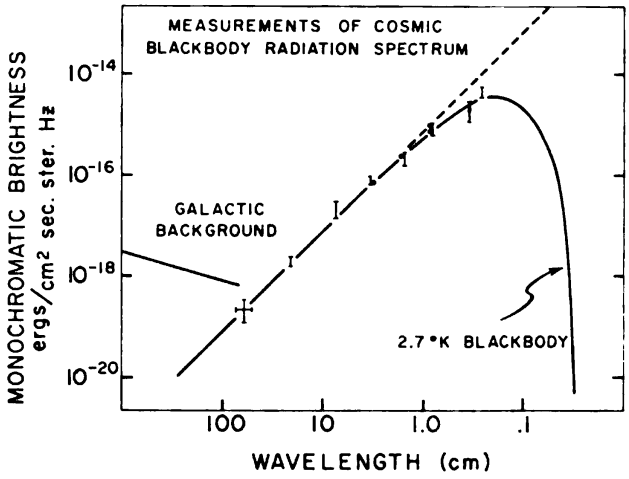


Figure 13 – The "cosmic background." A summary of observed values with error bars. The points near the peak shown as upper limits are measured indirectly by absorption of near-ultraviolet light by interstellar cyanogen. The solid curve represents the calculation for a 2.7°K blackbody.

that were within the field of view and had infrared luminosites comparable with optical luminosities of quasars. On the same flight the intensity of the 63 μ emission of atomic oxygen in the nighttime high atmosphere was measured. This is thought to be the principle mechanism of radiation cooling of the thermosphere.

NRL has also collaborated on another flight with Cornell University in February 1968 to make observations in the 400-1300 μ range (23). One of the results was a measurement of the intensity of the background infrared from without the galaxy. Recent results obtained by radio astronomy at longer wavelengths which reach the earth's surface, have suggested that this background radiation comes from the remnants of the explosion in which the universe was created, *i.e.*, the "Big Bang" theory of LeMaitre (24). Figure 13 shows a calculated 2.7°K blackbody curve with the radio observations superimposed on it. The fit is very good indeed but because the shorter wavelengths are absorbed by the atmosphere the essential observations needed to confirm or deny the theory could only be obtained by a rocket or satellite experiment. The infrared observation obtained from the rocket experiment appears to be, in essence, an ultraviolet catastrophe for the theory because the experimental points did not fall on the 2.7°K blackbody curve, but rather fell along the linear extension of the line drawn through the plot of the radio observations. It is emphasized that this data comes from just one observation and that it could result from phenomena other than the remnants of the "Big Bang" (25), but it is giving proponents of this theory a chance to exercise their reasoning.

The longest wavelength range observed by the NRL Space Science Division is that of mm and cm waves. This study, known as radio astronomy, has been responsible for quite a few significant advances. One of the most recent is the discovery by a group at the University of California in collaboration with the NRL Radio Astronomy Branch of

water molecules; H_2O, by observing the 1.35 cm radiation of the rotational transition of water (26). The sources, 10 in number, are quite small, less than 1.0′ of arc, and the molecules appear to be in rapid motion.

Figure 14 illustrates some of the data from several of these sources. The ordinates (vertical scale) are the antenna temperature. The abscissa (horizontal scale) are radial velocities which extend over a large range.

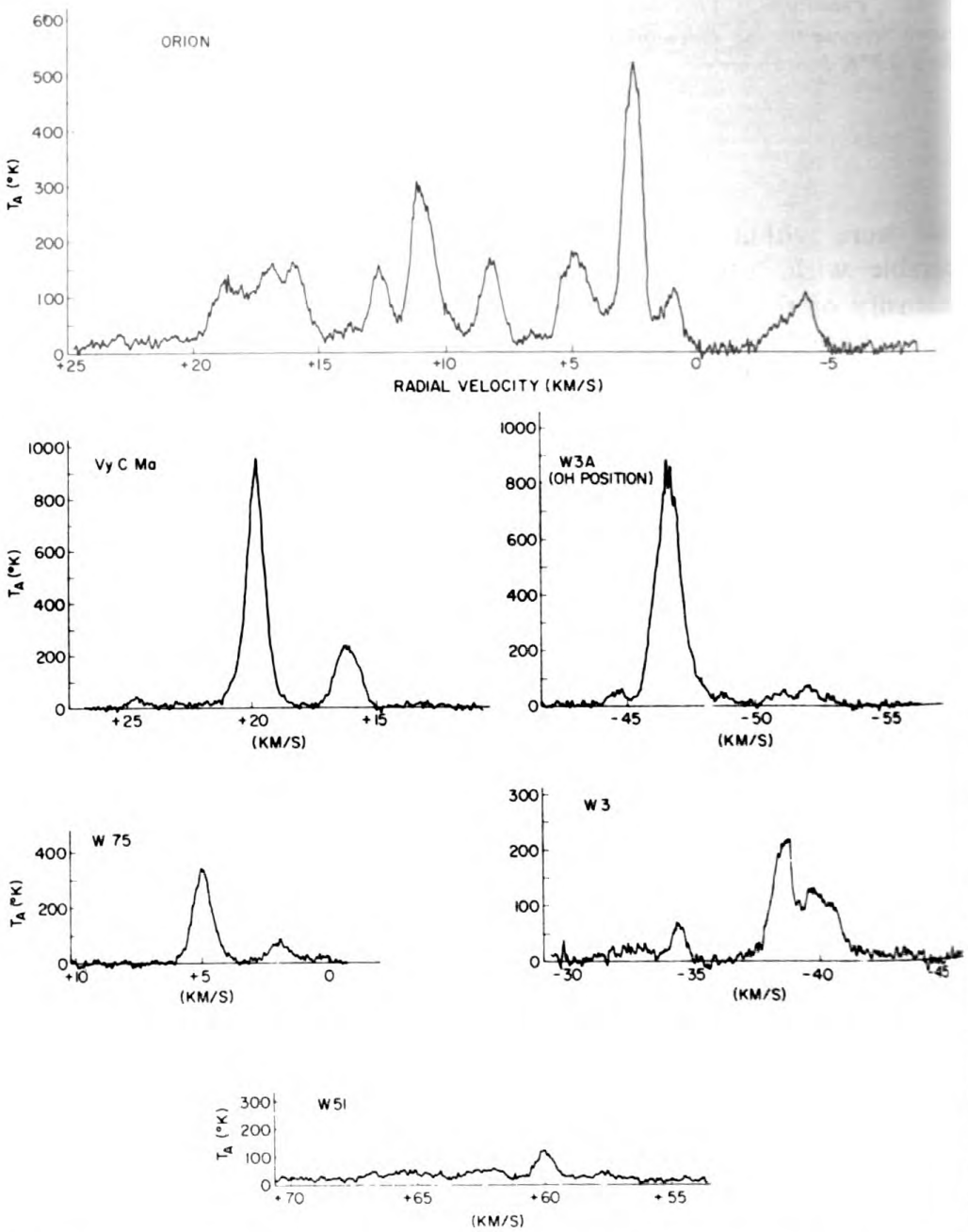


Figure 14 — Radio emissions from the 1.35 cm rotational transition of H_2O from various extra terrestrial sources. These were observed in early 1969.

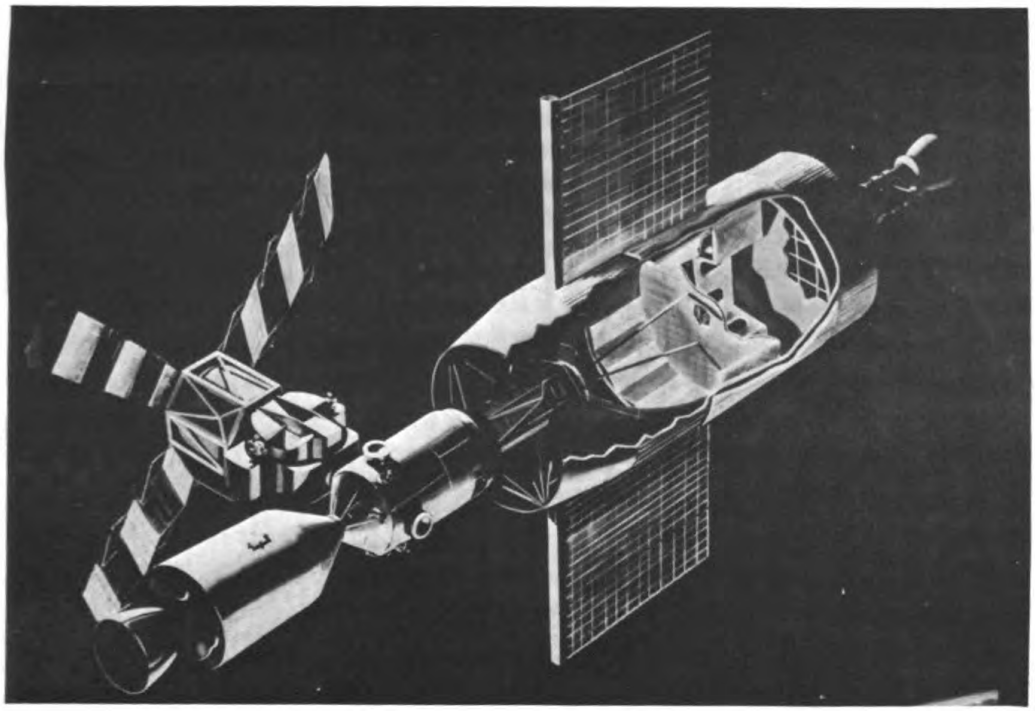


Figure 15 — AAP space-station configuration (courtesy of NASA Marshall Space Flight Center).

The observed water line emission is very intense. This high intensity of received radiation, together with the measured source size of 0.7′ of arc or less, implies a brightness temperature of 50,000°K or more. If the sizes of some of the intense source regions are two orders of magnitude smaller, as implied by the variability observed for one of them, much higher brightness temperatures of the order of 10^{9}°K are indicated.

The properties of this radiation indicate that it is caused by stimulated emission (maser action) rather than normal spontaneous or thermal emission. Clearly the molecular motions are not in thermal equilibrium, since water would dissociate rapidly at 10^{9}°K or even 50,000°K, the temperature of the radiation. Also, from the measured line intensity, knowing the source distance and assuming an isotropic flux radiation, the number of radiators would have to be equivalent to 50,000 solar masses which is excessive for such small sources. Hence one appeals to maser-type amplification to account for the production of such copious amounts of radiation.

At this point it would be well to give a brief resumé of some future experiments (27) which NRL is presently preparing for the Apollo Telescope Mount (ATM). This will be part of the first NASA prototype manned space station, now scheduled for launch in 1971-72. Figure 15 illustrates this station. A workshop will be built inside an S-IVB rocket stage. A multiple docking adapter, in the center, will join the

command and service module on the left, the S-IVB, and the lunar module (LM) ascent stage which houses the ATM control and display panel. The ATM is positioned at the end of the LM opposite the multiple docking adapter.

The ATM contains nine instruments which will observe the sun over a fifty-day period. NRL is preparing three of them. Two are photographic instruments, a spectroheliograph to cover the 150 Å-630 Å waveband and a spectrograph to cover the 970 Å-3940 Å waveband. The photographic film will be carried back by the astronauts. The third instrument is a XUV monitor which will present a heliogram, integrated over the 170 Å-550 Å waveband, on a TV display in the Lunar Module to enable the astronauts to select suitable targets for the other ATM instruments. Copies of these heliograms will periodically be transmitted to the ground for further study.

The information presented in this review illustrates the technology which NRL has developed to observe the non-visible portion of the electromagnetic spectrum emitted by extra terrestrial sources, and shows some of the results obtained since the beginning of rocket spectroscopy in 1946. NRL has pioneered the efforts to observe these sources in many of the non-visible regions of the spectrum. The resulting breakthrough of several thresholds in astronomy has enabled man to gain a better understanding of the universe and the effects which it has on the terrestrial environment. The technology developed for this has been used in a number of significant applications to military needs and other scientific fields of endeavor.

REFERENCES

1. R. Tousey, C. V. Strain, F. S. Johnson, and J. J. Oberly, *Astrophys. J.* **52,** 158A (1947)
2. R. L. Blake, T. A. Chubb, H. Friedman, and A. E. Unzicker, *Astrophys. J.* **142,** 1 (1965)
3. L. R. Canfield, G. Hass, and W. R. Hunter, *Le Journal de Physique* **25,** 124 (1964)
4. G. F. Jacobus, R. P. Madden, and L. R. Canfield, *J. Opt. Soc. Am.* **53,** 1084 (1963)
5. G. Hass and R. Tousey, *J. Opt. Soc. Am.* **49,** 593 (1959)
6. D. W. Angel, W. R. Hunter, R. Tousey, and G. Hass, *J. Opt. Soc. Am.* **51,** 913 (1961)
7. W. R. Hunter and R. Tousey, *Le Journal de Physique*, **25,** 148 (1964); W. R. Hunter, D. W. Angel, and R. Tousey, *Appl. Optics* **4,** 891 (1965)
8. R. Tousey, *Appl. Optics* **1,** 679 (1962)
9. H. Friedman, *Physics of the Upper Atmosphere*, Ed: J. A. Ratcliffe, (Academic Press, New York, 1960) pp. 155-163
10. P. D. Feldman and D. P. McNutt, *Appl. Optics* (to be published) (1969)
11. S. Bowyer, E. T. Byram, T. A. Chubb, and H. Friedman, *Annales d'Astrophysique* **28,** 791 (1965)
12. G. Fritz, R. C. Henry, J. F. Meekins, T. A. Chubb, and H. Friedman, *Science* **164,** 709 (1969)
13. R. W. Kreplin and D. M. Horan, NRL Report 6800 (1969); D. M. Horan, R. W. Kreplin, A. T. McClinton, Jr., and L. C. Schneider, NRL Report 6884 (1969)

14. W. E. Astin, J. D. Purcell, C. B. Snider, R. Tousey, and K. G. Widing, *Space Research VII*, Vol 2, Ed: R. L. Smith-Rose (Amsterdam:North Holland Publishing Co., 1966) pp. 1252-1261
15. B. C. Fawcett, A. H. Garbiel, W. G. Griffin, B. B. Jones, and R. Wilson, *Nature* **200**, 1303 (1963)
16. M. J. Koomen, R. T. Seal, J. D. Purcell, and R. Tousey, *Sky and Telescope* **37**, 356 (1969)
17. D. M. Packer and I. G. Packer, private communication
18. G. R. Carruthers, *Astrophys. J.* **156**, L97 (1969). G. R. Carruthers, *Applied Optics* **8**, 633 (1969)
19. R. Tousey, J. D. Purcell, W. E. Austin, D. L. Garrett, and K. G. Widing, *Space Research IV*, Ed: P. Muller (Amsterdam:North-Holland Publishing Co., 1964) p. 703
20. R. R. Meier, *Astronautics and Aeronautics* **7**, 68 (1969)
21. J. D. Purcell, D. L. Garrett, and R. Tousey, *Space Research III*, Ed: W. Priester (Amsterdam:North-Holland Publishing Co. 1963) pp. 781-786
22. P. D. Feldman, D. P. McNutt, and K. Shivanandan, *Astrophys. J.* **154**, L131 (1968). P. D. Feldman and D. P. McNutt, JGR (to be published) (1969)
23. K. Shivanandan, J. R. Houck, and M. O. Harwit, *Physical Review Letters* **21**, 1460-1462 (1968)
24. LeMaitre, *Ann. Soc. Sci. Bruxelles* **47A**, 49 (1927)
25. R. B. Partridge, *American Scientist* **57**, 37 (1969)
26. S. H. Knowles and C. H. Mayer, *Science* **163**, 1055 (1969)
27. T. C. Winter, Jr., *Astronautics and Aeronautics* **7**, 64 (1969)

Fast Gaseous Reactions

Princeton University has submitted to ONR the final report on "Fundamental Processes in Gaseous Reactions." The report traces some ten years of progress with several fundamental contributions to combustion, fast reactions, and other areas relevant to military propulsion technology.

The work was started by Professor D. F. Hornig concentrating first on fast reactions in shock waves. This was one of the first shock tube chemistry efforts in this country and much pioneer work in equipment and instrument design was accomplished. Dissociation of bromine, Br_2, was first studied and then recombination of bromine atoms was studied using flash photolysis (1961). Later the thermal dissociation of N_2F_4 and related work on NF_2 decomposition at shock temperatures was done (1963) laying the fundamental groundwork for the understanding of combustion reactions which would arise from the use of N-F compounds as oxidizers in rocket fuels.

In the area of hydrocarbon combustion reactions, the ultraviolet emission from acetylene-oxygen flames was done. Infrared emission resulting from vibrational relaxation of the simple diatomics HCl, HBr, CO_2, and N_2O at 1000°K was also studied. These studies are basic to gas lasers.

Professor Hornig left the program in 1964 to become Presidential Science Advisor being succeeded by Professor George Leroi. Under Professor Leroi attention was focussed on the use of photolysis as a tool for initiating chemical reactions. Use of the ruby laser as a source of high intensity coherent light was explored leading to the important discovery of a two-photon absorption and subsequent chemical reaction in solid silver chlorine, AgCl. This discovery followed by only a few months the discovery by Bell Telephone Laboratory of a similar laser induced photopolymerization of polystyrene. The significance of the two-photon absorption discoveries lies in the fact that the longer wavelength (less energetic) coherent light can be used to initiate reactions which would otherwise not be activated by ordinary light (of same wavelength) (1965).

Graphical Processors

W. J. Kubitz and W. J. Poppelbaum
University of Illinois

During the past five years, the Hardware Research Group at the University of Illinois, Department of Computer Science under contract with the Office of Naval Research has been engaged in the application of hybrid digital-analog circuit techniques to pictorial information processing. Several graphical processors have been constructed on an experimental basis. Graphical processors are capable of recognizing patterns in pictorial data. An example of the value of such a capability is to recognize objects camouflaged to the eye.

Paramatrix

One type of graphical processor is Paramatrix (Figure 1). Its essential feature is the ability to translate, rotate, and magnify a two-dimensional input and to display the resulting output pattern. Such a system could be used as a preprocessor to recognize patterns in data. After the input pattern is obtained, the output is displayed on a square array of indicator

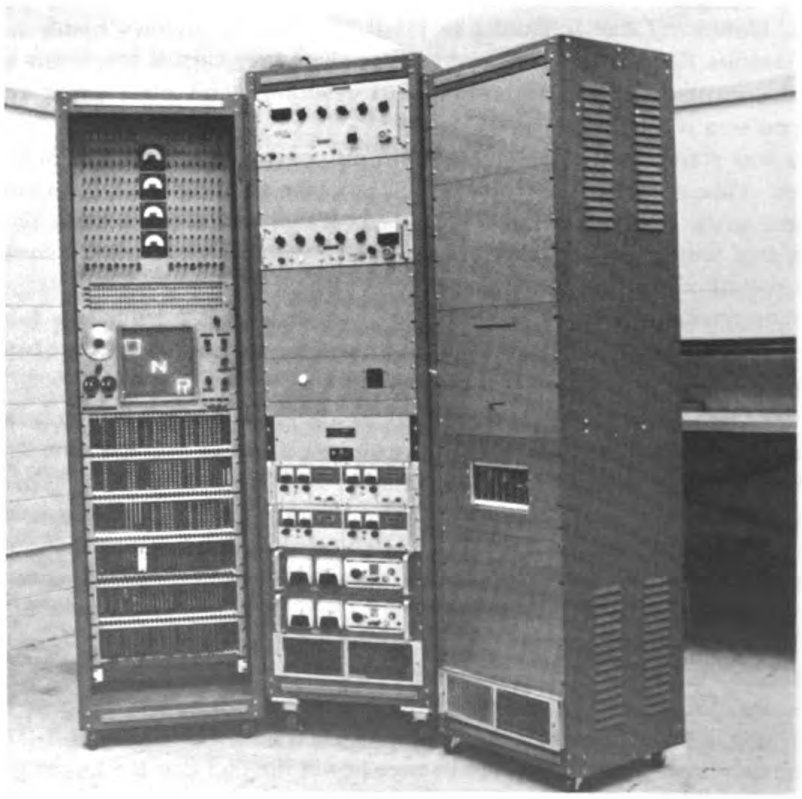


Figure 1 — Paramatrix

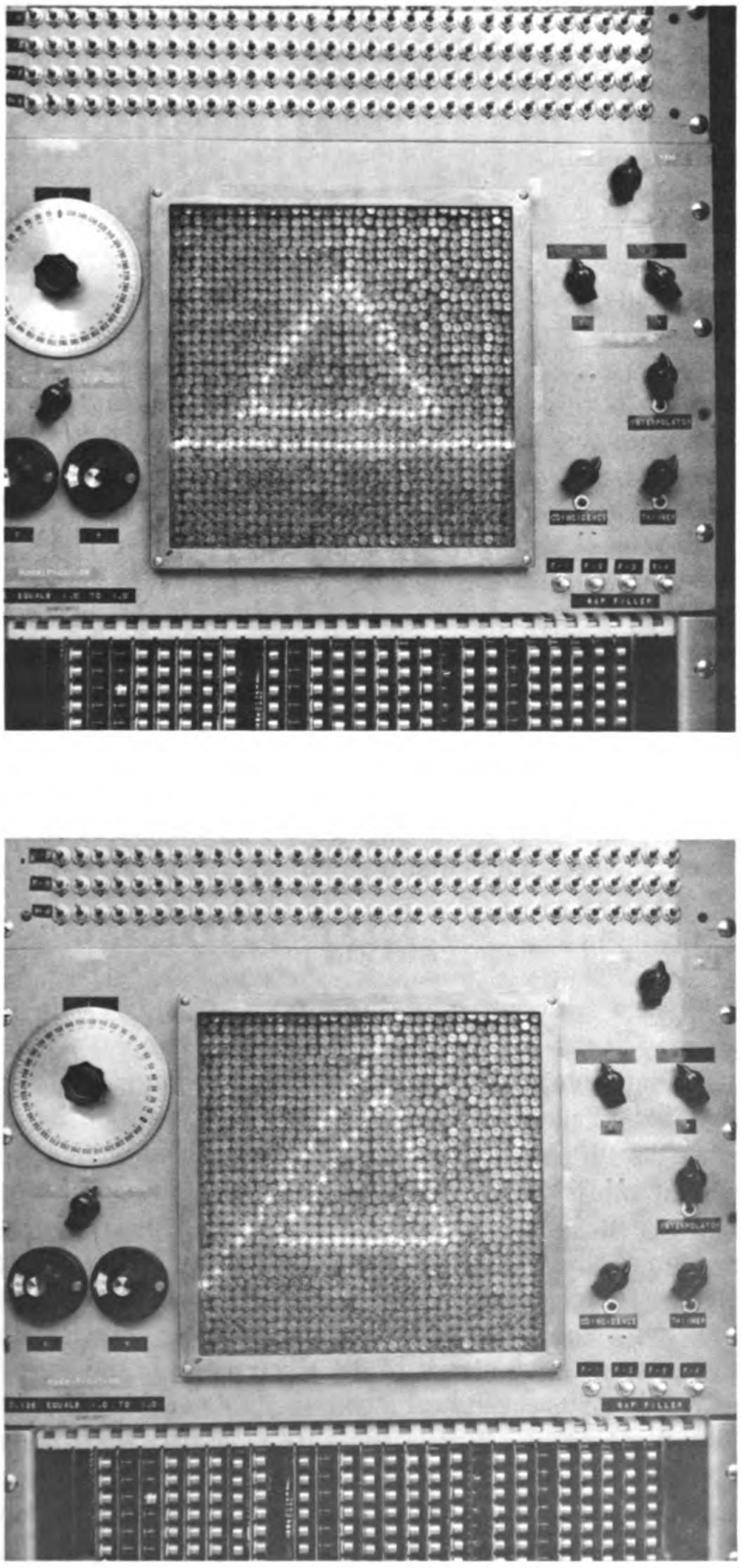


Figure 2 — Before and after rotation

lamps. The output format is digitized in such a way that the translated pattern could be sent to a pattern processing computer.

The operation of the system relies heavily on the use of hybrid circuit techniques. This is accomplished by means of digital circuitry which is controlled by an analog signal and analog circuitry which is under the control of digital signal.

The circuitry is arranged so that the picture displayed on the output array is a magnified, translated, rotated version of the input picture. This transformation is actually performed in reverse. That is, Paramatrix actually examines each output point on an individual basis and determines if there is a corresponding input point (taking into consideration any rotation, magnification and translation). Whether or not there is a corresponding input point is determined by examining the input slide at the point in question. Thus, after a complete scan of the output field, all points in the input field which have corresponding points in the output field are determined; and then the transformation is complete. This is accomplished in about two milliseconds in the model. The magnification, translation and rotation are adjusted by means of potentiometers under operator control in the model. In a more automated system, these parameters could be put under computer control. Figure 2 shows a pattern before and after rotation.

The success of this prototype system shows that small, high speed, graphic interpreters can be built using hybrid circuit techniques at reasonable cost and that great savings in computation time can be obtained over conventional digital processing.

ARTRIX

Another hybrid system, Artrix, produces graphical constructions on a TV display at the command of an operator (Figure 3). The display utilizes a standard black and white television monitor. A light pen is used in conjunction with the display in order to write on or construct lines and circles on the display. The light pen uses a photodiode to detect the raster of the television monitor. The output of the pen is used either to write into a graphic memory or to perform the logical operations required by the processor for the automatic construction of lines or circles. The graphic memories in Artrix are units composed of a direct-view storage tube with two stable states and a television camera. Input to the memory is by means of the writing gun in the storage tube. The output from a storage tube or cell is obtained from the television camera. The cameras of all cells run synchronously with the display. Thus, the information on the display is obtained directly from the output of the memory. All information stored in the memory is in pictorial form. Writing on the display is accomplished by allowing the light pen signal to drive the write gun in the storage tube of the memory. This

Figure 3 — Artrix

written signal (which appears on the storage tube face) is scanned by the television camera and displayed on the monitor.

When constructions are performed, the light pen is used to specify the endpoints of lines to be constructed or, in the case of circles, to specify the center and a point of the circumference. Construction operations are accomplished in the processor.

The line or circle specified by the operator is formed by means of a Lissajous pattern, curves formed by the combination of sine waves, and is subsequently written into the memory. Locations on the display are determined digitally by means of counters which are under the control of the light pen. In this way, the horizontal and vertical amplitudes of the appropriate Lissajous pattern are determined in digital form. These digital signals control the amplitude of the appropriate horizontal and vertical deflection signals which form the Lissajous pattern. For lines and circles, the appropriate horizontal and vertical deflection signals are sinusoids. Thus, for example, a line would require sinusoidal voltages both horizontally and vertically. The sign of one of these signals can be made positive or negative in order to take care of lines of positive and negative slope. As mentioned, the actual slope is controlled by the amplitude of the sinusoids. Similarly, for a circle, a sine and a cosine signal are used. In the actual system, the amplitude of the line is halved and the position of the line is shifted in order to make the line pass

between the endpoints. It is possible to generate any conic section in this manner although in the working model only lines and circles have been implemented.

Local erasure in the system is complicated by the fact that the storage tubes have no provision for it. In the present system, local erasure is accomplished by a selective transfer method. In this method, the information in the memory cell from which information is to be erased is transferred temporarily to another cell. During the transfer, the information to be erased is deleted. The original memory is then erased and the modified contents of the temporary storage cell is rewritten into the original memory cell. Maintaining registration between cells during this operation is difficult.

Utilizing the construction capabilities of Artrix, any geometric constructions which are possible on paper using a straight edge and compass may be accomplished and stored.

A system such as Artrix, with somewhat more sophistication, can readily be used as a graphics display console in conjunction with a general purpose computer. In such a configuration, it could be used for drafting, circuit design, flow charting or any other use requiring the rapid construction of straight lines, circles or other simple geometric shapes.

TRICOLOR CARTOGRAPH

The Tricolor Cartograph is a hybrid system which can automatically color the interior of closed, bounded areas in a choice of colors. It is shown in Figure 4. The colors are selected by the operator from the choices red, blue, green and their combinations. The information is displayed on a red, green, blue color television monitor. A light pen is used in conjunction with the monitor in order to write or color on the display. To write, the operator simply selects the color desired and writes on the display. There is no restriction on the shape of an outline or the number of outlines other than the resolution of the system. To color, the operator, using the light pen, first draws the closed boundary of the area to be colored. The pen is then directed to any interior point of this bounded area and the system automatically colors the interior. Automatic erasure is also possible using basically the same scheme as for coloring. An example of a figure which has been drawn using automatic coloring and erasing is shown in Figure 5.

The color information as well as the outline information is stored on a magnetic disc. As in the Artrix system, the information is stored in pictorial form rather than by some digital encoding scheme. The color monitor operates in a normal raster scan mode with one revolution of the disc corresponding to one television frame. There is one track for each color and one track for the outlines. The coloring is accomplished

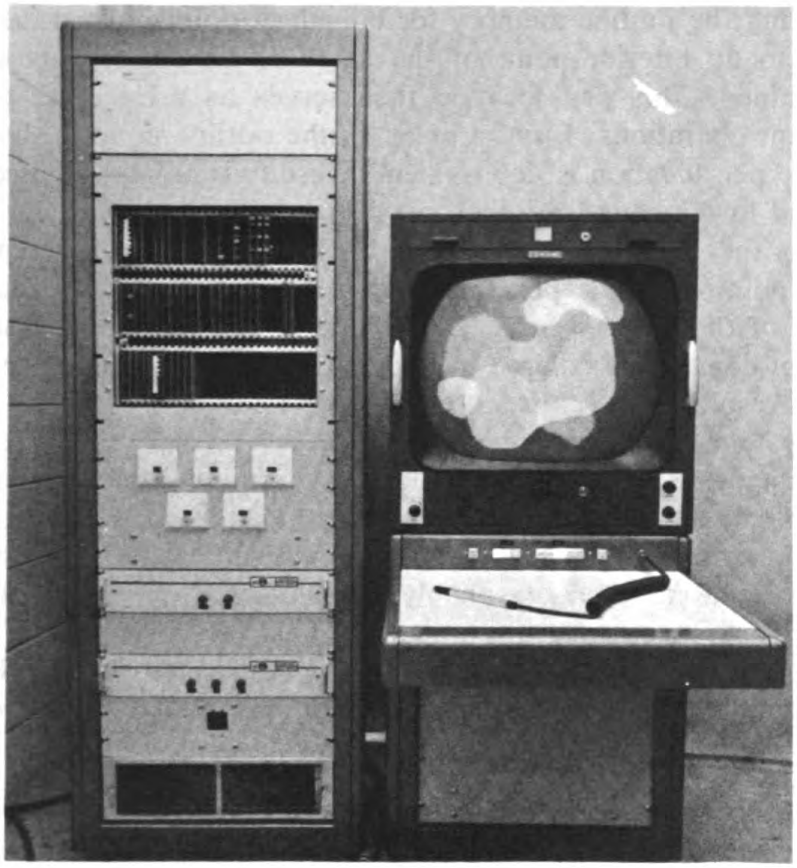


Figure 4 — Tricolor cartograph.
(Shading indicates color.)

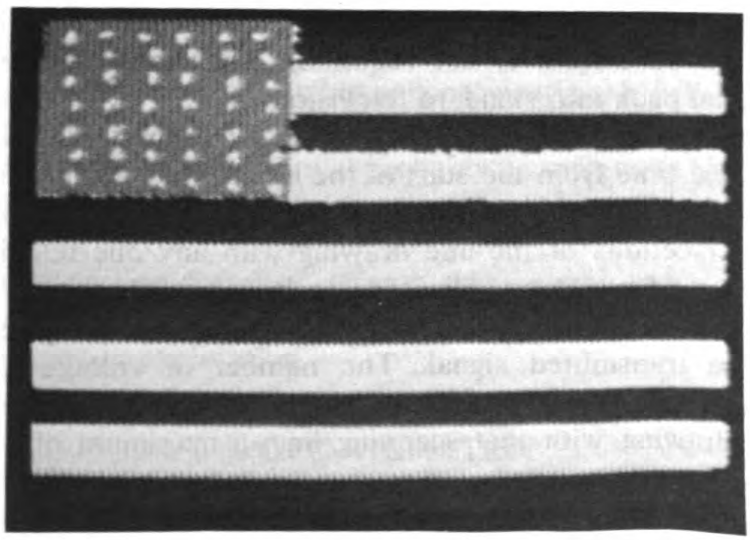


Figure 5 — An automatically colored figure.
(Shading indicates color.)

by scanning the outline memory for boundary points. When the pen is directed to an interior point of the figure to be colored, its location is determined. This pen location then serves as a reference point in subsequent operations. First, a point on the outline directly above and below the pen location is determined. These two points are used as an upper and lower bound for the area which will be colored during one frame. As the next frame is scanned, the last point prior to the pen and the first point after the pen are used to determine the horizontal extremities of the colored area. This process is repetitive so that if the area is not completely colored in one operation a slight movement of the pen soon results in the entire interior being colored.

The system is self-contained an, as a result, can readily relieve a larger computer system of the duties of determining the boundary, the interior points and performing the coloring. In addition, no storage space in the main computer memory would be utilized for the storage of the color information. Even reasonably sized colored areas demand large amounts of storage space in computers. This fast and efficient way of coloring and storing colored areas, as demonstrated by the Tricolor Cartograph, may have applications in operations involving map coloring, in traffic control, radar, art, education and integrated circuit layout as well as others.

FUNCTIONAL ENCODER

The Functional Encoding System (shown in Figure 6) is a system for encoding and transmitting pictures of line drawings. These drawings are input by means of a television camera operating at normal scanning rates. A transmitter then encodes the video in such a way that less bandwidth is required than for normal television (for line drawings full television bandwidth is not required). The receiver converts the encoded signal back into standard television.

The scheme utilized examines each television line as it is scanned and determines the time from the start of the line to the occurrence of each part of the line drawing. It has been found that an allowance of 32 possible intersections of the line drawing with any one television line is adequate even for very complicated line drawings. These time intervals are converted to voltage levels and it is these voltage levels which comprise the transmitted signal. The number of voltage levels per television scanning line then corresponds to the number of intersections of the line drawing with that scanning line, a maximum of 32. These voltage levels are now distributed over the duration of the scanning line and this signal is transmitted. Thus, if there were 16 intersections, each of the corresponding 16 voltage levels would be allocated 1/16 of the duration of the horizontal line. In the worst case, 32 intersections, the length of time that a given voltage is transmitted, is about 1.5 μ

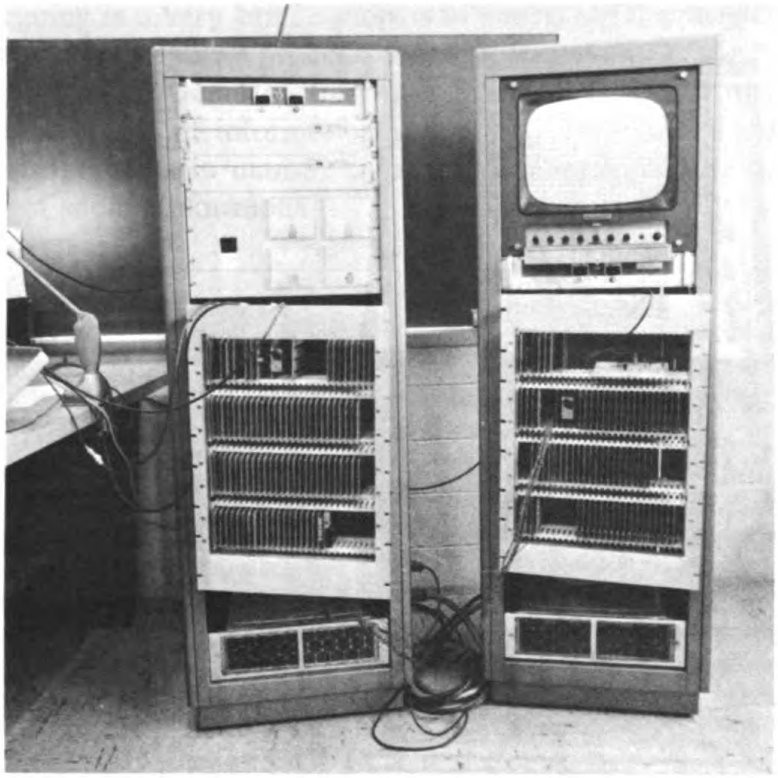


Figure 6 — Functional encoding transmitter and receiver

(micro or 1/1,000,000) seconds. At the transmitter, the average voltage during a μ second, say, can be used and thus the system is less noise prone than ordinary transmission. The transmitter converts the voltage levels to time intervals and the picture is reconstructed. Because the system operates at standard TV rates, it should be possible to reduce the bandwidth required form the 4.5 MHz used by standard television to 15.751 kHz. However, for stable synchronization, it will be necessary to transmit at least some harmonics of the synchronization signal. Thus, the actual bandwidth required will probably be somewhat higher than the above figure in practice.

This system offers a reduced bandwidth, less noise prone scheme for transmitting line drawings. Such a scheme may prove useful in the accurate communication of drawings over extremely large distances such as in future space exploration.

POTENTIOMATRIX

Potentiomatrix is shown in Figure 7. Potentiomatrix is a system on which an operator may designate potential boundaries on a square array of indicators. The system will then display the entire family of equipotential curves determined by the designated boundary conditions.

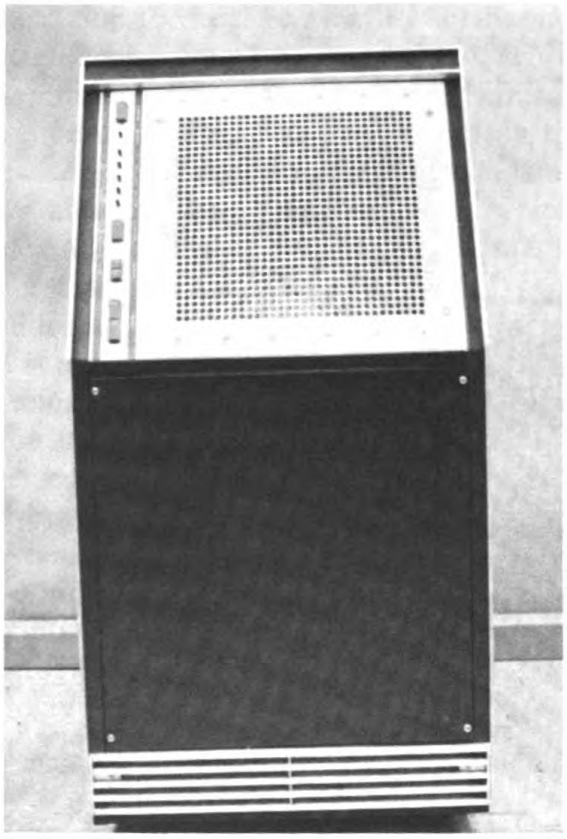


Figure 7 — Potentiomatrix

The resistor grid on which the boundary conditions are specified simulates an infinite conducting sheet. A choice of two boundary potentials is allowed (± 10 volts). As the points of the boundary conditions are specified, the corresponding indicators light and the internal circuitry connects those points to ± 10 volts. The system can now be made to sweep through all equipotential lines from $-\infty$ to $+\infty$. This is accomplished by means of a comparator at each grid point and by sweeping the reference voltage of the comparators from −10 to +10 volts. Thus, as the reference voltage passes within the window of the comparator at each grid point, the comparator signal causes the corresponding indicator to light. In this way, all indicators representing comparators whose input voltage equals the reference voltage are lit at any one time and thus the equipotential lines are indicated. The input voltage to each comparator is a result of the distributed effect of the boundary condition voltages over the "infinite" grids.

Potentiomatrix displays a desired general curved line on the basis of implicit information in the sense that only boundary conditions must be specified. Very frequently, specifying boundary conditions provides a much less complex way of defining a given curve than trying to specify the curve itself. Also the boundary conditions specify a whole family of curves from which a user may select those of interest.

The foregoing is a very brief synopsis of several of the projects which may be classed as graphical processors. The general goal of the hardware research effort at the Department of Computer Science is the exploration of uncommon forms of information processing. It is hoped that badly needed improvements in man-machine communications may be one of the results of such explorations.

Bends Research

Holographic microscopy, a concept developed by Dr. Richard J. Buckles of the Naval Medical Research Institute is being used as a means for studying decompression sickness. The system combines the speed and versatility of holography with the detail of microscopy. It is the first known combination of these two techniques with motion pictures for biological studies on living tissue. The development of optical parameters and the construction of a prototype, in connection with this work, are being sponsored by the Bureau of Medicine and Surgery and the Office of Naval Research under two separate contracts.

The system employs a TRW model 71-A argon laser with 0.4-watt output and 2-watt peak power. It operates in a hyperbaric chamber capable of developing pressure of 600 pounds per square inch—equivalent to that found 1,200 feet below the ocean surface. The subject in current studies is a hamster, whose small blood vessel reactions are captured on 16-millimeter motion picture film by a camera that operates forward and backward either in single frames or at 24 frames per second.

The optical system is aligned with ports in the pressure chamber. As the pressure increases, observations are made of the hamster's blood cell changes and how tiny gas bubbles form after the hamster is returned to atmospheric pressure. This animal was chosen because its cheek pouch is thin and contains many blood vessels.

It is anticipated that the work will lead to the development of rational procedures for treatment and prevention of the bends, a decompression sickness.

Rotating Plug Nozzle for Attitude Control

Under a recently completed project at MIT, a new and rather novel method of thrust vector control (TVC) was investigated to determine its operating principles and utility for rocket missile attitude control. The method, described in a final report just issued, involves use of a modified plug nozzle designed to spin as a gyroscopic mass, hence permitting exhaust gas flow to be modulated between the plug and the rocket casing in such manner as to cause a stabilizing moment when the rocket longitudinal axis deviates from the plug-spin axis. Stable operation of a rotating plug nozzle system with successful attitude stabilization for short periods was demonstrated in small scale tests utilizing turning slots in the area of the exhaust annulus. In this cold flow testing, sufficient gyroscopic rigidity was obtained which countered the unbalanced pressure field effects around the rotating plug. Further exploratory development type effort seems in order. The work was performed by CAPT John E. Drain, while a postgraduate student at MIT in fulfillment of requirements for an Engineering Degree in Aeronautics and Astronautics. CAPT Drain is now stationed in OPNAV 07 with the Navy Space Program Division.

Navy Science Cruiser Program

The Navy Science Cruiser Program was established by the Chief of Naval Operations in 1958 to encourage the nation's youth to develop an active interest in science. Specifically, it is aimed at encouraging outstanding high school students whose scientific projects and talents are of potential interest to the Navy.

Each year Science Service Inc. sponsors fairs for high school students throughout the country. At 225 regional, state, and district science fairs, the Navy selects winners for its Science Cruiser Award. Each winner is presented a certificate signed by the Chief of Naval Operations and is invited to participate in the Navy Science Cruiser Program during the summer as a guest of the Navy. Newport, Rhode Island and San Diego, California, are the permanent East and West Coast sites to host the annual cruise. Usually winners East of the Mississippi go to Newport, and those West of it go to San Diego.

The Public Affairs Office for ONR monitors the program in selecting Science Fair winners and furnishing them with details on the Cruise. The Public Affairs Offices at the host Navy facilities plan the programs, which include visits to points of interest at the naval bases as well as nearby industrial research sites. In this way the Cruisers become aware of the Navy's most recent scientific and engineering developments. The highlight of the program in both San Diego and Newport is a daylight cruise aboard a destroyer. The Navy host facilities provide the escorts, billeting, and eating arrangements for the Cruisers.

The Navy also promotes scientific interests by offering a trip to Tokyo to one young scientist who wins the Cherry Blossom Award at the International Science Fair. This program is in conjunction with the Army and Air Force who also give the same award.

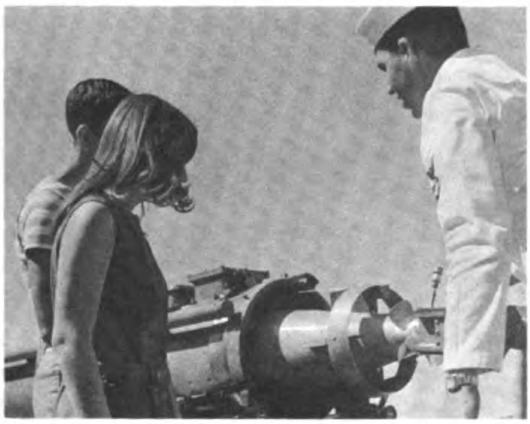
An exciting 23 minute color motion picture, which shows how the Navy rewards Science Cruiser winners, is now available. Interested science oriented youth groups wishing to borrow this film should contact Miss Diane Oliver, Department of the Navy, Office of Naval Research Code 109, Washington, D.C. 20360.

Cheryl Engleman, a winner from Hazelton, North Dakota, reports enthusiastically on her five days in California. Cheryl, whose exhibit was the Navy's second choice, is the alternate for the trip to Japan.

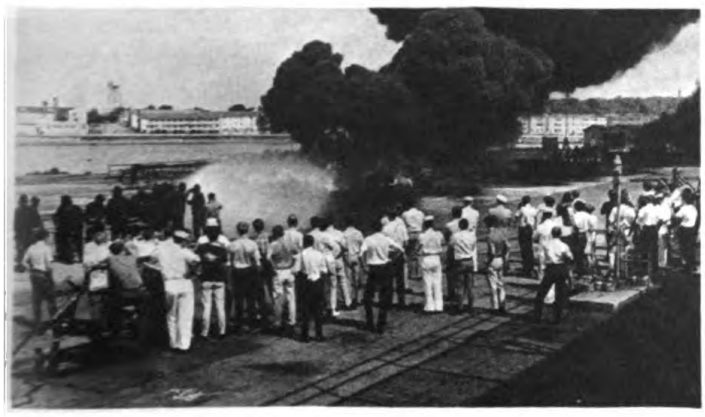
> The captain's voice boomed over the loudspeaker. "Ladies and gentlemen we are now approaching San Diego, California. Ground temperature is 75° with winds out of the southeast at 10 miles per hour. Please observe the fasten your seat belt sign." Up until that time, I hadn't really realized that my week in San Diego as a guest of the United States Navy had actually arrived. Last spring when I was given the Navy Science Cruiser Award at the district science fair, the week of August 18-23 seemed a long way off, but now, here I was ready to begin an educational and enjoyable five days.

Learning about the signal lamp aboard the USS Talbot

Cruisers trying out a life raft during a visit to Quonset Naval Air Station



Explaining torpedo tube aboard USS Compton to Navy Science Cruisers during the visit to the Newport, Rhode Island, Naval Base



Watching fire-fighting demonstration at Newport, Rhode Island, Naval Base

All six of us from North Dakota entered the San Diego airport together and began to locate our host for the week, the U.S. Navy. Almost immediately, we were whisked off to our respective lodgings. The girls were deposited at the beautiful Royal Inn, a new motor hotel with colored television, heated swimming pool, and sauna. The less fortunate boys spent the week in barracks at the Naval Recruit Center. All science cruisers ate at the Recruit Center's Mess Hall. In spite of our numerous jokes concerning Navy food, we found the food very much to our liking.

Almost immediately, our action-packed week began. The deputy mayor of San Diego welcomed us on behalf of his city. The next hour and a half were spent touring the famous Balboa Park. A few of us were even able to say we stepped inside the largest zoo in the world, the San Diego Zoo.

Official Naval welcoming ceremonies began after supper. We were very fortunate to meet and talk with the chief of the helicopter crew which picked up the Apollo 11 astronauts. We were able to view pictures of the Apollo 11 mission which have never been made public.

Tuesday morning came far too early for many of us, as we were on our way to Miramar Naval Air Station by 7:30. Here we were shown through the station's photo lab, control tower, meteorological stations and given first-hand observations of the Navy Pacific Fleet fighter squadrons.

Scripp's Institute of Oceanography was next on our agenda. Climbing around on the ships which are sent out in the Pacific for the study of ocean life made us well aware of the importance of the sea.

Cruisers watch as helo lands

A game of catch at a beach party

A Raytheon Corporation employee explains equipment to a science cruiser

Here instructions are being given on use of boatswain's pipe

We were all glad to have the rest of the day for relaxing on the beaches of Silver Strands State Park. The beach party also gave us a better chance to become acquainted with the eighteen girls and eighty-seven boys who were our fellow science cruisers.

Eight o'clock Wednesday morning found us boarding the USS Bradley, the anti-submarine destroyer which was to take us forty miles out into the Pacific. The group was subdivided so as to give us a better chance to become acquainted with the ship. Tours of the engine and boiler rooms, galley, first-aid station, bridge, and communications center of the Bradley were conducted by the officers of the ship. The sonar and radar equipment fascinated those interested in electronics, but the rest of us found the demonstration of the firing of the torpedoes and refueling exercises more to our liking. Our seven hours on board the Bradley were both educational and enjoyable.

All of us were anxiously awaiting our trip to Fiesta 200, the celebration of San Diego's two hundredth birthday. Bits of Mexico and old California found their way into Old Town San Diego. A fiesta atmosphere prevailed everywhere, and we found ourselves gladly joining the festivities.

Thursday was, perhaps, the highlight of the trip for many of us,—our trip to Disneyland. We arrived bright and early and spent nine hours in a

true fantasyland. The Navy gave us enough tickets to see most anything we wished. Exhausted but happy, we returned to San Diego with many wonderful memories of a fine day.

The Naval Electronics Laboratories Center treated us to tours of its facilities high atop Point Loma Friday morning. Those interested in the biological sciences found the demonstration on using brain waves to detect amblyopia very interesting. Those interested in electronics found the computer center and radar equipment more likeable. The cruisers then divided themselves in the categories of physics, chemistry, math and computers, electronics and engineering, medicine and psychology, and Navy research and development for group discussions with top scientists as discussion leaders. This gave us a chance to discuss our scientific problems and goals with some of the nation's finest scientific minds.

After a picnic lunch at beautiful Gabrillo Monument, we attended graduation exercises at the Naval Recruiting Center. The bands and drill teams brought us a feeling of pride and awe for our nation's young men.

The week's activities ended with a dance given in our honor by a San Diego science club. A group of teen-agers always enjoys a dance, and we were no exception. We were a little saddened, though, at the thought of leaving all the wonderful friends we had made.

As we left San Diego and our many friends Saturday morning, I was unhappy to realize I might never see my cruiser friends again. But yet, I had so many wonderful memories, I knew I couldn't truly be sad. My week in San Diego had given me a great insight into the Navy's many scientific facets. I never realized education and enjoyment could be so expertly mixed into only five days.

Aircraft Safety Device

Preliminary conclusion of tests performed with a hyperextension device, designed under ONR contract, is that this apparatus holds the possibility of being an effective system for the prevention of vertebral fracture in pilots ejecting from high-speed aircraft. The data has shown that the device is very effective in minimizing the peak strains on the anterior aspect of the vertebral body and also indicates a redistribution of the load over the entire vertebral body. Projecting to actual hardware, it is proposed that the device take the form of an air bag which can be deployed just prior to ejection. The estimated pressure required is of the order of 50 psi. The theories and concepts for this device originated with Dr Channing Ewing of the Naval Aerospace Medical Center.

Termite Trail-Following Pheromones

Deterioration of wood by termites is of major concern to the Naval Facilities Engineering Command. Dr. Coppel is extracting the trail-following pheromone (ectohormone from the Formosan termite. This substance, when used as an attractant, may possibly provide an effective means for termite control. Preliminary effort has shown that the worker termite will follow the train of a crude hexane obtained from an extract of termites. This hexane has also been found to be present in extracts from wood blocks decayed by the fungus *Lenzites trabea*.

Research Notes

Improved Theory of Condensation

The recent publication of "A Kinetic Theory of Cluster Formation in the Condensation of Gases" by E. R. Buckle (Trans. Far. Soc. **65**, No. 557, Part 5, 1267 (1969)) describes the theory developed by the author under Office of Naval Research sponsorship. The work was done in association with Dr. Pouring at the U.S. Naval Academy. This theory represents a new approach to nucleation/condensation in that it depends only on "hard sphere" molecules, and the growth (or decay) of nuclei is described by chemical kinetic principles. It thus departs from the classical macroscopic formulation of condensation worked out by Volmer in 1939, and it reveals in a fundamental way the reasons for controversies which have arisen in recent attempts to incorporate atomistic parameters into the frame work of the classical theory. In parallel work, Buckle's theory has been tested in analyzing the flow of humid air in nozzles, where it has been shown to correctly predict the onset of condensation and the subsequent pressure rise – "thermal choking" – in the nozzle.

Laser Potential in Curing Disease

Dr. Irwin Sherman, University of California, Riverside, and Dr. Donald E. Rounds, Pasadena Foundation for Medical Research have recently collaborated in a feasibility study for ONR showing that laser energy may possibly be used for the control of selected diseases in man. These workers have shown that the malaria parasite may be stained with methylene blue while inside human or avian red blood cells. When these infected cells are afterward exposed to ruby laser energy, the methylene blue stain selectively absorbs the laser wavelength. Both the stained malaria parasite and the infected host cell in which it resides are thereby destroyed. Normal cells do not accept the methylene blue stain, do not absorb the laser energy, and apparently remain unharmed.

There are still some hitches in this new laser approach to therapy. One must keep in mind that the malaria parasite does not appear in the blood stream until the final stage of its life cycle, after it has multiplied in vital organs of the body. The problem of hitting enough of the parasites to bring about a cure, and without damage to the human host, remains unanswered. Dr. Rounds will be encouraged to investigate more promising and more relevant applications of laser technology in the solution of biological problems.

Thermal Protection for Divers

Operating in the cold ocean waters has always placed a severe constraint on man's capability to work effectively in the sea. The use of the He/O_2 mixtures required at great depth has increased the severity of this constraint because of the greater thermal conductivity of helium *vs* the nitrogen in air. In an ONR sponsored investigation undertaken by Duke and the Naval Experimental Diving Unit a physiological and psychomotor study was carried out on subjects wearing a water warmed diving suit in 45°F water at a simulated depth of 600 feet. The suit system was based on a design concept used by NASA in its Apollo 11 mission. Although there is room for improvement, the thermal protection afforded by this suit system permitted subjects to carry out specific work patterns in this extremely cold environment for a period of one hour.

On the Naval Research Reserve

NRRC 8-3

The Seventh Annual Naval Research Reserve Seminar on Electronic Computers was conducted this Fall by NRRC 8-3, College Station, Texas. All participants, which included Army and Air Force as well as Naval Reservists, programmed FORTRAN IV and COBAL problems, key punched their own cards, and loaded card readers at Texas A and M's Data Processing Center.

In addition to the working experience, instruction was given in Operations Analysis, PERT, Game Theory, Linear Programming, Information Retrieval, Remote Job Entry, and Computer Graphics. The seminar observed data processing systems, particularly in simulation applications, at the Manned Spaceflight Center at Houston.

Dr. Robert J. Lundgard, Acting Director of ONR's Mathematical and Information Services, addressing the opening session of the 7th Annual Seminar on Electronic Computers.

NRRC 9-26

The Director, Office of Naval Research Branch Office Chicago, recently awarded NRRC 9-26 Colorado Springs, Colorado, an excellency award for the Company's outstanding planning, organization and management of a two-week Research Reserve Seminar on the subject of Aerospace Defense. The Honorable John A. Love, Governor of Colorado, presented the award to LCDR H. W. Elkins, Commanding Officer of 9-26. This award is in recognition of individual units and/or member's outstanding performance, with special emphasis on scientific and professional achievements which enhance the favorable image of Naval Research and Development.

Selected Contract Research Reports

The contract research reports listed below have been extracted from U.S. Government Research & Development Report 69, No. 14 of 25 July and 69, No. 15 of 10 August 1969. Government agencies and their contractors who are registered with the Defense Documentation Center of the Defense Supply Agency may obtain copies from the Center at Cameron Station, Alexandria, Virginia 22314. Abstracts of the reports are found in USGRDR 69, Nos. 14 and 15.

For non-DDC users, most reports may be purchased from the Clearinghouse for Federal Scientific and Technical Information, Department of Commerce, Springfield, Virginia 21151.

AERONAUTICS

Effects of Variations in System Data Rates and Measurement Accuracies on Pilot Performance in Helicopter IFR Formation Flight Mode; Honeywell, Inc.; Anderson and Toivanen; AD-688 200

Remarks on a Study of a "New" Procedure for the Statistical Evaluation of Design Criteria; Columbia U.; Brown; AD-688 437

Rotor Jet Power Alternate Systems; Ga. Tech.; Gray and Hubbartt; AD-688 470

ATMOSPHERIC SCIENCES

Analysis of Ionospheric Data; IIT Research Inst.; Sears; AD-687 535

Transient Response of a Differentially Heated Rotating Annulus; Woods Hole; Snyder and Goutz; AD-687 950

Initial Observations of VLF Electric and Magnetic Fields with the Injun 5 Satellite; Iowa U.; Gurnett *et al;* AD-688 440

Large Temporal Variations of Energetic Electron Intensities at Midlatitudes in the Outer Radiation Zone; Iowa U.; Yeager and Frank; AD-688 441

BEHAVIORAL AND SOCIAL SCIENCES

Probabilistic Depreciation and its Implications for Group Depreciation; Carnegie-Mellon U.; Fri and Kaplan; AD-688 843

Analysis of Merchant Shipping and International Commodity Flows; Center for Naval Analyses; Breckner *et al;* AD-688 427

Japan, The United Kingdom, and Selected European Countries: The Importance of Trade; Center for Naval Analyses; Hyde and Weiher; AD-688 428

Underwater Work Measurement Techniques: 68 Studies; Calif. U.; Weltman *et al;* AD-688 438

Variables Influencing Cooperative Escape and Aggressive Behavior; Western Mich. U.; Ulrich *et al;* AD-688 204

Binomial Error Models in Mental Testing; Educational Testing Service; Lord; AD-688 430

The Effect of two Levels of Success Incentive on Persistence in the Face of Failure; Bucknell U.; Burkick and Svoboda; AD-688 439

Development of Test Theory and Methods; Educational Testing Service; Lord; AD-688 463

Structural Determinants of Cue Utilization in Judgment; Oregon Research Inst.; Slovic and Lichtenstein; AD-688 474

An Economic Appraisal of Soviet Merchant Shipping Policy; Center for Naval Analyses; Athay; AD-687 464

The Effect of the Operator's Handedness on Some Directional Stereotypes in Control-Display Relationships; Johns Hopkins U.; Chapanis and Gropper; AD-687 586

Readability of Dials at Different Distances with Constant Visual Angle; Johns Hopkins U.; Chapanis and Scarpa; AD-687 587

Studies in the Phonology of Asian Languages. Vietnamese Tones; U. of S. Calif.; Han; AD-687 519

Automatic Determination of Parts of Speech of English Words; Lockheed Missiles and Space Co.; Earl; AD-687 629

Human Factors and Biotechnology—a Status Survey for 1968-69; Lockheed Missiles and Space Co.; Kraft; AD-687 488

Measurement of Personality Dimensions. Psychological Measurement; Washington U.; Horst; AD-481 142

Measurement of Personality Dimensions. Special Problems; Washington U.; Horst; AD-481 143

Robbins-Monro Procedures for Tailored Testing; Educational Testing Service; Lord; AD-687 471

Punishment of Shock-Induced Aggression; Western Michigan U.; Ulrich *et al;* AD-687 521

Reinforcing Behavior of "Naive" Trainers; Dartmouth Coll.; Lanzetta and Hannah; AD-687 588

Communication, Cooperation, and Negotiation in Culturally Heterogeneous Groups; Ill. U.; Fiedler and Triandis; AD-687 735

The Effect of Target Area on Grating Acuity; Columbia U.; Pokorny; AD-687 914

BIOLOGICAL AND MEDICAL SCIENCES

Serological Heterogeneity of the IgM Components of Mixed (Monoclonal IgM-Polyclonal IgG) Cryoglobulins; Calif. U.; Mackenzie *et al;* Ad-687 548

Current Status of the Chemical Structure of Bovine Pancreatic Carboxypeptidase A; Washington U.; Neurath *et al;* AD-687 589

Immunochemistry of Some Artificial Human Hemoglobins; St. U. of N.Y.; Atassi and Skalski; AD-687 812

Specific Reduction of Carboxyl Groups in Peptides and Proteins by Diborane; St. U. of N.Y.; Atassi and Rosenthal; AD-688 009

Distribution of C14-Labeled Dimethyl Sulfoxide in Tissues of Intact Animals; American Foundation for Biological Research; Malinin *et al;* AD-687 941

Helminths of Vertebrates and Leeches Taken by the U.S. Naval Medical Mission to Yemen, Southwest Arabia; Southwest Foundation for Research and Education; Kuntz and Myers; AD-687 606

Alternating-Current Field-Induced Forces and their Biological Implications; Pa. U.; Schwan and Sher; AD-687 817

Gastric Autoimmunity in Pernicious Anemia; Calif. U.; Goldberg *et al;* AD-687 547

Effect of pH on the Vitamin B12-Binding Capacity of Intrinsic Factor; Calif. U.; Goldberg and Fudenberg; AD-687 813

Immunologic Aspects of Adrenocortical Insufficiency; Calif. U.; Wuepper *et al;* AD-687 814

Renal Function during the Early Post-Burn Period: a Comparison of Colloid Versus Non-Colloid Containing Balanced Salt Solution; Yale U.; Hoyle *et al;* AD-687 905

Schistosoma Mansoni Uptake and Host Disposition of Tracer Antimony during a Course of Stable Drug; Vanderbilt U.; Girgis *et al;* AD-687 944

Dielectrophoresis in Lossy Dielectric Media; Pa. U. Sher; AD-688 296

Evolutionary Origin of the Gm (a) Peptide of Immunoglobins; Calif. U.; Wang *et al;* AD-688 346

Homocytotropic Antibodies in the Primary and Secondary Immune Response; Calif. U.; PageFaulk *et al;* AD-688 292

Aging, Noise and Choice; Syracuse U.; Goldman; AD-688 294

Successive Competition Hybridization to Detect RNA Species in a Shock Avoidance Task; York U. (Canada); Machlus and Gaito; AD-688 741

The Effect of Various Stresses on Thyroid Function; Harbor General Hospital; Solomon; AD-688 938

CHEMISTRY

Chemiluminescence and Chemi-Ionization in Nitrogen Atom/Oxygen Atom/Carbon Compound Reactions; Purdue U.; Fontijn; AD-687 432

Rheo-Optics on two Continents—an Example of International Cooperation in Science; Mass. U.; Stein; AD-687 466

Mobilities, Diffusion Coefficients, and Reaction Rates of Mass-Identified Nitrogen Ions in Nitrogen; Ga. Tech; Moseley *et al;* AD-687 573

Silver and Sodium Ion Transport Numbers into Pyrex from Binary Nitrate Melts; Miami U.; Keenan and Duewer; AD-687 916

Hole Theory of Light Scattering by Liquids; New Mexico St. U.; Theimer and White; AD-688 012

Mossbauer-Effect Measurements of the Thermal Shift of 119Sn in beta-Sn Below 90K; Harvard U.; Snyder; AD-687 915

Solutions of Boltzmann Equation and Transport Processes; M.I.T.; Desai and Ross; AD-688 302

Energy Transients in Harmonic Oscillator Systems; Princeton U.; Tobolsky *et al;* AD-688 451

Microscopic Theory of Force Constants in Solids; Chicago U.; Cohen *et al;* AD-688 476

Mossbauer Study of Metamagnetic Transition in FeCl2 and FeBr2; Chicago U.; Simkin; AD-688 733

Statistical Theory of Satellite Bands; Yale U.; Royer; AD-688 742

Fluorescence Lifetimes of Pyrene Monomer and Excimer at High Pressures; Calif. U.; Kim *et al;* AD-688 928

Kinetics of the Elementary Reactions; Catholic U.; Darwent and Flores; AD-848 918

EARTH SCIENCES AND OCEANOGRAPHY

Bioacoustic Studies on Sharks; Miami U.; Myrberg, Jr. *et al;* AD-688 735

Water Waves at the Shoreline; Wisconsin U.; Taylor; AD-478 688

The Effects of Empirical Dissipation Terms in the Solution of the Undular Bore; Calif. U.; Byatt-Smith; AD-688 153

An Experimental Study of the Unsteady Forces Causing Vortex-Excited Oscillations of a Circular Cylinder; M.I.T.; Pearce; AD-688 934

Geography and the Properties of Surfaces. The Use of the Geodesic Curvature in the Determination of Geodesic Lines; Harvard U.; Lindgren; AD-688 457

Physical Geography Reconnaissance: West Pakistan Coastal Zone; La. St. U.; Snead; AD-688 466

The Human Ecology of Coastal Flood Hazard in Megalopolis; Thornthwaite (C.W.) Associates; Burton *et al;* AD-688 712

Arctic Ice Type Identification by Radar; Kansas U.; Rouse, Jr.; AD-688 936

Formulation of a Three-Dimensional, Steady Ocean Circulation Model Using a Similarity Hypothesis; Texas A & M; Nowlin, Jr. and Reid; AD-687 544

Observations of Inertial-Period Motions in the Deep Sea; Woods Hole; Webster; AD-687 955

Morphology and Evolution of the Norwegian-Greenland Sea; Lamont; Johnson and Heezen; AD-687 546

Basalts Dredged from the Amirate Ridge, Western Indian Ocean; Scripps; Fisher *et al;* AD-687 540

Consolidation and Cementation of Recent Sediments in the Atchafalaya Basin; La. St. U.; Ho and Coleman; AD-687 549

Early Diagenesis and Compaction in Clays; La. St. U.; Coleman and Ho; AD-687 550

Rifting Origin for the Vema Fracture in the North Atlantic; Woods Hole; Van Andel *et al;* AD-687 952

ELECTRONICS AND ELECTRICAL ENGINEERING

ONR Structural Computer Programs Project (Store); TRW Systems; Hrzina; AD-687 453

Some Considerations of Supervisor Program Design for Multiplexed Computer Systems; M.I.T.; Corbato and Saltzer; AD-687 551

Dicanne, a Realizable Adaptive Process; Scripps; Anderson; AD-687 906

Locked Frequency Modification of a Mark 6 (b) Source; Columbia U.; Weisman and Adler; AD-688 199

Economic Feasibility of Microwave Power Transmission in Circular Waveguide; Stanford; Dunn and Loewenstern, Jr.; AD-805 553

Digital Technology Research; Calif. U.; AD-688 197

Adaptive Plans Optimal for Payoff Only Environments; Mich. U.; Holland AD-688 839

Von Neumann's Self-Reproducing Automata; Mich U.; Burks; AD-688 840

Mathematics of the Decision Sciences. Lectures in Applied Mathematics; American Mathematical Society; Dantzig and Veinott, Jr.; AD-688 899

An Interactive Graph Theory System; Pa. U.; Wolfberg; AD-688 931

ENERGY CONVERSION (NON-PROPULSIVE)

Electrochemistry of Fuel Cell Electrodes. Hydrogen Evolution at a Solid Indium Electrode; Tyco Labs.; Butler and Dienst; AD-440 751

MATERIALS

Basic Research in Nonoxide Ceramics; M.I.T.; Coble; AD-688 201

High-Quartz Solid Solution Phases from Thermally Crystallized Glasses of Compositions (Li20.MgO)-Al203-nSiO2; Owens-Illinois Technical Center; Ray and Muchow; AD-688 338

Properties of Metal Oxide Composities; Battelle Memorial Inst.; Duga; AD-688 171

Formation, Stability and Structure of Palladium-Silicon Based Alloy Glasses; Harvard; Chen and Turnbull; AD-688 142

Theory of Dispersion Toughening of Brittle Materials; Westinghouse Electric Corp.; Lange; AD-688 847

On the Dilute Solutions of Gold in Bi-Sn Alloys; M.I.T.; Jena *et al;* AD-688 930

Surface and Interfacial Studies of Ice and Interaction of Water and Polymeric Materials at Temperatures Below OC. (Adsorption of Water Vapor on Polymers and Freezing of Aqueous Polymer Solutions with Reference to Cyobiology); Clarkson Coll. of Technology; Jellinek *et al;* AD-688 473

Fractographic and Thermal Analyses of Shocked Alumina; N. Carolina St. U.; Palmour, III *et al;* AD-687 415

Dislocation Climb Theory of Steady-State Creep; Northwestern U.; Weertman; AD-687 545

The Use of Deformation Voids to Refine the Austenite Grain Size and Improve the Mechanical Properties of AFC 77; Boeing Co.; Webster; AD-687 724

Stress Corrosion Crack Branching in High-Strength Steels; Boeing Co.; Carter; AD-687 725

The Effect of Silicon on the Stress Corrosion Resistance of Low-Alloy, High-Strength Steels; Boeing Co.; Carter; AD-687 726

Ultrasonic Reflectivity of Single and Polycrystalline Samples of Copper; Midwest Research Inst.; Rollins, Jr.; AD-687 729

Spheroidization of Binary Iron-Carbon Alloys over a Range of Temperatures; Drexel Tech.; Heckel and Vedula; AD-687 738

Viscoelasticity of Inorganic Polymers; Mcgill U.; Eisenberg; AD-687 449

The Effect of Morphology on the Mechanical and Rheo-Optical Properties of a Styrene-Butadiene-Styrene Block Copolymer; Mass. U.; Wilkes and Stein; AD-687 467

The Determination of the Inhomogeneity of Crosslinking of a Rubber by Light Scattering; Mass. U.; Stein; AD-687 468

MATHEMATICAL SCIENCES

Heuristic Analysis of Numerical Variants of the Gram-Schmidt Orthonormalization Process; Stanford; Mitchell and McCraith; AD-687 450

Very Regular Tournaments; Delaware U.; Remage, Jr.; AD-687 472

Some Optimal Control Results for Differential Difference Systems; Harvard; Bryson, Jr. and Budelis; AD-687 473

Second Order Sufficient Conditions for Weak and Strict Constrained Minima; Research Analysis Corp.; Fiacco; AD-687 555

The Method of Odd/Even Reduction and Factorization with Application of Poisson's Equation; Stanford U.; Buzbee *et al;* AD-687 717

Handbook Series Linear Algebra Singular Value Decomposition and Least Squarer Solutions; Stanford; Golub and Reinsch; AD-687 718

Matrix Decompositions and Statistical Calculations; Stanford; Golub; AD-687 719

Adaptive Nonlinear Modeling with Quantizers; Bell Aerosystems Co.; Powell; AD-688 194

On Testing Some Linear Relations Among Variances; Southern Methodist U.; Davenport; AD-688 403

Estimating the Parameter k of the Rayleigh Distribution from Censored Samples; Southern Methodist U.; Brock; AD-688 404

Poisson Counts of a Markovian Renewal Process; Southern Methodist U.; Kshirsagar; AD-688 405

A Parametric form for Theta in a Combined Statistic of the Form (P sub 1) (P sub 2) Superscript Theta); Southern Methodist U.; Pape; AD-688 406

An Investigation of Bivariate Normal Lognormal Distributions; Southern Methodist U.; Crofts, Jr.; AD-688 407

Robust Variables Control Charts Based on Sample Means; Southern Methodist U.; Walsh and Kelleher; AD-688 408

Generalized Asymptotes for Extreme Value Distributions; Southern Methodist U.; Anderson; AD-688 409

On the Sampling Theory of Reliability Estimation; Educational Testing Service; Kristof; AD-688 429

Geography and the Properties of Surfaces. Notes on the Methodology for Generation of the Representative of a Set; Harvard; Lindgren; AD-688 455

Upper Bounds for the Abscissa of Stability of a Stable Polynomial; Calif. U.; Henrici; AD-688 942

Infinitestimal Look-Ahead Stopping Rules; Calif. U.; Ross; AD-688 150

Asymptotic Properties of Isotonic Estimators for the Generalized Failure rate Function. Asymptotic Distributions; Calif. U.; Barlow and van Zwet; AD-688 151

An Optimum Discrete Space Sequential Search Procedure Which Considers False Alarm and False Dismissal Instrument Errors; Southern Methodist U.; Smith; AD-688 410

Game Theory, Behavior, and the Paradox of the Prisoners' Dilemma—3 Solutions; Yale U.; Shubik; AD-688 450

Plant Location Under Economies of Scale for the Stochastic World of a Multi-National Manufacturer; Carnegie-Mellon U.; Rutenberg; AD-688 842

A Bound-and-Scan Algorithm for Pure Integer Linear Programming with General Variables; Stanford; Hillier; AD-688 889

Mathematics of the Decision Sciences. Lectures in Applied Mathematics; American Mathematical Society; Dantzig and Veinott, Jr.; AD-688 898 and AD-688 899

MECHANICAL, INDUSTRIAL, CIVIL, AND MARINE ENGINEERING

Geography and Properties of Surfaces. A Minimum Path Problem Reconsidered; Harvard; Ernesto and Lindgren; AD-688 456

Geography and the Properties of Surfaces. The Law of Travel and its Application to Rail Traffic; Harvard; Lill; AD-688 453

Sputtering; Litton Systems, Inc.; Anderson *et al;* AD-688 939

Elastostatic Load-Transfer to a Half-Space from a Partially Embedded Axially Loaded Rod; CalTech; Muki and Sternberg; AD-688 162

A Stress-Gradient-Dependent Yield Condition; Columbia U.; Gou and Freudenthal; AD-688 436

Refined Solution of Pneumatic Hammer Instability of Inherently Compensated Hydrostatic Thrust Gas Bearings; Mechanical Technology, Inc.; Chiang and Pan; AD-687 447

METHODS AND EQUIPMENT

Continuous-Writing Streak Camera for Diffraction Studies; North Carolina St. U.; Kelly and Douglas; AD-687 416

Digital Image Formation from Detected Holographic Data; Stanford; Goodman; AD-687 818

A Generalized Engineering Design Procedure; Pa. St. U.; Lang; AD-688 787

MILITARY SCIENCES

Search and Information Theory. The Logical Basis of Combat Simulation; Columbia U.; Koopman; AD-687 534

NAVIGATION, DETECTION, COMMUNICATIONS, AND COUNTERMEASURES

Ultra High Contrast, Solid State Teletype Display; Sigmatron, Inc.; Soxman and Hebert; AD-687 740

Exact Theory of Tracking of Moving Underwater Object by Short-Base Navigation System Attached to Imperfectly Stabilized Moving Ship; Catholic U.; Vaishnav and Magrab; AD-688 458

Speech Research; Haskins Labs.; Cooper. AD-688 946

ORDNANCE

Research on the Generation and Propagation of Water Waves Produced by Underwater Explosions. A Generalized Method for Predicting the Surface Water Wave Spectrum; National Marine Consultants; AD-468 855

PHYSICS

The Influence of Chemisorption on the Electronic Properties of Thin Semiconductors. Oxygen Chemisorption on the (11-20) Surface of CdS; Princeton; Goodwin and Mark; AD-688 945

Extensions of Extremum Principles for Slow Viscous Flows; Columbia U.; Skalak; AD-688 156

Transient Excitation of a Liquid Half-Space by a Decelerating Load and the Associated Transonic Effects; Columbia U.; Myers and Bleich; AD-688 157

Cavitating Flows; CalTech; Plesset; AD-688 160

Tensile Strength of Liquids; CalTech; Plesset; AD-688 161

On the Universal Functions of a Binary Boundary Layer (1) Analysis; Ohio St. U.; Li and Director; AD-688 202

Hypersonic Cone Drag at High Latitude; Space Sciences, Inc.; Hu and Grad; AD-688 205

Study of Laminar Incompressible Viscous Flow Near the Sharp Trailing Edge; Calif. U.; Paek; AD-688 431

Constant Current Anemometer Diagnostics of Flow Fields; Polytechnic Inst. of Brooklyn; Weinberg and Lederman; AD-688 432

An Experimental and Theoretical Investigation of the Interaction of a Turbulent Free Shear Layer with the Rear Edge of a Hole; Aeronautical Research Associates; Contiliano; AD-688 447

A Light Scattering Investigation of Droplet Growth in Nozzle Condensation; M.I.T.; Roberts. AD-688 469

Hear Transfer to Drag-Reducing Polymer Solutions; M.I.T.; Smith *et al;* AD-688 740

Secondary Flow in a Boundary Layer; Colorado St. U.; Veenuizen and Meroney; AD-688 926

Infrared Transmitting Materials; Pa. St. U.; White; AD-688 933

Energy Levels of Light Nuclei: A = 13; CalTech. Ajzenberg—Selove; AD-688 468

Temperatures and Thermal Stresses in Thin-Walled Spherical Segments; Polytechnic Inst of Brooklyn; Cassenti and Nardo; AD-688 433

Elasto-Plastic Analysis of Orthotropic Plates and Shells; M.I.T.; Whang; AD-688 471

On the Ising Model with Long Range Interaction. Critical Region Analysis; Northwestern U.; Thompson *et al;* AD-688 203

U. S. GOVERNMENT PRINTING OFFICE : 1969 O - 350-218

Concept of Line Energy for a Crack Front; Westinghouse Electric Corp.; Lange; AD-688 846

A Reformation of Fick's First Law for Solid-State Diffusion; Fla. U.; DeHoff; AD-688 347

Microscopic Dielectric Function of a Model Semiconductor; Chicago U.; Srinivasan; AD-688 475

Phase Transitions of the Electron Fluid; Chicago U.; Wiser and Cohen; AD-688 477

Propagation of Sound in Matter; Calif. U.; Rudnick; AD-687 523

Acoustic Imaging in a Turbid Underwater Environment; Lockheed Missiles and Space Co.; Green *et al;* AD-687 635

Rejection of a Coherent Arrival at an Array; Scripps; Anderson and Rudnick; AD-687 907

Directional 420-Hz Sound Source; Miami U.; Kronengold and Roulis; AD-687 997

Dynamics of a Pad Supported on a Highly Compressible Gas Film; Mechanical Technology Inc.; Hsing and Cheng; AD-687 448

Asymptotic Solutions of Normal Shock Waves Structured by Nonequilibrium Radiative and Collisional Ionization; Brown U.; Clarke and Onorato; AD-687 465

A Mixture of Elastic Continua; Calif. U.; Green and Maghdi; AD-687 707

Dusty Hypersonic Flows; M.I.T.; Probstein and Fassio; AD-687 710

The Effect of Charge Transport on the Disintegration of Liquid Jets; Rocketdyne; Huebner; AD-687 743

Structure of Turbulent Free-Convection Boundary Layers along a Vertical Plate; Notre Dame U.; Yang and Nee; AD-687 769

The Atomic Hydrogen Maser; Harvard; Ramsey; AD-687 871

High Precision g-Factor Determinations; M.I.T.; Kleppner; AD-687 522

The Correction of Scattered-Electron Spectra for Radiative Effects; Stanford; Crannell; AD-687 711

The Partition Function of a Two-Dimensional Plasma; Iowa U.; Knorr; AD-687 811

Two Kinds of Bosons and Bose Condensates; Calif. U.; Kohn and Sherrington; AD-687 713

Optical Diffraction Techniques for Strain Measurement, North Carolina St. U.; Blake *et al;* AD-687 414

Shock Analysis of Structural Systems; Pa. St. U.; Neubert *et al;* AD-687 429

An Experimental Study of Defect Ordering and Transport Phenomena in Nonstoichiometric Metal Oxides; Arizona St. U.; Kevane; AD-687 737

On Heat Conduction and Wave Propagation in Rigid Solids; Calif. U.; Bogy and Naghdi; AD-687 706

Convection in a Variable Viscosity Fluid Heated from Within; Yale U.; Foster; AD-687 936

PROPULSION AND FUELS

Project Squid; Purdue U.; Alber *et al;* AD-687 431

Development of Experimental Stress Analysis Methods to Determine Stresses and Strains in Solid Propellant Grains. A Modified Method of Holographic Interferometry for Static and Dynamic Photoelasticity; Catholic U.; Clark and Durelli; AD-688 148

Development of Experimental Stress Analysis Methods to Determine Stresses and Strains in Solid Propellant Grains. Photoelastic Analysis of Flexural Waves in a Bar; Catholic U.; Clark and Durelli; AD-688 149

A Selection Rule for Caratheodory's Multiple Entropies; Pa. St. U.; Essenhigh; AD-688 932

The Burning Mechanism of Ammonium Perchlorate-Based Composite Solid Propellants; Princeton; Steinz *et al;* AD-688 944

SPACE TECHNOLOGY

An Application of a Modified Mass Spectrometer to Shock Tube Diagnostics; Polytechnic Inst. of Brooklyn; Lederman and Dawson; AD-688 943

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important Naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Washington, D.C., 20360. The magazine is listed for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

NAVSO P-510

IN THIS ISSUE

VOL. XXII, NO. II

A highpoint during the Navy Science Cruiser Program is a day aboard a destroyer. *See page 30.*

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
WASHINGTON, D.C. 20360

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY