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RELEVANCE GUIDE
VOL. I: GENERAL, SPACE SCIENCE AND UTILIZATION

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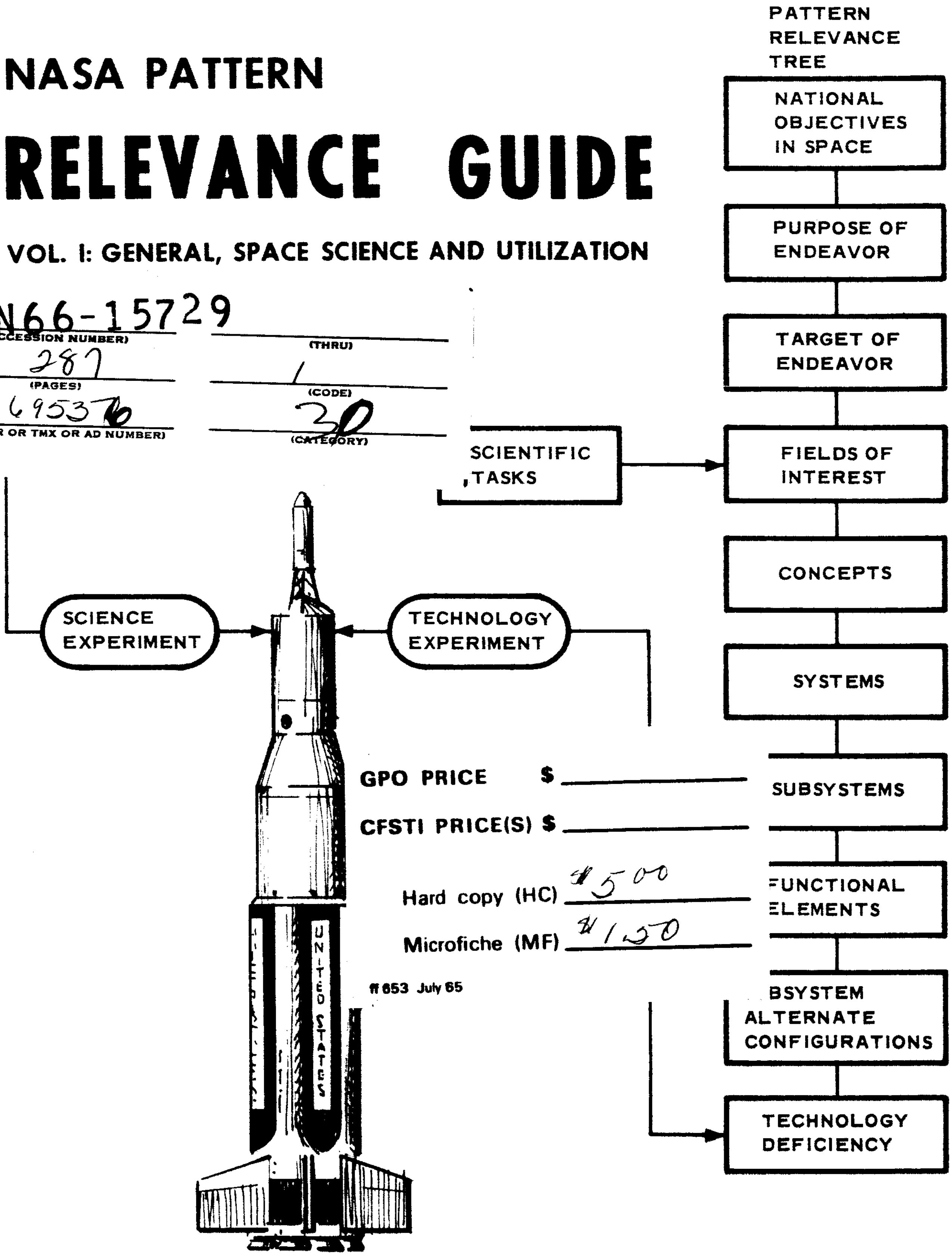

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NASA PATTERN

RELEVANCE GUIDE

Volume I

General, Space Science, and Utilization

Honeywell
Military Products Group
AERONAUTICAL DIVISION-ST. PETERSBURG, FLORIDA

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This volume is intended to contain summary information to be used in assigning relevance to elements on the PATTERN Relevance Tree, levels one through four. The elements on these levels are provided as a foldout on Page xv and in Appendix B herein.

The use of Volumes II and III are described on pages 1 and 2 herein.

PATTERN (Planning Assistance Through Technical Evaluation of Relevance Numbers) is a Honeywell-developed management planning aid. A description of the NASA PATTERN methodology and how it is used to determine the relevance of space flight experiments is described in the final report, "Operation and Procedure Manual."

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In addition to published references, the following scientists have contributed directly or indirectly to this study through personal conversation or correspondence; their assistance is greatly appreciated. This does not necessarily imply their approval of the contents of this document. Further suggestions and criticisms are solicited in order that revisions of this document may represent the current objectives of scientists in space exploration.

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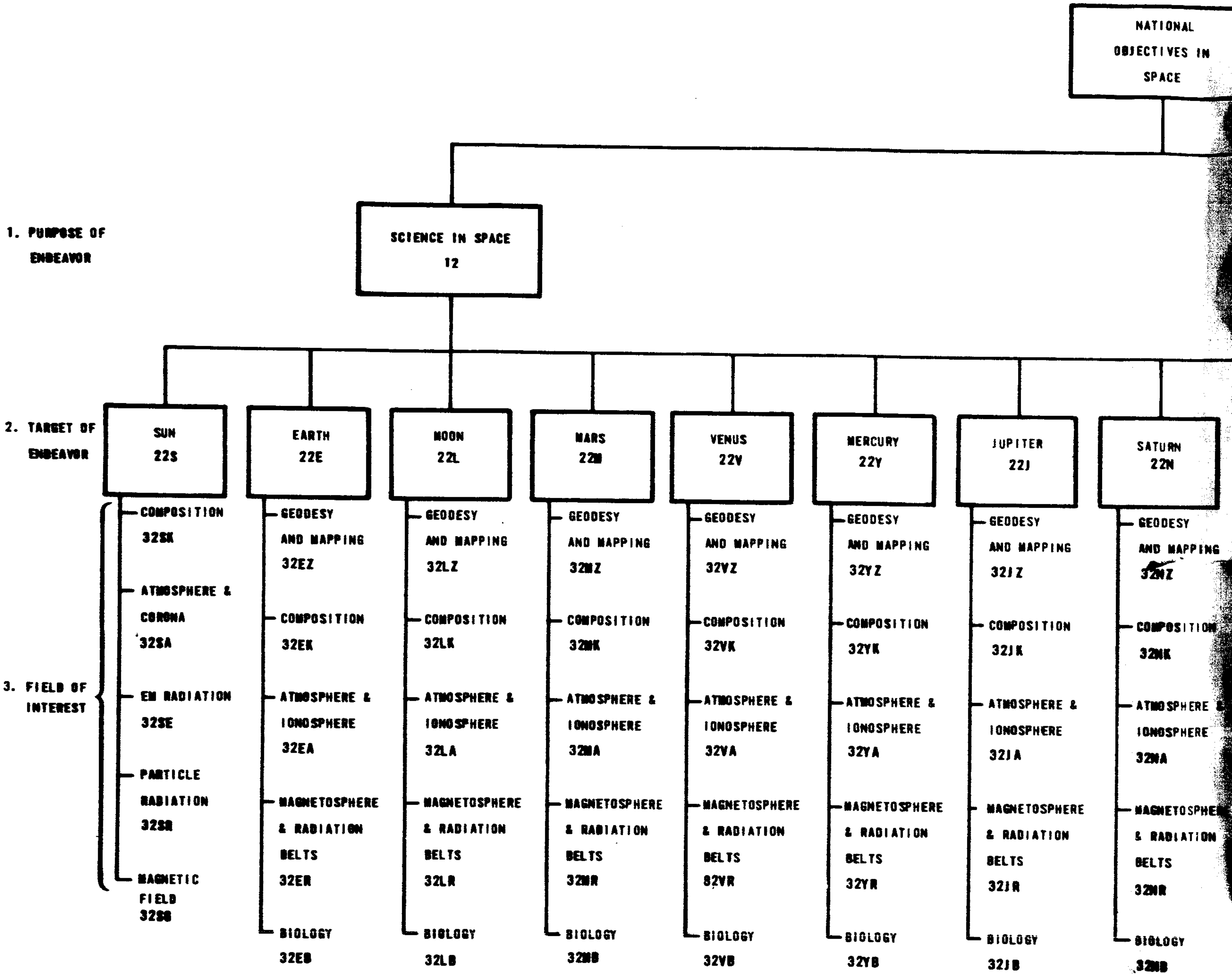
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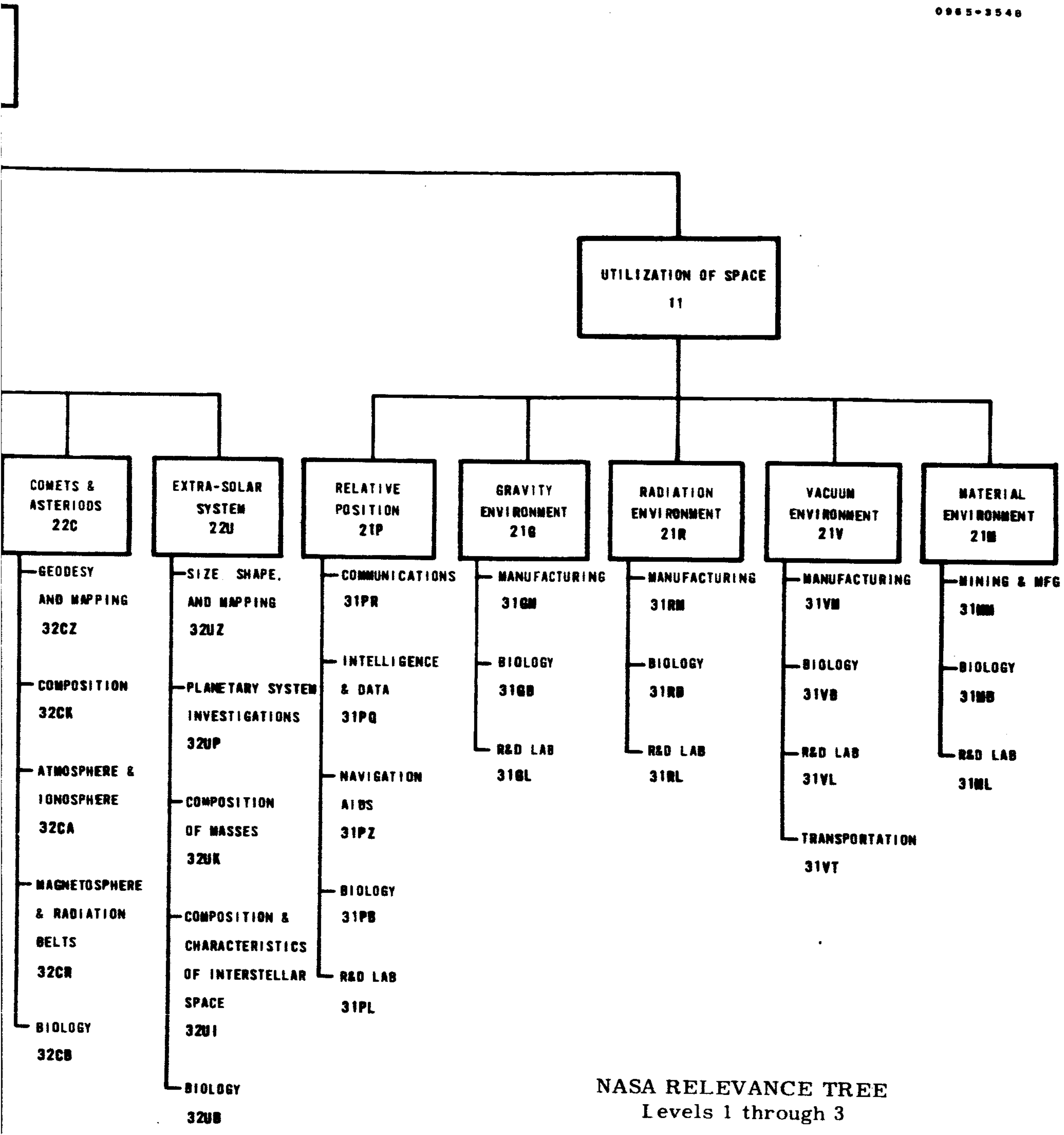


NASA RELEVANCE TREE
Levels 1 through 3

Section 1

GENERAL

1.1 PURPOSE OF THE RELEVANCE GUIDE

The NASA PATTERN Relevance Guide consists of three volumes for the purposes described:

Vol. I - General, Space Science and Utilization. This volume contains the material relevant to voting the first four levels of the PATTERN Relevance Tree. It discusses:

- the U.S. and Soviet goals and capabilities in space
- the relevance of the scientific exploration of space and the utilization of space for practical purposes
- the summary reasons for interest in each of the targets of space exploration and utilization
- the scientific disciplines involved and how they will benefit from space flight
- the principal tasks or scientific interests in each discipline

Included as Appendix B is the NASA PATTERN Relevance Tree through level 3 (Fields of Interest), and the lists of scientific tasks for each target.

The relevance of these tasks is a factor in determining the relevance of the space programs or concepts designed to accomplish these tasks, and hence the relevance of the technology deficiencies involved in each program.

Vol. II - Space Exploration & Utilization Concepts. This volume contains a description of some fifty different concepts or programs for the exploration and utilization of space. These are concepts that have not yet been programmed but appear feasible by 1985. Each concept contains a general description of the concept, a description of each major system, a list of each subsystem and its performance requirements, one or more proposed configurations for each subsystem, and a list of the technology deficiencies which have been identified for each configuration.

Where the subsystem requirements can be met by existing equipment, or can be met by state-of-the-art design, generally no configuration or technology deficiencies will appear.

Vol. III - Technology Document. This is a reference book to describe the state-of-the-art and promising developments in each space subsystem. Each configuration which has been selected for PATTERN concepts is discussed and its technical problem areas described. This information is a guide to voters in judging the relevance of subsystems, configurations, and technology deficiencies.

1.2 OPPORTUNITIES IN SPACE FLIGHT

Space flight offers unique opportunities for science and utilization not available until now. In summary, these include:

- exploration of the earth from above the atmosphere
- in situ exploration of the earth's magnetosphere, the moon, planets, and interplanetary space
- astronomical observations without the atmospheric restrictions of limited band pass filters, distortion, and background radiation
- distant vantage points
- large volumes of vacuum comparable to the best laboratory standards
- velocities in the 8 to 15 kilometers per second regime

- zero-g and provisions for 0 to 1-g experiments
- prospects of the availability of new materials
- availability of high particle and electromagnetic radiation levels over a wide spectrum

Figure 1-1 shows the limited electromagnetic frequencies which can pass through the radio and optical windows of the earth's atmosphere, severely restricting astronomical observations from earth.

The science and utilization tasks described herein are designed to take advantage of these opportunities.

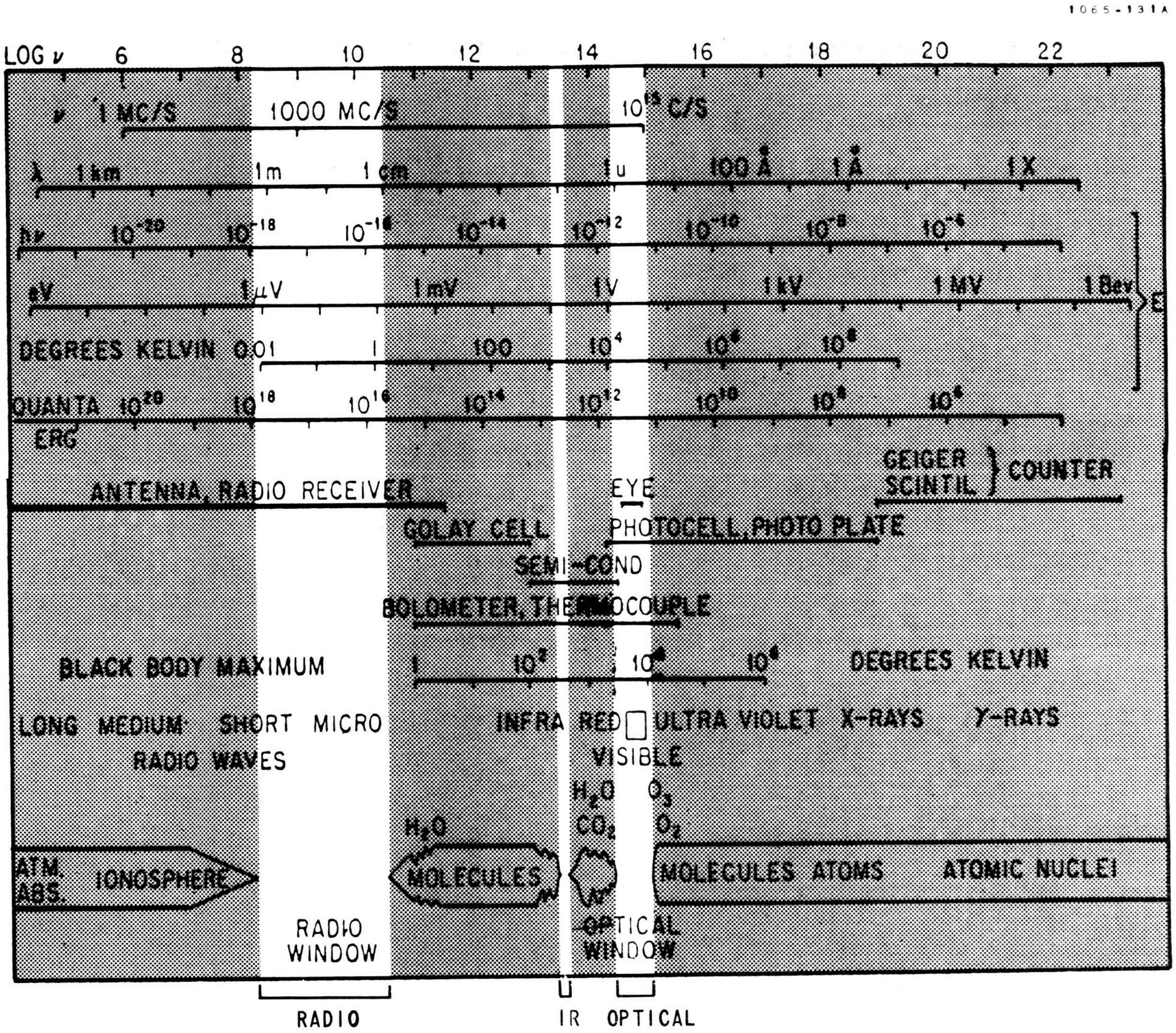


FIGURE 1-1. WINDOW IN THE EARTH'S ATMOSPHERE
(After A. D. Cole, The Astronomical Journal)

2.0 ECONOMIC AND POLITICAL FACTORS

This section of the relevance guide considers the non-technical side of the U.S. space program. It details the goals and problems of the program and discusses the political and economic impact of the program on domestic affairs, foreign relations and international programs. It outlines the Soviet space program, including both the U.S. impact on it and the effects of a possible Soviet space superiority. It defines prestige and considers the influence of prestige in international affairs.

2.1 THE U. S. PROGRAM

The U. S. space program has both a military and non-military sector. The National Aeronautics and Space Administration is charged with non-military applications. The NASA program, as planned in 1961, is designed to develop every capability required in space, manned and unmanned, to boost heavy vehicles and specialized vehicles into earth orbit, to be able to launch these accurately from earth orbit outward for any purpose required, and to orbit and land on other bodies in space. Specific goals (Ref. 1) include:

- Lunar landing within the decade
- Studies on the use of Saturn launch vehicles
- Studies on the Apollo-LEM manned space flight system
- Voyager-Mars mission 1971
- Advanced orbiting solar observatory

New programs, necessary to maintaining a position of leadership, include:

- Exploration of the planets
- Research and development necessary for effective extension of Apollo and Saturn for manned flight
- Integration of Centaur stage with the Saturn I B for planetary and other unmanned payloads

In particular, we need a good deal of additional work with respect to materials for higher propulsion and advanced power generation systems. Preeminence in space demands continuous evolvement of new technology, on which the formulation of responsible requirements directed toward a class of related objectives rather than a single requirement may rest.

The Department of Defense is responsible for the military effort in space. At present, this consists of deterring an enemy threat from space, establishing military communications satellites, utilizing space for reconnaissance, and researching the military role in space. The Manned Orbiting Laboratory is the principal project handled by the Department of Defense. However, the Air Force Spacetrack system and the anti-satellite system are also important.

The space program, as are all government activities, is limited by economic, political and social considerations. The principal resulting factor is, of course, the allocation of funding to the space program. Viewed in terms of the overall economy (GNP = $666 billion in 1965), the $5 plus billion allocated for space amounts to about 1%. The military budget comes to slightly more than 7%. In this respect, changes in space spending have lesser impact on the overall economy. If arms control or arms cutbacks should occur, the space program could take up some of the slack enabling the aerospace firms to remain in business. As long as the space program works at specific goals, e. g., Apollo, Mars-Voyager, the present funding levels at about 1% of the GNP may well be maintained.

Political and social factors interact and include building a concensus to go to the moon, combat ting the pressures to reduce space funds in favor of health research or on the earth-bound scientific research, and maintaining a backup to arms control measures.

2.2 THE RELEVANCE OF PRESTIGE

Major criteria in PATTERN include material benefits to mankind, improved human knowledge and national prestige. The latter is particularly relevant to this discussion. Prestige is the standing or estimation in the eyes of people, the weight in general opinion, the commanding position in men's minds. The relevance of prestige as a criteria is subjective, of course, and a definitive, objective assessment of prestige in the space race is not possible because of the lack of data on the distribution of attitudes and expectations within a country's population according to the role each group plays in shaping politically relevant decisions.

In general terms, however, prestige involves present attitudes and future expectations of allies, neutrals and enemies about the nation's strength, intentions and value-as-a-model. Strength includes such factors as capabilities, now and in the future, in military, economic, scientific and moral matters. Intentions encompass such factors as reaction, e.g., to fight or to yield, to negotiate or to stand off, to arm or to disarm. Value-as-a-model includes such factors as the symbolization by capabilities and accomplishments of the superiority of the political and economic system, the provocation of voluntary emulation and international support in relevant issues as opposed to the stimulation of passive deference, if not active opposition (Ref. 2).

The important area of influence is on the leaders of the country, particularly in countries where the people have little influence. However, even in democracies such as England the man-on-the-street can be shockingly uninformed as to the status of power or events in the world, except in the case of short-term events. Also, factors such as literacy rate, number of radios and televisions, and the degree of government censorship must be accounted for.

In summary, prestige, a euphemism for influence, implies the authority given by conspicuous excellence or by a reputation for superiority. It is important because one cannot lead unless those one is attempting to lead have trust in one's desires and capabilities to support those interests which to them seem to be most basic and fundamental. Point of impact of prestige is its influence on the government and leaders, the elite, of a country.

2.3 PRESTIGE AND THE SOVIET UNION

Today there exists an almost universal tendency to equate space leadership with broad scientific and technical leadership and even with military superiority. The Soviets, in fact, have waged and are waging a deliberately calculated campaign to establish this tendency, because for the first time a Soviet governmental endeavor has an emotional appeal for the people at large. Successes in space may be presented as evidence of the success and advancement of the Soviet man and generalized as successes for all men. Prestige gains of this sort have appreciable political value for the Soviets when combined with their slogan of "peaceful coexistence."

Growth of Soviet prestige shakes confidence in American technical and military strength, sharpening doubts as to the wisdom of alliance with the U.S. Prestige factors are likely to be of large consequence in international politics unless the magnitude or national prestige gains and their repercussions on the international and national balance of power are minimized by a competitive national effort. Present polls show that many people throughout the world believe the Soviets will lead the U.S. in ten years in space. Thus, prestige could become an important factor in the creation and leadership of coalitions and in the domestic political strength of governments (Ref. 2).

2.4 SOCIAL AND ECONOMIC EFFECTS OF THE U.S. PROGRAM

The domestic impact of the U.S. space program is widely varied ranging from improved communications and navigation to political maneuvering for new NASA facilities. In the economic sphere, better and less expensive long distance communication would stimulate transcontinental trade lines and the decentralization of large corporations. These kinds of things are really products of the space program and not inherent in the type of program. A reduction in the space effort, as already mentioned, would affect the overall economy only very little. However, in the areas where NASA facilities are growing such as Huntsville, Michoud, and Houston, severe economic problems could ensue from a cutback. Direct economic benefits are localized because of the relatively small amounts being spent. The political impact is directly related to economics because of the benefits to areas where the funds will be spent. Competition for new NASA sites is also a political issue. Social impacts include infusion of highly educated personnel into the local areas, raising demands for better education and more competent civil government. In general, then, the domestic impact in all aspects is localized around specific centers receiving funding.

2.5 INTERNATIONAL EFFECTS OF THE U. S. PROGRAM

International influences of the program are significant. Political influence is evinced in prestige, as already discussed, in insurance and backup to the aerospace companies, and in international cooperative programs which expand and strengthen U. S. links to the foreign scientific community. The insurance factor is important for two reasons: first, arms control is a possibility and maintenance of the capacity to produce arms is a necessity even should direct activity cease or become highly regulated; second, additional protection against the possibility of a foreign technical breakthrough in any of the important areas which could alter the present power structure in the world is extremely important.

International political issues arise over a variety of matters. The following list (Ref. 2) includes a representative sample:

- ground support facilities on foreign soil
- launching sites
- nth country problem in space
- international participation in communication satellite
- weather satellites
- contamination of space and celestial bodies
- military development of space technology
- arms control and space
- the U. N. and space

One real problem is the student status of Europe in space. Any U. S. aid appears to dominate and restrict initiative, yet launching facilities and space technology are so expensive that Europe cannot develop them alone.

Economic and social benefits accrue through international cooperative programs and international exchange programs as well as through some areas of scientific exploration. The NASA program opens channels to the best foreign brainpower and contributes to the technical capabilities of our friends and allies (Ref. 1). The possibility of including both foreign and U. S. experiments on our launches has been realized promoting scientific exchange. Foreign activity creates a wider and deeper technical capability abroad and creates interests that do not now exist. Benefits develop in the form of expanded higher education and the entrance of these additional technical graduates into prestige areas. The increasing collective, scientific efforts of organizations such as European Space

Research Organization and European Launcher Development Organization can provide real competition in certain selected fields (Ref. 4).

Direct benefits such as faster, less expensive communications and more accurate navigation have direct influence on the economy by promoting international trade and exchange. Accurate weather prediction also will have great economic impact.

2.6 THE SOVIET PROGRAM

The principal competition with the U.S. is, of course, the Soviet Union. The two national programs stimulate one another and in many ways have become a battlefield for the cold war.

Goals and timing of the Soviet program are estimated (Ref. 5) as follows:

●	1964-65	Lunar soft lander
●	1967-70	Man around moon
●	1968-70	Man on moon
●	1972-75	30-50 man lunar base
●	1975-80	Manned Mars or Venus mission
●	1980-82	Manned Mars or Venus lander

The Soviet program has the advantages of selectivity and better overall planning and the handicap of a limited economy, forcing early rejection of more expensive alternatives and a need for sharply defined objectives. The Soviets are able to allocate resources first to those tasks the party and national leadership deem most important. The research, development, engineering and production phases are completely separated in Soviet industry. They utilize task forces to solve specific problems.

The Soviet program is expanding. They launched twice as many space spectacular missions during 1964 as in any previous years.

They are certainly developing all of the capabilities to do the same kind of advanced missions that the U. S. regards as being in its best interests to pursue (Ref. 1). The following table shows a comparison of U. S. and Soviet space efforts.

TABLE 2 - 1. COMPARISON OF THE SOVIET AND U. S. SPACE PROGRAM

	Soviet Union	United States
Achieved:		
Initial Satellite	Oct 1957	Jan 1958
Manned Orbiter	Apr 1961	Feb 1962
Multi-Manned Orbiter	Oct 1964	Mar 1965
Extended Time Manned Orbiter (20+ orbits)	Aug 1962	May 1963
Deep Space Probe	None successful	Dec 1962
Lunar close-up photographs	Oct 1959	Jul 1964
Planetary close-up photographs	None to date	Jul 1965
Estimated:		
Lunar Soft Lander	1965	1967
Manned Space Station	1968	1969 (MOL)
Manned Lunar Landing	1969	1969
Large Manned Lunar Base	1973	1976
Manned Planetary Flyby	1977	1977
Manned Planetary Lander	1980	1980

The paramount feature of the Soviet program is its close relation to political and economic goals. It is a major element in the total strategy of the Soviet leadership. That total strategy is, of course, world domination and one means is the destruction or weakening of Western alliances. Through the Cold War period, Western European confidence in the U. S. and U. S. self-confidence vis-a-vis the

Soviet Union has rested heavily on the assumption that the U. S. possessed and could maintain military, scientific, and technological superiority. The Soviets are attempting to convince the people that space capability is a major factor in gauging relative military, scientific, and technological strength of the two sides and that the U. S. is hopelessly outclassed. The present detente with the Soviet Union, particularly in science, will likely be continued as long as the Soviets continue to benefit from it.

At the same time, the Soviets accuse the U. S. program of being militarily oriented hoping to discourage third countries from participation in international programs, to embarrass the U. S. in international negotiations, while providing justification for Soviet non-participation, and to lay the groundwork for the exposure of Soviet space weapons.

The Soviets have exploited their successes to enhance their world position, to change favorably the world image of the Soviet Union as a great power, to divide the Western alliance, and to further the propaganda campaign of peaceful coexistence. The Soviet program is devoted to maximizing the political impact at home and abroad of the space program through space spectaculars. The desire to beat the U. S. is great and, consequently, the U. S. program has great impact on the Soviet program. Because of the high cost of space technology, U. S. competition is important. The Soviet economy does not have vast resources that the U. S. has and keeping money tied up in the space program could be strategically relevant.

2.7 THE SOVIET ECONOMY

Comparison of the Soviet and U. S. economies is at best difficult because of data suppression by the Soviet government. While GNP

(Gross National Product) is a fair measure of economic stature, it should be noted that war strength cannot be measured by real GNP alone. An example is that of the Soviet Union where they allocate two times our fraction of GNP to defense in order to come up with the same values. Another problem is the fact of "rapid growth rate" in the eyes of important neutrals. It is tempting to imitate a system that is going "full speed ahead" as the Soviet appears to be. Growth rates are controversial but the challenge is shown in Figure 2 - 1 (Ref. 6).

Another possible comparison of the economies are the various data on communications, consumer goods, work time per consumer goods and industry. A selected list (Ref. 7) follows:

TABLE 2-2. COMPARISON OF SOVIET AND U. S. ECONOMY

	USSR	USA
Communications:		
telephones in use	3, 167, 000	80, 964, 000
televisions in use	8, 300, 000	56, 300, 000
daily newspaper circulation	39, 555, 000	58, 900, 000
citizens going abroad	772, 000	2, 159, 857*

*Not including Mexico and Canada temporary visits

Work time per consumer goods (1961 estimates):	USSR	USA
bread 1 lb	11 minutes	5 minutes
sugar 1 lb	1 hr. 24 min.	3 minutes
man's suit	86-350 hours	21 hrs. 8 min.
man's shoes	62 hrs. 20 min.	3 hr. 48 min.

In spite of recent setbacks, over the long run, the Soviets know what they want, have a plan for it, and are rapidly reaching this very ambitious goal. Estimates of the Soviet GNP as a percentage of that of U. S. varies. The University of Virginia's Professor Nutting estimates 35 percent, the CIA uses 45 percent, and the USSR claims 65 percent. Russell Bowen of Arthur D. Little feels 40 percent is a good estimate (Ref. 65). Estimates of the growth rate of the USSR's GNP also vary. The CIA uses 2 1/2 percent per year, several U. S. experts on Russia (Ref. 19) use 4 percent to 5 percent, the Soviets claim 6 percent to 8 percent. This compares with 2 1/2 percent to 3 percent for the U. S. Bowen suggests that the present Soviet rate of growth will not be sustained. Depending on whose figures are used, the Soviet GNP may overtake that of the U. S. by 1980. Since the relative GNPs are themselves controversial, we won't really know when they have become equal.

Of more immediate significance perhaps than the relative GNP are the comparative budgets and the comparative value of the ruble and dollar in buying space programs. A conversion rate of $1.11 = 1 ruble is currently accepted. Although the hourly output of the Soviet skilled worker is probably about the same as that of the U. S. worker, typical industrial projects require about 2 1/2 times as many manhours (depending upon the industry) as U. S. projects because of the large amount of handwork still done in Soviet Russia. Another factor is that

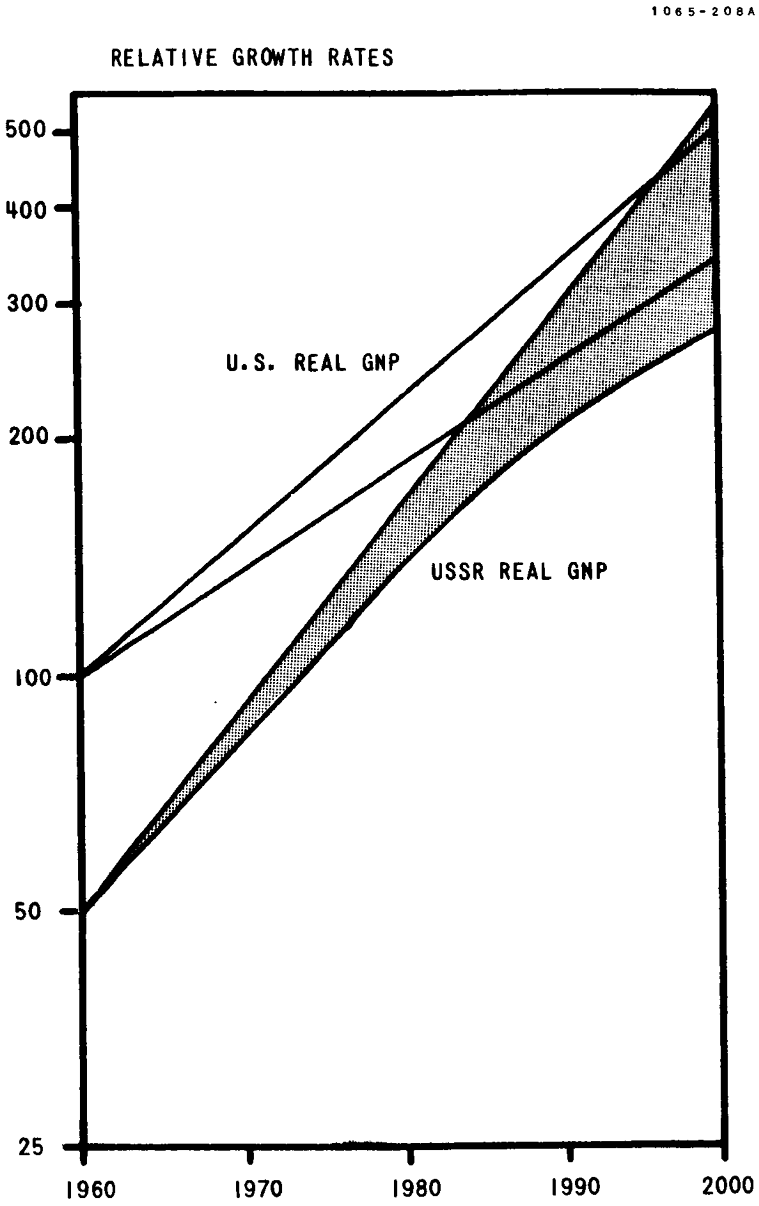


FIGURE 2 - 1. RELATIVE GROWTH RATES (REF. 6)

the average wage of the Soviet industrial worker is about $100 per month compared to $400 in the U. S. Therefore, it appears that in evaluating Soviet expenditures, a dollar buys about 60 percent more program in the USSR than does a dollar in the U. S., and a ruble about 67 percent more.

While these estimates are based on industrial productivity, they are probably fairly valid for scientific work. The productivity rates of the Soviet scientists compare more favorably with the U. S. than the productivity rate of Soviet labor. So does the salary rate (Ref. 8).

The U. S., on the other hand, has a stronger economy and is aroused. While short in numbers of scientists, the more extensive use of computers has magnified their effectiveness. Also, U. S . industrial labor is more productive. The U. S. reliability program should permit more advanced and sophisticated systems than Russia's. And finally, the U. S. will soon have a booster to more than overtake the Soviet lead.

2.8 SOVIET EMPHASIS ON SCIENCE

The Soviet Union has a limited economy but high national enthusiasm for the manned space program. Their output of scientists from colleges exceeds that of the U.S. In addition, they are much more active in translations of technical papers than other nations (Ref. 10).

- In one recent year the Soviet translated 4,648 foreign papers (mostly English); the U. S. translated 764.
- Of 900,000 Soviet chemists, 600,000 can read German, 500,000 read English, 400,000 read French.
- The number of Soviet scientists who read English is two-thirds the number of U.S. and British scientists combined.

Because of this and the fact that the U.S. space program is open, Soviet scientists benefit many times more from U. S. programs than the U.S. benefits from the Soviet programs.

Reliability seems to be an even greater problem for the Soviets than for the U.S. in spite of her policy of simplicity and shelf-hardware utilization. It appears that three Soviet astronauts have been killed to date (Ref. 11). Further, about ten attempts to launch planetary probes have failed. Most of the latter failures are connected with the launch from earth orbit techniques which is basic to their lunar and interplanetary exploration program. There is little evidence to suggest that their reliability program is as formal and sophisticated as ours (Ref. 12).

The Soviets have rather limited launch facilities compared with the U.S.'s Cape Kennedy and Vandenberg. Two sites, Kapustin Yar and Tyuratam, handle space launches. Kapustin Yar is primarily an ICBM test site and has launched up to 3,000 pounds into earth orbit. The range is laid out in an easterly direction to give about 48 degrees orbital inclination. Baikonur (Tyuratam) is equipped with two pads for space launches. Launches are to the northeast with orbital inclinations of 65 degrees. The Vostoks were launched from this pad.

In summary, the influence of the space program on political, economic and social affairs at home and abroad is important. Prestige and its international effects is perhaps the most important factor, impacting directly on alliances and domestic political problems. Real economic effects of the program itself are difficult to isolate. On the other hand, economic advantages resulting from the improved technology and the utilization of satellite communications produced by the program could be great. Social influences evince themselves in the kind of charisma the space program holds for people throughout the world, creating a sense of wonder and excitement about science and technology and, consequently, about education.

3.0 SCIENCE IN SPACE

It is often insisted that because science is important in its own right, there is no basis for determining relevance of scientific work. Science is the search for knowledge and knowledge need not have a clear immediate application to be "good."

However, if one is faced with the problem of determining relevance of scientific efforts--and someone in most every institution, scientific laboratory, research group, foundation and institution, and indeed the highest levels of the Federal Government itself, must make relevance decisions--it can be seen that there are other factors than simply the quest for knowledge. Some knowledge is trivia; some is exploration in an entirely new field. Some is critical in order to choose between major hypotheses; some may open the way to whole new fields of science. To a certain extent, the relevance of an effort to these various interests can be subjectively judged, with humility in the realization that history can, and often has, proved such judgements wrong.

Some criteria, then, for evaluating relevance among scientific fields of interest or tasks are:

- The relative probability of useful applications resulting from the work.
- The relative degree to which this effort is in a new field of knowledge (rather than simply adding data points where general characteristics are already known).
- The relative degree to which new fields of research may be opened by this effort.
- The relative degree to which this effort contributes to the solution of critical questions.

Rarely can scientific work "solve" a task and further effort in that direction be abandoned. The careful building up of the brickwork of scientific knowledge often requires many different efforts to complete a sound foundation, and sometimes requires tearing out previously accepted work. A recent example is the case of the period of rotation of Mercury which was "known" to be the same as its period of revolution--88 days. The literature and handbooks of astronomy left no doubt as to the full acceptance of this "fact": But in April 1965, Cornell University scientists at the Arecibo, Puerto Rico radar observatory determined that Mercury does, in fact, rotate with a period of about 59 days, not 88 (Ref. 13). During the August 1965 opportunity this was confirmed and a tolerance of ±3 days was calculated. Pettingill of Arecibo (Ref. 14) says there is no doubt of the results and Goldstein of Goldstone (Ref. 15) says he has confidence in Arecibo's work and the observations of Mercury from Goldstone do not confirm or disprove the Arecibo report.

Whether this is the final answer or not obviously has bearing on the relevance of certain scientific interests in Mercury.

Another case: Venus was "known" to be dry. Recent work indicates the clouds are ice particles and Strong (Ref. 16) even suggests heavy snowfall to account for the evenness of temperature on the light and dark sides. Strong says, "I don't know how well accepted is the presence of water on Venus, but it is well proven."

The inference is clear: Even well known scientific facts can stand a review when new types of measurements become available, as in the case of the new astronomies and space flight.

So continuous work is done to test, confirm, revise work that has already been done. Several scientists in various organizations may be engaged in experiments on different space programs which appear to ask essentially the same questions, but sometimes from different aspects. The accumulated answers will integrate into our storehouse of knowledge.

Dr. Paul Campbell (Ref. 17) says that America's greatest strength lies in her storehouse of knowledge. Continuous work to investigate, study, experiment, theorize, to add to our investment of knowledge is of utmost importance. The immediate application is not important. The knowledge must be there when we need it.

The extent to which psychological factors are involved in judging the relevance of scientific work is difficult to evaluate. A large portion of the scientific community is painfully aware of important scientific work that is not getting proper attention or support. When one looks at the current interest in charged particle studies, for example, the possibility comes to mind that an equally detailed investigation program could be outlined for an analogous study of, say, ocean currents. Such a program might include three-dimensional mapping on a global basis of velocity, salinity, and temperature; the study of diurnal, monthly and long term seasonal and secular variations; land-sea and thermal interfaces; iceberg genesis, development and paths; the origin of current motion and so on. And an analogous rationale for such intensive effort could be presented: its influence on world weather, on communication and commerce, on food distribution, tsunami prediction, coastline erosion, etc.

But whether these scientific interests receive the support that charged particle work in space now enjoys depends on much more than rational criteria.

3.1 EXPLORATION OF A PLANET OR MOON

In surveying the scientific interest in each of the planets and its satellites, the asteroids, and to a certain extent the comets, it becomes apparent that there is a general body of knowledge which science seeks to acquire about all of these solar system bodies. The degree of interest varies from one body to another due to the individual characteristics of the particular body, to the fact that much is already known about certain bodies, and to the fact that some bodies have more relevance to man than others.

This chapter will discuss these general scientific objectives for the exploration of any of these bodies and, for each task, includes a rationale for any exceptional interest in the various planets, satellites, asteroids, and comets as summarized in Section 3.4.

Any system of classifying scientific disciplines has problems and faces the difficulty of overlapping interests. For the purpose of this study, the general body of scientific interest in solar system bodies has been divided into the following Fields of Interest.

Geodesy and Mapping - Geodesy includes scientific interest in the mass, axis and rate of rotation, equatorial and polar radii, definition of the geoid and gravity field. Mapping includes the location and referencing of gross and detailed physical features.

Composition - includes determining the chemical composition and distribution of materials and resources of the target body.

Atmosphere and Ionosphere - includes determining the constituents of the atmosphere, the density, temperature, pressure, and dynamic changes such as caused by weather, diurnal, seasonal, and solar cycles; also the definition, extent, and characteristics of the ionosphere, including dynamic changes. Interaction of solar radiation on planetary atmospheres is included here.

Magnetosphere and Radiation Belts - includes mapping the location and magnitude of the magnetic lines of force and magnetic anomalies, determining the location of magnetic poles; also the composition, distribution, and characteristics of energetic particle fields about the target body, and the dynamic effects of diurnal, seasonal, and solar cycles on these fields.

Biology - includes studies to determine the life forms present or at one time present on the target body, and the classification, distribution, habits and behavior of life forms on that body.

There is a certain amount of cross-support in the relevance of these fields of interest. For instance, from the mass and mean radius (considered under Geodesy and Mapping) can be found density, which is of interest in determining composition. Chemical composition, in turn, is of interest to biologists. In assigning relevance to a Field of Interest or to a Task, its significance to other Fields of Interest should be considered.

3.1.1 Geodesy and Mapping. If a planet has observable satellites, the mass of the planet can best be determined by observation of the satellite orbit mean radius and the orbital period. Lacking satellites, the mass may be determined by its perturbation on the orbits of nearby planets, asteroids, and to a certain extent, comets.

The size of a planet (mean radius) is measured optically. From the size and mass can be calculated the mean density, which is of interest in postulating composition. In the case of Pluto, the optically observed radius and the dynamically-determined mass infer an incredible density, ten times that of the earth. An alternate possibility is that Pluto is a polished sphere--a huge ball bearing--whose real size is much greater than the observed disc of reflected light.

The shape of the planet has two aspects: the optically determined physical shape and the dynamically-measured geoid shape. If both measurements are precise and if the planet is homogeneous and in isostatic equilibrium (i.e., free to assume a spheroid of revolution), then they should agree.

The shape of the geoid (equipotential field) which serves as the reference model for mapping, may be determined by the perturbation of its satellites'orbits or, more accurately, gravimetric measurements.

The reduction of orbit perturbations to sea-level geoid definition involves a divergent series equation. For accurate sea-level geoid modeling, gravimetric measurements of 1° x 1° areas of planet surface are preferred. On the other hand, satellite orbits, especially those of artificial satellites, cover a larger area faster and can reach areas inaccessible to surface gravimetric measurements. Airborne gravimeters are some two orders of magnitude inferior to surface gravimeters. Orbit observations can be used to locate local gravity anomalies for more detailed surface measurement.

If the planet has a sharply defined limb and if it is close enough and large enough, an accurate optical measure of its flattening (ellipticality) can be made. If both optical and dynamic measurements are precise, and if the planet is in isostatic equilibrium (i.e., is free to assume the shape of a spheroid of revolution), then the two ellipticality measurements should agree. If they do not--as in the case of Mars--it indicates an unusual mass distribution ("froth" at the equator) or raises questions about the validity of the measurements.

The significance of geodesy and mapping then is to provide the basic information about mass, size, shape, and a reference math model for accurately locating features with respect to each other, from which implications can be drawn about composition, structure and (since retention of an atmosphere requires certain mass) the possibility of an atmosphere. These are among the first questions raised in the exploration of a planet, the satellites of the planets, asteroids, and comets.

3.1.1.1 Determination of the Mass of the Planet

Present knowledge of the mass of planet varies in accuracy due to the number of its satellites, the mass and distance of its nearest neighbors, and the accuracy of observation of the planet. A list of the planets in order of the error in knowledge of its mass is (based on References 18 and 19):

Poorly known:	Pluto*
	Mercury
Fairly well known:	Mars
	Uranus
	Neptune
	Venus
	Saturn
Well known:	Jupiter
	Earth

A knowledge of mass is important in order to calculate precise influence of the planetary mass on nearby trajectories--of spacecraft, or of comets and asteroids--and of orbital periods of artificial satellites. Combined with information on the size of the planet, mass determines density, which is of interest in determining the composition.

*Ehricke (Ref. 18) would reverse Pluto and Mercury.

3.1.1.2 Determine Mean Radius

In addition to the interest in the size of the body, the mean radius of a planet is also important in determining the density of the planet. Brouwer (Reference 19) would rank our present knowledge of planetary radius:

Poorly known:	Pluto
	Mercury
Fairly well known:	Venus
	Neptune
	Uranus
	Saturn
	Mars
Well known:	Jupiter
	Earth

Density of the planets is of special interest because of the marked difference in density between the group of inner planets (Mercury through Mars) and that of the outer planets (Jupiter through Neptune). That Mercury's density is nearly the same as the earth's is surprising because its much smaller size should mean less compressive force on the interior. Clearly, the composition of the planets varies greatly.

3.1.1.3 Determine Polar Axis and Rotation Rate

The rate of rotation, direction of rotation, and location of the polar axis is known to varying degrees of accuracy for the various planets. Venus, Jupiter, Saturn, Uranus and Neptune are known to have cloudy surfaces, making direct observation difficult. The visibility of Pluto's surface is unknown. Although Mercury has a solid visible surface, its rotation rate was only recently revised from 88 days to about 59 days. (Ref. 20) Brouwer of Yale Observatory (Reference 19) would give the ranking of error in knowledge of rotation rate and axis as:

Poorly known:	Pluto
	Venus
	Mercury
Fairly well known:	Neptune
	Uranus
	Saturn
	Jupiter
Well known:	Mars
	Earth

Knowledge of the harmonic coefficients of the planet's gravitational field would probably be ranked (Ref. 21 and 19):

Oblateness poorly defined:	Pluto Mercury
Approximation of oblateness:	Venus Neptune Uranus
Oblateness rather well known:	Saturn Jupiter Mars
Oblateness and higher order terms known:	Earth

The oblateness of Mars is of special interest because the visually-measured oblateness is much greater than the geodetic oblateness as shown by Mars satellite precessions. Taken at face value this means there is a very deep equatorial layer of low-density material (Ref. 22).

The geoid of the moon is also of interest. It has an irregular shape which suggests the moon is not in isostatic equilibrium--it either has great strength to maintain a non-plastic shape, or has great variations in density. Improvements in the precision of formulating the math model of the lunar geoid would aid in pinpointing the location of major anomalies and lead to a better understanding of the internal composition, age, and history of the moon (Ref. 22).

3.1.1.4 Determine Mathematical Model of the Geoid

The shape of the planet's gravity field is expressed analytically by the generalized spherical harmonic equation. As more and more accurate coefficients of the equation become known, the model will express:

a. The difference between the polar and equatorial radii of the geoid. This is of interest because it is the major gravitational perturbation of spacecraft trajectories once the mass of the planet is known, and because it is a clue to the mass distribution and whether the planet is plastic or under internal stress.

b. The difference between the north and south polar axes.

c. The ellipticity of the equatorial plane.

d. The location of major gravitational anomalies. . . and so on

b, c and d add to the accuracy of satellite orbit prediction and to an understanding of the stresses (hence, composition) of the planet's structure.

For the earth (a), (b), (c) and (d) are known well enough to be able to predict satellite position to some 50 m accuracy. Further refinements in the coefficients of the earth's geoid will permit more precise satellite prediction, improve geodetic survey accuracy, and contribute to the knowledge of the earth's interior. For instance, it has been theorized that regions of negative gravitational anomalies have lighter density material down to the earth's core, possibly caused by lighter warm material flowing upward. This theory has been enhanced by finding that negative anomalies are warmer and positive (dense) anomalies are cooler (Reference 23). As for satellite orbit prediction, even higher-order harmonics can contribute serious resonant effects to orbiting satellites (Reference 24).

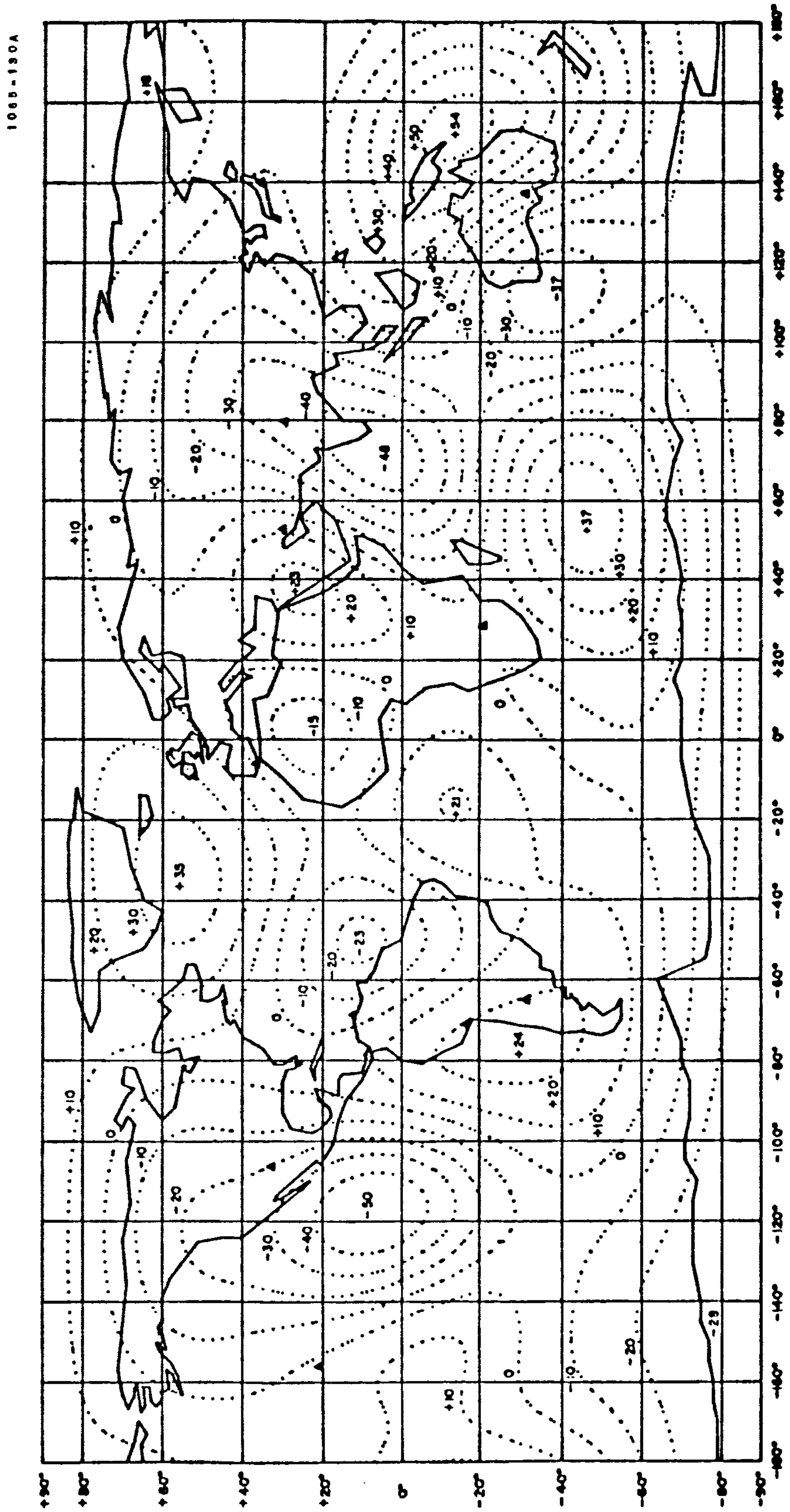


FIGURE 3-1. LEVEL CURVES OF GEOID HEIGHTS, AT 10-M INTERVALS (REF. 25)

3.1.1.5 Gross Photography of the Surface

The exploration of space is certain to bring surprises which from time to time redirect the emphasis of scientific inquiry. A basis for scientific study of any planet is the availability of high quality photographs of representative areas of the planet's surface. These give a preliminary gross indication of the degree of erosion, the surface roughness, characteristics, the consistency of variety of surface material, and the presence of craters, fissures and seas, and seasonal variations in frost and gross biological activity. Such gross photography is an aid in formulating scientific questions for additional study, and is often sufficiently detailed to be surprising, as were the Mariner IV photographs of Mars.

The front side of the moon has had the benefit of many years of detailed photography to a resolution of about 500 feet and Ranger photos of limited areas to resolution of about 20 feet. However, the only clue to the geography of the back side of the moon are Soviet photos of poor quality, but which clearly indicate a different surface. Hence, gross photography of good quality of the back side of the moon is of interest.

Mars has had poor quality telescopic photography of its entire surface, and good quality close-up photography of limited areas by Mariner IV which gave the somewhat surprising information that the surface is remarkably similar to the moon's. It has left unanswered a number of questions which call for more extensive photography.

Of the other planets, only Mercury and perhaps Pluto also have clear visibility for photography. Most of the satellites and asteroids have clearly visible surfaces. The rings of Saturn would also be of interest photographically.

These rings appear to be made up of a large quantity of small solid objects, each in nearly circular orbit about the planet and so precisely in the equatorial plane that the total thickness has not been determined but recent studies lead us to believe they are now no more than 20 centimeters thick (Ref. 25). A solid or liquid ring would be dynamically unstable. Furthermore, the gaps between rings are neatly accounted for by astrodynamics--material in space would eventually be attracted into the rings. The outer radius of the rings is within the Rocke limit at which point a satellite, according to the theorem, would disintegrate due to excessive field forces. It is not known whether the rings once were a satellite, or whether they are a portion of the nebulae from which the solar system was formed. Being within Saturn's Rocke limit, it is impossible for them to condense. Why the objects orbit in precisely the same plane is not clear.

3.1.1.6 Photographic Mapping with Geodetic Precision

Accurate maps can be prepared from aerial photographs with geodetic precision between relatively close points (50 miles). If ground control such as bench marks in a triangulation net is available, large area photographic mapping is possible. Precision aerial photography is extensively used for this purpose in the United States with resulting accuracy of locating prominent objects (trees, houses, towers) on large scale maps to about 50 feet (Ref. 26).

Although considerably inferior to aerial photography, photographic mapping of the moon, planets, largest asteroids, and major planet satellites by spacecraft is of interest as a preliminary to exploration, to select areas of special scientific interest, for clues to composition, biological development and distribution, and geological formations. The following targets have clear surfaces visible for photography: (Ref. 21)

Moon
Mars
Mercury
Pluto (?)
Most Planetary Satellites
Most Asteroids

3.1.1.7 Major Geodetic Datum Tie-In

There are 14 major geodetic datums on earth. Locations within these datums are known with respect to each other with accuracies in inches. Of these fourteen, there are three which cover the most important areas--North America, European, and Tokyo datums. The accuracy of tie-ins at present is 500 - 1000 feet. The worldwide system of reference control points to 30 feet accuracy, tied to the earth's center of mass, is now possible with satellite geodesy, permitting a 10X to 100X improvement in position mapping (Ref. 27).

There are no geodetic datum systems on the moon or planets as yet.

3.1.2 Composition. The composition of the surface and interior of the planets which have not had on-site investigation is highly conjectural, but highly relevant to the questions of extraterrestrial biology, possible utilization and origin and history. Conjectures are based on such information as knowledge of density, the presence or absence of a magnetic field, albedo, and variations in reflectivity, color, polarization, temperature, rate of change of temperature. More recently, radar sounding has contributed sketchy information about surface roughness and dust layer thickness.

The availability of this information falls off rapidly with distance of the target from the earth. And even for the case of the moon, most of the information is more useful for delineating discrete areas of the moon's surface by their characteristics than for determining actual chemical composition. However, a considerable amount of information about the atmosphere can be obtained by spectroscopy, especially high altitude balloon work. Although composition of the atmosphere is not included in this Field of Interest, it helps provide limited information on the composition of the planet. The appearance of hydrogen and gas and molecular carbon gas (Ref. 28) above craters on the moon has bearing on the volcanic interior.

Another dubious source of chemical analysis of the moon's surface is the possibility that tektites, or, less likely, stoney meteorites, are lunar surface material ejected by meteorite impacts (Ref. 29). This, however, is of little help in the study of the other bodies of the solar system.

The interest in composition will continue throughout the exploration of space, for not only is there known to be a great difference in composition (based on density estimates) between the comets and the planets, but also between the terrestrial planets and the major planets and even great difference between a planet and its satellites.

Here is an area where great advances in astronomy will be made by space flight--the composition of the solar system bodies as each is explored by on-site instrumentation. Only then will the geologic history of each planet and the origin of the planets, satellites and asteroids become clear.

3.1.2.1 Surface IR Mapping

Variations in surface temperature provide a clue to biological distribution and to internal physical processes such as convection currents. For instance, hundreds of "hot spots" on the moon's surface are being mapped by Boeing with differential temperatures as great as 85°F. This sort of mapping is also an aid to further direction of close-up scientific efforts.

The "clear" planets which permit direct IR mapping of the surface are Mercury, Mars, the moon and perhaps Pluto. Some IR mapping can be done with cloudy planets if the radiation originates below the atmosphere (as indicated by darkening of the limb).

Hundreds of "hot spots" have been located on the moon's surface. The craters Tycho and Kepler, for example, measure 86°F hotter at the center than at the periphery (Ref. 23, 30).

Study of these areas, correlation with geographic features, and correlation with the red spots and outgassing may shed light on the current activity of the moon and its interior.

3.1.2.2 Determine Gross Physical Characteristics

An early determination of the gross physical characteristics is of importance in preliminary reconnaissance to select local areas of scientific interest and to provide information on the origin and history of the target. These characteristics include the size and frequency of occurence of mountains, craters, rills, faults, crevices, rocks and small particles and granules, the surface layers, etc. The larger features of the moon have been studied (Figure 3 - 2) and very limited close-up photography of the moon and Mars has been made, nearly all in the "megasurface" dimension.

Many observed features, such as the "methodical" pattern of rills in the vicinity of Triesnecker (Figure 3 - 3) are interesting areas for close-up surface and subsurface investigation.

Both the moon and Mars are of special interest: Mars because of the observed variations in albedo and the close-up evidence of light and dark areas in the Mariner IV photographs (Ref. 31). The moon because of the difference in back side and front side features observed in Soviet lunar probe photos.

No satisfactory explanation has been given for this contrast in lunar composition and further information is highly desired.

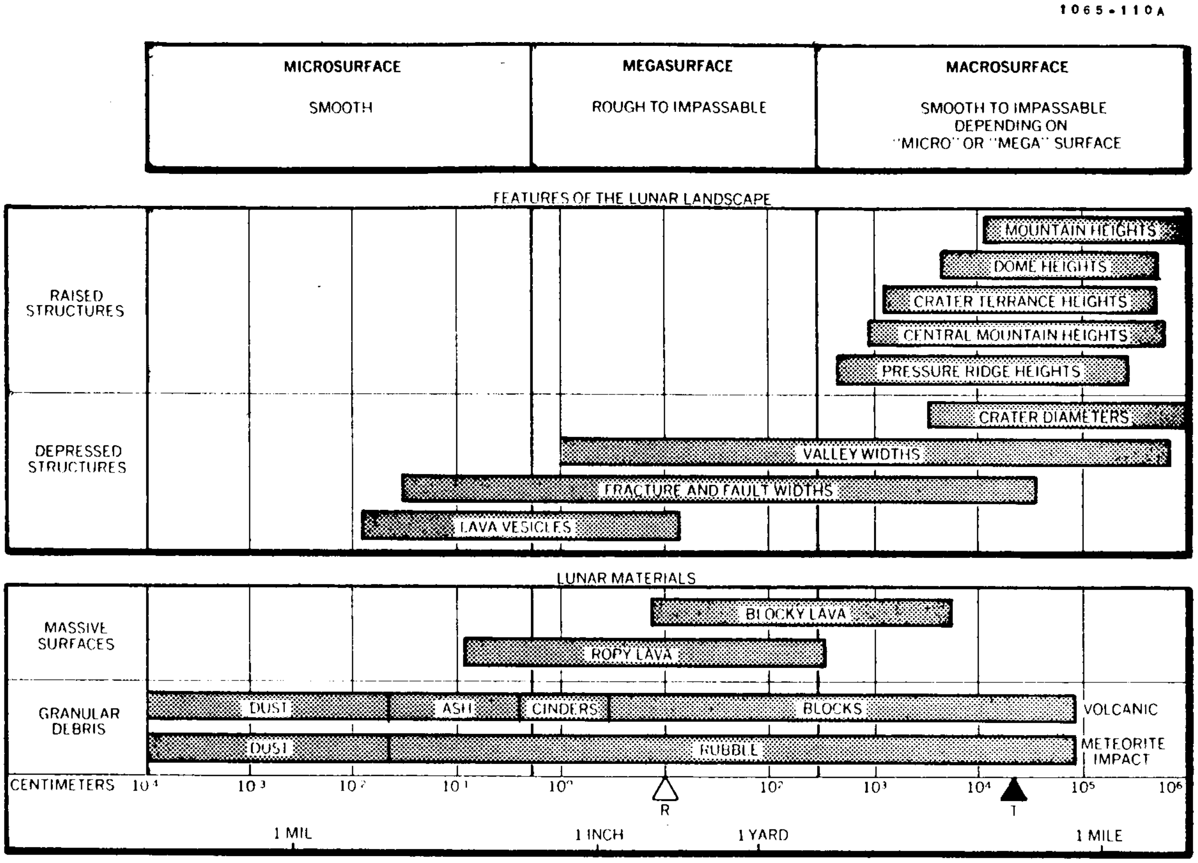


FIGURE 3 - 2 . NAVIGABILITY OF THE MOON'S SURFACE in terms of a bicycle wheel, as seen by Jack Green of North American Aviation. Triangle T on the abscissa shows limit of telescopic resolution; triangle R the shortest wavelength used yet in radar studies. Greater resolution, such as would be provided by successful Ranger missions, will be needed before operational boundaries between "smooth" and "rough to impassable" areas can be defined. (Ref. 28)

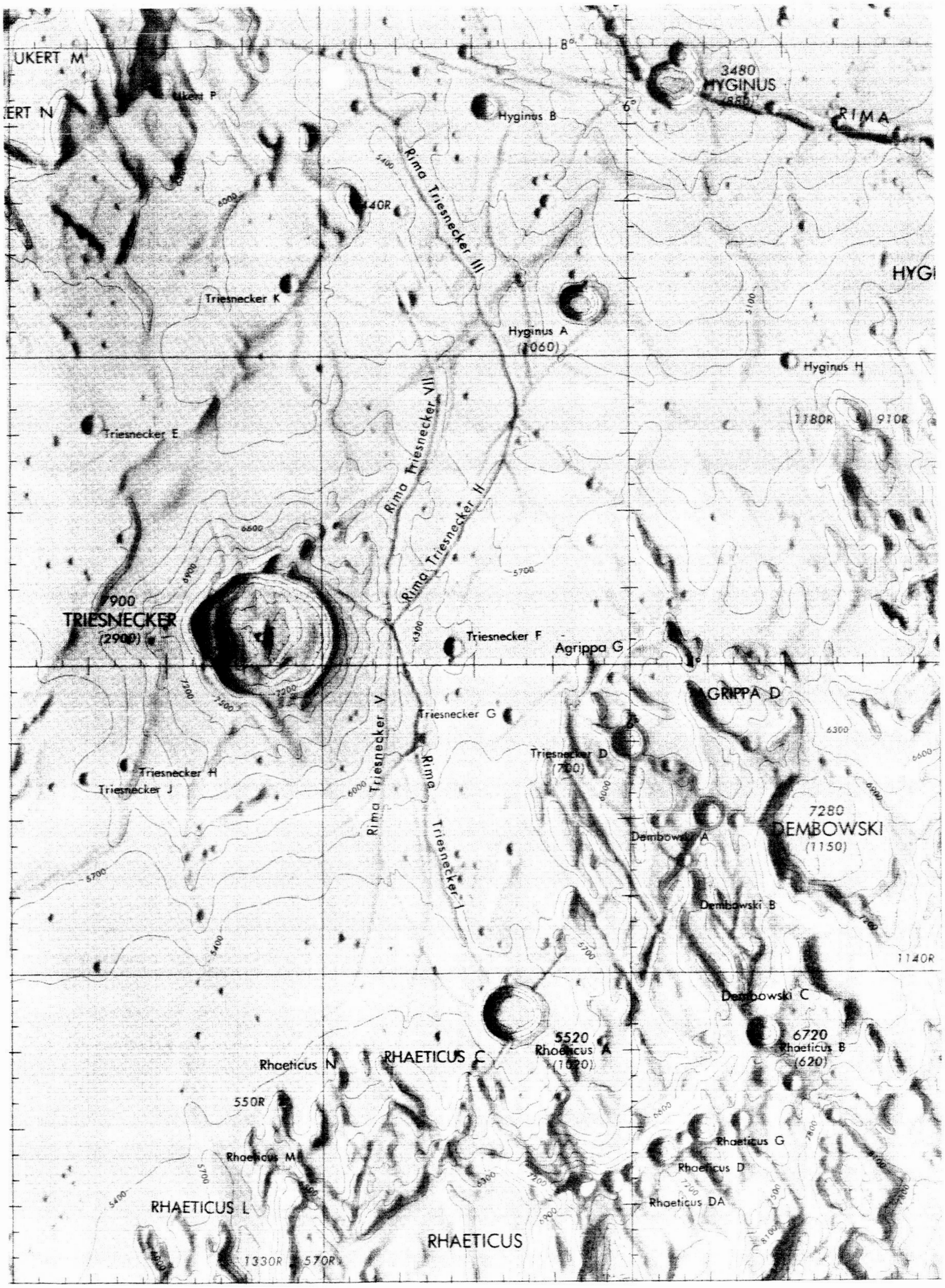


FIGURE 3-3. MAP OF MOON AROUND TRIESNECKER
(USAF Aero Chart & Information Center)

3.1.2.3 Determine Gross Chemical Composition

The single most meaningful question about any planet may be "what is it made of?" The answer sheds light on the origin and history, biochemistry, and possible utilization. It is desired to know whether surface material is meteoritic or volcanic, what elements are present and in what proportion, and whether water exists in molecular combinations. This task does not include the search for free water or ice. Of particular interest is the presence of water molecules because of its implications in biology and utilization. Also of high interest to biologists are the presence of the organic-forming elements--carbon, hydrogen, oxygen and nitrogen, and the basic compounds methane and ammonia. The abundance of various isotopes would help determine the age of the body.

The moon and Mars are of especial interest because of the possibility of utilization and biological prospects. The major planets are of interest because they are less dense than the terrestrial planets, clearly implying a fundamental difference in composition. Saturn is the least dense of any planet or satellite in the entire solar system. Pluto is of great interest because the observed size and the dynamically-measured mass imply a fantastically high density ten times that of the earth. Of the planetary satellites, Jupiter's inner satellites (V, I, II, III, IV) are denser than Jupiter and two (I, II) are denser than the moon. No information is available on their composition.

3.1.2.4 Determine Whether Bodies of Water or Ice Exist

This task is of great interest because of its implications in biology, in erosion processes, and utilization. Interest centers around the moon and Mars because of the possibilities of subsurface water (Ref. 32), and Venus because of the known presence of ice in the atmosphere (Ref. 33).

The search for water in the atmosphere or in molecular combination in materials is not included in this task.

3.1.2.5 Map the Distribution of Materials of Interest

After gross chemical composition has been determined at several sites, it will probably be desirable to map the distribution of any materials of interest over large areas and eventually over the entire planetary surface. Geological maps of the moon are already being prepared by the U. S. Geological Survey (Ref. 28) but the information will be scant until extensive surface exploration is underway.

3.1.2.6 Determine Interior Structure

It is of interest to know what structural layers exist in the interior, whether a liquid core exists, whether the core is iron, and whether there is a distinction between the crust and mantle. It is generally believed that the presence of a magnetosphere indicates a liquid metallic core (and a rotating planet). Hence the earth and Jupiter are thought to have such cores. Mars, Venus and the moon do not have measurable magnetospheres but in the case of Venus this may be due to low rotation rate. Geodesy provides information indirectly to assist in postulating the interior, and IR mapping can help locate convection near the surface. But the most direct evidence for the location of structural layers is provided by seismology.

3.1.2.7 Study of Lunar Outgassing

Both molecular carbon and molecular hydrogen have been observed several times by several workers (Ref. 23, 34, 28) in recent years, and suggested earlier, in the form of gas emission from the central peaks of the crater Alphonsis (for C_2) and Aristarchus (for H_2) lasting an hour or so. This phenomenon may indicate either volcanic activity or, as Urey suggests, the action of water on calcium carbide beneath the surface may release acetylene (C_2H_2) which is broken down by intense solar radiation upon reaching the surface. In any event, the activities were quite large to have resulted in clouds visible from the earth. Confirmation of this phenomena and a study of its sources have implications in determining the state of volcanic activity of the moon, its subsurface composition, and perhaps the presence of large amounts of water. It may also prove to be a useable source of heat and pressure.

3.1.2.8 Study of Lunar Red Spots

In 1963 several observers at the Lowell Observatory noticed reddish orange, glowing ruby red, and streaked and diffused pink areas in the general region surrounding Aristarchus and the nearby Herodetus craters (Ref. 23, 28). Although of similar short duration to the outgassings, these seem to be a different phenomenon--an area discoloration rather than a gas cloud, and located on hilltops and rims rather than crater peaks.

In situ, or closeup investigation of this phenomenon may correlate it to the outgassing or may indicate an entirely different source. In either event, since it represents a dynamic activity, it is of considerable interest.

3.1.2.9 Study of Surface Erosion Processes

Variations in atmosphere, distance from the sun and asteroid belt, and surface composition can greatly affect the erosion of surface materials. A study of the erosion processes of the moon and each planet--the degree to which wind, water, radical temperature changes, outgassing into vacuum, meteorite impact, electrostatic charge, and solar and cosmic radiation may cause erosion--is of interest both from the practical standpoint of durability of men and materials and from the scientific interpretation of the surface geological records. These erosion processes may be greater or less than the earth's, but they will be different.

This is of special interest for the moon, where it is hoped to find the surface in its primordial state, a record of the "beginning" of the history of that body.

3.1.3 Atmosphere and Ionosphere

An atmosphere is the gaseous envelope of a solid or liquid body. When the temperature of the body is such that the matter near its "surface" is highly ionized, the definition is less clear because of the absence of an abrupt phase change. Thus, the distinction between the "body" and the "atmosphere" of the sun is less clear than for the planets, etc. The atmosphere of a body includes all of the various subdivisions such as troposphere, stratosphere, chemosphere, and ionosphere which are descriptive terms used to characterize regions according to various physical properties.

Figure 3-4 shows the various physical criteria for stratifying the earth's atmosphere, and planetary atmospheres in general. COSPAR and other space science organizations recognize three altitude regions:

30 - 100 km
100 - 200 km
Above 200 km

The outer boundary of an atmosphere is usually regarded as the region where the density of the gas associated with the parent body is the same as that of the surrounding region.

Solid or liquid material more or less permanently suspended in the gaseous envelope is considered to be part of an atmosphere. Again, an area of vagueness arises when one considers such phenomena as precipitation and temporary dust. For the purpose of this work, they are included.

The object of studying atmospheres is to obtain a physical description thereof. This includes the composition, density, temperature and the variation of these elements with time and location. The elaboration of tasks consists in choosing the specific features to be investigated.

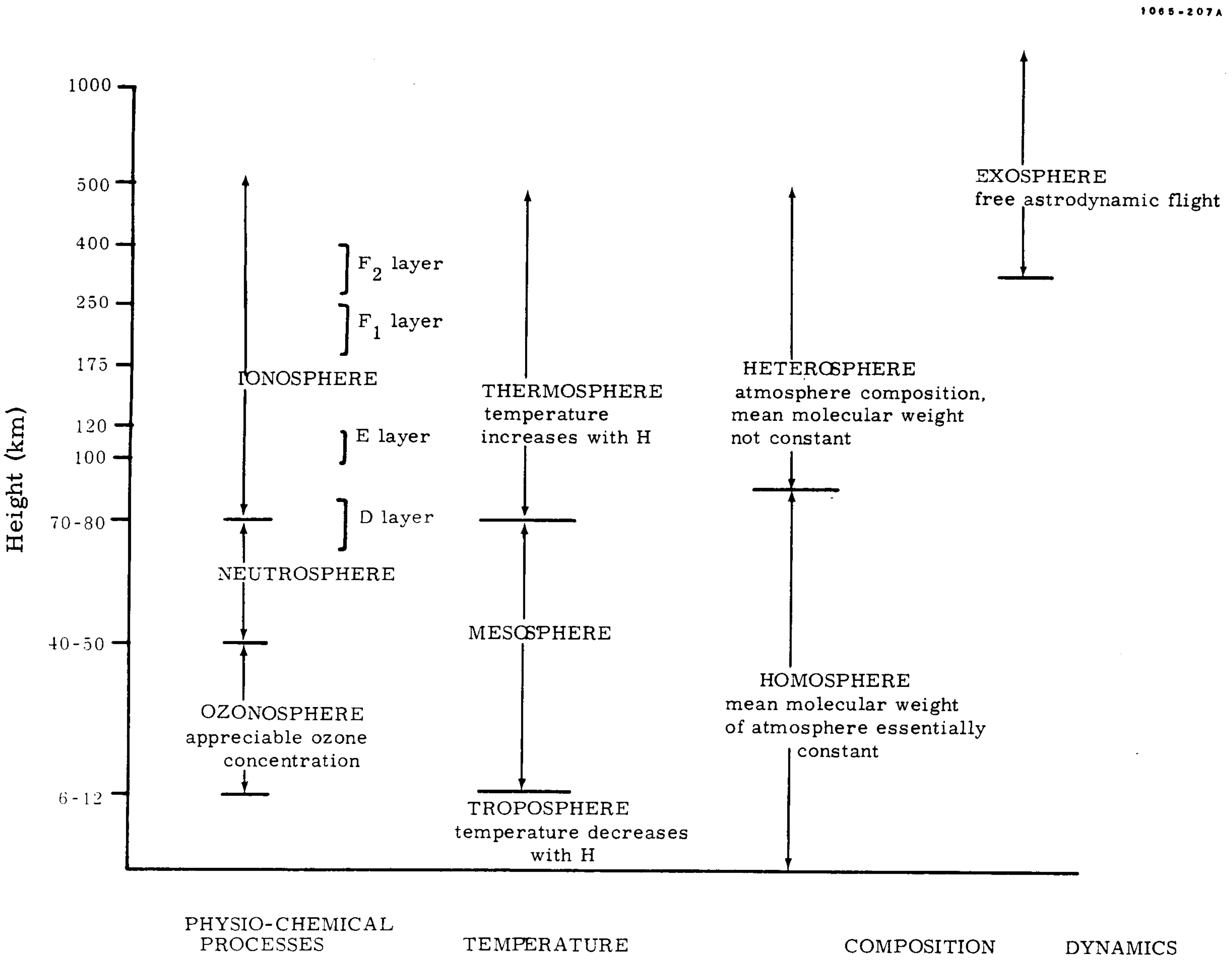


FIGURE 3-4. CRITERIA FOR STRATIFYING THE ATMOSPHERE

There are several reasons for the importance of atmospheric studies. In the first place, there is the practical one of understanding a prospective environment so that one is better able to cope with it. In the case of earth, there is almost instinctive concern with weather. Related considerations apply to other planets when one considers placing instruments or people on them.

The behavior of planetary atmospheres depends upon the interaction of numerous factors, principally radiation from the sun and from the parent body, the gravitational attraction and rotation of the parent body, and phase changes of components of the atmosphere itself. Thus we see that atmospheres are an intrinsically interesting physical system. An understanding of atmospheres tends to satisfy intellectual curiosity in the same manner as any scientific understanding.

Finally, the present state of planetary atmospheres gives clues as to the origin and metamorphoses of the parent bodies, the evolution of the solar system and hence general cosmology.

An atmosphere such as earth's is so complex that at the present time its study involves a large proportion of description. Perhaps the availability of descriptions of the atmospheres of planets which differ from earth in gravity, radiation, rate of rotation, and composition will suggest approaches to deciding what factors are dominant in the earth's atmosphere.

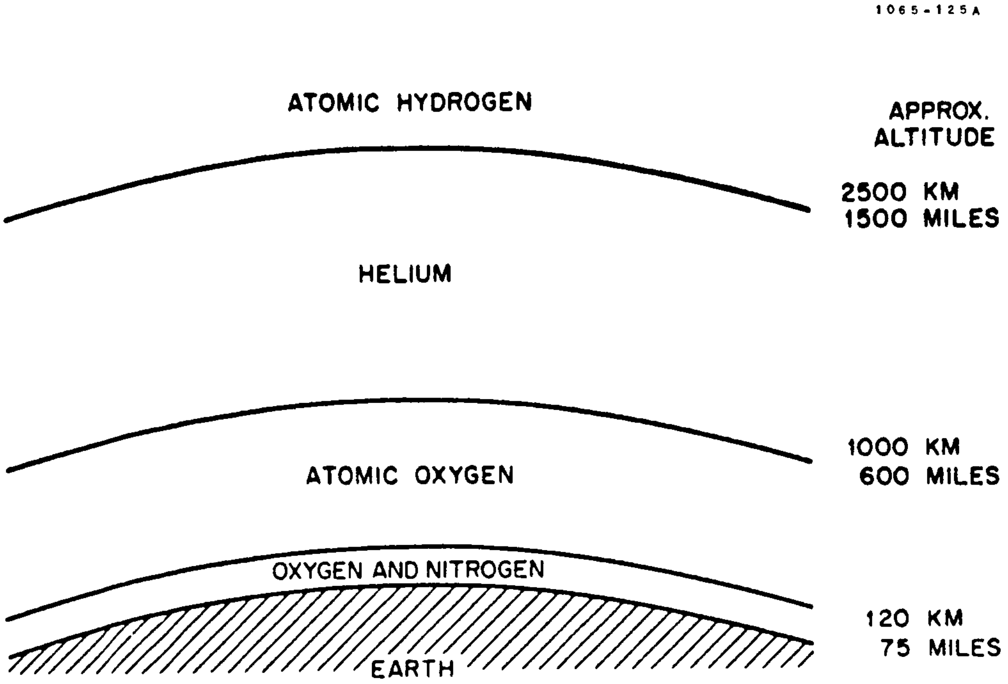


FIGURE 3-5. CHIEF COMPONENTS OF THE ATMOSPHERE (after R. Jastrow)

3.1.3.1 Determine composition of atmosphere

A description of the composition of an atmosphere consists of describing the quantity or number of various molecular species contained per unit area of the atmosphere. This includes, as the ionosphere, the various charged particles. The composition is relevant to the history of the parent body as well as to the environment to be encountered by man or instruments during prospective exploration.

There is considerable uncertainty about the composition of the atmospheres of Venus, Mars and Jupiter, all of which are known to have atmospheres. Much of this uncertainty arises because a great deal of the information available has been obtained by earth based spectroscopic observation of the radiation from the planetary atmospheres. The state of knowledge could be considerably enhanced by making such observations from outside earth's atmosphere, e.g., from the surface of the moon.

It is possible to make relevant statements about the possible composition of the atmospheres of a body under investigation by considering the factors which govern the containment of particles by its gravitational field. Consider a particle of atomic weight A, in an atmosphere at temperature T, at a distance R from a body of mass M. If such particles have a Maxwellian velocity distribution the probability, P, that a particular particle in this situation will possess sufficient speed to escape from the planet is given by

$$\log P \approx - 3 \times 10^{-15} \frac{MA}{RT}$$

where M, R and T are measured, respectively in kgm, meters and degrees Kelvin. Unless P is very small near the top of an atmosphere the component in question will be lost from the planet. It is thus of interest to consider the ratio M/R for various bodies. A large value of this ratio favors containment, a small value loss.

The composition of an atmosphere can best be determined by the analysis of actual sample. This has already been done for earth but studies of the variation with time and altitude continue to be interesting (see 3.1.3.2).

3.1.3.2 Determine the variation with altitude of pressure and composition

This task is relevant to a general description of any atmosphere. It is equally informative to determine number density and composition or mass per unit volume and composition because there is a physical relationship among these factors. Present knowledge of this variation contains a large element of speculation in the case of planetary atmospheres. Some data are available from observing rare occultations of stars by planets. Particular attention should be paid to the occurrence of future opportunities to make this sort of observation from outside earth's atmosphere.

The gross features of the atmosphere such as we envisage in connection with this task are particularly important when designing vehicles to penetrate a planetary atmosphere because the difficulty of such entry can be considerably reduced by optimizing approach trajectories and by such devices as parachutes, wings, etc., if adequate information is available.

For the earth, the density of the atmosphere in the 100 - 200 km region is poorly known.

A great deal of information is available about earth's atmosphere but much remains to be learned about the interaction between the troposphere and the higher regions.

The nature of the ionosphere of a planet sets some limitations on the communication techniques which may be used. The principal factor here is the density of electrons because this limits the frequencies which can be used to penetrate to earth or to a satellite orbiting the planet. An ionosphere would also be expected to contribute electromagnetic noise which might be a problem. It should be relatively straightforward to obtain important information concerning the distribution of free charges by sounding from a spacecraft orbiting the planet. Knowledge of this sort would then be helpful in interpreting other observations such as earth-based temperature measurements based on the emission of radiation at various wavelengths.

3.1.3.3 Determine Temperature Profile of Atmosphere

The lapse rate of any quantity is defined as the rate of decrease with altitude of that quantity, e.g., the lapse rate of the temperature, T, is $-\frac{\partial T}{\partial z}$ where z is altitude. The lapse rate depends upon altitude except for the special case in which the quantity in question decreases linearly. From the point of view of developing a general picture of an atmosphere it is particularly important to know where the thermal lapse rate changes abruptly or where its sign changes because such changes frequently separate regions in which different mechanisms are of dominant importance, e.g., the tropopause in earth's atmosphere.

From the point of view of weather phenomena, a crucial question is whether the thermal lapse rate is more or less than the adiabatic lapse rate. In cases where the atmosphere contains a component that may undergo phase changes under the prevailing conditions and which has appreciable latent heat, two adiabatic lapse rates, the "wet" and the "dry", are relevant. In case the lapse rate exceeds the adiabatic, convective instability is present and vertical mixing is to be expected. This provides an effective mechanism for transport of material and energy vertically.

The mixing which occurs in a region of instability in an atmosphere has an important bearing on the vertical variation of pressure and composition.

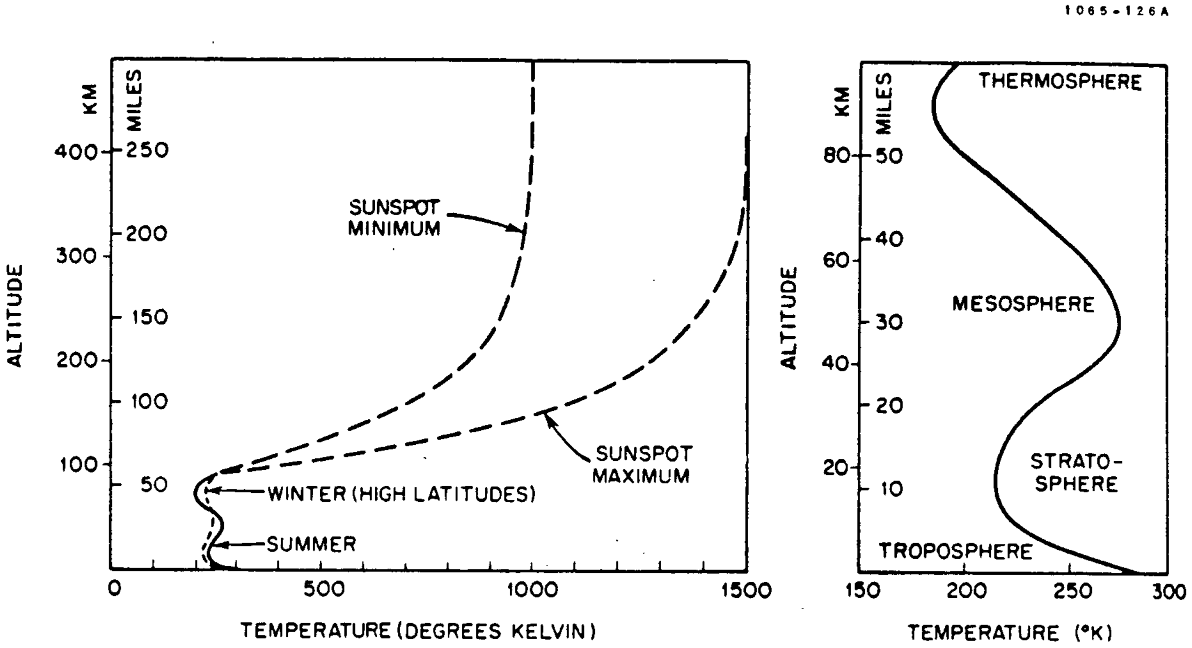


FIGURE 3-6. TEMPERATURE OF ATMOSPHERE AT DIFFERENT ALTITUDES (after F.S. Johnson)

The temperatures in the lower atmosphere are shown at the right.

3.1.3.4 Determine motion of the atmosphere on diurnal and seasonal time scales

Observe the variation of such elements as temperature, phase changes, winds, and stability with latitude and on diurnal and seasonal time scales as the amount of radiation put into the atmosphere fluctuates. These variations are important for planets such as Venus, Mars and Jupiter which have atmospheres that might interfere with instruments. The variations are also important because of the insight they give into the mechanisms responsible for the response of atmospheres to changing radiant input.

The magnitude of seasonal modulation of an atmosphere depends upon two factors: (1) The inclination of the axis of rotation to the planet's orbital plane and (2) the eccentricity, e, of the planet's orbit. The first factor determines the fluctuation in the amount of radiation received by the northern and the southern hemispheres. The second determines the fluctuation in the total radiation received by the planet. The ratio of energy received at perigee and apogee is $\left(\frac{1 + e}{1 - e}\right)^2 \approx 1 + 4e$.

In the case of earth, the inclination of the axis is more important but by no means dominant. In the case of Jupiter, the eccentricity is dominant, suggesting wide seasonal variations.

The circulation of an atmosphere provides a mechanism for transporting material and energy from one region of the surface to another. This transport is particularly interesting when the flow is turbulent.

Very little is known about the circulation of planetary atmospheres except that of earth. Such phenomena as the migration of the Martian polar cap may be understood in terms of such motions. One theory invoked to explain the high temperature of the Venetian atmosphere is that violent winds dissipate kinetic energy via friction between dust particles and a solid surface (the Aeolean model).

The general features of atmospheric motions could be studied by orbiting spacecraft such as Tiros when clouds are an important factor. Other techniques such as observing doppler shifts in emitted radiation would also be useful.

Information could also be obtained by radar techniques at various frequencies. Finally, telemetering instruments might be placed in the atmosphere itself.

3.1.3.5 Determine atmospheric trends with the solar cycle.

The magnitude of solar activity has a period of eleven years. Thus only sketchy preliminary data can be accumulated on this phenomenon during the time period to 1985 for any target except earth. The effects of the variation in solar activity are probably manifest principally as changes in the intensity of x-rays and high energy particles. These factors operate mainly on the outer layers of atmospheres unless the atmosphere is so tenuous that the radiation penetrates through an appreciable fraction of the atmosphere. In the most interesting cases of Venus, Earth, Mars and Jupiter, this suggests that the main effect would be in the ionosphere.

It is believed that such changes in the earth's atmosphere influence the weather at the surface. This point requires further study and it is suggested that the elucidation of interaction between the solar cycle and weather on earth is the most important part of this task.

3.1.3.6 Determine the location, composition, and temporal variation of the ionosphere.

This task is really included in the more general tasks described in 3.1.3.1 to 3.1.3.5 above. It is listed separately because of the qualitative difference between charged and uncharged particles.

The task is important because of the bearing which the electrical conductivity of the atmosphere has on communication problems between points on the surface of the planet and between the surface and points outside the atmosphere. In addition to the influences which free charge carriers and other species present in the ionosphere have on electrical conductivity, they are important because of their absorption of short wavelength radiation and the unusual thermal transport properties. It is thus probable that, although the mechanisms are currently obscure, the ionosphere plays an important role in the energy budget of the lower un-ionized portion of the atmosphere.

This problem is so complex that it would seem wise to continue to devote most of the effort assigned to ionospheric studies to earth and to limit planetary studies to rather qualitative, descriptive work. Hopefully the insight gained from a detailed earth program and qualitative planetary programs can cross-fertilize each other.

3.1.3.7 Determine the composition and density of satellite atmospheres

Since the masses of the satellites and asteroids are at most of the same order as that of the moon, and generally quite smaller, they probably do not retain extensive atmospheres. Any component will necessarily have a relatively high molecular weight. Therefore, it is suggested that attention be directed only to determining whether or not these bodies have an atmosphere and if so, approximately how much of which principal constituent. This information would be interesting mainly for possible bearing on the origin of the solar system. Titan (Saturn) is the only satellite known to have an atmosphere, but Ganymede and Callisto (Jupiter) are quite likely to have atmospheres.

3.1.4 Magnetosphere and Radiation Belts

The term magnetosphere refers to the volume of space surrounding a planet which contains its magnetic field. The magnetosphere is limited at least for planets of the inner solar system by the interplanetary magnetic field and plasma. Plasma is continually streaming from the sun as a result of coronal expansion (the solar wind) and carries solar magnetic fields with it to form the interplanetary medium. The shape of the magnetosphere of a planet therefore is dependent on its own magnetic field strength and configuration as well as its interaction with the solar wind (or possibly an interstellar wind).

In 1958, the Van Allen trapped radiation surrounding the earth was discovered. This radiation is in large part confined by the magnetic field of the earth. Where the earth's field maintains its dipole-like nature, the radiation drifts around the earth and bounces between hemispheres. However, in those regions where the magnetic field of the earth is highly distorted, radiation is still present but its dynamics are not well understood at the present time. Mapping of the radiation belts has given a great deal of information about the configuration of the magnetic field of the earth and vice versa. The origin of the earth's trapped radiation is not fully understood except that the sun is its ultimate energy source. The solar wind transports energy and plasma particles to the earth where a local acceleration mechanism apparently operates. The interaction of the solar wind with the earth's magnetosphere is undoubtedly responsible for other geophysical phenomena such as magnetic storms, ionospheric disturbances and aurorae.

Corpuscular measurements made in the vicinity of planets would be useful in the mapping of planetary magnetic fields. Knowledge of the strength of a planet's field and measurements of its trapped radiation would give information about the propagation of the solar wind through interplanetary space by observing its influence on the planetary magnetosphere. Confirmation of trapped radiation about Jupiter could explain its strong radio properties.

It is believed that a planetary magnetic field is caused by the rotation of a planet having a molten metallic core, and that radiation belts are interplanetary particles trapped by a planet's magnetic field.

Hence, a slowly rotating planet would have no magnetic field; the absence of a magnetic field from a rapidly rotating planet signifies a non-metallic or solid core, and the absence of a radiation belt indicates the absence of a magnetic field, and the size (or energy) of a radiation belt is a function of the strength of the magnetic field and of the planet's distance from the sun. Further, radio emission from a planet in non-thermal frequencies which could be caused by charged particle emission strongly suggests the presence of a magnetic field. We presently know only that

- the earth has a magnetic field and radiation belt
- the moon, Mars, and Venus have no measureable magnetosphere and no radiation belt
- Jupiter emits radio frequencies which suggest a radiation belt and hence a magnetosphere
- Mercury rotates too slowly to have a magnetosphere

3.1.4.1 Determine Gross Strength and Orientation of Magnetosphere.

The existence of planetary magnetospheres other than that of the Earth has been postulated. Jupiter's magnetosphere has been reasonably ascertained in recent years. The detection technique -- to date -- has been radio observations in the wavelength range from millimetric to decametric. Thus far, only Mercury, Venus, Earth, Moon, Mars, Jupiter, and Saturn have been observed by radio.

All the above mentioned planets emit thermal and non-thermal radiation. The shorter waves representing, in general, thermal radiation and ranging from millimetric to decimetric wave lengths are ascribed generally to a planet's surface or atmospheric temperatures. When in the case of Jupiter the centimetric and decimetric radio wave measurements gave inconsistent brightness temperatures -- ranging from 150°K to 50000°K -- these radio waves have been assumed to have been generated by cyclotron or synchrotron radiation resulting from the interaction of Jovian belt electrons with the planet's strong magnetic fields. The hypothesis seems confirmed, and provides an indication of the existence of if not a measure of the planet's field.

Polarization studies of radio waves also offer clues to origin of waves. For the case of the longer wave radiation of Jupiter -- decimetric to decametric -- the source of the waves is still uncertain, but is again assumed connected with the Jovian radiation belts. In general, however, the non-thermal emission permits studies of origin, time variations, precipitation or acceleration of trapped charged particles from radiation belts located within planetary magnetospheres, and may even give indication of field strengths and eccentricities of dipolar fields. The mechanisms of suggested types of radiation which bear a relationship to planetary magnetic fields are cyclotron, synchrotron, and Cerenkov.

3.1.4.2 Map Magnetospheric Fields.

The geomagnetic field is confined within the magnetosphere, shaped perhaps like an elongated cavity in the solar wind. Satellite measurements now give a broad outline of the magnetosphere, but the complex interactions between charged particles and magnetic fields within the magnetosphere have made model representations difficult. The size and shape of the magnetospheric tail and the location of neutral points is still not altogether predicted. The mechanisms generating the shock front outside the magnetopause still requires elucidation.

Oscillations of the magnetopause seem to result in the formation of magnetohydrodynamic waves which are detected as sudden impulses on board satellites or on ground stations. Other long period magnetohydrodynamic waves generated in the magnetosphere have been observed, and their influence on charged particles trapped in the radiation belts is not clearly defined. Study of particle acceleration mechanisms requires observation of particles of a wider range of energies and of waves of a broader range of frequencies than so far undertaken. This is a fundamental problem requiring investigation.

Another unexplained phenomenon is the relation of the morphology of observed magnetic storms with ring current or currents whose existence is hypothesized. Monitoring of particle spectral flux, together with field measurements at various altitudes is desired. Also, closely related to storms, the relationship of auroral phenomena with electromagnetic fields and charged particle fluxes in the exosphere require investigation. More experiments for improved mapping, and further analysis will contribute toward more accurate models of the magnetosphere and better understanding of large-scale interactions of fields and plasmas.

Satellite probes have shown no measurable magnetic field for the Moon, Mars, and Venus. Due to its slow rotation, none is expected (based on theory) for Mercury, Saturn is likely to have a strong magnetic field.

3.1.4.4 Map Surface Magnetic Fields.

Large scale magnetic surveys of surface fields of planets and satellites will not probably be within the capabilities of technology within the next two decades, except perhaps for the Moon. However, the possibility of establishing a few magnetic field monitoring stations on some planets and satellites is not remote. The Moon, Venus, Mars, Jupiter, Saturn, and some satellites are potential candidates.

For planets having appreciable magnetic fields, the measurement of surface fields is of interest in more accurately defining the field, since it establishes "initial conditions" on terminal points for the lines of force.

For planets not having an appreciable magnetic field, surface mapping is of interest to define magnetic anomalies in the planets composition.

3.1.4.5 Determine Gross Shape and Constituent Characteristics of Radiation Belts.

The gross shape of radiation regions around a planet is due to the configuration of the magnetic field of the planet and the interaction of the solar wind with this field. A planet with a magnetic field will create a cavity in the solar plasma stream. Within the cavity it is quite likely that corpuscular radiation will exist which probably receives its energy from the solar plasma. For the earth's case, space probes have failed to observe particles of sufficient energy and intensity in transit from the sun in interplanetary space to populate the Van Allen radiation. Therefore, it is believed that the particles are locally accelerated in the vicinity of the earth. The mechanism of energy transfer from the solar plasma to accomplish this local acceleration process is unknown but knowledge of the constituents of the radiation belts would be very useful information.

The cavity shape depends on the planet's magnetic field orientation and the relative energy densities of the field and the solar plasma. Information about the planet's field would be obtained by measuring the gross shape of its radiation belts. The radiation around the earth has been pretty well measured with the exception of that in the tail of the magnetosphere or cavity in the anti-solar direction. It has been speculated that radiation in this region is undergoing acceleration as it convects back to the earth along a neutral (zero magnetic field) sheath in the cavity.

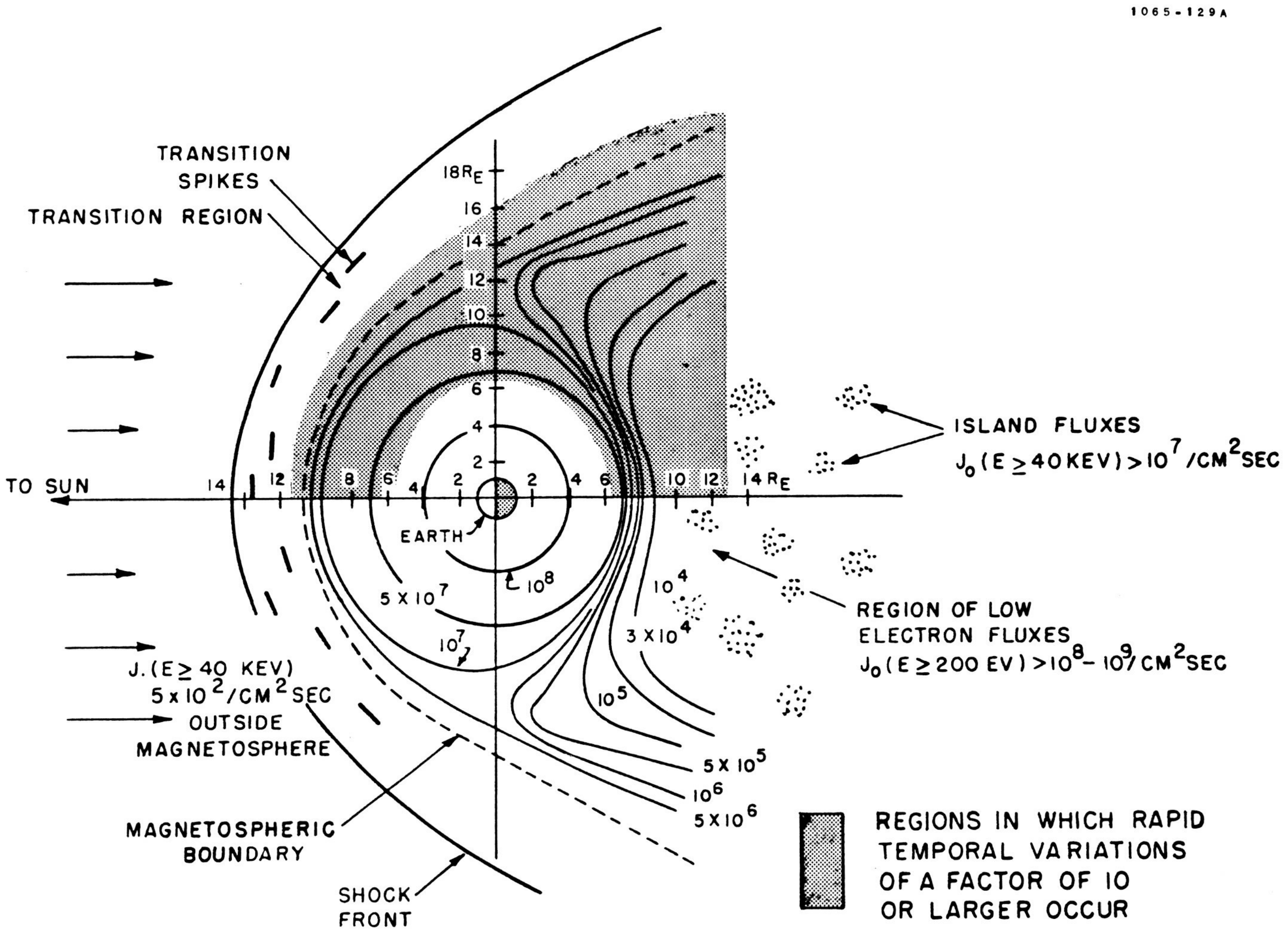
Geiger counters with a threshold of 40 kev for electrons and a plasma probe aboard the Mariner II spacecraft as it passed within 22,000 miles of the planet Venus measured no excess radiation over that observed in interplanetary space. The magnetic field of Venus, if any, must have a strength less than 10% of the earth's. Recent data from the Mariner IV probe to Mars likewise indicates that this planet has little, if any, trapped radiation. Mercury, having a rotational period of about 88 days, probably does not possess a magnetic field, consequently, no radiation belts. Saturn, on the other hand, rotating with a period of about ten hours might possess a field. However, the intensity of its radiation would be very small because there may be limited particle acceleration (or injection) due to its large distance from the sun.

The radio emission of Jupiter is evidence for its possessing radiation belts. Radio energy at the decimeter wavelengths could be generated via synchrotron emission from trapped radiation. The long wavelength waves from Jupiter suggest that its magnetic field is arranged around the planet in an eccentric way. Solar particles easily weaken the magnetic field and precipitate trapped particles which normally mirror close to the atmosphere down into the atmosphere where they produce Cerenkov radiation.

3.1.4.6 Map Radiation Belts

By mapping the radiation belts it is meant that variations in each component as a function of sun-earth-probe angle and radial distance from the planet are studied. In mapping the earth's corpuscular radiation it is found that it occupies a region of space (the magnetosphere) shaped somewhat like a teardrop with a tremendously elongated tail. Within the magnetosphere there is in general two types of radiation. First, that which is trapped in a fairly regular magnetic field and drifts around the earth. This radiation is located approximately between 2 and 8 earth radii. It contains the higher energy particles and is relatively stable. The second type is radiation confined by the highly distorted earth's field but not trapped in the sense of conservation of the adiabatic invariants. This is radiation predominantly in the distant dawn and evening sides of the magnetosphere and in the tail beyond about ten earth radii. Much more extensive mapping of these regions for the different types of particles and particularly at low energies is needed before an understanding of the origin of the earth's radiation belts and their association with other geophysical phenomena can be obtained.

In the case of the earth, there is also corpuscular radiation in a shock front produced on the sunward side of the earth by the solar wind and in the region between this front and the boundary of the cavity (the transition region). Preliminary measurements of these particles indicates that acceleration might be occurring here. (Figure 3-7)



(PEAK PROTON FLUXES EXIST AT RANGES~3R_E $J_0(120\,KEV < E < 4.5\,MEV) \sim 10^8/CM^2SEC\,SR$)

FIGURE 3-7. QUASI-STATIONARY CONTOURS CONSTANT OMNIDIRECTIONAL FLUX ELECTRONS ($E \geq 40$ KEV) IN THE MAGNETIC EQUATORIAL PLANE AS MEASURED WITH EXPLORERS XII AND XIV

3.1.4.8 Determine the Interface Between the Magnetosphere and the Solar Wind.

The boundary of the magnetosphere is the region of injection of solar plasma energy into the trapping region. The nature of this boundary or interface provides information about the magnetic field of the planet. Dynamical processes occurring in the corpuscular radiation in this region have been observed in the case of the earth. Spikes or "islands" of radiation have been measured and suggest that these are particles that have been accelerated in the shock front or transition region. Alternatively, it has been suggested that these islands of radiation represent particles that break away from the Van Allen belts and represent a loss to the trapped radiation.

It is probably not possible for radiation to readily penetrate into the sub-solar magnetosphere from outside unless access was by way of a neutral point or as a result of a large perturbation of the earth's field at the boundary. A neutral point would be established as a result of cancellation of the earth's field by the interplanetary field. Diffusion of energetic particles across the boundary is possible, however, a large supply of particles outside the boundary would have to prevail to provide an adequate source. Such an intensity outside the magnetosphere has not yet been observed.

The flow of plasma around the earth cavity or magnetosphere and its possible acceleration in doing so and convection into the tail has been postulated as a means of populating the trapping region. At the present time, a great deal more data about the magnetospheric boundary is needed.

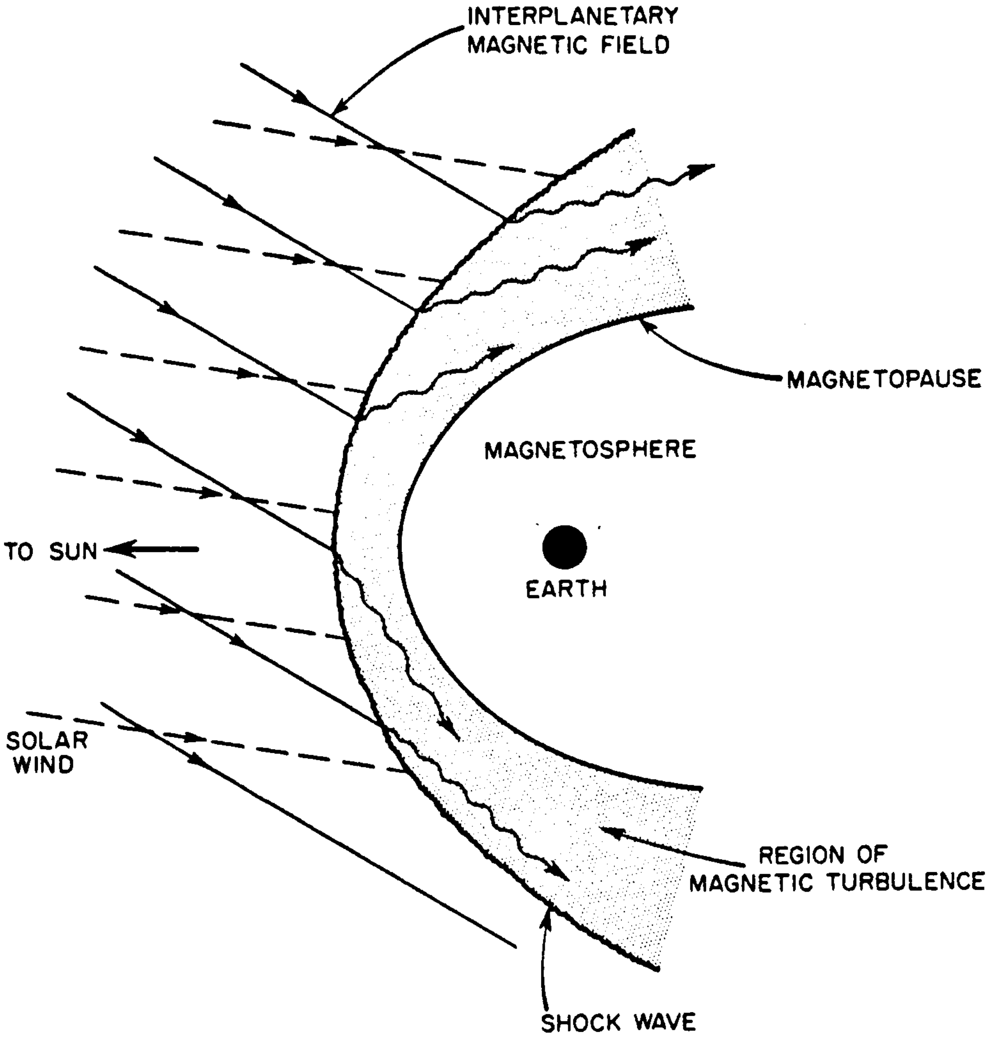


FIGURE 3-8. FORMATION OF HYDROMAGNETIC SHOCK WAVE BY THE SOLAR WIND AND DISTURBED REGION BEYOND EARTH'S MAGNETOPAUSE (after N.F. Ness, C.S. Scearce, and J.B. Seek)

3.1.4.7 Determine Dynamics of Radiation Belts.

In determining the dynamics of the radiation belts the time variations of all the components as a function of spatial and solar disturbances must be measured.

Knowledge of the dynamics will be necessary before the origin of the radiation can be ascertained and the relationship between the radiation and other planetary phenomena understood.

In the case of the earth, for example, a study of the dynamics of the radiation near the sub-solar boundary of the magnetosphere and beyond it in the transition and shock regions, should provide data on the coupling of magnetospheric energy and solar plasma energy. The dynamics of the radiation in the tail of the earth's magnetosphere is at this time relatively unknown, particularly at large distances. Of particular interest in the tail is the radiation in the vicinity of the neutral sheath.

For Jupiter, one would correlate radiation belt dynamics with Jovian radio waves and solar activity in an attempt to ascertain the origin of both the radio energy and the trapped radiation.

3.1.4.9 Determine the Correlation Between the Radiation Belts and the Other Planetary Phenomena.

Studies of the correlation between the radiation belts and such phenomena as magnetic storms, aurorae and ionospheric disturbances might further our understanding of the radiation belts as well as the nature of planetary phenomena. Data available at the present indicate that the relationship between earth aurorae and the Van Allen radiation is one of common origin. As a result of enhanced solar streams, a mechanism is set into operation which accelerates particles with a large fraction of them moving down magnetic lines of force into the polar regions to cause the auroral luminoscity and x-radiation. It is possible that the trapped radiation represents those particles that remain trapped in the earth's magnetic field after this process has occurred. In particular, correlation of particle measurements near the boundary of the magnetosphere and outside of it with auroral observations will be valuable.

It is believed that magnetic storms are the result of enhancements of a ring current in the earth's magnetosphere by solar streams. At the present time such a ring current of particles has not been observed. The trapped radiation acts as a ring current but intensities of the known radiation are insufficient to produce magnetic storm effects. Measurements to lower energies are needed in investigating the Van Allen trapped radiation.

3.1.5 Biology

The relevance of biological experiments appears in three places in the Relevance Guide:

TECHNOLOGY DEFICIENCIES - If a biological experiment is needed primarily to get information which is needed or may be needed for space flight, the task will be described under Technology Deficiencies in the Technology Document (Relevance Guide, Volume III).

EXPLORATION OF A PLANET - BIOLOGY - If an experiment is needed primarily to understand more about life forms as found on other planets for theoretical biology purposes (hence the experiment is not necessary for space flight), the task would be described under Exploration of a Planet - Biology in the Science in Space Document (Relevance Guide, Volume I). Exploration of Earth - Biology, is very limited.

UTILIZATION OF SPACE - R&D LABS - If an experiment is needed primarily to study life forms (assumedly earth life forms) in the unique laboratory environment offered by space, the task would be described in the Utilization of Space - R&D Labs section of the Science in Space Document (Relevance Guide, Volume I).

These categories quite closely correspond to the conventional categories of Space Medicine (man in space), Exobiology (extraterrestrial life) and Experimental Biology (effect of space environment on lower forms of earth life). A significant exception is that biological contamination and micro-organisms in the earth's upper atmosphere are treated as Technology Deficiencies in the Relevance Guide, and the distribution of spores in the upper atmosphere as Exploration of Earth.

The biology of other planets is one of the top items of interest to science and to the world. Our knowledge of earth-developed life has progressed almost to the point of synthesizing life itself. So close, in fact, that the very definition of life is involved. Many life processes are now rather well understood, and many processes common to all life have been identified. Lederberg (Ref. 35) says:

> "For example, an aqueous environment with moderate temperature in which large carbonaceous molecules are reasonably stable, is implicit in terrestrial biology. There remains an abstract possibility of nonaqueous life or noncarbonaceous molecules that might characterize temperatures of less than 200°K or greater than 500°K.
>
> "Nucleic acids play a central role in the unification of terrestrial biology, underlying both heredity and (through their control of protein synthesis) development. No other self-replicating polymers are known.
>
> "Equally general among living cells are proteins. B vitamins also have a perfectly general distribution.
>
> "Polyphosphates (adenylpyrophosphate) occur in all organisms as coupling agents for the storage and transfer of metabolic energy."

Are these aqueous mechanisms and biochemical processes the only ones possible for life, ones that we will recognize wherever life has evolved or spread, or are these the choices selected by earth-evolved systems from among numberless possibilities? Life chemistries based on silicon and germanium rather than carbon have been postulated by some scientists (Ref. 36). However, Ponnamperuma (Ref. 37) points out that silicon similarities to carbon are superficial and shows sound reasons why silicon life form would be very difficult to attain.

Even a sterile planet would be of universal interest to biology for the insight it should give on the actual progress of probiotic chemical evolution. Lederberg also mentions the possibility of finding new organisms that might be economically useful to man.

Because man himself is a biological organism which feeds off of other biological systems, he has gained and stands to gain much more from advances in biological science. But every bit of his knowledge about living systems has been based on earth-developed systems. Although he has been able to study the effects of certain changes in the earth's environment--changes in gravity, synthetic radiation from different parts of the electromagnetic spectrum, charged particle radiation, changes in atmospheric constituents and pressure, it is impossible to completely isolate the samples from the earth's environment.

Furthermore, the very biological samples the scientist uses and the biological processes he is studying are all the product of evolution in the earth milleu. There has been absolutely no opportunity to compare earth-developed life with life developed in another planetary environment. In fact, although it is generally assumed that our insignificant planet cannot be the only spot in the entire cosmos to have developed life, this assumption must be based on extremely high probability and the fact that we know of no reason why not. But the fact of the matter is that no extraterrestrial life of any form has yet been discovered. The closest approach to such a momentous discovery is the appearance of organic-like chemicals in certain types of meteorites (Ref. 29).

Space, then, offers biologists two significant opportunities: First, the chance to observe earth-developed life systems in environments that could not be provided before, and second, the chance to find life forms which evolved in an extraterrestrial environment and compare them with the known characteristics of earth systems.

However, a third basic area of critical interest, besides the behavior of earth organisms in extraterrestrial life, is the panspermia hypothesis. It is important to know whether spores can migrate through space from one planet to another.

For experiments of the first sort--observing earth-developed life systems--the earth orbiting flights will provide for many tests and the lunar and Martian bases for others. Most of these can be performed in earth-orbiting laboratories and will be described in Section 4.2, Utilization of Space, R&D Labs. For the second sort--finding and studying extraterrestrial life--Mars, of course, is the most likely target. There is little doubt that many simpler organisms similar to those found on earth could thrive there. Venus is not out of the question. Even if the surface of Venus is too hot, this need not preclude a viable temperate zone at another level. Jupiter is of interest to biochemists in studying pre-earth conditions. For the third area of interest--panspermics--any extraterrestrial object is of interest, including the moon and meteorites.

Dr. Cyril Ponnamperuma (Ref. 38) would rank biological interest in the moon and planets as follows:

Mars	Great interest
Moon	Considerable interest
Jupiter	
Venus	Some interest

with little or no interest in the others.

The significance of biological science is obvious: further understanding of life processes will back up the biomedical technology required to permit better life support for man in space, oceans, and other alien environments. But also it could lead to further conquest of disease, rejuvenation or replacement of failing organs, great extension of useful life, and perhaps even the modification of man himself to increase his capabilities (Ref. 39) to name some of the more spectacular. Life is still probably the greatest mystery of science, and the new research opportunities of space may be the key to its solution.

3.1.5.1 Determine the Existence of Life Forms

The discovery of a living organism of any type anywhere outside the earth is a very significant step to biology. There is no known reason why there should not be extraterrestrial life, but so far it has not been found. The discovery, of course, would provide the basis for answering many important questions in theoretical biology.

There is the practical problem of "just what are we looking for?"

Microorganisms are the best prospects for discovery (Ref. 35). For one thing, they are more likely to flourish in a minimal environment than larger organisms. The microbe would precede the macrobes in evolutionary sequence. There very well may be worlds occupied only by microbes, but it is unlikely to have other forms of life while lacking microbes. Considering the earth as a whole, large organisms occupy only a small part of the earth's surface, making them more likely to be overlooked, whereas microbes are found everywhere--in water, sand, or air. The greatest diversity of biochemical mechanisms will be represented among the microbiota of a small sample. Furthermore, microbes can easily be cultivated within the confines of an experimental space system, and are readily adapted to automation and telemetric recording.

The National Academy of Sciences has said that the discovery of Martian life may well rank as the most important outcome of space research in our generation (Ref. 36). However, if extraterrestrial life is found in forms far different from earth-developed systems, then there will be great interest in exploring the major planets where there is a wealth of light elements subject to solar irradiation at temperatures and in gravitational fields far different from the Earth's.

3.1.5.2 Determine the Past Existence of Life Forms

Even if no living organisms are discovered outside the earth, the search for fossils or artifacts will be important to determine whether life ever existed on the planet, or perhaps find meteoric evidence of biological strains. This discovery would be in many ways as significant as the discovery of extraterrestrial life, although much less could be learned about its ecology. In addition to Mars and Venus, the moon's surface and protected crevices are of interest in the search for past life forms.

3.1.5.3 Classify Life Forms

If extraterrestrial life of any form is found, it will set off a search for as many different life forms as possible in order to map the "family tree" of biological organisms for the target planet. The search for life may originally concentrate on microbiology. If successful, it will increase in scope to identify all possible forms of plant and animal life.

This task assumes that life forms have been discovered.

3.1.5.4 Study the Comparative Ecology of Life Forms

If any extraterrestrial life form is discovered, it will be necessary to study its biochemistry and ecology in order to determine whether the alien system has developed an independent form compared to familiar earth systems. This will aid in answering questions of whether life was transported from planet to planet, or whether it developed indigenously from its own raw material. And if indigenous, to what extent it developed along the same lines as earth biology.

An important aspect here is the determination of the compatibility of earth and alien life forms, evaluating the possibility that cross contamination could upset the balance of nature on either planet.

Another aspect is that it will give a clue as to the probability of life on more hostile planets: if only struggling microbiota based on the same chemistry as earth forms are found, the incentive for further planetary biological exploration is reduced. If, however, it is found that life forms can develop and thrive based on whatever chemistry and environment is available, there will be great incentive for biological exploration of the entire solar system.

This task assumes that life forms have been discovered.

3.1.5.5 Map the Distribution of Life Forms

The effort to determine what life forms exist and their geographical distribution on another planet is important in the orderly study of the planet's biology. Compositional variations, climate variations, and long periods of sun or darkness can create a variety of life systems on any particular planet that should be compared.

This task assumes that life forms have been discovered.

3.1.5.7 Study the Behavior and Habits of Life Forms

For each identified life form, it is of interest to study the reproduction, growth, and enzymatic capabilities. Should higher life forms be found, much more advanced studies of photosynthesis, gravity dependence, environmental adaptability, sensory types and capability, migration, family life, intelligence, memory, trainability, creativity, etc., are of interest. Implications here are both to get a more universal understanding of behavior and the possibility of finding abilities useful to man, as are so many earth life forms, either directly (as hunting dogs) or indirectly through bionics (as frogs-eye target discriminators) and possibly utilization by space exploration teams.

This task assumes that life forms have been found and that they are high enough to create interest in their habits.

3.1.5.8 Determine the Existence of Panspermia

Whether life forms are found or not, it is important to biologists to know whether spores can be transported from one planet to another and survive. If panspermia are found on the moon, or on early planet explorations, it will suggest that life can be transported. And if life is found, the existence of panspermia will help explain its origin.

The moon is a gravitational trap for meteorites and hence its hidden crevices may contain evidence of panspermia. Since exposure to solar radiation could degrade such spores, the confirmation that Mercury exhibits trapped rotation (i. e., a period of 88 days) would mean that it has a permanently dark side of interest to biological exploration.

This task assumes that no other life forms have been found.

3.2 EXPLORATION OF THE SUN AND INTERPLANETARY SPACE

This section describes the scientific tasks which have been identified under the following Fields of Interest:

Composition of the Interior and Photosphere
Atmosphere and Corona
Electromagnetic Radiation
Particle Radiation
The General Magnetic Field

3.2.1 Composition of the Interior and Photosphere

Demarcation between the photosphere (which for this purpose is considered the "surface" of the Sun) and the chromosphere (or lower atmosphere) is vague (Figure 3-9). Nearly all of the visible and IR radiation from the Sun originates from the relatively thin (400 Km) photosphere. Thus the observed radius of the Sun and most of the observed spectacular solar phenomena occur, or at least originate, in the photosphere and interior and are included here.

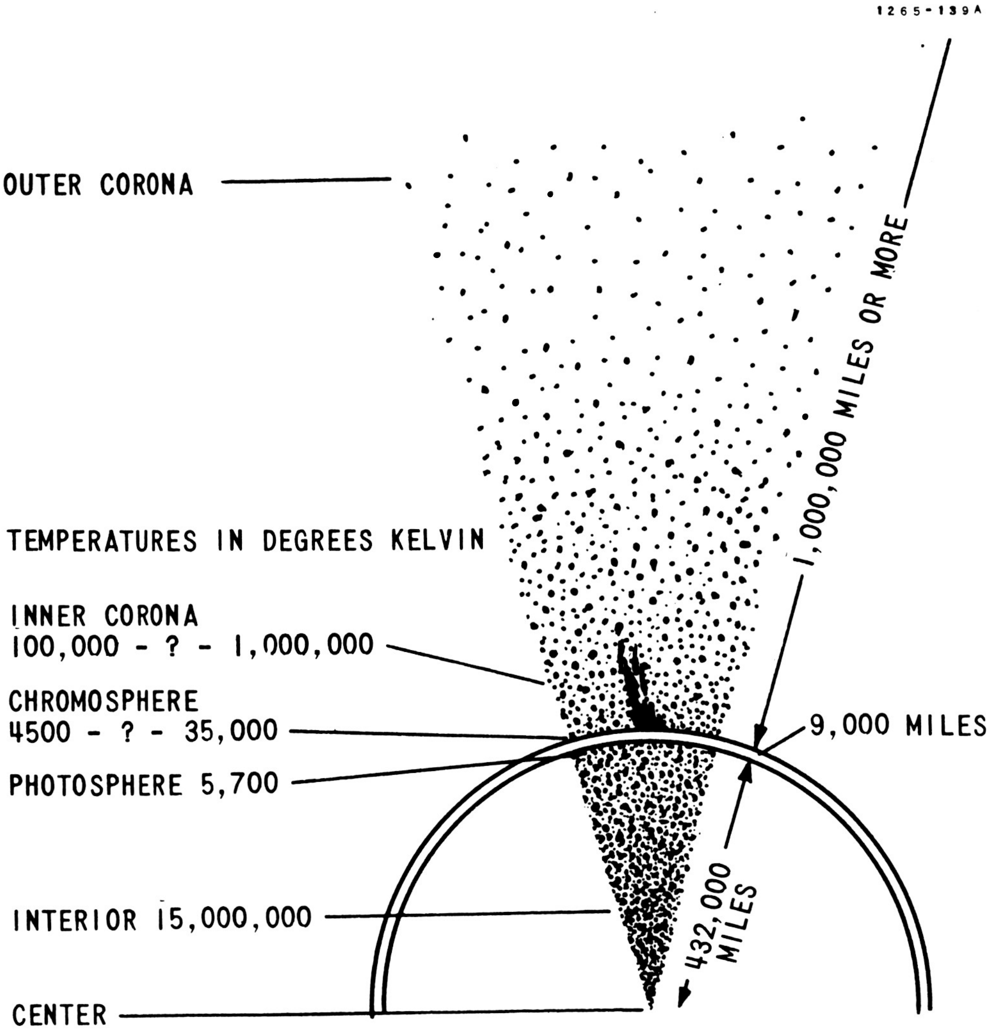


FIGURE 3-9. SOLAR SPHERES OF INTEREST (REFERENCE 40)

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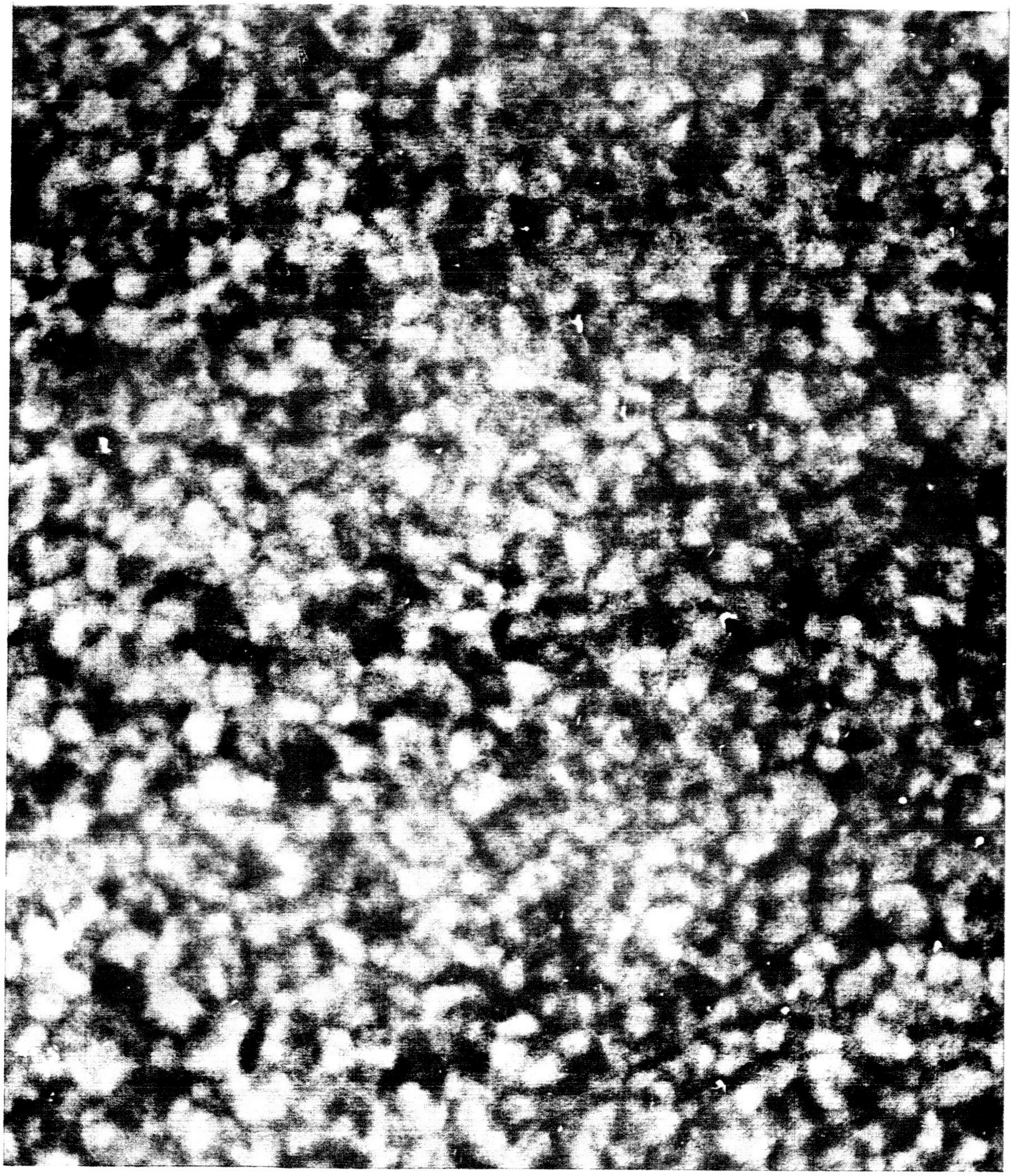

FIGURE 3-10. GRANULATION ON THE SUN'S SURFACE
(Mt. Wilson and Palomar Observatories)

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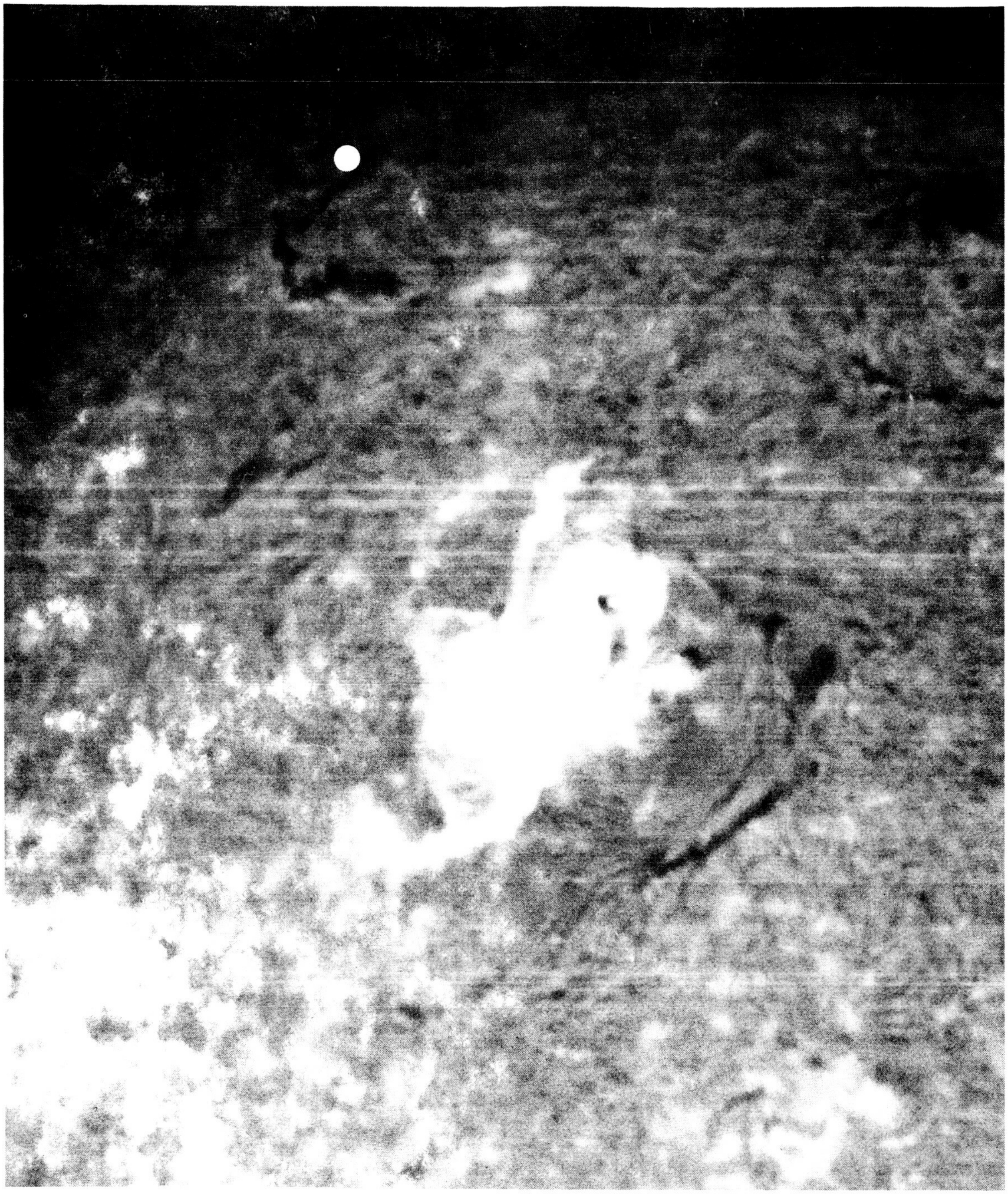

FIGURE 3-11. SOLAR FLARE PHOTOGRAPHED IN RED LIGHT OF HYDROGEN α LINE
(Mt. Wilson and Palomar Observatories)

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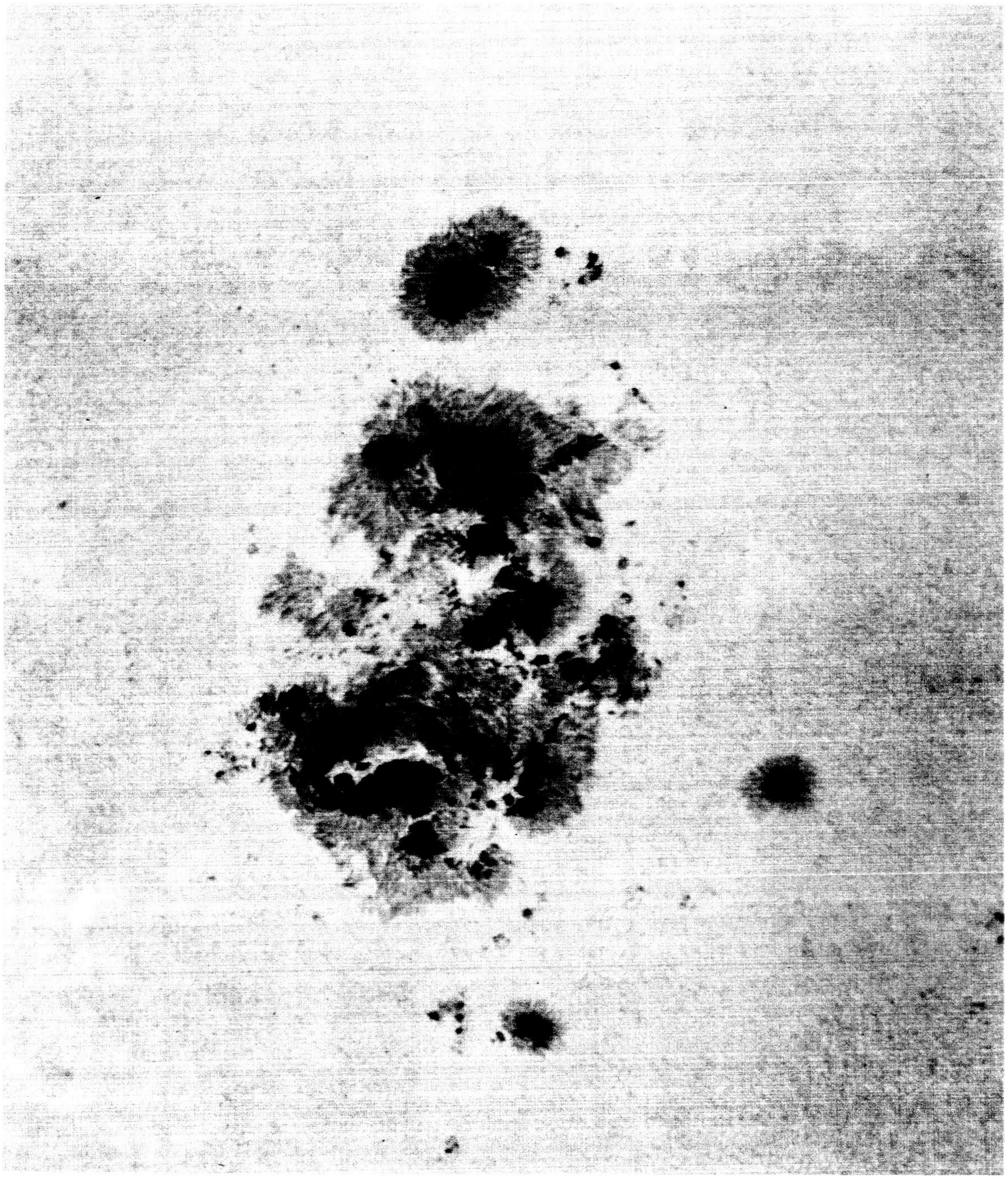

FIGURE 3-12. SUNSPOT GROUP
(Mt. Wilson and Palomar Observatories)

3.2.1.1 Study the Mechanism of Granulation

The granules are certainly the tops of convective cells emerging through the photosphere from the convectively unstable layer immediately below. The fact that the observed granules have a pronounced cellular structure and a bright-dark asymmetry has not yet been explained by theory. Much additional information remains to be secured before the problem of the granulation will be completely solved, especially information on the distribution of the granules with respect to velocities and magnetic fields. Such investigations will obviously require a high degree of stability in directional control of the equipment.

The detailed nature of granules and of the mechanism underlying them has eluded understanding, chiefly because the turbulence of the earth's atmosphere has prevented precise measurements of the distribution of granular sizes, velocity and temperature. (Ref. 41).

3.2.1.2 Study the Mechanism of Flares

The mechanism of the sudden onset and development and the acceleration of the high-velocity particle streams of solar flares requires explanation. Various theoretically possible interactions between the fairly strong local magnetic fields and the matter in which they are embedded have been suggested. What is needed is a detailed time sequence of the magnetic fields--their strength, polarity, direction, and rate of change with time--in the regions of near-zero longitudinal field intensity where flares have a tendency to break out. A parallel time sequence of ultraviolet and X-ray spectra and of detailed spectroheliograms is also necessary to supply data on excitation temperatures and electron density. From the spectral distribution of the X-ray flux, a collection of thermal sources is inferred which would require local temperatures of the order of 100 million degrees Kelvin in the solar atmosphere.

Strong flares are nearly always accompanied by a strong increase in radio noise.

Flares occur only in active regions occupied by plages, usually near sunspots. They frequently break out near the boundary between two strong, opposing spot-connected fields where the local field intensity is close to zero. The detailed mechanism is not clear, although the abruptness of their onset has suggested that they are sudden electric discharges. Various theories have been advanced, based on a variety of ideas such as the local building up of charge density, magnetic pinch effects, local changes in conductivity, the rate of change of the magnetic flux, etc. (Ref. 41).

3.2.1.3 Study of the Mechanism of Sunspots

Since many of the aspects of the sunspot phenomenon can be and have been studied in visible radiation, the difficulty here, more than in other cases, is one of theoretical interpretation: How is the sunspot cooled? Is the gas pressure reduced because part of the load has been taken over by the magnetic pressure? Or is the cooling due to a forced expansion of a rising gas column whose ionized elements spread out when following the diverging lines of force? On the other hand, there is no clear-cut evidence that the gas column is really rising. This last is not a theoretical but an observational difficulty, which might be resolved by data of higher resolution or deduced from radiation from a greater variety of optical depths, either of which would indicate the mode of vertical circulation inside a spot. (Ref. 41).

3.2.1.4 Study the Mechanism of Local Magnetic Fields

In addition to the general solar magnetic field of about 1 gauss, there are localized bipolar and unipolar fields of several gauss lasting from days to months, the strongest of which are associated with faculae. As is well known, the field in a large sunspot may reach a value higher than 3000 gauss.

Although these strong local fields apparently do not persist to high latitudes, and thus do not interfere there with the detection of a general dipole field, the observational difficulties become worse near the poles because the line-of-sight component of the field approximately normal to the surface approaches zero.

We know enough about the behavior of solar activity to say positively that any theory which claims to explain such things as coronal and chromospheric heating, the support of prominences, the generation of flares, the production of sunspots, together with the cyclical nature of solar activity, must take account of the presence of magnetic fields. The liberation of energy by a flare provides a good example of the crucial role played by magnetic fields in the origin of solar phenomena. The energy liberated per unit volume during a typical flare is frequently greater by more than a factor of 10 than the combined thermal and turbulent energy of the gas, which is no more than 10 ergs per cm^3. On the other hand, the magnetic energy associated with a field of only 50 gauss is 100 ergs per cm^3.

It is no exaggeration to say that the relation of these local fields to the phenomena, on the one hand, and to the weaker general magnetic field of the Sun, on the other, together constitute the central problem.

The clarification of the relation of the fields to the phenomena really requires detailed measures of field strength in the specific features, e.g., in the specific flare or coronal streamer. These measurements are perhaps no more easily performed with the help of a satellite than by more conventional methods, except insofar as it is possible to isolate some particular short-wavelength radiation coming only from a given source. The relation of the local fields to the general field, however, and origin of the general field itself are largely theoretical problems, although one may still hope that the detailed treatment of interactions between fields and phenomena will provide fresh insights leading to a more satisfactory and comprehensive magnetohydrodynamic theory of solar activity. (from Ref. 41).

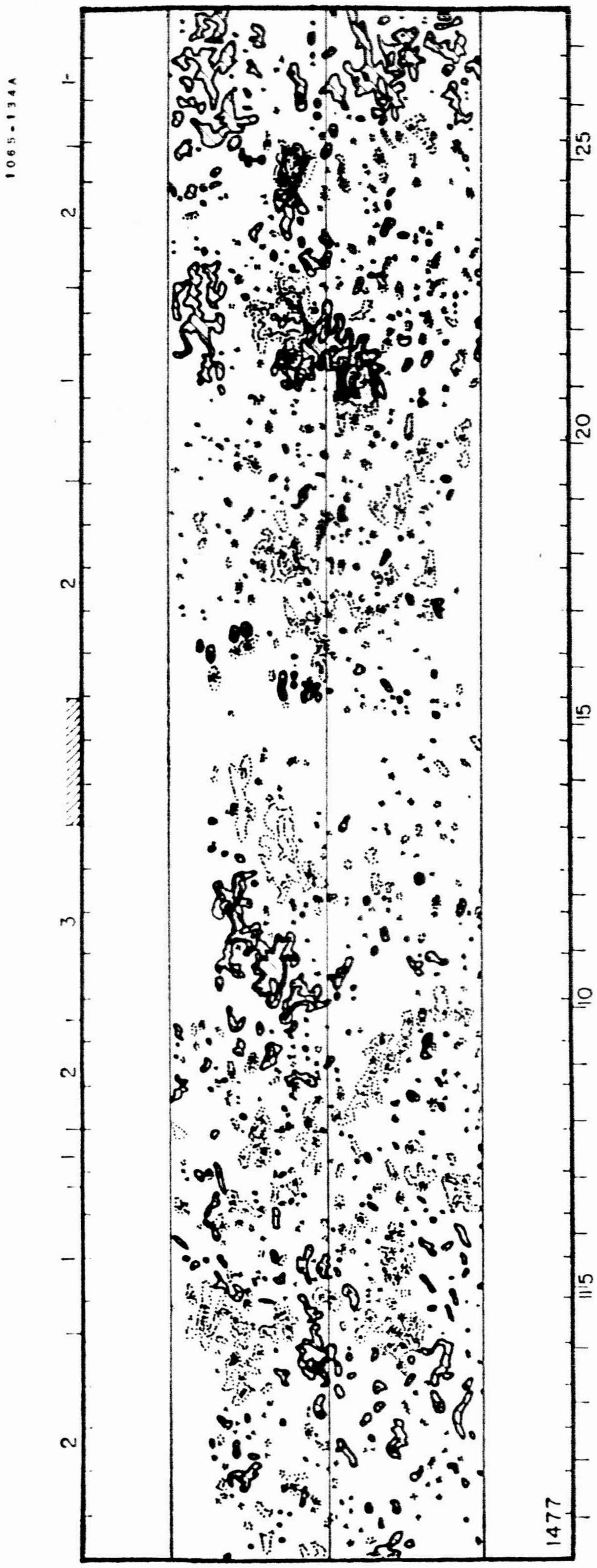

FIGURE 3-13. SYNOPTIC CHART FOR SOLAR ROTATION NUMBER 1477 (FEBRUARY 1964)

Designations are the same as for Figure 3-14. Observations beyond ±40° are not included. (Ref. 62)

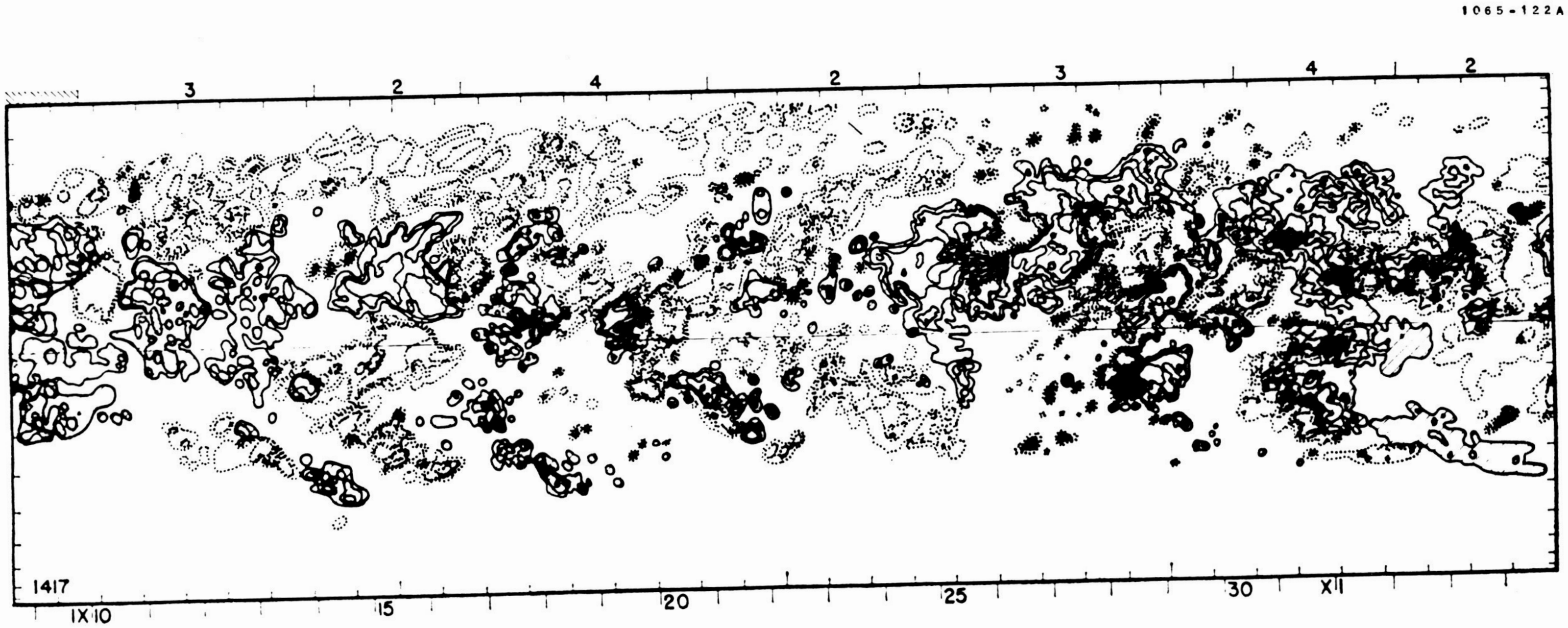

FIGURE 3-14. SYNOPTIC CHART OF SOLAR MAGNETIC FIELDS FOR SOLAR ROTATION NUMBER 1417 (AUGUST 1959)

This is a rectangular equal-area projection. Solid lines and hatching represent positive polarity; dotted lines and shading represent negative polarity. The first isogauss level is 2 gauss. The equator is drawn across the center, and every 10° in latitude is marked at the sides. The scale at top gives an indication of the quality of the magnetograms from which the synoptic chart was drawn, with 4 the best; the hatching at left end of the scale represents an area drawn more than 40° from the central meridian of a magnetogram. The date (Roman numerals) and longitude are given on scales at bottom. (Ref. 62)

3.2.1.5 Determine the Abundance of Chemical Elements

The ultraviolet spectrum on the longward side of 1000Å contains the resonance lines of many elements, most of which are known or believed to occur in the sun, but whose abundances are not well determined because the existing data are based on weak absorption lines representing transitions between two states of moderately high excitation, or because lines are entirely absent in the visible spectrum. Examples are C, N, O; the inert gases Ne, A, Kr, Xe, Rn; the halogens; As, Se, TI, etc. (Ref. 41).

3.2.2 Atmosphere and Corona

Again, the delineation of "Atmosphere and Corona" is necessarily imprecise, but essentially includes the gases that rotate with the Sun--the chromosphere and corona (Figure 3-15)--and exclude interplanetary media originating at the Sun.

The transparent chromosphere transmits nearly all of the radiation originating in the photosphere below. The chromosphere in itself originates very little radiation and is generally visible only when the photosphere is completely covered by the Moon, when it is seen as a thin red crescent.

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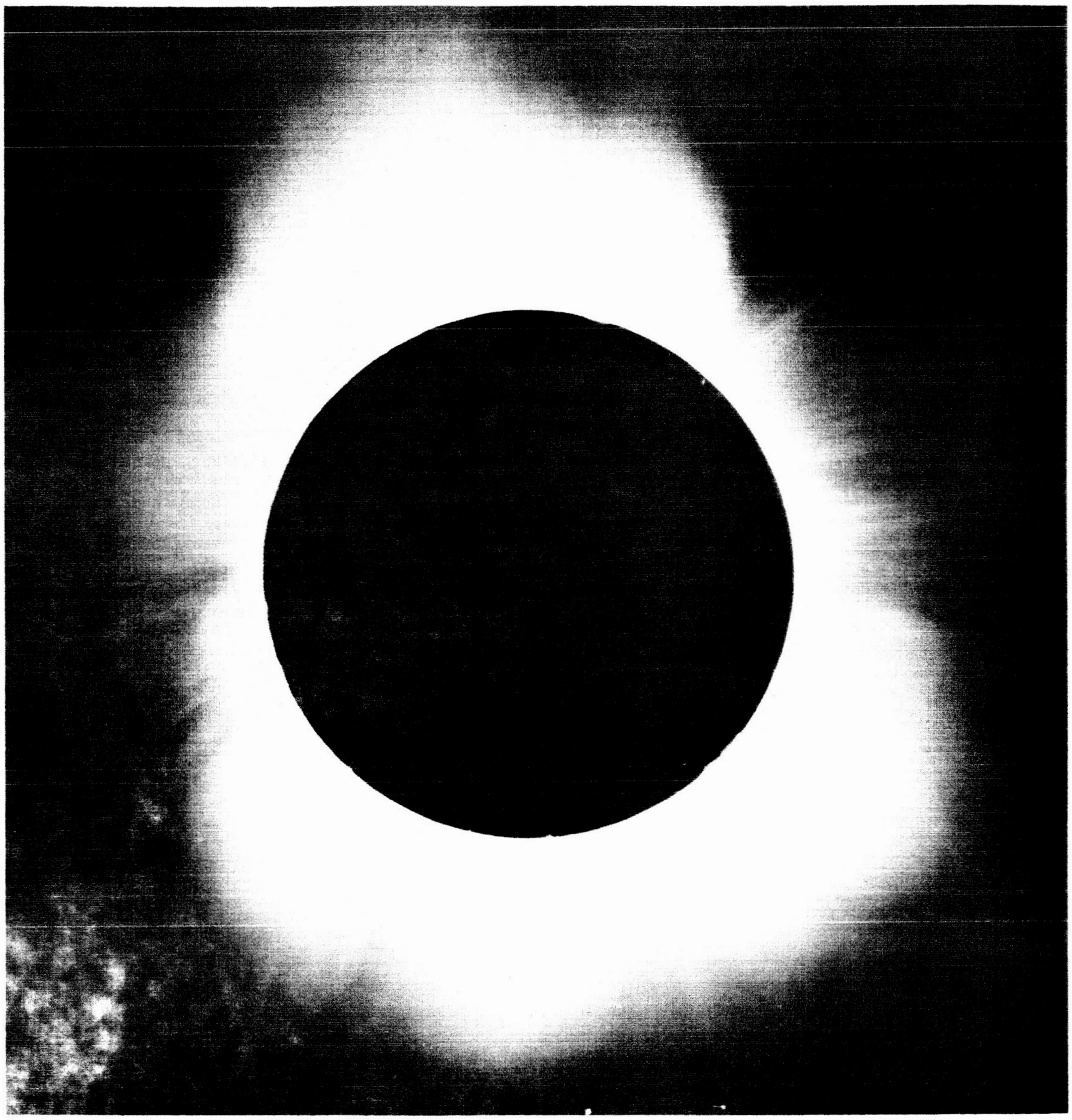

FIGURE 3-15. SOLAR CORONA PHOTOGRAPHED DURING TOTAL ECLIPSE
(Mt. Wilson and Palomar Observatories)

3.2.2.1 Determine the Structure of the Chromosphere

The chromosphere is a dynamic transition region about 10,000 to 15,000 km thick, lying between the relatively cool outer layers of the photosphere (about 4500°K) and the million-degree corona. It is extremely inhomogeneous, and small volumes are far from being in a steady state.

Types of activity associated most closely with the chromosphere (aside from the spicules which may be regarded as a feature of the "quiet" chromosphere) are plages, flares, and prominences. Flares may occur in the upper photosphere as well as in the chromosphere, and are treated under "Composition of the Photosphere and Interior." Further, there is no sharp division between the top of the chromosphere and the base of the corona since the tops of spicules sometimes project into the corona.

The normal structure of the chromosphere consists of fairly closely packed spicules--small jetlike prominences with lifetimes of the order of several minutes and upward velocities of the order of 20 km per sec--whose tops reach a height of roughly 10,000 km. Theoretical astrophysicists have been attempting to construct a coherent model of the chromosphere which explains both the low- and high-temperature phenomena, both the optical and radio results. There is little uniformity of opinion among them.

Theoretical disagreements about the structure of the chromosphere (which apply equally to the corona) arise only partly from the difficulty of securing data of high resolution, as in the case of the photosphere. In addition to this grave difficulty, there have been two other stumbling blocks. It is intrinsically harder to construct a model for the very complex and dynamic outer envelopes than for the relatively simpler photosphere. Furthermore, most of the radiation from the photosphere is in the visible region of the spectrum and has thus been under detailed investigation for some time. By contrast, the most distinctive and, relative to the photosphere, strongest radiations that emanate from the outer envelope are in the extreme short-wave (ultraviolet and X-ray) and long-wave (radio-frequency) regions of the spectrum. On this account it is only very recently that we have begun to accumulate data through the new techniques of radio astronomy and rocketry.

Scientists are interested in knowing what is the structure of the chromosphere. In particular, what is the explanation for the simultaneous appearance of spectral features indicating temperatures ranging from about 4500° to 30,000°K? Can we verify the suggestion that it is a highly inhomogeneous mixture of cells of hot and cool gases?

What is the nature of the spicules? Are they either the hot or the cool elements in the suggested chromospheric structure? How are they related to the other features, like granules and flocculi? High-resolution spectra and spectroheliograms in the extreme ultraviolet and the millimeter-wave radio regions would help to decipher these questions, from which one might evolve a comprehensive and coherent theory of magnetohydrodynamic turbulence applicable to these phenomena. This type of investigation would require a high degree of stability and control of the satellite vehicle. (Ref. 41).

3.2.2.2 Determine the Structure of the Corona

The corona is the very tenuous outer atmosphere of the Sun, which can be traced out into space for a distance of several solar radii. In it the electron density is believed to fall from about 10^9 per cubic centimeter at the base to interplanetary values (up to 10^2 per cubic centimeter) at the outside. The intensity of this coronal light is approximately 10^{-6} of the total sunlight, and most of this is continuous radiation from the photosphere scattered by electrons, as shown by its color and radial polarization. Most of the sun's X radiation originates in the corona and in certain active regions of the chromosphere. A number of phenomena concur in indicating that the kinetic temperature of the corona is of the order of 10^6°K.

The corona is only very approximately spherically symmetrical. Actually, it exhibits a considerable amount of both regular and irregular structure. The regular structure goes through a cycle in phase with the 11-year activity cycle: at sunspot minimum the corona shows broad extensions above the equatorial region and fine striated streamers fanning out from each pole, while at sunspot maximum the structure is more nearly the same over equator and pole, with the polar streamers much less pronounced. The corona also shows localized inhomogeneities, e.g., regions of greater radio opacity when occulting radio stars, "hot spots" over regions of obvious activity in the chromosphere, etc. Some of these features are more properly associated with the active sun. The two sorts of active regions, as indicated by strong line emission and strong radio noise, respectively, are by no means identical. There is some evidence, chiefly from radio observations, that the outer corona is a relatively loose collection of clouds of highly ionized gas.

In view of the observed clumpiness in the corona, what is its detailed fine structure (electron density, magnetic fields, temperature, particle streams, etc.)? To what extent is this fine structure related to phenomena in the chromosphere or to possible or hypothetical events on the outside (e.g., particle infall)? (Ref. 41).

3.2.2.3 Determine the Temperature Gradient

Figure 3-16 shows the temperature gradient in the solar chromosphere according to different authors. This reflects the uncertainty which exists in the knowledge of the solar temperature gradients.

What is the nature of the sharp rise in kinetic temperature from about 4500°K in the upper photosphere to about 1,000,000°K in the quiet corona? Here we might look at three of the competing mechanisms without considering their present apparent merits or their relative contribution: (a) The turbulent energy of granules, spicules, etc., in the photosphere and lower chromosphere is dissipated by acoustic waves into thermal energy in the upper chromosphere through shock-wave heating. (b) As strong magnetic fields decay, their energy is devoted to the acceleration of charged particles in great quantities; this kinetic energy is in turn dissipated into heat. (c) The kinetic energy of interstellar matter falling into the sun is dissipated by collisions into heat. Probably the first two of these processes, and possibly the third, are all going on with various degrees of effectiveness.

It is difficult to decide the relative merits of these theories or the relative importance of the contribution of each mechanism on the basis of heating effects alone. On the other hand, certain attendant phenomena other than heating would be different. For example, theory (a) calls for a spectrum of turbulent velocities which would vary with height in a regular way; theory (b) requires certain patterns of fluctuating electromagnetic fields; theory (c) demands a fairly dense cloud of infalling particles around or near the sun. These effects should all be observable in the foreseeable future with space techniques.

For an unambiguous determination of the temperature gradient, the spectrum should be observed at various points along a solar radius,

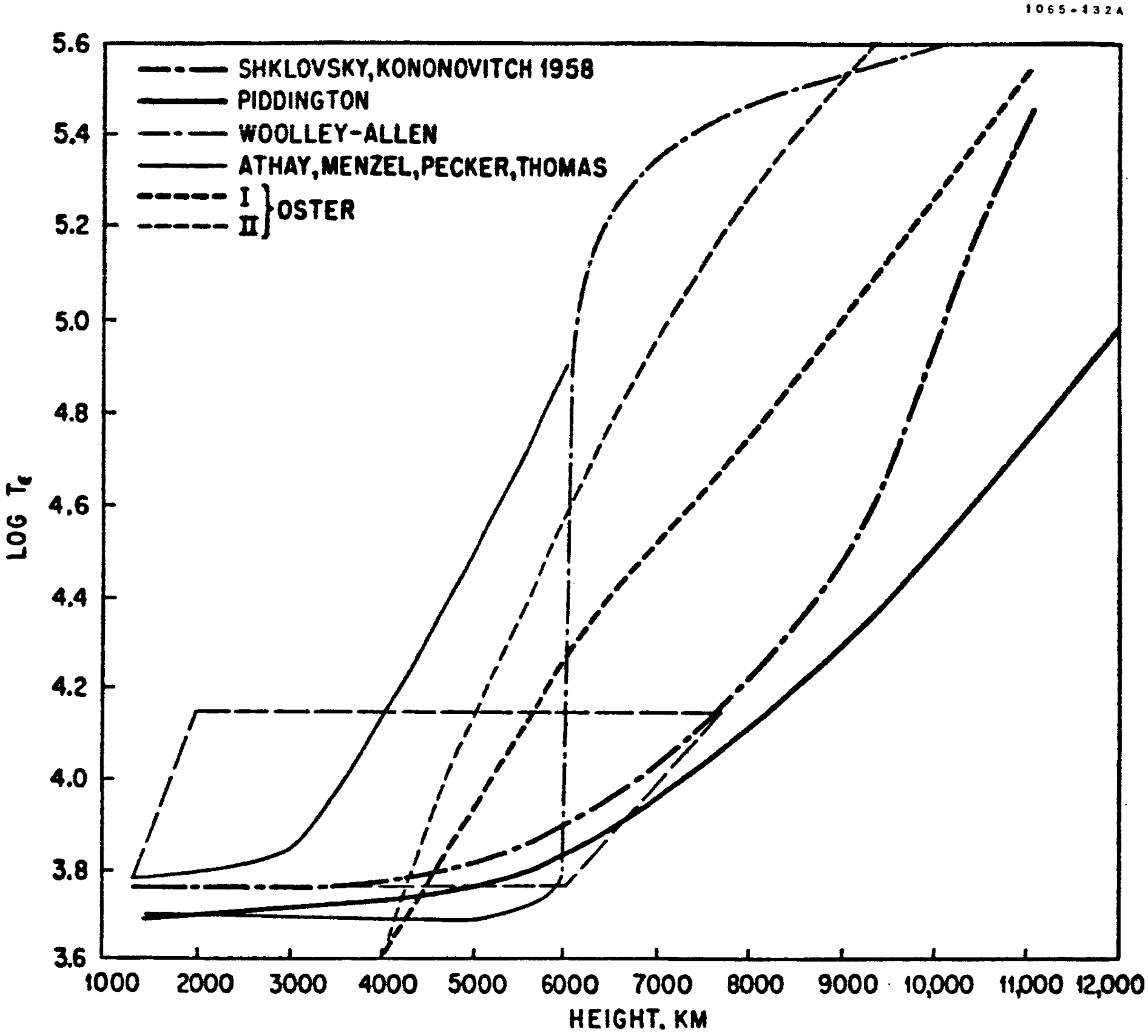

FIGURE 3-16. TEMPERATURE GRADIENT IN THE SOLAR CHROMOSPHERE ACCORDING TO VARIOUS AUTHORS (REF. 41)

and this requires very high precision in pointing, which can probably only be achieved with a stabilized platform. (Ref. 41)

3.2.2.4 Mapping of the Corona Hot Spots

"Hot Spots" are regions in the corona from which the emission lines of multiply ionized iron, etc., are particularly strong. They are transitory and seem to be closely correlated in position with obviously disturbed regions in the photosphere.

The mapping of these "hot spots" which seem to exist even in the quiet corona, by extreme ultraviolet and X-ray spectroscopy, and the detailed study of the emission lines and continua of the highly ionized atoms in these localized regions would go a long way toward producing a satisfactory model of the corona. (Ref. 41).

3.2.2.5 Study of Electromagnetic Corona Radiation

Electromagnetic corona radiation originates entirely in the ionized solar atmosphere. It is characterized by its great diversity in frequency, intensity, and in time. The variable components of radiation are associated with solar activity. Their characteristics are complex and vary with the wavelength. Several distinct types of bursts have been identified.

Space flight experiments will permit radio astronomers to reach portions of the spectrum below about 20 Mc, which are filtered by the earth's ionosphere. This low frequency region is of particular interest because radiation in this band corresponds to plasma oscillations originating in clouds of very low electron density.

New information about the photosphere and chromosphere will also become available by UV mapping and by higher resolution visible light studies.

Studies of the electromagnetic fields in interplanetary space are not included in this task.

3.2.3. Electromagnetic Radiation Fields

Most experiments involving measurement of the sun's electromagnetic energy are directed at tasks such as determining the composition of the photosphere, study of flare phenomena, etc., and are described elsewhere. The task of determining the solar constant (the total solar energy falling on the earth), is included in this Field of Interest, as well as determining the quality, time variance, transmission and distribution of the electromagnetic radiation through interplanetary space.

3.2.3.1 Map frequency and intensity characteristics throughout interplanetary space and temporal variations.

The total amount of energy received from the Sun in one minute on a 1 cm^2 surface perpendicular to the sun's rays at the earth's distance is of interest in understanding the Sun itself and its radiation input to the Earth. The quantity is not known precisely because the energy is received over a wide portion of the spectrum (Fig. 3-17), and because it no doubt varies somewhat from time to time. This task will determine the solar constant, the spectrum distribution of the radiated energy, and its time variance. It is also concerned with the sun's electromagnetic radiation field at other planets and throughout interplanetary space.

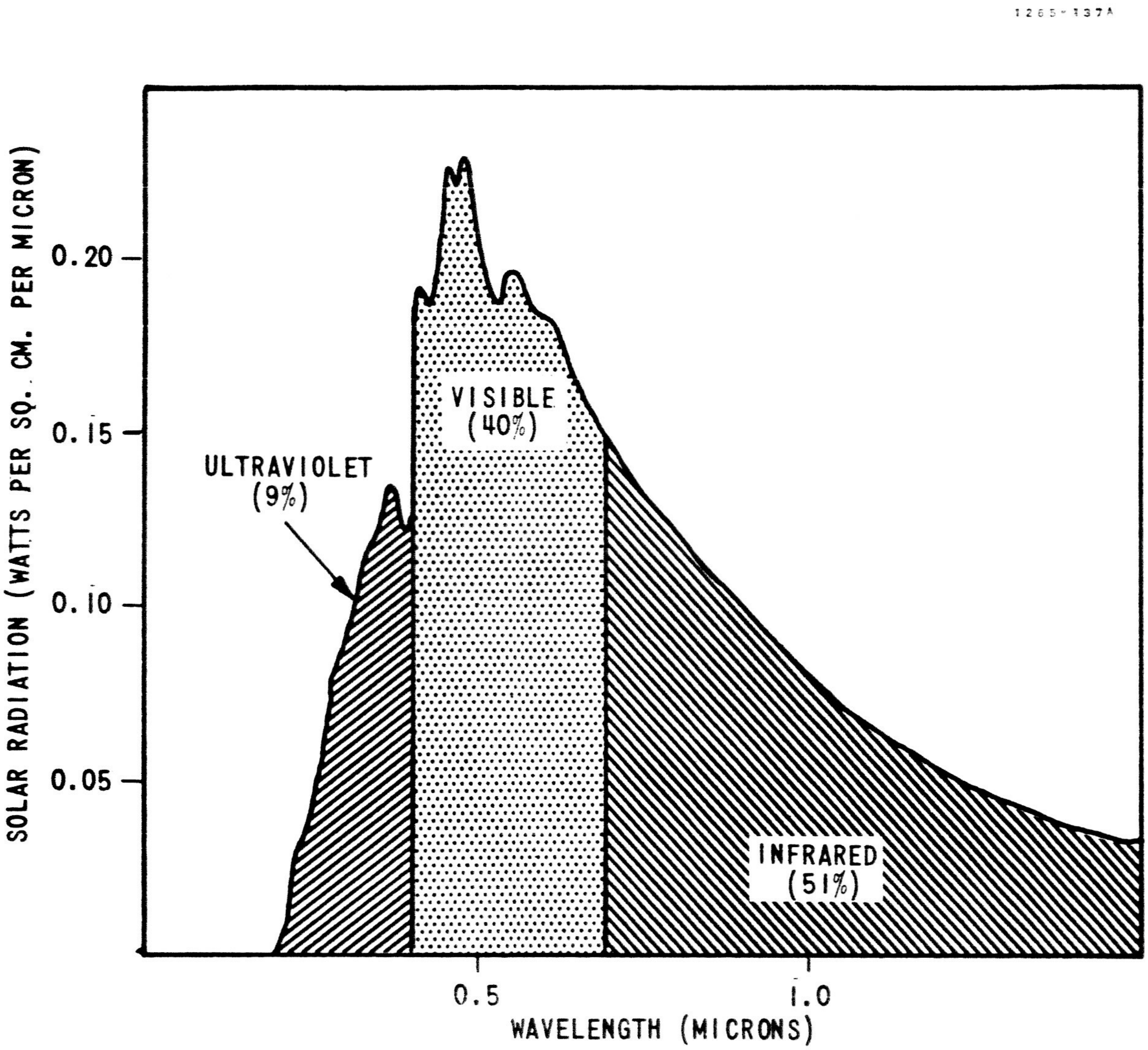

FIGURE 3-17. SOLAR RADIATION ABOVE THE ATMOSPHERE (REFERENCE 23)

3.2.4 Particle Radiation

This Field of Interest is concerned with studies of the energetic particles and plasma originating at the Sun and distributed through interplanetary space. Space flight has tremendously increased the opportunities for study of these particles, many of which are shielded from the Earth's surface by the magnetosphere. Also, it is now possible to measure the distribution of particles as a field about the Sun rather than being limited to the Earth's distance.

3.2.4.1 Measure the Charge Composition and Spectrum of the Quiescent and Disturbed Radiation.

The energetic particles emitted from the sun (solar cosmic rays) in association with solar flare activity are of interest to scientists because they provide them with information about solar processes, are produced in a relatively close astrophysical source of relativistic particles, and finally, since they are influenced in traveling to the earth and beyond by the interplanetary medium they provide indirectly a means of studying the medium itself.

Knowledge of the charge composition and spectrum of solar cosmic rays would provide information concerning the relationship between the electromagnetic radiation of solar flares and the acceleration of particles. It has been suggested that the continuum radiation from flare regions both at radio and visible frequencies might be synchrotron radiation from an exponential rigidity distribution of electrons. Protons produced at times of solar flares over the energy intervals so far measured appear to fit exponential rigidity spectra. It appears then that the same acceleration mechanism that imparts an exponential rigidity spectrum to positive particles in the flare region also accelerates the electrons but they are not observed in the solar cosmic radiation because they lose energy by synchrotron radiation and remain trapped in the magnetic fields of the flare region.

Solar cosmic rays are better suited as probes of the interplanetary medium than the galactic cosmic radiation for several reasons. First, they are injected into the medium in a better defined manner, second, the time of injection is known hence a particular group of particles could conceivable be traced and studied through the interplanetary medium and, finally, the spectrum of the source particles is better known.

Solar plasma fills the interplanetary medium. A study of the composition and propagation of the quiet solar wind would provide information about the dynamics of solar coronal expansion. The propagation of enhanced solar streams or blast waves from flares as well as the solar cosmic rays in the interplanetary medium depends on the previous history of the medium. Thus the inner solar system is one vast laboratory for the investigation of dilute plasmas, magnetic fields, hydromagnetic waves and shock phenomena--none of which can be scaled down properly for laboratory investigation.

It is of interest to study these particles in the vicinity of the earth as well as closer to and farther from the sun, both in and out of the ecliptic.

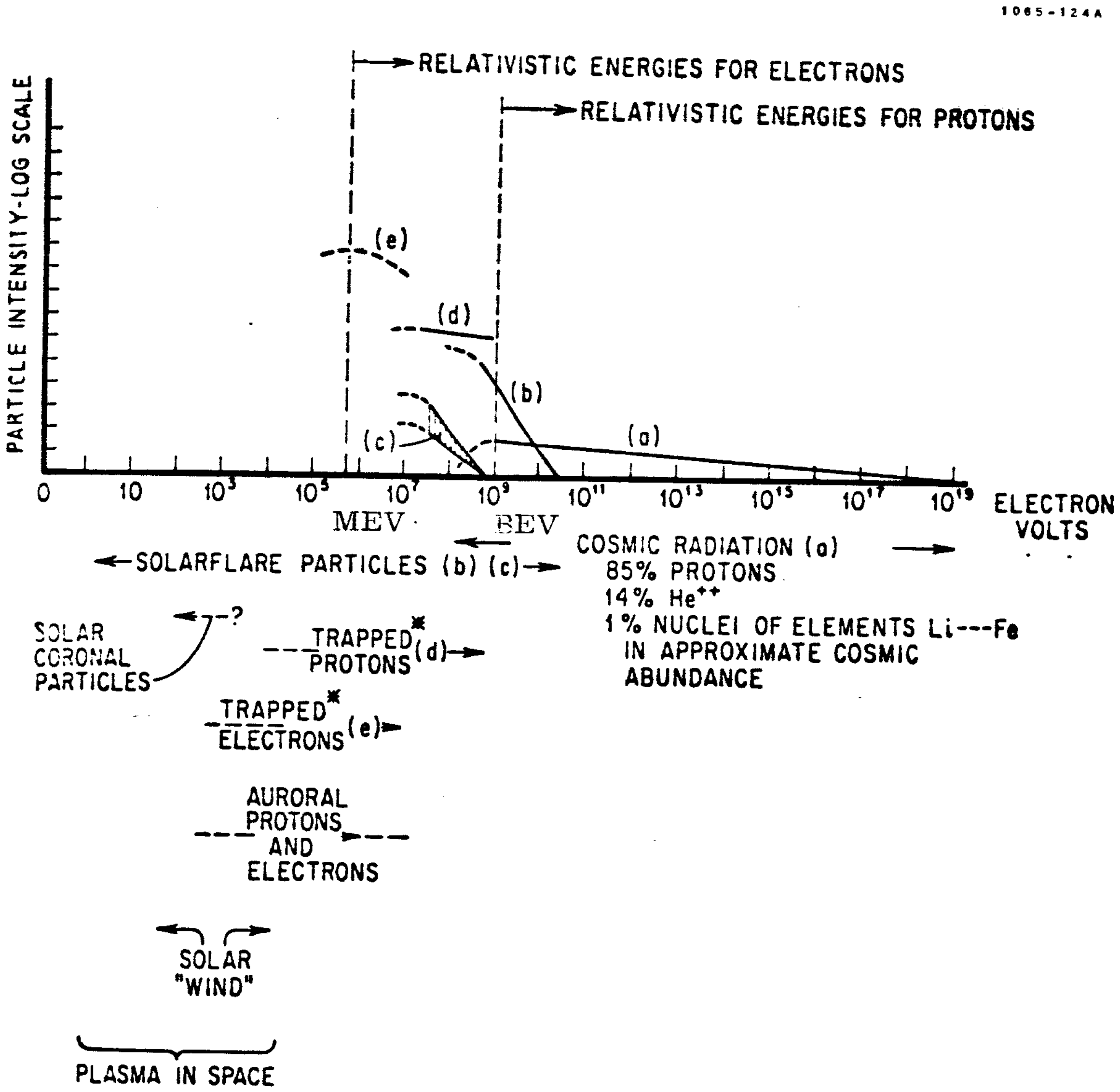

FIGURE 3-18. SPECTRA OF ENERGETIC PARTICLES OBSERVED IN THE SOLAR SYSTEM

Dash lines indicate unknown extension of the spectrum; asterisk denotes trapping in the geomagnetic field (some of these particles are from neutron decay). (Ref. 41)

3.2.5 The General Magnetic Field

Geophysical phenomena such as radio wave absorption, magnetic storms, and auroras are a reflection of the effects of energetic charged particles arising from the sun and entering the earth's magnetic field. These energetic particles are themselves affected by the interplanetary magnetic fields. Recent theories indicate that these fields are stretched lines from the sun, embedded in the corona of the sun and radially transported out by fluxes of charged particles. The source of these fields naturally lies in the sun. The sun itself is a turbulent state of plasma wherein the existence of magnetic fields seems to create a profound relationship between it and observed solar activity.

Finally, recent increased awareness of electromagnetic forces acting in conjunction with the classical mechanical forces in shaping our solar system gives models on "the origin of the solar system" greater functional scope and provides more plausible and realistic mechanisms. Whether the present magnetic fields in the sun and extending to its outermost boundaries of the solar corona is a relic of a past state of magnetization or is actively maintained cannot be answered as yet, but the investigation of these fields may provide some day the clues for the "archaeological" findings regarding solar and planetary origin, formation, and evolution.

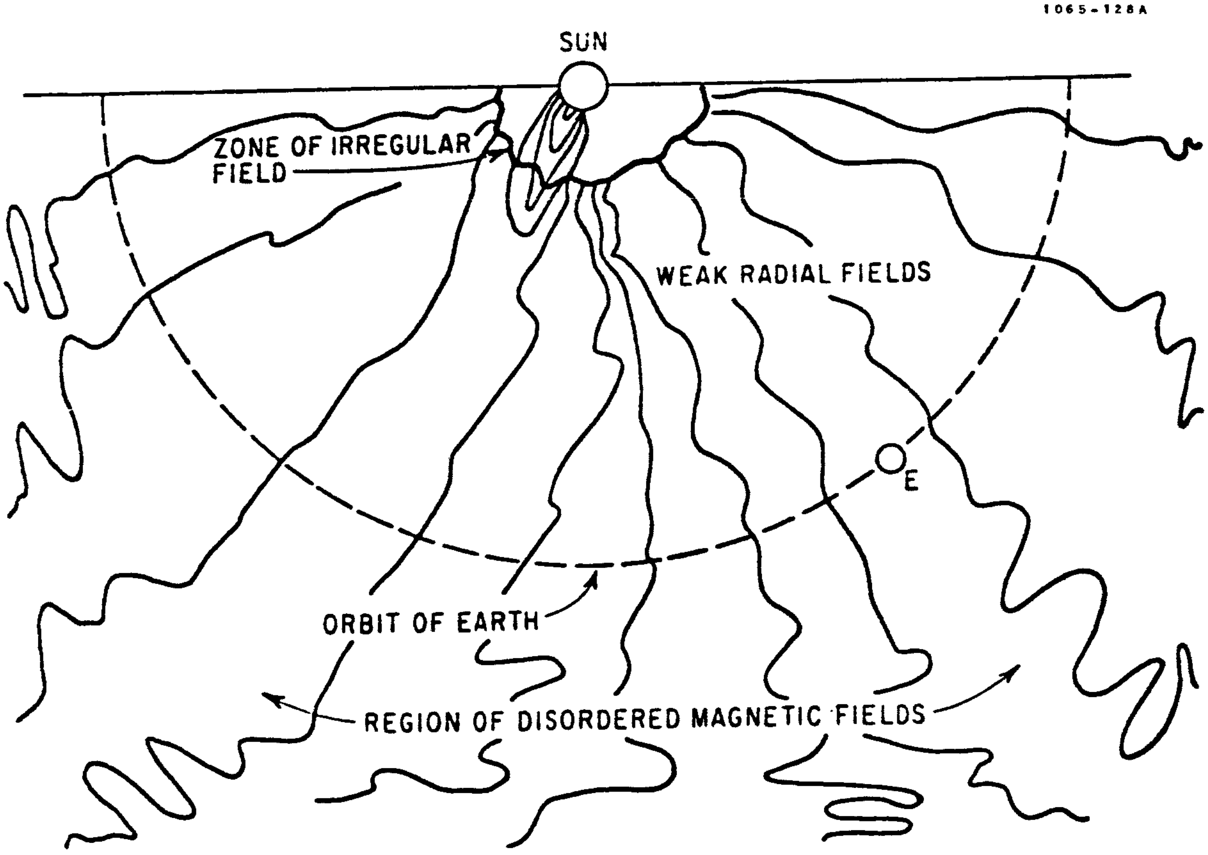

FIGURE 3-19. THEORETICAL MODEL OF THE SUN'S GENERAL MAGNETIC FIELD (REFERENCE 63)

3.2.5.1 Map the General Magnetic Field of the Sun

The Sun's general magnetic field has poloidal and toroidal components. The poloidal component is a few gauss in magnitude or less. The toroidal component is assumed to be submerged and is parallel to the solar equator. This toroidal component presumably accounts for visible features of solar disturbances. During the past sunspot cycle, it has been observed that the poloidal field polarity is cyclic with a period of twenty-two years, i. e., the same as the sunspot cycle.

The solar fields have been measured to-date by the magnetograph and by a photographic technique (Leighton method). Both of these methods look at the Zeeman split circularly polarized light.

Mapping, more accurate and for longer periods are required to describe poloidal and toroidal field interrelationship, determine obliquity of magnetic equator, explain what maintains the fields and what controls their intensity, motion and changes, and also what governs slow torsional oscillations of the Sun.

The possibility of carrying magnetic observations of the sun through a larger spectral window without the interfering action of the earth's atmosphere may lead to improved measurements. Orbital or satellite stations are assumed. The spatial distribution, extent, rotation of the general magnetic field of the sun and its temporal variations require investigation. Heliocentric probes inclined at various angles to the ecliptic may make such measurements in situ.

3.2.5.2 Map the Disturbed Magnetic Fields On and Around the Sun.

The highly ionized gaseous material of the sun is strongly coupled to the magnetic field within and around the solar plasma. The local magnetic fields in sunspots may range from a few hundred to as much as 4000 gauss, and their perturbations in the sun's general magnetic field are of interest.

Magnetic fields originating at the sun stretch to the outer boundaries of the corona and into interplanetary space. The mapping of temporal and spatial variations of the magnetic fields in interplanetary space is important for the investigation of fluid motions and a better understanding of interplanetary space. Correlation of the disturbed fields with the local magnetic field and with other solar activities--flares, X-ray emission, radio emission and corpuscular radiation--are essential to the understanding of solar dynamics.

The measurements may be made by analysis of electromagnetic radiations from ground or satellite based stations, or they may be made in situ by probes and spacecraft using magnetometers.

The study of local magnetic fields on the sun is not included in this task, but their effect on the general magnetic field is included.

3.3 EXPLORATION BEYOND THE SOLAR SYSTEM

This section describes the tasks of interest to scientists concerned with studies of the universe beyond the solar system, as related to the capabilities provided by space flight. For a number of years, these will be largely confined to extensions of classical astronomy and the new astronomies by utilizing space platforms or the lunar surface as a base for better observations of extra-solar system space, rather than actual probes for outside the solar system.

3.3.1 Size, Shape and Mapping

Overcoming the atmospheric limitations imposed on astronomical observations opens the way to increased reliance on non-optical astronomies as well as an extension of optical capabilities. This Field of Interest is concerned with locating additional celestial objects by the use of extended optical, extended radio, and the X-ray and Gamma ray astronomies, and determining the distance and velocities of celestial objects with a view toward a better understanding of the size, shape and distribution of objects of the universe. It does not include the use of these primarily to determine the composition of known objects or interstellar mediums.

3.3.2 Planetary Systems Investigations

The existence of other planetary systems is presumed, and is supported both by the presence of "dark twin" stars which are identified by their perturbation on their luminous twin, and by the fact there is no known or suspected reason for our solar planetary system to be unique. The confirmation and description of other planetary systems would be of interest to science in confirming the non-uniqueness of the solar system, and to enhance the probability and direct the search for extraterrestrial intelligence.

3.3.3 Composition of Masses

The use of non-optical astronomies will add to our knowledge of the chemical composition and temperatures of celestial objects, hence improve our understanding of the origin of the universe and stellar evolutionary processes. Since much of the radiation as well as Fraunhoeffer spectroscopic lines are in the UV portion of the spectrum, the availability of this information is very important. Additional RF bands, not available through the atmosphere, are also of use in determining temperatures.

3.3.4 Composition and Characteristics of Interstellar Space

There exist several general fundamental observations regarding cosmic rays which have led scientists to speculate about the origin of cosmic rays and the mechanisms of their acceleration. These observations are:

- The existing discrepancy between the measured relative abundances of cosmic ray particles of different masses and the relative abundances of elements in the stars.
- The energy spectrum of cosmic ray particles trailing up to 10^9 ev or greater.
- The essential isotropy of these particles.
- The kinetic energy density and the kinetic energy flux of cosmic ray particles being respectively approximately the same as the energy density and energy flux of starlight.

Although the origin of cosmic ray particles is the more speculative, two fundamental conclusions have been arrived at to date:

- Primary cosmic rays are stored in galaxies or parts thereof by magnetic fields in galaxies but the storage mechanisms are leaky.
- Acceleration mechanisms are electromagnetic but not electrostatic or nuclear. The Fermi mechanism is to date the most attractive, if it can be worked out.

Thus, it is seen that the association of cosmic ray particles and magnetic fields--extragalactic, galactic, interstellar, and stellar--play a most important role in the physics of the universe which consists solely of particles (largely a plasma) and fields (largely magnetic).

To date information regarding magnetic fields in the universe is still scant--and greatly needed. Measurements and observations are needed to give the theoreticians the necessary clues for (1) constructing their models of the universe and (2) theorizing the evolution of the universe as a whole and that of its parts in particular.

3.3.4.1 Map Galactic Magnetic Fields.

Evidence for interstellar magnetic fields is based on i) theoretical interpretation of observed polarization of starlight, ii) the Zeeman effect on the 21 cm radio line of hydrogen, and iii) observation of synchrotron radiation.

All three methods have established that the field within our galaxy are a few microgauss for the radiation emanating from the galactic halo, and an order of magnitude larger for the radiation from the galactic disk. Observation of extra-galactic radio sources for Faraday rotation of polarized synchrotron radiation has been used for estimating direction of galactic fields.

Large scale magnetic fields permeate the galaxies and seem to play a major role in the structure and evolution of these galaxies. The magnetic fields and angular momentum in the interstellar medium carry a large store of the energy of the universe. Both the angular momentum and the magnetic fields are considered important factors associated with stellar formation, rotation, and stellar magnetism. The continued recycling process between interstellar gas and stars necessitate the understanding of magnetic fields and associated phenomena for furthering cosmological studies.

The mapping of magnetic field in galactic or interstellar space is recent. The methods call for refined techniques of telescopic observation, both optical and radio.

3.3.4.2 Map Distribution of Radio Sources in the Sky and Their Associated Magnetic Fields.

A large segment of observed radio sources are distant galaxies similar to ours. Other sources are: i) exploding cosmic matter, or structures in motion emitting synchrotron radiation, ii) quasi-stellar radio sources, and iii) stars generally of type A and early F, and in relatively fast rotation. (Figure 3-20).

Quasi-stellar sources have diameters one or two orders of magnitude smaller than a typical galaxy. Their characteristic red shifts indicate high recession velocities ($\rho = 0.15$ to 0.30) and large distances of the order of a billion light years. Their nature and time variation characteristics are unknown. Whether they consist of gas or developed stars is uncertain, and so is their source of energy and their connection with theories of the evolutionary forms of the universe. The existence of magnetic fields in quasi-stellar sources are conjectured.

Observation of stellar flare and magnetic activity is not an uncommon phenomena. Hypotheses similar to ones explaining solar activity have been advanced for certain stars. Field strengths ranging from a low limit of observability of 200 gauss to fields exceeding 3000 gauss have been measured. Temporal variations in the magnetic field have been observed, but proposed explanations are different from the suggested mechanisms on the Sun. Magnetic stars providing an injection source of fast charged particles into the interstellar accelerating mechanism has been proposed. It also appears, however, that the data available on the subject of flares and fields are scant. Improved measurements and their time variation and correlation with stellar characteristics, brightness, spectrum, etc., are desirable for a better understanding of cosmological processes.

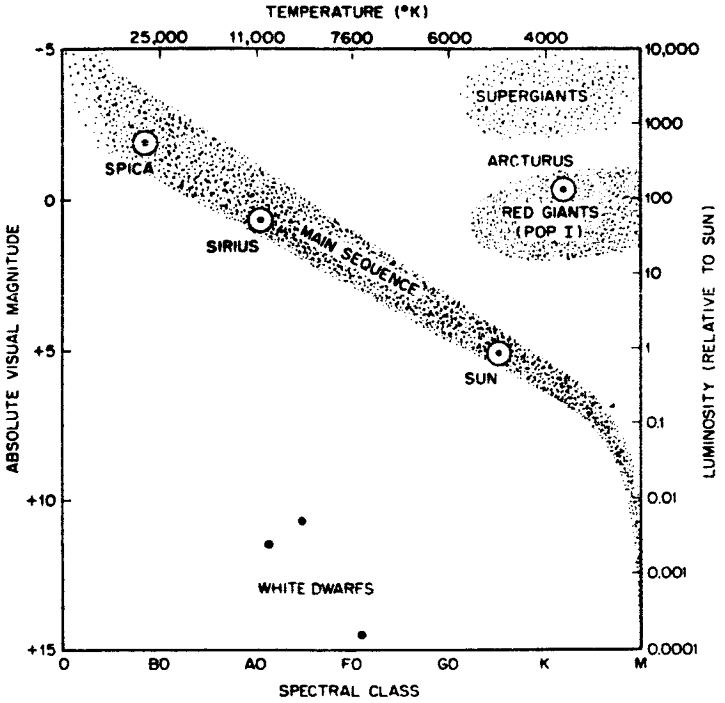

FIGURE 3-20. SIMPLIFIED REPRESENTATION OF THE HERTZSPRUNG-RUSSELL DIAGRAM (REF. 23)

TABLE 3-1. CHARACTERISTIC FEATURES OF SPECTRAL CLASSES

Class	Main Spectral Lines
O	Ionized helium, nitrogen, oxygen, and silicon; hydrogen weak.
B	Neutral hydrogen and helium; ionized oxygen and silicon; ionized helium absent.
A	Hydrogen strong; ionized magnesium and silicon; ionized calcium, iron, and titanium begin to appear; helium absent.
F	Ionized calcium (Ca II) strong; some ionized and neutral metal atoms (iron, manganese, chromium, etc.); hydrogen weak.
G	Ionized calcium strong; neutral metal atoms increasing and ionized forms decreasing; molecular bands of CH and CN appear.
K	Neutral metal atoms (including calcium) strong; molecular bands stronger; hydrogen very weak or absent.
M	Neutral metal atoms very strong; TiO bands appear.
R-N	Similar to K and M, but molecular bands of CH, CN, and C_2 strong; TiO absent.
S	Neutral metal atoms strong; oxide (ZrO, LaO, YO) bands strong.

Exploding galaxies and expanding nebulae have been hypothesized. These models have provided interpretation for astronomical data, e.g., duality of galactic radio sources, prescription of age of young stars in a nebulae, etc. Detailed and precise magnetic field measurements of these celestial objects to date are few.

3.3.4.3 Measure the Charge Composition and Spectrum of the Galactic Cosmic Rays as a Function of Time and Space.

The cosmic radiation is of interest to astrophysicists for the following reasons: a) they contain in relatively few particles, an appreciable fraction of the energy in the astronomical environment, b) they apparently come from distant as well as from local sources and traverse interplanetary and interstellar media, and c) their abundances are among the most accurately determined of cosmic material. Since the cosmic rays are modulated by solar plasma streams in the interplanetary medium, they can be used as probes to investigate the spatial extent of such streams as a function of time in the solar cycle. It is suggestive from cosmic ray studies that solar plasma streams reach out to about 100 A.U. before their energy density becomes comparable to that of the interstellar field. Measurement of the charge composition and spectrum beyond this point would therefore be more representative of the source except for the influence of interstellar and intergalactic fields and matter. Deep space studies of the charge composition and spectrum of the cosmic radiation besides probing modulation fields might investigate the quantity of matter traversed by the radiation between two points in space. Since all known possible sources of the cosmic radiation are poor in lithium, beryllium and boron, the abundance of these elements in the radiation at a point in space is an indication of the number of grams per square centimeter of matter which has been traversed by the primary beam since leaving the source.

3.3.5 Extra Solar System Biology

During the next twenty years most of the space biology studies will be directed at determining whether life exists outside the earth, whether such life must have the same biochemistry and other features common to earth forms, and whether life can be transported from planet to planet by panspermia.Most of these studies will be contained within the solar system, and most of the solar system studies will be directed at the Moon, Mars and Venus.

Two areas of investigation, however, may involve experiments in space during this time period: intragalactic panspermia and communication with extra solar system intelligence.

3.3.5.1 Search for Intragalactic Panspermia

If the existence of solar system panspermia is proved (transportation and survival of living spores from planet to planet), it will then be of great interest to determine whether intragalactic panspermia can occur, thus possibly relating life forms of the solar system with extra-solar system life.

3.3.5.2 Communication with Extraterrestrial Intelligence

It appears almost certain that no extraterrestrial intelligent life exists in the solar system. It appears equally certain to some scientists, based purely on probability calculations, that there must be many bases of intelligent life in the universe. The U.S. project OZMA was a brief attempt to listen for intelligent signals, and it is known that the Soviet scientists agree on the probability of life in the universe (Ref. 42). The 21 cm wave length is favored as being the most "natural" but by no means the only wave length for extraterrestrial communication. Information already has been coded in such a way that it can be translated by a totally alien intelligent culture. Continuation of such work will probably be done from radio telescopes on the earth's surface but additional portions of the EM spectrum will become available from earth orbiting and lunar observatories, and longer continuous listening periods from lunar observatories.

While success is discouragingly improbable in the near future, such work can be an inexpensive corollary of radio astronomy and its significance, if successful contact can be established, is overwhelming.

Just as an emerging nation on earth benefits by contact with civilized universities, libraries, and scientific societies, so our culture could benefit by contact with an extraterrestrial civilization which, if it is able to establish contact at all, must most likely be far in advance of our own (the "step capability" theory).

The relevance of this task must reflect not only its significance, but the degree to which space concepts would add to earth-based efforts.

3.4 RELEVANCE OF THE TARGETS OF SPACE EXPLORATION

For the time period through 1985, the following targets of scientific interest were selected for this study:

The Sun
Earth
Moon
Mars and its satellites
Venus
Mercury
Jupiter and its satellites
Saturn and its satellites
Comets and Asteroids
Extra-solar system

In determining relevance, several things should be kept in mind. The groupings are targets of scientific interest, not necessarily operational areas. In many cases the scientific tasks can be performed only by in situ experiments. In other cases an orbiting observatory or a lunar observatory will supply the information. A radio telescope on the backside of the moon, for instance, will be aimed at the "EXTRA SOLAR SYSTEM" target, not at the moon.

Another point is that "scientific interest" is rather conservatively defined for this purpose. Any interest in a target for direct practical utility will be treated elsewhere. "Possible" future applications is, of course, a valid, perhaps even the most relevant, reason for scientific interest. Therefore, scientific interest for possible space flight applications is acceptable here, but known problem areas will be treated separately under "technology deficiencies." Thus, any scientific interest in micrometeorite density mapping must be for more abstract reasons than danger to space flights, as this is an identifiable technology deficiency.

This section discusses the reasons for scientific interest in the selected targets and what space operations can contribute.

A list of scientific tasks under each field of interest for each of these targets is included in Appendix B.

3.4.1 The Sun

Goldberg and Dyer (Ref. 41) summarize the relevance of the Sun as a space science target:

"The Sun is a typical member of the family of stars in which energy production takes place in the core, but in which the conversion of hydrogen into helium has not progressed far enough to introduce profound changes in the structure. This family appears on the Hertzsprung-Russell diagram (plot of luminosity versus spectral type or surface temperature) as the main sequence. Luckily for stellar astrophysics, the Sun is an average sort of star, occupying a central position in the distribution of main-sequence stars according to luminosity and surface temperature, radius, mass, and perhaps even relative age. This fact gives the astrophysicist a good deal of confidence in extending theories derived from solar studies toward the two extremes of bigger, brighter stars and smaller, fainter ones.

"Furthermore, the Sun is tremendously important from the standpoint of astrophysics because it is the only star that can be examined in considerable detail from a relatively close distance. Other stars are so remote (the nearest is 300,000 times as far as the Sun) that they appear as optical point sources, and only the integrated starlight from their disks is received on the Earth. In the case of the Sun, however, which appears about 1/2 degree in diameter, it is possible by existing techniques to resolve details smaller than 1 second of arc. Details two or three orders of magnitude smaller are easily observable from above our lower atmosphere.

"Naturally the scrutiny, analysis, and correlation of the detailed features of the visible surface of the Sun and its extended outer

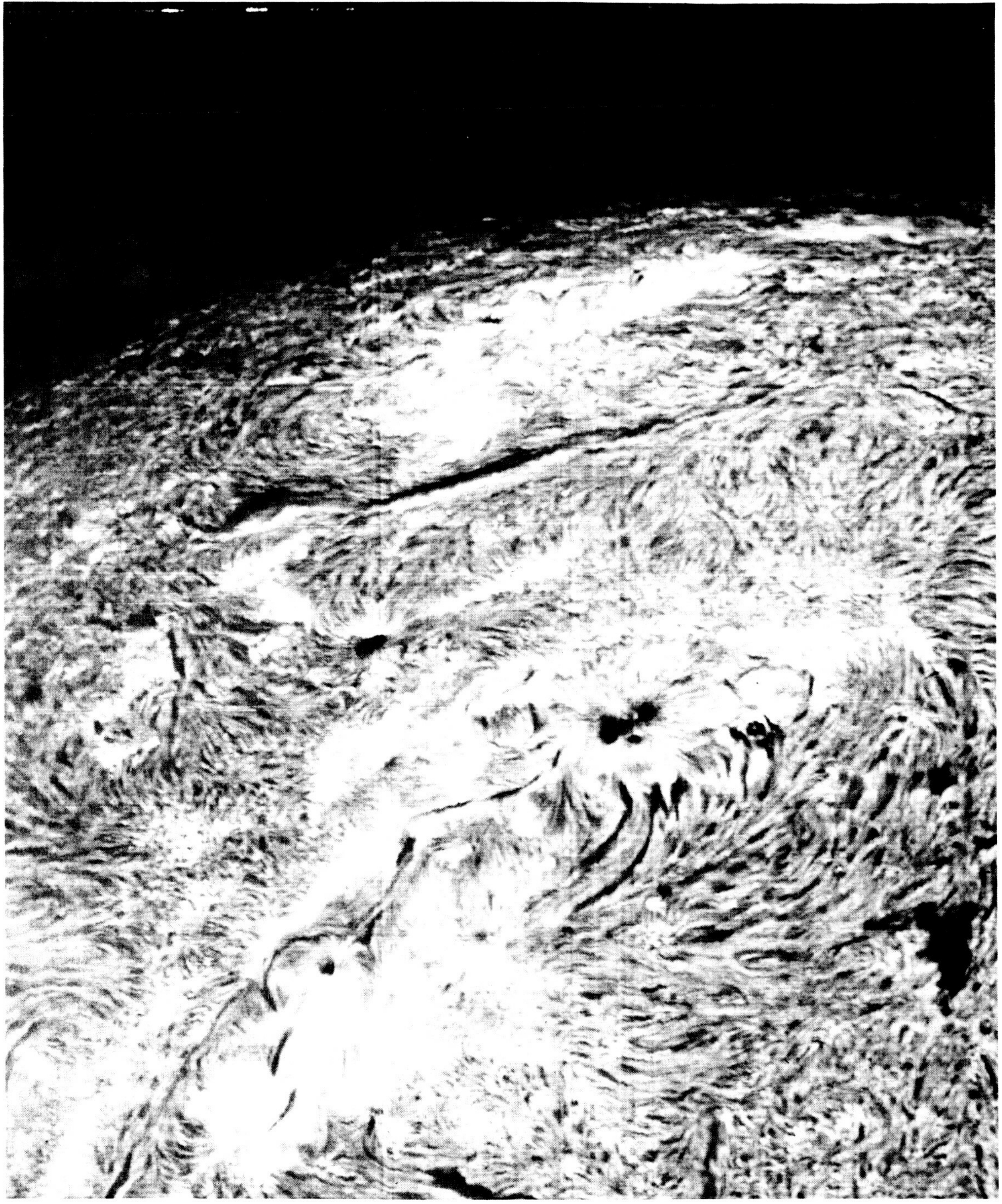

FIGURE 3-21. THE SUN PHOTOGRAPHED IN RED LIGHT OF THE HYDROGEN α LINE
(Mt. Wilson and Palomar Observatories)

atmosphere yield vastly more data than does integrated light for the formulation of theories about energy production, transfer, and conversion and for the formulation of models for the interior and atmosphere. Despite the Sun's proximity, however, the amounts and types of data that have been secured till now with earth-bound instruments are inadequate for the solution of most of the basic solar problems. Extension of the range of observation to cover the entire electromagnetic spectrum and the elimination of bad seeing caused by the Earth's atmosphere are likely to fill the most important gaps in our knowledge."

In particular, the heretofore unavailable information in the UV, X-ray and long-wave radio frequencies and in charged particles that do not penetrate our magnetosphere is expected to add greatly to our understanding of solar activity.

To this can be added Glasstone's comments (Ref. 23):

"Furthermore, the Sun is responsible for many of the phenomena on Earth, including the maintenance of life. Long-range climatic changes, such as the occurrence of glacial periods, and also relatively short-range variations in weather, are probably related in some manner to the energy received by Earth's atmosphere from the Sun. In addition, magnetic storms, capable of disrupting long-range radio communication, and auroral displays, commonly visible in the polar regions, are associated with solar events.

"As a consequence of developments in space exploration, there are additional reasons for needing to know more about the Sun. At all times, the Sun emits electrically charged particles which travel millions of miles into space. These particles constitute a potential health hazards to human beings but, as a general rule, the space vehicle will provide ample protection. There are certain periods, however, when the Sun is especially active and the spacecraft must be designed to allow for such situations. More knowledge is needed about the factors that determine the Sun's activity and the magnitude of the hazard in order that steps may be taken to protect space travelers. On Earth and in satellites orbiting Earth at moderate altitudes, the terrestrial magnetic field prevents direct access of the electrically charged solar particles."

Radiation from the Sun as a whole is only very slightly variable. But the radiation from localized regions or in restricted frequency ranges is extremely variable, and this variability is associated with activity in the solar atmosphere in the form of sunspots and sunspot groups, prominences, flares, etc. In astrophysical studies of the Sun, it is useful to make a distinction between those that refer to the "quiet" and the "active" Sun. The terms "quiet" and "active" were originally introduced by radio astronomers to contrast the radio behavior of the Sun during periods of solar activity with that in the absence of activity, but they now also serve more generally to distinguish the normal Sun from its disturbed regions. (Ref. 41).

The scientific tasks which have been identified for the exploration of the Sun are listed on pages B-3 through B-7.

3.4.2 The Earth

The relevance of the earth as a target of scientific interest cannot be disputed. But most of information that scientists want to know about other planets which requires space flight is readily available in the case of the earth without spacecraft. The question of relevance then is based on scientific interests to which space flight can make a contribution.

Life may not be unique to the earth, but it is the only place known to intermingle water, air, and land, making a life zone possible. Most scientific tasks in the field of biology have been assigned to the R&D Labs section of the UTILIZATION OF SPACE, hence are excluded from the tasks under the target EARTH.

This intermingling of water, air, and land, however, also provides unparalleled variety of atmospheric phenomena which include clouds and weather, the dynamic ionosphere, aurora, airglow, whistlers, and a variety of other sun/atmosphere effects.

Also, the earth is the only small planet with a magnetosphere. Its ability to trap solar radiation particles and form a radiation belt was a major discovery of the early space age. There is much more to do to understand this phenomena--the distribution of various types of particles in the belts, the shape of and characteristics of the elongated tail of the magnetosphere, and the frontier where solar particles meet the magnetosphere.

Space flight will assist in detailed mapping of the earth's gravity field which in turn will provide clues to composition. Direct observation from satellites will also contribute to studies of the composition and characteristics of land and ocean areas.

The scientific tasks which have been identified for the exploration of the Earth are listed on pages B-8 through B-11.

3.4.3 The Moon

The importance of lunar studies is stated by Glasstone (Ref. 23):

"The prospect of investigations by means of instrumented spacecraft and by manned expeditions has made the study of the Moon one of the most important current aspects of space science. Telescopic observations extending over a period of more than three hundred years have revealed the general characteristics of one side of the lunar surface and in recent years photometric, radar, and other techniques have provided information on some details. But there are few aspects of the Moon's origin, history, and structure concerning which there is general agreement among scientists. Moreover, there is little hope that the controversial issues can be resolved without direct access to the Moon. The photographs taken from the Ranger spacecraft in 1964 and 1965 have clarified some points, but there are still many questions that remain unanswered. When more is known, however, of the chemical and mineral composition, physical characteristics, and distribution of the lunar material, both on and below the surface, the situation may well undergo a spectacular change.

"Among the bodies of significant size in the solar system, the Moon is probably one of the few that have preserved many of the basic features of their past history. The factors which produce changes on Earth's surface, namely, erosion by the atmosphere (wind) and by flowing water, are virtually or completely absent from the Moon. The appearance of the lunar landscape, with the numerous craters in many areas, indicates that there has been little large-scale distortion of the surface as a result of tectonic (deformation) activity such as has led to the formation of the mountains on Earth.

"The Moon's surface has undoubtedly disintegrated to some extent under the continuous impact of small meteorites and perhaps as a result of the action of cosmic (including solar) radiations. The effect of such bombardment would be expected to be greater than on Earth because the virtual absence of an atmosphere on the Moon would mean that the meteoroids are not slowed down and the radiations are absorbed to a minor extent only. On the whole, however, the changes, other than those produced by large meteorites, are relatively minor. Consequently, many of the existing broad features of the Moon are probably more than four billion (4×10^9) years old."

The origin of the moon is uncertain. Is it a passing body that "somehow" was captured by the earth? "Capture" has been suggested too casually by people who should know better. Dr. Urey (Ref. 43) says that capture requires a very special set of circumstances, indeed. Was the moon once a part of the earth that was torn off, perhaps by a near pass of a giant body? Or was it formed simultaneously with the earth? The estimated density (3.34 gm/cm^3) is much less than that of the earth (5.52 gm/cm^3), which casts doubt on the latter two theories. Again, Urey says that all theories of the origin of the moon are improbable.

Lunar phenomena of interest include:

- the apparent difference in topography of the backside as compared with the front
- suggestions of outgassing from craters
- the inability to distinguish between volcanic and meteoric craters, or even to know which is most common
- red spots of short lifetime around crater edges
- hot spots over the entire visible surface of the moon

- its triaxial shape, where the equatorial axis pointing toward the earth is longer than the equatorial axis normal to that
- its dimensions indicate the moon is not in hydrostatic equilibrium, suggesting either a very strong composition or extremely unhomogenous one.
- the ratio of the moon's mass to that of the earth (1:81) is unprecedented in the entire solar system

As the first extraterrestrial body to be subject to in situ exploration (with the exception of meteorites), the moon will provide the first opportunity to look for extraterrestrial organic compounds. Further, it is believed that a detailed study of the lunar surface not only will provide information concerning the history of the moon itself, but also that of the earth and important clues relating to the origin of the solar system.

The scientific tasks which have been identified for the exploration of the Moon are listed on pages B-12 through B-16.

3.4.4 Mars and its Satellites

Outside of the Sun, Earth and Moon, Mars is the best known body in the solar system. It is conspicuous and has been studied since antiquity. It is the only planet known to have a transparent atmosphere. It has received more concentrated attention than any other planet.

Mars is the only planet with a possibility of life similar to that found on earth. This fact is probably the most important reason for the exploration of Mars. The value in determining the existence of extraterrestrial life and in comparing it with life evolved on earth is very significant to biology, which discipline has developed right up to the threshold of fantastic breakthroughs affecting all mankind.

The phenomenology of Mars is well known. To summarize:

- it has three distinct surfaces--polar ice caps, dark maria, and bright desert
- the maria change color seasonally, from gray-green in summer to gray-brown in winter
- desert areas retain a constant bright orange-red
- that the maria may be living matter is supported by spectral, photometric, and polarimetric evidence (Ref. 44)
- large yellow clouds move across the surface, suspected of being duststorms
- smaller white clouds appear at higher altitudes
- an invisible blue haze in the ultraviolet spectrum often prevents radiation in the blue, violet, and UV region from reaching earth. When the haze clears up, it does so almost simultaneously all over the planet.
- canals--apparently in regular networks, change seasonally. They have been observed by eye only; no photographic

confirmation has been made, and there is not unanimous agreement of their existence. Prominent astronomers have stated that they have not personally seen the canal phenomena.

- the contradiction between the optically-observed and the dynamically determined oblateness which might mean a large equatorial band of very light material. The dynamically-determined value agrees generally with the figure based on hydrostatic equilibrium.

Many of these phenomena will be understood only after on-site exploration of the planet. Other information can be gained by non-landers. For example, the spectroscopic absorption bands of nitrogen are in the UV wavelength. Therefore, although the Martian atmosphere is suspected of being largely nitrogen, scientists are unable to determine the amount of nitrogen present from earth surface observations.

The first successful Mars probe, Mariner IV, shook up generally accepted views of the Martian surface. Festa (Ref. 45) says that the finding that Mars' surface is moon-like was one of the biggest surprises in space science.

No doubt there will be others.

Mars' two satellites, Phobos and Deimos, are of interest because they are the smallest known planetary satellites in the solar system (6 Km and 3 Km radius), comparing with the group of outer four satellites of Jupiter. Phobos is so close to the planet (9,000 Km) that its orbital period is less than Mars' polar rotation rate--the only such situation known.

The scientific tasks which have been identified for the exploration of Mars and its satellites are listed on pages B-17 through B-21.

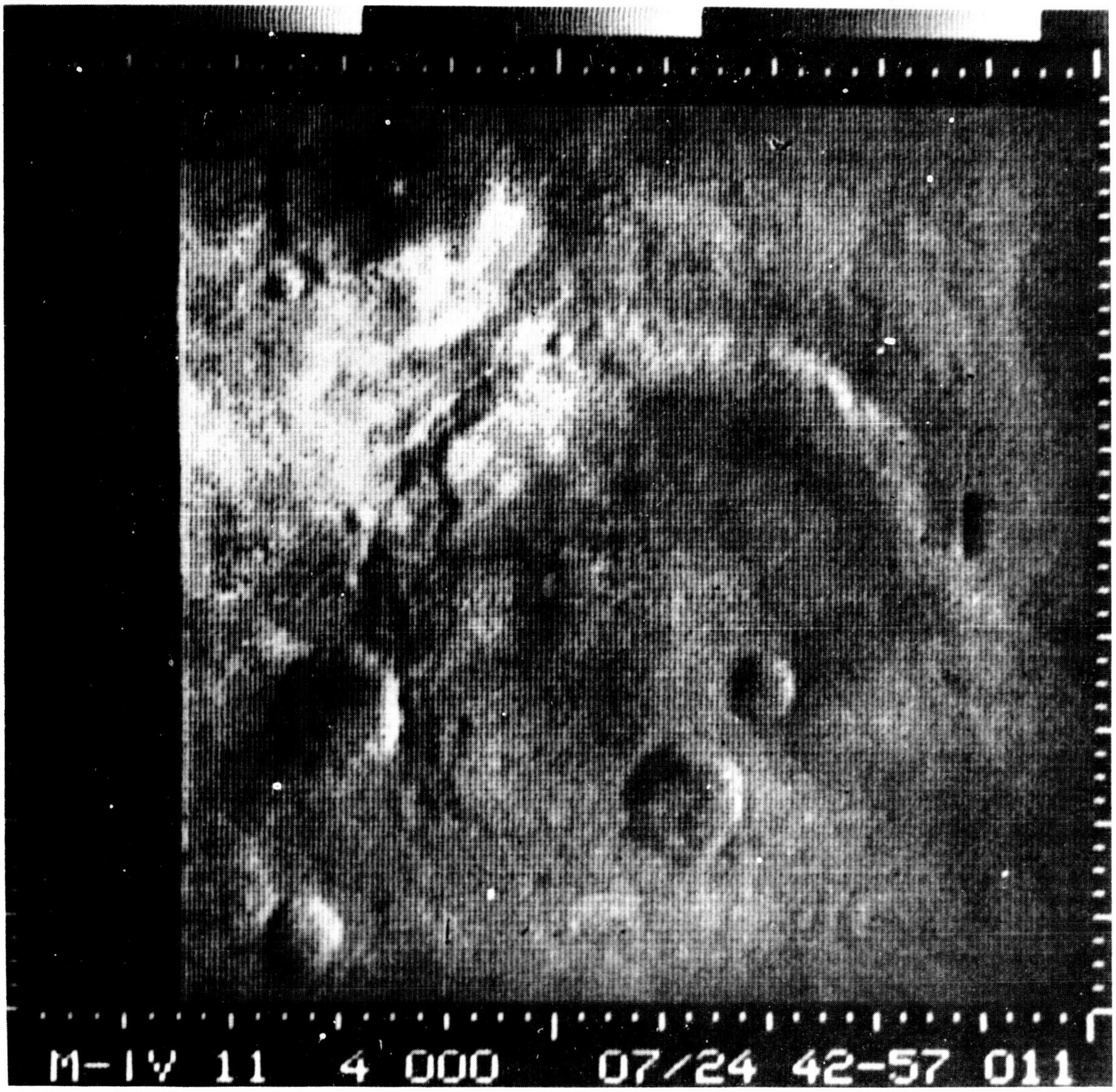

FIGURE 3-22. MARINER IV PHOTOGRAPH OF MARS NO. 11
(Courtesy Jet Propulsion Laboratory)

3.4.5 Venus

Venus is covered by dense clouds at all times; its surface has never been seen. It has the highest albedo (0.85) of any planet (Ref. 21). Its surface is very conjectural. It is generally agreed to be smooth, either all ocean or all arid terrestrial soil. The latter hypothesis is most likely, especially in view of the Mariner II findings that surface temperature is about 800°F on both sides of the planet. Infrared mapping of the upper atmosphere temperature (Figure 3-23) shows no change in temperature across the terminator: the day/night dividing line.

Strong (Ref. 16) has found water vapor in the Venus atmosphere, and hypothesizes heavy snowfall at night to account for even temperatures around the globe. This could be verified by space probes.

At any rate, temperature measurements at different wavelengths do not agree.

Various models have been proposed for the Venus atmosphere to account for the range of temperature determination. Mariner II findings serve to support the aeolosphere model (Ref. 46.) which suggests the higher temperatures originate at the surface and are caused by the friction of high winds.

The atmosphere contains cloud-like formations which can only be seen in the ultraviolet.

Not being able to detect the surface of Venus by optical means, some attempts to measure its rotation rate by short wave electromagnetic radiation have been made. Results are inconclusive since the rotational axis may not be orthogonal to the ecliptic.

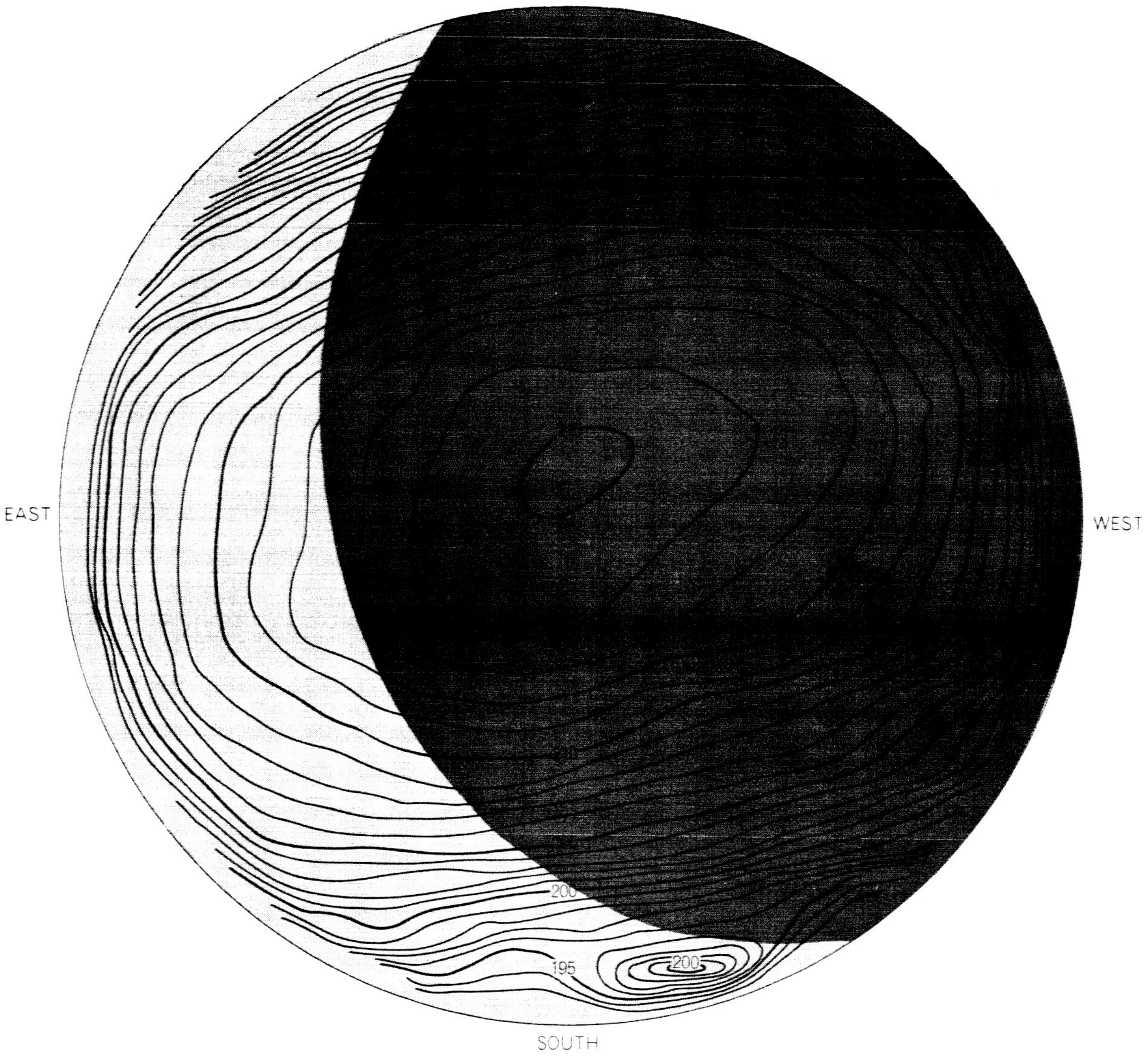

FIGURE 3-23. VENUS ISOTHERMAL CONTOURS (IN DEGREES KELVIN) OF THE UPPER ATMOSPHERE

(Ref. 48)

The Soviets have determined a period of 9 or 11 days but Mariner II gave a period of 230 ±50 days (Ref. 47). Radar observations from JPL and Arecibo produce a period of 245 ±5 days, with retrograde rotation (Ref. 14, 15). If so, it is the only planet in the solar system with retrograde rotation.

Venus is not known to have satellites of its own. Its polar axis has been defined to ±6° by radar. The surface features of Venus are being mapped by radar from JPL's Goldstone radar telescope. Evans, of MIT's Millstone Hill radar, says that the Venus surface appears to be rock (Ref. 49).

The scientific tasks which have been identified for the exploration of Venus are listed on pages B-22 through B-26.

3.4.6 Mercury

Mercury is the smallest of the planets; comparable in size to the four largest moons. Its orbit eccentricity (0.206) and inclination (7°) are the largest in the solar system, except for Pluto's eccentricity. It is very difficult to observe (being the innermost planet, when it is closest to the earth it is dark, when it is light it is behind the sun, and it is never more than 28° from the sun--when maximum elongation occurs at aphelion). For this reason, and that it has no known satellites, its size and mass are poorly known, and its orbital parameters are least well known of all inner planets (Ref. 25).

It has a very high density--about the same as the earth's, which is unusual because if the composition of Mercury were the same as the earth, its density would be considerably less due to the smaller diameter.

Its surface is clear, and Mercury probably resembles the moon in surface features and surface elevations. Its very low albedo (0.06) is almost identical to the moon's.

The rotation of Mercury was long "known" to be trapped--that is, it kept the same face to the sun. On this basis, there was considerable interest in the fact that its hot side must be very hot (775°F at perihelion) considering the low albedo and proximity to the sun, and the cold side very cold.

It would therefore present both the hottest and possibly one of the coldest surfaces of any planet. Also, the terminator (day/night line) would be relatively stable, providing a permanent band of any temperature between the two extremes. But the recent Arecibo radar findings (Refs. 20, 50, 14) of a period of 59 ±3 days means that Mercury does not keep the same face to the sun.

This changes the relevance of scientific interests in Mercury and raises the possibility that Mercury may be much younger than previously thought, or it would have "trapped" rotation.

Due to this slow rotation, Mercury probably has no magnetic field. Due to its weak gravity, it is unlikely to have much of an atmosphere, though H_2 captured from the sun is possible.

Space flight experiments are important to the study of Mercury because of the observational difficulties of seeing a planet close to the sun. Space probes face severe problems, however: the energy requirements, the orbit inclination, and the high temperatures near the sun (0.4 A.U.).

Radar studies from MIT's Millstone Hill observatory have produced accurate range measurements which revise the position of Mercury in its orbit.

The scientific tasks which have been identified for the exploration of Mercury are listed on pages B-27 through B-31.

3.4.7 Jupiter and its Satellites

Jupiter is of especial interest because of its position as "gateway to the major planets", because of its satellites, and in its own right.

Jupiter is the largest planet in the solar system. Its volume could contain all the other planets. It is the nearest of the group of outer or major planets which differ markedly from the inner or terrestrial planets because of their large mass and light density. Jupiter's density, for example is 1.3 gm/cm^3 compared to the earth's 5.5 gm/cm^3. It has the largest family of moons--12--of any planet, and the fastest rotation period--$9^h 50^m.5$.

The planet is an important source of three types of radio waves, each with distinct interest:

- centimeter length--thermal radiation
- decimeter length--attributed to either synchrotron radiation (from trapped electrons at relativistic energy levels) or cyclotron radiation (from trapped electrons at non-relativistic energy levels)
- decameter length--which remain unexplained. These are characterized by short bursts, appear to be inversely correlated to solar activity, and resemble lightning on earth except they occur at fantastic energy levels on the order of 10^9 times lightning on earth. The source of such high energy is an important question.

The decimeter radiation indicates Jupiter has a very strong magnetic field. If the source is synchrotron radiation (which is the favored view) the strength of magnetic field at the poles is computed to be 5 gauss, compared with about 0.7 gauss for that of the earth. The possibility of it being cyclotron radiation is not ruled out; this would mean a field strength of 1000 gauss.

The main emission originates at the equatorial region, about three planetary radii altitude.

The magnetosphere of Jupiter extends four times as far as the earth's in terms of their own planetary radii, but due to the reduced level of plasma received, the field is five times weaker at the magnetopause than the earth's.

Phenomena of interest at Jupiter include:

- color-banded structure of the cloud layer, reason unknown
- hot shadows of satellites Ganymede and Europa. Thermal emission in the 8 - 14 micron region was found to be enhanced by 60°C. Later, during a passing of the satellite Io, no enhancement was found, suggesting a time relationship (Ref. 51)
- the Red Spot--most famous of Jupiter's phenomena, is a large relatively stable red discoloration of the atmosphere extending 25,000 miles x 18,000 miles. It has been suggested that it is a rising column of atmosphere deflected upward by a single large topographical prominence on the Jovian surface.

Jupiter's moons hold a number of points of interest. For one thing, the grouping (Figure 3-25) shows three clusters with distinct characteristics. With the exception of V, the inner group are all large and the two outer groups small. Ganymede (III) is the largest satellite in the solar system, and is larger than the planet Mercury. Because of its size, Ganymede may have an atmosphere.

The inner group have essentially zero orbit inclinations while the outer two groups have inclinations around 20 to 30 degrees. The inner two groups have posigrade orbit revolution, the outer group has retrograde motion. The semimajor orbital axes of the second (middle) group are very similar and that of the outer group are also similar, suggesting each group may have originated from a single body.

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FIGURE 3-24. JUPITER PHOTOGRAPHED IN BLUE LIGHT
SHOWING GANYMEDE AND ITS SHADOW
AND THE LARGE RED SPOT
(Mt. Wilson and Palomar Observatories)

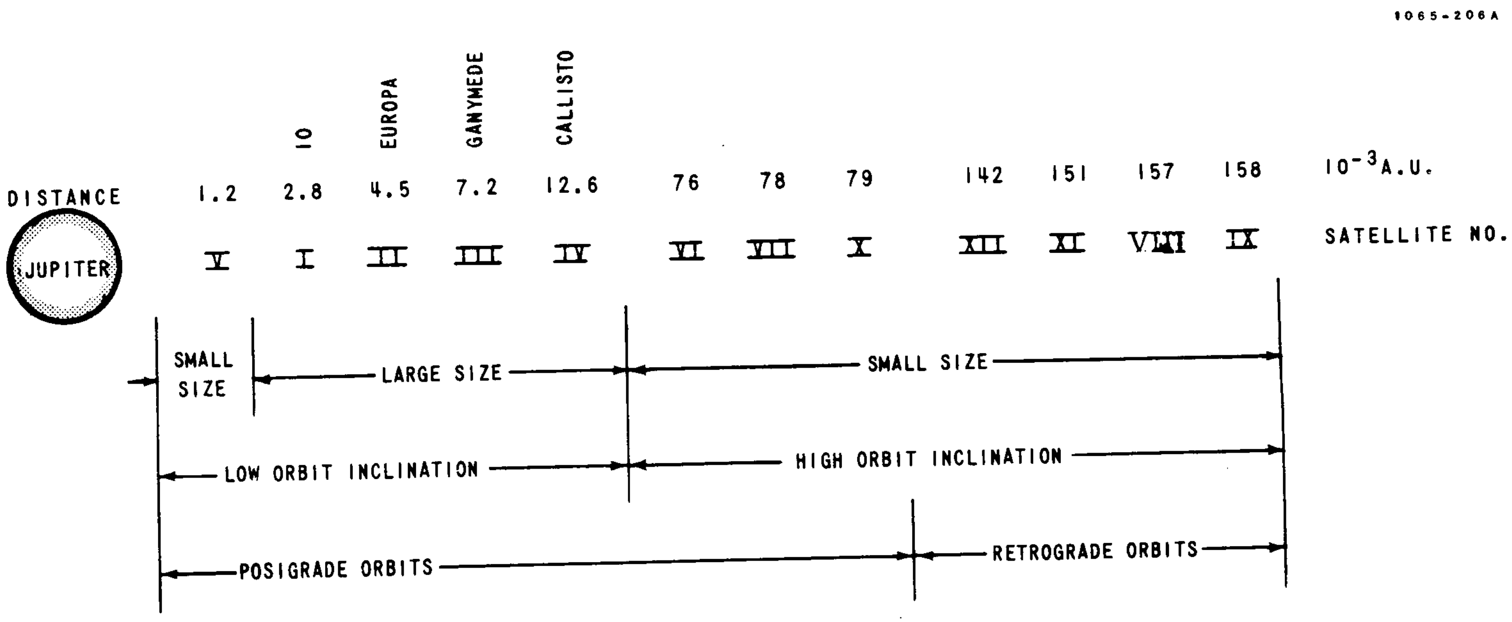

FIGURE 3-25. GROUPING OF JUPITER'S SATELLITES

Direct surface landings, particularly manned ones, on Jupiter are unlikely for a long time due to the large surface gravity (2.6 times that of earth) and dense atmosphere. Ganymede, because of its large mass and nearness to Jupiter, has been suggested as a base for manned exploration. Dr. Block of the University of Sweden (Ref. 52) cautions that the Jovian magnetosphere probably extends 40 planet radii in the solar direction and the five inner satellites would all be in the radiation belt. Unfortunately, the two outer groups are all small satellites and very far from the planet.

Because of its low density, the surface of Jupiter may be poorly identified.

The scientific tasks which have been identified for the exploration of Jupiter and its satellites are listed on pages B-32 through B-36.

3.4.8 Saturn and its Satellites

Saturn has a tremendously thick atmosphere, and a density less than water. Two characteristics are of especial interest: its extremely thin rings are the only such phenomena in the solar system. Their origin is not understood. One of its nine known moons--Titan--is the second largest (next to Ganymede) in the solar system. It is considerably larger than the other Saturn moons.

Titan may turn out to be the most interesting satellite in the solar system: not only because of its size, but it is the only satellite known to have an atmosphere. Its orange color is not explained.

Another satellite, Iapetus, is of interest because its albedo varies, suggesting a surface compositional difference in its two hemispheres. Phoebe is the only Saturn satellite with a retrograde orbit.

Decimeter radio emission from Saturn suggests synchrotron radiation, hence a radiation belt, hence a magnetosphere. A magnetosphere is strongly indicated (Ref. 52) but the radiation belt may not be significant due to the reduced level of solar particles reaching Saturn's orbit. Polarization of the radiation indicates the interesting possibility that the magnetic axis may be at right angles to the axis of rotation, though other explanations are possible.

The scientific tasks which have been identified for the exploration of Saturn and its satellites are listed on pages B-37 through B-41.

3.4.9 Comets and Asteroids

Comets are commonly pictured as spectacular celestial objects (Fig. 3-26) with brilliant heads, and long luminous tails extending across the sky. However, by far the greatest number of known comets are relatively faint, and many apparently do not have tails. The peculiar and unusual properties of comets are manifested in their reactions to solar radiation as they approach the perihelia of their orbits. At small distances from the sun large amounts of dust and gas are liberated as the nucleus of the comet becomes heated. This material is repelled by solar radiation and is lost to the comet, and thus, one must conclude that the lifetime of a comet which periodically approaches close to the sun must be limited. Indeed, more than one comet has been observed to disintegrate into several fragments during its perihelion passage. Most of the observable comets today are faint telescopic objects which do not have a tail and do not exhibit an appreciable coma of nebulous matter about their heads. It is conceivable that these less spectacular objects may have been forced to divest themselves of their volatile constituents over a period involving many perhelia passages.

The residual matter lost by comets may exist for a considerable time in solar orbit. It has been shown that the bodies which are responsible for certain copious meteor showers move in the same orbits as certain comets. Examples are the August Perseids which move in the same orbit as Comet 1862 III, the Leonids moving in the orbit of Comet 1866 I, the April Lyrids identified with the orbit of Comet 1861 I, and orbit of the November Andromedids identified with that of Biela's comet.

The cometary fragments or dust associated with these meteor showers is of such small size that none survive atmospheric attrition, and do not reach the surface of the earth. Thus, a distinction between a

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FIGURE 3-26. HEAD OF HALLEY'S COMET
(Mt. Wilson and Palomar Observatories)

meteorite and a meteor may be the fact that a meteorite is an object supposedly of asteroidal origin which may survive atmospheric attrition, and impact the surface of the earth in the form of an iron, stony iron, or stone, while a meteor is usually of cometary origin, and disintegrates in the atmosphere. However, the Tunguska meteorite which impacted (or exploded before impacting) in Siberia in 1908 is thought to have been a comet. No recognizable fragments have ever been recovered.

Another peculiar property of comets is concerned with mass. These objects, although very large, have such small masses that they have no measurable perturbative action on other bodies. Estimates place the upper limit of cometary mass to be less than 10^{-5} that of the earth. This low mass factor coupled with the volatile properties exhibited by close approach to the sun has led to the "dirty snowball" concept of cometary structure. This concept holds that a comet consists of a nucleus of frozen gases, liquids, and particles of "dust". The cohesive forces holding this conglomeration together are weak, thus the comet loses matter quite easily as described previously.

These processes of attrition and deterioration have led to a classification of "old" and "new" comets by Oort (Ref. 53). Old comets are those with short period orbits which have lost most of their volatile material after having spent considerable time near the sun. New comets are those that have recently been forced into short period orbits from their positions in the vast Oort cloud of comets thought to surround the solar system at distances extending out to 200,000 AU.

Whipple (Ref. 54) states:

"In general, any satisfactory theory of planetary evolution must simultaneously explain, or allow for a satisfactory explanation of, cometary origins. Conversely, a continued study of comets and meteoritic material may provide the basic key to an understanding of planetary origin."

Whipple further states that a space probe made to land on a cometary nucleus could provide much information regarding the nuclear structure:

"Cores of the nucleus should be stratified like geological sedimentary strata and should give the oldest and least disturbed material record of ancient processes."

Further cometary investigations should include spectrophotographic studies of atmospheres, photographs, and chemical and radiographic studies of samples returned to earth.

In the PATTERN format, the cometary core or nucleus is treated under "Composition"; the coma is treated under "Atmosphere and Ionosphere"; and the tail is treated under "Magnetosphere and Radiation Belts." "Geodesy" of a comet covers photography and determination of mass; "biology" covers the search for spores and organic compounds, possibly originating from outside the solar system.

Investigations of asteroids and asteroidal particles should involve photographic studies as well as the capture and return to earth of uncontaminated samples which should be subjected to chemical, petrological, geological, mineralogical, and radiological studies.

Asteroids or minor planets are small objects that revolve around the sun, most having orbits that lie between the orbits of Mars and Jupiter. A few, thought once to have been Jovian satellites, orbit around the sun at the stable Lagrangian points of Jupiter's orbit. The largest asteroids are Ceres, Palla, Vesta and Juno which have diameters ranging from 488 miles for Ceres to 118 miles for Juno.

There is some speculation that the asteroids are the remaining fragments of a planet which once existed between the Jovian and Martian orbits, particularly since they occupy a position which calls for a planet in Bode's empirical rule of planetary spacing. However, this is unlikely, since the total estimated volume of this interplanetary debris is less than one-twentieth that of the moon.

The mean distances of the known asteroids range from 1.29 (Hermes) to more than 5 AU. The perhelia of Adonis, Apollo, and Hermes are within the orbit of Venus, and that of Icarus within the orbit of Mercury. Some asteroidal orbits pass close enough to the orbit of the earth so that occasionally one is captured, falling to the earth as a very bright fireball or meteorite. These meteorites are the only recognizable extraterrestrial objects which we had acceissible to laboratory investigation to date. Knowledge gained from the analysis of meteoritic material has an important bearing on problems related to the cosmic abundances of the elements, the origin of the asteroids, and the age and origin of the solar system. Due to the meteors or asteroidal particles captured in space, we would be provided information on composition and structure which is destroyed during earth entry.

"Free ride" on asteroids. One occasionally hears of the advantages of "hooking onto" an asteroid or satellite whose orbit is attractive to space operations, such as the highly elliptical orbit of Icarus ($e = .827$, $i = 23°$) whose perihelion is only 0.19 AU, or Hidalgo, whose aphelion extends almost to Saturn's orbit (Figure 3-27) or one of the moons as a base for observation of its planet. This scheme is not as attractive as it sounds because it requires the same energy to land on an asteroid or moon as it does to inject into that body's orbit. Hence there is not only no "free ride" but the scheme imposes a rendezvous and docking requirement, a limited launch opportunity and inflexibility in the orbit. If exploration of other targets from a satellite or asteroid has merit, it is because

- its mass offers a stable (though generally rotating) base for absorbing instrument torques
- it provides a chance to "get out and walk around" for astronauts
- it provides a larger target for rendezvous operations of several cooperative operational flights
- it provides raw material of use in operations

The scientific tasks which have been identified for the exploration of comets and asteroids are listed on pages B-42 through B-46.

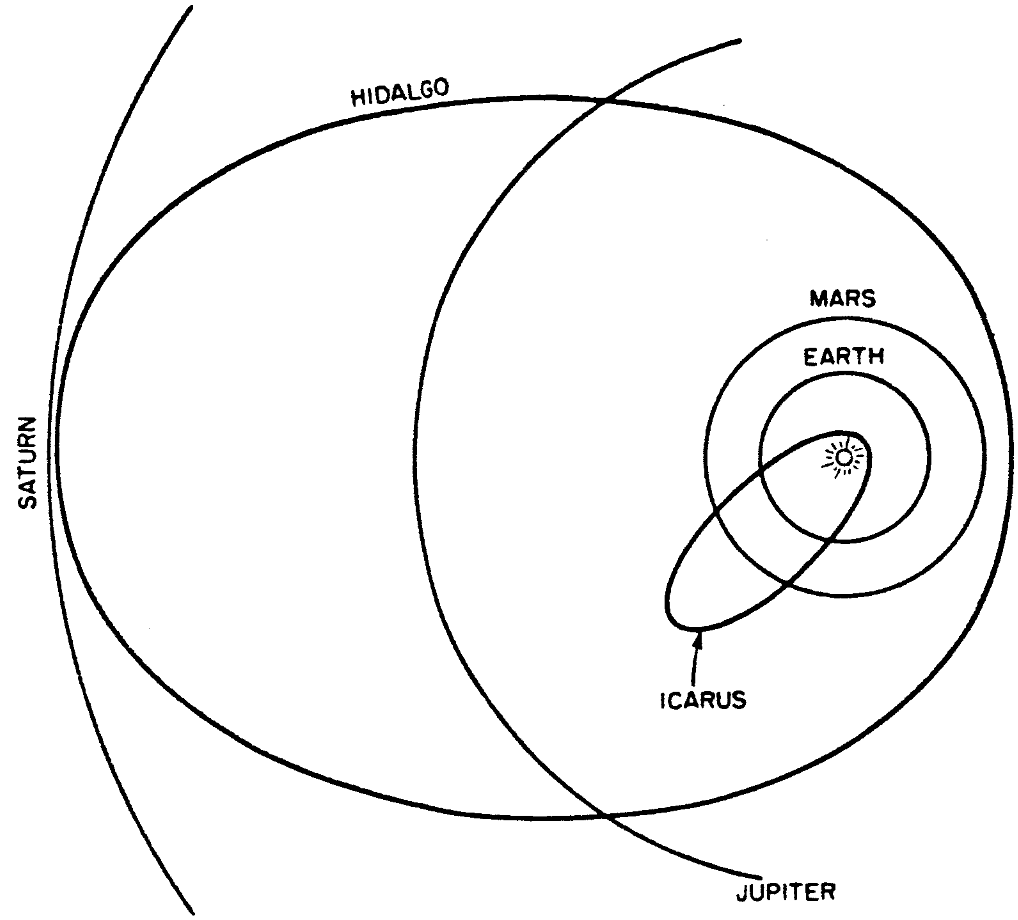

FIGURE 3-27. ORBITS OF THE ASTEROIDS ICARUS AND HIDALGO RELATIVE TO THE ORBITS OF THE PLANETS (REF. 23)

3.4.10 Extra-Solar System

Actual probes far beyond the solar system are not expected for many years, but space flight can contribute to the exploration of the universe in several ways.

The new non-optical astronomies that have emerged very recently--radio, IR, UV, X-ray, Gamma ray, and neutrino--are essentially extensions of the spectrum of photons that carry different amounts energy. The earth's atmosphere is not responsible for late development in all of these areas; neutrino astronomy must be carried out underground, and radio astronomy from the earth's surface is already an important field. But other portions of the radio spectrum, and ultraviolet, X-ray, and Gamma ray astronomy are dependent on balloons or space flight to get the observing equipment above the atmosphere. And even astronomy in portions of the spectrum which pass through the atmosphere will benefit from higher resolution and less noise on space or lunar bases.

The non-optical astronomies have each contributed significant new knowledge by supplying additional characteristics about celestial bodies already known, and in discovering the presence of new celestial bodies, even entirely new types of bodies and phenomena. One of the most revolutionary is the quasi-stellar source (quasar), discovered by radio astronomy, which are neither stars nor galaxies. They are particularly puzzling because of the enormous rate of energy emission, which is some five orders of magnitude higher than galaxies of comparable mass. (Ref. 23)

X-ray astronomy also has located sources not visible in optical or radio frequencies. X-rays may be able to provide information concerning local densities of electrons, temperatures, and magnetic field strength.

Gamma rays evidently come from outside the galaxy. Although the field is still in its infancy, it may shed light on extra-galactic sources and on the origin of the universe. (Ref. 55)

Ultraviolet astronomy is most promising. Not only has it also discovered new celestial sources, but it will add greatly to our knowledge of the composition of stellar sources, since many important spectroscopic resonance lines are in the UV region.

Space flight will also increase the resolving power of telescopes enough to permit resolving stars into disks for the first time. Greatly improved measurements of stellar distances can be made.

But possibly the most relevant interest in scientific exploration of the universe, though largely ignored by orthodox astronomers, is the search for extraterrestrial intelligence. No reason is yet known why life is unique to earth, but reasons are known why it probably has not developed to intelligent levels elsewhere in the solar system. Therefore, it appears very possible that it occurs in many places throughout the universe.

The scientific tasks which have been identified for the exploration of the extra-solar system are listed on pages B-47 through B-51.

4.0 UTILIZATION OF SPACE

Utilization of space includes all the applications of space flight for other than the exploration of space itself. It includes the practical tasks of commercial value, the government-sponsored services to man, and the use of the space environment to conduct research and development that cannot be done as well or at all on earth.

Spacecraft provide the opportunity to isolate specific physical effects in the study of terrestrial organisms. Space offers to biologists a completely sterile lab environment, variable g from zero to several g's, the absence of certain geophysical cycles, and the option of certain electromagnetic and particle radiations in huge doses. These features of space as a lab environment will greatly expand the opportunities for biological research.

Lindberg (Ref. 56) says, "I am not aware of a single environmental stimulus to which some form of life does not respond." It is important to determine the response to each stimulus.

For example, it is not known just what life processes rely upon gravity. Clinostat experiments (Ref. 57) have simulated zero to one-g environments for determining the threshold of growth sensitivity to gravity. Several plant processes are g-sensitive and have thresholds in the order of 10^{-5} g. The clinostat rotates the gravity vector but does not eliminate it. The non-linearities of gravity-sensitive life functions below 1 g are not well defined.

Also, attempts to study circadian rhythms by blocking all influence from natural cycles (the daily, monthly, yearly effects, etc.) are impossible in earth-based laboratories. Thus, it is not known which of these life cycles require natural reference or are self-contained, and which would adapt to new cycles.

Life may also respond to stimuli of which we are not aware, but will become aware of by their absence.

These tasks should be evaluated for their scientific interest and possible future application, including undefined space flight uses. Biological gasks which are defined as technology deficiencies in space flight will be treated in Volume III.

Voting the relevance of the targets and, to a lesser extent, the Fields of Interest in the utilization branch is somewhat abstract. The voter is advised to become familiar with the sort of utilization tasks that are included in the scope of each Target and of each Field of Interest. The relevance of the Field of Interest is the most meaningful decision; the breakdown of Targets is somewhat arbitrary, based on the particular characteristic of space flight which makes it useful:

- Relative Position
- Gravity Environment (zero to one g)
- Radiation Environment (both electromagnetic and particle radiation)
- Vacuum Environment and high velocity
- Material Environment from extraterrestrial sources

4.1 RELATIVE POSITION

This Target includes those Fields of Interest which can utilize the positional advantage of spacecraft for mapping, surveillance, communications, etc.

4.1.1 Communications

The positional advantage of space flight permits very low cost commercial communication satellites for telephone, digital transmission of business data, radio, and television. Government services to citizens and to foreign nations may be provided. This includes educational, technical, and information services with simultaneous transmission in many languages. Stationary satellites permit continuous coverage between points in the middle latitudes.

4.1.2 Intelligence and Data

A great amount of observational data is available from satellites. They have the advantage over aircraft in being able to cover a wider area more often, independently of weather or political cooperation. Military applications are not included in this Field of Interest.

Lowe (Ref. 58) suggests a number of uses of satellites for collecting intelligence and data:

- Map of world vegetation and forest inventory
- Forest fire detection
- Forest disease detection
- Agricultural crops survey
- Land use studies
- Oil and mineral location
- Mining and oil drilling activities survey
- Snow and water resources survey; flood prediction
- Remote population assessment
- Ocean current and sea state survey
- Fish resources survey
- Damage assessment

To which could be added:

- Iceberg tracking
- Shipping survey

and, of course, worldwide weather observation.

In agriculture alone, Lowe suggests that by proper identification of its radiation signature, the following features could be observed from space:

- soil identification
- soil temperature
- soil moisture
- frozen soil
- soil areal extent
- water vapor over vegetation
- forest maturity
- natural vs. cultivated vegetation

Resources management--the capability to detect depletion trends and the corrective action well in advance--is a promising aspect of data gathering from space.

4.1.3 Navigation Aids

The characteristics that satellite position can be precisely predicted, that they can pass over any area of the world, and that they can actively transmit radio signals permits satellite systems to make a unique contribution to low cost, world-wide, all-weather navigation. Due to the time between passes over a given area (for any reasonable number of satellites), air navigation probably will not benefit as greatly as marine navigation.

4.1.4 Biology

The opportunity to study life processes independent of the earth's rotation opens up the study of circadian rhythms. Biological rhythms are present in all living things. Many of these rhythms, because of their period, appear to be related to the geophysical cycles--the day (potassium excretion), the month (human ovulation), the year (animal ovulation), the solar cycle (vintage wines), are examples.

Earth laboratories have been able to partially exclude geophysical influence. The 24-hour light-dark cycle can be easily controlled, for instance, but work-rest cycle studies show that the best cycles are sub-multiples of 24 hours. "Physiological clocks" have been postulated--internal biological mechanisms that have evolved with geophysical influence but are capable of independent operation. Such a mechanism has not been satisfactorily identified. "Geophysical clocks" or cycles which regulate the "physiological clocks" are also a possible explanation.

Orbiting laboratories will permit isolation from certain geophysical cycles. Lunar laboratories will substitute others. Both will permit observation of the degree of dependence of biological rhythms to geophysical cycles.

Some lesser known biological cycles which supposedly have been empirically identified by the Foundation for the Study of Cycles, but which remain unexplained are (Ref. 59):

- A 37 1/2 hour time delay in human response to trauma.
- A 24-hour cycle in the color change of a fiddler crab. Cooling below 40°F will halt the cycle; warming will restart it at the phase where it left off.
- An 11-year "mass excitement" cycle involving wars and exploration.
- A 33-week intellectual and creative cycle.
- A 164-year cycle of world scientific activity which, incidentally, is scheduled to reach a peak again in 1973.

4.1.5 R&D Lab

Using the position advantage of a laboratory in space, long line-of-sight experimental work will become possible. This will include studies of electromagnetic transmission characteristics, particularly laser research, but also in wavelengths where atmospheric or ionospheric attenuation prevent long distance experiments on earth.

4.2 GRAVITY ENVIRONMENT

This Target includes the Fields of Interest which can make use of the weightlessness of orbital space flight and, by use of on-board centrifuges or a rotating space station, precisely controllable gravity in the range of zero g to one g, which is not available for more than a few seconds on earth.

4.2.1 Manufacturing

Utilizing the weightless environment of space flight for manufacturing purposes may take the form of orbiting space stations where precision assembly of very small parts, and assembly involving small amounts of liquids may be found to be much easier in a weightless environment, either by skilled workmen or by automatic tools.

4.2.2 Biology

Until recently, all knowledge of biological systems has been based upon observation of organisms which have evolved and live in a one-g field. Zero-g clinostat experiments have helped identify some gravity-referenced functions, particularly plant growth. It is important to a basic understanding of life processes to identify all processes which are influenced by gravity, to find the threshold sensitivity and to plot the processes as a function of the magnitude of gravity.

Among such processes of interest and significance are:

- the role of g at the microbiotic level in influencing chemical kinetics and exchange processes
- the behavior of chromosomes and other cellular constituents in cell division during prolonged zero-g
- the influence of zero-g on growth rate
- the influence of zero-g on mutation rate
- the influence of zero-g on cellular transport phenomena

These effects are of considerable interest. Many biological processes could be markedly changed, for instance, as soon as surface tension becomes much larger than g forces (Ref. 36).

4.2.3 R&D Labs

The utilization of the zero-g environment of space for R&D work is especially attractive in fluid studies. Fluid flow, behavior of mixed fluids in zero-g, and surface tension studies will all benefit from laboratories in space as well as zero-g chemistry and crystal growth.

4.3 RADIATION ENVIRONMENT

The Fields of Interest which can utilize the wide electromagnetic spectrum and charged particle radiation from the sun are included here. In the electromagnetic spectrum, the intense ultraviolet radiation which does not reach the earth's surface is of particular interest. In the charged particle category, the Van Allen belt provides radiation of electrons and protons in the 5 to 50 ev and in the 100 Kev to 10 Mev range. In addition, solar plasma and galactic cosmic rays are more abundant than on earth.

4.3.1 Manufacturing

Polymerization of plastics has been consideres as a possible utilization of the radiation environment of space for manufacturing purposes.

4.3.2 Biology

The radiation environment in space provides an opportunity to study the biological effects of exposure to radiation of quality, intensity, and duration unavailable on earth. Resistance to such exposure has implications in space flight; mutations produced by radiation are of interest in developing useful products. Most of our presently useful foods and domesticated animals are the result of biological mutations.

4.3.3 R&D Lab

The use of space as a laboratory to take advantage of the radiation present will center principally around nuclear physics--the study of the charged particles in the earth's radiation belt, and the characteristics of cosmic rays from a basic physics point of view.

This Field of Interest includes only the use of space to study charged particles--the study of the radiation belts themselves, and their dynamic mechanisms has been treated in Section 3.1.4.

4.4 VACUUM AND VELOCITY ENVIRONMENT

The space vacuum of some 10^{-12} torr, and consequently, speeds up to 8 Km/sec (in earth orbit) provides opportunities for application and for research and development of particular interest to vacuum applications in the unlimited volume and the high "pumping speed", or ability to maintain vacuum in the presence of outgassing.

The vacuum environment also permits velocities unavailable in the atmosphere, permitting eventual point-to-point transportation of mail, cargo, and passenger traffic.

4.4.1 Manufacturing

Manufacturing in space in order to use the large vacuum available, is usually assumed to mean manufacturing in earth orbit or manufacturing on the moon. While costs to earth orbit are lower, the lunar surface may offer other advantages such as a stable base, longer day-night cycle, more comfortable for workers, etc. Much of the manufacturing in space may be for use in space exploration; other manufacturing may be of products to be returned and used on earth. In either case, a number of possibilities of vacuum manufacture have been suggested by Ruzic (Ref. 60):

- electron beam welding
- levitation melting
- vacuum cast alloys
- vacuum welds
- electron optical systems
- semiconductors
- microcircuitry
- precision optical components
- degassing
- freeze drying foods by sublimating ice in vacuum

4.4.2 Biology

The vacuum of space offers two important features to biology: a large contamination-free area, and a controllable atmosphere where precise amounts of gas may be introduced to the test area.

Most of the new drugs which have revolutionized the treatment of disease were developed in super sterile environments. Further, bacteria may be isolated and grown free from contamination more easily.

4.4.3 R&D Lab

The high vacuum and high "pumping speed" of space offer major exciting opportunities for research and development.

- Nuclear Transitions. There may be many individual atomic transitions which are masked by other effects in the laboratory. A typical example is the electron spin flip transition responsible for the hydrogen radio line which cannot ordinarily be seen because of the long lifetime of the upper state.
- Adhesion of deposited materials is inhibited by atmosphere, or by the difficulty in operating in air vacuum chambers.
- Brilliance and purity of plating is limited by oxidation and contamination in the atmosphere.
- Vacuum welding of "cold" pure surfaces.
- Electron beam welding of dissimilar materials, even metals to ceramics, is possible.
- Materials surfaces and emission of electrons from materials.
- Vacuum tube technology. The ability to adjust mechanical part size and spacing while operating the tube in vacuum will speed up design of new large tube types such as Klystrons.
- Friction studies. Most friction coefficients inescapably include surface contamination effects. Pure surface-to-surface friction can be studied in large vacuums.

- Lubrication research - related to pure friction studies and surface tension studies, with space flight implications.
- Outgassing of materials - investigation of what gases are released by various materials and at what rate, with implications in space technology.
- Pure spectroscopy to detect weak Fraunhoffer lines and trace elements without atmospheric absorption and distortion.
- Vacuum Distillation.
- Heat transfer in the absence of atmospheric conduction and convection.
- Physical changes. Some unexpected changes in physical characteristics occur at vacuum pressures, such as the electrical conductivity of materials, dielectric strength. Graphite, for example, becomes abrasive below 10^{-6} Torr. The pressure in Torr at various altitudes and in space is shown:

Height in Miles	Pressure in Torr*
Sea Level	7.6×10^2
10	10^2
100	10^{-5}
1000	10^{-11}
Lunar Surface	10^{-14} (estimated)
Interplanetary Surface	10^{-16}

* 1 Torr = 1/760 atmosphere

4.4.4 Transportation

Development of aerodynamic controllable reentry vehicles, reuseable boosters, and higher reliability will permit regular commercial use of ballistic flight for intercontinental transportation of mail, cargo, and eventually passengers at flight times ranging around a half hour to one hour anywhere on earth. Present costs would be around $500 per pound, with estimated reduction to as low as $3 to $5 per pound by 1985, which would be comparable to present jet air transportation costs.

4.5 MATERIAL ENVIRONMENT

The accessibility of large extraterrestrial bodies opens the way for possible utilization of its materials. For a number of years, interest in utilizing the materials of the moon or a planet will center around indigenous applications for space exploration (such as protective shelters, water supply, etc.) and to a limited extent, recovery of rare materials. However, as space transportation costs are reduced, it will become more feasible to use extraterrestrial materials for manufacturing on the moon and even for return of materials for use on earth. Figure 3-28 shows the estimated reduction in the cost per pound of transporting materials from the earth to the surface of the moon.

4.5.1 Mining and Manufacturing

Colonization and exploration of the moon and Mars, at least, will take place sooner or later. Mining and manufacturing to utilize the materials available in space will largely center around use of the moon's surface materials, and to a lesser extent the materials of the colonized planets. For many years, most of the manufacturing and a large part of the mining will be for the purpose of supporting space bases and flights. However, some lunar materials may be needed on earth and if space transportation costs are reduced as much as Cole (Ref. 60) and Hunter (Ref. 61) forecast, bulk shipment of certain lunar processed materials and manufactured materials will become feasible. Which materials will be worth mining and using in manufactured products is not known at present, but based on expected findings and on known needs, the following have been proposed:

- derivation of water from lunar, Martian surface material (actual water and ice deposits are not ruled out, and volcanic rock contains 1% water)

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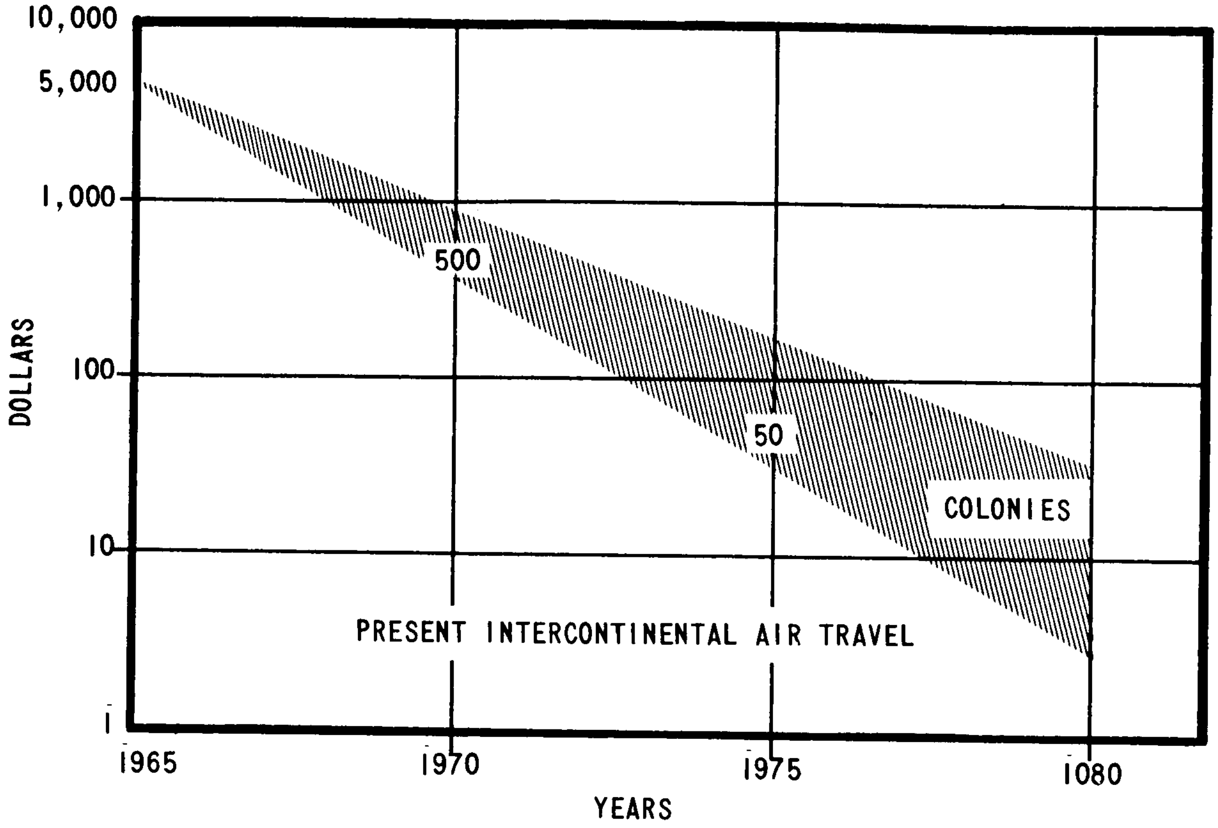

FIGURE 3-28. HYPOTHESIZED COST PER POUND - TRANSPORTATION TO THE SURFACE OF THE MOON (REFERENCE 60)

- derivation of H_2 and O_2 for breathing and for fuel from water
- derivation of O_2 from surface material (reduction of 2.6 tons of iron yields one ton of O_2)
- sulfuric acid from volcanic material
- propellants and fertilizers from sulfuric acid
- scarce radioisotopes

4.5.2 Biology

If extraterrestrial biological forms are discovered, it will certainly be of interest to determine whether they exist in the forms and quantities (or can be grown in quantities) which can be used for biological functions by space crews and base personnel. Such usage could range from waste disposal through food for lower forms. If higher forms exist, their capabilities for being trained and doing work will be exploited.

4.5.3 R&D Lab

Research and development using materials from space will include not only the surface materials from the moon and planets, but the materials of interplanetary space.

Actually, it is not expected that the surface materials of the moon and planets will contain much of interest to R&D work. However, the opportunity to use interplanetary space as a lab to study the wall-free fully ionized plasma is of interest.

The so-called vacuum of space is actually filled with a plasma composed mainly of hydrogen ions and electrons. The absence of walls containing this plasma permits the study of interactions in the plasma which are ordinarily indetectable because they are hidden by wall perturbations. An example of such an interaction might be the reaction between a plasma and photons. This sort of interaction has an extremely low cross section and is therefore quite difficult to see. Another example might be the study of low pressure plasmas. It is quite difficult to produce unperturbed plasmas of this sort because the mean free path of particles is often larger than the dimensions of the vacuum system. Space provides an ideal laboratory for this sort of study.

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APPENDIX A

Astronomical Reference Tables

PLANETARY ORBITS

Planet	Semi-major axis of orbit		Sidereal period		Synodic period	Mean daily motion	Mean orbital vel.	Eccentricity	Inclination to eliptic
	AU	10^6 km	Tropical years	Days	Days	''	km/s		° ' ''
Mercury	0.398 099	57·91	0·240 85	87·968 6	115·88	14 732·420 2	47·90	0·205 615	7 00 10·6
Venus	0·823 332	108·21	0·615 21	224·700	583·92	5 767·671	35·05	0·006 820	3 23 37.1
Earth	1·000 000	149·60	1.000 04	365·257		3 548·192 6	29·80		
Mars	1·523 69	227·94	1·880 89	686·980	779·94	1 886·518 6	24·14	0·093 312	1 51 01·1
Jupiter	5·202 8	778·3	11·862 23	4 332·587	398·88	299·127 8	13·06	0·048 332	1 18 31·4
Saturn	9·540	1 427	29·457 72	10 759·20	378·09	120·456	9·65	0·055 890	2 29 33·1
Uranus	19·18	2 869	84·013	30 685	369·66	42·234	6·80	0·047 1	0 46 21
Neptune	30·07	4 498	164·79	60 188	367·49	21·53	5·43	0·008 5	1 46 45
Pluto	39·44	5 900	248·4	90 700	366·74	14·29	4·74	0·249 4	17 10

PHYSICAL ELEMENTS

Planet	Semi-diameter (equatorial)		Radius (equatorial) R_e		Ellipticity $\frac{R_e - R_p}{R_e}$	Volume	Reciprocal mass (including satellites)	Mass (excluding satellites)	Density	Surface gravity		Escape velocity	Rotation period (equatorial)	Inclination of equator to orbit
	at 1 AU	at mean C or O								attractive	equator centrifugal			
	''	''	km	$\oplus = 1$		$\oplus = 1$	$1/\odot = 1$	$\oplus = 1$	$g\ cm^{-3}$	$cm\ s^{-2}$		km/s		° '
Mercury	3·34	5·45	2 420	0·38	0·0	0·055	6 050 000	0·054	5·4	360	-0·0	4·2	59^d	
Venus	8·43	30·5	6 100	0·96	0·0	0·88	408 600	0·815	5·1	870	-0·0	10·3	$245^d \pm 5^d$	23?
Earth	8·80		6 378	1·00	0·003 4	1·000	328 700	1·000	5·52	982	-3·39	11·2	23h 56m 4s·1	23 27
Mars	4·68	8·94	3 380	0·53	0·005 2	0·150	3 089 000	0·108	3·97	376	-1·71	5·0	24h 37m 22s·6	23 59
Jupiter	98·47	23·43	71 350	11·19	0·062	1 318	1 047·38	317·8	1·334	2 600	-225	61	9h 50m·5**	3 05
Saturn	83·33	9·76	60 400	9·47	0·096	769	3 497·6	95·2	0·684	1 120	-176	37	10h 14m***	26 44
Uranus	32·8	1·80	23 800	3·73	0·06	50	22 930	14·5	1·60	940	- 62	22	10h 49m	97 55
Neptune	30·7	1·06	22 200	3·49	0·02	42	19 100	17·2	2·25	1 500	- 28	25	15h	28 48
Pluto	4·1	0·11	3 000	0·47		0·1	400 000?	0·8?	*				6^d·39	

* Density of Pluto uncertain because of apparent discrepancy between radius and mass

** 9h 55m·4 for latitude > 12 degrees

*** 10h 38m for temperate zones

Satellites

Planet	Satellites	Distance from planet		Sidereal Period	Orbit incl.	Orbit Eccen-tricity	Radius	Reciprocal Mass	Mass
		10^3 km	10^{-3} AU	days			km	1/planet	10^{24} g
Earth	Moon	384	2·571	27·321 661		0·054 9	1 738	81·33	73·5
Mars	1 Phobos	9	0·062 7	0·318 910	1·1	0·021	6		
	2 Deimos	23	0·157 0	1·262 441	1·6	0·002 8	3	-	
Jupiter	1 Io	422	2·819 6	1·769 138	0	small	1 670	26 000	73
	2 Europa	671	4·486 2	3·551 181	0	and	1 460	40 000	47·5
	3 Ganymede	1 070	7·155 9	7·154 553	0	vari-	2 550	12 300	154
	4 Callisto	1 883	12·586 5	16·689 018	0	able	2 360	20 000	95
	5	181	1·207	0·498 179	0·4	0.003	70		
	6	11 470	76·70	250·59	28	0·158	50		
	7	11 740	78·47	259·7	26	0·206	10		
	8	23 500	157·20	737	33 R	0·40	10		
	9	23 700	158·5	758	25 R	0·27	8		
	10	11 850	79·21	255	28.5	0.135	7		
	11	22 560	150·83	692	16·5R	0·207	8		
	12	21 200	141·7	631	33 R	0·16	6		
Saturn	1 Mimas	186	1·240 4	0·942 422	1·5	0·020 1	300	15 000 000	0·04
	2 Enceladus	238	1·591 3	1·370 218	0·0	0·004 4	300	8 000 000	0·07
	3 Tethys	295	1·970 0	1·887 802	1·1	0·0	500	870 000	0·65
	4 Dione	377	2·523 0	2·736 915	0·0	0·002 2	500	550 000	1·0
	5 Rhea	527	3·523	4·517 50	0·3	0·001 0	700	250 000	2·3
	6 Titan	1 222	8·166 4	15·945 452	0·3	0·029 0	2 440	4 150	137
	7 Hyperion	1 481	9·893	21·276 66	0·5	0·104	200	5 000 000	0·31
	8 Iapetus	3 560	23·798	79·330 82	14·7	0·028 3	500	500 000	1
	9 Phoebe	12 950	86·58	550·41	30 R	0·163 3	100		
Uranus	1 Ariel	192	1·282 0	2·520 38	0	0·003	300	70 000	1·2
	2 Umbriel	267	1·785 9	4·144 18	0	0·004	200	170 000	0·5
	3 Titania	438	2·930 3	8·705 88	0	0·002 4	500	20 000	4
	4 Oberon	586	3·918 7	13·463 26	0	0·000 7	400	34 000	2·6
	5 Miranda	128	0·85	1·414		<0·01	100	1 000 000	0·1
Neptune	1 Triton	353	2·363 5	5·876 83	20·1R	0·0	2 000	750	140
	2 Nereid	5 600	37	360	27·5	0·76	100	3 000 000	0·03

PRINCIPAL METEOR STREAMS

H.R. = hourly rate visible by a single observer.

Stream	Maximum	Normal Period of Visibility	H.R.	Associated Comet
Quadrantids	Jan. 3	Jan. 2-4	30	
Lyrids	Apr. 21	Apr. 20-22	8	1861 I
η Aquarids	May 4	May 2-7	10	Halley ?
δ Aquarids	July 30	Jul. 20-Apr. 14	15	
Perseids	Aug. 12	Jul. 29-Aug. 18	40	1862 III
Draconids	Oct. 10	Oct. 10		1933 III, G.-Z.
Orionids	Oct. 21	Oct. 16-26	15	Halley ?
Taurids	Nov. 4	Oct. 20-Nov. 25	8	Encke
Andromedids	Nov. 10			Biela
Leonids	Nov. 16	Nov. 14-19	6	1866 I Temp.
Geminids	Dec. 13	Dec. 8-15	50	
Ursids	Dec. 22	Dec. 19-23		Tuttle
		Permanent daytime streams		
Arietids	June 8	May 29-June 17	40	
ξ Perseids	June 9	June 1-15	30	
β Taurids	June 30	June 23-July 7	20	

Selected minor planets

Number and name	Radius	Mass	m_{pg} at $r\Delta = 1$	Rot. period		Orbital data Period	a	e	i
	km	g		h	m	d	AU		°
1 Ceres	350	60×10^{22}	4·0	9	05	1 681	2·767	0·079	10·6
2 Pallas	230	18×10^{22}	5·1			1 684	2·767	0·235	34·8
3 Juno	110	2×10^{22}	6·3	7	13	1 594	2·670	0·256	13·0
4 Vesta	190	10×10^{22}	4·2	5	20	1 325	2·361	0·088	7·1
6 Hebe	110	20×10^{21}	6·6	7	17	1 380	2·426	0·203	14·8
7 Iris	100	15×10^{21}	6·7	7	07	1 344	2·385	0·230	5·5
10 Hygiea	160	60×10^{21}	6·4	18?		2 042	3·151	0·099	3·8
15 Eunomia	140	40×10^{21}	6·2	6	05	1 569	2·645	0·185	11·8
16 Psyche	140	40×10^{21}	6·8	4	18	1 826	2·923	0·135	3·1
51 Nemausa	40	9×10^{20}	8·6			1 330	2·366	0·065	9·9
433 Eros	7	5×10^{18}	12·3	5	16	642	1·458	0·223	10·8
511 Davida	130	3×10^{22}	7·0			2 072	3·182	0·177	15·7
1566 Icarus	0·7	5×10^{15}	17·7			408	1·077	0·827	23·0
1620 Geographos	1·5	5×10^{16}	15·9			507	1·244	0·335	13·3
Apollo	0·5	2×10^{15}	18			662	1·486	0·566	6·4
Adonis	0·15	5×10^{13}	21			1 008	1·969	0·779	1·5
Hermes	0·3	4×10^{14}	19			535	1·290	0·475	4·7

(REF. 21)

RATE of discovery of comets:

New nearly parabolic	3 per year
New periodic	1·0 per year
Periodic, predicted, and recovered	2·5 per year
Comets visible annually	2

Periodic comets

The table gives the periodic comets that have appeared at least three times and are expected to be recovered on next appearance. The orbital elements are for the equinox 1950·0 [2], P = period, ω = angle from ascending node to perihelion, Ω = longitude of ascending node, i = inclination, e = eccentricity, q = perihelion distance, and a = semi-major axis. Name abbreviations are: Skj. = Skjellerup, W. = Wachmann, Z. = Zinner, Schwass. = Schwassmann.

Comet	Recent perihelion date, and return number		P	ω	Ω	i	e	q	a
			y	°	°	°		AU	AU
Encke	1961·10	46	3·30	185	335	12·4	0·847	0·339	2·21
Grigg-Skj.	1957·09	9	4·90	356	215	17·6	0·704	0·855	2·89
Tempel (2)	1957·10	12	5·28	191	119	12·5	0·545	1·38	3·0
Kopff	1958·05	8	6·3	160	120	5	0·556	1·51	3·4
Giacobini-Z.	1959·82	7	6·5	172	196	30·8	0·72	0·94	3·5
Schwass.-W. (2)	1961·68	6	6·53	358	126	3·7	0·384	2·155	3·50
Wirtanen	1961·29	3	6·67	343	86	13·4	0·543	1·62	3·55
Reinmuth (2)	1960·90	3	6·7	45	296	7·0	0·46	1·93	3·6
Brooks (2)	1960·46	10	6·75	197	177	5·6	0·50	1·76	3·6
Finlay	1960·67	7	6·85	321	42	3·5	0·705	1·07	3·6
Borrelly	1960·45	7	7·01	351	76	31·1	0·604	1·450	3·67
Faye	1955·17	14	7·42	201	206	10·6	0·565	1·655	3·80
Whipple	1955·91	4	7·42	190	189	10·2	0·356	2·450	3·80
Reinmuth (1)	1958·23	4	7·67	13	124	8·4	0·478	2·03	3·90
Oterma	1958·44	Annual	7·89	355	155	4·0	0·144	3·39	3·96
Schaumasse	1960·29	6	8·18	52	86	12·0	0·705	1·195	4·05
Wolf (1)	1959·22	10	8·42	161	204	27·3	0·396	2·505	4·15
Comas Solá	1961·26	5	8·57	40	63	13·5	0·577	1·775	4·19
Väisälä (1)	1960·35	3	10·5	44	135	11·3	0·635	1·745	4·79
Schwass.-W. (1)	1957·36	Annual	16·1	356	322	9·5	0·132	5·53	6·4
Neujmin (1)	1948·96	3	17·9	347	347	15·0	0·774	1·54	6·8
Crommelin	1956·80	6	27·9	196	250	28·9	0·919	0·744	9·2
Olbers	1956·45	3	69·6	65	85	44·6	0·930	1·18	16·8
Pons-Brooks	1954·39	3	70·9	199	255	74·1	0·955	0·775	17·2
Halley	1910·30	29	76·2	112	57	162·3	0·967	0·587	17·8

(REF. 21)

APPENDIX B

List of Space Science Tasks

This section lists the basic tasks of scientific interest in each discipline (or Field of Interest) for each of the targets of space exploration included in the scope of this report.

Each Target, Field of Interest, and Task represents an element on the NASA PATTERN Relevance Tree. Code numbers preceding each element are the Relevance Tree designators by which the element is identified in the computer. Numbers following the element refer to the paragraph of the Relevance Guide, Volume I, where the task is described.

TARGET:	22S The SUN	REF.
FIELD OF INTEREST:	32SK Composition of the Photosphere and Interior	3.2.2
TASKS:		
42SK02	Study the mechanism of granulation	3.2.2.1
42SK04	Study the mechanism of flares	3.2.2.2
42SK06	Study the mechanism of sunspots	3.2.2.3
42SK08	Study the mechanism of local magnetic fields	3.2.2.4
42SK10	Determine the abundance of chemical elements	3.2.2.5

		REF.
TARGET:	22S The SUN	
FIELD OF INTEREST:	32SA Atmosphere and Corona	3.2.3
TASKS:		
42SA02	Determine structure of the chromosphere	3.2.3.1
42SA04	Determine structure of the corona	3.2.3.2
42SA06	Determine temperature gradient	3.2.3.3
42SA08	Mapping of the corona hot spots	3.2.3.4
42SA10	Study of radio-frequency radiation	3.2.3.5

TARGET: 22S The SUN		REF.
FIELD OF INTEREST: 32SE Electromagnetic Radiation		3.2.4
TASKS:		
42SE02	Map frequency and intensity characteristics throughout interplanetary space and temporal variations	3.2.4.1

TARGET: 22S The SUN

REF.

FIELD OF INTEREST: 32SR Particle Radiation 3.2.5

TASKS:

42SR02	Measure the charge composition and spectrum of the quiescent and disturbed radiation in vicinity of earth	3.2.5.1
42SR04	Measure the charge composition and spectrum of the quiescent and disturbed radiation between earth and sun	3.2.5.1
42SR06	Measure the charge composition and spectrum of the quiescent and disturbed radiation in outer solar system	3.2.5.1
42SR08	Measure the charge composition and spectrum of the quiescent and disturbed radiation out of the ecliptic, inner solar system	3.2.5.1
42SR10	Correlate the emission of corpuscular radiation with solar, interplanetary, and planetary disturbances	

		REF.
TARGET: 22S The SUN		
FIELD OF INTEREST: 32SG Solar Magnetic Field		3.2.6
TASKS:		
42SG02	Map the general magnetic field of the Sun	3.2.6.1
42SG04	Map the disturbed fields on the sun and through interplanetary space	3.2.6.1

TARGET:	22E EARTH	REF.
FIELD OF INTEREST:	32EZ Geodesy and Mapping	3.1.1
TASKS:		
42EZ02	Define gravitational anomalies and improve precision of mathematical model of the geoid	3.1.1.4
42EZ04	Photographic mapping with geodetic precision	3.1.1.6
42EZ06	Accurate tie-in of major geodetic datums	3.1.1.7

TARGET: 22E EARTH		REF.
FIELD OF INTEREST: 32EK Composition		3.1.2
TASKS:		
42EK02	IR mapping of surface	3.1.2.1
42EK04	Determine gross physical characteristics of surface	3.1.2.2
42EK06	Determine the geological history of the target body	

TARGET: 22E EARTH		REF.
FIELD OF INTEREST: 32EA Atmosphere and Ionosphere		3.1.3
TASKS:		
42EA02	Determine composition of atmosphere	3.1.3.1
42EA04	Determine variation with altitude of pressure and composition	3.1.3.2
42EA06	Determine temperature profile of atmosphere	3.1.3.3
42EA08	Determine changes of atmosphere on diurnal and seasonal scales	3.1.3.4
42EA10	Determine atmospheric trends with the solar cycle	3.1.3.5
42EA12	Determine location of ionospheres	3.1.3.6
42EA14	Determine composition of ionospheres	3.1.3.6
42EA16	Determine motion of ionosphere on diurnal and seasonal time scales	3.1.3.6

TARGET:	22E EARTH	REF.
FIELD OF INTEREST:	32ER Magnetosphere and Radiation Belts	3.1.4
TASKS:		
42ER02	Determine gross strength and orientation of magnetosphere	3.1.4.1
42ER04	Map magnetic fields	3.1.4.2
42ER06	Determine influence of diurnal, seasonal, and solar cycles magnetic lines of force	
42ER08	Locate and map surface magnetic anomalies	3.1.4.4
42ER10	Determine gross shape and constituent characteristics of radiation belts	3.1.4.5
42ER12	Map radiation belts	3.1.4.6
42ER14	Determine dynamics of radiation belts	3.1.4.7
42ER16	Determine the interface between the magnetosphere and the solar wind	3.1.4.8
42ER18	Determine the correlation between the radiation belts and the other geophysical phenomena such as magnetic storms, aurorae, and ionospheric disturbances	3.1.4.9

TARGET:	22E EARTH	REF.
FIELD OF INTEREST:	32EB Biology	3.1.5
TASKS:		
42EB02	Determine existence of spores in the upper atmosphere	3.1.5.8

TARGET: 22L MOON		REF.
FIELD OF INTEREST: 32LZ Geodesy and Mapping		3.1.1
TASKS:		
42LZ02	Determine mass of planet	3.1.1.1
42LZ04	Define gravitational anomalies and develop mathematical model of the geoid	3.1.1.4
42LZ06	Gross photography of surface details	3.1.1.5
42LZ08	Gross photography of back side	3.1.1.5
42LZ10	Photographic mapping with geodetic precision	3.1.1.6

TARGET: 22L MOON

		REF.
FIELD OF INTEREST:	32LK Composition	3.1.2
TASKS:		
42LK02	IR mapping of surface and study of hot spots	3.1.2.1
42LK04	Determine gross physical characteristics of surface	3.1.2.2
42LK06	Determine gross chemical composition of surface material	3.1.2.3
42LK08	Determine whether bodies of water or ice exist	3.1.2.4
42LK10	Map distribution of geological materials of interest	3.1.2.5
42LK12	Determine composition and strength of deep core samples	3.1.2.6
42LK14	Determine geological history of the target body	
42LK16	Study of lunar outgassing	3.1.2.7
42LK18	Study of lunar red spots	3.1.2.8
42LK20	Study of lunar erosion processes	3.1.2.9

TARGET: 22L MOON REF.

FIELD OF INTEREST: 32LA Atmosphere and Ionosphere

TASKS:

42LA02	Determine compositional difference between lunar atmosphere and interplanetary space
42LA04	Determine energy distribution and differences between lunar atmosphere and interplanetary space

		REF.
TARGET: 22L MOON		
FIELD OF INTEREST: 32LR Magnetosphere and Radiation Belts		3.1.4
TASKS:		
42LR02	Map surface magnetic anomalies	3.1.4.4

TARGET: 22L MOON		REF.
FIELD OF INTEREST: 32LB Biology		3.1.5
TASKS:		
42LB02	Determine the existence of life forms on the target body	3.1.5.1
42LB04	Determine the past existence of life forms	3.1.5.2
42LB06	Classify the life forms	3.1.5.3
42LB08	Study the ecology of life forms, how differ from earth	3.1.5.4
42LB10	Determine the existence of panspermia	3.1.5.8

TARGET: 22M MARS

		REF.
FIELD OF INTEREST: 32MZ	Geodesy and Mapping	3.1.1
TASKS:		
42MZ02	Define gravitational anomalies and develop mathematical model of the geoid	3.1.1.4
42MZ04	Gross photography of surface	3.1.1.5
42MZ06	Photographic mapping with geodetic precision	3.1.1.6
42MZ20	Determine mass of satellite Phobos	3.1.1.1
42MZ22	Determine axis and rate of rotation of satellite Phobos	
42MZ24	Determine polar and equatorial radii of satellite Phobos	
42MZ26	Gross photography of the surface of satellite Phobos	3.1.1.5
42MZ40	Determine mass of satellite Deimos	3.1.1.1
42MZ42	Determine polar and equatorial radii of satellite Deimos	
42MZ44	Gross photography of the surface of satellite Deimos	3.1.1.5

TARGET: 22M MARS		REF.
FIELD OF INTEREST: 32MK Composition		3.1.2
TASKS:		
42MK02	IR mapping of surface	3.1.2.1
42MK04	Determine gross physical characteristics of surface	3.1.2.2
42MK06	Determine gross chemical composition of surface material	3.1.2.3
42MK08	Determine whether bodies of water or ice exist	3.1.2.4
42MK10	Map distribution of geological materials of interest	3.1.2.5
42MK12	Determine composition and strength of deep core samples	3.1.2.6
42MK14	Determine the geological history of the target body	
42MK16	Study of surface erosion processes	3.1.2.9
42MK20	Determine gross physical characteristics of surface of satellite Phobos	3.1.2.2
42MK22	Determine gross chemical composition of surface material of satellite Phobos	3.1.2.3

TARGET: 22M MARS		REF.
FIELD OF INTEREST: 32MA Atmosphere and Ionosphere		3.1.3
TASKS:		
42MA02	Determine composition of atmosphere	3.1.3.1
42MA04	Determine variation with altitude of pressure and composition	3.1.3.2
42MA06	Determine temperature profile of atmosphere	3.1.3.3
42MA08	Determine changes of atmosphere on diurnal and seasonal scales	3.1.3.4
42MA10	Determine atmospheric trends with the solar cycle	3.1.3.5
42MA12	Determine location of ionospheres	3.1.3.6
42MA14	Determine composition of ionospheres	3.1.3.6
42MA16	Determine motion of ionosphere on diurnal and seasonal time scales	3.1.3.6

TARGET: 22M MARS		REF.
FIELD OF INTEREST: 32MR	Magnetosphere and Radiation Belts	3.1.4
TASKS:		
42MR02	Map surface magnetic anomalies	3.1.4.4

TARGET: 22M MARS		REF.
FIELD OF INTEREST: 32MB Biology		3.1.5
TASKS:		
42MB02	Determine the existence of life forms on the target body	3.1.5.1
42MB04	Determine the past existence of life forms	3.1.5.2
42MB06	Classify the life forms	3.1.5.3
42MB08	Study the ecology of life forms, how differ from earth	3.1.5.4
42MB10	Map the distribution of life forms	3.1.5.5
42MB12	Determine the existence of basic organic molecules	3.1.5.6
42MB14	Study the behavior and habits of life forms	3.1.5.7
42MB16	Determine the existence of panspermia	3.1.5.8
42MB20	Determine the existence of life forms on satellite Phobos	3.1.5.1
42MB30	Determine the existence of life forms on satellite Deimos	3.1.5.1

TARGET: 22V VENUS

		REF.
FIELD OF INTEREST:	32VZ Geodesy and Mapping	3.1.1
TASKS:		
42VZ02	Determine mass of planet	3.1.1.1
42VZ04	Determine polar and equatorial radii	3.1.1.2
42VZ06	Determine polar axis and rotation rate	3.1.1.3
42VZ08	Define gravitational anomalies and develop mathematical model of the geoid	3.1.1.4

TARGET: 22V VENUS		REF.
FIELD OF INTEREST: 32VK Composition		3.1.2
TASKS:		
42VK02	IR mapping of surface	3.1.2.1
42VK04	Determine gross physical characteristics of surface	3.1.2.2
42VK06	Determine gross chemical composition of surface material	3.1.2.3
42VK08	Determine whether bodies of water or ice exist	3.1.2.4
42VK10	Map distribution of geological materials of interest	3.1.2.5
42VK12	Determine composition and strength of deep core samples	3.1.2.6
42VK14	Determine the geological history of the target body	

TARGET; 22V VENUS		REF.
FIELD OF INTEREST: 32VA Atmosphere and Ionosphere		3.1.3
TASKS:		
42VA02	Determine composition of atmosphere	3.1.3.1
42VA04	Determine variation with altitude of pressure and composition	3.1.3.2
42VA06	Determine temperature profile of atmosphere	3.1.3.3
42VA08	Determine changes of atmosphere on diurnal and seasonal scales	3.1.3.4
42VA10	Determine atmospheric trends with the solar cycle	3.1.3.5
42VA12	Determine location of ionospheres	3.1.3.6
42VA14	Determine composition of ionospheres	3.1.3.6
42VA16	Determine motion of ionosphere on diurnal and seasonal time scales	3.1.3.6

TARGET: 22V VENUS		REF.
FIELD OF INTEREST: 32VR	Magnetosphere and Radiation Belts	3.1.4
TASKS:		
42VR02	Map surface magnetic anomalies	3.1.4.4

TARGET: 22V VENUS

FIELD OF INTEREST: 32VB Biology

TASKS:

		REF.
		3.1.5
42VB02	Determine the existence of life forms on the target body	3.1.5.1
42VB04	Determine the past existence of life forms	3.1.5.2
42VB06	Classify the life forms	3.1.5.3
42VB08	Study the ecology of life forms, how differ from earth	3.1.5.4
42VB10	Map the distribution of life forms	3.1.5.5
42VB12	Determine the existence of basic organic molecules	3.1.5.6
42VB14	Study the behavior and habits of life forms	3.1.5.7

[redacted]

		REF.
TARGET: 22Y MERCURY		
FIELD OF INTEREST: 32YZ Geodesy and Mapping		3.1.1
TASKS:		
42YZ02	Determine mass of planet	3.1.1.1
42YZ04	Determine polar and equatorial radii	
42YZ06	Define gravitational anomalies and develop mathematical model of the geoid	3.1.1.4
42YZ08	Gross photography of surface	3.1.1.5

TARGET: 22Y MERCURY		REF.
FIELD OF INTEREST: 32YK Composition		3.1.2
TASKS:		
42YK02	IR mapping of surface	3.1.2.1
42YK04	Determine gross physical characteristics of surface	3.1.2.2
42YK06	Determine gross chemical composition of surface material	3.1.2.3
42YK08	Determine whether bodies of water or ice exist	3.1.2.4
42YK10	Map distribution of geological materials of interest	3.1.2.5
42YK12	Determine composition and strength of deep core samples	3.1.2.6
42YK14	Determine the geological history of the target body	
42YK16	Study surface erosion processes	3.1.2.9

TARGET: 22Y MERCURY

		REF.
FIELD OF INTEREST: 32YA	Atmosphere and Ionosphere	3.1.3
TASKS:		
42YA02	Determine if Mercury has atmosphere	
42YA04	Determine composition of atmosphere	3.1.3.1

TARGET: 22Y MERCURY		REF.
FIELD OF INTEREST: 32YR	Magnetosphere and Radiation Belts	3.1.4
TASKS:		
42YR02	Determine presence of magnetosphere and trapped radiation	
42YR04	Determine gross strength and orientation of magnetosphere	3.1.4.1
42YR06	Determine gross shape and constituent characteristics of radiation belts	3.1.4.5

TARGET: 22Y MERCURY		REF.
FIELD OF INTEREST: 32YB Biology		3.1.5
TASKS:		
42YB02	Determine the existence of life forms on the target body	3.1.5.1
42YB04	Determine the past existence of life forms	3.1.5.2
42YB06	Classify the life forms	3.1.5.3
42YB08	Study the ecology of life forms, how differ from earth	3.1.5.4
42YB10	Map the distribution of life forms	3.1.5.5
42YB12	Determine the existence of basic organic molecules	3.1.5.6
42YB14	Study the behavior and habits of life forms	3.1.5.7

TARGET: 22J JUPITER		REF.
FIELD OF INTEREST: 32JZ Geodesy and Mapping		3.1.1
TASKS:		
42JZ02	Determine polar and equatorial radii	
42JZ04	Determine polar axis and rotation rate	
42JZ06	Define gravitational anomalies and develop mathematical model of the geoid	3.1.1.4
42JZ20	Determine mass of a satellite in inner group	3.1.1.1
42JZ22	Determine axis and rate of rotation of a satellite in inner group	
42JZ24	Determine polar and equatorial radii of a satellite in inner group	
42JZ26	Gross photography of the surface of a satellite in inner group	3.1.1.5
42JZ40	Determine mass of a satellite in outer group	3.1.1.1
42JZ42	Determine polar and equatorial radii of a satellite in outer group	
42JZ44	Gross photography of the surface of a satellite in outer group	3.1.1.5

TARGET: 22J JUPITER		REF.
FIELD OF INTEREST: 32JK Composition		3.1.2
TASKS:		
42JK02	IR Mapping of surface	3.1.2.1
42JK04	Determine gross physical characteristics of surface	3.1.2.2
42JK06	Determine gross chemical composition of surface material	3.1.2.3
42JK08	Determine whether bodies of water or ice exist	3.1.2.4
42JK10	Determine the geological history of the target body	
42JK40	Determine gross physical characteristics of surface of a satellite in inner group	3.1.2.2
42JK42	Determine gross chemical composition of surface material of a satellite in inner group	3.1.2.3
42JK60	Determine gross physical characteristics of surface of a satellite in outer group	3.1.2.2
42JK62	Determine gross chemical composition of surface material of a satellite in outer group	3.1.2.3
42JK80	Determine gross physical characteristics of surface of a satellite in inner group	3.1.2.2

TARGET: 22J JUPITER		REF.
FIELD OF INTEREST: 32JA Atmosphere and Ionosphere		3.1.3
TASKS:		
42JA02	Determine composition of atmosphere	3.1.3.1
42JA04	Determine variation with altitude of pressure and composition	3.1.3.2
42JA06	Determine temperature profile of atmosphere	3.1.3.3
42JA08	Determine changes of atmosphere on diurnal scale	3.1.3.4
42JA10	Determine atmospheric trends with the solar cycle	3.1.3.5
42JA12	Determine location of ionospheres	3.1.3.6
42JA14	Determine composition of ionospheres	3.1.3.6
42JA16	Determine motion of ionosphere on diurnal time scale	3.1.3.6
42JA40	Determine pressure, temperature density profiles of atmosphere of satellite I - IV	3.1.3.2 and 3.1.3.3
42JA42	Determine composition of atmosphere of satellite I - IV	3.1.3.1

TARGET: 22J JUPITER		REF.
FIELD OF INTEREST: 32JR	Magnetosphere and Radiation Belts	3.1.4
TASKS:		
42JR02	Determine gross strength and orientation of magnetosphere	3.1.4.1
42JR04	Map magnetic lines of force, locate poles	3.1.4.2
42JR06	Determine influence of diurnal, seasonal, and solar cycles on magnetic lines of force	
42JR08	Locate and map magnetic anomalies	3.1.4.4
42JR10	Determine gross shape and constituent characteristics of radiation belts	3.1.4.5
42JR12	Map radiation belts	3.1.4.6
42JR14	Determine dynamics of radiation belts	3.1.4.7
42JR16	Determine the interface between the magnetosphere and the solar wind	3.1.4.8
42JR18	Determine the correlation between the radiation belts and the other phenomena, such as magnetic storms, aurorae, and ionospheric disturbances	3.1.4.9

TARGET: 22J JUPITER		REF.
FIELD OF INTEREST: 32JB Biology		3.1.5
TASKS:		
42JB02	Determine the existence of life forms on the target body	3.1.5.1
42JB04	Determine the past existence of life forms	3.1.5.2
42JB06	Classify the life forms	3.1.5.3
42JB08	Study the ecology of life forms, how differ from earth	3.1.5.4
42JB10	Determine the existence of basic organic molecules	3.1.5.6
42JB20	Determine the existence of life forms on satellites of the inner group	3.1.5.1
42JB30	Determine the existence of life forms on satellites of the middle group	3.1.5.1
42JB40	Determine the existence of life forms on satellites of the outer group	3.1.5.1

TARGET:	22N SATURN	REF.
FIELD OF INTEREST:	32NZ Geodesy and Mapping	3.1.1
TASKS:		
42NZ02	Determine polar and equatorial radii	
42NZ04	Determine polar axis and rotation rate	
42NZ06	Define gravitational anomalies and develop mathematical model of the geoid	3.1.1.4
42NZ08	Gross photography of surface	3.1.1.5
42NZ20	Determine mass of satellite Phoebe	3.1.1.1
42NZ22	Determine mean radius of satellite Phoebe	
42NZ24	Gross photography of surface of satellite Phoebe	3.1.1.5
42NZ40	Determine mass of satellite Titan	3.1.1.1
42NZ42	Determine mean radius of satellite Titan	
42NZ44	Gross photography of the surface of satellite Titan	3.1.1.5
42NZ50	Gross photography of the rings	3.1.1.5

TARGET: 22N SATURN REF.

FIELD OF INTEREST: 32NK Composition 3.1.2

TASKS:

42NK02	IR mapping	3.1.2.1
42NK04	Determine gross physical characteristics of surface	3.1.2.2
42NK06	Determine gross chemical composition of surface material	
42NK08	Determine bearing strength of surfaces	
42NK10	Determine composition and strength of deep core samples	3.1.2.6
42NK12	Determine the age and origin of the planet	
42NK40	Determine gross physical characteristics of surface of satellite Phoebe	3.1.2.2
42NK42	Determine gross chemical composition of surface material of satellite Phoebe	3.1.2.3
42NK60	Determine gross physical characteristics of surface of satellite Titan	3.1.2.2
42NK62	Determine gross chemical composition of surface material of satellite Titan	3.1.2.3
42NK80	Determine gross physical characteristics of the rings	
42NK82	Determine gross chemical characteristics of the rings	

TARGET: 22N SATURN REF.

FIELD OF INTEREST: 32NA Atmosphere and Ionosphere 3.1.3

TASKS:

42NA02	Determine composition of atmosphere	3.1.3.1
42NA04	Determine variation with altitude of pressure and composition	3.1.3.2
42NA06	Determine temperature profile of atmosphere	3.1.3.3
42NA08	Determine changes of atmosphere on diurnal scale	3.1.3.4
42NA10	Determine atmospheric trends with the solar cycle	3.1.3.5
42NA12	Determine location of ionospheres	3.1.3.6
42NA14	Determine composition of ionospheres	3.1.3.6
42NA16	Determine motion of ionosphere on diurnal time scale	3.1.3.6
42NA60	Determine pressure, temperature profiles of atmosphere of satellite Titan	
42NA62	Determine composition of atmosphere of satellite Titan	

TARGET: 22N SATURN. REF.

FIELD OF INTEREST: 32NR Magnetosphere and Radiation Belts 3.1.4

TASKS:

42NR02	Determine gross strength and orientation of magnetosphere	3.1.4.1
42NR04	Map magnetic lines of force, locate poles	3.1.4.2
42NR06	Determine influence of diurnal, seasonal, and solar cycles on magnetic lines of force	3.1.4.3
42NR08	Locate and map magnetic anomalies	3.1.4.4
42NR10	Determine gross shape and constituent characteristics of radiation belts	3.1.4.5
42NR12	Map radiation belts	3.1.4.6
42NR14	Determine dynamics of radiation belts	3.1.4.7
42NR16	Determine the interface between the magnetosphere and the solar wind	3.1.4.8
42NR18	Determine the correlation between the radiation belts and the other phenomena such as magnetic storms, aurorae, and ionospheric disturbances	3.1.4.9
42NR50	Determine existence, strength, and orientation of satellite magnetosphere	3.1.4.1
	Determine interaction of satellite with magnetosphere and radiation belts of parent body	

TARGET: 22N SATURN		REF.
FIELD OF INTEREST: 32NB Biology		3.1.5
TASKS:		
42NB02	Determine the existence of life forms on the target body	3.1.5.1
42NB04	Determine the past existence of life forms	3.1.5.2
42NB06	Classify the life forms	3.1.5.3
42NB08	Study the ecology of life forms, how differ from earth	3.1.5.4
42NB10	Determine the existence of basic organic molecules	3.1.5.6
42NB20	Determine the existence of life forms on satellite Phoebe	3.1.5.1
42NB30	Determine the existence of life forms on satellite Titan	3.1.5.1

TARGET: 22C COMETS AND ASTEROIDS		REF.
FIELD OF INTEREST: 32CZ Geodesy and Mapping		3.1.1
TASKS:		
42CZ02	Determine mass of asteroid Ceres	3.1.1.1
42CZ04	Determine polar and equatorial radii of asteroid Ceres	
42CZ06	Gross photography of the asteroid Ceres surface	3.1.1.5
42CZ20	Determine mass of asteroid Vesta	3.1.1.1
42CZ22	Determine polar and equatorial radii of asteroid Vesta	
42CZ24	Gross photography of the surface of asteroid Vesta	3.1.1.5
42CZ40	Determine mass of asteroid Icarus or Geographos	3.1.1.1
42CZ42	Gross photography of the surface of asteroid Icarus or Geographos	3.1.1.5
42CZ60	Determine mass of a comet of elliptical orbit type	3.1.1.1
42CZ62	Determine mass of a comet of parabolic orbit type	3.1.1.1

TARGET: 22C COMETS and ASTEROIDS REF.

FIELD OF INTEREST: 32CK Composition 3.1.2

TASKS:

42CK02	Determine gross physical characteristics of surface of asteroid Ceres	3.1.2.2
42CK04	Determine gross chemical composition of surface material of asteroid Ceres	3.1.2.3
42CK06	Determine the geological history of asteroid Ceres	
42CK20	Determine gross physical characteristics of surface of asteroid Vesta	3.1.2.2
42CK22	Determine gross chemical composition of surface material of asteroid Vesta	3.1.2.3
42CK24	Determine the geological history of asteroid Vesta	
42CK40	Determine gross physical characteristics of surface of asteroid Icarus or Geographos	3.1.2.2
42CK42	Determine gross chemical composition of surface material of asteroid Icarus or Geographos	3.1.2.3
42CK60	Determine the composition of the nucleus of a comet in the elliptical group	
42CK70	Determine the composition of the nucleus of a comet in the parabolic group	

TARGET: 22C COMETS and ASTEROIDS REF.

FIELD OF INTEREST: 32CA Atmosphere and Ionosphere

TASKS:

42CA02	Determine the composition of the atmosphere of a comet in the elliptical group
42CA04	Determine the composition of the atmosphere of a comet in the parabolic group

TARGET: 22C COMETS and ASTEROIDS REF.

FIELD OF INTEREST: 32CR Magnetosphere and Radiation Belts

TASKS:

42CR02	Determine charged particle distribution in tail of comet of elliptical orbit
42CR04	Determine charged particle distribution in tail of comet of parabolic orbit

TARGET: 22C COMETS and ASTEROIDS REF.
FIELD OF INTEREST: 32CB Biology 3.1.5
TASKS:

42CB02	Determine the existence of life forms on asteroid Ceres	3.1.5.1
42CB04	Determine the past existence of life forms on asteroid Ceres	3.1.5.2
42CB06	Study the ecology of life forms, how differ from earth	3.1.5.4
42CB22	Determine the existence of life forms on asteroid Vesta	3.1.5.1
42CB24	Determine the past existence of life forms on asteroid Vesta	3.1.5.2
42CB26	Study the ecology of life forms, how differ from earth	3.1.5.4
42CB42	Determine the existence of life forms on asteroid Icarus or Geographos	3.1.5.1
42CB44	Determine the past existence of life forms on asteroid Icarus or Geographos	3.1.5.2
42CB46	Study the ecology of life forms, how differ from earth	3.1.5.4
42CB64	Determine the past existence of life forms on meteorites captured in space	3.1.5.2

TARGET: 22U EXTRA-SOLAR SYSTEM REF.

FIELD OF INTEREST: 32UZ Size, Shape and Mapping

TASKS:

42UZ02	Map distribution of radio sources
42UZ04	Map distribution of X-ray sources
42UZ06	Map distribution of Gamma ray sources
42UZ06	Map distribution of optical sources
42UZ08	Study limits of universe and rates of expansion
42UZ10	Determine the evolution or steady state of the universe

TARGET: 22U EXTRA-SOLAR SYSTEM REF.

FIELD OF INTEREST: 32UR Planetary System Investigation

TASKS:

42UR02	Determine the presence of other planetary systems
42UR04	Determine masses and orbits of planets in other systems
42UR06	Determine composition of planets in other systems

TARGET: 22U EXTRA-SOLAR SYSTEM		REF.
FIELD OF INTEREST: 32UK Composition of Masses		
TASKS:		
42UK02	Spectroscopic astronomy in the ultraviolet region	
42UK02	Study of stellar radiation in far IR region	
42UK04	Study of stellar radiation in the long wave RF region	

TARGET: 22U EXTRA-SOLAR SYSTEM REF.

FIELD OF INTEREST: 32UI Composition and Characteristics of Galactic Space 3.3.4

TASKS:

42UI02	Map galactic magnetic fields	3.3.4.1
42UI04	Map distribution of radio sources in the sky and their associated magnetic fields	3.3.4.2
42UI06	Measure the charge composition and spectrum of the galactic cosmic rays as a function of time and space	3.3.4.3

TARGET: 22U EXTRA-SOLAR SYSTEM		REF.
FIELD OF INTEREST: 32UB Extra-Solar System Life		3.3.5
TASKS:		
42UB02	Search for intergalactic panspermia	3.3.5.1
42UB04	Communication with extraterrestrial intelligence	3.3.5.2