AEROSPACE
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SOME MAJOR IMPACTS OF THE NATIONAL SPACE PROGRAM

III ASTRONOMY AS AN EXAMPLE OF SCIENTIFIC IMPACTS

Prepared for:

I.P. HALPERN
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
WASHINGTON, D. C.

June 1968

STANFORD
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III ASTRONOMY AS AN EXAMPLE OF SCIENTIFIC IMPACTS

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FOREWORD

This is the third in a series of task reports within a brief study of "Some Major Impacts of the National Space Program."

Within this investigation, many candidate impacts were first screened and those that appeared (1) minor or (2) not likely to yield to sufficient study within the short time available were eliminated. The remaining impacts were subjected to further study, and each is separately reported within this series.*

The results of this study are the first concrete assays within a welter of conflicting, incomplete, exaggerated, and frequently unsupported information. Stanford Research Institute considers its objective study an important task and is looking forward to extending the scope of this study in the future by application of the background, methodologies and initial results obtained to date.

John G. Meitner
Project Manager

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* The titles are: "Economic Impacts," "Identification of New Occupations," "Impacts of New Materials Technology," "Impacts Upon Aviation and Aeronautics," Impacts Upon Health, Biology, and Medicine," "Some Total Impacts of NASA Capability," and "The Impact of the Space Program Upon Science--1. Astronomy."

CONTENTS

SUMMARY AND CONCLUSIONS

One of the great positive impacts of the U.S. space program is upon science. This appears to be a two-way phenomenon. On the one hand, the exploitation and exploration of space has made great demands on all fields of science, so as to provide the fundamental information required to embark into space. This great flurry of pointed scientific inquiry has, of course, also resulted in many new scientific discoveries that are not related to space exploration. On the other hand, once space exploration was under way, a great number of new scientific facts were discovered in space, and new theories ranging from the origin of life to the magnetic field of the Earth were thus established:

- There is no single endeavor or phenomenon that has increased the discovery of scientific facts and theories as much as the advent of space exploration, and in the near future those new discoveries will exceed all total prior scientific knowledge.

This report (1) describes in some detail the great impact of space exploration upon science by examplification of one discipline--astronomy--and (2) discusses the impacts of astronomy upon our culture, again as an example of the impact of science upon the nation, and by conjunction of (1) and (2), the impact of the space program upon an important aspect of our society.

The impacts of astronomy upon human culture from the dawn of recorded history to this very day are indeed astonishing:

- The beginning of civilization--man's adoption of agriculture--was based upon astronomical finding...
- Man's discoveries of his earth--ranging from geography to navigation throughout the ages--are also largely due to the findings of the astronomers.

  Many discoveries of major consequences to mankind--ranging from the discovery of infrared to telescopy and from instrumentation and optics to fundamental physics--are also accomplishments of astronomy; even to this day, many of the world's great mathematicians were originally astronomers.
- Astronomy has given rise to our modern-day philosophy and placed man appropriately within his universe.
- The tremendous sweep of science and much of a sparking of the young, their search for knowledge, and their appreciation of factual observations are similarly due to the findings and exhibits of astronomers.

In relating astronomy to man's culture, it is important to do justice, in turn, to the great progress that astronomy owes to the advent of space exploration. Some of the past achievements (P) and some of the likely accomplishments to be made in the future (F) by space-based astronomy include the following:

- The chief advantages of space-based observation are of course the absence of refraction, the elimination of systematic observation errors, and the resulting capability for the determination of surface detail of masses in celestrial bodies (P).

In addition to these astrometric advantages, a great deal of the physical properties of the galaxies and their chemical composition was determined by orbital observations through spectroscopy (P) and future studies in the infrared region will bring valuable information regarding protostars. Similarly, standardization of magnitude systems will be accomplished through orbital photometry (F).

Orbital astronomy has permitted the determination of thermal emissions from planets (P) and will in the future permit the determination of such paramount items as maps of the Milky Way, the background of stellar evolutions (cocoons), and perhaps a test of the steady state theory of the universe (F).

- Within our solar system, orbiting probes have led to the discovery of X-ray and ultraviolet emission from the sun, determination of planetary atmospheres, and much detail about the physical parameters of Venus (P). In the future, masses and densities of other planets, effects of solar winds, composition of atmospheres, and nature of magnetic fields of trans-Martian planets will similarly be based upon orbiting probes (F).

- One of the greatest scientific findings of the near future will be the determination of life or protolife in the solar systems, and the consequent clues to the origin of life on Earth (F).

- The discovery of X-ray and gamma-ray sources with extra-atmospheric probes has already permitted the determination of physical processes and new astronomical events (P). Based on (presumably manned) probes in the future, X-ray and gamma-ray astronomy will probably permit the determination of cosmic ray origin and perhaps test the continuous creation theory (F).

- Other cosmological determination accessible with future extraterrestrial observations will determine the fitness of several cosmological models and determine the open or closed nature of the universe and exact nature of red-shifts (F).

The relation between the past and future accomplishments of space astronomy concerning these and other items is concisely described in the body of this report. The last chapter deals with the relation of these and other findings to mankind, or the role of astronomy in society.

BACKGROUND AND INTRODUCTION

A revolution equivalent to Galileo's turning his telescope to the sky is currently underway as a consequence of our ability to pursue astronomical observations above the atmosphere of the earth. Prior to the invention of the telescope, the astronomer's view was circumscribed by the limit imposed by an imperfect optical system--the eye. With the advent of the telescope, the astronomer suddenly discovered it was behaving as a funnel to channel a flood of celestial light into the eye. With this flood of light also came increased resolution detailing features of naked eye objects like the Sun, Moon and planets and disclosing other celestial objects whose presence was previously unknown.

In a similar fashion, the application of orbiting observatories has permitted astronomers to probe critical regions of the electromagnetic spectrum. These regions had been denied to the astronomer because of the incredibly complex atmosphere which envelops the earth. As in the case of the telescope, orbiting observatories represent a powerful tool for the study of those previously inaccessible regions. The value of this tool lies primarily in its ability to rise above and, thus, eliminate the deleterious and masking effects of the atmosphere.

Because terrestrial observations are made from the bottom of a hazy, turbulent sea we call the atmosphere there are limits imposed by the atmosphere which cannot be transcended. The atmosphere is a effective absorber of radiations and except for a narrow set of radiation windows in the visible, infrared and radio windows, nothing can penetrate to the surface of the earth. The atmosphere provides total absorption of radiations shorter than 2,910 A. It also scatters light to render the sky bright with a background radiation which dictates an exposure limit on photographic processes involving celestial objects. This means it is impossible to record objects below a certain magnitude.

The turbulence of the atmosphere produces a shimmering effect which causes stars to twinkle and prohibits attaining the high resolution inherent in sophisticated optical systems. Finally, because they are on the earth's surface, the largest and, therefore, the most significant optical instruments are subject to the gravitational forces on the earth with resultant instrument flexure. As a consequence, an upper limit is imposed on the sizes of telescopes. It appears highly unlikely that this Country will ever build a telescope larger than the 200-inch Hale telescope at Mt. Palomar though a 236-inch telescope is currently being constructed in the Soviet Union. In the case of these giant telescopes, when working in the visible region, atmospheric "seeing" generally limits the attainable angular resolution to that obtained using a telescope with an aperture of approximately eight inches under ideal conditions.

Because of these serious handicaps the astronomer must, in some fashion, eliminate the effects of the atmosphere which means going to an orbiting telescope. While the astronomer understood this problem, he was also cognizant of his inability to cope with it except to seek higher altitudes for his telescopes. With the development of the rocket engine a means was provided to rise above the earth's atmosphere.

The first rocket launched into space, the V-2 carrying photosensors, clearly demonstrated the potential of an extra-atmospheric system. When a spectrograph made the first recordings of the Sun's radiation in the ultraviolet region of the spectrum, it was realized that a problem existed in that high altitude rockets did not remain above the atmosphere long enough to exploit this potential. The astronomer then looked to the satellite to develop this approach. Only when highly reliable satellites in precise orbits began being launched could this newly discovered potential be fully exploited.

In the ten years during which satellites have been in orbit astronomical data have been continuously relayed back to the earth. The very first satellite launched by this Country, Explorer I on January 31, 1958, relayed back data on the meteoroid content of space. Each succeeding satellite has become more reliable, intricate, sophisticated and versatile until, within the next few years, the astronomers will possess the equipment to probe and deal with the most challenging questions in all astronomy. Today, astronomers are researching facets of astronomy which a few short years ago were both unknown and uncontemplated. X-ray and Gamma Ray astronomy was unknown and the solar wind was a speculative subject.

Today, we look forward to orbiting the most complex astronomical satellites conceived by man; tomorrow, we expect the astronomer to take his place as an observer in space.

To acquire some concept as to astronomical objectives of the future it may be well to review current achievements in space astronomy resulting from satellites which have already gone into orbit.

Knowledge of celestial objects has literally exploded as a consequence of satellites and probes which have been launched since 1958. Instrumentation aboard the very first satellite launched by this Country on January 31, 1958 discovered the radiation belts and gave some indication as to the meteoroid content of space. Following Explorer I, satellites carried more complex instrumentation again relaying to the earth information which was new, challenging and most significant concerning celestial bodies. As might be expected, the brightest object in the sky -- the Sun -- was subject to the most intense study for the tremendous volume of radiation from this body permitted the use of marginal instrumentation only operable when exploring intense sources of radiation. Following the Sun the Moon became the object of detailed study. Then the planets of the solar system became the targets of study but, here, the great distances from the earth indicated that probes must be launched to the planets to maximize definitive information. This also was done and by 1968 a significant volume of information had been realized about the planets Venus and Mars. Then, in a remarkable display of serendipity, the search for X-rays from the Moon led astronomers to discover X-rays coming to us from the sky and a diligent search was undertaken to find the X-ray sources in the sky. If there were X-rays sources in the sky, could there be gamma-ray sources? The answer is that these are expected in space, but the implementation of this search is a most difficult one. However, the ingenuity of scientists will overcome the instrumental difficulties and gamma-ray searches will be undertaken. Finally, the astronomer is cognizant of the absorption properties of the atmosphere on the long-wave length region of radio. The discovery of radio signals of many wavelengths and various intensities coming from space has excited scientists. Radio observatories in space will overcome the handicaps of the atmosphere to permit them to seek the unabsorbed, unaltered and unattenuated radio signals coming from space. A more comprehensive understanding of the physical universe must result from these studies.

To see where we are going in the future it is convenient to divide astronomy into its various facets and deal with these individually. In this fashion we can see what has been done on the earth; what we can ultimately expect from terrestrial observations and then explore the path we may expect to take when orbiting observatories become a reality.

DISCUSSION OF ASTRONOMY AND SPACE

ASTROMETRY

Recent advances in astrometry have disclosed the presence of large planets orbiting around some of the nearer stars. The detection of these objects and the tracing of their motions are so critical that skills, patience and techniques of the highest magnitude are necessary to accumulate the data upon which these discoveries are based. Dr. Peter van de Kamp, (1) of the Sproul Observatory of Swarthmore College, has indicated that the principal advantage of the space observatory will be the absence of the atmosphere which will eliminate troublesome refraction. Refraction has always presented a problem in positional astronomy for it alters the positions of the stars and is different for stars of different colors. Because differential refraction, i.e. dispersion, changes with exposure time it makes observations of faint stars susceptible to greater errors.

The absence of an atmosphere will eliminate the important sources of systematic errors -- imperfect transparency, imperfect seeing and atmospheric dispersion. The elimination of these errors will give rise to smaller star images on photographic plates, which means that fainter stars can be reached and more accurate measures made.

Van de Kamp indicates that there must exist more stars of small mass with associated large planets in the vicinity of the Sun which have, as yet, not been detected. Actually, a star with a luminosity of about 1/100th that of the Sun can be detected, but when we go to fainter objects the critical factors involved in their detection prelude their discovery. Using mirror optics means that high optical resolution in the ultraviolet and infrared can be obtained to aid in the search for the faint, but highly important, white dwarf stars, and the ability to search in the infrared region may disclose the even more significant red dwarfs.

Astrometric observations could extend parallax and proper motion studies to involve more distant stars. It is estimated that thousands of faint large proper-motion stars are still being discovered mostly by Luyten. Some of these stars are as faint as the 21st magnitude. These stars represent a large field of astrometric research, first for parallax and then for orbital motion.

One should also mention the unresolved astrometric binaries of which Mu Cassiopeiae and Alpha Ophiuchi are well known examples. The companions in these two systems while still unseen from the earth could be resolved with the orbiting telescope.

Perhaps one of the most important overtones from astrometric studies may be the overlapping of the various methods of determining the parallax of the stars; for it is hoped that astronomers could precisely measure the parallaxes of stars at distances on the order of 3,000 light years. A correlation in these various methods would provide more precise information upon which to base stellar distances.

Spitzer (2) indicates that a 400-inch telescope could provide a resolution of 0.01 arc seconds. This could resolve a 50-foot object at 200,000 miles. But more important, it could for the first time resolve surface features of a few of the supergiants like Alpha Orionis, Alpha Scorpii, and Omicron Ceti, whose diameters lie between 0.04 and 0.05 arc seconds. Thus, from space there is the challenging prospect that surface detail on some of the stars may be recognized.

It is felt that even with a resolving power of 0.1 arc seconds, the giant stars in the center of globular clusters can be resolved and their spatial distribution measured. Since kinetic equilibrium exists at the center of the cluster, the relative density gradient for stars of different types should provide the ratio of the masses.

It is also reasonable to assume that significant advances may be expected in the resolution of close double stars. Schwarzschild is hoping to do this with his balloon observations and even closer doubles may be resolved from space. The observation of close visual binaries could lead to an improvement of our knowledge of stellar masses.

Dr. van de Kamp (3) believes that separations of 0.1 arc seconds could be obtained. Close separations might be measured with errors well below 0.01 arc seconds. If such accuracy could be assured, it would lead to a vast improvement in our knowledge of stellar masses.

SPECTROSCOPY

Spectroscopy represents the most rewarding approach to the determination of the physical properties of celestial objects. It is in this field that atmospheric instabilities provide the greatest handicap. The atmosphere prevents critical regions of the electromagnet spectrum from reaching telescopes on the earth's surface. As a consequence those regions containing some of the most significant information concerning the celestial object are screened from our view. Due to atmospheric turbulence, a stellar image instead of being a minute point of light in a terrestrial telescope is spread into a small disk. When the astronomer attempts to obtain high resolution sprectra, theory dictates that the spectrograph slit must be as narrow as possible and still permit the entrance of light. Unfortunately, in terrestrial instruments the minute bit of light falling onto the slit is spread out farther, reducing its intensity to the point where inordinately long exposure times are necessary. When the spectroscope is used in space, the tiny point of light for the star dictated by the diffraction pattern of the telescope can then fall completely on the slit. This is a critical factor in spectroscopically exploring regions where the star density is high. A space spectrograph used in a dense star region can provide individual spectra of selected stars of maximum interest to the astronomer.

Many model stellar atmospheres have been proposed to account for the observational evidence instruments disclose. By extending the spectrum into both the ultraviolet and infrared regions, i.e., with wavelengths shorter than 3000 A and longer than 6800 A, verification may be obtained for various models which correspond to the observational evidence. The cool stars will have a significant fraction of their total energy output concentrated in the infrared region of the spectrum. Likewise, a very hot star will have a significant portion of its energy concentrated in the ultraviolet region of the spectrum. A space observatory can survey the sky in these regions to recognize the stars of various types and temperatures. It is highly likely that a survey of this type can provide many surprises, for some stars, perhaps too faint and too cool to be observed from the earth's surface, may show up in a survey from space.

Drs. Donald C. Morton and Edward B. Jenkins (4) of the Princeton University Observatory, using a stabilized objective spectrograph mounted on an Aerobee rocket on September 20, 1966 obtained spectra of seven O and B stars with wavelengths as short as 1130 A, at which wavelength the optical efficiency deteriorates rapidly. Measurements of the triply ionized silicon and carbon absorption lines indicated they were displaced by nine angstroms. These shifted lines presumably originate in shells of gas escaping from the stars at velocities of 1,900 kilometers per second, representing roughly three times escape velocity at the stellar surface. This is evidence of mass loss from otherwise normal O and B supergiant stars.

Various models to obtain estimates of the rates of mass loss undertaken. Preliminary results indicate they range from 10^{-4} to 10^{-6} solar masses per year. One consequence of this loss is that it is possible for O B supergiants, after leaving the main sequence, to lose enough mass to eventually become white dwarfs without passing through the supernova phase.

One might further conclude that rapidly expanding gas shells surround all luminous O and B stars. Therefore, when a massive star evolves through this phase it will gradually eject some of its mass back into the interstellar medium.

With the same spectrograms, it was learned that the Lyman-alpha line of hydrogen is present as a strong, broad absorption. This absorption is clearly due to gas in interstellar space. Dr. Jenkins' (5) preliminary measurements indicate an average density of 0.1 atoms/cc in the intervening space. This is only about one-tenth the density of neutral hydrogen between the earth and the Orion region as indicated by radio astronomers' measurements at 21 centimeters.

These findings represent some of the new and, in some ways, unexpected spectrographic results from the use of instrumentation projected high above the atmosphere of the earth. The use of orbiting observatories which can provide long exposure times for spectrographic studies will provide additional data to enhance our understanding of the supergiant stars.

Stromgren developed a method whereby from precise measurements of a star's radiation within narrow, specially selected spectral regions he was able not only to determine the true luminosity but also to derive the stage in the evolution of the star and, in principle, its age. He used this to determine age and distance of thousands of stars with telescopes no larger than 36 inches. A space telescope would open up more spectral regions for this process.

The space observatory represents an ideal place to study the gaseous nebulae for clues to the formation of the stars. In the Orion nebula photographic evidence indicates the formation of a small cluster of stars within the past two decades. However, had it been possible to scrutinize this region prior to 1947 the pre-birth details might have been revealed.

Scattered through the Milky Way are tremendous numbers of gas and dust nebulae up to 100 light years in diameter. Some are seen as systems whose components move and twist with speeds up to 10 miles a second. Knots and concentrations are also seen, and in the evolutionary processes taking place in these regions it is highly likely that the concentrations become protostars and, eventually, stars.

A large telescope in space would permit screening "suspicious" clouds with high magnifications to search for suspect areas where protostars are in the process of formation. Once these are discoverd, the spectrograph can screen these areas in the infrared for the detection of protostars. Some astronomers believe an infrared survey of the gaseous nebulae would provide the first clues to this event. With evidence that a star is "in the making" a concentrated observational program of this region can be undertaken. The birth of a star marks one of the most important milestones in its life history. The combination space telescope and spectrograph would permit recording this milestone.

The ultraviolet regions of the spectrum are important to the work of the astronomer. The fundamental lines of many of the elements such as carbon, nitrogen, oxygen and silicon are in the ultraviolet. The line profiles of the resonance lines for these elements are highly significant.

It is estimated that earth-based telescopes are able to observe only about 20% of the radiation from a BO star. This represents radiation on the red side of the atmospheric cutoff point at about 3,000 A. This means our knowledge of the total radiation of the O and early B stars is based on an extrapolation from the rather small fraction of their radiation in the visible region of the spectrum. The ultraviolet radiation distribution will reveal the opacity of the stellar atmosphere. Observations in the ultraviolet will improve our extrapolations and may disclose unexpected effects which may alter our ideas concerning the life histories of the stars. The total radiation in these stars determines the length of time the stars remain on the main sequence. It is also known that the distribution of radiation in the ultraviolet permits us to improve our measures of stellar temperatures which, with the total radiation, leads to an improved accuracy in our knowledge of the radii of the stars.

Even low dispersion spectroscopy on the order of 300A/mm can provide useful information. An objective prism mounted on large orbiting telescope can produce many spectra of the stars in a single field. Whereas, for definitive work on single stars to yield temperatures, pressures, ionization, composition, magnetic fields and motions requires high dispersion spectrograms, the low dispersion spectrograms provide a tremendous advantage for initial surveys. From these initial surveys stars of special properties and odd-ball stars can be culled for further scrutiny with high dispersion equipment. In this work it is possible to reach to about 1800A using a quartz prism. If the astronomer wants to reach radiations of still shorter wavelengths, he must go to a lithium fluoride prism or even a reflection grating.

PHOTOMETRY

From earliest time, the monitoring of the brightness of a star has been recognized as important and with the development of astronomy this parameter has led to a significant increase in knowledge concerning the behavior of stars. Variations in the brightness of some stars have led to a qualitative analysis of double star systems which cannot be resolved optically. Other stars with variations in brightness have achieved the role of a yardstick in space to measure distances. Photometry has proved a powerful and useful tool to astronomers.

The marriage of the photometer to the spectroscope to enable involvement in spectrophotometric observations has proven fruitful. Also, the use of multi-color filters has proved rewarding to the astronomer. While results of this instrumentation have been rewarding on earth, the application of this branch of stronomy in space will enhance these studies. By going into space the astronomer will be able to reach a larger portion of the energy coming from the star because of the absence of an atmosphere. Also, the variations in the sky background will remain stable throughout the measures.

Epstein and Scott (6) indicate that by extending the available electromagnetic spectrum better estimates may be made of the total stellar energy output of the stars or what is loosely called luminosity. This information is important in constructing various models as, for instance, nebular luminosities excited by hot stars. As we have seen the hottest stars of the O and B class with temperatures between 20,000°K and 50,000°K radiate only a small portion of their total energy in the visible region. Spectrophotometric observations of these stars may change the existing models which are based on extrapolations from the visible region. Such changes will, in turn, alter our notions of chemical abundances which, though derived primarily from spectroscopy are contingent on radiation models.

The most fruitful branch of this discipline has been multicolor photometry. By measuring the brightness of a faint star (perhaps too faint to produce a good spectrum), through several color filters, the star's color index is obtained. The ability of the space photometer to work with fainter stars because of the absence of the atmosphere will mean the astronomer will be able to reach the highly intriguing close faint stars. Because of the lack of an atmosphere, not only will the accuracy be increased, but different color indices may be chosen. Blitzstein (7) indicates there is no reason why yellow-infrared or even red-infrared photometry cannot be undertaken. These results will lead to a better determination of a star's temperature and an estimate of interstellar dust reddening.

Extension of the law of interstellar reddening will provide further information on the refractive index, numbers and diameters of the interstellar grains. Such information will lead to better estimates of interstellar absorption. This absorption alters the relative intensities of some spectral lines as well as the absolute magnitudes of stars.

Perhaps one of the most immediate consequences of space photometry will be a standardizing of the magnitude systems. Another possible consequence could be the monitoring of the uniformity of the rotation of the earth by using the times of minima for eclipsing binaries.

Kopal believes that narrow field photography from space will permit the search for stellar objects of mass generally less than 0.1 solar masses. Astronomers can measure displacements with time to eventually establish elements of visual orbits. This combined with the parallax may yield the absolute mass of the stars. Here would be a welcome extension of the mass luminosity relationship in the domain of the faint stars.

RADIO ASTRONOMY

By getting away from the earth with its ionospheric cutoff, the resolution of a radio telescope will be limited only by the achievable size of the directive antenna at long wavelengths. There exists today a map of radio sources at 18.3 megahertz over a portion of the celestial sphere. The reason for the concentration on this wavelength is the inability of radio signals of higher frequency to penetrate the ionosphere. One of the first tasks would be to complete a map of radio sources in the Milky Way over a wide spectrum of frequencies.

One must realize that optical observations in the night sky are restricted to a relatively small region centered on the sun for interstellar matter is most effective at absorbing light in the visible part of the spectrum. However, radio waves are so long compared to the size of the dust particles that they pass through tremendous distances relatively unaffected.

Ionized hydrogen, because of its absorption characteristics, is important in determining the brightness distribution on the celestial sphere. In the low frequency regime, that is, below one or two megahertz, this absorption exists, and it is anticipated that observations of absorption near the galactic plane may reveal clouds heretofore unsuspected.

Mezger and Palmer (8) point out that by carefully probing the regions of space where clouds of ionized hydrogen are found with radio telescopes and infrared observations, we may hope to follow the evolution of protostars long before they become visible in the optical range. It has been suggested that early-type stars at one stage of their evolution become "cocoon stars". A cocoon star is a recently formed star that is still surrounded by the remnant of the originally contracting cloud out of which the star was formed. It may be that the outer part of the remnant forms the cocoon of dust and neutral matter that may be opaque to optical light. Thus, the detection of these newly formed objects lie in the province of the radio telescope.

One of the more fascinating studies today is associated with the radio emissions coming from the moon and planets. These emissions represent only the thermal radiation of the planets and are, therefore, very weak. Radio astronomers have succeeded in detecting thermal emissions from the sun, moon, Mercury, Venus, Mars, Jupiter and Saturn. The irregular and intense meter-wave, and therefore non-thermal, emission from Jupiter is an exception. In the case of Jupiter this emission is strongly polarized, indicating the presence of a magnetic field on Jupiter. Synchrotron radiation immediately suggests itself.

A radio telescope in space would be able to study these in many wavelengths. This, along with spectroscopic studies of the atmospheres, especially of Mars and Venus, may resolve many of the problems associated with these bodies.

The use of radio telescopes in space may cast new light on the gaseous nebulae which abound in the galaxy. Studies in the Netherlands have shown that many gaseous nebulae provide radio emissions at 22 cm. These nebulae are not visible optically but this is to be expected, for interstellar dust absorbs every thing beyond 1,000 to 2,000 parsecs in the plane of the galaxy. It has been possible to estimate the diameters of these radio sources and in general they coincide with those of optical nebulosities. Flux-density measurements permit the number of electrons per unit volume of the nebula to be determined. The electron density is of the order of 10 to 50 electrons per cubic centimeter, with the central region approaching several thousand electrons per cubic centimeter. These values also agree with optical measurements.

Radio astronomy offers the possibility of something close to a direct test of the creation of matter in space to test the steady-state universe concept. The steady-state theory predicts that the average density of matter should be 10 times that generally accepted today. The difference is accounted for by hydrogen spread through intergalactic space. Up to now there has been no possibility of detecting intergalactic matter. But a large radio telescope in space tuned to the 21 cm wavelength may be able to determine quantitatively the hydrogen distribution that may exist in intergalactic space. Dutch investigators (9) have derived the total mass of galaxies in solar masses and have been able to determine the mass of hydrogen in these galaxies and this fraction appears to vary considerably.

The mass of hydrogen appears to be a function of type of galaxy with the greater the intrinsic luminosity of the galaxy, the greater the mass of neutral hydrogen. This fact provides considerable complication to the problem of determining the average density of matter in the universe.

SUN

A self-evident truth positions the sun as the nearest astrophysical laboratory known to man. Because it is a star and the stars are suns, the sun represents one of the most important celestial bodies to be studied. It is a variable star, exhibiting a 22-year period of magnetic activity and an 11-year sunspot period. It is the only star whose surface features can be resolved. Already solar phenomena such as flares have been postulated as occurring on distant stars which exhibit erratic light fluctuations. On the disk of the sun can be seen sunspots, granules, faculae, and flares. Prominences are found on the solar limb when the sun is viewed in hydrogen light. Its effect on the members of the solar system is partially charted, for solar particles affect planetary ionospheres and magnetic fields. It produces auroras and affects the moon, comets, meteoroids, and asteroids. The solar wind probably engulfs the entire solar system. It is also from the behavior of the sun and its relationship to our solar system that may come indications of the possibility of life elsewhere in the universe.

Clues to the ultimate reach which astronomers will achieve when observing the sun from space were yielded by the flight of the Stratoscope I. The remarkable fine granulations of the complex solar surface and the intricately fine structure of sunspots were observed in white light. The extraordinary resolution and detail obtained from an altitude of 100,000 feet indicate that tremendous advances may be expected when photographing the sun from space platforms. To implement this approach the Apollo Telescope Mount will be used for it is designed to yield high angular resolution and, therefore, represents the ideal follow-up for the stratoscope programs. The photograph remains unsurpassed as a bulk data storage medium and astronomers expect that photography will continue to play a major role in solar researches from orbit.

While balloon astronomy has provided the most significant photographs of the sun we possess today, sounding rockets have been exploring some of the physical characteristics of the sun for over 20 years. Significant data have been realized involving radiations in the normally inaccessible regions of the solar spectrum. Gamma rays, X-rays and ultraviolet radiation were denied to the astronomer until he could position his instruments above the atmosphere. Once beyond the atmosphere, then the entire electromagnetic spectrum opened up to reveal previously forbidden spectral regions. Rocket flights in the past have been able to probe the solar spectrum to wavelengths under one angstrom.

The follow-on to the rocket flights to investigate solar phenomena has been the eminently successful Orbiting Solar Observatory (OSO). These were developed primarily for observing the sun to measure its X-ray and ultraviolet emissions.

To take advantage of this ability to rise above the atmosphere many scientific satellites have been launched. Explorer XXX monitored solar radiations in the X-ray range from 0.1 to 60 angstroms. This was developed to monitor the sun during the time of the last sunspot minimum. Other satellites are being developed to monitor the sun during the time of the next sunspot maximum. One will be an Explorer satellite to monitor the sun's radio frequency spectrum in the range

0.25 to 10 megahertz. The Sunblazer probe will come within a half astronomical unit of the sun to study the electron density gradient and inhomogeneities in the solar corona. But the principal tool for the astronomer will remain the OSO's. These observatories have carried spectrometers, spectroheliographs, polarimeters, photometers and miscellaneous equipment to monitor sun-related phenomena. While the lifetimes of the early OSO's were shorter than desired, the results obtained even from these limited lifetimes permitted astronomers a veiled view of the promise of the future in exploiting these observatories. There had been high hopes for an Advanced Orbiting Solar Observatory, but current budgetary restrictions of the United States indicate that this observatory will be greatly delayed. However, in 1971 the Orbital Workshop is scheduled for launching and with this launching the Apollo Telescope Mount (ATM) will be placed in operation.

The ATM, because it will be a manned operation and stabilized to 5 arc-seconds, will provide a workbench of enormous potential to astronomy for it will permit direct photography of the sun. Because this system will contain a long optical bench it will be able to concentrate on small selected areas and in this way provide extremely high resolution data on solar activity. In addition to the greater pointing accuracy available with the ATM, it can harbor a significant volume of scientific instruments which can be placed into orbit sequentially. When the need arises, these can be launched to rendezvous with the Orbital Workshop. This will provide a capability for testing and assessing solar research instrumentation to build toward the optimum solar observing platform. It will have greater storage capacity for accumulated data -- especially if photography plays a major role in its operation -- and its telemetering capacity will be very high.

It will also permit the integration of man into the instrument loop. With a man monitoring the ATM it means that the versatility so important in this observatory will be achieved. The presence of a man will permit changes in programs as the necessity arises. It will mean the ability to alter a program to take immediate advantage of what the man senses in space. It will permit repairs and adjustments to be made; to initiate new and unplanned observational programs.

Because man is so versatile he can record the early stages of flares and can monitor the active regions of the sun. He may be able to detect flares by other means so that as soon as a flare is indicated he may attempt a time sequence of high resolution flare spectra. He may also initiate surveys of spectra of specific regions, such as coronal condensations, plages and prominences. Some astronomers speculate that one may begin to look for the Zeeman splitting of coronal lines to acquire basic information on the solar magnetic field. In the future, space telescopes will be employed to record the important fine structure in the solar atmosphere down to a fraction of one arc second. This knowledge is considered fundamental to understanding processes governing the chromosphere and corona. Eventually we may derive an understanding of the energy balance in coronal and chromospheric structure and of the mechanism that heats the corona and drives the solar wind.

PLANETS

One of the most surprising aspects of astronomy is our lack of knowledge of the physical characteristics of the planets. Considering that they have been observed since man first turned his eyes to the sky and they were the first celestial objects studied with the telescope, our lack of basic information on these bodies is overwhelming.

While it is true we know many of the physical characteristics of these bodies because we have measured them, weighed them, scrutinized them and plotted their paths, the subtle features and internal characteristics of these bodies still elude us. It is for this reason that we will only highlight the problems in planetary research and indicate specific areas where observations from space can contribute to the resolution of problems that vex astronomers.

With the success of the superbly functioning Mariner spacecraft, astronomers have learned much about the atmospheres of Venus and Mars. The fact that these data had to be collected by flybys brings into sharp focus the role of the earth's atmosphere in probing planetary problems. The earth's atmosphere has proven an insurmountable impediment to the investigation of planetary atmospheres because the absorption lines in the atmospheres of distant planets are drowned in the telluric lines of the same molecule. Thus it is inevitable that there be a continuation of the highly successful methods employed in the Venus and Mars probes. In the years to come it is hoped that "samplers" of planetary atmospheres may be employed to provide definitive information on this problem. These samplers can take the form of probes which fall to the surface and provide a temperature and composition profile of the atmosphere. In the case of Venus and the other planets with dense atmospheres these probes may be designed to float in the atmosphere to reveal atmospheric data. However, even if the problem of planetary atmospheres is resolved, there still remains a vast volume of data we would like to collect. For this paper we propose to point out the significant unknowns about the planets.

Mercury

Because this planet is so close to the sun it cannot be observed in the night sky for it is never more than 27 degrees from the sun. Thus, photography is not rewarding and visual observations take place only under the most difficult "seeing" conditions. It is these visual observations which have provided what little knowledge we have. As Mercury is the smallest planet and closest to the sun it has no atmosphere and one is led to inquire as to whether this planet has surface features like those on the moon. One might speculate that there may be considerable outgassing from the interior because of proximity to the sun and capture of the solar wind might provide a minimal surface pressure. However, its low gravitational field and high sub-solar temperatures may aid in the escape of any atmosphere so generated. It is for this reason that most astronomers would deny the presence of an atmosphere. However, with a 60° F. temperature for the dark side as obtained by Australian radio astronomers, it appears that there must be enough of an atmosphere to provide some measure of heat transfer from the hot side to the dark side of the planet. One might suspect it is pockmarked with craters, but if craters are formed by the impact of asteroidal particles, then one may ask: is Mercury far enough from the asteroid belt to avoid these impacts? And if there are no impacts, would this planet possess a relatively smooth surface? Because it is so close to the sun it must be subject to severe tidal action. The high eccentricity and very slow rotation must also give rise to major librations.

The use of a flyby probe could provide television pictures of its surface and the tracking of the spacecraft could provide a better value for the mass and density of the planet. Because the mass and radius of the planet are not too well determined the density lies between 3.6 and 6.6. A close flyby to provide a precise value of its mass would (as was the case with Mariner V and Venus) aid greatly in our understanding of the planet. It could tell us whether Mercury is like the moon or the earth in terms of density and internal characteristics. As in the case of Venus, the planet's magnetic field could be measured as well as the determination of the effect of the solar wind on the planet. A lander could provide much more detailed surface information but, currently, a Mercury lander is not contemplated.

Venus

There have been three successful spacecraft which have investigated Venus. Mariner II and Mariner V launched by the United States and the Russian Venera IV have uncovered data on the controversial magnetic field, ionosphere, solar wind, temperature surface pressure and probable atmospheric composition of the planet. However, even with these data there remains a vast volume of challenging unknowns concerning the planet. We know very little about the surface of the planet despite radar investigations which indicate the presence of a steep mountain range on the planet. Imaging experiments can be performed by a flyby or an orbiter. If an orbiter is used, then an atmospheric probe to relay a temperature and pressure profile would be a inestimable value. It could also provide correlations between parameters defined by remote sensing and those in contact with the atmosphere to provide a degree of confidence in all data acquired by remote sensing.

We know nothing about the surface or internal composition. The reason is that while the measured mass indicates it is similar to that of the earth, yet the magnetic field has a value between 10% and 0.03% that of the earth, while the Russians deny the existence of any magnetic field. Why? A lander could carry a seismometer to learn more about the internal character of the planet and some mechanical aids to detail the other surface features such as hardness, density, strength, moisture, etc. However, if the surface temperature is close to 600 degrees F., as indicated by various measures, then the design of an instrument complex to operate on the surface presents a severe challenge to the scientist and engineer.

Mars

This planet is easily the most exciting member of the solar system for it represents the only planet on which some form of life may be found. It is precisely for this reason that the space program was to have mounted a major mission in which a lander was to have descended to the surface at a cost of upwards of $2 billion. Current budgetary restrictions have scrapped this major mission in favor of less ambitious ones. However, there are carefully planned programs which can be undertaken with more modest expenditures to provide significant information about this planet.

The Mariner IV flyby provided enough data for a reassessment of our plans for investigating Mars. The determination of its atmospheric composition was a surprise and the low surface pressure, about 1/2 of 1% of the earth's, crystallized thoughts on the design of Mars landers. It also determined the diurnal variation in temperatures which agreed with microwave temperature results. As a point of fact, results from the Mariner IV flyby seem to substantiate observations made from the earth.

Pictures of the Martian surface relayed to the earth showed a density of craters there which may surpass those of the moon in numbers. Some astronomers had predicted this surface feature because of the planet's proximity to the asteroid belt. Apparently the rarity of the atmosphere accounts for the lack of erosion which in the case of the earth obliterated impact craters of the past.

Flybys and orbiters are contemplated in 1969 and 1971 and important results are expected of them. If possible a drop sonde may also be programmed. The combination of these could provide a better value for the pressure profile and atmospheric composition. The structure of the Martian atmosphere can be determined with infrared and microwave radiometers. And most important, a detailing of the surface features can be obtained. An orbiting television camera relaying pictures to the earth can cover a wide swath of the surface depending upon the inclination of the orbiter to the planet equator. From these pictures a better comparison may be made with lunar craters both in sizes and in frequency.

The resolution obtained with Mariner IV was about two miles and left much to be desired. It is hoped that future spacecraft can provide a resolution of about 1,000 feet. Much can be learned from pictures with better resolution including evidence of water erosion on the planet. The presence of water bears heavily on the question of the presence of life forms in the present or past.

One of the most important aspects of the Mars problem is the nature of its surface and interior. No detectable magnetic field or radiation belts were detected by the Mariner IV flyby. The absence of the magnetic field does not provide convincing evidence that it possesses a liquid core. To determine this a seismometer must be emplaced on the Martian surface. We would like to know the nature of the "wave of darkening" that spreads over the planet at the appropriate season. We would also like to know what happens to the moisture in the polar caps when they disappear with the change in season. Is the dark edge of the polar cap water melting to darken the soil adjacent to the polar cap? These are some of the questions which can be answered with landers and, perhaps, with sophisticated orbiters.

Jupiter

Perhaps more questions can be asked of Jupiter and Saturn than all the other planets combined. Jupiter is the most massive planet in the solar system with a gravitational field so high as to possess the ability to retain even the lighter elements in its atmosphere. Thus it is covered by a dense atmosphere whose composition is little understood. Methane, ammonia and hydrogen have been detected in its spectrum; helium and neon are inferred. The thickness of its atmospheric layers represents a mystery which is, perhaps, beyond solution even in the distant future. Scientists speculate that the original primeval nebular material acquired by the planet at its formation may still be present in the planet atmosphere because of its inability to escape. They further speculate that prebiotic compounds may be present in the atmosphere.

Careful scrutiny of the planet indicates tremendous activity on its cloud surface which may be in part due to the rapid rotation of the planet and the turbulence creating a vertical (thermal) mixing of the atmosphere. The Great Red Spot has been seen since 1664 and while subject to exhaustive study by many astronomers its origin, composition, behavior and motion remain a mystery. It has been suggested that it may be related to the enormous Coriolis force present. But this is speculation. Quite recently Opik (10) speculated that the energy radiated by Jupiter appears to be more than can be accounted for by a reemission of radiation after irradiation by the Sun. This has led some astronomers to speculate that this planet may possess an internal source of energy. Now the question arises: If it is an internal source, is it gravitational or nuclear? And, if it is nuclear, is Jupiter a star? How do the high temperatures dissipate so that the tops of the cloud layers remain so cold?

We know nothing about the surface of this planet. The models postulated for the planet indicate that the atmosphere is literally thousands of miles thick. If the atmosphere is that thick, it is possible that the high pressure built up at the bottom of the atmosphere has created high temperatures and the result is that the interface between the planet and the atmosphere may be high enough so that the interface is one of molten lava. Is the core of Jupiter differentiated to give rise to a magnetic field, radiation belts and radio emissions? Do the satellites Io and Ganymede have magnetic fields which affect the Jovian radio bursts? While these questions are asked at this time it is hardly likely that they will be answered in the immediate future. A Jupiter flyby has been proposed for 1974 and a "Grand Tour" of the solar system has been proposed beginning in 1977.

A Jovian flyby can resolve many of the questions posed today. It can measure the extent, intensity and distribution of the radiation belts. It can also provide information about the extent of the magnetic field. It would provide an assessment of the magnetic field. It could measure the infrared emission from the dark side of the planet. Perhaps by the mid-1970's breakthroughs in guidance and communications will permit television pictures of this planet to be relayed back to the earth to, perhaps, provide a better insight as to the activity in the Jovian atmosphere. Even a look at the satellites of the planet is a possibility if the guidance and time are chosen with care.

An ideal solution would be the establishment of an orbiter. This spacecraft in a synchronous orbit could provide pictures with resolutions on the order of 6 miles. If the orbiter were in a highly eccentric orbit, it could provide a profile of the radiation belts and possibly determine the masses of the Jovian satellites.

Saturn

Saturn represents the most unique member of the solar system because of its ring system. It also has an atmosphere in which are cloud belts roughly parallel to the equator and whose composition is roughly the same as that of Jupiter. However, the state of the atmosphere is different because of the different temperatures of the two planets. The atmosphere of Saturn must be even deeper than that of Jupiter for its density is 0.68, indicating that it could float on water. Saturn's ring system has been subjected to spectroscopic analysis with the verdict that it is composed of billions of moonlets and they are made of ice! One question most often heard is: are these rings the remains of a satellite which moved too close to the planet so that the tidal action disrupted the satellite and broke it up into the ring system? Or, is it perhaps a satellite which never coalesced? If it is a broken up satellite, are there other satellites made of ice? The spectroscope shows that Titan gives a spectrum indicative of ice. If this is true, what mechanism must be invoked to have a system of satellites made of ice? There are no satisfactory answers to these questions.

Other questions revolve around the magnetic field of the planet. Does Saturn possess a magnetic field? Does the solar wind reach out to this planet? Should the combination of these two give rise to radiation belts?

Will we be able to find answers to these questions? Again the answer is that in time flybys and orbiters may be launched to the planet to relay information back to the earth in which the answers to the above questions are contained. A flyby can provide data on a magnetic field and radiation belts and if these are present, then an orbiter in an eccentric path may provide definitive information on the quantitative aspects of these parameters.

A trip to Saturn will take a long time and to relay data to the earth over a distance of over 800 million miles presents a formidable task. However, it is almost a certainty that before the end of this century this investigation may be undertaken.

One might speculate that in the late 1970's the nuclear rocket engine may become operational and with this engine manned trips may be undertaken to the major planets with the journeys extending over many years. The many questions the scientists pose about the distant, major planets of the solar system may well wait until the nuclear rocket becomes operational.

Because of the distance factor this section will not attempt to probe our missions beyond Saturn. While many questions are raised about the planets beyond Saturn, candor compels one to indicate that these questions may not be answered for a long time.

X-RAY AND GAMMA RAY ASTRONOMY

These ultra-short wave radiations provide tools for probing the most fundamental problems in astronomy. They offer an opportunity for providing greater understanding of the physical processes taking place in known celestial objects and point the way to the discovery of new and unsuspected astronomical events.

Because the ionization threshold for neutral hydrogen is 912A the presence of more energetic photons will cause ionization of interstellar hydrogen and will be absorbed. Radiations of still shorter wavelengths will reach the ionization potential for heavier atoms with the result that complete absorption of these radiations will also occur. However, when wavelengths approach 20A the interstellar medium becomes transparent and the entire galaxy becomes relatively transparent to X-rays in the wavelength region near 3A. If this is true for the interstellar medium, it can also be assumed that this is true of intergalactic space. Because these ultra-shortwave radiations are unaffected by both magnetic fields and particles they can travel unimpeded and unattenuated for literally billions of years. This means that essentially some of the radiations which arrive in this wavelength region are fossil radiations arriving after travel times of perhaps billions of years and may represent radiations emitted when the universe was quite young.

The precise origin of these ultra-short wave radiations is not too well understood but theories have been proposed which can account for them. (11) The source mechanisms proposed for the generation of X-rays are:

1. Bremstrahlung from a hot plasma.
2. The inverse Compton effect in which energetic electrons scatter starlight photons.
3. Synchrotron radiation produced by energetic electrons spiraling in a magnetic field.
4. Thermal emission of a Planck spectrum from the surface of a hot, compact, neutron star.

The source mechanisms proposed to account for gamma rays are:

1. High energy protons colliding with other proton or atomic nucleus to produce among other things one or more neutral pi mesons or pions. These are unstable particles which decay into a pair of gamma rays, each with a minimum energy of 72 Mev.
2. If the energy of the proton is greater than 10^9 ev it will create not only pions but nucleon - anti-nucleon pairs. Then the proton-antiproton or neutron-anti neutron can combine with the emission of gamma rays. (Cosmic rays can generate secondary gamma rays which are undistinguishable from those we are trying to detect and which originate beyond the atmosphere of the earth.)

The studies of X-rays and gamma rays are not without profound difficulties. They are not plentiful and, thus, their detection and quantitative histories necessitate the use of large scale detectors and long periods of observing times. Historically, it should be noted that the detection of X-rays represents one of those fortuitous accidents which occasionally occurs in science. Scientists were not really looking for these radiations in space. A group had been trying to detect them on the moon by launching instrumented rockets to observe them on the moon. In their attempt to find X-rays on the moon they discovered a strong X-ray source in Scorpius and a secondary source in Cygnus.

The Ranger 3 spacecraft carried a small three-inch diameter sodium iodide crystal surrounded by a plastic scintillator which could detect X-rays in the 1 Mev range. This provided the first indication of the presence of gamma rays in space. The Explorer XI launched in 1961 was designed to detect gamma rays and discovered that the upper limit of gamma ray background intensity was $3 \times 10^{-4}/cm^2/$ sec/sterad.

As indicated, the galaxy (12) is essentially an open window to photons with energies up to 10^5Mev. At higher energies, a gamma ray has a high probability of interacting with stellar photons to produce an electron-position pair. There is another window for photons with energies from 10^7Mev to 10^8Mev. At this point, the galactic background radiation photon gas becomes an important absorber.

The known source of X-rays indicates they are concentrated within a few degrees of the galactic plane which implies that these sources lie in the galaxy. However, there is some evidence that the diffuse X-ray flux is extragalactic. This diffuse X-ray flux can be measured but it is not certain that this arrives from outside the van Allen belt regions, or that it is extragalactic rather than the integrated effect of numerous galactic sources too weak to provide individual sources susceptible to detection. Recent observations made by a group of scientists at the University of California (Berkeley) show a marked increase in the background X-ray flux at high galactic latitudes which can easily be interpreted only if the X-ray background originates from outside the galaxy. The background could still be the integrated effect of distant galaxies.

There is one X-ray source, the Crab Nebula, that has been positively identified with an optical and radio source. The X-ray source measures one minute of arc and at the distance of the Crab Nebula represents a source about one light year in diameter. As the Crab Nebula represents the remnant of a Type I supernova which exploded in 1054 A.D. it suggests that other supernova may also be sources of X-rays. In the searches which have been undertaken it was believed that the source Ophiuchus XR-1 corresponds to the position of Kepler's supernova of 1604. However, it is now clear that none of the X-ray sources in the Sagittarius-Scorpius region correspond to Kepler's supernova; early reports of this correlation are now considered simply inaccurate. The difference in position is within 1.5 degrees. Sources are reported within about a degree of both Cassiopeia A and Cassiopeia B (Tycho's supernova.) (13)

A special X-ray source is ScoX-1 in the constellation of Scorpius. While it was the brightest object in the sky, at wavelength below 10A it could not be identified with any visible or radio object. Physically, the source should be a hot, optically thin cloud of fully ionized gas at a temperature of 50 million degrees K. It should have had a brightness equivalent to that of a 13th magnitude star. When finally discovered it was found to be a 13th magnitude blue star at a distance of 300 parsecs which was quite variable. Giacconi (14) does not consider it a run-of-the-mill star for it emits approximately 1000 times as much energy in the X-ray region as the sun does in visible light.

Theory indicates that there could also be a significant amount of gamma line emission from the decay of heavy radioactive elements in supernova remnants like the Crab Nebula. Yet no such gamma rays have been detected. As a point of fact, no discrete cosmic gamma ray source has been detected with any certainty.

The discovery of strongX-rays beyond the solar system represents one of the outstanding discoveries of space science to date. The fact that astrophysicists could not predict them leads to a feeling that astronomy dealing with these ultra shortwave radiations will play a fundamental role in advancing our understanding of the universe.

Astronomers have speculated on the type of instruments needed to acquire data to provide a clearer understanding of the nature and distribution of the shortwave radiations. For X-ray a focusing grazing incidence telescope of from 30 to 100 feet in length sensitive to the region between 2 and 10A which will unfold in space appears necessary to achieve the desired sensitivity and resolution. A telescope of this type may not be orbited by an unmanned spacecraft. It may well be that this type of telescope can only be sent into orbit accompanied by a man to provide the erection, adjustment, and alignment capabilities.

To detect gamma rays, scintillation counters will be used to detect low-energy gamma rays with energies on the order of 1Mev. For the high energy gamma rays, in the region of more than 50 Mev and in the most frequently discussed range, only spark chambers are seriously discussed. A combination spark chamber-emulsion detector has also been proposed. However, in this approach it necessitates a man in space for the film to be removed and recovered.

Once both X-ray and gamma ray detectors have been orbited a full scale program can be undertaken to initiate a supernova patrol for detection of these exploding stars in the galaxy. One feels that this could be a rewarding approach for bits of information obtained from these sta. ay provide clues to a fuller understanding of these sources.

By using detectors in orbit many pressing problems may be resolved by studying these radiations. These problems (15) concern themselves with the mystery of the origin of the cosmic rays, the density of cosmic rays in galaxies and the Universe, the strength of the galactic and intergalactic magnetic fields, the hypothesis of the continous creation of matter and the temperature, density and composition of galactic and intergalactic matter. Some of our fundamental concepts on stellar evolution and the life cycle of the stars leading from the formation to the collapse of stars and to the supernova catastrophe are involved in this study.

INTERSTELLAR PHYSICS AND GALACTIC STUDIES

Currently, little is known concerning the formation of interstellar dust grains, their relation with nebulae and their interaction. Similarly, interstellar radiation and magnetic fields require concentrated research to yield an understanding of the physical processes taking place in the galaxy. The content of interstellar space is only slightly understood, and this lack of knowledge affects our application of the law of reddening of distant objects. In the Milky Way are emission nebulosities of great extent whose relationship to the stars, both within and outside the nebula, is only casually understood. Finally, the non-thermal radiation of the interstellar medium must be studied to further our knowledge of its interaction. These topics represent special areas of interest in astronomy which are believed to be susceptible to resolution with the aid of a space telescope.

Meinel has indicated that if we look at a galaxy from outside the galaxy, and if intergalactic space is relatively free of hydrogen atoms, then the outermost atmosphere of the galaxy will appear as a luminous envelope in Lyman alpha radiation. The reason is that all radiations of wavelengths shorter than 912A will be converted to this radiation by successive ionizations and radiative capture outward from individual stellar envelopes and circumstellar gas. While some of the radiation may be lost by absorption, the remaining radiation will be converted to Lyman alpha, and will escape from the galaxy. Thus, if there is no hydrogen in intergalactic space, and if the red shift is sufficiently large, the doppler shifted Lyman alpha will be detectable to provide information about the distant galaxies. If the red shift is nominal, that is, for a relatively close galaxy, then a space telescope can reach the ultraviolet where the lines should reside. The distant galaxies should prove most interesting in Lyman alpha radiation.

If there is hydrogen in intergalactic space, then the absorption lines from distant galaxies should be sensitive indicators of the density of this gas. Because of the relative motions of our galaxy and the observed one, there should be a wide spread in the absorption line over a wide bandwidth, and this might provide an index to the distribution of hydrogen in the line of sight.

With a space telescope the astronomer should be able to determine the precise nature and location of most of the spiral arms of the galaxy, the arrangement in space of stars of varying ages and physical characteristics and investigate the physical similarities and differences of stars in the nearer galactic systems.

The space telescope with specialized accessories can take the astronomer into the direction of the galactic center. In general, this center is almost totally absorbed by the intervening interstellar dust. While the great Sagittarius star cloud is in that direction, astronomers still are not certain that this is part of the central condensation. There are, however, rare openings in this cloud and Baade with the Mt. Palomar Schmidt camera photographed stars at a distance of 8,000 parsecs which are believed to form part of the central condensation. The accessories such as image converters, photomultipliers and infrared photographic plates may be used to penetrate this region. The results of these space observations may be the observation of the galactic nucleus to then compare it to the nucleus of the Andromeda galaxy.

COSMOLOGY

Cosmology concerns itself with the large-scale properties and history of the Universe. Into this subject is funneled the results of observational studies and the results of theoretical studies which may be closely linked to the observational ones. Thus, in cosmology we are concerned with the ability of observers to penetrate deeply into the Universe to study a larger sample in order to make their conclusions approach the actual state of events.

When we probe deeply into space, once more the atmosphere sets up its severe barriers thereby limiting the reach which optical instruments can penetrate. This handicap has in the past proved formidable in our search for the raw data upon which theory is based and tested. The advent of orbiting observatories of many kinds will go far to provide the additional information which astronomers need for a better understanding of the world picture.

One of the first tasks which the astronomer can undertake is photographing galaxies in the remote depths of space. It is from these studies that they will be able to construct the various models of the universe and choose the model which most nearly fits the observational data.

With large orbiting telescopes galaxies can be counted to the limiting magnitude of the telescope. It is possible that we will be able to reach galaxies of magnitude 24 or 25 and, thus, provide the astronomer with a sufficient number of the faint magnitudes. Galaxy diameters might be determined as a function of distance which would in turn yield information on world geometry.

The red shifts for high recessional velocities could be augmented by spectroscopic observations in the ultraviolet and infrared. By being able to probe these regions we could furnish a hold on many more spectral lines than are now available. This, in turn, would give a better hold on such quasars as 3C-9, where the red shifted Lyman-alpha line is tied to only one other line (C 4), and 3C-286, where only one line is visible.

The most significant contribution of the space observatory can well be the resolution of the problem of cosmological models. The advantage of greater distance penetration is that the differences between various models become substantially greater. As a consequence, the increase in distance penetration should make the decision between the various models substantially easier.

With the classical work of Hubble on extragalactic objects, the edge of the observable universe has been constantly extended, and simultaneously we have become indoctrinated in the expanding or evolutionary universe concept. In this model the universe began about 10 billion years ago, with some thought that present values of the deceleration parameter would suggest a value 30% less. The universe is still expanding, so that all galaxies are receding from each other with speeds proportional to their distance. Later it was suspected that an alternate solution to the mathematics involved permitted a pulsating universe -- one which expanded for a time and then concentrated back to a primeval nucleus. The period of this oscillation is long, and may reach some scores of billions of years. Of rather recent origin is the steady-state universe proposed by

British cosmologists. These are the various models from which one may choose.

Hoyle has advanced some rather cogent arguments which favor his steady-state theory. He indicated that since this model requires no difference in large-scale properties between the past and the present, the theory is clearly susceptible to verification by penetrating deeply into space. He indicated that large-scale properties can be estimated from several different clues. These could be the population of galaxies, the magnitude and color of their radiation and other significant events.

Hoyle reasons that in the steady-state universe we should expect to see surviving only properties which have stabilized themselves, so that they are reproduced at precisely the same level from generation to generation. Galaxies represent a strictly controlled system with the origin of matter cast in a critical role. The crucial difference between the models can form the basis of stringent tests. The tests can be applied to such properties as the density of galaxies in space and the distribution of sizes and masses of galaxies. Studies may make it possible to determine whether distribution follows a regular frequency curve or shows no regular pattern.

While in a report of this type, the Steady-State universe must be treated, it is generally falling into disfavor so that Hoyle no longer strongly supports this view. It must be pointed out that a thorough search made by Walter Baade for young, blue-white supergiants in the ellipsoidal galaxies failed to disclose these supergiants which should have been easy to detect. Failure to detect these stars is a striking argument against the hypothesis of the continous creation of hydrogen.

Cosmologists who favor the expanding universe concept indicate that by penetrating deeply into space we are also moving back in time.

If we live in this evolutionary universe and the galaxies do change slightly with age, then a change in form, in substance, of only a few percent in a billion years can readily be determined if we can penetrate far enough into space to go far enough back into time. If such a change should be indicated it would be indicative of an evolutionary universe. It is this feature of deeper penetration in space that might be expected from a orbiting observatory.

It has long been recognized that the type of a universe in which we live depends upon a "world density" or the average amount of matter in a unit volume of space. Cosmologists indicate that the average density is associated with the value of recession. This value will permit us to indicate whether the Universe is open or closed and if it is closed will provide some indication of its radius. Thus, one of the most critical elements in cosmology is the knowledge of the average density of matter.

The quest for a realistic value for this density has been in progress for a long time. It hinges on the presence of matter between the galaxies. Some astronomers have shown methods by which tentative values can be determined. Messel and Butler (16) indicated that by studies of clusters of galaxies we can arrive at the mass of a system if the radius of the cluster and the velocity are known. Thus, they arrive at a mean density of Virgo cluster of 8×10^{-27} g/cm^3. For the Coma cluster they arrive at a mean density of 4×10^{-26} g/cm^3. Using these values and comparing distribution densities of galaxies in clusters with t ..erage density of galaxies throughout the universe one can arrive at an average density of matter in the universe. The most recent value obtained by Oort is 7×10^{-31} g/cm^3. However, there is not too much agreement on this value. The critical issue is the presence of matter in intergalactic space. The most likely form which this matter will take is hydrogen. Can we detect hydrogen in intergalactic space?

Sandage has indicated that galaxies lose hydrogen with age. The repeated collisions of the gases in the galaxies eventually sweep them out into intergalactic space. If this is true, then galaxies should possess a Lyman Alpha glow for this is the lowest state of the neutral hydrogen atom. Thus, while we may find it difficult to define the outer edges of a galaxy in visible light it may be well defined in Lyman Alpha radiation. This in turn can provide the accurate dimensions of the galaxies from which the average density of matter can be determined as indicated in the last paragraph. ..biting observatories designed to photograph distant galaxies in the extreme ultraviolet may reveal this glow from which astronomers can arrive at sizes.

The entire matter of the average mass of the universe is a many-faceted problem. While here we are speaking of intergalactic space with its tremendous volumes, there is also the problem of invisible material in the galaxies themselves which must be determined. Wheeler (17) indicates that the predicted density of matter exceeds by a factor between 10 and 100 the density that one is able to find in the dust and stars of galaxies -- imagined to be ground up and distributed over all space. This missing matter is actively being sought by many investigators. He further indicates that ionized hydrogen in substantial quantities occupies the space between the galaxies.

However, there is another approach to this search for material. This one deals with the death and extinction of stars. The evolutionary cycle of the stars has them progressing in a fairly well determined manner along the main sequence and, finally, when the nuclear fuel of the star is consumed the stars move into a dwarf stage and the light diminishes to the point where it ceases to radiate in the visible range. However, this is true only for the main sequence stars whose mass is about 1-1/2 times that of the Sun. If the mass should exceed that, then the star can undergo a catastrophic explosion in which a substantial fraction of its mass is blown off, the remaining core collapses to a small object in which the diameter may be a small fraction of that of the earth's, the density has risen to an incredibly high figure and the gravitational field of the remaining core is so intense that radiation can no longer escape from it.

The critical statement is that radiation can no longer escape from it. This means that essentially the star is a dark mass wandering in space without any way in which we on the earth can detect it. Actually, this is not quite so for Shklovsky has indicated that if the neutron star is a member of a binary system the visible star may eject matter. If this matter impacts the neutron stars, then X-rays should be generated. Thus, by searching the sky for X-rays a possible answer to this question may arise. The so-called "black holes" may be detected if they form part of a binary system in which they circulate about their common center of gravity. By doing this it may be possible to plot the oscillations of the visible component.

and from that deduce whether the perturbing body has a mass comparable to that of a star.

The significant point of this argument is that if there are many black holes scattered through the galaxies and if there are many stars which are ending their life cycles to emit only long wave radiations, then there may also be a significant fraction of the mass of the universe tied up in the invisible objects. If this is the case, then the average density of matter in the universe would be affected and with that the nature of the type of the universe. The density is intimately associated with the value of the velocity of recession. The density permits us to say whether the universe is open or closed and, if closed, what is its radius.

THE IMPACT OF ASTRONOMY ON OUR CULTURE

In 1825 John Quincy Adams became President of the United States and, because he was an avid supporter of an astronomical observatory, in his first message to the Congress said:

> "It is with no feeling of pride, as an American, that the remark may be made that, on the comparatively small territorial surface of Europe there are existing upward of one hundred and thirty of these lighthouses of the skies; while throughout the whole American hemisphere there is not one."

Following the Presidency he was drafted to serve in the House of Representatives where he found himself on a committee which was considering the proposed gift of James Smithson who left his fortune to this Country. History records he was unsuccessful in trying to get the Congress to use a portion of this money to erect an observatory.

While he was unsuccessful in this venture, far to the west a realization of his dream was materializing. In Cincinnati, Ormsby McKnight Mitchel was promoting the Cincinnati Astronomical Society in which members were contributing $25.00 each with the objective the establishment of an observatory. This goal was fulfilled and on November 9, 1843 Adams laid the cornerstone of the observatory and in his address traced the history of astronomy. One phrase he used bears testimony to his conviction that astronomy is the noblest of the sciences:

> "The progress of a people on their careers of civilization can be gauged by the number of observatories on its soil."

Now, a century and a quarter later, we might paraphrase the Adams statement by saying the stature and well-being of a people in this twentieth century world can be gauged by their ability to establish observatories in the sky.

We have come a long way since the time of John Quincy Adams when he pleaded in vain for a single observatory to permit man to raise his eyes to the sky. Today it is acknowledged that astronomy, far from an esoteric study, has made major contributions to the welfare of the United States. Specific details are always difficult to chronicle to everyone's satisfaction for we are inadvertently prone to subjective reactions. However, it is generally acknowledged that, indeed, these astronomical contributions have influenced the path this Country has taken.

To detail these benefits is not a difficult task. It is the interpretation which may not be universally accepted. However, when the detailing is done it falls into six general categories: education, social, economic, scientific, political and the arts in general, or literature to be specific. While some may not agree with the categorizing of some of the facets, few will find fault with the inclusion of the material in these facets.

Because of the orientation and background of the writer, there exists a strong, scientific bias and, thus, we might discuss the scientific advantages accruing to this Country through the scientific overtones of astronomy.

We might begin back some three or four thousand years ago and transport ourselves in our mind's eyes to Egypt on a July day to look into the east just before the dawn to observe the rising of the star Sirius. The farmers who watched the skies knew this was the giver of life for the heliacal rising of Sirius marked the time for the overflowing of the Nile and with this overflowing of the lowlands the lands were fertilized to yield life-giving crops. The Egyptian priests could compute this date of the flooding and this knowledge enhanced their positions among the farmers of the country. It was these same priests who used the sun and stars to measure time and while civilization was still primitive derived the length of the year with little error.

In Alexandria in ancient Egypt, Eratosthenes (about 250 B.C.) saw the sun 7 1/2 degrees from the zenith on the summer solstice. In the south was Syene, near the first cataract of the Nile, and there on that same day the sun's light shone vertically down a well indicating its zenithal position. When he had determined the distance between the two cities, Eratosthenes was able to compute the circumference of the earth with surprisingly small error.

Thales, of Miletus, studied a list of Babylonian observations of the sun and moon and from these observations, which he took on faith because he never knew who made them, computed the solar eclipse of May 28, 585 B.C. Of this prediction the eminent historian, the late James Henry Breasted, said: "In the history of human thinking, this was probably the most fundamentally important step ever taken".

From these few but dramatic examples are seen the colossal strides taken in the civilization of man by observations of the skies. The early astronomers contributed greatly to an understanding of nature and with this came an uplifting of the spirit of man. Time after time through the chronicles of history are found examples of astronomical discoveries which influenced and, in some cases, shifted the course of history.

When, following the Dark Ages, the age of exploration dawned, man turned to the skies to permit him to guide his path on the courseless sea to find his way around the earth. Knowledge of the skies with their star groups and an understanding of their motions inevitably led to the use of the skies for position finding and, thus, opened up the world to the traders and merchants who helped spark the Renaissance. At about this time the telescope was discovered and with this new "optic tube" man began to observe the skies in depth. He also began to understand more about this tiny bit of space and understand the natural laws holding sway. With Copernicus the heliocentric theory became widespread and accepted and with this acceptance came the downgrading of the position of man. He realized this universe was not a system placed in the sky solely for his benefit, but rather, he was destined to play a minor role in the affairs of the universe.

With early telescopes the astronomer was able to measure the distances to the nearer stars and here, again, a revolution was triggered for the scale of the universe became apparent and with this scale came a further downgrading of a man as the premiere inhabitant of this universe.

Herschel led the procession to modern astronomy and astronomical methods. He counted the stars and tried to discern the nature of our Milky Way. He also played with the spectroscope and discovered that beyond the visible red there were other radiations which affected a thermom t [illegible] discovered infrared radiation.

Wi[illegible] odern astronomy came the desire to learn more about the life history of the stars. With the suggested solution to this problem came the concept of nuclear reactions from which the applicatio of atomic energy burst upon the scientific horizon. And with this discovery came the promise of the future in which the energy dictates of a twentieth century civilization will be satisfied by thermonuclear reactions -- perhaps it will also provide a way out by preventing civilization from committing suicide by polluting itself beyond recovery.

This illustrates the impact which astronomy has had on the arousal and stimulation of the scientific community from the time of the philosophers to the present. Science lives by uncovering new facts, by developing new theories, by testing these theories and then taking results to weave them into the fabric of our living.

It is astronomy which has paved the way to the concept of living off the earth. The basic laws which govern the motions of planets in their paths around the sun as outlined several hundred years ago also govern the motions of satellites around the earth and spacecraft in their motions around the sun. Today it is difficult to say where astronomy ends and astronautics begins. They are inextricably interlocked and will remain so as long as spacecrafts are launched into the sky. Within another decade men will be living on the moon, perhaps in permanent settlements. Before the turn of the century astronauts will be leaving this earth for visits to the major planets, perhaps out to the edge of the solar system. In all these trips, in all these adventures, in all these explorations the underlying principles upon which these flights will be made are astronomical in nature.

One of the significant contributions of astronomy to the welfare of our nation has been its direct and indirect inputs to the economic field. If a science is judged by its contributions into the nation's economic mainstream, then astronomy is prominent on the list.

One remembers that at the entry of this Country into World War II there existed a critical need for optical technicians. Because of interest in astronomy some of our youth became amateur telescope makers and learned to work optical surfaces. Because of the acquisition of this basic skill they were integrated into the developing optical industry which sprang up all over the Country. In Philadelphia they streamed into the Frankford Arsenal to work in the optical shops. In Boston a large optical shop was installed at the Harvard College Observatory and many New England amateurs migrated to this shop to work through the War. There they constructed many novel lenses for aerial photography and other scarce optical items for the military. A direct offshoot from this achievement was the Baker-Nunn telescopes which are used today to photograph and track satellites. Following the war many of the youngsters who were amateur telescope makers went into the optical business and are still engaged in this industry. Much of the mushrooming optical industry in this Country is a direct result of their astronomical interests as amateurs.

The precision with which astronomical optics are worked has influenced the development of other highly sophisticated instruments. If we retrace this development in the past, it is discovered that the results of the involvement of astronomy in instrumentation have produced spectrophotometers, phototubes, spectrometers, infrared sensors, aspheric optics, not to slight the telephoto equipment which is commonplace today. The new optics found its way into navigational devices which improved celestial navigation to help make transoceanic journeys safer and more profitable.

Astronomers are a versatile lot an , thus, when peculiar talents are needed they represent a tremendous and invaluable pool of highly specialized technical skills which are available during a national emergency. As an example, when World War II began a significant number of astronomers were mobilized in the laboratories at MIT, Oak Ridge, Los Alamos, Argonne, etc. Here their special talents were used to create artifacts which in many cases were unknown prior to their work.

Astronomers possess an excellent mathematical background and, thus, can move into new fields to make substantial contributions. A large part of the mathematics underlying American technology and engineering was originally developed by astronomers to cope with astronomical problems. Astronomical necessity helped spur the development of computers and computer technology. The classic work of Dr. Wallace J. Eckert in this field is a prime example. The space effort also created a significant market for astronomers trained in celestial mechanics. Today, even the skilled engineer has a working knowledge in this field. It is safe to say that without the groundwork carefully prepared by astronomers the progress in our space effort could not have been maintained.

Astronomers have pioneered in the discovery and development of new materials. The element helium was discovered on the sun at the 1868 eclipse and it was not until 27 years later that Ramsay isolated it on earth. Here was an element whose very name belied its origin. Today it is a commercially valuable commodity. Materials prepared to increase the sensitivity of instrumentation have been channeled into commercial applications. Some sensors available today would never have been developed except for the demands of the astronomer.

The economic aspects of astronomy tend to be overlooked because it is considered so esoteric. However, when one scrutinizes the record we become aware of the dramatic economic contributions made by this science.

The social overtones of astronomy are not readily apparent in this modern age. Gentlemen of the past were well versed in astronomical lore simply to permit engaging in intelligent conversation with colleagues at purely social gatherings. While use of this knowledge was of no particular economic value it provided an interested group who could be relied upon to sponsor and support scientific missions. Gentlemen of the past "read" astronomy simply because it was the "in" thing to do. One had to possess a basic knowledge of astronomy to be counted among the literati.

The knowledge of astronomy did provide a fuller life for those of the past and astronomy provides a richer life at this time. In the literature of the past are found many allusions to astronomy. It might be recalled that the renowned English satirist Jonathan Swift wrote of the travels of the mythical Lemuel Gulliver in which Gulliver speaks of the discovery of the two moons of Mars by the Lilliputians The remarkable part of this fiction is that the figures deduced by Swift were so remarkably close to the truth. While Swift was conversant with David Gregory's Astronomy, published in 1713 which provided the background, he nevertheless used ingenuity and intuition in arriving at the sizes and distances of the Martian Moons. Voltaire in his MICROMEGAS alludes to two moons of Mars and even Cyrano de Bergerac predicted the moons of Mars. This was the conditioned type of speculation indulged in by gentlemen of that era. It indicated a social awareness of nature and an attempt to understand more about the universe. Science fiction abounds with allusions to celestial journeys for there existed a fascination with the heavens that defies rational explanation.

Currently, the social overtones to astronomy manifest themselves in many ways in our everyday lives. Planetaria in most of the major cities cater to the demands of the lay-public in providing a palatable form of information about the heavens. In many cities are found planetaria that sponsor regular programs which school children attend in organized groups as part of the school curriculum. As an example, in Philadelphia, of the 330,000 visitors per year who visit the Fels Planetarium, about 70 percent come in organized groups from schools. The level of comprehension provided by the planetarium varies from kindergarten to college, each demanding and receiving a program geared to its particular studies.

Astronomical societies abound all over the Country. These hold regular meetings in which prominent speakers are invited to provide current information on the latest developments in the science. Visits to observatories have long been recognized as part of the American scene. While comparatively little of this is practiced in other countries, in the United States major observatories set aside at least one night a month to provide the layman with a chance to look through a telescope. No one knows how much of a spark has been struck in the minds of our youth by visits to these research institutions. Of one fact we can be certain, the universal availability of astronomy to this generation has provided a powerful impetus to our technological advance.

Astrono[illegible]s contributed markedly to the general education of our youth and will continue to do so. There are many examples of youngsters who have become interested in astronomy in their youth who eventually pursue this as a profession. One particular example is brought to mind. In the late 1930's a young, curly haired boy join[illegible] T[illegible] Franklin Institute A[illegible]teur Telescope Making Section to build a telescope. He learned all about telescope making and helped others in this art. He was a brilliant young man with a keen mind which was reflected in his college work. He then took a Ph.D. in astronomy at the University of Pennsylvania and joined their Astronomical Staff. Even before he joined them in a professional sense he had designed and, with the help of the author, built the first pulse counting photoelectric photometer. This instrument is currently used in most observatories but its origin in 1946 resulted from a joint effort in Philadelphia. There are other examples including the case of Dr. John S. Clark, director of the Goddard Space Flight Center. Dr. Clark's curiosity was aroused by visits to the Museum of The Franklin Institute when a boy. He admits he chose a career in science as a result of these visits.

No one knows precisely what motivates a youngster to enter a career of science. If one were permitted to speculate it might be said that it could be a close contact with some facet of astronomy which crystallized ideas and started a rewarding career.

The stature of a nation in the community of nations is measured by its scientific and technological achievements. It is for this reason that the Soviet Union with its launching of Sputnik I captured the imagination of the entire world. From a nation whose technological competence was considered nonexistent to one with a mastery of sophisticated science necessary to launch a satellite is something which had never occurred before. With the consummation of the first satellite launch Russia assumed a premiere stature in the scientific world. Thus, we became painfully aware of the inordinate political implications of technological and scientific competence.

Astronomy is a prestige science. Its leaders are among the most honored in science. And in this science the United States dominates the field and is the acknowledged leader. Primarily, this enviable position has been achieved through the foresight of a few organizational geniuses who have successfully put together the world's most powerful telescopes. George Ellery Hale is one man who was dominant in this field for he sparked the building of the world's largest telescopes. He played a leading role in the building of the 40-inch refractor of the Yerkes Observatory. He collected funds to build the 100-inch telescope on Mt. Wilson and he also was the spark behind the erection of the 200-inch telescope on Mt. Palomar. Thus, one man appears responsible for the erection of the major observatories in the world.

Today observatory costs are so high that they no longer can be a one-man effort. Today observatories are a national effort and national observatories are just beginning to emerge on the scientific horizon.

The Soviet Union has produced some astronomical geniuses whose theoretical reach is almost unbelievable. Yet that country is backward in astronomy for they do not possess the instruments to implement their theoretical discoveries. There have been many new startling concepts proposed by the Russians only to find that the observational discoveries are made elsewhere. This is not something of which the Russians are unaware for they have bitterly complained in their controlled press this shortcoming in their scientific establishment. To correct this they are currently building a 236-inch telescope so that the priority of discovery will remain in Russia. These discoveries must enhance the global stature of a nation. This is another reason why it is so important to further the objectives of astronomy.

The dominant position which Americans have held in this science has added greatly to the political stature of this Country. This contribution is one which cannot be properly assessed at this time. However, with the future may come the complete awareness of this effort.

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