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ABSTRACTS AND SUMMARIES OF PAPERS PRESENTED FOR THE SYMPOSIUM ON THE EXPLORATION OF MARS.

SYMPOSIUM ON THE EXPLORATION OF MARS (Denver, Colorado, June 6-7, 1963). The following abstracts and summaries of papers prepared concerning the Symposium on the Exploration of Mars, sponsored by The American Astronautical Society, are presented for their value to those readers interested in the present planning toward establishing a scientific effort requisite for a manned exploration of Mars.

LAUNCH FACILITY REQUIREMENTS FOR MARS/NOVA VEHICLE. Howard Keyser (Nova Launch Facility Study, Martin-Denver) Launch facility and operations problems have been given early importance in the NOVA program. It may seem unusual to some that launch facility design is actually being considered before selection of the NOVA. However, the task of providing a facility is so great that the facility itself actually is a significant factor in what NOVA may eventually be selected. This paper presents some of the facility influences.

VEHICLE DESIGN FOR MARS LANDING AND RETURN TO MARS ORBIT. David M. Hammock and Bruce G. Jackson (Manned Spacecraft Center, NASA) This paper briefly describes three modes for accomplishing the Mars landing mission and compares them on a gross basis to indicate their probable order of merit and to identify design requirements placed on the Mars-excursion module (MEM) by the choice of mode. The

paper shows that a flyby-rendezvous mode, requiring low weight in Earth orbit, requires the MEM to enter the Mars atmosphere at velocities ranging from 6095.9 to 9143.9 m/sec (20,000 to 30,000 ft/sec). The MEM for the flyby-rendezvous mode is not covered in this paper but merits further study.

The MEM for the other modes of mission accomplishment begins its active operational sequence in Mars orbit and need not be greatly influenced by the method of delivery to Mars orbit.

Parametric studies of the entry problem for two vehicles typifying a ballistic-type and a lifting-body-type were conducted to identify the problems associated with design of a MEM to accommodate the extremes of Mars atmospheric density presently predicted.

This brief study indicates that: (a) the presently predicted density extremes of the Mars atmosphere present no serious design problems for a MEM which can operate across the entire band of predicted densities; (b) details of operational requirements and mission objectives will control the choice of configuration rather than entry requirements; and (c) the ballistic-type MEM is lighter and simpler but has less operational flexibility than a high L/D MEM.

A SYSTEMS APPROACH TO VEHICLE DESIGN FOR EARTH RE-ENTRY FROM AN INTERPLANETARY MISSION.
Franklin P. Dixon and Leonard D. Stimpson (Aeronutronic Division, Ford Motor Company) Earth return from Mars and Venus manned ventures during the 1970's places stringent requirements upon the Earth reentry vehicle design. These requirements are related to the high approach velocities ranging from 13 to 19 km/sec and include the possibilities of retro-propulsion, modulated lift and drag, heavy heat shields, advanced materials, control techniques which include maneuverability for landing side selection, and necessary safety provisions. Feasibility studies are presented for Earth reentry of a six-man crew by three basic vehicle configurations, which include an Apollo-type, a Drag-Brake, and a High Lift-to-Drag vehicle, with the main emphasis being placed upon the minimization of total reentry vehicle weight.

The effect of radiative heating in conjunction with convective heating upon vehicle design is analyzed; coupled with the modulated lifting requirement, it results in optimum tradeoffs between heat shield

and retro-propulsive weights. Realistic ablation technology limitations place upper bounds upon purely aerodynamic reentry based upon present knowledge of radiation heating behavior and advanced materials technologies.

The three vehicle types remain competitive in total weight; however, they differ considerably as to reentry corridor depth, landing site selection, g-loading, and control complexity. The High L/D vehicle is recommended for further study since it appears to have superior performance over the Apollo and Drag-Brake vehicles for Earth reentry from possible Early Manned Planetary and Interplanetary Round-Trip Expeditions in the 1970-75 period.

USE OF EXTRATERRESTRIAL RESOURCES FOR MARS BASING. Ernst A. Steinhoff (The Rand Corporation) The advent of manned space flights to destinations within our Solar System and the possible future establishment of more or less permanent exploratory bases on the Moon and Mars will lead to complex logistics if all supplies have to be provided from the Earth. Use of regeneration techniques to recover water and oxygen, and hydroponic gardening to grow food can reduce the logistics requirements to a small fraction of the original value and so reduce the cost of resupply. A further drastic reduction of space transportation costs can be achieved by using lunar and planetary resources for the local production of water, which together with its decomposition products represents over 90 per cent of all the logistic needs of humans and which can also satisfy rocket propulsion needs for spacecraft if used in its dissociated state and liquefied form as LH_2 and LO_2. With refueling facilities at the remote terminals, the use of locally produced fuels will drastically change the operating modes, resulting in a high degree of re-usability of spacecraft which otherwise would have to be discarded. An "Advanced Technology Program" is evolved in broad terms outlining areas of applied research and advanced development necessary to achieve this objective. Besides water, other locally produced chemical compounds suitable as fuels for spacecraft and extraterrestrial surface and flight vehicles or as nutrients for the local production of food and for the photosynthetic regeneration of oxygen are discussed. The early prototype development of mining, processing, and regeneration equipment for the above purposes is encouraged on the basis of economic pay-offs, resulting from their use at extraterrestrial exploratory bases where they should also contribute enhanced flexibility and increased safety to such operations.

PRELIMINARY DESIGN OF MARS BASING. Percy H. Bliss (The Rand Corporation) This paper is an attempt to focus attention on the design and construction problems for a Martian base. An immediate, prefabricated, inflatable shelter is proposed for the first crew that lands on Mars; it will serve for headquarters while additional base construction is performed. The use of indigenous materials for structures is proposed where possible to reduce transportation and construction costs. Prefabricated structures are advocated from imported materials, using steel, aluminum, wood, wood products, plastics, rubber fabrics, or polyurethane plastics. Block construction could be used with either imported cements or with blocks and cements manufactured from Martian materials. The design and construction of basing facilities on Mars appears to be within the limits of present technologies, but it is emphasized that designs proposed herein will probably require considerable modification as more information about the environment and available materials on Mars is obtained.

POWER SUPPLY ASPECTS OF THE MARS MISSION. R. Balent and J. R. Wetch (Atomic International, North American Aviation, Inc.) The manned Mars mission will probably be man's most ambitious undertaking of this century. One of the many subsystems which will be critical to the success of this mission will be the development of a compact, long-life, electrical power supply with an extremely high reliability to drive electronics and life support equipment.

The power requirements for 3-manned Mars missions (Mars orbit, Mars landing, and Mars base) show the range to be 40- to 200-kw electrical. Nuclear reactor power systems are the only conceivable method for supplying this level of power for the mission lifetimes of one-half to one year.

By utilizing a modular or building block approach, the technology within the current reactor SNAP (Systems Nuclear Auxiliary Power) program can readily lead to a power system which will meet all requirements for the manned Mars mission. A typical power supply for this mission rated at 55 kwe would utilize a SNAP 8 reactor with 704°C (1300°F) collant as the heat source to drive ten SNAP 2 mercury Rankine power conversion systems, each with a separate space radiator. A complete stand-by reactor subsystem would be available as a redundant heat source. With

two reactors and the multiple power conversion and separate radiator units, the system would have an extremely high reliability, even with a catastrophic meteorite event or major component failure, to meet the emergency mission power requirements for communications and life support.

By utilizing a split-shield design and a separation distance between the crew compartment and the reactor heat source of 30.4 m (100 ft), the total shielded system weight would be 5443 kg (12,000 lb). The space radiator would require an area totalling 120.7 m^2 (1300 ft^2).

(A) NON-CONVENTIONAL COMMUNICATION DEVICES FOR THE MARS MISSION, AND (B) USE OF RADAR TECHNIQUES TO SELECT MARS LANDING SITE.
Professor Keeve M. Siegel (Conductron Corporation)

(A) The advantages which are obtained from the use of non-conventional communication systems operating at wavelengths other than microwave, e.g., optical and millimeter, are weighed against the disadvantages. It is concluded that some small relative advantage can probably be gained in the millimeter range, but that this advantage is not significant and that there is no foreseeable advantage in the optical range. Therefore, it appears that improvements in space communication techniques are most likely to be found within the microwave region.

(B) A set of experiments to determine the geometrical character and material composition of the Martian surface are described. These experiments depend upon both passive and active electromagnetic radiation measurements. Bistatic and monostatic, multi-wavelength, high resolution radar mapping experiments are strongly recommended.

SOME METABOLIC ASPECTS OF EXTENDED SPACE FLIGHT. Ronald R. Young (Ames Research Center) This paper reviews some of the anticipated metabolic consequences and physiologic effects of space flight. The factors which have been considered are: (a) effect of immobilization and confinement, (b) cabin atmospheric requirements, (c) selection of an adequate diet for maintenance of fitness and for protection against radiation

damage, and (d) the effect of metabolic periodicities on performance. These are discussed from the point of view of extended missions for which there will be no capability for re-supply or crew rotation. Several methods for maintaining optimal health and operational efficiency have been examined. It is concluded that a systematic program of exercise as well as the selection of special diets is required in order to avoid hazardous complications and to maintain man in a state of well-being.

PSYCHOLOGICAL ASPECTS OF EXTENDED MANNED SPACE FLIGHT. Julien M. Christensen (Human Engineering Branch, Behavioral Sciences Laboratory) As is the case with virtually all of the other scientific disciplines, the adequacy of available psychological knowledge and principles will receive a severe test from the demands attendant to the development of a successful mission to Mars. This paper offers a sampling of some of the relevant information available in psychology, and an attempt is made to identify areas that will require further attention before predictions in the behavioral area for the Mars trip can be made with confidence. A two-fold thesis is developed. First, psychology has legitimate and important contributions to be made to the Mars trip. Second, the advantages, however, are mutual; i.e., it is confidently predicted that participation in this venture will force psychologists to reexamine their traditional principles and theoretical positions and will stimulate an attack on the basic issues of human behavior with refreshing insights gained from new points of vantage.

FULLY REGENERATIVE LIFE SUPPORT SYSTEMS FOR MARS MISSIONS. Robert D. Gafford (Martin-Denver) A manned Mars Mission may be planned for the early 1970's. The Mars spaceship will contain a crew of five men and will require a period of 420 days (including 40 days stay at Mars) to accomplish the round trip from Earth orbit to Mars orbit and return. Stored quantities of food, oxygen, nitrogen and CO_2 adsorbent, including reserves, will weigh between 4989.5 and 7257.4 kg (11,000 and 16,000 lb), depending upon the amount of food and oxygen regenerated on board. Estimates of total system weight will depend upon the development of functional prototype hardware.

GUIDANCE SIMULATION FOR A MARS MISSION. J. V. Breakwell, L. F. Helgostam and M. A. Krop (Lockheed Missiles and Space Company) The principal guidance phenomena for a manned nonstop round-trip to Mars are sought by geometric, mathematical, and physical examinations of the trajectory and its sensitivity to small perturbations. The two major findings are that (1) the deviations from the nominal trajectory in both the early and the final stages of the midcourse portions of each leg of the trip are fairly well described by uncoupled, straight-line motion, and (2) with reasonably good optical sighting accuracy, such as a standard deviation of 10 sec of arc in optical sightings on the planets against the star background, the entire interplanetary midcourse navigation and guidance problem can be solved in the vicinity of the two terminal planets with a modest expenditure of corrective velocity. On most relatively short-duration interplanetary trips it is advantageous to employ variable-time-of-arrival guidance procedures; on the relatively long ones, it is advisable to guide for fixed time of arrival early in the trip and variable, later. Guidance in the final phase of the midcourse appears to be amenable to fairly simple, straightforward methods based on observing only the magnitude and the plane of the angular rate of change of the line of sight to the target planet.

NOVA LAUNCH VEHICLE DESIGN STUDIES. Andrew Kalitinsky (NOVA, General Dynamics/Astronautics) The NOVA design studies currently being conducted under the direction of the Marshall Space Flight Center are aimed at defining the most desirable launch vehicle for the heavy space missions of the 1970's. To help make these missions technically and economically feasible, NOVA must achieve a big step forward in payload capability and cost effectiveness. The task of assembling, in Earth orbit, manned Mars expeditions weighing several thousand tons favors launch vehicles in the million pound payload class. Significant cost reductions can be achieved by recovery and re-use of high cost components or complete stages. Representative NOVA configurations developed by General Dynamics/Astronautics and Martin/Baltimore, the NOVA study contractors, are described.

ROLE OF LARGE THRUST NUCLEAR POWER IN MARS FLIGHT. Keith Boyer (Los Alamos Scientific Laboratory) A study of the manned exploration of Mars mission indicates that

the vehicle propulsion requirements could be met by the development of a 11,339.8 kg (250,000 lb) thrust nuclear propulsion engine to be used both singly and in clusters of four. It appears feasible to conduct the development on a time scale which permits a mission attempt in the 1973-1975 time period. No re-use of the engines is proposed, and the burning time is restricted to a maximum of 30 min.

ELECTRIC PROPULSION SYSTEMS FOR MARS MISSIONS.

Wolfgang E. Moeckel (Electromagnetic Propulsion Division, Lewis Research Center) The potential capabilities of electric propulsion systems for both unmanned and manned exploration of Mars are considered relative to those of other propulsion systems, primarily nuclear heat-transfer rockets. For unmanned explorations, a single electrically propelled vehicle, weighing about 11,339.8 kg (25,000 lb) and using a 250-450 kw power system with specific weights in the vicinity of 10 kg/kw, would be capable of performing most of the scientific interplanetary probe missions, not only to Mars but also to most planets and regions of the Solar System. Chemical or nuclear-rocket vehicles several times this initial weight can perform only part of these missions.

For manned exploration of Mars, the comparison depends on the specific powerplant weight attainable with electric propulsion and the specific impulse attainable with nuclear rockets. In general, if the specific weight is 10 kg/kw, electric-propelled vehicles require less initial weight for a given mission than nuclear rockets, but only at rather long mission times. A specific weight is reduced, the trip time for equal initial weight for nuclear and electric rockets moves toward lower values, reaching about 500 days and 400 days for specific weights of 6 and 4 kg/kw, respectively. Further reduction in specific weight makes electric propulsion superior at all trip times.

Consideration of shielding requirements for traversal of radiation belts and for crew protection during giant solar flares indicates that shielding equivalent to as much as 100 gm/cm^2 of graphite may be needed throughout the manned Mars mission. During the outward portion of the mission, propellant weight is more than adequate to provide this shielding, both for nuclear rockets and for electric propulsion. For the return trip, the best operation mode for electric-propelled vehicles consists of carrying reserve propellant

equal to the shielding required for solar flares and using a reentry-landing vehicle to return the crew to Earth, thereby avoiding slow descent through the radiation belt and consumption of propellant during the last portion of the return trip. For nuclear-rocket vehicles, the best operation mode depends on the magnitude of solar-flare shielding required. For high values (about 100 gm/cm^2) or very low values, use of a reentry-landing vehicle, rather than a final Earth capture propulsive impulse, yields the lowest initial weight. When the shielding needed is about the same as the propellant weight required for the final Earth capture impulse, however, the best initial weights are obtained by using propellant to provide some of the capture impulse.

The relative initial weights required for nuclear- and electric-rocket propulsion were not appreciably altered by consideration of shielding requirements.

EVIDENCE OF THE EXISTENCE OF LIFE ON MARS.

W. M. Sinton (Lowell Observatory) Various evidences are presented favoring the existence of vegetation on Mars: (a) red and green areas thought to be deserts and vegetated areas; (b) seasonal variation of dark areas; (c) failure of dark areas to be covered by dust storms; (d) temperature measurements of the surface; (e) changes in the light-polarizing abilities of dark areas; (f) the rate of absorption of infrared light by organic molecules; (g) an inconclusive spectroscopic test for chlorophyll bands; (h) an inconclusive test for bright infrared reflectivity.

Hypothetical remarks concerning modification of terrestrial plants for Martian conditions of low oxygen and freezing temperatures conclude the paper. Plants are perhaps shaped like cacti with moisture near the surface during the day but retracted at night, leaving cellular structure as insulation. The plants may contain their own oxygen-rich atmosphere.

THE HISTORY OF THE CONCEPTS ABOUT MARS.

Willy Ley (Fairleigh Dickinson University) Mars to the Greeks was the red planet, a token of war. About 1600, speculation began concerning its nature, by such men as Athanasius Kircher (1656); Christiaan Huyghens (1698); Giacomo Maraldi (1719); and Sir William Herschel (1784). Writers of early space stories conspicuously neglected Mars: Kepler, Francis Godwin, de Bergerac, de Fontenelle.

Recent discoveries and hypotheses began in 1877: (a) Asaph Hall discovered two small moons; (b) Giovanni Schiaparelli discovered a network of fine straight lines which he called canali; (c) Percivall Lowell explained these canali as an act of intelligent engineering; (d) Alfred R. Wallace opposed Lowell's theory and asserted that Mars was a cold and waterless planet that could not sustain life; (e) Svante Arrhenius asserted that change resulted from evaporation of watery solutions of various salts.

That Mars is a life-sustaining but cold planet where water is precious has been the majority opinion of the last decade. Dissent occurs, however, in the theory presented in 1960 by Drs. Kiess and Corliss: observed phenomena occur by the conversion of nitrogen tetroxide from a solid to a gaseous form. Dr. Ley believes that the assumption of life on Mars is the simplest explanation for the observed phenomena.

EARTH-ORBIT TO MARS-ORBIT VEHICLE DESIGN. Harry O. Ruppe (Future Projects Office, George C. Marshall Space Flight Center) Based on the mission of manned exploration of the planet Mars, a preliminary survey is given of typical mass data for orbit launched vehicles. Using nuclear heat exchanger propulsion systems and relatively short mission durations (one year), these vehicles are large - of the order of 10^3 tons. In the case of Mars, there are definitely "good" and "bad" launch time periods because of the eccentricity of its orbit. Limiting cases are discussed, and remarks as to costs, schedules, and further study requirements are presented.

THE ECOLOGICAL PROFILE OF MARS: BIOASTRONAUTICAL ASPECT. Hubertus Strughold (Aerospace Medical Division, Brooks Air Force Base) An ecological evaluation of the conditions on a planet in terms of bioastronautics must include the following components: the gravitational, magnetic, radiational, atmospheric, hydrospheric, lithospheric, and biotic environment. Characteristics are evaluated:

Gravisphere: 500,000 Kilometers
Magnetosphere: weaker than that of Earth
Atmosphere: corresponds to a height of seventeen kilometers; physiologically a critical atmosphere and the beginning of atmospheric partial space equivalence

Hydrosphere: no open bodies of water although perhaps subsurface ones

Lithosphere: three-fifths reddish considered desert; two-fifths green thought to be vegetation

Biosphere: aspects of chemistry, humidity, and temperature indicate that Mars has a biotic potential of much lower degree than Earth.

Conclusion: the Moon is closer to us topographically, but Mars is closer to us ecologically. Life conditions on Mars seem favorable, whereas the journey itself is long.

MARS - A TARGET FOR ADVANCED PROPULSION.

Harold B. Finger (Space Nuclear Propulsion Office)

Introduction: necessity for "demonstrable pre-eminence" in space achievements. Date for manned mission to Mars will be late 1970's or early 1980's.

Propulsion: large chemical rocket booster stages with nuclear propulsion for upper stages. Major new item in nuclear rocket is reactor. Six KIWI reactor tests have shown success in method of reflector drum control and use of liquid hydrogen but failure in cracking of fuel elements and damage to thermal insulation around core. These failures are due to mechanical engineering design, resulting from insufficient analysis and testing of components under conditions simulating those existing in reactor. Three tests are thus necessary: component, simulated environment, and power. Brief consideration is given to other systems of propulsion: (a) electric--20 to 40 megawatts required for Mars mission; (b) Orion concept--must be tested in space and disallows ground test, hence undevelopable; (c) gaseous--high temperatures necessary for converting uranium into hydrogen make testing unfeasible.

Conclusion: discrimination and realism must be exercised in research as well as in missions planned.

VEHICLE DESIGNS FOR EXPLORATION OF MARS.

A. M. Lippisch (Collins Radio) Key points in the paper are:

1. The atmospheric conditions on Mars will make it possible to use a flying vehicle for exploration of the planet.

2. Flight near the surface of the planet is similar to flight in the Earth atmosphere at altitudes of 18 km or 60,000 ft.

3. Power requirement in flight is reduced to 70 per cent of the power required to fly the same vehicle on Earth at ground level.

4. For flight of longer duration a power plant with a mass ratio of 50 lb/kw would be required under optimum conditions.

5. The development of ultra light weight structures for a high performance aircraft layout should be considered.