61

MDWG-63-2
April 1, 1963

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

A BIBLIOGRAPHY CONCERNING ASPECTS OF
THE METEOROID HAZARD

by

The MSFC Meteoroid Damage Working Group

National Aeronautics and Space Administration

NASA

MDWG-63-2
April 1, 1963

A BIBLIOGRAPHY CONCERNING ASPECTS OF THE METEOROID HAZARD

by

The MSFC Meteoroid Damage Working Group

John B. Gayle	Engineering Materials Branch Propulsion & Vehicle Engineering Division, Chairman
Charles C. Dalton	Aerophysics & Astrophysics Branch, Aeroballistics Division
Henry L. Martin	Physics & Astrophysics Branch, Research Projects Division
William D. Murphree	Assistant to Director, Aeroballistics Division
Charlotte F. Shenk (ex officio)	Redstone Scientific Information Center Army Missile Command

GEORGE C. MARSHALL SPACE FLIGHT CENTER
Huntsville, Alabama

FOREWORD

This bibliography, consisting of 876 entries, was compiled to present information on the physics of hypervelocity impact and the meteoroid hazard. Divided into nine general sections, it contains Surveys of Experimental Data, Vehicle Protection Analysis, Theoretical Studies (Hypervelocity Impact), Experimental Investigations, Experiments and Instrumentation, and Theoretical Studies (Meteoritics). An author index for Part A begins on page 143; the author index for Part B begins on page 283. Most of the references are fairly recent, having been published between January 1950 and October 1962. The entries were obtained from all known sources, and the author, title, agency, periodical, and ASTIA numbers (when known) are included. An abstract by the author is furnished where available, but in some cases the abstracts were prepaıed by the Meteoroid Damage Working Group.

Neither the Marshall Space Flight Center Library nor the Redstone Scientific Information Center can furnish copies of the abstracted material for outside loan. It is therefore suggested that users requiring copies request them from the author, publisher, or other sources.

TABLE OF CONTENTS

A BIBLIOGRAPHY CONCERNING ASPECTS OF
THE METEOROID HAZARD

PART A

SECTION I. SURVEYS OF THE EXPERIMENTAL DATA

1. PRELIMINARY SURVEY OF HIGH-SPEED IMPACT INFORMATION. REPORT FOR APRIL-SEPTEMBER 1958 ON MATERIALS ANALYSIS AND EVALUATION TECHNIQUES. Franken, Peter A. June 1959, Bolt, Beranek and Newman, Inc., Cambridge, Mass. WADC TR 58-577; ASTIA AD-216,029; Contract AF-33(616)4730.

This report summarizes studies of high-speed impact now underway. Experimental facilities for obtaining high velocities are considered, and advantages and disadvantages associated with the various propulsion systems are discussed. A separate classified table lists capabilities of existing propulsion systems. Methods of analyzing high-speed impact data are reviewed.

2. REVIEW AND ANALYSIS OF HYPERVELOCITY IMPACT DATA. Bruce, Edgar P. January 1, 1962, General Electric Co., Missile and Space Vehicles Dept., Philadelphia, Pa. MSVD TIS Series No. 62SD102; Contract AF-04(647)269.

A thorough review has been made of existing experimental data applicable to the impact of high velocity projectiles with semi-infinite metal targets. Empirical equations relating depth of penetration and crater volume to properties of the projectile and target have been derived based upon the assumptions that:

1) projectile shape does not affect crater shape for projectiles which range from spheres to cylinders up to one caliber in length, and

2) craters are hemispherical.

Both of these assumptions are supported by the available data. Additional data and/or a rigorous theoretical treatment of the problem are required to evaluate the utility of the equations at higher impact velocities.

3. SURVEY OF HIGH PRESSURE EFFECTS OF SOLIDS. De Vries, K. L., G. S. Baker and P. Gibbs. October 1960, University of Utah, Salt Lake City. WADC TR 59-341; Contract AF-35(616)5016, Project 7021.

This report contains a summary of all "known" high pressure work done on solids since 1947 with selected reference to work on liquids and gases. The data are presented in the form of 40 tables and more than 500 figures. Some 250 references have been summarized. Descriptions are given of apparatus, procedures, and results.

4. SURVEY OF HYPERVELOCITY IMPACT INFORMATION. Herrmann, Walter and Arfon H. Jones. September 1961 and Addendum, October 1961, Massachusetts Institute of Technology, Aeroelastic and Structures Research Lab., Cambridge. ASRL Report No. 91-1 and Addendum 1, ASTIA AD-267,289 and ASTIA AD-267,290; Contract AF-19(604)7400.

Information relating to cratering and penetration in metallic targets has been gathered. Impact of compact particles, micro-particles, and rods at normal and oblique incidence on quasi-infinite targets and on thin targets, multiple spaced targets, and shielded targets is considered. Experimental data are presented in tabular and graphical form for ready reference. Available theories and semi-empirical theories, as well as empirical correlation equations, are summarized and compared with each other and with the experimental data. For normal impact on quasi-infinite targets, two empirical correlation expressions are deduced which are more generally applicable than previous expressions. A qualitative description of the cratering process is given, and realistic regions of impact are defined. Recommendations for future experimental and theoretical work are made.

SECTION II. VEHICLE PROTECTION ANALYSES

5. ANALYSIS OF SOLID PARTICLES IN SPACE. PART I. PROBABILITY OF A HIT AND DAMAGE TO EXPLORER I AND EXPLORER III SATELLITES. Jonah, Fred C. September 23, 1959, Chance Vought Aircraft, Inc., Dallas, Tex. Report EGR-12529.

   This memo has been prepared to review the present state of our knowledge about the amount of the debris in that region of space where our first manned satellites and space laboratories will orbit. A number of areas of doubt are studied, and a new theory for analysis of surface penetration is presented in preliminary form.

6. ARTIFICIAL SATELLITES. Öpik, Ernst J. In The Irish Astronomical Journal, Vol. 4, No. 7/8, Sept-Dec 1957.

   Meteors are discussed with the probability of puncture; data are presented throughout the discussion.

7. BEHAVIOR OF MATERIALS IN SPACE ENVIRONMENTS. Jaffe, Leonard D. and J. B. Rittenhouse. November 1, 1961, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. JPL TR 32-150; ASTIA AD-266,584; Contract NASW-6.

   The quantitative effects of the environments encountered in various regions of space upon several kinds of engineering materials are discussed. The particles of the earth's radiation belts will cause radiation damage to organics and to optical properties of inorganic insulators. Semi-conductors will be damaged in the inner belt; their more sensitive properties will also be affected by solar flare emissions.

   Erosion by meteoroids is significant only close to the earth. The probability of penetration by meteoroids falls sharply with increasing distance from earth. Much more frequent than penetration is spalling of fragments from the inside walls struck by meteoroids. The efficiency of walls in preventing penetration and spalling can be increased by splitting the walls into a thin front plate and a thicker main plate; quantitative bases for the design of such space armor are presented.

8. A COMPARISON OF THE DISPLACEMENT OF SATELLITES CAUSED BY METEORIC IMPACT AND BY RADIATION PRESSURE. Holl, Herbert B. January 5, 1961, NASA, Marshall Space Flight Center, Huntsville, Ala. Report No. MSFC-MTP-AERO-61-5.

This report offers a comparison between the distance traveled by typical satellites under meteoric impact and under the effect of solar radiation pressure. No other forces are considered. A statistical distribution of the mass and frequency distribution of meteorites was prepared with due regard to already existing estimates. It was found that the effect of the solar radiation outweighs that of the meteoric impacts by several orders of magnitude.

9. CONFERENCE ON THE METEOROID HAZARD TO SPACE POWER PLANTS. Held in Washington, D. C., December 1 and 2, 1959. Anderson, G. M. and A. P. Fraas.

This conference reviews the probability of a surface in near orbit being hit and penetrated by a meteoroid. Whipple's data has been used for calculating meteor flux. Bjork's equations for estimating the penetration of a surface by a meteoroid, as well as an energy equation, have been employed. The Poisson frequency distribution function has been applied in estimating probability distribution of meteoroids in space. The effects of bumpers on penetration and recommended procedure for radiator design were among the subjects discussed. Future plans for testing were set forth.

10. CRITERIA FOR METEOR PROTECTION. Gemmell, Robert A., United Aircraft Corporation, Missiles Space System Division, East Hartford, Conn. Paper given at the American Rocket Society Structural Design of Space Vehicles Conference, Santa Barbara, Calif., April 6-8, 1960. American Rocket Society, New York. ARS Preprint 1097-60.

The study considers the effect of meteor bombardment in lunar mission design. Some parameters required for protection of a manned base on the moon are established. An investigation of meteor characteristics, impact, and damage is set forth, and construction methods for a lunar base are studied. The parameters are considered as initial steps to establish the criteria for meteor protection of a lunar base.

11. DAMAGE TO X-RAY DETECTORS BY METEORITES. Broyles, Arthur A. January 21, 1959, The RAND Corp., Santa Monica, Calif. RAND Report RM 2314; ASTIA AD-219,799.

The effect of meteorites on a beryllium window covering an X-ray detector on a satellite was estimated with the aid of the latest meteor density information from astronomical and satellite measurements. Bjork's formula for the depth of penetration of high velocity particles striking a surface was employed to obtain a fraction of the order of 10^{-6} of the area of the window punched out by meteorites per year. Methods for reducing the amount of sunlight leaking through the holes to the photomultiplier tube are considered. Splitting the beryllium sheet into 2 parts appears to be quite promising.

12. DIRECT EVALUATION OF METEOROID HAZARD. Davison, Elmer H. and Paul C. Winslow, Jr. NASA, Lewis Research Center, Cleveland, Ohio. In Aerospace Engineering, Vol. 21, No. 2, pp. 24-33, February 1962.

The difficulty in evaluating the hazard of space debris to spacecraft is discussed. Sporadic meteors constitute 80 percent of the influx into the earth's atmosphere, at a velocity of 11 to 75 km/sec. Estimates of damage resulting from their impact depend largely on laboratory hypervelocity impact studies. Self-storing sensors (pressure capsules, wire or foil grids) are used to measure penetration of meteoroids through known material thickness. A new capacitor-type micrometeoroid penetration sensor is being developed. Data from Explorer XIII and Vanguard II are presented.

13. THE EFFECT OF METEORIC PARTICLES ON A SATELLITE. Singer, S. Fred. May 1956, University of Maryland, College Park. Technical Report No. 41; ASTIA AD-102,634; also in Jet Propulsion, Vol. 26, No. 12, pp. 1071, 1075, 1087, December, 1956, and ARS Preprint No. 307-56.

Erosion effects of high velocity meteoric dust on space vehicles are of great importance but not easily predictable. This paper discusses some physical models to allow calculations of the erosion rate; they lead to widely differing values. Laboratory experiments with artificially accelerated dust particles should furnish more reliable guides for a theory. Even so, important indications are derived for the choice of material and construction of a satellite skin to minimize meteor effects. Atmospheric sputtering is shown to be unimportant, e.g., in the case of an aluminum skin. An erosion experiment for the Vanguard satellite is described. It is based on a radioactive method which has many advantages in terms of sensitivity and simplicity. The results can be used to study the effect of the sun on dust particles in interplanetary space.

14. THE EFFECT OF METEOROIDS ON THE STRUCTURAL DESIGN OF SPACE VEHICLES. Pereira, J. F. June 1, 1960, Republic Aviation Corp., Farmingdale, N. Y. Report No. RD SR-7.

This report presents an introduction to certain structural design aspects of vehicles designed for the environment of space, namely, the meteoroid impact problem. Several basic definitions are included to insure proper communication, along with a brief discussion of the origin of meteoroids. Methods of computation are included for determining probability of encounter, and high speed impact phenomena are discussed. Several penetration theories are presented and compared, plus some correlation with experimental data.

15. EFFECT OF MICROMETEORITE COLLISIONS ON SPHERICAL WIRE-MESH PASSIVE REFLECTORS. Bedrosian, Edward. August 1962, The RAND Corp., Santa Monica, Calif. Rand Report MEMO RM 3274-NASA; Contract NASr-21.

This memorandum discusses the possible effects of micrometeorites in reducing the useful lifetime of a spherical wire mesh passive-reflector communications satellite. Theoretical conditions are postulated under which a wire composing part of the mesh might be severed by a hypervelocity collision with micrometeorite. This criterion taken with the known flux of micrometeorites is used to compute the probability that such collisions will degrade the electrical performance of such a reflector. It is concluded that they will not significantly affect its useful lifetime.

16. EFFECTS OF HYPERVELOCITY PARTICLES ON SHIELDED STRUCTURES. Wallace, R. R., Jr., J. R. Vinson and Murray Kornhauser. April 1961, American Rocket Society, N. Y. ARS Preprint 1683-61.

This paper presents pertinent results of the test program and statistical analysis and, based upon these, sets forth design criteria, data, and trends. It was found, as an example, that in these structures over 50% of the external structural weight for single-walled particle protection can be saved by proper design and use of meteor bumpers without sacrifice of safety.

17. EFFECTS OF INTERPLANETARY DUST AND RADIATION ENVIRONMENT ON SPACE VEHICLES. Singer, S. Fred. In Physics and Medicine of the Atmosphere and Space: 2nd International Symposium on the Physics and Medicine of the Atmosphere and Space, San Antonio, Tex., 10-12 November 1959.

Discussed are (1) meteoric erosion and sputtering, and (2) the effects of high-energy, inc ing cosmic rays and the radiation belt, and the design of appropriate radiation shielding.

18. EFFECTS OF METEORITIC IMPACTS AND OTHER DISTURBANCES ON AN ORBITING VEHICLE WITH EMPHASIS ON THE TWENTY-FOUR-HOUR COMMUNICATION SATELLITE. White, J. B. January 17, 1961, NASA, Marshall Space Flight Center, Huntsville, Ala. MSFC Report No. MTP-M-G&C-61-3.

The purpose of this investigation is to determine absolute and relative magnitudes of perturbation torques on orbital vehicles. The report deals primarily with torques resulting from meteoric bombardment, the earth's gravitational field, solar radiation pressure, and moving parts within the vehicle. Emphasis has been placed on meteoric impingements.

19. EFFECTS OF METEOROID IMPACTS ON SPACE VEHICLES. Eichelberger, Robert J. and John William Gehring, Jr. October 15, 1961, Ballistic Research Labs., Aberdeen Proving Ground, Md. APG-BRL Report No. 1155, December 1961; ASTIA AD-272,340; ARS Preprint 2030-61.

The purpose of this paper is to present as clear and complete (but non-mathematical) a description of the mechanism of crater formation in hypervelocity impact as is possible at the present state of the art, together with such data and empirical relationships as have been well established.

20. EFFECTS OF METEOROIDS. Jaffe, Leonard D. and J. B. Rittenhouse. In Behavior of Materials in Space Environment, Section II, pp. 49-90, November 1, 1961. Jet Propulsion Lab., California Institute of Technology, Pasadena. Report JPL-TR-32-150, Contract NASw-60. Also in ARS (American Rocket Society) Journal, Volume 32, No. 3, pp. 320-346, March 1960; ARS Preprint 2033-61; ASTIA AD-266,548.

Special problems relating to the behavior of materials in outer space arise both from the absence and the presence of surrounding matter - that is, from vacuum and from particles in space. Although in the last few years much information has been gained with respect to the nature of these particles and the effect that they have upon materials, the gaps in our knowledge remain great. However, in order to design and build equipment to operate in space, we must form engineering judgments on the basis of available information. This paper attempts to synthesize the best of the current information while discarding that which is no longer applicable. Section VI deals specifically with meteoric particles in space, meteoric erosion and performance, space armor, and spalling by meteoroids.

21. EFFECTS OF METEORS UPON MISSILES OUTSIDE THE EARTH'S ATMOSPHERE. Hempy, F. S. May 27, 1957, Poulter Labs., Stanford Research Institute, Stanford, Calif. SRI-GU-1989 PR-3; Contract DA-04-200-ORD-597.

Controlled impact and penetration studies of various target materials using high velocity particles less than 1/8 inch in diameter are being conducted. This also includes some work which has been conducted and is being continued at our own expense. The development efforts, and particularly in the early stage of this work, are common to all projects and in the interest of completeness will be reported to each. The results obtained using special targets or in which there is proprietary interest will of course be reported only to those organizations concerned.

22. EFFECTS OF MICROMETEORITES ON SPACE VEHICLES: AN ANNOTATED BIBLIOGRAPHY. (Addendum to the Space Materials Handbook) Goldmann, J. B. and W. L. Hollister, Compilers. July 1961, Lockheed Corp., Missiles and Space Division, Sunnyvale, Calif. Report No. 3-34-61-5; SB 61-37; ASTIA AD 263,821; Contract AF 04(647)673.

The references included in this publication were gathered to present information on the effects of cosmic dust, micrometeorites, and meteorites on space vehicles. The erosive effects of micrometeorites and cosmic dust are included. Also included are the penetration effects of meteorites. Information on the effects of erosion and penetration on thermal contract surfaces, effects on structures and effects on optical devices were included. Theoretical and experimental research on erosion and penetration was also included. References are arranged alphabetically by author.

23. EFFECTS OF SPACE ENVIRONMENT ON MATERIALS. Report for May-August, 1960. Atkins, J. H. et al. December 1960, National Research Corp., Cambridge, Mass. WADD TR-60-721; ASTIA AD-254,075; Contract AF 33(616)6288.

An attempt is made to provide information regarding the effects that space environment will have on the performance of materials to assist in the selection of materials for space applications. The following topics are covered: (1) space radiation effects on materials, (2) mechanical properties in vacuum, (3) friction and bearings in vacuum, (4) surface electric properties in vacuum, (5) meteoroids and their influence on materials, and (6) status of vacuum technology.

24. THE EFFECTS OF THE NATURAL ENVIRONMENT IN CISLUNAR SPACE IMPORTANT TO THE SIMULATION OF SPACE VEHICLES. Livingston, W. A. and E. M. Hart. 1961, Cornell Aeronautical Lab., Inc., Buffalo, N. Y. American Rocket Society, New York. ARS Preprint 2140-61.

Environmental simulators can provide quick and economical solutions to many of the problems encountered in vehicle design and in training of space crews. This is true despite the fact that simulation can never provide as good a test as actual flight, nor will the results of such simulation warrant complete confidence in view of the inescapable uncertainty about the faithfulness of simulation. Nonetheless, it is a valuable tool.

The primary interest underlying the investigation discussed within this paper is the determination of those aspects of the environment that must be simulated in training a crew for a space mission.

25. ENVIRONMENT FOR MANNED SPACE FLIGHT. Evvard, John C. In Aerospace/ Engineering, Vol. 20, No. 12, pp. 9 and 79, December 1961.

Much interest is being shown in the environment beyond the upper atmosphere. Electronic and human systems must be shielded against the hazards of this environment. The first manned lunar spacecraft cannot be protected against all hazards that our solar system and galaxy might produce. Both by data and by analytical studies the proper compromises between shielding weight and survival probability must be determined. From such studies, both for meteoroid damage and for space radiation dangers, should come an understanding of the probability of man's survival in what could and may be very hostile space environment.

26. ENVIRONMENTAL PROBLEMS OF SPACE FLIGHT STRUCTURES. I. METEOROID HAZARD. Davidson, John R. and Paul E. Sandorff. In collaboration with the NASA Research Advisory Committee on Missile and Space Vehicle Structure (Preliminary Draft), March 1960.

This report is a result of a study conducted in collaboration with the NASA Research Advisory Committee on Missile and Space Vehicle Structure. This is a survey report, the first report of a series. Various theories of flux density and penetration are discussed.

27. ENVIRONMENTAL PROBLEMS OF SPACE FLIGHT STRUCTURES. II. METEOROID HAZARD. Davidson, John R. and Paul E. Sandorff. In collaboration with the NASA Research Advisory Committee on Missile and Space Vehicle Structures. January 1963, National Aeronautics and Space Administration, Washington, D. C. NASA TN-D-1493.

The meteoroid environment and the effects of hypervelocity impact on space vehicles are described, and the effects of the incompleteness of present knowledge of each are discussed. The over-all problem of the meteoroid hazard is evaluated and methods of reducing the probability of meteoroid damage are given. A partial listing of typical research projects on meteoroid-environment and hypervelocity-impact problems is presented.

28. ESTIMATED DAMAGE TO SPACE VEHICLES BY METEOROIDS. Bjork, Robert L. and Carl Gazley, Jr. February 20, 1959, The RAND Corp., Santa Monica, Calif. Rand Report MEMO RM-2332; ASTIA AD-230,073.

The probability of damage to space vehicles through collision with meteoroids depends on the frequency, velocity, and mass of meteoroids in space, and on the depth to which they will penetrate a vehicle skin. The probability of such damage is estimated in this report. Available estimates of the mass and frequency of meteoroids in space are combined with a new penetration theory to yield a range of estimates of skin-penetration probability, which has, however, appreciable uncertainty because of the difficulty of estimating meteoroid mass and frequency. The results indicate, for example, that a surface 1 meter square and 1 mm thick will be punctured sometimes between 7 weeks and 620 years.

29. ESTIMATES OF THE PENETRATION OF THE SKIN OF A SATELLITE BY METEOROIDS. Kornhauser, Murray. April 25, 1958, Missile and Ordance Systems Dept., General Electric Co., Inc., Philadelphia, Pa. Applied Mechanics Memo No. 50.

In order to predict the frequency of penetration of the skin of a satellite by meteoroids, estimates are made of the frequency of encounters with meteoroids and the cratering effect of each impact. The cratering effects are based on the correlation of the most recent laboratory experimentation using hypervelocity particles, and very conservative estimates of impact frequency are employed. The resulting calculations of frequency of penetration percentage of skin area covered by holes and average loss of skin thickness with time are expected to be conservative for design purposes.

30. EVALUATION OF SELF-SEALING STRUCTURES FOR SPACE VEHICLE APPLICATIONS. (A PROPOSAL.) January 1963, Northrop Space Labs., Hawthorne, Calif. Prepared for National Aeronautics and Space Administration. NSL 63-9.

A plan is given for evaluation of the concept of self-sealing structures for space vehicle applications. Source of the topics included are the combined Whipple bumper self-sealing wall concept, the dynamic response of self materials, rheology of self-sealing materials and other similar parameters.

31. THE EVASION OF HAZARDOUS OBJECTS IN SPACE. PART I. THE CONDITIONS FOR MISSING. Proell, Wayne. In Journal of Space Flight, Vol. 3, No. 4, pp. 1-6, April 1961.

The evasive process "missing" is defined as the operation in which two moving objects are prevented from interception and collision. Some principles and apparatus for the operation will be developed. (See also Part II, entry 163 in Part B of the Bibliography.)

32. GENERAL RESEARCH IN FLIGHT SCIENCES FLUID MECHANICS. PART X. ON METEORITIC IMPACT. APPENDIX. ON THE ABSENCE OF CRATERS ON THE FAR SIDE OF THE MOON. Beard, David B. January 1959-January 1960, Lockheed Aircraft Corp., Missiles and Space Division, Palo Alto, Calif. Lockheed LMSD-288139, Vol. 1, Pt. 2.

Study concludes that surface erosion from micrometeoritic dust would be too slight to cause significant changes in the thermal and radiative properties of the skin and that puncture from rare larger particles would be very much less than has been generally assumed.

33. HYPERENVIRONMENT SIMULATION. PART I. DEFINITION AND EFFECTS OF SPACE VEHICLE ENVIRONMENT, NATURAL AND INDUCED. McCoy, T. M. January 1961, Northrop Aircraft, Inc., Hawthorne, Calif. Report NOR 60-289; WADD TR 60-785, Pt. I; ASTIA AD-254,077; Contract AF-33(616)6679.

This report summarizes current knowledge of the natural and induced environments associated with space exploration. Terrestrial and lower atmospheric parameters are not specifically covered. All hyperenvironmental variables are individually discussed, and pertinent data are presented in graphical or tabular form wherever possible. Known and possible effects for each of the environments are examined for qualitative consideration.

34. HYPERVELOCITY IMPACT EFFECTS ON ABLATIVE NOSE CONE MATERIALS (U). Carnevale, E. H., W. L. McKay and Joseph A. Hull, Research and Advanced Development Division, Avco Corp., Wilmington, Mass. In Transactions of the Fifth Symposium on Ballistic Missile and Space Technology, Vol. I, Re-Entry Vehicles. Held 29-31 August 1960, on Campus of the University of Southern California at Los Angeles. Sponsored by Headquarters, AFBMD, Space Technology Lab., Inc. and Aerospace Corporation. Report No. STL-AS-60-VOO1-02622. Report SECRET. Abstract SECRET.

35. HYPERVELOCITY KILL MECHANISMS. FEASIBILITY STUDY - INTERNAL HEATING (U). May 28, 1962, Missile and Space Vehicle Department, General Electric Co., Philadelphia, Pa. GE-62SD560. Prepared under Contract No. Nonr-3295 (00) (X), Naval Research Lab, Washington, D. C. ARPA Order 149-60; Project Defender. Report SECRET. Abstract SECRET.

36. HYPERVELOCITY KILL MECHANISMS PROGRAM. PROGRESS REPORT NO. 7. VOL I. Semi-Annual Technical Progress Report for the Period ending 20 March 1962 (U). Naval Research Lab., Washington, D. C., June 1962. Report No. NRL-5813. NRL Problem No. F04-11; ARPA order No. 149-60; Project Defender. Report SECRET. Abstract SECRET.

37. HYPERVELOCITY KILL MECHANISMS PROGRAM. PROGRESS REPORT NO. 7. VOL II. Semi-Annual Technical Progress Report for the period ending 20 March 1962 (U). June 1962, Naval Research Lab., Washington, D. C. Report No. NRL-5813. NRL Problem No. F04-11; ARPA Order No. 149-60; Project Defender. Report SECRET RD. Abstract SECRET.

38. IMPACT EFFECTS AGAINST PROPULSION SYSTEMS (U). Kreyenhagen, K. N., Rene B. Mortensen and H. S. Zimney. December 1961, Aerojet General Corp., Downey, Calif. Report DYD61-2669(0404)SH; Contract AF08(635)1382. In 5th HVIS. Report SECRET. Abstract SECRET.

39. INFLUENCE OF METEOROID HAZARDS ON SELECTION OF SPACECRAFT PROPELLANTS. Weber, Richard J., NASA Lewis Research Center, Cleveland, Ohio. In American Rocket Society Journal, Vol. 32, No. 7, pp. 1105-1106, July 1962.

The note considers the weight of a hypothetical space stage whose tank thickness is determined on the need for protection against meteoroid damage. Reference is made to other studies concerning type of propellants to use in spacecraft. More detailed studies are necessary for any specific application.

40. INTERACTIONS WITH METEOROID ENVIRONMENT. SECTION III. In Liquid Propellant Losses During Space Flight. (Second Quarterly Progress Report). Wiederhorn, Norman M. May 1961, Arthur D. Little, Inc., Cambridge, Mass. Report No. C-63270-00-02; ASTIA AD 260,545; Contract NAS5-664.

Progress is reported in a theoretical and experimental evaluation of "meteor bumpers" as protective devices against the meteoroid hazard. The experimental results indicate that theory may be over-optimistic with respect to estimating the protection that bumpers will afford.

Consideration is given to the development of a protection system in which meteoroids are detected while they are distant from the vehicle and moved out of the path of the particle. However, the large power requirements to achieve even the minimum acceleration for any reasonable size shield or vehicle would appear to preclude this as a practical approach to the solution of the meteoroid problem. As a consequence of this, it is concluded that optical sighting may be a useful method for obtaining meteoroid data in satellite experiments.

41. INVESTIGATION OF ICBM VULNERABILITY TO ARPAT DART. HYPERVELOCITY KILL MECHANISMS PROGRAM (U). April 30, 1962, Naval Research Lab., Washington D. C. NRL Memo Report 1314; ARPA Order 149-62; Project Defender. Report SECRET RD. Abstract SECRET.

42. LEAST-WEIGHT DESIGN AND CONFIGURATION FOR SPACE-VEHICLES STRUCTURES. Dow, N. F. April 10, 1959. In Summary of Technical Reports. January-June 1959. Vol. II. Space Mechanics, Plasma Physics, ARC Research, Life Support. 1959, General Electric Co., Aeroscience Lab., Philadelphia, Pa. GE Report 269R-June 1959, Vol. 2; ASTIA AD-266,832.

This paper includes a plot of the ratio of total thickness penetrated for a shielded wall to the depth of penetration in an unshielded wall against the ratio of total shield thickness to crater depth in unshielded wall.

43. LIQUID PROPELLANT LOSSES DURING SPACE FLIGHT. FIRST QUARTERLY REPORT. January 1961, Arthur D. Little, Inc., Cambridge, Mass. Report No. C-63270-00-01.

The program objectives are to provide evaluation techniques, methodology and data for the evaluation of liquid propellant storage system concepts and to design optimum systems for vehicles for any mission within the solar system. Consideration is given to launch from earth or other planet, orbit about earth or other planet, journey in interplanetary space, and landing on earth or other planet. Effort is made to quantitatively describe those aspects of the environment which may be contributory to propellant losses, the interaction of the propellant and its storage system with the environment, and the performance of the protective system to limit such losses. The study is divided into the following areas: (1) space environment; (2) interaction of thermal radiation with the propellant and its storage systems; (3) interaction of meteoroids with the propellant and its storage systems, and (4) interaction of ionizing radiation with the propellant and its storage system.

44. LIQUID PROPELLANT LOSSES DURING SPACE FLIGHT, 2nd QUARTERLY PROGRESS REPORT. Wiederhorn, Norman M. May 1961, Arthur D. Little, Inc., Cambridge, Mass. Report No. C-63270-00-02; ASTIA AD 260,545; Contract NAS5-664.

Contents:
Thermal interaction studies
- Theoretical aspects of the behavior of multiple-foil radiation shielding
- Analytic studies of thermal protection system.
- Experimental study of multilayer radiation shielding insulation

Interactions with meteoroid environment
- The evaluation of meteor bumpers
- The impact of pellets with thin plates
- Other protection systems

Effects of ionizing radiation
- The calculation of radiation dose rates
- Effect of proton sputtering of absorptivity and emissivity of reflecting surfaces
- Embrittlement of structural materials
- Effect of hydrogen diffusion on vacuum insulation
- Radiation-induced desorption of absorbed gases.

45. LIQUID PROPELLANT LOSSES DURING SPACE FLIGHT: COMBINED THIRD AND FOURTH QUARTERLY PROGRESS REPORTS FOR THE PERIOD JUNE 1, 1961 TO NOVEMBER 30, 1961. Wiederhorn, Norman M. Arthur D. Little, Inc., Cambridge, Mass. Report No. C-63270-00-03; ASTIA AD-270,974; Contract No. NAS5-664.

Contents:
Analytical studies of thermal protection systems
- Control of intercomponent heat leaks due to supports and piping
- Heat in leakage due to discontinuities
- Effect of gas leaks or outgassing on heat transfer between foils
- Incident heat flux for the general vehicle and orbit

Experimental study of thermal interactions
Calibration data
Study of meteoroid interactions
The meteoroid hazard
The physics of meteor bumper penetration
Experimental evaluation of meteor bumper
A satellite experiment for observing the meteoroid flux and size distribution
Effect of zero G on the storage of liquid propellants
Effect of ionizing radiation and other space environmental factors on the thermal decomposition of energetic propellants

46. THE MECHANICAL PENETRATION OF BUMPER SCREENS. Langton, N. H. In British Interplanetary Society Journal, Vol. 3, pp. 283-294, September 1954.

The mechanical penetration of bumper screens of different materials by an iron or stone meteorite is investigated theoretically, tables and graphs showing the penetrations for different sized meteorites at varying impact velocities being given. These values are compared with those for the thermal penetrations, and conclusions about the design of bumper screens and spaceship hulls thereby obtained.

47. METEORIC EFFECTS ON ATTITUDE CONTROL OF SPACE VEHICLES. White, J. B. NASA, Marshall Space Flight Center, Huntsville, Ala. In American Rocket Society Journal, Vol. 32, No. 1, pp. 75-78, January 1962.

Development of general methods for determining meteoric disturbances for any known vehicle configuration is discussed. These methods are then applied to the 24-hour communications satellite for illustration purposes. Probable disturbance is in the order of 10^{-3} deg. per sec. Calculated impact density agrees favorably with that measured by Explorer I and a Vanguard.

48. METEORITIC IMPACT. Beard, David B. Lockheed Aircraft Corp., Missiles and Space Div., Sunnyvale, Calif. In American Rocket Society Journal, Vol. 31, No. 1, pp. 87-88, January 1961.

The impact of meteoroids on a space vehicle skin is examined from a consideration of the different physical processes by which energy transfer can occur. It is shown that only evaporation is significant, that erosion is negligible, and that puncture is less likely than previously thought by many authorities, the threshold thickness in centimeters being only 0.6 cm for one puncture per year per 100 m^2 of surface.

49. THE METEORITIC RISK TO SPACE VEHICLES. Whipple, Fred L. October 12, 1957, American Rocket Society, New York. ARS Preprint 499-57, also in Vistas in Astronautics, Vol. 1, Pergamon Press, New York, 1958.

Consideration is given to the distribution of meteoritic material and its rate of fall on the earth as functions of mass and velocity. With a simple theory, the probabilities are calculated that surfaces in space in the neighborhood of the earth may be punctured by meteoric action. A table of data and probabilities is given. It is calculated that a near-earth satellite of radius 20 inches and skin thickness 0.5 mm Al will be punctured on the average of once in five days.

Upper limits to the effects of skin erosion on a space-exposed surface are calculated on the basis of erosion by meteoritic dust, by corpuscular radiation from the sun and by gases of the extended solar corona. The erosive effect from meteoritic dust is comparable to the combined effects from the other two causes and gives a rate of skin (Al) erosion of the order of 2×10^{-13} gm/cm^2/sec or less. Optical surfaces exposed to space should not be affected functionally by erosion over periods less than about a year. Attention is given to the expected degree of accuracy of the observed data and the conclusions, particularly for the meteoritic material. The uncertainties arise from combined theoretical and observational limitations.

50. METEOROID BUMPERS FOR SPACECRAFT. Rolsten, Robert F. General Dynamics/Astronautics, San Diego, Calif. Report No. ZS-MT-014.

This report propounds the assessment by the Materials Technical Group, Convair-San Diego of the meteoric environment of space, the hazard to spacecraft, protection concepts, results from preliminary ballistic tests and facilities to conduct hypervelocity impact experimental programs. This report shows that meteoric material with a mass as low as 10^{-15} grams can erode and damage radomes, windows, solar cells and surfaces designed for temperature control and heat balance systems. In addition to this relatively slow destructive action from minute particles, there exists the possibility of catastrophic destruction via total demolition, puncture and fluid (gas and liquid) loss from larger particle impacts.

51. METEOROID BUMPERS FOR SPACECRAFT. PART II. Rolsten, Robert F. and Harold H. Hunt. October 1961, General Dynamics/Astronautics, San Diego, Calif. Report No. GDC-61-16.

Part I entitled "Meteoroid Bumpers for Spacecraft" covered

1. Meteoric particle environment of space
2. Fundamentals of hypervelocity impact
3. Phenomena associated with hypervelocity impact
4. Protection concepts investigated at General Dynamics/Convair

Part II is an extension of 4 above and covers the experimental investigations of single and multi-walled meteoroid bumpers and the impact behavior of composite, pressurized and self-sealant structures.

52. METEOROID HAZARD TO NUCLEAR SPACECRAFT. Bjork, Robert L. The RAND Corp., Santa Monica, Calif. In Nucleonics, Vol. 19, No. 4, pp. 91-92, April 1961.

In calculating the meteoroid hazard, one must collect and analyze available experimental data about large meteoroids recorded by photographic or radar techniques as well as about the tiny meteoroids that hit detectors in satellites and rockets. Combining this information with experimental and theoretical data on hypervelocity impacts, one can estimate how deeply and how often meteoroids penetrate different materials in space.

53. METEOROID SHIELDING FOR SPACE VEHICLES. Rodriguez, David. Aeronutronic Systems, Inc., Div. of Ford Motor Co., Newport Beach, Calif. In Aerospace Engineering, Vol. 19, No. 12, pp. 22-23, 55, 58, 60, 62, 64-66, December 1960.

The most certain aspect of the hazard to space vehicles from meteoroids is the great uncertainty underlying any attempt at a quantitative assessment of the problem. All available information including even the most recent experimental and theoretical results constitutes only the most meager knowledge of the meteoroid environmental characteristics of space and of the response of materials and structures to this environment. Tremendous areas of ignorance and uncertainty exist, and even much of the available information is itself subject to considerable uncertainty. Thus, within the current state of the art, any quantitative predictions must be regarded as only crude estimates indicative of the orders of magnitude involved. However, using the best information available at present, these order-of-magnitude indications can be established and, if properly interpreted, serve as useful guides. In addition, logical and systematic design procedures, adaptable to changing state-of-the-art information, can be developed.

54. METEOROIDS AS A HAZARD IN SPACE FLIGHT: A SURVEY OF PRESENT INFORMATION. Thompson, Allen B. and Charles F. Gell. Chance Vought Corp., Dallas, Tex. Paper presented at ARS Space Flight Report to the Nation, New York, 9-15 October 1961. ARS paper 2138-61.

A review is made of present knowledge of meteoritic material in space - flux, mass, density, velocity, etc. - based on satellite, rocket, radio and visual sources. Results of hypervelocity impact tests are analyzed to better define penetration relationships for development of a meteoroid risk probability. The effects of meteoroid penetration into manned space cabins are deduced based on animal tests, and a brief review is made of the effectiveness of various wall structures for reducing possible penetration.

55. METEOROIDS-IMPLICATIONS FOR THE DESIGN OF SPACE STRUCTURES. Kaechele, Lloyd E. and Arnold E. Olshaker. The RAND Corp., Santa Monica, Calif. and Massachussetts Institute of Technology, Cambridge. In Aero/Space Engineering, Vol. 19, No. 5, pp. 44-45, May 1960; also in Institute of Aeronautical Sciences Manned Space Stations Symposium, Los Angeles, April 1960.

The nature of the meteoroid environment and the effects of meteoroid impact are briefly described with respect to their relationships and their bearing on the design of space structures.

56. MULTI-WALL STRUCTURES FOR SPACE VEHICLES. REPORT FOR 1 JUNE 1959-31 MAY 1960 ON CONSTRUCTION TECHNIQUES AND APPLICATION OF NEW MATERIALS. Lampert, Seymour and D. G. Younger. Aeronutronic Systems, Inc., Div. of Ford Motor Co., Newport Beach, Calif. Report No. U-910; WADD TR 60-503; ASTIA AD-250,269; Contract AF-(616)6641.

A design study for a three-man vehicle which could be placed in a 500 km orbit for a thirty day mission is given. The plan is for a double wall construction, and the parameters studied include mechanical loading, pressure vessel loading, solar radiation and high energy radiation in addition to a chapter on meteoroid penetration.

57. ORBITING PELLET COUNTERMEASURES STUDY (U). Period Covered 18 December 1961 through 30 April 1962, Final Report. Hughes Aircraft Co., Culver City, Calif. Report No. SDN 2-5812/22; Contract AF 04(695)12. Report SECRET. Abstract SECRET.

58. THE PHYSICS OF SELF-SEALING SHIELDS (A PROPOSAL TO INVESTIGATE). March 7, 1962, General Dynamics/Astronautics, San Diego, Calif. Report No. AE62-0222, PIN 62-165.

The solid meteoroid material in space presents a considerable hazard to manned and unmanned vehicles that must operate for long periods of time. Due to this obvious hazard many investigations have been conducted. However, theory and design have generally followed separate paths, and there are only a few attempts to integrate theoretical and recognized impact phenomena in the development of structural systems.

The proposed investigation includes a carefully controlled experimental study of the performance of the various material components of a self-sealant structure and of the mechanistic behavior of these components when subjected to hypervelocity impact.

59. A POSSIBLE SOLUTION TO METEOROID DAMAGE CONTROL. Tuckerman, A. J., V. I. Mizuno and P. J. D'Anna. Paper presented at American Ordnance Association Meeting, Cleveland, Ohio, 20 October, 1960. Northrop Aircraft, Inc., Norair Div., Hawthorne, Calif. Report No. NOR-60-312, October 3, 1960. For condensation, see "Self-Sealing Sandwich for Meteoroid Protection," entry 64 in Part A of the Bibliography.

The incorporation of repair or damage control equipment into the structure of pressurized space vehicles is described. Some type of self-sealing mechanism appears to be the most suitable approach to repair of damage in space and to reduction of hazards from meteoric penetration. Under the self-sealing concept, the arrangement of the structure of the cabin wall would play an important role in the self-sealing configuration. In the preliminary phase of this work, a study of several self-sealing configurations was made under static test conditions. These tests proved the self-sealing concept quite feasible. In order to test the structures under dynamic conditions, a particle accelerator was constructed. On the basis of the results obtained in this exploratory program, it is felt that a satisfactory self-sealing membrane can be developed for meteoroid damage control of space vehicles.

60. PRELIMINARY INVESTIGATION OF IMPACT ON MULTIPLE SHEET STRUCTURES AND STUDIES OF THE METEORITIC HAZARD TO SPACE VEHICLES. Nysmith, C. Robert and James L. Summers. September 1961, NASA, Ames Research Center, Moffett Field, Calif. Report No. NASA TN D-1039; ASTIA AD-263,199.

Glass spheres impact multiple-sheet structures. Results indicate increased penetration resistance with increased number of sheets (total weight constant) and with increased spacing between sheets and with glass-wool filler added.

Evaluation of two lunar vehicles shows significant increase in flight time but still the meteoroid hazard exists.

61. A PRELIMINARY INVESTIGATION OF THE DESTRUCTION OF SOLID-PROPELLANT ROCKET MOTORS BY IMPACT FROM SMALL PARTICLES. Carter, David J., Jr. September 1960, NASA, Langley Research Center, Va. NASA TN D-442.

An investigation was conducted to determine whether solid-propellant rocket motors could be ignited and destroyed by small particle impacts at particle velocities up to approximately 10,940 feet per second. Spheres ranging from 1/16 to 7/32 inch in diameter were fired into simulated rocket motors containing T-22 propellant over a range of ambient pressures from sea level to 0.12 inch of mercury absolute. Simulated cases of stainless steel, aluminum alloy, and laminated fiberglas varied in thickness from 1/50 to 1/8 inch. Within the scope of this investigation, it was found that ignition and explosive destruction of simulated steel case rocket motors could result from impacts by steel spheres at the lowest attainable pressure.

62. A PRELIMINARY REPORT ON THE PRINCIPLES OF METEOROID PROTECTION. Prepared by the Materials Technical Group, General Dynamics/Convair, San Diego, Calif., 1961.

Vehicles operating in space will be exposed to the natural environments of vacuum, meteors and dust, thermal, solar and cosmic radiation and force fields. Propulsion products, space debris and enemy action are of human origin and will contribute to the entire environment. Unfortunately, the space environments are inadequately defined due to the paucity of experimental data. This can be attributed to the infancy of rocket and satellite programs for space testing and to the variable environment resulting from meteor and solar flare activity.

The solid meteoric material in space presents a considerable hazard to manned and unmanned vehicles that must operate for long periods of time. Meteor material with a mass as low as 10^{-15} grams can erode and damage radomes, windows, solar cells and surfaces designed for temperature control and heat balance systems. In addition to this relatively slow destructive action from minute particles, there exists the possibility of catastrophic destruction via total demolition, puncture and fluid (gas and liquid) loss from larger particle impacts.

63. THE PRODUCTION OF METEOROID HOLE AREA IN A SPACE VEHICLE NEAR THE EARTH. Edmiston, R. M. January 1962, Aeronutronic Systems, Inc., Div. of Ford Motor Co., Newport Beach, Calif. Paper given at Institute of the Aeronautical Sciences, 30th Annual Meeting, New York, January 22-24, 1962. IAS Paper No. 62-29.

A method is presented for determining the time dependence of the production of meteoroid hole area in the skin of a space vehicle in the vicinity of the earth. It is assumed that the vehicle is constructed of a single wall. Also assumed is that the penetrating particle makes only one hole in the skin; i.e., it does not pass through the vehicle and out the opposite wall. The present work indicates that for relatively long missions of a sizeable vehicle, a reasonable probability that the hole area will be limited to a small value cannot be assured without tremendous weight penalties if a single wall is employed. Extension of the present analysis is required in order to make it applicable to multiple wall concepts.

64. SANDWICH INSULATION MATERIAL FOR CENTAUR MISSILE. Hertz, J. June 3, 1959. General Dynamics Corp., Convair/Astronautics, San Diego, Calif. Report No. MRG-75.

Samples of sandwich insulations were fabricated and subjected to environmental conditions. Sandwich which showed greatest promise utilized 0.010" Conolon 506 laminate faces bonded to 0.5" Stafoam AA-202 foam core with 1217 adhesive.

65. SATELLITE PRESSURE LOSSES CAUSED BY METEOROID IMPACTS. Kornhauser, Murray. General Electric Co., Philadelphia, Pa. In American Rocket Society Journal, Vol. 30, No. 5, pp. 475-478, May 1960.

In order to predict the frequency of hull penetration of a satellite capsule by meteoroids, estimates are made of the frequency of encounters with meteoroids and the cratering effect of each impact. The cratering effects are based on the correlation of recent laboratory experimentation using hypervelocity particles, and very conservative estimates of impact frequency are employed. The resulting calculations of percentage of hull area covered by holes, and loss of internal pressure vs time, are expected to be conservative for design purposes. Application of this method to a manned satellite capsule having a given surface area and time of exposure to meteoroids results in predictions of probability of penetration of several hull designs, time required for air pressure to drop to 1/3 atm, and weight of reserve air needed to replace leakage and maintain internal pressure at 1 atm.

66. SELF-SEALING SANDWICH FOR METEOROID PROTECTION. Tuckerman, A. J., V. I. Mizuno and P. J. D'Anna, Norair Div., Northrop Corp., Hawthorne, Calif. In Space/Aeronautics, Vol. 35, No. 3, pp. 56-57, March 1961 (Abridged). See entry 57 in Part A of the Bibliography.

This is a condensation of a paper, "A Possible Solution to Meteoroid Damage Control," given at a meeting of the American Ordnance Association's Missiles and Astronautics Division, in Cleveland, Ohio, October 1960. Dynamic tests prove self-sealing is feasible. Limiting the puncture's size is most important.

67. SETTING THE STRUCTURAL DESIGN CRITERIA FOR SPACE DEBRIS EFFECTS IN CISLUNAR AND OUTER SPACE TRAVEL. Black, Syndey D., Republic Aviation Corp., Farmingdale, N. Y. Paper given at National Aeronautic Meeting, Society of Automative Engineers, New York, April 3-6, 1962. Report No. SAE 520 E.

Although much is known about the space debris environment, there are enough knowledge gaps in this area to cause concern to space vehicle designers. This paper is directed toward evaluating the limits to be set in material selection and structural design so that the existing space debris environment can be tolerated by a space vehicle.

Equations depicting the present state of knowledge are presented, and interpretations of these and other data by various scientists are offered. Particle impact, pitting and erosion, and sputtering and vaporization are discussed, with equations and present-day theories presented for each selection.

68. SHIELDING PROBLEMS IN MANNED SPACE VEHICLE. Allen, R. I., A. J. Dessler, J. F. Perkins and H. C. Price. July 1960, Lockheed Aircraft Corp., Georgia Div., Marietta, Ga. Report No. NR-104.

This semiannual technical report (for the period December 31, 1958-June 30, 1960) summarizes the principal technical findings and conclusions obtained in the first phase of a study of shielding problems in manned space vehicles. In this first phase of the study, emphasis is placed on determination of the radiation environment to be encountered in spaceflight. The development of basic attenuation data and computational methods for predicting dose rates due to trapped protons and to the bremsstrahlung produced by electrons stopped in the outer layer of a space vehicle is also discussed in detail.

69. SOME ASPECTS OF THE DESIGN OF METEOROID BUMPERS. Dow, N. F. In Summary of Technical Reports. January-June 1959, Vol. II. Space Mechanics, Plasma Physics, ARC Research, Life Support. 1959, General Electric Co., Aeroscience Lab., Philadelphia, Pa. GE Report 269R, Vol. 2; ASTIA AD-226,832.

A semi-empirical formula based on the work of Kornhauser is derived for the design of a meteoroid bumper. The bumper considered is in the form of a relatively thin shell mounted externally on the wall to be shielded.

Sample calculations with representative values for the constants employed in the formula show that if the equations have any meaning they may suggest that the bumper should be made of a low-density material, that optimum bumper thickness (or equivalent thickness on a weight basis) is less than half the crater depth in an unprotected wall, and that a multiple-walled shield should be better than a double wall.

70. SPACE ENVIRONMENT, SECT. II, pp. 4-23 and INTERACTIONS WITH THE METEOROID ENVIRONMENT, SECT. IV. pp. 39-48. In Liquid Propellant Losses During Space Flight (Second Quarterly Report). January 1961, Arthur D. Little, Inc., Cambridge, Mass. Report No. C-63270-02-1.

In Section II a discussion of the meteoroid environment is presented; in Section IV a description is given of the interaction of meteors with vehicle structure, and a design study is made of systems to protect against meteors.

71. THE SPACE ENVIRONMENT AND ITS EFFECTS ON MATERIALS.
Rolsten, Robert F., Convair, Div. of General Dynamics Corp., San Diego, Calif. Report No. ZS-MT-010.

The capabilities of materials for operation in space are inadequately supported by experimental investigation or analytical treatment, and at least part of this situation can be attributed to an incomplete understanding of the space environment. It is quickly recognized, however, that materials are now operating satisfactorily in space. Conversely, as the requirements and complexity of equipment and design increase, care must be taken to avoid over-extending the use of materials. Therefore, emphasis must be placed on the importance of giving early attention to all materials problems arising from operation in near space.

The secondary purpose of this proposed study is to carefully, accurately, and reliably obtain data on materials from a systematic investigation with earth-located space simulated facilities.

72. THE SPACE ENVIRONMENT AND ITS INTERACTIONS WITH LIQUID PROPELLANTS AND THEIR STORAGE SYSTEMS. Wiederhorn, Norman M. September 1961, Arthur D. Little, Inc., Cambridge, Mass. Report No. C-63270-02-1; ASTIA AD-266,034; Contract No. NAS 5-664.

The storage of liquid propellants on the surface of the moon or in space vehicles, which are in orbit or interplanetary flight, presents a series of unusual problems. This report discusses the pertinent factors of the space environment that influence the storage of liquid propellants in space and the mechanisms whereby these may interact with a liquid propellant or its storage systems. An extensive bibliography, including abstracts, is contained in this report. This bibliography provides a survey of the space environment, which is a prerequisite to the consideration and study of any interaction or effects which might occur in the environment of space.

73. SPACE STATION DESIGN METEOROID PROTECTION. Burkitt, W. C. February 1962, Martin-Marietta Corp., Aerospace Div., Denver, Colo. Martin SSPDR-34-2-62 (Internal Report).

The meteoroid hazard involves three main areas of study

1. The meteoroid environment
2. Hypervelocity impact
3. Damage predictions based on the above

A non-critical review of the literature of the particulate contents of space serves to introduce the problem. Thereafter the literature pertaining to each of the problem areas above is reviewed as critically as possible in the light of present uncertainties in order to permit useful selections to be made. The selections made herein are certainly tentative, and probably conservative. Original work toward improving the rationale behind some selections is included.

In particular, the prediction of damage is carried somewhat beyond anything found in the open literature, perhaps approaching some degree of usefulness. Areas and requirements for further work are noted. General recommendations for further study of the meteoroid hazard are made.

74. SPACECRAFT MATERIALS PROBED BY SYMPOSIUM, (A NOTE ON). McGuire, Frank G. In Missiles and Rockets, Vol. 5, No. 21, pp. 56 and 59, May 25, 1959.

Technical aspects of temperature, erosion, sputtering, lubrication and vacuum effects on materials were thoroughly discussed at the first symposium on "Surface Effects on Spacecraft Materials," co-sponsored by Lockheed and ARDC. The action of particles of varying sizes in space on the surface of a spacecraft was looked at from a number of angles, micrometeorites, dust, and individual atoms and molecules.

75. STRUCTURAL CONSIDERATIONS OF MANNED SPACE VEHICLES. Coppa, Anthony P. November 1958, General Electric Co., Missiles and Space Vehicles Div., Philadelphia, Pa. ARS Preprint 732-58, American Rocket Society, New York. Also in ARS Journal, Vol. 30, No. 1, pp. 34-40, January 1960.

This paper considers the structural requirements for a manned space vehicle. It gives approaches leading to an optimum vehicle considering the requirements of thermodynamics and human factors in addition to structures. The necessity of early and thorough integration of these different requirements is emphasized. Several space vehicle configurations are presented including a ballistic and a glide type in order to exemplify some of the various structural problems encountered in each type during the phases of space flight, entry into an atmosphere, and landing. These include aerodynamic heating and loading, meteoroid impact, and other problems. Materials and constructions suitable for optimum space structures are discussed sufficiently to demonstrate available choices and indicate areas of required development.

76. STRUCTURES FOR SPACECRAFT. Sandorff, Paul E. Massachusetts Institute of Technology, Cambridge, Mass. November 21, 1958. ARS Preprint 733-58, American Rocket Society, New York.

Some problems of structural design to be encountered in vehicles specifically intended for interplanetary operations are reviewed. Consideration is given to the relative merits of different types of shell structure, dynamic surging effects possible in this wall tankage, and the problem of meteor protection. Some effects of structural considerations on the system design are indicated.

77. STRUCTURES IN SPACE. Licciardello, Michael R. January 1959, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio. WADC Technical Note 59-13; ASTIA AD-209,412.

The detailed inputs into a generalized space structure are discussed with regard to estimates of the natural environments of space. The effects of controlling absorptivities of the outer surface of a space shell are illustrated by a typical example. A discussion of the meteoritic penetration phenomenon is presented. The nature of the problem is such that a band of allowable gages for each material considered is readily indicated. The various inputs to a space structure are illustrated on a preliminary design of a manned lunar probe.

78. STUDY OF PRINCIPLES OF METEOROID PROTECTION. Rolsten, Robert F. July 1961, NASA, George C. Marshall Space Flight Center, Huntsville, Ala. General Dynamics/Astronautics, San Diego, Calif. Progress Report No. 1; Contract NAS-8-875.

A study was made of the hypervelocity impact theories published in the technical literature in order to develop guide lines for the study program. The standard theories and penetration equations of Bjork, Partridge, Charters and many others were examined.

A particular search was made for penetration theories that would cover puncturing thin plates in tandem. The experimental program to be followed was detailed as the result of the foregoing studies. This program would consist of firings of metallic and glass pellets into targets of the same and different materials at velocities up to 18,000 ft/sec using explosive drivers.

79. STUDY OF PRINCIPLES OF METEOROID PROTECTION. Rolsten, Robert F. and Harold H. Hunt. October 1951, NASA, George C. Marshall Space Flight Center, Huntsville, Ala. General Dynamics/Astronautics, San Diego, Calif. Progress Report No. 2; Contract NAS-8-875.

Literature data pertinent to the phenomena associated with the hypervelocity impact behavior of relatively thin plates and the principles of the meteoroid bumper were given in Progress Report No. 1.

The experimental data resulting from the impact of a cylindrical steel projectile (-15,000 ft.sec. $^{-1}$) on aluminum (7075, 2024-T3 and 6061-T6), titanium (75-A) and magnesium alloy (HK-31A) are given in this report.

80. STUDY OF PRINCIPLES OF METEOROID PROTECTION. Rolsten, Robert F., Harold H. Hunt and J. N. Wellnitz. January 1962, NASA, George C. Marshall Space Flight Center, Huntsville, Ala. General Dynamics/Astronautics, San Diego, Calif. Progress Report No. 3; Report No. GD/AE 62-0092; Contract NAS-8-875.

Literature data pertinent to the phenomena associated with hypervelocity impact of relatively thin plates and the principles of meteoroid protection were given in Progress Report No. 1. The preliminary data resulting from the impact of the cylindrical steel projectile (approximately 15,000 ft/sec) on thin plates of aluminum (7075, 2024-T3 and 6061-T6), titanium (75-A) and magnesium alloy (HK-31A) were presented in Progress Report No. 2.

81. STUDY OF PRINCIPLES OF METEOROID PROTECTION. FINAL REPORT. Rolsten, Robert F., Harold H. Hunt and J. N. Wellnitz. April 1962, NASA, George C. Marshall Space Flight Center, Huntsville, Ala. General Dynamics/Astronautics, San Diego Calif. Report No. GD/AE62-0413; Contract NAS-8-875.

The purpose of this report was to refine all the experimental data evolved during the program, and to develop the tentative concepts into a synthesis of the individual relationships in order to evolve the principles of meteoroid protection. This required the establishment of experimental data on the projectile behavior, projectile mass, bumper material and structure, energy-absorbing core materials, and on pressurized vessel behavior during impact from a high velocity particle. High speed photographic equipment was utilized in order to study the impact phenomena.

82. SUMMARY OF TECHNICAL REPORTS. JANUARY-JUNE 1959. VOLUME I. GAS DYNAMICS. 1959, General Electric Co., Aerosciences Lab., Philadelphia, Pa. GE Report 269-R-June 1959, Vol. I; ASTIA AD-220,173; Contract AF 04(647)269.

This document contains a collection of selected papers prepared by the Aeroscience Laboratory in the period January-June 1959. This volume contains papers concerned with gas dynamics. Titles of some of the papers are:

Materials for re-entry protection of satellites
A thermal protection of re-entry satellites
A contribution to the theory of meteor ablation
Laboratory experimental studies in re-entry aerothermodynamics
A solution for heat transfer in laminar, separated and wake-flow regions
Transport and thermodynamic properties in hypersonic laminar boundary layer; properties of pure species
The quasi one-dimensional flow of an electrical conducting gas for the generation of electrical power
Vaporization processes in the hypersonic boundary layer
Turbulent boundary layer equations with binary diffusion
Combustion of a gas injected into a hypersonic boundary layer
The application of pressure and force transducers in shock tunnel aerodynamic studies
Stable shapes of slender ablating graphite body

83. SUMMARY OF TECHNICAL REPORTS. JANUARY-JUNE 1959. Vol. II. SPACE MECHANICS, PLASMA PHYSICS, ARC RESEARCH AND LIFE SUPPORT. 1959, General Electric Co., Aerosciences Lab., Philadelphia, Pa. GE Report 269-R-June 1959, Vol. 2; ASTIA AD-226,832; Contract AF 04(647)269.

The collection of selected research papers was prepared by the Aeroscience Laboratory in the period January-June 1959. This volume is concerned with space mechanics, plasma physics, ARC research, and life support.

84. SURFACE ROUGHNESS CAUSED BY METEOROID IMPACTS. Kornhauser, Murray. General Electric Co., Missiles and Space Vehicles Dept., Philadelphia, Pa. In 3rd HVIS, Vol. 1.

The author treats the problem of meteoroid erosion in terms of the root mean square roughness scale. Data are presented in graphical form where target physical properties are varied. The effect of crater lips is largely ignored.

85. SURVEY OF METEOROID HAZARD. Straly, Warren H. February 12, 1962, NASA, George C. Marshall Space Flight Center, Huntsville, Ala. Internal Note.

The survey serves two purposes: First, it indicates the order of magnitude of the hazards of meteoroids to spacecraft; second, it is intended to alarm design personnel of the hazards in time to incorporate meteoroid protection into their thinking, and later into their designs. When optimistic values are taken for each of the parameters that enter into a meteoroid protection computation, it is found that for reasonable probabilities of success some shielding is required. This survey offers reasonable estimates to compute minimum shielding requirements.

86. THERMAL EFFECTS IN HYPERVELOCITY KILL MECHANISMS (U). Hoercher, H., T. O'Connor, A. Dhanak and G. Henry. Avco Corp., Research and Advanced Development Div., Wilmington, Mass. Report No. AVCO RAD-61-1812. Report SECRET. Abstract SECRET.

87. A VISCO-PLASTIC MODEL FOR HYPERVELOCITY IMPACT. FIRST QUARTERLY REPORT. Period covered, 3 November 1960-3 February 1961. Riney, T. D. April 1961, General Electric Co., Space Sciences Lab., Philadelphia, Pa. Prepared for Air Proving Ground Center, Eglin AFB, Fla. APGC TN-61-16; MSVD Req. Nr. 214-769, AFSC Project 9860; Contract AF 08(635)1713.

Existing experimental results of hypervelocity impact tests have been gathered from various sources and the composite data is presented and discussed. The extrapolated results to higher velocities are seen to differ with the theoretical prediction from the hydrodynamical model of R. L. Bjork. Re-examination of his assumptions and the experimental results indicate the desirability of including the effects of the viscosity and the strength of the materials into the mathematical model. A visco-plastic model is then formulated to meet these requirements.

SECTION III. THEORETICAL STUDIES

88. ANALYSIS OF THE FORMATION OF METEOR CRATER, ARIZONA: A PRELIMINARY REPORT. Bjork, Robert L. July 6, 1961, The RAND Corp., Santa Monica, Calif. Rand Report P-2370, also in Journal of Geophysical Research, Vol. 66, No. 10, pp. 3379-3387, October 1961.

A theoretical study is made of the cratering process accompanying the impact of a 12,000-ton iron projectile on a semi-infinite half-space of soft rock at a velocity of 30 km/sec. The constituents and velocity approximate those involved in the formation of Meteor Crater, Arizona. The assumption is made that the process is hydrodynamic in nature, since the pressures generated so greatly exceed the strengths of the materials. At these high pressures, the compressibilities of the materials must be taken into account, with the result that shocks are generated. The motion is solved by numerical means, and graphs showing details of the motion are presented. The conclusion in this preliminary report is that the meteorite had a mass between 30,000 and 194,000 tons, the range being due to the uncertainty in the impact velocity.

89. AN ANALYTICAL APPROACH TO HYPERVELOCITY IMPACT MECHANICS. Zaid, Melvin. Technik, Inc., Research Analysis Development, Garden City, N. Y. In 4th HVIS, Vol. III.

It is the purpose of this paper to present a rational theory of target perforation by ultra high-speed penetrators. Although the original work was not specifically performed for meteoric particles, it applies to this case equally well, the only requirement being one of relative velocities, not of geometry.

The overall approach is much the same as that taken previously by the author in the theoretical and experimental studies of thin plate perforation by non-deforming projectiles; that is, the perforation process is idealized to retain only its essential characteristics. Then, based upon this idealization, a mathematical description will be written and solutions obtained. The case considered here is that of normal perforation of a deformable target by a non-deformable cylindrical penetrator traveling at hypervelocities, its extension to the deformable penetrator of other geometry and obliquity or target thickness being directly obtainable from the techniques presented in this paper.

90. THE ANOMALOUS BEHAVIOR OF LEAD-TO-LEAD IMPACT. Vanfleet, Howard B., William S. Partridge and Emerson T. Cannon. University of Utah, Salt Lake City, Utah. Research and Development Co., Inc., Salt Lake City. In 3rd HVIS.

A linear relationship between impact energy and crater volume appears to apply over a limited energy range. Over a larger energy range, the relationship seems to be $V = V_o (1 - e^{-ce})$. The crater area is linearly related to the momentum. Extrapolation of these relations to high energy leads to large shallow craters. These relations also apply to other projectile materials impacting into targets at high velocity; pellet strength variations do not affect the basic hemispherical crater shape.

91. APPLICATION OF "HYDRODYNAMIC" THEORY TO THE LOW STRESS RANGE OF HYPERVELOCITY IMPACT PROBLEMS. Fyfe, Ian M. Boeing Co., Aerospace Div., Seattle, Wash. In 5th HVIS, Vol. I.

An essential feature of a mathematical model for a physical phenomenon is that it be tractable to known methods of solution. This is often achieved in stress wave propagation by making certain simplifying assumptions as when the material behaves elastically, or for higher stresses when it follows a particular elasto-plastic rule of behavior. It is the purpose of this paper to show that, by limiting the physical configuration of the phenomena, it is possible to reduce the mathematical complexity of a mathematical model without imposing an undue restriction on the physical properties of the material under consideration.

92. APPLICATION OF THE BALDWIN CRATER RELATION TO THE SCALING OF EXPLOSION CRATERS. Hill, J. E. and J. J. Gilvarry. January 27, 1956, The RAND Corp., Santa Monica, Calif. Rand Report P-801, also in Journal of Geophysical Research, Vol. 61, No. 3, p. 501, September 1956.

An attempt was made to predict the dimensions (diameter and depth) of a crater produced in the earth by detonation of a charge of high explosive situated on or near the surface. Two methods of scaling were developed.

93. APPROXIMATE THEORY OF ARMOR PENETRATION. Thomson, W. T. In Journal of Applied Physics, Vol. 26, No. 1, p. 30, January 1955.

The problem of armor penetration of thin plates is considered from a quasi-dynamical approach. Equations are derived for the energy dissipation due to plastic deformation and for heating of the projectile target interface. Both the conical and the ogival head are considered in the application of the general equations.

94. "APPROXIMATE THEORY OF ARMOR PENETRATION," NOTE ON. Thomson, W. T. University of California, Los Angeles, Calif. In Journal of Applied Physics, Vol. 26, No. 7, pp. 919-920, July 1956.

A brief note concerning the subject.

95. ARMOR PENETRATION. Zaid, Melvin and Burton Paul. In Ordnance, Vol. 41, pp. 609-611, 1956-57.

The study of the penetration of armor has interested ballisticians for many years, but only recently clearer concepts have arisen due largely to a new approach to the basic problem and to advances in the related sciences. A brief review of the problem is presented.

96. AN ATTEMPT AT A THEORY OF ARMOR PENETRATION. Bethe, Hans Albrecht. 1941, Frankford Arsenal, Philadelphia, Pa. Ordnance Lab. Report.

97. BEHAVIOR OF METALS UNDER IMPULSIVE LOADS. Rinehart, John S. and John Pearson. American Society of Metals, Cleveland, Ohio. ASM Publication No. 39, 1954.

This book discusses the character of impulsive loading, indicates the conditions under which such loading can develop, and describes the main phenomena that become involved when materials, primarily metals, and systems of material bodies are subjected to rapidly applied loads of short duration. The approach is broad and general. The basic concepts and ideas expressed in the book have been gathered from many sources, although a large proportion of the illustrative examples have been taken from the authors' own researches.

98. BEHAVIOR OF MATERIALS IN SPACE. Simons, John C., Jr. National Research Corp., Cambridge, Mass. In Astronautics, Vol. 4, No. 6, pp. 32-33, 84, 86-87, June 1959.

Relatively new, the study of materials behavior under space-equivalent conditions calls for high vacuum systems of advanced engineering design and performance. NRC's Research Division developed this unit, which goes below 10^{-9} mm Hg (simulated density of space 400 miles above earth), both to study materials and to evaluate new methods for producing ultra-high vacuum.

99. CALCULATION OF EROSION IN SPACE FROM THE COSMIC RAY EXPOSURE AGES OF METEORITES. Whipple, Fred L. and E. L. Fireman. In Nature, Vol. 183, No. 4671, p. 1315, 9 May 1959.

Very little is known about erosion in space - the action of dust, gas, ions and electrons in wearing away material from exposed surfaces in interplanetary space. A cosmic ray exposure age is obtained from the measurement of one radioactive and one stable spallation isotope produced in a meteorite by cosmic rays. This indicates a new upper limit on the erosion rate of meteorites.

100. CLASSIFICATION OF COLLISIONS; ELASTIC COLLISIONS ON A MACROSCOPIC SCALE. Barnes, George, J. W. Patmore and S. J. Fountain, University of Nevada, Reno. In American Journal of Physics, Vol. 26, No. 2, pp. 122-127, February 1958.

Although a number of well-known physics textbooks imply, and some state definitely, that perfectly elastic collisions never occur, it is pointed out here that collisions between atoms and molecules are frequently elastic. A classification of collisions into three groups, depending upon the nature of the interaction forces, indicates that certain kinds of collisions between macroscopic objects may be perfectly elastic. Simple laboratory experiments illustrating two of these cases are described.

101. COMMENTS ON "THE EFFECT OF MICROMETEORITES ON REFLECTING SURFACES." Bjork, Robert L. February 29, 1960, The RAND Corp., Santa Monica, Calif. Rand Report P-1936.

Comments were made by the author, as discussion leader, following the presentation of the paper cited in the title at the national meeting of the Institute of Environmental Sciences at Los Angeles, California, April 6-8, 1960. This paper is published in the Proceedings of the Meeting.

102. CONCERNING THE IMPACT OF SOLIDS AT HIGH VELOCITIES. Stanyukovich, K. P. In Soviet Physics (JETP), Vol. 36 (9), No. 5, p. 1141, November 1959.

The TNT equivalent of hypervelocity impact is derived. This mass is determined by the relation $M_s = N\ M_o U_o^2/2Q$, where N is the efficiency of utilization of the energy, M_o is the mass of the projectile, U_o is the impact velocity, and Q is the caloric content per gram of explosive. This relation does not apply at large values of the angle of incidence.

103. CONSTITUTIVE RELATIONS FOR HYPERVELOCITY IMPACT. Quarterly Progress Report No. 6, May-August 1962. Riney, T. D. November 1962, General Electric Co., Space Sciences Lab., Valley Forge Space Technology Center, King of Prussia, Pa. Air Proving Ground Center, Eglin AFB, Fla. APG-TDR-62-59. OAR Project No. 9860; Contract AF-08(635)-1713.

Tentative relations are presented for the equation of state, the thermodynamic and strain rate dependent flow-resistance coefficient, and the fracture criteria for a dynamic triaxial stress condition. These constitutive relations are required for the theoretical calculations being made for the axisymmetric hypervelocity impact problem. Improved hypotheses are expected to evolve as more experimental data become available and as computational experiments are performed. To facilitate the evaluation and comparison of various hypotheses, the relations are written into the computer program as sub-routines.

104. DAMAGE TO X-RAY DETECTORS BY METEORITES. Broyles, Arthur A. 21 January 1959, The RAND Corp., Santa Monica, Calif. Rand Report RM-2314; ASTIA No. AD-219,799; Contract AF 33(038)6413.

The effect of meteorites on a beryllium window covering an X-ray detector on a satellite has been estimated with the aid of the latest meteor density information from astronomical and satellite measurements. Bjork's formula for the depth of penetration of high velocity particles striking a surface was employed to obtain a fraction of the order of 10^{-6} of the area of the window punched out by meteorites per year. Methods for reducing the amount of sunlight leaking through the holes to the photomultiplier tube are considered. Splitting the beryllium sheet into two parts appears to be quite promising.

105. THE DESTRUCTIVE ACTION OF METEORITE IMPACTS. Stanyukovich, K. P. and V. V. Fedynskiy. 14 May 1947, Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report No. ATIC 262907; Translation No. F-TS 8961/V from Doklady Akademii Nauk SSSR, Vol. 57, No. 2, pp. 129-132, 1949; ASTIA AD-124,240.

The explosive and destructive action produced by the fall of a meteorite at high velocity is a peculiar manifestation of its immense kinetic energy. At an impact velocity of more than 4-5 km/sec, bodies behave like a strongly compressed gas, since the force of molecular cohesion is small by comparison with their initial energy. For this reason, the phenomena taking place on meteoric impacts may be described by the equations of gas dynamics.

106. DIFFERENCE SCHEME FOR AXISYMMETRIC IMPACT PROBLEM. QUARTERLY PROGRESS REPORT NO. 4, NOVEMBER 3, 1961 - FEBRUARY 3, 1962. Riney, T. D. March 1962, General Electric Co., Space Sciences Lab., Valley Forge Technology Center, King of Prussia, Pa. Air Proving Ground Center, Eglin AFB, Fla. APGC TDR 62-19; Contract AF-08(635)1713.

A numerical scheme which has been successfully employed for two-dimensional hydrodynamics is extended to the axisymmetric visco-plastic equations governing the hypervelocity impact phenomenon. Computing procedures are outlined which are complete enough for interior regions of the medium. The formulation must be further developed, however, to allow for such contingencies as free boundaries, interior empty cells and the axis of symmetry before a computing code can be written for the impact problem.

107. DYNAMIC COMPRESSIBILITY AND EQUATION OF STATE OF IRON UNDER HIGH PRESSURES. Al'tshuler, L. V., K. K. Krupnikov, B. N. Ledenev, V. I. Zhuchikhin and M. I. Brazhnik. In Soviet Physics (JETP), Vol. 34 (7), No. 4, pp. 606-614, October 1958.

Two methods for measurement of the dynamic compressibility of solids are described which are based on determination of the kinematic parameters of shock waves - their velocity of propagation and the mass velocity of the substance behind the front. The adiabates of shock compression of iron possessing various initial densities were determined by these methods in the pressure range from 4×10^5 to 5×10^6 atm. The compressibility curve of iron at absolute zero is derived from the experimental data. The curve is extrapolated to pressures at which statistical atomic models are valid.

108. DYNAMIC COMPRESSIBILITY OF METALS UNDER PRESSURES FROM 400,000 TO 4,000,000 ATMOSPHERES. Al'tshuler, L. V., K. K. Krupnikov and M. I. Brazhnik. In Soviet Physics (JETP), Vol. 34 (7), No. 4., pp. 614-619, October 1958.

A method for the determination of pressures and densities of shock compressions is proposed which is based on the measurement of the velocities of propagation of strong shock waves. The dynamic compressibility of copper, zinc, silver, cadmium, tin, gold, lead and bismuth was measured by this method in the pressure range from 400,000 to 4,000,000 atm. The highest degrees of compression (by factors 2.26 and 2.28) were observed in lead and bismuth, which possess the largest atomic volumes. The highest absolute density (32.7 g/cm^3) was recorded for gold.

109. DYNAMIC EXPANSION OF SPHERICAL CAVITIES IN METALS. Hopkins, H. G. Armament Research and Development Establishment, Fort Halstead, Sevenoaks, England. In Progress in Solid Mechanics, Vol. I, Chapter III, pp. 83-164, edited by Snedden, I. N. and R. Hill. Interscience, New York, 1960.

This paper presents a survey of the present state of knowledge concerning the dynamic expansion. Not discussed is work on cylindrical cavity formation in metals or work on cavity formation in soils. Relationships exist between situations in cavity formation and situations of impact and penetration involving deformations at the free surfaces of soils of limited extend. Relationships not traced.

110. EFFECTS OF A METEOROID IMPACT ON STEEL AND ALUMINUM IN SPACE. Bjork, Robert L. December 16, 1958, The RAND Corp., Santa Monica, Calif. Rand Report P-1662, also in Proceedings of the Tenth International Astronautical Congress, Vo. II, London, 1959. Springer-Verlag, Vienna, 1960.

This paper is concerned with estimating the effects of a collision between an individual meteoroid and some component of a space vehicle.

An attempt is made to calculate the phenomenology of an impact at meteoric velocities from fundamental principles, making only simple assumptions which may be justified by order-of-magnitude arguments. The validity of the assumptions receives support in the end by the agreement with experiments of the calculated shape and dimensions of the craters.

111. EFFECTS OF HYPERVELOCITY IMPACTS ON MATERIALS. FINAL REPORT. Scherrer, Victor E. August, 1962, Technical Operations, Inc., Burlington, Mass. Air Force Systems Command, Aeronautical Systems Div., Wright-Patterson AFB, Ohio. Report ASD-TDR-62-762; Contract AF-33(616)-8423.

A novel exploding-foil gun is described which routinely accelerates small particles (mass 1-100 mg) to velocities up to 60,000 ft/sec when coupled to a slow capacitor energy storage system. When the gun was efficiently coupled to a fast-capacitor energy storage system, a single, solid particle was accelerated to a velocity of 102,000 ft/sec. A detailed study of various particles impacting quasi-infinite lead targets was made, and preliminary results are given for particle velocities from 7,000 to 40,000 ft/sec. These results indicate a deep penetration for a particle velocity of 15,000 ft/sec. If similar phenomena are observed in materials of interest in space vehicle construction, the results will be very important in the design of such structures. Plans are presented for expanding the hypervelocity facility and improving its performance in the future.

112. EXPLOSIVES WITH LINED CAVITIES. Birkhoff, Garrett, Duncan P. MacDougall, Emerson M. Pugh and G. I. Taylor. In Journal of Applied Physics, Vol. 19, No. 6, pp. 563-582, June 1948.

Explosives detonated in contact with thick steel plates produce much deeper holes in the steel when there is a cavity in the explosive in contact with the plate. While this phenomenon has been known for more than 150 years, the enormous increase in penetrating power that can be produced by lining the explosive cavity with thin metal has been discovered only recently. During the war a number of light, low velocity, antitank weapons (e.g., the rocket-propelled Bazooka) were developed which made use of this phenomenon to perforate thick armor plate.

A fairly complete mathematical theory of this essentially new phenomenon is presented together with some of the experimental data that aided in the formulation and testing of the theory.

113. A FLUID-DYNAMIC MECHANISM OF METEORITE PITTING. Williams, David T. Smithsonian Institution Astrophysical Observatory, Washington, D. C. Smithsonian Contributions to Astrophysics, Vol. 3, No. 6, pp. 47-67, 1959.

Flow lines on meteorites were photographed to determine the nature of airflow inside the "thumb pits" in the surface. The flow is shown to be consistent with that occurring if a hairpin-shaped vortex were lying with bent portion in the pits, with vortex legs trailing off to infinity downstream. Since such a flow is not unique to supersonic fluid speeds, the prediction is made that pits similar to those on meteorites would be observed on salt cakes pushed through a lake. Experiments demonstrated that salt cake erosion may indeed be accompanied by pit formation due to vortices precisely like those detected in meteorite pits. The evidence, supplied by photographs, leads to the conclusion that pitting is a general phenomenon in eroding fluid flow, and that tests at low speeds may provide valuable information regarding certain problems in astroballistic ablation.

114. THE FORMATION OF CRATERS BY HIGH SPEED PARTICLES. Rostoker, Norman. Carnegie Institute of Technology, Pittsburgh, Pa. In Meteoritics, Vol. I, No. 1, p. 11, 1953.

Some investigators have discussed the formation of craters by high speed particles on the basis of experimental data taken over a limited velocity spectrum for the incident particle. Their interpretation of the data has been that the crater volume is proportional to the kinetic energy of the incident particle. In this paper, we discuss an approach to this problem that was originated by Öpik for the formation of meteorite craters. Öpik's theory is based on a hydrodynamic approximation similar to the approximation that has been successfully employed by Pugh in explaining the penetration produced by shaped-charge jets. The estimates of the mass of a meteorite based on Öpik's theory differ radically from the estimates made by Rinehart that are based on the assumption that crater volume is proportional to the kinetic energy of the incident particle up to meteoritic velocities. The essential purpose of this paper is to reexamine both points of view in order to illuminate the details of their differences. Experimental evidence is presented from the study of shaped-charge jets that indicates that Rinehart's extrapolation is incorrect. The data from shaped-charge experiments are in rough agreement with Öpik's theory.

115. FUNDAMENTALS OF SHAPED CHARGES. FINAL REPORT. Pugh, Emerson M. 30 June 1962, Carnegie Institute of Technology, Pittsburgh, Pa. Report No. CIT-513-FR.

A brief summary of the research conducted under Contract No. DA-36-061-ORD-513 is given. No attempt is made to present technical information not already presented in the quarterly progress reports. Prepared under Contract No. DA-36-061-ORD-513:

1) Effects of Target Temperature on Hypervelocity: Cratering
2) Cratering of Lead by Oblique Impacts of Hypervelocity Steel Pellets
3) Projector Studies
4) Spatial Distribution of Fragments Behind Thin Targets
5) The Perforation of Thin Plates by High Velocity Fragments
6) Oblique Impact Cratering in Lead at 3.8 km/sec

116. HIGH VELOCITY IMPACT. Partridge, William S., Utah Research and Development Co., Salt Lake City. In Materials and Space Environment. Proceedings of the Fifth Sagamore Ordnance Materials Research Conference. Conducted at Sagamore Conference Center, Racquette Lake, N. Y., September 15, 17, 18, and 19, 1958. Syracuse University Research Center, N. Y. SURI MET-597-596; ASTIA AD-205,880.

This paper is a discussion of the general topic of high velocity penetration. It covers briefly theory, scaling laws, crater shape, penetration, crater volume, thin targets, and wax modeling. Many plots of existing data are given.

117. HIGH VELOCITY IMPACT STUDIES. Scully, Charles N., North American Aviation, Inc., Aero-Space Labs., Missile Division, Downey, Calif. In Proceedings of Lunar and Planetary Exploration Colloquium, January 12, 1959, Vol. 1, No. 4. Report NAA Publ. 513W4.

Some qualitative information on the nature of hypervelocity impact is presented. Hypervelocity does not refer to a definite velocity regime as does "supersonic," but is determined in each case by the nature of the projectile and target material. Hypervelocity impact refers to an event in which a peculiar and definite phenomenon occurs, i.e., the appearance of a smooth hemispherical crater. Above a critical velocity this type of impact crater appears, regardless of the shape of the impacting projectile.

118. HIGH VELOCITY IMPACT STUDIES DIRECTED TOWARDS THE DETERMINATION OF THE SPATIAL DENSITY, MASS AND VELOCITY OF MICROMETEORITES AT HIGH ALTITUDES. Bohn, J. Lloyd and Otto P. Fuchs. 31 January 1958, Temple University, Philadelphia, Pa. Scientific Report No. 1; AFCRC TN 58-243; ASTIA AD 243,106; Contract AF 19(604)1894.

The particular problem of the development of analytical expressions describing micrometeorite impact processes is studied. Observations suggest an hypothesis about the microstructure of impact processes which takes into consideration all physical magnitudes inherent to the process. This hypothesis is described and should provide an interpretation of the responses of various kinds of transducers. The credibility of this hypothesis is established by comparison of experimental results obtained from the hypothesis in question. The experiments were conducted at a shooting range constructed at Temple University in the velocity range of between 100 and 200 m sec^{-1}, at the shooting range at Kunnersdorf with a velocity of 700 m sec^{-1}, and as far as extremely high velocities are concerned a previous published result has been used with the velocity of 45 km sec^{-1}. The comparison shows that the hypothesis adopted approximates fairly well the experimental results.

119. HYPERVELOCITY PENETRATION STUDIES. Atkins, Walter W., U. S. Naval Research Lab., Washington, D. C. In 4th HVIS, Vol. 1.

In this paper the author discusses various parameters which affect penetration and shape of the crater. He derives an empirical equation for penetration. Mr. Atkins' curves indicate that P_c/D_c is independent of projectile material or target material if the projectile velocity is above 6 km/sec.

120. IMPACT MECHANICS AT METEOR CRATER, ARIZONA. Shoemaker, E. M. July 1959, U. S. Department of the Interior, Geological Survey, Menlo Park, Calif. Open File Report.

The cratering problem is analyzed and the requirements for theory are deduced from a study of the geology of Meteor Crater and its structural similitude to a nuclear explosion crater. The question of how and in what form the meteoritic material reaches certain depths indicated by geological relations and how the energy is distributed is considered.

121. THE IMPACT OF LARGE METEORITES. Gilvarry, J. J. and J. E. Hill. April 1956, The RAND Corp., Santa Monica, Calif. Rand Report P-836. Also in Astrophysical Journal, Vol. 124, No. 3, pp. 610-623, November 1956.

The impact of large meteorites on the moon or earth is discussed on the basis of a one-dimensional idealization of the flow problem in which a plane shock wave is considered in both meteorite and impact surface. Conditions are discussed under which such a model can yield physically valid estimates of pressure and temperature generated on explosive impact of meteorites. Computations are carried out for an equation of stage and internal energy from the statistical Thomas-Fermi atom model; departures from complete degeneracy are taken into account by means of results of a first-order perturbation with respect to temperature. It is assumed that the meteorite and impact surfaces are composed of the same pure element, taken as silicon, iron, and an average element (in a sense defined) for meteorites. The range of impact velocity considered goes up to the limit possible for meteorite origin in the solar system, which is well in excess of Whipple's estimates of mean atmospheric velocity for meteorite falls. Over this range, values of compression ratio, pressure, and temperature behind the shocks and of shock velocities are exhibited as functions of impact velocity; at the lowest and the highest velocities, results are only qualitative. Shock temperatures computed for iron agree reasonably with extrapolation of experimental data of Walsh and Christian for copper at lower pressures. The results yield pressures and temperatures of explosive magnitude behind the shock waves, in confirmation of the views of Gifford and Baldwin. Computed fusion temperatures behind the shocks show no inconsistency with Urey's mechanism of formation of lunar maria.

122. THE IMPACT THEORY OF THE ORIGIN OF LUNAR CRATERS. Gilvarry, J. J. January 4, 1956, The RAND Corp., Santa Monica, Calif. Rand Report P-785. Also in Publications of the Astronomical Society of the Pacific, Vol. 68, No. 402, pp. 785, June 1956.

The results of computations on the pressures and temperatures attained in the impact of large meteorites on the lunar surface are presented. These computations are based on the equation of state as obtained from the Thomas-Fermi statistical model of the atom.

123. INERTIAL, VISCOUS, AND PLASTIC EFFECTS IN HIGH SPEED IMPACT. Riney, T. D. and P. R. Chernoff. November 1951, General Electric Co., Space Science Lab., Missiles and Space Vehicle Dept., Philadelphia, Pa. Report R61SD182, Proj. 9860; Contract AF-08(635)1713. In HVIS, Vol. I.

A visco-plastic model for hypervelocity impact is proposed which takes into account inertial, viscous, and plastic effects. This is accomplished by introducing a viscosity factor μ_0, a dynamic yield stress τ_0, and incorporating these into the compressible fluid equations. From an examination of the resulting system of equations, several dimensionless parameters are found which control the relative importance of the three effects at the various stages of the cratering process. The inertial effect is important throughout the early stages while the strength of the medium is dominant during final stages. Immediately after impact the viscous effect is large in the zone near contact interface. Its magnitude decreases as the strain-rate gradient decreases, but it may remain important throughout the flow process. In the absence of definitive data in the hypervelocity impact regime, computations are performed on a one-dimensional model in which the values of μ_0 and τ_0 are varied. The above qualitative conclusions are verified, amplified, and related to the qualitative model of crater formation that has evolved from experimental studies in which the actual cratering process has been remonitored. It is found that all three effects are significant.

124. LIMITING CONDITIONS FOR JET FORMATION IN HIGH VELOCITY COLLISIONS. Walsh, John M., R. G. Shreffler and Frank J. Willig. In Journal of Applied Physics, Vol. 24, pp. 349-359, March 1953.

The high velocity collision of two solids is discussed as a problem in compressible fluid hydrodynamics. Such collisions may conveniently be divided into jetless and jet-forming categories. A theory is presented which describes flow in the collision region for the jetless case and determines a critical collision angle (as a function of material velocities and equation-of-state properties of the materials) above which a jet must arise from the collision. The experimental study of solid collisions utilizes metal plates driven by high explosives, the impact of the plates being recroded with a high speed smear camera. Two experimental arrangements are used, and data for collisions employing Dural, mild steel, brass and lead are presented. Jetless and jet-forming collisions are observed, and critical angles separating the two types are compared with theoretical predictions. Agreement seems sufficiently good to indicate that the theory is valid.

125. MATHEMATICAL METHODS IN THEORETICAL MECHANICS OF HYPERVELOCITY IMPACT OF METALS. Hopkins, H. G. Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent, England. In 5th HVIS, Vol. I, Part 1.

This paper gives a discussion of the place of mathematical methods in research into the theoretical mechanics of impact phenomenology of metals. The relevance of investigation of nonlinear stress-wave propagation to the mechanics of hypervelocity impact is made clear.

In conclusion, reference is briefly made to some of the recent studies at ARDE of stress-wave propagation, which involves attention to rate of strains and nonlinear compressibility effects.

126. MECHANICS OF HIGH SPEED PROJECTILE PERFORMATION. Zaid, Melvin and Burton Paul. In Journal of the Franklin Institute, Vol. 264, No. 2, pp. 117-126, February 1957.

The problem of perforation of thin plates by high-speed projectiles is considered from a momentum viewpoint. Equations representing the magnitude and direction of forces, velocity, etc., as a function of penetration distance are derived for the conical projectile under normal impact. Good correlation between the theory and experiment is obtained.

127. MECHANICS OF HYPERVELOCITY IMPACT OF SOLIDS. Hopkins, H. G. and H. Kolsky. Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent, England. In 4th HVIS, Vol. I.

In general, the unsteady motion produced during the impact of solid projectiles and targets involves, in a highly complex manner, combinations of fundamentally different physical regimes characterized through the occurrence of elastic and plastic deformation, incompressible and compressible flow, and, in the limit, explosion conditions. A severe compromise is necessary between physical realities and mathematical complexities in theoretical studies of hypervelocity impact, and accordingly only a limited degree of precision is possible.

In this paper, a general discussion is given of the mechanics of hypervelocity impact of solids and also of related situations, and some suggestions are made for future experimental and theoretical studies bearing upon the subject.

128. MECHANISM OF CRATERING IN ULTRA-HIGH VELOCITY IMPACT. Cook, Melvin A. 10 July 1957, University of Utah, Salt Lake City. AFOSR TN-57-486; ASTIA AD-136,479; Contract AF-18(603)100.

The hydrodynamic theory of penetration of targets by shaped-charge jets is summarized and extended to account for crater volumes produced by shaped-charge jets. It is then applied in discussing cratering by single-particle projectiles in high velocity and in ultra-high velocity impact, and cratering by multi-particle streams of independently penetrating particles. The conditions for impact explosions of targets and/or projectiles are discussed and theoretical results presented. Finally, impact and explosion cratering are compared.

129. MECHANISM OF CRATERING IN ULTRA-HIGH VELOCITY IMPACT. Cook, Melvin A. 30 January 1959, University of Utah, Salt Lake City. AFOSR TN 59-50; ASTIA AD-209,413; Contract AF-18(603)100.

The equations of the hydrodynamic theory of penetration of targets by shaped-charge jets are presented first in general form. These equations are expressed in the ideal form and examined by experimental observations. Then a non-ideal theory is presented that takes into account heat losses by compression, shock heating, and radiated shock waves. The conditions for impact explosions of targets are discussed and a theory extended to cover the entire velocity range of impact from the plastic deformation threshold v_c, to well above the impact explosion threshold v_c. Some experimental evidence relating to this more general theory is also presented.

130. A METALLURGICAL APPROACH TO THE HYPERVELOCITY PROBLEM. Glass, Coy M. and Robert B. Pond. Ballistic Research Labs., Aberdeen Proving Ground, Md. and Johns Hopkins University, Baltimore, Md. In 4th HVIS, Vol. III.

The influence of physical properties, such as modulus, ductibility, fracture stress, etc., on metal deformation at high velocity is often ignored, and hydrodynamic conditions are assumed to hold true during the deformation. This approach introduces large sources of error in many cases. Under hypervelocity impact conditions of a fragment striking a semi-infinite target, the physical properties of the target are the determining factors in the target reaction. The crater-produced and total stressed regions in the target are described in terms of stress-strain relations in the target material. This approach predicts a linear variation of crater volume, and stressed region volume, with the energy of the incoming fragment.

131. METEOR DISTRIBUTION AND CRATERING. Rinehart, John S. 28 October 1957, Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. Technical Report No. 3; AFOSR TN 57-700; ASTIA AD-136,693. In 2nd HVIS, Vol. I.

Nature and distribution of meteoric material, physical concepts basic to terminal ballistics, the kinds of problems we face, and some suggestions for future experimentation are presented.

132. METEOR IMPACT ON SOLID SURFACE. Öpik, Ernst J. In the Irish Astronomical Journal, Vol. 5, No. 1, March 1955.

The physical conditions prevailing at high velocity impact of a solid projectile into solid surface are reviewed. Formulae and numerical data for the calculation of the depth and volume of erosion, as depending upon the mass and velocity of the projectile, are given. The theory presented for the Canyon Diablo, Arizona, meteor crater can be applied, with little modification, to skin erosion of interplanetary vehicles by meteors. Includes tables.

133. METEORIC INTERACTION WITH THE ATMOSPHERE; THEORY OF DRAG. Gazley, Carl, Jr. August 1959, The RAND Corp., Santa Monica, Calif. Rand Report R-339, Paper No. 6. Also Rand Report P-953. Presented before the RAND Symposium on Aerodynamics of the Upper Atmosphere. June 8-10, 1959.

The entry of meteoroids into the earth's atmosphere involves velocities higher than presently available in any terrestrial laboratory facility. While meteoric interaction with the atmosphere obviously does not provide a controlled type of experiment and many of the test conditions must be deduced indirectly, it offers the opportunity of aerodynamic data at extreme velocities and altitudes. Extensive observations of meteor velocity, luminosity, and altitudes, together with atmospheric-density observations, now enable certain deductions to be made about the aerodynamic drag and heating.

134. METEOROID HAZARD TO SPACE VEHICLES IN ORBIT NEAR THE EARTH: A FUNCTIONAL INTERPRETATION OF THE INFORMATION FOR DESIGN AND OPERATIONS DECISIONS. Dalton, Charles C. 1962, NASA, Marshall Space Flight Center, Huntsville, Ala. MSFC-MTP-AERO-62-50.

In this survey and analysis of the meteoroid hazard to space vehicles in near-earth orbits, operations research methods have been used to establish and to propagate confidence levels with respect to all of the pertinent functional relations involving design and operations parameters. The graphically illustrated results show that the wall thickness, necessary for specified operational results, must be increased by a factor 2.00 to increase confidence from 50 percent to 75 percent, and that this factor would still be 1.81 if there were no uncertainty with respect to hypervelocity impact phenomena. Both the median values and the upper and lower fiducial limits for the 50 percent confidence interval for the mean flux, closing velocity relative to the earth, closing velocity relative to a vehicle in a near-earth orbit, density (specific gravity), just-puncturable thickness of hard aluminum, and just-puncturable thickness of hard stainless steel are shown for values of meteoroid mass between 10 grams and 100 micrograms.

135. A MODEL OF OBLIQUE IMPACT. Bryan, George M. Carnegie Institute of Technology, Pittsburgh, Pa. In 4th HVIS, Vol. III.

An attempt has been made to describe cratering by hypervelocity impact at oblique angles in terms of a simple geometrical model which would predict the characteristic crater shapes observed. The model treats oblique impact as normal impact on a laterally moving target, and predicts that the crater eccentricity (ratio of major to minor dimensions), considered as a function of the angle of incidence, will be unity for obliquities smaller than a certain angle and will increase abruptly as the obliquity is raised above this value. (The predictions are compared with available experimental results which appear to exhibit this behavior quite clearly.)

136. NORMAL PERFORATION OF A THIN PLATE BY A TRUNCATED PROJECTILE. Zaid, Melvin and Burton Paul. In Journal of The Franklin Institute, Vol. 265, No. 4, pp. 317-334, April 1958.

The general solution to the problem of perforation of thin plates by high speed projectiles is extended to truncated conical and ogival projectiles. The velocity-distance relationships are obtained for these general cases, and the forces are evaluated for pointed ogival projectiles. Comparison of theory and experiment is made, and the agreement is satisfactory.

137. NUMERICAL INVESTIGATION OF ONE-DIMENSIONAL VISCO-PLASTIC MODEL. THIRD QUARTERLY REPORT, MAY 3, 1961-SEPTEMBER 3, 1961. Riney, T. D. October 1951, General Electric Co., Space Science Lab., King of Prussia, Pa. MSVD Reg. No. 214-796; AFSC Project 9860. Prepared for Air Proving Ground Center, Eglin AFB, Fla. APGC TN 61-43; ASTIA AD-268,221; Contract AF 08(635)1713.

An explicit finite difference formulation of the equations governing the one-dimensional visco-plastic model was presented in the Second Quarterly Report. The scheme has been programmed on the IBM 7090 and exploratory calculations made for several values of parameters U (viscosity factor), T (yield stress) and V (impact velocity). Excellent results are obtained for certain ranges of the parameters; these results are discussed in detail. For larger values of U and V, however, the restriction on the size of increment T is very severe. A stability analysis is performed which explains this requirement. To circumvent this difficulty the governing equations are recast in an implicit finite difference scheme which is only valid for U exceeds 0, but which is then unconditionally stable. The method is described in detail, and a flow chart is given for the machine program which is currently being written.

138. OBLIQUE PERFORATION OF A THIN PLATE BY A TRUNCATED CONICAL PROJECTILE. Zaid, Melvin and Burton Paul. In Journal of The Franklin Institute, Vol. 368, No. 1, pp. 24-25, July 1959.

The authors' previous analyses of normal perforation of thin plate by high-speed projectiles are generalized to include truncated cones, at oblique striking angles. A complete velocity-displacement history is obtained for the most general case. Results are presented in graphical form.

139. OBSERVATIONS OF CRATER FORMATION IN DUCTILE MATERIAL.
Kineke, John H., Jr. Ballistic Research Labs., Aberdeen Proving Ground, Md. In 5th HVIS, Vol. I, Part 2.

Additional observations on the BRL qualitative model of crater formation described by Eichelberger and Gehring. This model divides the crater formation process into four parts: (1) the transient regime, (2) the steady-state regime, (3) the cavitation regime, and (4) the recovery regime.

New data at 12 km/sec impacting seven metals indicate the same previous relationship: volume of crater is proportional to the energy of the projectile. The ratio of the volume of the crater to the energy of the impacting projectile varies as the reciprocal of the Brinell hardness of the target, independently of the mass of the projectile, and independently of the density of the projectile, for impact velocities greater than the dilatational wave velocity of the target material.

Rate of crater formation is explored in lead, aluminum, lucite, and wax.

Details of shock propagation and attenuation are explored using transparent targets and optical photography.

140. OBSERVATIONS OF THE PHENOMENA OF HYPERVELOCITY IMPACT.
Gehring, John William, Jr. Ballistic Research Labs., Aberdeen Proving Ground, Md. In 4th HVIS, Vol. II.

A critical examination is made of the step-by-step mechanism of crater formation under conditions of hypervelocity impact. The formation of a crater is treated as a three-step process, encompassing the primary penetration of the impacting pellet, the descriptive analysis of the stress field causing cavitation within the material, and lastly, the elastic and/or plastic recovery of the walls of the crater. A model of crater formation is developed based upon both available theory and experimental techniques which permit the monitoring of the complete process. The experiments described are specifically designed to permit the actual measurement of the necessary parameters from which the physical phenomena are then described.

141. ON COHERENT IMPACT ACCELERATION. Veksler, V. and V. Tzytowitch. Institut Fiziki im P. N. Lebedeva. 1959, Atomic Energy Commission, Oak Ridge, Tenn. Report AEC-NP-8064.

The coherent impact acceleration is defined as a mechanism in which the peculiarities of collision between bodies moving with relativistic velocities are used for the acceleration of charged particles; the conditions (relations between the dimensions of the bunches, number of particles, etc.) under which the elastic character of collisions will not be disturbed by radiation and consequently very high energies will be transferred to bunches of small mass are determined. The problem of bunch deformation will not be considered and bunch dimensions will be taken as constant. The treatment is for the general case; i.e., the bunches are considered either quasi-neutral or charged. Both bunches are ring-shaped with radius greatly exceeding thickness. The planes of the rings are parallel. The direction of motion of the relativistic ring coincides with that of the ring at rest v. The light particle currents in both rings are directed along the circumference. The problem is considered in the center-of-mass system.

142. ON THE IMPACT OF PELLETS WITH THIN PLATES: THEORETICAL CONSIDERATIONS. PART I. Bull, Gerald V. January 1962, McGill University, Dept. of Mechanical Engineering, Montreal, Canada. Arthur D. Little, Inc., Cambridge, Mass. Report No. C-63270-03-01; ASTIA AD-273,236; Contract NAS5-664.

This note outlines the results of a short theoretical investigation into the impact of pellets with thin plates at very high velocities. In order to render the problem tractable to analysis, a model has been assumed which allows use of essentially one-dimensional theory to predict both the impact shock-induced conditions and the subsequent expansion flow, although the latter state has been treated subsequently as a general axisymmetric three-dimensional flow. The problem has been considered in three phases. The first phase is the shock-induced impact state, which, for thin bumper plates, permits one-dimensional theory to be reasonably applicable. The second phase results from the extremely high temperatures generated on impact. The third phase, the break-up of the pellet into an expanding particle cloud, has been approached in this note from the restricted point of view of one-dimensional shock and rarefaction waves interacting with a cylindrical rarefaction.

143. ON THE THEORY OF METAL BODIES IN HIGH SPEED IMPACT. Zlatin, N. A. In Zhurnal Tekhnicheskoi Fiziki, Vol. 31, August 1961, pp. 982-990. Soviet Phys. - Tech. Phys., Vol. 6, February 1962, pp. 714-719. (Translation).

A method is presented for determining the threshold collision velocities above which the impact is accompanied by explosion of the stressed volumes during the course of interaction. It is shown that in the case when the interaction of metal objects after a short initial settling period can go over to a stationary (or quasi-stationary) process, the threshold velocities turn out to be 2.2 to 2.4 times greater than in the case when the interaction of the same objects is confined to the nonstationary period of the process. A minimum threshold value for the impact velocity of 2.8 km/sec is obtained for the case of lead objects interacting under nonstationary conditions, a maximum value of 18.6 km/sec for the case of aluminum objects interacting under stationary conditions.

144. ON THE USE OF "HYDRODYNAMIC" THEORY FOR STRESS WAVE PROPAGATION IN SOLIDS. Fyfe, Ian M. January 1962, The Boeing Co., Aerospace Division, Seattle, Wash. Report No. D2-90102.

Arguments which permit the use of hydrodynamic theory in stress wave propagation in solids are discussed. It is shown that the usual hydrodynamic theory, in addition to being applicable at high-intensity stress levels, is valid at all stress levels when described by a one-dimensional rectangular Cartesian coordinate system.

145. PERFORATION AND PENETRATION EFFECTS OF THIN TARGETS. Partridge, William S., C. Richard Morris and Merlin D. Fullmer. Utah Research and Development Co., Inc., Salt Lake City, and Sperry Utah Engineering Labs., Salt Lake City. In 3rd HVIS.

An attempt was made to obtain (1) the energy required to just barely perforate the target, and (2) the energy lost by the pellet while perforating the target. The authors concluded that there appears to be a linear relationship between the target thickness and the penetration velocity, i.e., to the momentum.

146. PENETRATION BY HIGH VELOCITY ("MUNROE") JETS. I. Pack, D. C., and W. M. Evans. Armament Research and Development Establishment, Fort Halstead, Kent, England. In Proceedings of the Physical Society of London, Series B, Vol. 64, Part 4, pp. 298-302, April 1951.

By means of certain simplifying assumptions, a formula is derived for the penetration into a ductile target by a high-velocity jet. The action is divided into two stages, each making its contribution to the total penetration. First, a hole is formed by the lateral compression of the target as the jet penetrates it, and the second stage begins when the last particle of the jet has ceased to act. The hole continues to deepen until the residual energy in the target has been spent.

147. PENETRATION BY HYPERVELOCITY PARTICLES. Zaid, Melvin. November 1960, Technik, Inc., Research Analysis Development, Garden City, N. Y. Technik Report 60-28; Contract DA-30-069-507-ORD-2674.

In this paper additional equations are presented for the solution to the problems of a non-deformable ultra-high speed penetrator striking a semi-infinite deformable target. These, together with the ones of a previous paper, provide a complete mathematical description of a penetration model. Based on these equations, and on an assumed stress-velocity relationship, various "growth" laws are postulated and solutions for penetration distance velocity and time history are obtained.

148. PERFORATION OF PLATES BY HIGH-SPEED PROJECTILES. Chou, Pei Chi. Drexel Institute of Technology, Philadelphia, Pa. In Developments in Mechanics, Vol. 1, pp. 286-295, Plenum Press, New York, 1961.

An analytical approach is employed for the study of perforations of plates by high-speed projectiles. It is assumed that the material of the plate behaves like a visco-plastic solid under high-speed impact. The equation of motion is developed and then simplified to a heat transfer type of differential equation. This equation, together with proper boundary and initial conditions, is solved by Laplace transform methods. The solution is plotted in the form of curves of shear strain vs radial distance at different time intervals. It is also assumed that separation or failure occurs when the shear strain is higher than a critical value and the shear strain-rate is lower than a critical value. This criterion is used to determine the size of the perforated hole.

Perforation diameters predicted on the basis of this theory agree qualitatively with existing experimental observations.

149. PIC FORMULATION OF VISCO-PLASTIC MODEL FOR HYPERVELOCITY IMPACT. Quarterly Progress Report No. 5, February 3, 1962-May 22, 1962. Riney, T. D. July 1962, General Electric Co., Space Science Lab., King of Prussia, Pa. Prepared for Air Proving Ground Center, Eglin AFB, Fla. APGC-TDR-62-24; AFSC Project 9860; Contract AF-08(635)1713.

The visco-plastic equations governing the axisymmetric impact situation are reformulated in a form appropriate to the particle-in-cell method of calculation. A step-by-step description of the computational procedure is presented which allows for such contingencies as free boundaries, interior empty cells and the axis of symmetry. A programmer may work directly from this report.

150. PITS IN METALS CAUSED BY COLLISION WITH LIQUID DROPS AND SOFT METAL SPHERES. Engel, Olive G. In Journal of Research of the National Bureau of Standards, Vol. 62, No. 6, pp. 229-246, June 1959. See also NBS Research Paper 2958.

An equation is developed to give pit depth as a function of collision velocity for pits formed in soft to medium-hard metal plates as a result of collision with liquid drops. The rear face of the target plate must be a free surface. The plate thickness must not be less than 1.5 to 2.0 times the drop diameter nor greater than 4 to 5 times the drop diameter.

151. PITS IN METALS CAUSED BY COLLISION WITH LIQUID DROPS AND RIGID STEEL SPHERES. Engel, Olive G. In Journal of Research of the National Bureau of Standards, A. Physics and Chemistry, Vol. 64A, No. 1, pp. 61-72, January-February, 1960.

A pit-depth-versus-velocity equation developed earlier was tested further with experimental data obtained using target plates of electrolytic tough pitch copper, 1100-0 aluminum, and 2024-0 aluminum, the static strength properties of which were measured by testing tensile specimens. The projectiles used to produce the pits were mercury drops, waterdrops, and steel spheres. Numerical equations were found for the equations for projectiles which do not flow (hardened steel spheres).

152. THE PROBLEM OF PIERCING AT COSMIC VELOCITIES. Lavrent'yev, M. A. May 1960, National Aeronautics Space Agency, Washington, D. C. NASA TT F-40. Translated from Iskusstvennyye Sputniki Zemii (Artificial Earth Satellites), No. 3, Academy of Sciences, USSR (Moscow), 1959.

Consideration is given to the cases where a hard flat surface strikes a small cylinder and also where a hard curved surface strikes a small sphere. After the collisions, both the cylinder and sphere are assumed to vaporize. It is pointed out that the results do not agree with the deductions of K. P. Stanyukovich.

153. PROBLEMS IN METEORIC EROSION. Hoenig, S. A. and A. Ritter. Armour Research Foundation, Chicago, Illinois. In 2nd HVIS, Vol. I.

The authors suggest that meteoric impacts above a certain velocity are similar in many ways to TNT explosions and similar to meteor craters on earth and moon. The diameters vary with square root of energy.

Baldwin curve of diameter-depth of crater, including earth and lunar meteor craters, and curves for energy release versus crater diameter are shown.

154. PUNCTURE PROBLEM AT COSMIC VELOCITIES. Lavrent'yev, M. A. In American Rocket Society Journal, Vol. 30, No. 4, pp. 386-388, April 1960.

Few investigations have been made in the puncturing problem at 50-100 km/sec; the experimental difficulties at such velocities require particular caution as regards the main hypothesis made in the theory of each phenomenon. An incompressible-medium model is presented for the theoretical prediction of hypervelocity cratering for which the calculations can be carried out to conclusions.

155. RE-EXAMINATION OF THEORIES OF JET FORMATION AND TARGET PENETRATION BY LINED CAVITY CHARGES. Eichelberger, Robert J. June 1954, Carnegie Institute of Technology, Dept. of Physics, Pittsburgh, Pa. Report CIT 394; CEL-1; ASTIA AD-52,992.

This report presents the results of a comprehensive study of shaped-charge theories and experiments. The author discusses the development of shaped-charge technology since the principle was established by Munroe in 1888. The report contains a complete treatment of shaped-charge theory along with much useful experimental data.

156. RESEARCH ON THE EFFECTS OF COLLISIONS OF SMALL PARTICLES WITH BODIES MOVING AT HYPERSONIC SPEED. Wehner, G., G. Whitnah, J. Nash, F. Bollag, R. Pohl, W. Torgeson, and H. Zeller. July 1958, General Mills, Inc., Minneapolis, Minn. Wright Air Development Center, Wright Patterson AFB, Ohio. WADC TR-58-498; ASTIA AD-155,894; Contract AF 33(616)5565.

Collisions between small particles and hypersonic bodies were studied for the purpose of predicting erosion and the subsequent effects on flow and heat transfer. The flow conditions at the boundary layer of a hemispherical body, the location of the transition point, and the momentum thickness of the boundary layer were calculated at several altitudes to provide a basis for evaluation of surface roughness effects. The heat transfer coefficient over the face of a smooth hemisphere was calculated by means of van Driest's equations. Experiments in the field of hypervelocity impaction were reviewed and predictions were made of the depth, area, and volume of the craters.

157. RESEARCH ON THE EFFECTS OF COLLISIONS OF SMALL PARTICLES WITH BODIES MOVING AT HYPERSONIC SPEEDS. Second Quarterly Progress Report, 15 December 1958-15 March 1959. Whitnah, G., G. Wehner, A. Gaalswyk, J. Upton, W. Torgeson, Duane Rosenberg, and D. Rotenberg. 6 April 1959, General Mills, Inc., Minneapolis, Minn. Report No. General Mills-1898; ASTIA AD-216,154; Contract AF-33(616)5565.

The purpose of the studies which are discussed in this report is to further explore several technical problems in this field for which adequate data are not yet available. The scope of the project includes (1) theoretical and experimental study of the effects of major surface roughness on heat transfer during reentry, (2) study of surface pitting caused by formation of alloys with impinging particles, (3) study of hypervelocity cratering, and (4) analysis of techniques for creating and maintaining particle clouds in the atmosphere.

158. RESEARCH ON THE PHYSICAL THEORY OF METEOR PHENOMENA. II. THE POSSIBLE CONSEQUENCES OF THE COLLISIONS OF METEORS IN SPACE. Öpik, Ernst J. In Tartu. Obs. Publication 28, No. 6, 1936.

159. RESEARCH ON THE PHYSICAL THEORY OF METEOR PHENOMENA. III. BASIS OF THE PHYSICAL THEORY OF METEOR PHENOMENA. Öpik, Ernst J. In Tartu. Obs. Publication 29, No. 5, 1937.

The paper prepares a foundation for the general theory of meteor phenomena.

A first approximation theory is applied for the purpose of obtaining estimates of the physical conditions in meteors of different size, velocity, and composition. The first approximation formulae may be used for a study of observational data referring to the dependence of the mean height of meteors upon velocity and magnitude, and to estimates of the density gradient of the atmosphere; absolute estimates of the density of the atmosphere and the calculation of the range in height for meteors cannot be made with sufficient reliability on the basis of the first approximation.

160. REVIEW OF HYPERVELOCITY IMPACT THEORIES (U). Canadian Armament Research and Development Establishment, Valcartier, Quebec. Report CARDE TM 623/61. Report CONFIDENTIAL. Abstract CONFIDENTIAL.

161. A REVIEW OF THE THEORIES CONCERNING CRATER FORMATION BY HYPERVELOCITY IMPACT. Allison, Floyd E. Carnegie Institute of Technology, Pittsburgh, Pa. In 3rd HVIS, Vol. I.

The author asks and answers four basic questions as follows:

1. Should the theorist explain crater formation by means of an explosion model or a hydrodynamic model? Answer - The hydrodynamic model appears to be the dominant processes.

2. Can Baldwin's correlation between chemical energy and crater dimensions be used to determine the kinetic energy of a projectile from its crater dimensions? Answer - Baldwin's correlation cannot be used for this purpose.

3. For velocities over 2 km/sec, does the data indicate that crater volume per unit energy is a constant? Answer - For lead targets and steel pellets, crater volume is not directly proportional to either energy or momentum.

4. Are crater parameters dependent upon the bulk mechanical perfection of the targets? Answer - It appears as though target mechanical and plastic flow properties dominate in the crater-forming process.

162. SCIENCE OF HIGH EXPLOSIVES. Cook, Melvin A. Rinehold Publishing Corp., New York, 1958.

163. SHOCK WAVE COMPRESSION OF HARDENED AND ANNEALED 2024 ALUMINUM. Fowles, G. R. October 25, 1960, Poulter Labs., Stanford Research Institute, Menlo Park, Calif. SRI PL-TR 011-60; ASTIA AD-249,875; Contract AF 49(638)625.

Measurements of the Hugoniot equations of state of hardened and annealed 2024 aluminum at pressures below 50 kilobars are presented. The major aim of the experiments was to determine the validity of elastic-plastic theory, which predicts that, at a given compression, the stress normal to the shock front is larger than the hydrostatic pressure necessary to produce the same compression by an amount equal to two-thirds the yield strength in simple tension. Oblique shock geometry was employed. Shock and free-surface velocities were recorded with a streak camera by means of a light reflection technique employing the principle of the optical lever. This technique provides continuous recording of free-surface motion with time, an essential requirement because of the existence of a double shock system. The observed elastic wave amplitudes (5.4 ± 0.2 kb and 0.9 ± 2 kb) for hardened and annealed material, respectively, agree within experimental precision with values predicted from static tensile specimen data. The shock wave data, in the range 25 to 50 kb, yield one-dimensional strain isotherms which, while significantly different for the two different hardness conditions, agree within experimental precision with semi-theoretical curves based on Bridgman's hydrostatic data to 30 kb and a simple tension stress-strain data. No significant strain rate effects are evident. It is concluded that elastic-plastic theory is valid for the description of plane shock waves in this material.

164. SHOCK WAVE PROPAGATION IN CRATER FORMATION. Davids, Norman and S. W. Huang. December 31, 1960, The Pennsylvania State University, Dept. of Engineering Mechanics, University Park. Technical Report No. 2; NASA Research Grant NsG-66-60.

The authors attempt to make an analysis of hypervelocity penetration of small pellets into metal plates. A simplified spherical shock zone is assumed. Reasonable agreement is found with existing relatively low-speed data.

165. SHOCK WAVES IN SOLID CRATERS. Davids, Norman and Y. K. Huang. Pennsylvania State University, University Park. In Journal of the Aerospace Sciences, Vol. 29, No. 5, pp. 550-557, May 1962.

A theory of crater formation in solids by impact of ultra high-speed particles is studied from the standpoint of radially symmetric advancing shock fronts. The equations of motion lead to a solution based on progressing waves, which leads to a 2/5-power law for penetration versus velocity. Some particular results for steel agree with Charters' and Summers' data. The variations of pressure and density with radius are also obtained.

166. SIMILARITIES BETWEEN LUNAR AND HIGH VELOCITY IMPACT CRATERS. Partridge, William S. and Howard B. Vanfleet. In the Astrophysical Journal, Vol. 128, No. 9, pp. 416-419, September 1958.

Craters formed by firing pellets into targets at velocities of from 1 to 3 km/sec exhibit many of the characteristics observed in lunar craters. The mechanism of crater formation is very similar whether the target is (1) a low-strength wax, (2) plaster of Paris, or (3) a metallic substance. The following similarities between lunar and high velocity craters have been noted: (1) the over-all shape in many cases is very similar; (2) the material in the crater lip and in the raised portions of the surface around the crater is approximately equal to the volume of the crater; (3) systems of rays extending from the center of the crater have been observed under both conditions; (4) a wrinkled appearance has been observed around metallic craters which was caused by slippage of crystal planes and resembles very closely the surface surrounding some lunar craters; (5) it is possible to form impact craters with central peaks very similar to those observed in craters on the moon.

167. SOLUTION OF VISCO-PLASTIC EQUATIONS FOR AXISYMMETRIC HYPERVELOCITY IMPACT. SECOND SUMMARY REPORT, 3 NOVEMBER 1961-2 NOVEMBER 1962. FINAL REPORT. Riney, T. B. December 1962, General Electric Co., Space Science Lab., Valley Forge Space Technology Center, King of Prussia, Pa. Air Proving Ground Center, Eglin AFB, Fla. APGC-TDR-62-74; AFSC Project No. 9860; Contract AF 08(635)1713.

The dynamic response of a metallic body when impacted by a hypervelocity projectile is a complicated phenomenon involving the introduction of damage mechanisms which are not completely understood, even when independently operative. In Part I of this report, tentative phenomenological relations are proposed for the hypervelocity impact regime. They include (a) the flow resistance coefficient (which is of fundamental importance in the visco-plastic model for high speed impact), (b) the equation of state for both compressive and rarefaction regions of the metal, and (c) a fracture criterion for high intensity tri-axial stress distributions of extremely short duration. In Part II of the report a step-by-step description of a computational procedure is presented for the solution of the visco-plastic equations governing the axisymmetric hypervelocity impact situation. The procedure incorporates the above phenomenological relations which are necessary for a realistic description of the penetration and cratering processes. Finally, a brief resume is given of the considerations that were involved in developing PICWICK, an IBM 7090 computer program for carrying out the complex and lengthy computational procedure. This unique program is a basic tool in the development of a more complete theoretical understanding of the hypervelocity impact phenomenon.

168. SPUTTERING AS IT IS RELATED TO HYPERBOLIC METEORITES. Baker, R. M. L., Jr. In Journal of Applied Physics, Vol. 30, No. 4, pp. 550-555, April 1959.

A theoretical discussion is presented of the phenomenon of cathode sputtering as it is related to high speed meteorites, i.e., to meteorites whose speeds are high enough to have reached the earth from interstellar space. The paper shows that theoretically sputtering can account in part, at least, for the discrepancy between meteor photographs, which show no extra-solar meteorites, and certain visual-telescopic data which, on the contrary, show a significant number of meteorites to have an extra-solar origin.

169. STUDY OF COLLISIONS. I. A SURVEY OF THE PERIODICAL LITERATURE. Barnes, George. University of Nevada, Reno. In American Journal of Physics, Vol. 26, No. 1, pp. 5-8, January 1958.

A review of the periodical literature on the subject of impact and the coefficient of restitution shows that the latter depends not only on the materials (elastic moduli) of the colliding objects, but also on (1) their relative normal velocity at the instant of impact, (2) their shapes and sizes, (3) their masses, and (4) the medium in which the impact occurs.

170. STUDY OF COLLISIONS. II. SURVEY OF THE TEXTBOOKS. Barnes, George. University of Nevada, Reno. In American Journal of Physics, Vol. 26, No. 1, pp. 9-12, January 1958.

A survey of physical and engineering textbooks and periodicals indicates that there is lack of agreement on the subject of impact and the coefficient of restitution. The confusion arises primarily because of (1) the way in which the coefficient of restitution is so often defined, (2) the nature of the usual discussions of it, and (3) the reason given for its being less than unity for most collisions between objects of ordinary size. Ways of eliminating the difficulty are discussed.

171. STUDY OF EQUATIONS GOVERNING THE VISCO-PLASTIC MODEL. Quarterly Progress Report No. 2. 3 February-3 May 1961. Riney, T. D. July 1961, General Electric Co., Space Science Lab., Philadelphia, Pa. Prepared for the Air Proving Ground Center, Eglin AFB, Fla. APGC-TN-61-30; AFSC Project 9860; ASTIA AD 263,817; Contract AF 88(635)1713.

The equations governing the visco-plastic model proposed in the First Quarterly Report are examined to determine the relative importance of inertial, viscous and strength terms. Exploratory calculations are found to be desirable since no definitive data for the important parameters are available in the impact regime. A one-dimensional model is formulated in finite difference form for the purpose of making these calculations.

172. A STUDY OF METEOROID IMPACT PHENOMENA. Quarterly Progress Report, 14 December 1961-14 March 1962. Rae, William J. and Henry P. Kirchner. Cornell Aeronautical Lab., Buffalo, N. Y. Report CAL RM-1655-M-1; Contract NAS3-2121.

In this investigation, modern blast wave theory will be applied in an examination of the phenomena that occur when meteoroids collide with satellites and other space vehicles. The blast wave model will be developed to include the strong interactions between fluid dynamic effects and material properties during very high energy collisions. The nature and extent of processes that result in crater formation, plastic and elastic deformation and spalling, are studied.

173. STUDY OF SHOCK PROPAGATION IN FERROUS METALS, FINAL REPORT. Katz, Samuel and R. E. Peterson. December 20, 1966, Poulter Labs., Stanford Research Institute, Menlo Park, Calif. Report SRI PL-TR 010-55, Project No. GU-863; Contract No. DA-04-200-ORD-257.

Explosive loading of ferrous metals produces deformation zones which may be used to study shock velocity, peak stress, attenuation, and shock front rise time. These zones are strikingly revealed in macro-etched specimens of iron and low-carbon steels and correlate with a marked increase in low density and microhardness. The inclination of the diagonal collision zone and the detonation velocity determine a shock velocity.

174. STUDY OF TARGET PENETRATION PREDICTION BY HIGH SPEED AND ULTRA HIGH SPEED BALLISTIC IMPACT. FOURTH QUARTERLY REPORT. 1 April-30 June 1962. July 1962, Hayes International Corp., Birmingham, Ala. Hayes Eng. Rpt. 634. Prepared for Air Proving Ground Center, Eglin AFB, Fla. AFSC Project 9860; Contract AF 08(635)2155.

A statistical analysis of the penetration depth in semi-infinite targets divided by the diameter of the projectile (P_c/D_p) on 1272 experimental shots has been completed. These data were split into 985 low velocity shots and 297 high velocity shots according to the bulk wave velocity in the target material. Separate analyses of the two groups show interesting relationships with existing theoretical and empirical equations.

A semi-rational penetration expression has been developed from a work-energy consideration which suggests that the nonrecoverable target compression and shear strain energies may account for most of the kinetic energy of the projectile. Judging from a preliminary comparison with existing experimental data, a penetration model of the form developed herein shows some promise for predicting impact behavior over a wide velocity range and for different projectile and target materials.

175. STUDY OF TARGET PENETRATION PREDICTION BY HIGH SPEED AND ULTRA HIGH SPEED BALLISTIC IMPACT. THIRD QUARTERLY REPORT. 1 January-31 March 1962. May 1962, Air Proving Ground Center, Eglin AFB, Fla. APGC-TDR-62-35; AFSC Project 9860; Contract AF 08(635)2155.

Complete results of the preliminary statistical analysis which were partially reported in the previous quarterly reports are reported herein. This statistical correlation, based on all hypervelocity terminal ballistic data gathered prior to December 1961, attempts to relate the depth of penetration in semi-infinite targets with ten independent variables.

Also reported are initial attempts to formulate a theoretical model for the purpose of testing accumulated experimental data. This theoretical model is developed from a consideration of energy conversion during impact.

176. SURFACE ENERGY, A MODE FOR ENERGY ABSORPTION DURING IMPACT. Rinehart, John S. In American Journal of Physics, Vol. 21, No. 4, pp. 305-307, April 1953.

The role that pulverization of the target material may play in absorbing the energy of an impacting missile is discussed. The energy that can be absorbed in this way will, in general, depend on the area of new surface that is created. Approximate calculations suggest that, for impacts against rock-like materials and glass, very considerable amounts of energy could be absorbed. The The production of rock flour at the Barringer Meteorite Crater in Arizona is cited as an example.

177. THE SYSTEM OF SHOCK WAVES GENERATED BY THE FALL AND EXPLOSION OF METEORITES. Stanyukovich, K. P. In Meteoritika Akademiya Nauk, SSSR, Vol. 14, pp. 62-69, 1956. Translated by Z. Jakuski. October 1961, Space Technology Labs., Inc., Los Angeles, Calif.

Given is a preliminary analysis of the complex interactions of shock waves originating at a violent meteoritic impact. This paper logically follows earlier papers in which this author has postulated that the effects of a meteorite impact may be equated approximately to those caused by detonation of some equivalent weight of H. E. at the impact point.

178. THEORY OF HIGH SPEED IMPACT: SUMMARY REPORT FOR PERIOD 3 NOVEMBER 1960-2 NOVEMBER 1961. Riney, T. D. March 1962, General Electric Co., Missiles and Space Vehicles Dept., Philadelphia, Pa. Air Proving Ground Center, Eglin AFB, Fla. Project No. 9860; APGC-TDR-62-20; ASTIA AD-274,048; Contract AF-08(635)1713.

Existing experimental results of hypervelocity impact tests have been gathered from various sources, and the composite data are presented and discussed. The results of the calculations are related to the qualitative model of crater formations that has evolved from experimental studies in which the actual cratering process has been monitored. It is concluded that the viscous and strength effects strongly affect the cavitation process which is the essential mechanism of crater formation. Finally, experiments are suggested which would provide the necessary data to verify and extend the theory.

179. THE THERMAL DISSIPATION OF METEORITES BY A BUMPER SCREEN. Langton, N. H. August 1954, National College of Rubber Technology, The Northern Polytechnic, Holloway Road, London, England. In Bericht uber den V. Internationalen Astronautischen Kongres, Innsbruck, Springer-Verlag, Wien, 1955.

The method, proposed by Whipple, of protecting an interplanetary vehicle or artificial satellite from the effects of colliding meteorites by using a bumper screen is investigated theoretically. It is assumed that when a meteorite hits a bumper screen, the whole of its kinetic energy is transformed into heat. This heat, which is generated at the point of collision, is considered to spread through a hemispherical volume of the screen, and if the resultant temperature rise is sufficient to melt the metal of the screen, it is said to have been thermally penetrated. The thicknesses of screens which will just be penetrated by various sizes of meteorites with a range of collision velocities are calculated. Results are given for both iron and stone meteorites, and general penetration equations derived which can be applied to screens of various metals. It is concluded that a bumper screen which would be practicable from the weight point of view would give reasonable protection; in fact, a dural screen of thickness 0.1 cm would provide protection for meteorites up to about the 10th magnitude.

180. TREATMENT OF MICROMETEORITE DATA OBTAINED FROM A HYPOTHETICAL ROCKET FLIGHT. Poss, H. L. 10 May 1957, AVCO Mfg. Corp., Research and Advanced Development Div., Lawrence, Mass. Report No. RAD-2-TM-57-13.

A simple statistical analysis of micrometeorite data obtained from a hypothetical rocket flight, of a type proposed by AVCO, is presented. Numerical examples are given which show how the thickness of a protective cover necessary to shield the ICBM nose cone from micrometeorite pitting can be determined directly from the data collected during such flights. On the basis of a range of assumed values for micrometeorite frequency and penetration, it is demonstrated that the data collected would substantially reduce the present uncertainty in protective cover weight.

181. VISCO-PLASTIC FLOW THEORY IN HYPERVELOCITY PERFORATION OF PLATES. Chou, Pei Chi. Drexel Institute of Technology, Philadelphia, Pa. In 5th HVIS, Vol. I, Part 1.

The author treats the perforation of plates theoretically. While pointing out that the incompressible hydrodynamic theory and the compressible shock wave theory have been rather widely accepted, he shows that viscosity is possibly an important parameter. This effect is included and equations are developed.

182. VOLUME-ENERGY RELATION FOR CRATERS FORMED BY HIGH VELOCITY PROJECTILES. Culp, F. L. Carnegie Institute of Technology, Pittsburgh, Pa. In 3rd HVIS, Vol. I.

The author states that crater volume in lead from steel projectile is not a direct fraction of either energy or momentum at low velocities. It is impossible to infer the energy responsible for a given crater from the crater geometry alone.

SECTION IV. EXPERIMENTAL INVESTIGATIONS

183. THE ADDITION OF ELECTRICAL ENERGY TO HELIUM. Kymer, James R., Frankford Arsenal, Philadelphia, Pa. In 4th HVIS, Vol. I.

In order to increase the launch velocity of a compressed helium projector, it has been proposed that heating by electrical discharge could supply substantial increase in energy.

To optimize performance of existing launchers and assess the feasibility of proposed launchers, a knowledge of the properties of light gases under firing conditions would be invaluable. Due to extreme conditions of pressure, temperature, density voltage current, field strength, and time, the conventional methods of measuring the properties are not applicable.

This report describes the efforts, to date, in conducting the experimental determination of the properties of light gases at high temperature and pressure.

184. AN IMPACT AND PENETRATION EFFECTS STUDY. Ferguson, J. E. January 1963, Aerojet-General Corp., Ordnance Div., Downey, Calif. Air Proving Ground Center, Eglin AFB, Fla. AFSC Project No. 5841; APGC-TDR-63-2; Contract AF 08(635)975.

The Shaped Charge Hypervelocity Projectile Accelerator is being used to study impact and penetration effects upon various thicknesses of targets at velocities between 24,000 and 39,000 feet per second. This Special Report presents and analyzes 208 data points gathered for impacts in the 29,000-33,000 feet per second velocity range, with 0.03-0.8 gram aluminum projectiles against 0.375-inch, 0.500-inch, 1.00-inch and 4.0-inch thick 2024-T4 aluminum target plates; 19 data points gathered for impacts in the 35,000-39,000 feet per second velocity range with 0.01-0.7 gram aluminum projectiles against 0.100-inch thick 2024-T4 aluminum target plates; and 63 data points gathered for impacts in the 22,000-26,000 feet per second velocity range with 0.02-0.7 gram copper projectiles against 0.100-inch thick 2024-T4 aluminum target plates and 0.500-inch thick soft copper target plates. Angles of obliquity between the velocity and the target surface for these experiments were 90°, 50° and 20°. Curves, photographs, and flash radiographs illustrating the data are presented.

185. ANALYSIS OF IMPACT OF HYPERVELOCITY PELLET WITH THIN SHIELD: A MEMO. Lull, David B. December 1959, Arthur D. Little, Inc., Cambridge, Mass.

186. AN ANALYSIS OF MICROPARTICLE CRATERING IN A VARIETY OF TARGET MATERIALS. Gehring, John William, Jr., Ballistic Research Labs., Aberdeen Proving Ground, Md. In 3rd HVIS.

The author describes the cratering of microparticles into many target materials. It was found that the craters in ductile targets were slightly deeper than the classic hemispherical form, but craters in Mg. and Al. tend to be somewhat deeper. The author believes that penetrations are deeper when target metal grain boundaries impacted. Brittle materials yielded craters flatter than hemispherical. At 10 km/sec impact craters in lead are 10 times the diameter of the impacting particle and in nickel and copper, 2.5 times. Vacuum used was 5×10^{-4} torr.

187. THE ANOMALOUS BEHAVIOR OF LEAD-TO-LEAD IMPACT. Vanfleet, Howard B., William S. Partridge and Emerson T. Cannon, University of Utah, Salt Lake City. In 3rd HVIS.

Work done at the University of Utah High Velocity Laboratory indicates that over a limited energy range of lead-to-lead impact a linear relationship between crater volume and impact energy seems to apply, but that over a larger range of energy the relationship seems to be $V = V_0 (1 - e^{-CE})$. The area of the crater in the surface of the target is linearly related to the area and the volume per unit area is linearly related to the penetration or depth of the crater. The extrapolation of these relationships to high energy leads to craters which are large in area but shallow in depth. The volume and energy relationship noticed in lead-to-lead impact is also observed where spheres of other materials are impacted into lead.

188. ARTIFICIAL METEORS INTO INTERPLANETARY SPACE. Zwicky, F. In Annuals of the IGY, Vol. 11, 1961, pp. 265-267. Comite' Special de l'Annee Geophysique Internationale Meeting, 5th, Moscow, July 30-August 8, 1958. Pergamon Press, New York, 1961.

A brief survey is given of work done in connection with the production and launching of artificial meteors.

189. BALLISTIC IMPACTS BY MICROSCOPIC PROJECTILES. Friichtenicht, J. F. and B. Hamermesh. Ramo-Wooldridge, Div. of Thompson Ramo-Woolridge, Inc., Canoga Park, Calif. Report RW-RL-169. In 4th HVIS, Vol. III.

The determination of the validity of size scaling relationships is the long range goal of terminal ballistics studies with the electrostatic accelerator. A description is given of the techniques involved in using the accelerator for terminal ballistics experiments and presentation is made of preliminary data on the impact of iron spheres onto lead targets.

190. BIOLOGICAL EFFECTS OF SIMULATED MICROMETEOROID PENETRATION OF A SEALED CHAMBER CONTAINING ANIMAL SPECIMENS. Gell, Charles F., Allen B. Thompson and Verne Stembridge. Presented at the Aerospace Medical Association Meeting in Chicago, April 26, 1961. In Aerospace Medicine, Vol. 33, No. 2, pp. 156-161, February 1962.

Chance Vought Corporation, in its inhouse research, has been firing aluminum pellets at hypervelocities into a small chamber containing rat specimens. This chamber was located inside a large vacuum tank and the projectiles fired through a vacuum attained velocities of 23,000 fps or approximately 17,000 mph. Evidence of oxidative explosion within the chamber was secured by photography. Animal experiments demonstrated the pathological effect of these explosions on incarcerated rats as ranging from mild to lethal, depending on certain physical factors and the internal environment of the animal chamber.

191. COLLISIONS IN SPACE. In Engineering, Vol. 185, pp. 164, February 7, 1958. See also entry 55 in Part B of the Bibliography.

This is a summary of the paper by N. H. Langton, "Meteoric Hazards to Space Flight," presented at a meeting of the British Interplanetary Society. It dispels the still-held impression of danger by large particles. Laboratory experiments on dust particles have been done in the past at velocities no larger than 5 km/sec using 1/8-in. ball bearings. The implication is that these experiments are not realistic.

192. COLLISIONS OF LIQUID DROPS WITH LIQUIDS. PART I. A REVIEW WITH SOME PRELIMINARY DATA. Engel, Olive G. February 1961, National Bureau of Standards, Washington, D. C., Wright Air Development Div., Wright-Patterson AFB, Ohio. WADD Tech Report 60-475, Part I.

The information available on collisions of liquid drops with liquids is reviewed, and some preliminary quantitative data on cavity depth and depth/diameter ratio for collisions of waterdrops with water are given. A plot of the depth of cavity in the target liquid against time elapsed since the collision can be fitted by a parabola or by an ellipse tangent to the cavity-depth axis at the origin. The depth/diameter ratio for the cavity formed in the target liquid is found to vary with time elapsed since the collision; the cavity has a depth/diameter ratio of 0.5 at only two points in time. An equation for maximum cavity depth is derived on the assumption that, at the time of maximum depth, the volume of the cavity in the target liquid is proportional to the kinetic energy of the impinging drop. Apparatus that is now being assembled at the National Bureau of Standards to carry out an exhaustive study of this type of collision is described.

193. CRATER FORMATION IN METALLIC TARGETS. Partridge, William S., Howard B. Vanfleet and Charles R. Whited. University of Utah, High Velocity Lab., Salt Lake City. In Journal of Applied Physics, Vol. 29, No. 9, pp. 1332-1336, September 1958.

Spheres of copper, lead, tin, iron, aluminum, zinc, silver, and lead-tin alloys were accelerated to velocities of 0.75 to 2.25 km/sec and impacted normally upon targets of the same material as the pellets. Conditions were maintained so that pellets lost no mass before striking the target. The target mass was large compared to the mass of the pellet, so the targets could be considered semi-infinite.

The volume of the crater produced was found to be directly proportional to the kinetic energy of the pellet in the energy range investigated.

The penetration varied linearly with the velocity of momentum of the pellet. The area of the crater as measured in the plane of the original surface of the target was found to be directly proportional to the momentum of the pellet at the time of the impact.

194. CRATER FORMATION IN MISSILE SURFACE MATERIALS (U). Dante, James G. February 1962, Ballistic Research Labs., Terminal Ballistics Lab., Aberdeen Proving Ground, Md. In 5th HVIS, Vol. II. Report SECRET. Abstract SECRET.

195. CRATERING AND EXPERIMENT THEORY. Palmer, E. P., R. W. Grow, D. K. Johnson and G. H. Turner. University of Utah, High Velocity Lab., Salt Lake City. In 4th HVIS, Vol. I.

In order to determine the importance of various target and projectile characteristics in cratering produced by high-velocity impact, experiments have been carried out in which target and projectile materials were systematically varied. In one series of experiments, steel spheres were impacted upon targets of copper, lead, aluminum, magnesium, zinc, silver, and steel. In another series, projectiles of nylon, K-monel metal, pyrex glass, stainless steel types 302 and 440, naval brass and lead, were impacted upon lead targets. Velocities up to 2.5 km/sec were used. Crater volume was found to be directly proportional to projectile energy for all targets and projectiles.

196. CRATERING AND SHOCK WAVE PHENOMENA IN STEEL PLATES AT HIGH IMPACT SPEEDS. Mayfield, Earle B. and James W. Rogers. U. S. Naval Ordnance Test Station, Michelson Lab., China Lake, Calif. In Journal of Applied Physics, Vol. 31, No. 2, pp. 472-473, March 1960.

The impact of aluminum projectiles on steel plates for impact velocities of 2500 m/sec to 3000 m/sec and about 1100 m/sec was studied. Crater volume and penetration were measured. Shock wave velocity from the free surface was determined and the particle velocity calculated. For annealed 4130 steel plates impacted at 2750 m/sec average velocity, the average free surface particle velocity was 0.205 mm/sec. Existing theory on cratering and penetration gave excellent agreement with the observed values.

197. CRATERING BY A TRAIN OF HYPERVELOCITY FRAGMENTS. Allison, Floyd E. and George M. Bryan. Carnegie Institute of Technology, Pittsburgh, Pa. In 2nd HVIS, Vol. I.

Experimental verification of the penetration process by shaped-charge jets on the basis of a steady-state hydrodynamic model is discussed.

198. CRATERING BY HIGH VELOCITY MICROPARTICLES. Anderson, Gordon D., D. G. Doran, F. S. Hempy and M. C. Kells. Poulter Labs., Stanford Research Institute, Menlo Park, Calif. In 3rd HVIS, Vol. I.

The authors describe the characteristics of craters obtained when metal microparticles impact into various targets, including effect of oblique angle and heating of target. Correlation of V/C vs P/D (particles diameter/crater diameter) data points with 2 penetration formulas ($p/d = 2.5\ (V/C)^{1.4}$ and $p/d = 2.28\ [(\rho_P/\rho_T)\ (V/C)]^{0.69}$.

199. CRATERING BY HIGH VELOCITY MICROPARTICLES. SUMMARY REPORT, COVERING THE PERIOD DECEMBER 1956 TO MARCH 1959. Anderson, Gordon D. April 8, 1959, Poulter Labs., Stanford Research Institute, Menlo Park, Calif. SRI Project GU-1989; Contract DA-04-200-ORD-597.

This report summarizes the work done on this project during the period December 1956 to March 1959. The work has consisted of development of techniques for particle acceleration and velocity measurement which has led to quantitative cratering studies.

200. CRATERING OF LEAD BY OBLIQUE IMPACTS OF HYPERVELOCITY STEEL PELLETS. Bryan, George M. and Emerson M. Pugh. Carnegie Institute of Technology, Pittsburgh, Pa. In Journal of Applied Physics, Vol. 33, No. 2, pp. 734-738, February 1962.

The present work is an investigation of both the volume and the shape of the craters formed in massive lead targets by a steel projectile of fixed energy as a function of the angle of incidence. Lead was chosen in order to minimize effects due to the mechanical strength of the target material since such effects, even in much harder materials, probably play a relatively small role in impact phenomena at actual meteoric velocities.

201. CRATERING PRODUCED IN METALS BY HIGH VELOCITY IMPACT. Johnson, D. K., Emerson T. Cannon, E. P. Palmer and R. W. Grow. July 1959, University of Utah, Salt Lake City. UU Tech Report No. 4; AFBMD TR 59-21; Contract 04(647)176.

Steel spheres were accelerated to velocities up to 2.5 km/sec and impacted on targets of copper, lead, aluminum, magnesium, zinc, silver, and 4140 steel. Volume, area, and depth of the resulting craters are plotted as functions of projectile energy or momentum. Crater volume was found to be proportional to projectile energy. Relationships between volume per unit energy and compressive yield strength and shear strength of the targets were found. Area and penetration were dependent on projectile deformation as well as velocity.

202. CRATERS, FRACTURES AND DEFORMATIONS PRODUCED IN ROCK BY CONFINED EXPLOSIONS. Rinehart, John S., Colorado School of Mines, Golden. Presented at American Geophysical Union, Forty-third Annual Meeting, April 25-28, 1962, Washington, D. C.

A large number of small (approximately one-half gram) explosive charges, buried within but close to one free surface of a plaster of Paris block, have been detonated, with observations being made on the resulting craters, camouflets, fracture patterns, and deformations. The blocks were fitted internally and externally with special electrical switches, permitting determination of fracture sequence and fracture velocity. Complementary tests were run in which fractures were produced by static pressures, the intent being to compare dynamically and statically formed craters. When the explosion was completely contained and a camouflet formed, the material around the camouflet was compacted as much as 50 percent. For depths of burial near the limit of breakout, the crater is formed by the ejection of a one-piece more-or-less conical plug, fracturing apparently being caused by the high quasi-static pressure developed by the explosion products in the camouflet that they generate rather than by the initial shock wave. At shallower depths, the plug breaks into pie-shaped pieces, the number increasing as the charge is brought closer to the surface. The fractures forming these pieces were shock waves initiated and developed earlier than the plug-forming fracture. In addition, the crater surface exhibits heavy undulations or ripples that can be attributed to shock-wave reflections and interferences.

203. CRATERS PRODUCED BY THE HYPERVELOCITY IMPACT OF ALUMINUM CYLINDERS ON STEEL PLATES. Mayfield, Earle B. and James W. Rogers. 20 February 1956, Naval Ordnance Test Station, China Lake, Calif. NOTS-1366; NAVORD-5025; ASTIA AD 90,039.

Experimental results of the impact of .50 caliber-aluminum cylinders on 4130 annealed steel plates at velocities from 2,400 to 3,000 m/sec are reported. Craters created by the impact are 13.8 times greater than those due to impact at ordnance velocities for the same projectile and target. Penetration of the target plate at these hypervelocities averages 5.4 times the penetration at ordnance velocities. Photographs of the wakes of the hypervelocity projectiles indicate that material eroded from the projectile burns vigorously in air. High-speed photographs of the projectile and its shock waves indicate that the turbulent wake may burn explosively.

204. DAMAGE TO SOLIDS BY LIQUID IMPACT AT SUPERSONIC SPEEDS. Bowden, F. P. and J. H. Brunton. In Nature, Vol. 181, No. 4613, pp. 873-875, March 29, 1958.

A study was made of the deformation and damage sustained by metallic and plastic specimens subjected to impact by a cylinder of water of about 0.01 cm^3 in volume travelling at about 3100 ft/sec. With a stainless steel specimen, impact produced a shallow saucer-shaped depression with a central pit and a highly deformed annular region just inside the rim of the depression. The area of deformation corresponded closely to the area over which the spreading cylinder exerted pressure. With an Al specimen, the area of the affected surface was similar to that with stainless steel, but the depression was ten times greater. The annular region with metals seemed to have been sheared open by water flowing at high speed over it. The intensity of this deformation increased with the viscosity of the liquid used. With plastic targets, the main feature of the damage was a ring crack on the surface and a central star crack below the surface. Sometimes rear scabbing also occurred. Under repeated impact, the cracks spread until a piece of plastic was dislodged from the surface. The flow of liquid parallel to the surface of the specimens was found to be between 2 and 3 times as great as the impact velocity.

205. THE DEPENDENCY OF PENETRATION ON THE MOMENTUM PER UNIT AREA OF THE IMPACTING PROJECTILE AND THE RESISTANCE OF MATERIALS TO PENETRATION. Collins, Rufus D., Jr. and William H. Kinard. May 1960, NASA, Langley Research Center, Va. NASA TN D-238; ASTIA AD-236,118.

The results of this investigation indicate that the penetration of projectiles into quasi-infinite targets can be correlated as a function of the maximum momentum per unit area possessed by the projectiles. The penetration of projectiles into aluminum, copper, and steel targets was found to be a linear function while the penetration into lead targets was a nonlinear function of the momentum per unit area of the impacting projectiles. Penetration varied inversely as the projectile density and the elastic modulus of the target material for a given projectile momentum per unit area. Crater volumes were found to be a linear function of the kinetic energy of the projectile, the greater volumes being obtained in the target materials which had the lowest yield strength and the lowest speed of sound.

Results of impact into quasi-infinite targets indicate that penetration varied inversely as projectile density and elastic modulus of the target material for a given projectile momentum per unit area. Crater volumes were found to be linear functions of the kinetic energy of the projectiles.

This investigation was based on a survey of existing penetration equations.

206. DYNAMIC DETERMINATION OF THE COMPRESSIBILITY OF METALS. Goranson, R. W., Dennison Bancroft, Blendin L. Burton, T. Blechav, E. E. Houston, E. F. Gittings and S. A. Landeen. Los Alamos Scientific Lab., N. Mex. In Journal of Applied Physics, Vol. 26, No. 12, pp. 1472-1479, December 1955.

Equation of state data for Duralumin in the pressure range from 0.1 to 0.3 megabar have been determined dynamically by measuring shock and free surface velocity electrically in a plate of 24 ST Duralumin that has been stressed by a high explosive detonation. A theory is presented which allows comparison with data obtained by other experimenters, and which yields the relationship between pressure and compression either at constant entropy or constant temperature. The empirical form chosen for the equation of state ($p = \alpha\mu + \beta\mu^2$) expresses the pressure as a quadratic function of the compression. Experimental techniques are described in detail. Five points are given for the equation of state of Duralumin in the pressure range from approximately 0.15 megabar to 0.33 megabars. Some data are also presented for cadmium and steel.

207. DYNAMIC EXPANSION OF SPHERICAL CAVITIES IN METALS. Hopkins, H. G. Armament Research and Development Establishment, Fort Halstead, England. In Progress in Solid Mechanics, Vol. I, Chapter III, ed. by Snedden, I. N. and R. Hill. Interscience, New York, 1960.

Presented is a survey of the present state of knowledge concerning the dynamic expansion of cavities in solids, more especially ductile metals. Theoretical investigations may be classed rather broadly, according to either purely elastic or elastic-plastic deformation. A wide variety of particular problems exists. The more important are cited. Attention is confined almost exclusively to the general problem of the dynamic expansion of spherical cavities in ductile metals with special attention on the problem of spherical cavity formation under high explosive conditions.

208. DYNAMIC RESPONSE OF IRON AND IRON ALLOYS TO SHOCK WAVES. Minshall, F. Stanley. In Response of Metals to High Velocity Deformation of Metallurgical Society Conferences, Vol. 9, held at Estes Park, Colo., July 11-12, 1960. Interscience Publishers, Inc., New York, 1961.

When a metal is subjected to a shock wave, such as that produced by the detonation of an explosive, the behavior of the shock in the metal will depend upon the dynamic properties of the metal. In particular, if the incident shock is of appropriate pressure, it will separate into a series of shocks. The first will be the fastest and weakest, the second slower and stronger and so on. The pressures and profiles of the shock waves can be related to the dynamic properties of the metal. The dynamic shock properties of various alloys of iron are presented in this paper.

209. DYNAMICS OF A PROJECTILE PENETRATING SAND. PART I.
Allen, William A., Earle B. Mayfield and Harvey L. Morrison. Naval Ordnance Test Station, China Lake, Calif. In Journal of Applied Physics, Vol. 28, No. 3, pp. 370-375, March 1957. Paper presented at the American Physical Society Meeting at Los Angeles, Calif., December 28-30, 1955.

The experiment reported in this paper was designed to obtain data on the dynamics of a nonrotating, conical-nosed projectile penetrating randomly-packed sand. Position versus time measurements for the projectile in sand were obtained by means of a photographic-electronic chronograph developed for the purpose.

210. DYNAMICS OF A PROJECTILE PENETRATING SAND. PART II.
Allen, William A., Earle B. Mayfield and Harvey L. Morrison. Naval Ordnance Test Station, China Lake, Calif. In Journal of Applied Physics, Vol. 28, No. 11, No. 3, pp. 1331-1335, November 1957.

Additional data are reported that confirm a theory presented in a previous paper for the penetration of a stable flat-nosed projectile in sand.

211. EFFECT OF TARGET THICKNESS ON CRATERING AND PENETRATION OF PROJECTILES IMPACTING AT VELOCITIES TO 13,000 FEET PER SECOND.
Kinard, William H., C. H. Lambert, Jr., David R. Schryer and Francis W. Casey, Jr. December 1958, NASA, Langley Research Center, Langley Field, Va. NASA MEMO 10-18-58L.

In order to determine the effects of target thickness on the penetration and cratering of a target resulting from impacts by high-velocity projectiles, a series of experimental tests has been run. The projectile-target material combinations investigated were aluminum projectiles impacting aluminum targets and steel projectiles impacting aluminum and copper targets. The velocity spectrum ranged from 4,000 ft/sec to 13,000 ft/sec.

212. EFFECTS OF HYPERVELOCITY IMPACTS ON MATERIALS. FINAL REPORT. Scherrer, Victor E. August 1962, Air Force Systems Command, Aeronautical Systems Div., Wright-Patterson AFB, Ohio. Report No. ASD-TDR-62-762. AFSC Project 7360; Contract AF 33(616)8423.

A novel exploding-foil gun is described which routinely accelerates small particles (mass 1-100 mg) to velocities up to 60,000 ft/sec when coupled to a slow capacitor energy storage system. When the gun was efficiently coupled to a fast-capacitor energy storage system, a single, solid particle was accelerated to a velocity of 102,000 ft/sec. A detailed study of various particles impacting quasi-infinite lead targets was made, and preliminary results are given for particle velocities from 7,000 to 40,000 ft/sec. These results indicate a deep penetration phenomenon for a particle velocity of 15,000 ft/sec.

213. EFFECTS OF METEORS UPON MISSILES OUTSIDE THE EARTH'S ATMOSPHERE. Anderson, Gordon D. December 1959, Stanford Research Institute, Menlo Park, Calif. Report SRI GU-1989-PR-29; Contract DA-04-200-ORD-597.

Poulter Laboratories of Stanford Research Institute is at present conducting research in the field of high velocity particle impacts. The purpose of this work is to evaluate the damage that might be inflicted on a space vehicle due to micrometeorite collisions. The work consists of the development of techniques for producing high velocity particles, and for measuring the impact effects of the particles on various target materials.

214. EFFECTS OF TARGET TEMPERATURE ON HYPERVELOCITY CRATERING. Eighteenth Quarterly Report. Allison, Floyd E., K. R. Becker and R. Vitali. April 30, 1960, Carnegie Institute of Technology, Pittsburgh, Pa. Contract DA-36-061-ORD-513. In 4th HVIS, Vol. I.

Hypervelocity steel pellets (0.18 grams, 5,010 m/sec) have been fired into targets of commercially-pure lead, cadmium, zinc, and copper. The initial target temperature was varied over a wide range and the crater parameters determined as a function of target temperature.

215. EFFECTS PRODUCED BY EXPLOSIVES WITH LINED CAVITIES IN STEEL. Singh, Sampooran, Defence Science Lab., New Delhi, and P. N. Gandhi, Machine Tool Phototype Factory, Ambarnath, India. In Research, Vol. 9, pp. 55, 1956.

This article describes the changes in microstructure and microhardness and the types of fracture produced in massive steel targets by jets squirted from high explosives with copper-lined conical cavities.

216. ELASTIC AND PLASTIC BEHAVIOR IN THE IMPACT OF CYLINDERS AGAINST PLATES. Backman, Marvin E. Naval Ordnance Test Station, China Lake, Calif. In Journal of Applied Physics, Vol. 30, No. 9, pp. 1397-1402, September 1959.

A theory of indentation of a thick plate from impact by a flat-ended elastic cylinder is derived from elastic and plastic theories and compared to experimental values for 2024-T4 aluminum alloy, half-hard-naval brass and Armco iron. Plastic conditions in plates of the aluminum alloy are considered in detail by assuming an exponential increase in hardness to a maximum value. These results are sensitive to projectile length and are compared to experimental results for five projectile lengths.

217. ENERGY ABSORBED BY ELASTIC WAVES DURING IMPACT. Hunter, S. C. In Journal of the Mechanics and Physics of Solids, Vol. 5, pp. 162, 1957.

The absorption of vibrational energy in the form of elastic waves generated by a transient localized force acting normally to the free surface of a semi-infinite solid is calculated in terms of the Fourier components of the force. The result is applied to the Hertzian collision of a small body with the plane surface of a massive specimen. It is concluded that for impact velocities small compared with the propagation velocity of elastic waves in the specimen, a negligible proportion of the original kinetic energy of the small body is transferred to the specimen by the collision. The result is of some interest in justifying the validity of the Hertz theory for collisions between a small and a massive body.

218. ENGRAVEMENT OF TRANSIENT STRESS WAVE PARTICLE VELOCITIES. Rinehart, John S. and John Pearson. Colorado School of Mines, Golden. In Journal of Applied Physics, Vol. 24, No. 4, pp. 426-269, April 1953.

Quantitative information on the high intensity transient waves set up by impulsive loading is usually required in order to design rationally against failure under such loads. To obtain reliable data is often difficult when the loads last only a few microseconds and reach magnitudes of several hundred thousand pounds per square inch. A technique is described which enables quantitative determinations to be made either of particle velocity within the transient wave or of velocity of propagation of the wave. The scheme consists basically of measuring the depth of the permanent impression or engravement that is left on a surface when a pellet that has been previously affixed to that surface flies off. The engravement is a direct consequence of the impingement of a transient wave against the surface. Considerable numerical data are presented which establish the validity of the scheme. The simplicity of the technique suggests that it may find extensive application in impulsive investigations.

219. EQUATION OF STATE FOR NINETEEN METALLIC ELEMENTS FROM SHOCK-WAVE MEASUREMENTS TO TWO MEGABARS. McQueen, Robert G. and S. P. Marsh, Los Alamos Scientific Lab., N. Mex. In Journal of Applied Physics, Vol. 31, No. 7, pp. 1253-1269, July 1960.

Plane-wave explosive systems were used to accelerate thin metal plates to high velocities. Shock pressures resulting from the collision of these driver plates with a stationary target plate are approximately three times greater than the original shock pressure in the driver plate. The photographic flash-gap technique was used to record velocities associated with the shock waves. The new experimental data extend the Hugoniot loci into the one-to-two-megabar region for 19 metallic elements: Ag, Au, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sn, Th, Ti, Tl, V, W, Zn, Bi, Fe, Sb.

220. EQUATION OF STATE OF METALS FROM SHOCK WAVE MEASUREMENTS. Walsh, John, M. and Ronald H. Christian, Los Alamos Scientific Lab., N. Mex. In Physical Review, Vol. 97, No. 3, pp. 1544-1556, 1955.

Shock wave pressure magnitudes from about 150 to 500 kilobars have been attained for metals by using high explosives. A photographic technique for the nearly simultaneous determination of shock and free surface velocities is presented, and measurements for aluminum, copper, and zinc are given.

Expressions are derived which permit the calculation of pressure-compression points from measured velocity pairs. Consequent Hugoniot curves are presented, probable errors for which are 1 to 2 percent in compression for a given pressure. Finally, the known Hugoniot curves are employed in a calculation which determines temperature and isotherms.

221. EROSION DAMAGE TO SOLIDS CAUSED BY HIGH-SPEED COLLISION WITH RAIN. Engel, Olive G. In Journal of Research of the National Bureau of Standards, Vol. 61, No. 1, pp. 47-52, July 1958. NBS Research Paper 2882.

Stresses produced by impact pressure and radial flow are discussed.

222. EROSION OF SURFACE BY LIQUID DROPS. Jenkins, D. C. In Nature, Vol. 176, No. 4476, pp. 303, 1955.

The question of erosion of aircraft surfaces due to flight at high speed in rain has for some time been the subject of study at research establishments both in Britain and in the United States.

To study the fundamental mechanics of the erosion process an apparatus is required which will reproduce the high speed impact between a single drop and a surface. Due to the low relative speeds at which water drops shatter, difficulty is experienced in accelerating a water drop of the size occurring in rain to the speeds at which surface erosion occurs (above 400 ft/sec). The alternative method of shooting the surface at a stationary drop has been developed at the Royal Aircraft Establishment.

223. EXPERIMENTAL HYPERVELOCITY IMPACT CRATERS IN ROCK. Moore, H. J., D. E. Gault and R. V. Lugn. NASA, Ames Research Center, Moffett Field, Calif. and Geological Survey, Menlo Park, Calif. Report No. NASA N-104-335. In 5th HVIS, Vol. 1, Pt. 2.

The report discusses the experimental investigation of hypervelocity impact on rock being carried on at Ames Research Center. The craters and ejecta produced in these experiments are being studied. The structural features of the craters are described and the mechanisms by which they are formed are inferred.

224. AN EXPERIMENTAL INVESTIGATION IN LEAD OF THE WHIPPLE "METEOR BUMPER." Olshaker, Arnold E. The RAND Corp., Santa Monica, Calif. In 4th HVIS, Vol. II. See also Journal of Applied Physics, Vol. 31, No. 12, pp. 2118-2120, December 1960.

Experimental results are presented to indicate the effects of a thin protective shield on reducing the penetration of meteoroids. The study is mainly of lead impacting lead at 2.5 kilometers per second. The effects of thickness and separation of the shield are investigated. It is shown that a shield of thickness slightly less than half the projectile diameter at a separation of about five projectile diameters reduces the penetration. This shield is more protective than if divided into two half-thickness shields at the same overall separation.

225. AN EXPERIMENTAL INVESTIGATION OF SINGLE ALUMINUM "METEOR BUMPERS." Humes, Don, Russel N. Hopko and William H. Kinard. NASA, Langley Research Center, Langley AFB, Va. In 5th HVIS, Vol. II.

Results indicate impact damage was greatly reduced by using a bumper shield. Moreover, damage was limited to a maximum value which occurred at relatively low velocities. Optimum spacing was found to be more than 8 projectile diameters. Optimum bumper thickness was found equal to the projectile diameter, main-wall 2 x projectile diameter and 2 x bumper shield.

226. EXPERIMENTAL INVESTIGATION OF SPRAY PARTICLES PRODUCING THE IMPACT FLASH. Grow, R. W., R. R. Kadesch, E. P. Palmer, W. H. Clark, J. S. Clark and R. E. Blake. University of Utah, Salt Lake City. In 4th HVIS, Vol. III.

Spectrograph observations were made for copper projectiles impacting into copper targets in various controlled atmosphere. An atomic copper line with a 7.1 ev excitation energy was excited in an argon atmosphere so that an energy of at least this magnitude was available for the excitation of copper atoms. These results indicated that in argon, the light was produced by micron-size copper particles ejected from the target with velocities no less than 7 km/sec. A collision process between copper atoms evaporated from the heated spray particles and atoms of the argon atmosphere can account for the observed copper lines.

227. EXPERIMENTAL RESULTS IN HYPERVELOCITY IMPACT. Eichelberger, Robert J., Ballistic Research Labs., Aberdeen Proving Ground, Md. In 5th HVIS, Vol. I, Pt. 2.

The purpose of this paper is to present a brief general account of the progress in experimental research in hypervelocity impact. It discusses cratering and oblique impact, with emphasis on the former. Penetration theory is discussed. Photos and graphs are included.

228. EXPERIMENTAL STUDIES OF PENETRATION BY SHAPED CHARGE JETS. James, H. J. and J. S. Buchanan, British Joint Services Mission, Washington, D. C. In 3rd HVIS, Vol. I.

Using jet particles, the authors evolve the following concepts:

1. The total depth of penetration in Al, Cu, & Pb fits the simple law

$$P = 16\sqrt{\frac{\rho_J}{\rho_T}} - 4.6.$$

2. For that portion of the jet in the velocity range 4.5-7-8 sec, both the penetration depth and the velocities produced are governed only by the target densities.

3. For that portion of the jet with velocity less than 4.5 km/sec, the penetration process does not fit the theory.

4. There is marked change in the profile of the hole diameter in each target material at that plane at which the impinging jet velocity is 4.5 km/sec.

5. No relation is evident between depth of penetration and strength of target, although there are relations between the crater volume and target strength.

229. AN EXPERIMENTAL STUDY OF CRATER FORMATION IN LEAD.
Kineke, John H., Jr., Ballistic Research Labs., Aberdeen Proving Ground, Md. In 3rd HVIS, Vol. I.

Penetration varies as the 1/3 power of the impact velocity. This is in agreement with a proposed relationship $P_c \propto p^{\rho/3}$, where p is the momentum.

Crater profile Pc/Dc for impact velocities from 2-4 km/sec in lead is 0.5 or hemispherical, indicating that most of the crater is formed by a cavitation process rather than a penetration process such as in Öpik's hypothesis.

230. AN EXPERIMENTAL STUDY OF CRATER FORMATION IN METALLIC TARGETS.
Kineke, John H., Jr., Ballistic Research Labs., Aberdeen Proving Ground, Md. In 4th HVIS, Vol. I.

This report is an extension of the results presented at the third hypervelocity symposium. The points plotted on the various curves consist of the average of 10 to 20 craters. The standard deviations of the mean are plotted with the points. The author attempts to fit a 2/3 power curve to each set of impact data. There is a curve for each target material. The author points out some of the drawbacks to his data. It is obvious that the investigators at APG are working with maximum cooperation.

231. AN EXPERIMENTAL STUDY ON MULTI-WALL STRUCTURES FOR SPACE VEHICLES. Younger, D. G. and Seymour Lampert. January 1961, Aeronutronics Systems Inc., Div. of Ford Motor Co., Newport Beach, Calif. Report for 1 June 1960-30 November 1960 on Construction Techniques and Applications of New Materials. Report No. U-1042; ASTIA AD-253,530. WADD-TR-60-800; Contract AF-33(616)6641.

This report contains the results of an experimental study performed to evaluate the design techniques developed in an earlier report on this program, WADD-TR-60-503, ASTIA AD-250,269. The structural index and design-constraint parameters reflecting the structural index and design-constraint shell are developed using the principles of minimum-weight design. Using specimens of half-scale cross sectional dimensions, tests are performed on both wide columns and cylindrical shells.

232. EXPERIMENTAL TEST OF THE THEORY OF PENETRATION BY METALLIC JETS. Eichelberger, Robert J. In Journal of Applied Physics, Vol. 27, No. 1, pp. 63-68, January 1956.

Experimental measurements of jet velocity and of penetration velocity as functions of depth of penetration are described for lined cavity charges fired into several types of target material and under a variety of experimental conditions. The results show that the hydrodynamic theory of penetration of Pugh and of Hill, Mott, and Pack describes very accurately the early stages of the penetration process. Strength of the target becomes an appreciable factor in the later stages, however. A simple modification of the theory is described which appears to account adequately for these strength effects. Some alternations in ideas concerning the mechanism of penetration by the jet after fracture are also described.

233. EXPERIMENTS WITH A TWO MILLION VOLT ELECTROSTATIC ACCELERATOR. Friichtenicht, F. F., Space Technology Labs., Inc., Canoga Park, Calif. Report STL-8628-0001-RU-000. In 5th HVIS, Vol. I.

A two million volt particle accelerator designed to increase the particle size and velocity ranges previously available from the 120 kilovolt accelerator has been constructed and tested at the Research Lab. of Space Technology Laboratories. A description of the accelerator and a discussion of experiments performed using it are included in this document.

234. EXPLOSIVES WITH LINED CAVITIES. Birkhoff, Garrett, Duncan P. MacDougall, Emerson M. Pugh, and Sir Geoffrey Taylor. In Journal of Applied Physics, Vol. 19, No. 6, pp. 563-582, June 1948.

Explosives detonated in contact with thick steel plates produce much deeper holes in the steel when there is a cavity in the explosive in contact with the plate. While this phenomenon has been known for more than 150 years, the enormous increase in penetrating power that can be produced by lining the explosive cavity with thin metal has been discovered only recently. During the war a number of light, low velocity, antitank weapons (e.g., the rocket-propelled Bazooka) were developed which made use of this phenomenon to perforate thick armor plate.

A fairly complete mathematical theory of this essentially new phenomenon is presented together with some of the experimental data that aided in the formulation and testing of the theory. The process is separated into two phases: first, the formation of part of the metal liner into a long thin jet traveling longitudinally at very high velocities (30,000 ft/sec) and, second, the forcing aside of the target material by the extremely high pressures (0.3-million atmos.) produced by the impact of the high speed jet.

The theories of both of these phases are based upon the classical hydrodynamics of perfect fluids, which is applicable because the strength of the metals involved can be neglected at the high pressures encountered.

235. FAST SHAPED CHARGE JETS. Willig, Frank J. In Proceedings of the RAND Symposium of High Speed Impact (U), 1955. RAND Report S-34; ASTIA AD-79,284. Report CONFIDENTIAL. Abstract CONFIDENTIAL.

236. FLASH ASSOCIATED WITH HIGH-VELOCITY IMPACT ON ALUMINUM. Atkins, Walter W. Letter in Journal of Applied Physics, Vol. 26, No. 1, pp. 126-127, January 1955.

By spark photography, a time history was recorded of the growth of the luminous impact flash produced by a high-velocity projectile perforating an aluminum target. The spark system actually recorded only one shadowgraph per perforation, and the continuous history was obtained by recording a number of impacts with varied delay times between the instant of impact and the time the spark fired. Large fragments from the entry side of the target emerged through the flash generated on that side and were clearly visible after 250μ sec. The duration of the luminous flash was 4-5 msec. Small fragments diverged radially at 60°-70° to the path of the projectile and a displacement-time plot of them indicated their speed to be about 10,500 ft/sec.

237. A FLUID-DYNAMIC MECHANISM OF METEORITE PITTING. Williams, David T., University of Florida, Gainesville. In Smithsonian Contributions to Astrophysics, Vol. 3, No. 6, 1959. Smithsonian Institution, Washington, D. C.

Flow lines on meteorites were photographed to determine the nature of airflow inside the "thumb pits" in the surface. The flow is shown to be consistent with that occurring if a hairpin-shaped vortex were lying with bent portion in the pits, with vortex legs trailing off to infinity downstream. Since such a flow is not unique to supersonic fluid speeds, the prediction is made that pits similar to those on meteorites would be observed on salt cakes pushed through a lake. Experiments demonstrated that salt-cake erosion may indeed be accompanied by pit formation due to vortices precisely like those detected in meteorite pits. The evidence, supplied by photographs, leads to the conclusion that pitting is a general phenomenon in eroding fluid flow, and that tests at low speeds may provide valuable information regarding certain problems in astroballistic ablation.

238. FLUID MECHANICS OF COPPER. Allen, William A., H. L. Morrison, D. B. Ray and James W. Rogers., Naval Ordnance Test Station, China Lake, Calif. In 3rd HVIS.

The authors present theoretical and early experimental phases of work leading to an equation of state (Hugoniot curves) for copper at pressures higher than any previously reported.

239. FORMATION AND ENLARGEMENT OF A CIRCULAR HOLE IN A THIN PLASTIC PLATE. Taylor, G. I. In Quarterly Journal of Mechanics and Applied Mathematics, Vol. 1, pp. 103-124, 1948.

Experiments made with lead show that the symmetrical deformation contemplated in this analysis does not occur, but an alternative unsymmetrical deformation is produced which calculation shows to require less work, in the ratio 2.6 to 1.0, than the symmetrical mode.

240. FRAMING CAMERA OBSERVATIONS OF ULTRA-HIGH VELOCITY PENETRATIONS IN TRANSPARENT TARGETS AND A MECHANISM FOR CRATER EXPANSIONS. Keys, Robert T., R. W. Bartlett and Melvin A. Cook, University of Utah, Institute of Metals and Explosives Research, Salt Lake City. In 4th HVIS, Vol. III.

A mechanism of cratering in metal targets impacted by shaped charge jets in which the hole diameter is expressed as a function of striking velocity, jet diameter, densities of target and jet, and the yield strength of the target is presented and compared with measured hole diameters in several different metals struck by iron, copper and aluminum jets at various velocities. The same mechanism is expanded to account for the dynamics of crater formation, i.e., the lateral rate of expansion of the crater as a function of forward penetration of the crater. Theoretical curves are compared with experimental results obtained by means of microsecond framing camera techniques for steel jets penetrating several transparent substances of different densities. Some additional results pertaining to vaporization in ultra-high velocity impact also are given.

241. FUNDAMENTALS OF SHAPED CHARGES. Pugh, Emerson M. April 30, 1960, Carnegie Institute of Technology, Pittsburgh, Pa. CIT-QPR-18; ASTIA AD-236,214; Contract DA-36-061-ORI-513.

Hypervelocity steel pellets (0.18 grams, 5,010 m/sec) have been fired into targets of commercially-pure lead, cadmium, zinc, and copper. The initial target temperature was varied over a wide range and the crater parameters determined as a function of target temperature. The crater dimensions in lead were found to increase uniformly with temperature; in zinc and cadmium, the crater dimensions showed a marked change at the brittle-to-ductile transition temperature; and, in copper, certain changes in the crater dimensions showed a marked change at the brittle-to-ductile transition temperature; and, in copper, certain changes in the crater dimensions were related to the softening temperature and annealing properties of this metal. As a group, the data show that hypervelocity cratering is a complex phenomenon in which mechanical and metallurgical properties play an important role.

242. FURTHER STUDIES OF MICROPARTICLE CRATERING IN A VARIETY OF TARGET MATERIALS. Gehring, John William, Jr. and L. G. Richards, Ballistic Research Labs., Aberdeen Proving Ground, Md. In 4th HVIS, Vol. III.

This paper describes the micro-craters produced at 10 km/sec in both ductile and brittle target materials. The difference in crater profile between ductile and brittle materials is shown, and the effects on crater formation of grain boundaries, grain size, and crystal orientation are discussed.

A statistical distribution method is described for treating the particle size vs crater size determination, from which it has been possible to obtain accurate quantitative relationships for crater volume and particle energy. These data are then shown to agree with those obtained in the larger pellet macro-crater studies.

243. GEAR TO SIMULATE MICROMETEORITES. In Electronics, Vol. 33, No. 47, pp. 50, November 1960.

A technique for accelerating particles to hypervelocities is discussed. The plan is to accelerate particles which have been electrically charged through the use of a high current, low voltage proton beam.

It is expected that such research will lead to more reliable estimates of the effects of micrometeorite impact on space vehicles.

244. HIGH-SPEED IMPACT. Charters, Alex C., Jr., NASA, Ames Research Lab., Moffett Field, Calif. In Scientific American, Vol. 203, No. 4, pp. 128-131, 135-140, October 1960.

This paper presents a discussion of high-speed impact experiments carried out at the Ames Research Center of NASA. Experiments were made with metals involving the firing of projectiles into targets and the observation of the craters produced by the impact. It is shown that penetration increases steadily with the four-thirds power of the velocity, that is, by a factor of about 2.5. A second distinguishing feature of the low-velocity impacts is that the sphere retains its shape as it forces its way into the target. At some velocity, depending on the strength of the projectile and target, the projectile no longer withstands the forces of impact and starts to deform or, if it is brittle, to break to pieces.

245. HIGH-SPEED IMPACT OF METAL PROJECTILES IN TARGETS OF VARIOUS MATERIALS. Summers, James L. and Alex C. Charters, Jr., NASA, Ames Research Center, Moffett Field, Calif. In 3rd HVIS, Vol. I.

Metal spheres and rods were fired at the targets at normal and oblique angles, delineating the undeformed projectile region, the transition region, and the fluid impact region. For the fluid region, the penetration of metal spheres in metal targets, in diameters, can be expressed as a function of an impact parameter composed of the densities of the projectile and target, the projectile velocity, and the speed of sound in the target. The penetration of rods (in terms of length) was shown to be of the same order of magnitude as that for spheres for a given value of the impact parameter.

246. HIGH VELOCITY IMPACT. Partridge, William S. _In_ Materials in Space Environment. Proceedings of the Fifth Sagamore Ordnance Materials Research Conference. Conducted at Sagamore Conference Center, Racquette Lake, N. Y., September 16,17,18 and 19, 1958. Syracuse University Research Center, Syracuse, N. Y. SURI MET 597-596; ASTIA AD-205,880.

247. HIGH VELOCITY IMPACT CRATERS IN LEAD-TIN ALLOYS. Vanfleet, Howard B., Charles R. Whited and William S. Partridge. January 1958, University of Utah, Salt Lake City. Air Force Office of Scientific Research Tech. Report ORS-13; AFOSR-TIV-58-28; ASTIA AD-148,067.

Impact phenomena have been investigated for the lead-tin alloys by firing 3/16" spherical pellets from an experimental gun at velocities up to 2.2 km/sec into targets which were large compared to the resultant craters. The pellets and targets were of the same lead-tin composition in all cases. Quantitative data for the volume, diameter, and depth, along with mass and velocity of the impinging pellet were obtained for each crater. Correlation has been made between the crater parameters and various functions of the pellet mass and velocity for the following samples: 100% Pb; 90% Pb, 10% Sn; . . . ; 10% Pb, 90% Sn; 100% Sn.

248. HYPERVELOCITY IMPACT EFFECTS ON SOME ABLATIVE RE-ENTRY HEAT SHIELD STRUCTURES (U). Hull, Joseph A., Murray Rockowitz and W. L. McKay. 1961, AVCO Corp., Research and Advanced Development Div., Wilmington, Mass. Report No. AVCO RAD-61-1758; Contract AF-04(645)305. Report SECRET. Abstract SECRET.

249. HIGH VELOCITY IMPACT OF SMALL METAL SPHERES UPON FLAT METAL TARGETS. McKenzie, R. J., F. F. Martin and H. M. Kenworthy, Rheem Manufacturing Co., Downey, Calif. In 3rd HVIS, Vol. I.

The authors state that cratering, over the velocity ranges tested, is a function related directly to impact energy. Laminated targets demonstrated superior stopping ability.

250. HIGH VELOCITY PHENOMENA WITH HYPERSTRENGTH PARTICLES (U). Howard, Fred E., Jr. and R. Lenton Hill, Jr. _In_ 5th HVIS, Vol. II. Report SECRET. Abstract SECRET.

251. HYPERVELOCITY IMPACT RESEARCH STUDIES (U). Atkins, Walter W. and Donald A. Hall. January 1959, Naval Research Lab., Washington, D. C. NRL Memo 890. Report CONFIDENTIAL. Abstract CONFIDENTIAL.

252. HIGH VELOCITY IMPACT STUDIES. Scully, Charles N. In Proceedings of Lunar and Planetary Exploration Colloquium, Vol. I, No. 4, May 13, 1958-April 25, 1959. 1960, North American Aviation, Inc., Aero-Space Labs., Missile Div., Downey, Calif. NASA Publication 513W4.

Some qualitative information on the nature of hypervelocity impact is presented. Hypervelocity does not refer to a definite velocity regime as does "supersonic" but is determined in each case by the nature of the projectile and target material. Hypervelocity impact refers to events in which a peculiar and definite phenomenon occurs, i.e., the appearance of a smooth hemispherical crater. Above a critical velocity this type of impact crater appears, regardless of the shape of the impacting projectile.

253. HIGH-VELOCITY IMPACT STUDIES AT THE UNIVERSITY OF UTAH. Partridge, William S., University of Utah, Salt Lake City. In 2nd HVIS, Vol. I.

This paper is a survey of some of the work done over the last three years concerning (1) interaction of pellets with the atmosphere, and (2) factors affecting crater formation.

Data are presented in the form of curves which show crater volume vs energy of pellet.

254. HIGH VELOCITY IMPACT STUDIES DIRECTED TOWARDS THE DETERMINATION OF THE SPATIAL DENSITY, MASS AND VELOCITY OF MICROMETEORITES AT HIGH ALTITUDES. Bohn, J. Floyd and Otto P. Fuchs. January 31, 1958, Temple University, Philadelphia, Pa. Scientific Report No. 1; AFCRC TN 58-243; ASTIA AD-152,478 and AD-243,106; Contract AF-19(604)1894.

The particular problem of the development of analytical expressions describing micrometeorite impact processes is studied. Observations suggest a hypothesis about the microstructure of impact processes which takes into consideration all physical magnitudes inherent to the process. This hypothesis is described and should provide an interpretation of the responses of various kinds of transducers. The credibility of this hypothesis is established by comparison of experimental results obtained from the hypothesis in question. The experiments were conducted at a shooting range constructed at Temple University in the velocity range of between 100 and 200 m sec^{-1}, at the shooting range at Kunnersdorf with a velocity of 700 m sec^{-1} and, as far as extreme high velocities are concerned, a previously published result has been used with the velocity of 45 km sec^{-1}. The comparison shows that the hypothesis adopted approximates fairly well the experimental results.

255. HIGH-VELOCITY-PROJECTILE DRAG DETERMINATION. Halperson, Stanley M., P. T. Boltz and Donald A. Hall. Naval Research Lab., Washington, D. C. In 4th HVIS, Vol. III.

A projectile drag determination system is in operation at the U. S. Naval Research Laboratory, and drag coefficients of spheres at supersonic velocities have been obtained. The drag coefficients are obtained by accurately measuring the velocity at specified points along the trajectory. The velocity measuring technique, originated at NRL, uses a Fastax Camera, from which the framing prism has been removed, and a simple optical system substituted. A shadowgram picture is taken of the projectile, and timing markers are placed in the film by a high frequency stroboscopic lamp. This allows the projectile velocity to be computed. Having the velocity displacement record and knowing other physical parameters, an average drag coefficient was determined. Fair agreement is found with other published data. Future plans include a longer range and a larger gun for better data accuracy and higher velocities.

256. HYPERVELOCITY BALLISTIC RESEARCH AT THE U. S. NAVAL RESEARCH LABORATORY (U). Swift, Hallock F. and Walter W. Atkins. 11 May 1959, Naval Research Lab., Washington, D. C. Report No. NRL-5319; ASTIA AD-307,269. Report CONFIDENTIAL. Abstract CONFIDENTIAL.

257. HYPERVELOCITY IMPACT FACILITY. Fendick, R. B. June 1961, Air Proving Ground Center, Eglin Air Force Base, Fla. Report No. APGC-TR-61-31.

Major accomplishment during this report period was launching of a 1/8 in. diameter aluminum projectile at a velocity of 22,030 ft/sec. Refinements were made in saboting techniques that produced clean projectile impacts on the target. Modifications to the light weight piston (4 ozs.) were responsible for achieving higher velocities.

258. HYPERVELOCITY IMPACT OF HEATED COPPER. Rockowitz, Murray, Charles A. Carey and John F. Dignam. AVCO Corp., Research and Advanced Development Div., Wilmington, Mass. In 5th HVIS, Vol. I.

Hypervelocity impact of semi-infinite blocks of heated OFHC type copper has been made with aluminum chrome alloy steel and tungsten carbide projectiles of 1/4 gram mass at velocities up to 6.5 km/sec. The target temperature varied between room temperature and 1600°F. All impacts were made normal to the target surface. An investigation is made to determine how the importance of target temperature and mechanical properties varies with increasing projectile velocity. Also a correlation of the variation of energy/volume and target tensile strength is made.

259. HYPERVELOCITY IMPACT ON PRESSURIZED STRUCTURES. PART I. Rolsten, Robert F., Harold H. Hunt and J. N. Wellnitz. January 31, 1962, General Dynamics/Astronautics, San Diego, Calif. Report No. GD AE 62-0207; Contract No. AF-18(600)1775.

Diaphragms of thin titanium, aluminum alloy and stainless steel sheet have been pressurized with liquid and gaseous oxygen and gaseous nitrogen, and subjected to impact from a high velocity, small steel projectile. Titanium alloys burn in the oxygen environment, but do not burn in either the sea level air environment or pure nitrogen at pressures up to 60 psi. Films of WD-40 may inhibit the oxidation of titanium in liquid oxygen. Although stainless steel and aluminum are relatively unreactive in the oxygen environment, these metals will burn when placed in contact with burning titanium. Moreover, all metal diaphragms under 60-psi pressure may catastrophically rip when a certain crack length or perforated area is attained.

Care should be exercised in the design of an aerospace vehicle to keep thin gauge titanium sheet away from contact with liquid or gaseous oxygen.

260. HYPERVELOCITY IMPACT SPRAY PARTICLES. Clark, W. H., R. R. Kadesch and R. W. Grow. May 1, 1960, University of Utah, Salt Lake City. Technical Report No. 18; AFOSR TN-60-990; ASTIA AD-245,113; Contract AF-49(638)462.

A spray of small fast particles is ejected from a fast metal-to-metal impact. The velocity of the fastest spray particles previously observed, measured relative to the more massive body involved in the impact, was twice the impacting velocity. Under certain conditions very much faster spray particles appear. When a 3/16-in diameter carbon steel sphere, with a velocity of 2 km/sec impacted on a massive steel target in air at 8 cm mercury pressure, spray particles of about 0.5 micron diameter left the impact at velocities up to 15 km/sec. The velocity was measured by a time-of-flight technique. The effect of varying pellet and target materials and the atmosphere on the characteristics of the spray particle was investigated. All three variables have strong and complicated effects. A partial theory of the acceleration of spray particles was developed. Tests made on impacts of special geometry confirmed the theoretical predictions. These fast spray particles will be useful as artificial meteors for research purposes. It is demonstrated that the faster spray particles observed are luminous due to the same process whereby the average visual meteor leaves a luminous trail.

261. HYPERVELOCITY IMPACT STUDIES IN WAX. Frasier, J. T. and B. G. Karpov. February, 1961, Ballistic Research Labs., Aberdeen Proving Ground, Md. APG BRL Report No. 1124. In 5th HVIS, Vol. I, Part 2.

Authors describe development and use of experimental techniques capable of providing significant data concerning the transient response of targets to micro-particle impacts and the condition of targets subsequent to completion of the cratering process.

(Exterior Ballistics Laboratory program: (1) quantitative experiments defining stress levels, deformation rates, and behavior of solids under the severe conditions of loading associated with the cratering mechanism, (2) methods for more detailed evaluations of the predictions of theoretical analyses.)

262. HYPER-VELOCITY IMPACT STUDIES WITH A LIGHT GAS GUN (U). Crews, George C. September 1957, Ballistic Research Labs., Aberdeen Proving Ground, Md. APG BRL Memo Report No. 1104. Report CONFIDENTIAL. Abstract CONFIDENTIAL.

263. HYPERVELOCITY MICRO-PARTICLE IMPACT ON THIN FOILS. Richards, L. G. and John William Gehring, Jr. February 1961, Ballistic Research Labs., Aberdeen Proving Ground, Md. APG BRL Tech. Note No. 1380.

Micrometeorite bombardment of thin foils was simulated by a ballistic method of projecting cast iron particles less than 100 microns in size to 12 km/sec. The Mylar and Testlar target foils tested were prospective balloon satellite materials. Bare and metal coated specimens, 0.5 and 2 mils thick were included. Perforations were analysed by a photographic enlargement technique particularly adapted for complete survey of exposed target area without gaps or duplications. Statistical distributions of perforation diameters were obtained and matched with a similar distribution of the impacting fragments. Thus, the integrated impact intensity sustained by a particular target was determined. Results are reported in tabular form suitable for evaluation of changes in physical properties of the foils due to meteorite impact. These experimental methods are suitable for studies of impacts on simple metal foils.

264. HYPERVELOCITY PARTICLE EFFECTS ON MATERIAL. Scherrer, Victor E. and Robert R. McMath. 15 March, 1962, Technical Operations, Inc., Burlington, Mass. Quarterly Progress Rept. No. 3. Report No. TO-B-62-13; Contract AF 33(616)3423.

Research is continuing on hypervelocity particle effects on materials. Two major advances were made: (1) Higher particle velocities were attained by using a special fast-discharge capacitor; and (2) hypervelocity data were obtained using Cu and Al particles. In addition, new diagnostic experiments were conducted to study the exploding wire gun. Mylar particles were accelerated to a velocity of 102,000 ft/sec. Good single-particle impacts were obtained. Some ablation of the particle (initial mass of 11 mg) occurred. Extensive data of Al- and Cu-particle impacts on quasi-infinite Pb targets were taken. It is concluded that (for particle velocities above a certain level) the same crater shape is obtained for the disc-shaped particles that is obtained for spherical particles (or projectiles) by other researchers.

265. HYPERVELOCITY PENETRATION. Frost, V. C. November 1, 1960, Northrop Corp., Norair Div., Hawthorne, Calif. Report No. RASR 138.

This report summarizes the results of a literature survey on the penetration of metallic materials by small pellets. The information presented from various sources is examined critically and the degree of concurrence among the various investigators is indicated. Areas where additional information is required are given. The conclusions of this report, although based on the best information now available, should be periodically reviewed as additional information is received.

The various penetration equations are examined. It is recommended that the Broyles-Bjork equation be used on an interim basis. The characteristics of cratering and spalling are discussed. The use of multiple shields is considered.

266. IMPACT AND PENETRATION OF 0.100 INCH ALUMINUM PLATES BY ALUMINUM PROJECTILES AT 29,000-33,000 FEET PER SECOND. FINAL REPORT. Kreyenhagen, K. N., J. E. Ferguson and R. R. Randall. July 1962, Air Proving Ground Center, Eglin Air Force Base, Fla. APGC-TDR-62-40; AFSC Project No. 5841; Contract AF08(635)975.

The Shaped Charge Hypervelocity Projectile Accelerator is being used to study impact and penetration effects upon relatively thin targets at velocities between 29,000 and 38,000 feet per second. This Special Report presents and analyzes 128 data points gathered for impacts in the 29,000-33,000 feet per second range with aluminum projectiles against 0.100-inch thick 2024-T4 aluminum target plates. Angles of obliquity between the velocity and the target surface for these experiments were 90°, 50°, and 20°. Curves, photographs, and flash radiographs illustrating the data are presented.

267. IMPACT CRATER FORMATION IN ROCK. Maurer, William C. and John S. Rinehart, Colorado School of Mines, Mining Research Lab., Mining Engineering Dept., Golden, Colo. In Journal of Applied Physics, Vol. 31, No. 7, pp. 1247-1252, July 1960. In 4th HVIS, Vol. III.

Craters were produced by firing spherical steel projectiles of 3/16- and 9/32-in. diam. into sandstone and granite at velocities ranging from 300 to 6000 ft/sec. Impact angles of 30, 60, 90 deg. were used for the granite. The craters were formed by two mechanisms: (2) crushing of material in front of the projectile and (b) fracturing which takes place as fractures are initiated by a constant impulse in steplike fashion in front of the projectile and propagated along logarithmic spirals of maximum shear to the free surface of the rock. The volume of the material removed by crushing varies as the first power of the impact velocity and the volume removed by fracturing, as the second power of the impact velocity. Penetration varies linearly with the impact velocity and is inversely proportional to the specific acoustic resistance of the target material, the proportionality constant being dependent upon the shape of the projectile.

268. IMPACT OF A MERCURY SPHERE ON A THICK METAL PLATE. Meloy, Gerald E. and Earle B. Mayfield. March 31, 1959, Naval Ordnance Test Station, China Lake, Calif. NAVORD Report 6470; NOTS TP 2192; ASTIA AD-216,121.

Impact of the right circular cylinders of aluminum, brass and copper on 2-mm spheres of mercury was carried out by firing the cylinder at velocities of the order of 1 mm/sec.

The penetration, crater volume, and crater radius were measured.

The shape of the craters in aluminum is found to be at variance with those in brass or copper and with those noted by previous observers. Current theories of impact were in disagreement with experiment.

269. IMPACT OF HIGH SPEED PARTICLES WITH SOLIDS AND GASES. FINAL REPORT. APRIL 2, 1956-SEPTEMBER 30, 1958. Kells, M. C. and Douglas D. Keough. 15 December 1958, Poulter Labs., Stanford Research Institute, Menlo Park, Calif. AFCRC-TR-59-219; ASTIA AD 210,935; Contract AF-19(604)1892.

A successful technique has been devised for providing quantitative measurement of hypervelocity cratering variables using particles of sizes less than about 150 microns. Some results of tests are presented. Two micrometeorite detector systems used in Aerobee rocket studies and in earth satellite studies are mentioned. The use of shaped charges for simulating micrometeorites is discussed, as are the ablation of steel in a nitrogen ion beam and the study of light production when a microparticle impacts a target.

270. IMPACT PHENOMENA AT HIGH SPEEDS. Van Valkenburg, M. E., Wallace G. Clay and J. H. Huth. February 15, 1956, University of Utah, Dept. of Electrical Engineering, Salt Lake City. In Journal of Applied Physics, Vol. 27, No. 10, pp. 1123-1129, October 1956. ASTIA AD-81-046; Report AFOSR TN 56-54; Contract AF-18(600)217.

A study of high speed metal-to-metal impact in the velocity range 1 to 5 mm/μ sec. using 1/8 inch diameter spherical pellets is described. Cratering is discussed. The volume of the crater per unit energy of the impacting pellet is essentially constant for each material and the penetration is proportional to the velocity of the pellet so long as the pellet velocity is less than the velocity of sound in the target material.

271. IMPACT RESISTANCE OF SPACE STRUCTURES. Nysmith, C. Robert, NASA, Ames Research Center, Moffett Field, Calif.

The impact resistance of a variety of multiple-sheet structures was investigated. Test structures were impacted with small glass spheres at velocities ranging to 24,000 feet per second. The accompanying figures show the results of the investigation. The damage caused by low-speed and high-speed impact is compared by making use of the "ballistic limit" concept. This limit is defined as that critical projectile velocity just required to damage the rear or inner sheet of a structure to the point where it will no longer support a pressure difference of one atmosphere.

272. THE INFLUENCE OF TEMPERATURE ELEVATION ON THE PENETRATION OF MISSILES INTO COPPER TARGETS. Ferguson, W. J. and K. R. McKinney. November 19, 1959, Naval Research Lab., Washington, D. C. NRL-5407.

One-eighth-inch-diameter tungsten carbide spheres were fired into thick copper targets at room temperature and at 800°F at velocities from 1000 to 5000 ft/sec. It is shown that the depth of penetration, crater diameter, and volume of target material displaced increase as a consequence of the elevation of the temperature. The depth of penetration of the missile and the volume of target material displaced are essentially independent of cracking and breaking up of the missile until extensive fracturing makes it impossible to ascertain from visual observation that the missile was probably spherical.

273. INTERPLANETARY OPERATIONS. Ehricke, K. A. Convair/Astronautics, Div. of General Dynamic Corp., San Diego, Calif. Report No. AZM-053.

The material in this report is taken from the manuscript of the author's two books on space flight. The books are in the set Space Flight: Vol. I. Environment and Celestial Mechanics, 1960, Vol. II. Dynamics, 1961, Vol. III. Operations. (In Preparation.) Van Nostrand Co., Inc., Princeton, N. J.

274. AN INVESTIGATION OF CRATERS FORMED BY HIGH-VELOCITY PELLETS. Partridge, William S., Howard B. Vanfleet and Charles Whited. May 1957, University of Utah, Salt Lake City. Technical Report OSR-9; AFOSR TR 57-9; ASTIA AD-132,364.

Spheres of Zn, Sn, Cu, Pb, Al, and Fe were accelerated to velocities of 0.75 to 2.25 km/sec and impacted normally upon targets of the same material. Conditions were maintained so that the pellet lost no mass before striking the target. The target mass was large compared to the mass of the pellet, so they could be considered semi-infinite.

The volume of a crater produced by a high velocity pellet of the same material was found to be directly proportional to the kinetic energy of the pellet. Clay's reported value of the volume per unit energy for wax-to-wax impact was found to be in close agreement with this relationship.

The penetration varied linearly with the velocity over the velocity range and materials investigated. This relationship is compared with the one suggested by Huth.

This investigation has shown the area of the crater to be directly proportional to the kinetic energy of the pellet for the metals listed above over the energy range under consideration.

275. INVESTIGATION OF HIGH SPEED IMPACT: REGIONS OF IMPACT AND IMPACT AT OBLIQUE ANGLES. Summers, James L. October 1959, NASA, Ames Research Lab., Moffett Field, Calif. NASA TN D-94; ASTIA AD-227,647.

Small metal spheres of widely varying densities were fired into copper and lead targets at velocities to 11,000 fps. Analysis of the high-speed results of the investigation indicates that the target penetration and cavity volume can be correlated as functions of the ratio of projectile to target density and of the ratio of impact velocity to speed of sound in target material. Impacts for which the correlation equations apply are described as occurring in the fluid-impact region. This type of impact as well as other types is discussed. Penetration for impact at oblique angles is correlated with that for normal impact on the assumption that the component of velocity parallel to the target surface does not contribute to target penetration.

276. INVESTIGATION OF HIGH VELOCITY IMPACT AND SOME HIGH EXPLOSIVES PHENOMENA, FINAL REPORT. Keyes, Robert T. December 1961, University of Utah, Institute of Metals and Explosives Research, Dept. of Metallurgy, Salt Lake City. File No. 11-17W; Contract AF-18(603)100.

A brief summary of the important results obtained under Contract AF-18(603)100 is given. The subject matter covered by the investigations included: (1) high explosive generators for fast particles, (2) mechanism of cratering in ultra high velocity impact, (3) observations of vaporization accompanying ultra high velocity impact, (4) mechanism for crater expansion in shaped charge penetration (5) ionization and electron densities in detonating solid explosives, (6) electrical fields and electromagnetic radiation from chemical detonations, (7) external detonation generated plasmas, (8) the effect of pressure on the degree of ionization in gaseous detonations, (9) ionization and electrical conductivity and its relationship to the deflagration to detonation transition in solid explosives, and (10) transition to detonation in liquid explosives.

277. AN INVESTIGATION OF HIGH-VELOCITY IMPACT CRATERING INTO NONMETALLIC TARGETS AND CORRELATION OF PENETRATION DATA FOR METALLIC AND NONMETALLIC TARGETS. Kinard, William H. and Rufus D. Collins, Jr. February 1961, NASA, Langley Research Center, Langley Field, Va. NASA-TN-D-726.

The projectiles consisted of spheres with diameters ranging from 0.039 inch to 0.220 inch, right circular cylinders having diameters of 0.220 inch with length-to-diameter ratios of 1, and cone cylinders having diameters of 0.220 inch with length-to-diameter ratios of 0.910. The resulting penetration data have been shown to be predicted by a modified penetration equation established from impacts of metal projectiles into metal targets.

278. AN INVESTIGATION OF SPALLING AND CRATER FORMATION BY HYPERVELOCITY PROJECTILES. Maiden, C. J., Jacques J. Charest and Henri P. Tardif. Canadian Armament Research and Development Establishment, Valcartier, P. Q. Canada. In 4th HVIS, Vol. III. Also in CARDE Tech Memo AB-62, May 1960.

Experiments have been performed in which pellets of various shapes and materials have been fired into effectively semi-infinite targets of steel, aluminum, copper and lead. From tests using spherical projectiles, data have been obtained relating crater volume and depth of penetration to the target density and to the diameter, velocity, strength and density of the projectile. The maximum impact velocities used in these tests correspond to Mach numbers of 0.96, 1.0, 1.5 and 4.3 in the steel, aluminum, copper and lead targets, respectively. In addition to spherical projectiles, some cylindrical pellets which an inverted cone machined out of the front face have been fired into steel targets. The craters formed in such tests have shown significant shaped-charge effects.

279. LABORATORY SIMULATION OF MICROMETEORITE IMPACT DAMAGE. Martin, Henry L. February 3, 1960, Army Ballistic Missile Agency, Huntsville, Ala. ABMA DV-TN-2-60.

This report summarizes the conclusions gained from several years of microparticle hypervelocity impact research designed to simulate the effects of micrometeorite impact on materials. This research was performed by the Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, and by Stanford Research Institute and North American Aviation, Inc., which are under contract to the Research Projects Laboratory, Development Operations Division, ABMA.

Results indicate that micrometeoritic attack on man-made surfaces traveling in space will probably be limited to the formulation of relatively shallow impact craters on hard metal surfaces, but deeper penetrations into softer materials such as plastics may occur. Rarely, deep penetrations into all types of surfaces by large meteoroids can be expected.

280. MECHANISM OF RAIN EROSION. PART XIV. PITS IN METALS CAUSED BY COLLISION WITH LIQUID DROPS AND RIGID STEEL SPHERES.
Engel, Olive G. In National Bureau of Standards Journal of Research, J64A1, 61, 1960. NBS Research Paper 2958, June 1959.

A pit depth vs velocity equation developed earlier for high-speed collision of liquid drops and soft, ductile metal spheres against targets of the soft and medium hard metals was tested further with experimental data obtained using target plates of electrolytic tough pitch Cu, 1100-0-Al, and 2024-Al. Steel spheres and liquid drops were used to produce the pits. The velocities achieved were only as high as 1.05 km/sec.

281. METALLURGICAL OBSERVATIONS OF HIGH VELOCITY IMPACT.
Abbott, Kenneth H. September 1960, Watertown Arsenal, Watertown, Mass. WAL Report TR 161.85/1; Available from Department of Commerce, OTS, Washington, D. C. PB-161800. In 4th HVIS, Vol. II.

Annealed 1020 steel, hardened FXS-318 steel, and 2024-T4 aluminum alloy pellets with length-to-diameter ratios of 1.25 were fired at standard steel armor, aluminum armor, and 301 stainless steel plates at velocities from 2,000 to 13,000 fps. Plate sections containing crater half-sections were subjected to hardness, macrostructure and microstructure measurements to determine metallurgical phenomena which influence crater formation. Dynamic instabilities resulting in slip with the formation of transformed untempered martensite on maximum shear planes were observed in the standard steel armor. The number of these shear bands with associated cracking increased with increasing pellet velocity. Slip without transformation was observed in both the aluminum alloy and stainless steel plates. No local transformation from austenite to martensite was observed in the stainless steel. Extensive hardening in the vicinity of the crater was measured in all plate materials.

282. METEORITIC-IMPACT EFFECTS. Baldwin, R. B. In Proceedings of the RAND Symposium on High Speed Impact (U), 1955. RAND Report S-34. ASTIA AD-79,284. Report CONFIDENTIAL. Abstract CONFIDENTIAL.

283. MICROSECOND FRAMING CAMERA OBSERVATION OF HIGH VELOCITY IMPACT.
Cook, Melvin A. and Robert T. Keyes. University of Utah, Explosives Research Group, Salt Lake City. In HVIS, Vol. I.

The paper mainly concerns impact photography techniques, impact flashes, shock waves, luminosity of wakes of trails, spray ejecta clouds, ablation, explosions of pellet and targets. It claims hole volume proportional to pellet KE.

284. MODELING OF HIGH-SPEED IMPACT THROUGH THE USE OF PLASTICS. Van Valkenburg, M. E. March 1955, University of Utah, Salt Lake City. Tech. Rept. No. 3; AF OSR TN-55-48. Contract AF-18(600)1217.

The impact of high-speed plastic pellets on plastic targets has been studied for several plastic materials. Metal-to-metal impacts have also been studied using pellets of various shapes and with masses from 20 mg to 5 g. The experimental method for producing plastic pellets with velocities up to 5 km/sec is similar to that used by Pugh, and was first reported in the literature by Allen, Rinehart, and White (Phenomena Associated with the Flight of Ultraspeed Particles, in Journal of Applied Physics, Vol. 23, pp. 132, 1952). This method and techniques for recording pellet velocity are described. Crater characteristics including (1) crater volume, (2) penetration (or crater depth), and (3) crater area at the target surface have been studied for a range of velocities. These results are compared with those from metal-to-metal impact using aluminum and steel pellets. Comparison is also made with experimental results of Eichelberger and Rostoker using jets (from steel liners). The validity of several proposed empirical equations for penetration and crater volume is examined.

285. OBSERVATIONS OF HYPERVELOCITY IMPACT. Halperson, Stanley M. and Walter W. Atkins, Naval Research Lab., Washington, D. C. In 5th HVIS, Vol. I, Part 2.

The authors have studied the penetration, principally by nylon and aluminum projectiles, of 2014 and 1100 F aluminum and 1020 and 4340 steel. The highest velocity obtained was 6.03 km/sec. The craters were studied to determine their shapes, the particle energy was correlated with the crater volume. A study was made to determine what power law was obeyed.

286. OBSERVATIONS OF METALLIC PROJECTILE IMPACTS OF SMALL PARTICLES AT VELOCITIES RANGING FROM 5000 f.p.s. TO 7500 f.p.s. PART II. McDonough, J. P. and Edward N. Hegge. Watertown Arsenal Labs., Watertown Arsenal, Mass. In Proceedings of the National Symposium of Hypervelocity Techniques. Held at Denver, Colo., October 20-21, 1960. Institute of Aeronautical Sciences, New York, 1960.

The authors discuss results of impact experiments using titanium, aluminum, magnesium, and steel projectiles. Results were obtained for a number of target materials. The authors also consider ballistic parameters. It is concluded that titanium is extremely vulnerable to both particle impact and flight erosion. Aluminum is superior but not appreciably better than magnesium.

287. OBSERVATIONS OF PROJECTILE IMPACTS OF SAND PARTICLES AT VELOCITY RANGING FROM 2900 FT/SEC TO 7000 FT/SEC. McDonough, J. P. and Edward N. Hegge. July 1958, Watertown Arsenal Labs., Watertown, Mass. WAL TR 892/17; ASTIA AD-200,194. In 3rd HVIS, Vol. I.

The paper describes the firing of Al pellets through falling sand screens and the resulting target abrasion and cratering. Considerable variation in the distribution of the freely falling sand is evident.

288. OBSERVATIONS OF VAPORIZATION ACCOMPANYING ULTRA-HIGH VELOCITY IMPACT. Bartlett, R. W., Melvin A. Cook and Robert T. Keyes. January 4, 1960, University of Utah, Salt Lake City. AF Office of Scientific Research, ARDC, Washington, D. C. AFOSR-TN-60-327; Contract AF-17(603)100.

The study of the behavior of metals under ultra-high velocity impact emphasizes the vaporization and penetration of metals. Jets from shaped charges and discrete particles accelerated by high explosives were used as projectiles. Studies were made at velocities up to 8.5 km/sec using a variety of targets and projectile metals.

289. OBSERVATIONS ON HIGH SPEED PELLETS AND THEIR IMPACT UPON TARGET PELLETS. Gehring, John William, Jr. July 1953, Ballistic Research Labs., Aberdeen Proving Ground, Md. BRL Memo Report 704.

Stainless steel saucer-shaped pellets were fired intact at high speeds of approximately 1500 meters/second from the end of an explosive charge and allowed to impact both aluminum and steel pellets. It was found that the small sized target pellets were always fractured.

Certain critical dimensions were found for both the projected pellet and the explosive charge, for producing a pellet which remained intact during acceleration from the end of a detonating explosive.

290. PENETRATION OF A ROD INTO A THICK ALUMINUM TARGET. Allen, William A. and James W. Rogers. December 1960, Naval Weapons Bureau, Washington, D. C. NAVWEPS Report 7597; NOTS TP-2587.

The penetration of metal rods into semi-infinite metal targets has been investigated experimentally at velocities up to 0.3 cm/μsec. The rods were composed of Au, Pb, Cu, Sn, Al, and Mg; the target was aluminum. Results are compared with predictions from the hydrodynamic theory of jet penetration. The elementary hydrodynamic theory does not hold in the velocity range studied, but the modified theory is shown to be generally acceptable except where the density of the jet is much greater than that of the target. A gold jet penetrating an aluminum target, for example, reveals a new effect of secondary penetration which results in penetration greater than that predicted by theory. Crater volumes produced by impact were found to be roughly proportional to the initial kinetic energy of the jet.

291. PENETRATION OF MATTER BY SOLID PROJECTILES. Duvall, G. E. 1955, Stanford Research Institute, Menlo Park, Calif. SRI Internal Report No. 002-55.

292. PENETRATION OF METAL AND LUCITE TARGETS BY SMALL PARTICLES. Katz, Samuel and Gordon D. Anderson. 25 February 1957, Stanford Research Institute, Menlo Park, Calif. SRI Scientific Report No. 1, Project No. GU-1722.

One of the important problems in the design of hulls for upper atmosphere and space vessels is the impact of meteorites. Such impacts would produce craters and might perforate the hull. Craters, however tiny, might alter the aerodynamic properties of the vessel and affect its flight, especially upon re-entry into the atmosphere. As part of an experimental program to simulate meteoritic impact, this report describes the results obtained by firing particles of various materials into selected target materials.

293. PENETRATION OF THIN PLATES. Kreyenhagen, K. N. and Louis Zernow. 1961, Aerojet General Corp., Ordnance Div., Downey, Calif. In 5th HVIS, Vol. I, Part 2.

Titanium discs of one gram mass, 3/8 inch diameter by 1/8 inch were impacted at 5 km/sec on 0.100 inch plates of 2014 T-6 Al alloy in air at 1/50 atmosphere. Impacts at various angles of incidence were considered.

294. THE PENETRATION OF THIN RODS INTO ALUMINUM. Slattery, R. E. and Wallace G. Clay. April 1960, Lincoln Lab., Massachusetts Institute of Technology, Cambridge. In 4th HVIS, Vol. III.

The following work represents a departure from the main purpose of the Lincoln Laboratory Reentry Simulation Range. We are normally concerned with studying electronic and optical effects in the wake of hypervelocity projectiles as a function of pressure, time and velocity. Hence, we tend to ignore the projectile itself and concentrate upon the physics of the electrons, ions, and excited states of the gas in regions behind the pellet. This work grew out of a query within Lincoln as to whether or not a hypervelocity metallic rod, normally incident upon a target, would behave in the same manner as a shaped-charge jet.

295. PREDICTION OF CRATERING BY METEOROID IMPACTS. Kornhauser, Murray. General Electric Co., Missiles and Space Vehicles Dept., Philadelphia, Pa. In Advances in Astronautical Sciences, Vol. 2. Proceedings of Fourth Annual Meeting of AAS, December 1957. Plenum Press, Inc., New York, 1958.

Data from high-speed laboratory experiments, explosive craters, and meteorite impacts are correlated to obtain an approximate expression for depth of penetration in terms of target material properties and kinetic energy of the impacting particle.

296. A PRELIMINARY INVESTIGATION OF FLARING AND ABLATION OF HIGH SPEED PELLETS. Cannon, Emerson T. and William S. Partridge. Dec. 1956, University of Utah, Dept. of Electrical Engineering, Salt Lake City. Report UU 451-ITR-4; ASTIA AD-123,118; Contract DA 04(495) ORD-451.

Techniques for measuring the ablation and the minimum velocity at which flaring of ultra-speed pellets will occur are described. A velocity measuring system employing a "break" circuit is described which was successful in measuring velocities up to 1.5 km/sec. The ablation of ultra-speed pellets is determined by measuring the diameter of the hole punched by the pellets in a paper grid that was placed in their paths. No evidence was found that the minimum velocity at which flaring occurs is dependent on the presentation area of the pellet.

297. A PRELIMINARY INVESTIGATION OF HIGH SPEED IMPACT: THE PENETRATION OF SMALL SPHERES INTO THICK COPPER TARGETS. Charters, Alex C., Jr. and G. S. Locke, Jr. May 28, 1958, NASA, Ames Aeronautical Lab., Moffett Field, Calif. NASA RM A-58-B26; ASTIA AD-158,878.

Experiments on high-speed impact have been carried out by firing small spheres of different materials into thick plates of lead and copper. The tests have shown that the craters in the two metals had similar shapes and that the penetrations were nearly the same at the same impact Mach number, defined as the ratio of the velocity of impact to the speed of sound in the target metal. Since lead has a low speed of sound compared to copper, the results of impact in lead at moderate speeds have made it possible to predict the effects of impact in copper at very high speeds.

One particularly noteworthy result came from a series of tests in which the material of the sphere was varied but the mass of the sphere was held constant by changing its diameter. This series demonstrated that the denser materials produced greater penetrations in actual depths despite their smaller sizes.

298. PRELIMINARY INVESTIGATION OF IMPACT ON MULTIPLE-SHEET STRUCTURES AND ON EVALUATION OF THE METEOROID HAZARDS TO SPACE VEHICLES. Nysmith, C. Robert and James L. Summers. September 1961, NASA, Ames Research Center, Moffett Field, Calif. NASA TN D-1039.

Small pyrex glass spheres, representative of stony meteoroids, were fired into 2024 T3 aluminum alclad multiple-sheet structures to evaluate the effectiveness of multisheet hull construction as a means of increasing the resistance of a spacecraft to meteoroid penetration. In addition, the meteoroid hazard to vehicles in the space near the earth is evaluated on the basis of the meteoroid distribution as determined from astronomical and satellite measurements, high-speed impact data and hypothesized meteoroid structures and compositions for space vehicle structures.

299. A PRELIMINARY INVESTIGATION OF THE EFFECT OF BUMPERS AS A MEANS OF REDUCING PROJECTILE PENETRATION. Funkhouser, John O. April 1961, NASA, Langley Research Center, Langley Field, Va. NASA TN D-802; ASTIA AD-254,164.

Aluminum bumpers and main targets were impacted with 0.062-inch-diameter copper projectiles. The reduction in total penetration was caused primarily by the breakup of the projectile after impacting a 0.031-inch-thick bumper spaced 1 inch in front of the main target at a velocity between 8000 and 9000 feet per second. With an average projectile velocity of 11,500 feet per second, a bumper thickness between 0.01 inch and 0.02 inch gave the best protection against penetration, and an increase in the spacing of a 0.031-inch-thick bumper in front of the main surface beyond a distance of 2 inches had very little effect on the total penetration.

300. A PRELIMINARY INVESTIGATION OF THE PENETRATION OF SLENDER METAL RODS IN THICK METAL TARGETS. Summers, James L. and W. R. Niehaus. December 1959, NASA, Ames Research Center, Moffett Field, Calif. NASA TN D-137.

Slender steel and tungsten-carbide rods were fired into copper, lead, and steel targets at velocities to about 11,000 feet per second. Values of the fineness ratio of the rods ranged from 6.0 to 12.7. For copper and lead targets, the impact is described as occurring in the undeformed-projectile region at the lower impact velocities and in the transition region at the higher velocities. For steel rods impacting steel targets, the impacts were described as occurring in the undeformed-projectile region of impact at all test velocities.

301. PRELIMINARY INVESTIGATIONS OF SIMULATED MICROMETEORITE IMPACT. Kineke, John H., Jr. and John William Gehring, Jr. July 1957, Ballistic Research Labs., Aberdeen Proving Ground, Md. APG BRL Tech. Note No. 1134.

This note presents the results of preliminary observations on the impact phenomena associated with the collision of simulated micrometeorites and controlled target surfaces. Employing the shaped charge principle, cast iron particles one to 200 microns in size were fired into a variety of polished target materials at velocities of nine to ten km/sec. After the impact, observations were made on the targets by means of photo-micrography. The results of these tests clearly indicate anomalous effects which are obtained using such small particles having a very high velocity.

302. RESEARCH DIRECTED TOWARDS THE STUDY OF TRANSDUCING METEORIC IMPACTS. FINAL REPORT. Bohn, J. Lloyd, Otto P. Fuchs, E. Hewitt and E. J. Sherwood. December 1960, Temple University, Philadelphia, Pa. AFCRL TR 60-436; ASTIA AD-249,949; Contract AF 19(604)1894.

Contents:

- Transistor micrometeorite amplifier
  - Preliminary investigation (1956)
    - Transistors
    - Auto amplifiers
  - The equivalent circuit of the 2N94 transistor
    - Transport factor Beta and short circuit current-transfer ratio amplifier
    - Tuned sub-radio frequency amplifier circuit
  - Extended range amplifier
  - Double output and special amplifiers
  - Block diagram of the three pulse system
- Dual output amplifiers
- Report on micrometeorites.

303. RESEARCH ON THE EFFECTS OF COLLISIONS OF SMALL PARTICLES WITH BODIES MOVING AT HYPERSONIC SPEED. PART II. EROSION AND HEAT TRANSFER EFFECTS. Whitnah, G., G. Wehner, J. Upton, A. Gaalswyk, W. Torgeson and Duane Rosenberg. August 1959, General Mills, Inc., Minneapolis, Minn. WADC TR 58-498, Pt. 2; ASTIA AD-235,928.

Results of experimental work in the investigation of heat transfer to smooth and roughened nose cone models are discussed. Heat transfer coefficients for models roughened by sandblasting and by etching are compared with those of smooth models for the two stagnation pressures investigated. Large increases in average heat transfer coefficients were found for the roughened models.

Locations of maximum heat transfer were measured for both roughened and smooth models and were found to be considerably closer to the stagnation point for the roughened models than for the smooth model. The experimental apparatus and techniques employed in these investigations are described.

304. RESEARCH ON THE EFFECTS OF COLLISIONS OF SMALL PARTICLES WITH BODIES MOVING AT HYPERSONIC SPEED. PART III. EROSION AND HEAT TRANSFER EFFECTS. Wehner, G. and J. Upton. December 1960, General Mills, Inc., Minneapolis, Minn. WADC TR 58-498, Pt. 3; ASTIA AD-254,021; Contract AF 33(616) 5565.

Research includes (1) theoretical and experimental study of the effects of major surface roughness on heat transfer during re-entry, (2) study of surface pitting caused by formation of alloys with impinging particles, (3) study of hypervelocity cratering, and (4) analysis of techniques for creating and maintaining particle clouds in the atmosphere.

305. RESPONSE OF METALS TO HIGH-VELOCITY DEFORMATION. Proceedings of a Technical Conference sponsored by the Physical Metallurgy Committee of the Institute of Metals Division, The Metallurgical Society, American Institute of Mining, Metallurgical, and Petroleum Engineers (Metallurgical Society Conferences, Vol. 9) held at Estes Park, Colorado, July 11-12, 1960. Shewmon, P. G. and V. F. Zackay, Editors. Interscience Publishers, Inc., New York, 1961.

306. SHAPES OF CRATERS FORMED IN PLASTER OF PARIS BY ULTRA-SPEED PELLETS. Rinehart, John S. and W. C. White. In American Journal of Physics, Vol. 20, No. 1, pp. 14-18, January 1952.

Observations have been made on the craters produced in plaster of Paris targets by steel pellets that weighed 2 gm and impacted at a velocity of 2.5 km/sec and by aluminum pellets that weighed 2/3 gm and impacted at a velocity of 4.7 km/sec. The angle of impact was varied from normal incidence to 75°. For angles of incidence between 0° and 45°, the mouth of the crater was substantially circular. At 60°, it had roughly the shape of an arrowhead. At 75° obliquity, the pellet ricocheted and produced an elliptical crater. The area of the mouth of the crater in every case was many times the area of impacting particle. The craters were characterized by a large bowl-shaped excavation from 1/2 inch to 1 inch in depth with a shaft that extended a few inches into the plaster and whose area was approximately that of the pellet. The volumes of the holes have been measured and related to the impacting energy and momenta of the respective pellets.

307. SHOCK WAVE COMPRESSION OF TWENTY-SEVEN METALS. EQUATION OF STATE OF METALS. Walsh, John M., Melvin H. Rice, Robert G. McQueen, and Frederick L. Yarger. In Physical Review, Vol. 108, Series 2, No. 2, pp. 196-216, October 12, 1957.

An explosive system is used to drive a strong shock wave into a plate of 24ST aluminum. This shock wave propagates through the 24ST aluminum into small test specimens which are in contact with the front surface of the plate. A photographic technique is used to measure velocities associated with the 24ST aluminum shock wave and with the shock wave in each specimen.

308. SOME CHARACTERISTICS OF CRATERS FROM HIGH SPEED PELLETS IMPACTING INTO SEMI-INFINITE TARGETS. Van Valkenburg, M. E., Wallace G. Clay, F. W. Longson and W. Mayoda. September 1955, University of Utah, Dept. of Electrical Engineering, Salt Lake City. Technical Report No. 2; AF OSR TN-55-287; ASTIA AD-72,221; Contract AF-18(600)1217.

The penetration, crater volume and crater area resulting from the impact of pellets of various shaped with speeds in the range of 1 to 4 mm/μsec are tabulated in this report. Materials used in the experiments include aluminum, magnesium, steel, brass, zinc, lead, plastic pellets, and wax targets.

The method of producing ultra-speed pellets is described as well as the method of measuring velocity, crater volume, crater area, and penetration.

309. SOME COMMENTS ON THE PHENOMENA OF HIGH SPEED IMPACT. Charters, Alex C., Jr. and James L. Summers. May 1959, NASA, Ames Research Center, Moffett Field, Calif. Paper presented at the Decenniel Symposium on May 26, 1959 at U. S. Naval Ordnance Lab., White Oak, Silver Spring, Md.

The authors discuss the Ames Research Center's work in the fluid impact regime of hypervelocity impact. Small 1/8 inch diameter spheres of various metals including magnesium and tungsten were fired into lead and copper semi-infinite plates at velocities ranging from a few thousand to 12 thousand feet per second. Crater shape and volume measurements were taken. A theory of fluid impact is presented in which the crater volume is deemed proportional to kinetic energy of the projectile. Rayed lunar craters and the Arizona Barringer crater are briefly discussed.

310. SOME EXPERIMENTS ON HYPERVELOCITY IMPACT. Clayden, W. A. September 1961, Armament Research and Development Establishment, Fort Halstead, Kent, England. ARDE MEMO-(B) 49/61.

Crater dimensions have been obtained in various metal targets when attacked by 1/4 inch diameter spheres with velocities up to 10,000 ft/sec. The depth of penetration in "semi-infinite" targets attacked at normal incidence has been correlated with an empirical formula which is in agreement with existing work. When the semi-infinite targets were attacked at incidence, the depth of penetration was found to be proportional to the sine of the angle of incidence. When thin targets were attacked at varying incidence the crater dimensions were similar to those obtained for "semi-infinite" targets inclined at the same angle provided the thin targets were not penetrated. An empirical relationship is given for a minimum thickness of target for nonpenetration as a function of the impact velocity, the properties of the target and projectile and the angle of incidence.

311. SOME NEW DATA ON HIGH SPEED IMPACT PHENOMENA. Huth, J. H., J. S. Thompson and M. E. Van Valkenburg. In Journal of Applied Mechanics, Vol. 24, No. 1, pp. 65-58, March 1957.

This paper presents a summary of some recent experimental work aimed at evaluating the role of various physical parameters in high-speed impact phenomena. It is shown that penetration into thick targets by projectiles of the same material, for certain common metals, can be expressed approximately through a single relationship of the form $(p/d) = 2.5(V/c)^{1.4}$ in a range of about $0.1 \leq (V/c) \leq 1.0$. Here p represents penetration (crater depth) measured from the initial target surface, d a characteristic dimension of the projectile, and V the impact velocity; c is the "sonic" velocity in the projectile and target material as expressed by the formula $c = \sqrt{E/\rho}$, where E is Young's modulus and ρ the density. Experimental results are given for steel, aluminum, brass, lead, magnesium, and a magnesium-lithium alloy.

312. SOME OBSERVATIONS ON HIGH SPEED IMPACT. Rinehart, John S. In Popular Astronomy, Vol. 58, No. 9, pp. 458-464, November 1950.

Many of the experimental data that exist on phenomena associated with the impact of high-velocity particles are summarized. Impacts at 20,000 ft/sec produced by shaped charges and the mechanics and energetics of crater formulation are discussed. The probable mass of the meteorite that formed Meteor Crater, Arizona, is calculated and found to be 12,500 ordinary tons.

The principal conclusions drawn from the data are that (a) probably only a small fraction of the total mass of a meteorite is vaporized on impact; (b) a meteorite may or may not shatter on impact; (c) the volume of the crater fixes rather closely the striking energy of the meteorite; and (d) there is some likelihood that high-velocity meteorites do not embed themselves in the craters that they form.

313. SOME QUANTITATIVE DATA BEARING ON THE SCABBING OF METALS UNDER EXPLOSIVE ATTACK. Rinehart, John S. In Journal of Applied Physics, Vol. 22, No. 5, pp. 555-560, May 1951.

Fracturing, or scabbing, of a material near a free surface as the result of a transient compressional stress wave of high intensity impinging on that surface has been observed for many years; however, little quantitative data that relate the fracture to the nature of the stress wave and the physical properties of the material seem to exist. The phenomenon has been investigated for five metals, 1020 steel, 4130 steel, 24ST-T4 aluminum alloy, brass, and copper, by using an explosive charge to induce a high intensity stress wave in the metal. The distribution of pressure within the wave was determined by a modified Hopkinson-bar type of experiment.

Scabbing has been found to be governed principally by the spatial distribution of pressure within the wave and a critical normal fracture stress that is characteristic of the material and perhaps the state of stress. Numerical values of σc were obtained for each of the five metals.

314. SOME RESULTS OF HYPERVELOCITY EXPLOSIVE CHARGE INVESTIGATION. Clark, Eric N. and Alexander MacKenzie. Picatinny Arsenal, Dover, N. J. In 3rd HVIS.

These investigators had difficulty measuring pellet masses but found that the greater the pellet velocity, the deeper the crater formed. The authors refrained from giving results until greater statistical significance is achieved.

315. SPECTRAL ANALYSIS OF THE IMPACT OF ULTRA-VELOCITY COPPER SPHERES INTO COPPER TARGETS. Clark, J. S., R. R. Kadesch and R. W. Grow. September 1959, University of Utah, Salt Lake City. Tech Report No. OSR 16; AFOSR-TN-16-13; Contract AF-18(600)1217.

Spectrographic observations were made for copper projectiles impacting onto copper targets in various controlled atmospheres. Atomic copper lines are the predominant feature of the impact flash of copper-to-copper impacts in a medium of argon. Results indicate that in argon, the flash is produced by micron-size copper particles ejected from the target, some with velocities no less than 6-7 km/sec and heated by the medium. With a medium of hydrogen, the impact flash is dimmer by at least two orders of magnitude, giving smooth spectral contours.

316. SPHERES INTO THICK COPPER TARGETS. Chambers, A. C. and G. S. Locke, Jr. 8 May 1958, National Advisory Committee for Astronautics, Washington, D. C. Research Memo RM-A58B26; ASTIA AD-158,878.

Small metal spheres of various densities were fired at high speed into thick targets of copper and lead. In general it was found that all of the penetrations could be correlated quite well for engineering purposes by a function relating the depth of penetration to the impact momentum per volume.

317. STUDIES IN HYPERVELOCITY IMPACT. Anderson, Gordon D. December 7, 1959, Poulter Labs., Stanford Research Institute, Menlo Park, Calif. SRI No. 018-59; SRI Project No. GU 1989, Final Report; ASTIA AD-232,667; Contract DA-04-200-ORD-597.

A summary of work done on hypervelocity impact studies over a 3 year period is presented. Techniques were developed for accelerating individual microparticles to velocities near 4 mm/μsec. The methods by which their velocities may be measured and the craters that they produce are discussed. To obtain microparticles in the 10 mm/μsec range, jet charges were employed, and a method for selecting only the fastest jet particles is described. Craters produced by the high velocity jet particles are discussed. It is found that in many metals the craters are quite hemispherical in shape, and crater shape is relatively insensitive to velocity from about 2 to 12 mm/μsec. Craters in plastic and brittle materials are also described. A series of the jet producing charges was tested for particle velocity distribution, and the results are discussed.

318. STUDIES OF COPPER TARGETS ATTACKED BY SHAPED CHARGES. Singh, Sampooran and S. Soundrarj. Defence Science Lab., Ministry of Defence, New Delhi and Machine Tool Prototype Factory, Ambarnath, India. In Acta Metallurgia, Vol. 7, No. 11, pp. 725-754, November 1959.

Recently, intensive studies have been made of the changes in hardness and microstructure in steel samples attacked by jets squirted from high explosives with metal-lined cavities (shaped charges). The present note describes metallographic studies of a face-centered cubic metal (copper) attacked by shaped charges at room temperature (35°)C. and at -75°C.

319. STUDIES OF HIGH-VELOCITY IMPACT IN WAX. Partridge, William S. and Wallace G. Clay. In Journal of Applied Physics, Vol. 29, No. 6, pp. 939-942, June 1958.

Penetration of wax pellets into wax targets was found to vary linearly with the cube root of the pellet mass and the pellet velocity up to velocities in excess of twice the sonic velocity in the wax target. The crater area varies directly as the impact velocity, but there is a marked increase in the constant of proportionality above the target sonic velocity. The volume of the crater per unit energy of the pellet was found to be 2.23×10^{-8} m^3/j for the lower velocity range, and above the target sonic velocity the value was found to be 2.75×10^{-8} m^3/j. It was observed that a large part of the crater volume is created by deformation of the target material and that only a small part is due to ejection of the target material.

320. STUDY OF HYPERVELOCITY IMPACT OF PARTICLES ON MATERIALS. FINAL SUMMARY REPORT, PERIOD COVERED 25 FEBRUARY 1959-25 FEBRUARY 1960. June 24, 1960, North American Aviation, Inc., Missile Div., Downey, Calif. Report NAA MD 59-114; Contract DA-04-495-ORD-1477.

In order to gain information about the probable effects of micrometeorite impacts upon spacecraft construction material, a hypervelocity gun system was developed. This system, accelerating spherical projectiles by aerodynamic drag in the flowing high-temperature gas generated by high-energy capacitor discharge in a partially confined lithium mass, has produced impact data at velocities up to 9.5 kilometers per second (31,000 feet per second). The generated plasma flow through the accelerating channel does not disrupt 100-micron-diameter borosilicate glass spheres during the process. Sphere integrity is monitored in flight by a sensitive light-scattering technique.

Quantitative target damage is reported for 2024-0 aluminum, both clad and bare, and for LA 141 magnesium-lithium alloy. Both crater depth-to-diameter ratios and crater-to-projectile volume ratios are reported. The full potential of the accelerating technique has not yet been reached.

321. STUDIES OF HYPERVELOCITY IMPACT ON LEAD. Clark, Eric N., Alexander MacKenzie, F. H. Schmitt and I. L. Kintish. Picatinny Arsenal, Feltman Research and Engineering Labs., Dover, N. J. In 4th HVIS, Vol. I.

Since reporting at the last Hypervelocity Impact Symposium, the Picatinny group has made some modifications on the earlier charge designs. It was found that velocity of the pellet was limited by the mass per unit area. In order to avoid thin pellets which break up easily, and yet to allow small thickness to diameter ratios, the charge was doubled in size. This also left more space around the circumference of the pellet for saboting material. Successful sabot and velocity measurement techniques were found, and crater volumes were correlated with pellet energies.

322. STUDY OF CRATER PHYSICS. FINAL REPORT. Friichtenicht, J. F. July 18, 1961, Space Technology Labs., Inc., Research Lab., Canoga Park, Calif. STL 8980-0003-RU-000, Report No. 3; Contract NAS5-763, Subcontract C-135A-1043.

This report summarizes the work performed on the calibration and study of various meteorite detectors for the period from December 19, 1960, to July 19, 1961.

The impact of a high speed particle on a solid medium is a complicated process. The end result is usually the formation of a crater whose size and shape depend on many variables. It has long been the practice in hypervelocity research to examine the characteristics of the crater and relate these by empirical formulae to parameters of the impacting particle and the physical properties of the materials involved. The state of the art has not yet advanced to the point, however, where particle parameters can be deduced simply by examination of the craters. The characteristics of naturally occurring meteors are even more difficult to determine by this means because of the problems involved in retrieving the samples from space.

323. STUDY OF HYPERVELOCITY MICRO-PARTICLE CRATERING. Richards, L. G. and Lee S. Holloway. June 1960, Ballistic Research Labs., Aberdeen Proving Ground, Md. APG-BRL Memo Report 1286; ASTIA AD-242,221.

A ballistic projection technique capable of accelerating clusters of 10- to 100-micron particles to velocities of 12.0 km/sec is described. The problem of associating discrete particles from these clusters with the corresponding craters resulting from target impact is considered. For cast iron particles a prevalence of certain sizes in the fragments recovered is related to a corresponding size distribution of the craters in a specific target material. A particle mass responsible for a definite size of crater is thus obtained. The resulting values are correlated with similar data for larger particles at lower velocities. Scaling laws are found to hold over a size range of seven orders of magnitude.

324. STUDY OF IMPACT CRATERING IN SAND. Culp, F. L. and H. L. Hooper, Tennessee Polytechnic Institute, Cookeville, Tenn. In Journal of Applied Physics, Vol. 32, No. 11, pp. 2480-2484, November 1961.

An investigation of cratering in dry sand using 22-caliber long rifle bullets was carried out. Measurements of craters formed by bullets moving at velocities of 50 to 550 m/sec showed crater volume to vary directly with the square of the bullet velocity at the high end. An equation relating the crater volume to the bullet velocity was developed from a model which assumed hydrodynamic-like flow behind induced shock and was found to provide an excellent fit to the experimental data. It was further found that for velocities below 245 m/sec bullet deformation is small and increases rather slowly with increase in velocity. At 245 m/sec, however, an abrupt transition occurs, and the deformation increases very rapidly. Above 245 m/sec the deformation appears to become constant. This transition velocity is believed to be related to the appropriate velocity of sound in sand.

325. A STUDY OF IONIZATION IN THE TRAIL OF ULTRA-SPEED ALUMINUM PROJECTILES. Piccolo, J. F., R. W. Grow et al. July 1959, University of Utah, Salt Lake City. Interim Technical Report No. 11, on Investigation of Ionization Associated with Ultra-Speed Pellets. ASTIA AD-229,642; Contract DA-04-495-ORD-451.

Three basic experiments were conducted to obtain this relationship: (1) velocity vs pressure, (2) ionization vs velocity, and (3) ionization vs pressure. The combined results of the first two experiments enabled the third experiment to be conducted without monitoring the projectile velocity. The results showed that the ionization near the end of the gun barrel was about 10^{14} electrons per cc at atmospheric pressure.

326. A STUDY OF SOME IMPACTS BETWEEN METAL BODIES BY A PIEZOELECTRIC METHOD. Crook, A. W. In Proceedings of the Royal Society, London, Series A., Vol. 212, pp. 377-390, May 7, 1952.

Continuous measurements of the force throughout impacts between metal cylinders and between a hard sphere and metal flats are described. The force has been measured piezoelectrically. Within their appropriate ranges the theories of elastic impacts due to St. Venant and Hertz have been confirmed. For impacts so hard that the elastic regime preceding plastic deformation may be neglected, it is shown that the experimental results agree closely with force-time curves calculated, assuming that deformation is opposed by a constant pressure. This dynamic flow pressure is greater than the similarly defined pressure experienced in static tests, and the new information given by the piezoelectric method shows that this difference cannot be accounted for satisfactorily in terms of forces of a viscous type.

327. STUDY OF TARGET PENETRATION PREDICTION BY HIGH-SPEED AND ULTRA-HIGH-SPEED BALLISTIC IMPACT. (Third Quarterly Report, 1 January-31 March 1962). May 1962, Air Proving Ground Center, Eglin Air Force Base, Fla. APGC-TDR-62-35; AFSC Project 9860; Contract AF 08(635)2155.

Complete results of the preliminary statistical analysis, which were partially reported in the previous quarterly report, are reported herein. This statistical correlation, based on all hypervelocity terminal ballistic data gathered prior to December 1961, attempts to relate the depth of penetration in semi-infinite targets with ten independent variables. Without any initial assumptions being made regarding the process of ballistic impact or the shape of the craters formed, this analysis produced an equation quite similar to the empirical equation used by many investigators to fit their data.

Also reported are initial attempts to formulate a theoretical model for the purpose of testing accumulated experimental data. This theoretical model is developed from a consideration of energy conversion during impact.

328. SURFACE FRICTION IN BALLISTIC PENETRATION. Krafft, Joseph M. In Journal of Applied Physics, Vol. 26, No. 10, pp. 1248, October 1955.

The frictional adhesion between projectile and target during a ballistic penetration has been measured with a torsion-type Hopkinson bar. The apparatus allows measurement of the torsional adhesion of a spinning projectile during target penetration. By assuming the friction resisting rotation to be equal to that resisting axial penetration, the energy loss due to friction was computed. The results show that the torque-time pattern during penetration of a "mechanically" clear projectile can be predicted with the assumption of a frictional energy loss just sufficient to keep the sliding surfaces at the melting temperature of the metal. Metallographic analysis of the target metal at the projectile interface gives a further indication of a molten interface. In these tests, sliding friction accounts for about 3% of the striking energy of the projectile; common surface contaminants, not necessarily special lubricants, reduce this loss to less than 1%.

329. TEMPERATURE STUDIES AND EFFECTS IN PERFORATION OF THIN ALUMINUM TARGETS. McDermott, C. E., Emerson T. Cannon and R. W. Grow. 15 May 1959, University of Utah, Salt Lake City. Technical Report UU-3; Contract AF-04(647)176.

Chrome steel spheres 3/32 inches in diameter were accelerated to velocities in the range of 1200 to 7400 ft/sec and were impinged normally upon thin aluminum targets which were preheated to temperatures ranging from 70°F to 500°F. The quantity of energy lost by a projectile in perforating a target of uniform thickness was found to be a linearly decreasing function of increasing target temperature. The minimum velocity required for a projectile to perforate aluminum was found to be an increasing linear function of target thickness with the slope varying inversely with the temperature of the target.

330. TERMINAL BALLISTIC INVESTIGATION OF THE IMPACT AND EFFECT OF ULTRA-HIGH-SPEED MICRON-SIZE PARTICLES PRODUCED ON HYPERVELOCITY IMPACT. FINAL REPORT. November 1962, Utah Research and Development Co., Salt Lake City. Air Proving Ground Center, Eglin Air Force Base, Fla. AFSC Project No. 5841; APGC-TDR-62-69; Contract AF 08(635)2099.

This Technical Documentary Report reports the results of the investigations of spray particle impact. A method was devised to measure the velocity and calculate the diameter of the spray particle in flight. The crater produced at impact was measured to obtain the diameter and several attempts to measure penetration and volume are described. A scaling law relating macro size craters to micro craters produced at the same velocity is presented.

331. VAPORIZATION OF PROJECTILES ON IMPACT. Larikov, G. May 14, 1958, The Ordnance Research Institute, Paipei, Taiwan. In Nature, Vol. 182, No. 4633, pp. 468, August 16, 1958.

Reference is made to previous article in Nature, 181,873 (1958), about the damage to slides by liquid impact. In the Scientific Monthly of February 1951, pp. 79, it was remarked: Ballistic experiments have shown that particles, traveling at velocities about 4,250 ft/sec, explode into vapor on striking the target. Experiments were carried out to prove this.

332. VELOCITY AND SIZE DISTRIBUTION OF IMPACT SPRAY PARTICLES. Blake, R. E., R. W. Grow and E. P. Palmer. 20 May 1960, University of Utah, Salt Lake City. Air Force Office of Scientific Research, ARDC, Washington, D. C. Technical Report No. OSR-19; AFOSR No. TN-60-989; ASTIA AD-245,112; Contract AF 49(638)462.

Steel and pyrex spheres having a diameter of 3/16 inch were accelerated with a 220 caliber smooth-bore gun to a velocity of 2.0 kilometers per second. These spheres were impacted on a target of a composition of the same type as the sphere. The luminous spray resulting from the impact was detected by means of photocircuits which produced a voltage that was recorded by an oscilloscope camera. Maximum measured initial spray velocities for the steel-to-steel impacts varied between 8.5 km/sec and 10.3 km/sec, and a measured average velocity between two points for glass-to-glass impacts was in excess of 20 km/sec.

333. VOLUME-ENERGY RELATIONS FROM SHAPED CHARGE JET PENETRATIONS. Feldman, James B., Jr., Ballistic Research Labs., Aberdeen Proving Ground, Md. In 3rd HVIS, Vol. I. Similar title presented at 4th HVIS. See also Report APGC-TR-60-39.

The author concludes that crater efficiency (Vol/E) is not a constant but is some function of the impact velocity, that the ratio of any two of the crater efficiencies is not a constant, and that the crater efficiency is not a simple power function of the impact velocity of the projectile.

334. WAX MODELING STUDIES OF HIGH SPEED IMPACT. Clay, Wallace G. and William S. Partridge. June 1956, University of Utah, Salt Lake City. Tech Report No. 5; AFOSR TN-56-257; ASTIA AD-88,977; Contract AF-18(600)1217.

An investigation of wax-to-wax impact is presented in an attempt to "model" high-speed impact of metal into metal. Wax is chosen as the modeling substance because of its comparatively low-sonic velocity and the physical similarity of wax craters to craters found at the impact of metal to metal. The sonic velocity in wax is determined as a function of temperature; the work reported is made with the wax targets at a temperature of about 75°F, at which the sonic velocity in wax is approximately 0.7 km/sec. A method of accelerating wax pellets by means of laboratory guns is given; also, use is made of the static charge on wax pellets in some of the velocity measurements. The penetration of the impacting pellet is found to vary linearly with the cube root of the pellet mass and the pellet velocity to velocities in excess of twice the sonic velocity in the wax target. The crater area varies directly as the pellet area and the velocity, both below and above the sonic velocity, but there is marked increase in the constant of proportionality above the sonic velocity. The volume of the crater per unit energy of the pellet is discussed, and it is found that in wax this characteristic is not independent of velocity. Values of volume per unit energy range over 1.5-4.0 x 10^{-8} m^3/j, over the velocity range zero to 2 km/sec.

SECTION V. EXPERIMENTAL FACILITIES

335. ACCELERATION OF DUST PARTICLES BY SHOCK WAVES. Hoenig, S. A. Armour Research Foundation, Chicago, Ill. In Journal of Applied Physics, Vol. 28, No. 10, pp. 1218-1219, October 1957.

A particle is accelerated when it encounters a shock wave. The drag force is calculated and used to determine the time in which the particle attains a certain fraction of the shock-wave velocity. Integration gives the distance travelled in this time.

336. ACCELERATION OF EXPLODING WIRE PLASMAS BY ASYMMETRIC MAGNETIC FIELDS. Bohn, J. Lloyd. Temple University, Physics Dept., Philadelphia, Pa. In 2nd HVIS, Vol. I.

The technique of accelerating exploding wire plasmas is discussed. Particular emphasis is placed on the transfer of ions at various pressures. Velocities from 2 km/sec to 96 km/sec were measured. A major portion of the paper is devoted to a discussion of a multiple frame camera which was used primarily in the study of exploding wires.

337. ACCELERATION OF MASSES TO HYPERVELOCITIES BY ELECTROMAGNETIC MEANS. Mannal, C. and Yusuf A. Yoler. General Electric Co., Missile and Space Vehicles Dept., Philadelphia, Pa. In 2nd HVIS, Vol. I.

A short history of electromagnetic applications to linear acceleration is presented. Fauchon-Villiplie obtained a patent in 1922 for a dc gun.

Two points are noted: (1) Maxwell's laws are still true and thus a simple small-scale laboratory model of an electromagnetic accelerator can be constructed rapidly and at low cost, and (2) the feasibility of a large scale hypervelocity accelerator depends on incidental physical effects having little or nothing to do with the basic electromagnetic propulsion principle.

A description of the AC accelerator is presented. The design requirements were

Total Accelerated Mass	0.12 lb.
Sabot	0.08 lb.
Aerodynamic Model	0.04 lb.
Diameter	1.21 in.
Acceleration (Max.)	35,000 g
Terminal Velocity	25,000 ft/sec.

To achieve these results an extremely high electric power source is required resulting in extremely high cost.

The DC accelerator is also described along with associated problems. The conclusion reached by the authors is that ". . . many problems . . . must be considered in detail before a true estimate can be made of a large accelerator based on this principle."

338. ACCELERATION OF MASSES TO HYPERVELOCITIES BY EXPLOSIVE MEANS. Willig, Frank J. General Electric Co., Missile and Space Vehicle Dept., Philadelphia, Pa. In 2nd HVIS, Vol. I.

The problem of maintaining projectile shape during very high acceleration is presented.

A simplified explanation of the phenomena associated with the shock acceleration of a solid material is given.

339. ACCELERATION OF PROJECTILES WITH THE SEQUENCED HIGH EXPLOSIVE IMPULSE LAUNCHER. Fogg, Warren E. and C. W. Fleisher, Jr. Frankford Arsenal, Philadelphia, Pa. In 4th HVIS, Vol. I.

A sequential high-explosive hypervelocity launcher using a conventional propellant-driven first stage has been investigated.

Velocity increases of about 30 percent above a first stage velocity of 6,600 ft/sec were achieved. Experimental errors encountered were high, and must be considered when comparison with other types of launchers is made.

The limitations of currently available control techniques are discussed with respect to applying this type of launcher to studies requiring projectile velocities above the 20,000 to 30,000 ft/sec range.

Suggestions concerning the use of the high explosive element of this launcher in conjunction with other types are made.

340. THE ACCELERATION OF SMALL PARTICLES WITH HIGH EXPLOSIVES. Poulter, Thomas C., Jr., Stanford Research Institute, Menlo Park, Calif. In 2nd HVIS, Vol. I.

This paper describes physical techniques.

341. ANALYSIS AND DEVELOPMENT OF A LIGHT GAS GUN FOR ACCELERATING PELLETS TO HYPERSONIC VELOCITIES. Boyd, K. E., R. W. Grow et al. October 15, 1959, University of Utah, Salt Lake City. Technical Report No. OSR-17; AFOSR TN 60-81; ASTIA AD 235,436; Contract AF 49(638)462.

A light-gas gun employing hydrogen as a driving gas and using a piston-type compression cycle has been developed and fired in two different configurations under a variety of firing conditions. Pellets weighing one gram have been launched through a velocity range of from 7,000 ft/sec to 27,300 ft/sec. The high velocity of 27,300 ft/sec has not been verified because of the damage suffered by the gun when fired at the conditions required to achieve this velocity. Rather than risk destroying the gun by attempting to verify the highest velocity achieved, emphasis was placed on gaining data at reduced energy levels to study the launching cycle in a manner to gain maximum knowledge. Data are presented and analyzed for a gun having a compression tube length of 92 inches and a bore of 2.38 inches and designed to launch pellets either parallel to the longitudinal axis of the gun or perpendicular to the longitudinal axis. A study and analysis of the piston motion are made, and a basis for assuming a shock-wave compression process is determined. Equations describing pressure ratio and temperature ratio across a compression wave and a reflected wave are developed, and a comparison of a shock-wave compression process to a reversible-adiabatic compression process is made.

342. THE APPLICATION OF INTERIOR BALLISTIC THEORY IN PREDICTING THE PERFORMANCE OF LIGHT GAS HYPERVELOCITY LAUNCHERS. Baer, Paul G. Ballistic Research Labs., Aberdeen Proving Ground, Md. APGC TR-60-39; ASTIA AD 244,476. In 4th HVIS, Vol. II.

The author reviews types of light gas guns that have been used with particular attention to factors limiting the velocities attainable for each and compares different systems by a computer simulation technique. He concludes that limit is in 35,000 to 50,000 fps.

343. APPROXIMATE ANALYSIS FOR PREDICTION OF LOADS OF CALIBER -30 LIGHT GAS GUN IN PHYSICS RANGE. Sabin, C. (No date given.) General Dynamics/Convair, San Diego, Calif. Report No. Ph-086-M.

344. CARDE COUNTERFIRE HYPERVELOCITY IMPACT FEASIBILITY, PHASE I. Simpson, A. U. July 1961, Canadian Armament Research and Development Establishment, Valcartier, Quebec. CARDE TM-604-61; ASTIA AD 263,699.

A description is given of the joint CARDE-ARPA counterfire facility which is being developed at CARDE to study hypervelocity impacts at 20,000 to 40,000 ft/sec. Results may be obtained which will be useful for the evaluation of anti-missile systems and the effects of meteorites on various materials and target shapes. The high impact velocities are achieved by firing a fragment projectile from a multi-stage shock compression gun on an impact trajectory at a target from a 1/4 inch oxygen-hydrogen gun. Results of penetration of projectiles into rubber and a brief description of the development of a short delay charge are also presented.

345. THE COIL TYPE OF ELECTROMAGNETIC ACCELERATOR. Harris, L. Dale. University of Utah, Salt Lake City. In 2nd HVIS, Vol. I.

The basic principles of this type of accelerator are defined. For a final projectile velocity of 10 km/sec, it is estimated that 2500 coils, each delivering 100 joules of kinetic energy to the projectile, could be required. Total length of the accelerator would be 150 meters.

346. THE COMPARISON BETWEEN ORDVAC PREDICTIONS FOR THE PERFORMANCE OF A WSL/BRL LIGHT-GAS GUN AND SOME EXPERIMENTAL FIRINGS. Crews, George C. Ballistic Research Labs., Aberdeen Proving Ground, Md. In 4th HVIS, Vol. II.

This is a continuation of Paper No. 19, "The Application of Interior Ballistic Theory in Predicting Performance of Light-Gas Hypervelocity Launchers," by Paul G. Baer. It is concerned primarily with simulations of various aspects of the free-piston type light-gas guns with a high-speed computer.

347. CONSTRUCTION OF A HIGH-VELOCITY GUN FOR PROPELLING SMALL IRREGULAR-SHAPED PELLETS. Partridge, William S. March 1957, University of Utah, Dept. of Electrical Engineering, Salt Lake City. Interim Technical Report No. 8; Contract DA-04-495-ORD-451.

A .22 caliber accelerator capable of firing irregular shaped fragments weighing 1/2 to 15 grains was constructed by the University of Utah High Velocity Laboratory for Picatinny Arsenal. The gun barrel was made in two sections joined together with an O-ring seal and flange. The barrel was smooth-bored and had an adapter on the muzzle to allow evacuation of the barrel with a mechanical vacuum pump. The gun was chambered for a standard .022 Swift shell and fired electrically by means of a 110 volt A-C solenoid.

In order to fire the irregular shaped pellets, a sabot was constructed which will carry the pellets and separate from them within 36 inches from the end of the barrel. The problem of measuring the velocity of these small pellets is discussed and three systems described which were used successfully.

By evacuating the barrel and using 1/2 grain pellets, velocities over 9,000 ft/sec were obtained. Five grain pellets were accelerated to a velocity of approximately 1,000 ft/sec.

348. DESIGN OF LIGHT-GAS MODEL LAUNCHERS FOR HYPERVELOCITY RESEARCH. Anderson, D. E. and M. D. Price, Von Karman Gas Dynamics Facility, ARO, Inc., Tullahoma, Tenn. In Advances in Hypervelocity Techniques: Proceedings of the Second Symposium on Hypervelocity Techniques. Plenum Press, New York, 1962.

The parameters which influence the operating capabilities of two-stage, light-gas guns are discussed. Calculations are presented which illustrate the relationships of these parameters under idealized conditions, and empirical correlations derived from firings in several launchers are used to provide the necessary correction factors to adjust the idealized treatment.

The construction techniques which are used in the design of light-piston-type, two-stage, hypervelocity launchers are discussed.

349. EFFECTS OF METEORITES ON MATERIALS AND SIMULATION TESTING. Scully, Charles N., North American Aviation Co. In Materials and Space Environment: Proceedings of the Fifth Sagamore Ordnance Materials Research Conference. Conducted at Sagamore Conference Center, Racquette Lake, N. Y., September 16, 17, 18, and 19, 1958. Syracuse University Research Center, Syracuse N. Y. SURI MET 597-596; ASTIA AD-205,880.

This article is a general discussion of the devices that are used to project particles to high velocities for penetration studies.

350. ELECTRICAL AUGMENTATION OF A LIGHT-GAS HYPERVELOCITY PROJECTOR. Howell, William G., William R. Orr and Arthur M. Krill, University of Denver, Denver Research Institute. In Advance in Hypervelocity Techniques: Proceedings of the Second Symposium on Hypervelocity Techniques. Plenum Press, New York, 1962.

This paper reports progress on a program, the objective of which is to attain a 25-grain projectile velocity of 50,000 ft/sec through electrical augmentation of a light-gas projector. Augmentation is to be achieved by a sequence of electrical arc discharges in the expanding light gas immediately behind the projectile as it travels through the launch tube.

351. ELECTROBALLISTIC TECHNIQUES. Swift, Hallock F. Naval Research Lab., Washington, D. C. In 4th HVIS, Vol. I.

An ARPA-sponsored project at NRL includes the development of gas-powered ballistic accelerators capable of firing gram-weight, controlled-shape fragments to speeds of 10 km/sec. Electrical-arc heating was considered the most feasible technique available for increasing present light-gas accelerator performance.

A basic study of electric-arc guns with constant volume reservoirs indicates that they could achieve 10 km/sec projectile velocities if supplied with sufficient electrical energy. Further studies indicate that a considerable saving of electrical energy results if arc gas heating techniques are applied to the design of high-performance compression-type light-gas guns.

In order to extend present electroballistic experimentation to higher energy levels, a large capacitor energy storage bank with unique switching equipment was developed.

352. ELECTROSTATIC ACCELERATION OF MICROPARTICLES TO HYPERVELOCITIES. Shelton, H., Charles D. Hendricks, Jr. and R. F. Wuerker. Ramo-Wooldridge, Div. of Thompson Ramo-Wooldridge, Inc., Los Angeles, Calif. In Journal of Applied Physics, Vol. 31, No. 7, pp. 1243-1247, July 1960.

Recent interest in hypervelocity impact phenomena has resulted in a critical examination of the methods of obtaining impacts from single hypervelocity particles. One of the most promising methods of accelerating particles whose radius is in the micron range uses electrostatic fields.

353. ELECTROSTATIC ACCELERATOR FOR IMPACT STUDIES. Hendricks, Charles D., Jr., H. Shelton and R. F. Wuerker. Ramo-Wooldridge Corp., Los Angeles, Calif. In 3rd HVIS, Vol. I.

The authors describe their electrostatic technique for acceleration of microparticles. Tiny iron spheres are rained down on a charged tungsten point about 25 microns diameter and are thereby charged (positively). The particles are then attracted (through holes) toward the target with an electric field (25 mv/cm).

354. EM ACCELERATORS. Wennersten, D. L. Air Force Office of Scientific Research, Washington, D. C. In 3rd HVIS, Vol. I.

The author describes the general characteristics of electromagnetic accelerators with their future potentialities.

355. AN EXPENDABLE HIGH-EXPLOSIVE, LIGHT-GAS GUN FOR PROJECTING HIGH VELOCITY PROJECTILES. Gehring, John William, Jr. Ballistic Research Labs., Aberdeen Proving Ground, Md. In 3rd HVIS, Vol. I.

The author describes recent progress in improving the performance of BRL's light-gas gun. No test data are given.

356. EXPERIMENTAL PRODUCTION OF HYPERVELOCITY PELLETS BY MEANS OF CONDENSER DISCHARGES IN HYDROGEN. Bloxsom, Daniel E., Jr. Rhodes and Bloxsom, Canoga Park, Calif. In 4th HVIS, Vol. I.

One-half inch diameter nylon and magnesium pellets have been accelerated to 13,700 ft/sec by means of hydrogen heated by a capacitor discharge in a closed chamber.

A short review of the possibilities of this type gun is presented with respect to increasing the pellet velocity and overall efficiency.

357. AN EXPERIMENTAL STUDY OF THE INPUT PARAMETERS FOR AN NRL-TYPE H-GUN. Crews, George C., Ballistic Research Labs., Aberdeen Proving Ground, Md. In 3rd HVIS, Vol. I.

One of the light-gas guns at the BRL is described. No impact data are presented.

358. EXPERIMENTAL TECHNIQUES DEVELOPED FOR IMPACT STUDIES OF MICRO-PARTICLES. Kells, M. C., R. B. Burkdoll, Gordon D. Anderson, D. E. Davenport, D. G. Doran, F. S. Hempy and Thomas C. Poulter, Jr., Poulter Labs., Stanford Research Institute, Menlo Park, Calif. In 3rd HVIS, Vol. I.

A description of Stanford Research Institute's shaped-charge projectors and accompanying instrumentation is given. No test data are given.

359. EXPLODING-WIRE GUN FIRES PELLETS AT 56,000 FPS. Scherrer, Victor E., Technical Operations Inc., Burlington, Mass. In Space/Aeronautics, Vol. 37, No. 1, pp. 45, January 1962.

A super-voltage exploding wire "gun" is being used in studies aimed at developing materials and techniques of spacecraft construction to withstand micrometeoroid impacts. The record velocity achieved to date is 56,000 fps.

360. AN EXPLODING WIRE HYPERVELOCITY PROJECTOR. Scherrer, Victor E. and P. I. Richards. Technical Operations, Inc., Burlington, Mass. and Ballistic Research Labs., Aberdeen Proving Ground, Md. In 4th HVIS, Vol. I.

An underwater exploding wire is used as a source of very high temperature gases for a hypervelocity gun. The method consists essentially in using an electrically exploded wire as the "explosive charge," a water mass as the "breech" and a glass capillary tube as the "barrel." Not only are all parts of this "gun" cheap and therefore expendable as the projectile itself, but the system takes advantage of the very high temperatures which can be attained through the efficient coupling of a fast-capacitor, energy-storage system to a metallic conducting wire with its very small radiating surface. (High temperature of the propellant gas is of basic importance in hypervelocity guns since the maximum expansion velocity of the propellant gas is limited essentially by its speed of sound, which in turn is directly related to its temperature.) Previous experiments have demonstrated (see "Exploding Wires," ed. by Chace and Moore, Plenum Press, 1959, pp. 118-134) that temperatures certainly in excess of 250,000°K can be produced in a fine metallic wire when properly matched to a modern capacitor bank with high energy and rapid discharge time.

361. EXPLODING WIRES. Bennett, Frederick D. In Scientific American, Vol. 206, No. 5, pp. 103-112, May 1962.

Five copper wires exploded in the laboratory by a large burst of electrical energy produce shock waves that are analogous to those created by meteorites and missiles in the atmosphere.

362. FACILITIES AND INSTRUMENTATION OF THE NRL HYPERVELOCITY LABORATORY. Bailey, S. O., A. B. J. Clark, Donald A. Hall and Hallock F. Swift. February 18, 1959, Naval Research Lab., Washington, D. C. NRL Report 5271; ASTIA AD-212,988. In 3rd HVIS, Vol. I.

The authors describe the light-gas guns and allied instrumentation processed by the Research Laboratories. No test data are given.

363. FASTEST GUN IN THE WEST! In Northrop Technical Digest, Vol. 1, No. 5, unnumbered pages, January 1962.

Development of an electromagnetic ballistic "gun" capable of firing small metallic projectiles at 100,000 ft/sec speeds - the fantastic hypervelocity of meteorites in space - is under study at Northrop's Norair Division. Such a device, according to Dr. E. T. Benedikt, Head of the Norair Space Physics Laboratory, would triple the speeds of simulated meteorites thus far achieved in the laboratory.

364. FEASIBILITY STUDY FOR A HYPERVELOCITY PROJECTOR. Grubin, Eugene S., William G. Harrach and William R. Orr. December 1959, University of Denver, Denver Research Institute, Denver. Air Proving Ground Center, ARDC, Eglin AFB, Fla. ARDCM-80-4, Project 5827; APGC-TR-59-62, Project No. 196; Contract AF-08(603)4549.

This feasibility study report describes the basic thermodynamic, hydrodynamic and electrical augmentation principles of a laboratory hypervelocity projector with a theoretical capability of accelerating a 25 grain particle to a velocity of 50,000 ft/sec. A detailed analysis is presented of the propellant gas properties, as a function of time and position, for the nonsteady ballistic expansion of a perfect gas hydrogen column by the conventional method of characteristics. A characteristics solution of the equations of motion for a real, virial gas is developed, and the results are found to diverge appreciably from the perfect gas case. From the initial gas conditions of primary interest, 30,000 atmospheres and 6000°K, the expansion was examined to determine the feasibility of energy addition by electrical means to augment the normally adiabatic process.

365. A FOUR-COIL INDUCTION ACCELERATOR. Salisbury, Winfield W. Zenith Radio Research Corp., Redwood City, Calif. In 2nd HVIS.

Successive coils, each with its own storage capacitor can be used with prearranged timing. The projectile approaching a later coil can be considered a pseudo-capacitance partially charged, ready to receive more energy from a storage capacitance charged to a higher voltage. Four coils have been tested with a 1/2-inch projectile of up to 24 grams in mass. Acceleration produced was 10^5G's, producing a velocity of 1150 fps. An eventual velocity of 10-30,000 fps is a realistic design goal.

366. FUNDAMENTALS OF SHAPED-CHARGES (U). Allison, Floyd E. and Emerson M. Pugh. 31 July 1961, Carnegie Institute of Technology, Pittsburgh, Pa. Report CIT-QPR-23; Contract DA-36-061-ORD-513. Report CONFIDENTIAL. Abstract CONFIDENTIAL.

367. THE GENERATION OF HIGH-VELOCITY PROJECTILE WITH HIGH EXPLOSIVES. Keyes, Robert T. and Melvin A. Cook. 1 October 1957, University of Utah, Salt Lake City. Air Force Office of Scientific Research, ARDC, Washington, D. C. AFOSR TN-57-696; ASTIA AD-136,698; Contract AF 18(603)100.

A technique of controlling the shape of detonation wave fronts in high explosives by inert wave control inserts was applied to generate discrete ultra-high velocity pellets. Tests to determine the most suitable pellet shape as well as the optimum charge configuration are described and velocities up to 7600 m/sec were realized for 0.95 g aluminum pellets. The mechanism whereby pellets are accelerated by "shaped" waves is discussed.

368. A HIGH EXPLOSIVE GUN TEST RANGE. Semon, H. W. General Electric Co., Space Sciences Lab., Missile and Space Vehicle Dept., Philadelphia, Pa. APGC-TR-60-39. In 4th HVIS, Vol. II.

This report gives a cursory description of a gun test range. No data are given. Velocity measuring techniques include (1) triggering oscilloscope as projectile leaves tip of gun and again on impact, (2) passing projectile through core of core transformers, 1 foot apart, and monitoring with oscilloscope. Technique recovering projectile intact is to impact it successively into shaving cream, styrofoam and sawdust. These techniques appear limited to fairly large projectiles.

369. HIGH EXPLOSIVE HYPERVELOCITY PROJECTORS. Stresau R. and J. Savitt. Armour Research Foundation, Chicago, Ill. In 3rd HVIS, Vol. I.

A description is given of several schemes for boosting light-gun performance with explosives. No test data are given.

370. HIGH SPEED RADIOGRAPHIC AND OPTICAL TECHNIQUES APPLIED TO HYPER-VELOCITY IMPACT STUDIES. Gehring, John William, Jr., Research Labs., Aberdeen Proving Ground, Md. In Proceedings of the 5th International Congress on High-Speed Photography, SMPTE, Washington, D. C. October 16-22, 1960. SMPTE Paper D-10. Society of Motion Pictures and Television Engineers, New York.

It is the intent of this paper to describe some results obtained in an area of research which has long been of general interest; yet only with the advent of missile and space vehicle travel has a concentrated effort been made to describe the phenomena. This research is that of studying the behavior of target materials on impact by a meteor or projectile traveling at hypervelocities. Recent advances in hypervelocity guns and explosive devices have made possible the acceleration of projectiles to velocities in excess of 15 km/sec. Concurrently, radiographic and optical techniques have been refined in recent years to a degree which enables the observation of these ultra-rapid phenomena. Together, these advances now make possible a direct and accurate study of hypervelocity cratering, and most important, enable the direct measurement of several parameters previously unknown.

371. HIGH-TEMPERATURE EXPLODING WIRE EXPERIMENT. Scherrer, Victor E., C. B. Dobbie, I. M. Vitkovitsky and R. C. O'Kouke. Reprint from NRL Progress, June 1959 issue. Naval Research Lab., Washington, D. C. Adopted from a paper presented at the AFCRC Conference on Electrically Exploding Wires, Boston, April 2-3, 1959.

When electrical energy is deposited at a very high rate in a fine wire, one can expect the wire to heat to a very high temperature and literally explode. If one deposits power at a rate of 20 billion watts, it is reasonable to expect the wire to heat to a temperature near a million degrees. A special capacitor has been developed which is capable of delivering such power. Diagnostic experiments are in progress at the present time to determine the wire temperatures.

372. HIGH VELOCITY ELECTRIC ACCELERATOR SYSTEMS. REPORT FOR APRIL 1958-JUNE 1960 ON MATERIALS ANALYSIS AND EVALUATION TECHNIQUES. Baruch, Jordan J., Denis U. Noiseu et al. August 1960, Bolt, Beranek and Newman, Inc., Cambridge, Mass. WADD-TR-60-468; ASTIA AD-246,350; Contract AF-33(616) 5730.

Accelerators designed to convert electrical energy to particulate kinetic energy were investigated and their capabilities and limitations ascertained. Experimentally, speeds up to 14,500 ft/sec were obtained with a 20,000 joule energy input. Four different mechanisms for electrical-kinetic energy conversion were worked out and tested experimentally.

373. A HIGH VELOCITY GUN EMPLOYING A SHOCK-COMPRESSED LIGHT GAS. Bioletti, Carlton and Bernard E. Cunningham. February 1960, National Aeronautics and Space Administration, Washington, D. C. NASA TN D-307.

A light-gas gun is described which is relatively simple in construction and operation. Projectiles of 20mm diameter are launched by helium which have been compressed and heated by a two-stage shock process. Air explosion of powder is the source of energy.

The unusual feature is a light piston which operates at supersonic speed in the second-stage shock tube. Muzzle velocities of over 20,000 ft/sec are obtained with light projectiles.

374. HIGH VELOCITY LIGHT-GAS GUN. Crozier, William D. and W. Hume. In Journal of Applied Physics, Vol. 28, No. 8, pp. 892-894, August 1957.

A new range of muzzle velocities was achieved by propelling a projectile in a gun barrel by a column of hydrogen or helium instead of the conventional powder gas. The first gun built, the design of which probably was far from optimum, yielded muzzle velocities in excess of 12,000 ft/sec with spherical and cylindrical steel projectiles.

375. THE HYPERBALLISTICS LAUNCHER AT ARDE, FORT HALSTEAD, AND PRELIMINARY RESULTS ON IMPACT PHENOMENA. Cox, R. N. and W. A. Clayden, British Joint Services Mission, Washington, D. C. In 3rd HVIS, Vol. I.

Describes the ARDC launcher and presents 4 test curves, as follows:

1) Penetration vs Velocity
2) Volume in Energy
3) Area Ratio vs Velocity
4) Volume Ratio vs Velocity.

376. HYPERVELOCITY GUN FOR MICROMETEORITES IMPACT SIMULATION EMPLOYING CAPACITOR DISCHARGE IN A CONDENSED PHASE. Scully, Charles N. and David L. Cowan. North American Aviation, Inc., Downey, Calif. In 4th HVIS, Vol. I.

In order to predict effects arising from impact of micrometeorites on satellites and space vehicles, a precise definition of the micrometeorite environment and of the impact effects of single hypervelocity particles of proper composition is required. In support of the latter requirement, a hypervelocity particle accelerator employing a new concept has been designed, constructed, and operated. A high density, very high temperature gas is generated by high energy capacitor discharge into a partially confined lithium metal cylinder. The resultant gas, in flowing from the region of confinement through a tubular connection to a vacuum system, accelerates 100 micron diameter borosilicate glass spheres by aerodynamic drag to a considerable fraction of the gas velocity. Both the velocity and geometrical integrity of the projectiles are determined in flight by a sensitive light scattering system. Intact spheres have been accelerated to 9.5 km/sec (31,000 fps).

377. HYPERVELOCITY IMPACT. 5 July 1962, General Dynamics/Astronautics, San Diego, Calif. Report No. ERR-AN-170.

In this report the following items are discussed at length: philosophy of hypervelocity impact, capabilities and facilities. Numerous photographs and charts are included.

378. HYPERVELOCITY IMPACT BY COLLISION OF TWO PROJECTILES, PHASE II. Rogers, W. K. and W. S. Vikestad. January 1961, Ballistic Research Labs., Aberdeen Proving Ground, Md. BRL Tech. Note No. 1381.

A high-collision velocity was achieved by firing a steel pellet from a small light-gas gun at a target disk fired from a large smooth-bore gun. Through the use of a higher velocity target gun and a modified light-gas pellet gun, the impact velocities obtained were higher than those in the Phase I program reported in BRL Technical Note 1337, August 1960. The techniques exploit the use of existing equipment to reach these hypervelocities in a range where the need for impact data is urgent. Collisions were predicted with reliability and precision. The experiment demonstrates the feasibility of adding significant target velocities to many hypervelocity launching techniques. This report discusses the techniques, instrumentation and results of the experiment.

379. HYPERVELOCITY IMPACT FACILITY, LIGHT-GAS PROJECTOR. March 1960, Air Proving Ground Center, Eglin AFB, Fla. APGC TN-60-22.

A review of APGC's new hypervelocity projector and impact facility is presented pictorially. At present, velocities of greater than 15,000 ft/sec are obtainable at simulated altitudes up to 100,000 ft. High-speed cameras are used to record the impact data.

380. HYPERVELOCITY IMPACT FACILITY LIGHT-GAS PROJECTOR DEVELOPMENT. Fendick, R. B. June 1961, Air Proving Ground Center, Eglin AFB, Fla. APGC TR-61-31; ASTIA AD-263,373.

The major accomplishment during this reporting period was launching a 1/8-in. diameter aluminum projectile at a velocity of 22,030 fps. Refinements were made in saboting techniques that produced clear projectile impacts on the target. Launching 1/4-in. diameter tungsten carbide projectiles was successful up to 12,800 fps and 1/4-in diameter aluminum projectiles to 16,000 fps. Modifications to the lightweight piston (4 oz.) were responsible for achieving higher velocities.

381. A HYPERVELOCITY IMPACT SYSTEM USING THE RELATIVE VELOCITY OF TWO PROJECTILE ACCELERATORS. Hopko, Russel N. and William H. Kinard. NASA, Langley Research Center, Langley Field, Va. In 4th HVIS, Vol. II.

The authors demonstrate feasibility of firing target and projectile at each other. They expect to extend approach to use two light-gas guns thereby achieving velocities of 30,000 to 40,000 fps. One graph is given for velocities 0 to 20,000 fps using nylon projectiles and aluminum targets. Targets weigh approximately 77 gms; projectiles are 22 calibre and are filled in sabots.

382. HYPERVELOCITY LAUNCHERS AND HYPERVELOCITY IMPACT EXPERIMENTS AT ARDE, FORT HALSTEAD. Smith, F. W, W. A. Clayden, C. R. Wall and D. F. T. Winter. In 5th HVIS, Vol. I, Part 2.

This paper outlines the development of hypervelocity launchers at ARDE using fairly conventional techniques. Velocities up to 25,000 ft/sec have so far been attained.

The paper also summarizes a series of impact studies on solid targets and thin plates inclined to the direction of motion. Future tests are discussed. For more detail, see entry number 305, Part A of the Bibliography, "Some Experiments on Hypervelocity Impact," by W. A. Clayden.

383. HYPERVELOCITY LIGHT-GAS GUN DEVELOPMENT. Mapes, Joe M. and William A. Allen. April 10, 1957, Naval Ordnance Test Station, China Lake, Calif. NAVORD Report 5453; NOTS 1731.

This report outlines the development of a light-gas gun. The gun was invented by William D. Crozier of the New Mexico School of Mines where initial development work was begun. The project was transferred to the U. S. Naval Ordnance Test Station where the development was completed. The gun is a two-stage device where the initial chemical energy of the propellant is transferred into the kinetic energy of a piston that, in turn, compresses a light gas such as helium or hydrogen used to propel the projectile. The gun has fired projectiles at velocities in excess of 10,000 fps. It has been used as a research tool to fire simulated missiles. The associated exterior and terminal ballistics have been studied. The gun is considered a research tool for investigation in a fascinating new field of physical reality.

384. HYPERVELOCITY WEAPON FEASIBILITY STUDY. VOL. I. (U). Zimmerman, Frank J. and Louis A. C. Barbarek. February 15, 1961, Armour Research Foundation, Illinois Institute of Technology, Chicago, Ill. Summary Progress Report No. 1, Vol. I, AFSC Project 9850; WADD-TR-61-203 (I), April 1961; Contract AF-08(635)902. Report CONFIDENTIAL. Abstract CONFIDENTIAL.

385. HYPERVELOCITY WEAPON FEASIBILITY STUDY. VOL. II. Zimmerman, Frank J. and Louis A. C. Barbarek. February 15, 1961, Armour Research Foundation, Illinois Institute of Technology, Chicago, Ill. Summary Progress Report No. 1, Vol. II, AFSC Project 9850; WADD-TR-61-203 (II), April 1961; Contract AF-08(635)902.

This report consists of the unclassified appendices previously part of Volume I:

Appendix A: CATALOGUE OF HYPERVELOCITY PROJECTOR TYPES - gives general description of types, and gives summary sheets for 26 different accelerators.

Appendix B: ANALYSIS OF PERFORMANCE REQUIREMENTS FOR HYPER-VELOCITY GUNS - gives parameters of the tactical requirements for guns as weapons.

Appendix C: THE ARF TRAVELING CHARGE GUN PROGRAM - describes in-house feasibility program for the proposed weapon.

386. INTERIOR BALLISTIC ANALYSIS OF A TRAVELING CHARGE HYPERVELOCITY GUN. PART I. Barbarek, Louis A. C. and M. S. Nusbaum. Armour Research Foundation, Illinois Institute of Technology, Chicago. Presented at Second Symposium on Hypervelocity Techniques, Denver, Colo., 1962. Included in Addendum to the Proceedings: Advances in Hypervelocity Technique.

This paper is a report of the analytical and experimental investigation of the interior ballistics of a traveling charge gun. Part 1 of the paper presents the mathematical model and Part 2 describes the gun used for the experimental investigation and presents the results of the firings up to the date of the symposium.

387. INTERIOR BALLISTIC ANALYSIS OF A TRAVELING CHARGE HYPERVELOCITY GUN. PART II. Barbarek, Louis A. C. and M. S. Nusbaum. Armour Research Foundation, Illinois Institute of Technology, Chicago, Ill. Presented at the Second Symposium on Hypervelocity Techniques, Denver, Colo., March 1962. (Not in printed Proceedings.)

388. INTERIOR BALLISTICS OF HYPERVELOCITY PROJECTORS INSTRUMENTED LIGHT-GAS GUN AND TRAVELING CHARGE GUN. Baer, Paul G. and H. C. Smith. Ballistic Research Labs., Aberdeen Proving Ground, Md. In 5th HVIS, Vol. I.

The paper describes the light-gas gun and the traveling charge guns built by BRL. The purpose of these guns was to provide data to check the mathematical models used to predict the performance of the types of guns regardless of dimension.

389. INTERIOR BALLISTICS OF THE NRL LIGHT-GAS GUN. Halperson, Stanley M. and C. D. Porter. Naval Research Lab., Washington, D. C. In 4th HVIS, Vol. II.

This paper shows that projectile velocities of 20,000 ft/sec to 30,000 ft/sec are possible only if optimization of all pertinent parameters is undertaken.

390. INVESTIGATION OF TECHNIQUES FOR OBTAINING MASSIVE HYPERVELOCITY PARTICLES BY ELECTRICAL MEANS. March 31, 1961, Army Rocket and Guided Missile Agency, Huntsville, Ala. ARGMA-ARPA-115-60; SAT SR-2.

The objective of this program is to develop methods for producing very rapidly moving, small, dense agglomerations of matter with masses greater than a microgram and accelerating these agglomerations of matter to velocities in excess of 25 km/sec.

391. LIGHT-GAS GUN AND BALLISTIC RANGE FOR PHYSICS RESEARCH. Dana, T. A. August 15, 1961, General Dynamics/Convair, San Diego, Calif. Report No. Ph-203 M.

A light-gas gun and ballistic charge have been developed at Convair to study hypervelocity phenomena and controlled atmosphere range. Light-gas gun, powder gas guns, shadowgraph system, and velocity measuring instruments are described in detail. The 30-caliber light-gas gun is capable of projecting spheres weighing 1/3 gm at 30,700 ft/sec. The range can be evacuated at 0.1 mm Hg, which will simulate altitudes up 200,000 ft.

392. MACRO-PELLET PROJECTION WITH AN AIR CAVITY HIGH EXPLOSIVE CHARGE FOR IMPACT STUDIES. Kineke, John H., Jr. and Lee S. Holloway. April 1960, Ballistic Research Labs., Aberdeen Proving Ground, Md. BRL Memo Report No. 1264.

A series of high-explosive charges has been developed for projecting steel pellets at velocities sufficiently high for terminal ballistic investigations of hypervelocity crater formation. The air cavity charge suggested by Deas and Zimmerman has been the basis for designing a number of charges projecting pellets whose masses and velocities are statistically reproducible within 3%. Pellet masses range from 0.15 to 8.86 gm and velocities from 1.99 to 5.43 km/sec. Mass determination and velocity measurement techniques are described. These charges are currently being used for extensive and economical hypervelocity crater studies.

393. A METHOD FOR PRODUCING HIGH-VELOCITY METALLIC AND PLASTIC PELLETS. Van Valkenburg, M. E. and Charles D. Hendricks, Jr. 15 October 1954, University of Utah, Salt Lake City. Technical Report No. 2 on Studies of Ionization Created by Fast Moving Objects. ASTIA AD 45,473; Contract DA 04-495-ORD-451, Project No. TB2-0001(845).

Constructional details are given of a propelling mechanism in which a pellet is suspended on oil paper on a metallic rim at a distance from the explosive charge, with the space between the pellet and explosive charge filled with oil or other liquid. Detonation of the charge causes the pellet to be propelled at a velocity of 0.5 to 6 km/sec depending on the mass of the pellet, the cross sectional area of the pellet, the material in the explosive charge, and the type and thickness of the oil.

394. MULTI-PHASE MAGNETIC PROPULSION OF PROJECTILES. Salisbury, Winfield W., Varo Manufacturing Co., Inc., Garland, Tex. In 3rd HVIS.

A magnetic coil accelerator is described using the force due to the displacement of rapidly changing magnetic flux lines around a conductor. Main disadvantages are necessity for very accurate placement of the projectile in the magnetic field of the thrust coil, and the timing problem, which is very difficult for velocities over 1500 ft/sec. This accelerator is in early development stage.

395. A MULTI-STAGE H. E. ACTUATED HYPERVELOCITY GUN. Willig, Frank J. and H. W. Semon. General Electric Co., Missile and Space Vehicle Dept., Philadelphia, Pa. In 3rd HVIS, Vol. I.

An expendable explosive gun designed to be nearly competitive with light-gas guns is briefly described. Gun is in early development stage. No test data are given.

396. A MULTI-STAGE HYPERVELOCITY PROJECTOR. Bengson, M. H., T. K. Slawecki and Frank J. Willig. General Electric Co., Missile and Space Vehicle Dept., Philadelphia, Pa. In 4th HVIS, Vol. I.

The current need for impact information in the 25,000 to 50,000 ft/sec range has developed the requirement for hypervelocity projectors capable of accelerating projectiles to velocities far in excess of those feasible for current gun types. With this problem in mind, the study described in this report explored the feasibility of using a radically different acceleration technique in which a projectile is subjected to repeated accelerations by means of high pressure, high temperature light gas in an electrically-assisted light-gas gun.

397. THE NMSM-NOTS LIGHT-GAS GUN. Allen, William A. Naval Ordnance Test Station, China Lake, Calif. In 2nd HVIS, Vol. I.

Gun development and laboratory technique are described.

398. NOTE ON A LABORATORY APPARATUS TO STUDY THE HIGH-SPEED IMPACT BETWEEN A LIQUID DROP AND A SURFACE. February 1958, Royal Aircraft Establishment, Farnborough, Hants, England. RAE TN MECH ENG 256; ASTIA AD-205,104.

An improved apparatus is described which is being used to study the effects of high-speed impact between a liquid drop and a surface. A compressed gas gun and an arrester tube are arranged on a common axis with a 20-in. gap between the gun muzzle and the entrance to the tube. A drop of water is suspended by means of a fine web in front of the entrance to the tube on the axis of the gun. A projectile, whose nose forms the impact surface, is fired by the gun to strike the drop. After the impact, the projectile enters the arrester tube where it is decelerated without damage to the nose. The gun may be positioned to fire vertically or horizontally. The apparatus has been used at speeds up to 1750 fps. The impact phenomena may be studied conveniently with high-speed photography.

399. NRL HYPERVELOCITY ACCELERATOR (THREE-INCH LIGHT-GAS GUN). Halperson, Stanley M., R. H. Fuller and H. V. Schlemmer. In Report of NRL Progress, August 1962, Naval Research Lab., Washington, D. C.

There is much current interest in techniques to accelerate fragments to velocities comparable to those of missiles and meteoroids. One proposed method of defeating an enemy ICBM during reentry is by fragment impact on a vulnerable section. Damage to spacecraft and satellites by meteoroid impact also is of topical interest. The expendable central section light-gas gun developed at NRL is one of the more useful of the laboratory tools developed to attain very high velocities. Recently a light-gas gun facility designed to accelerate masses from 10 to 40 gm to velocities in excess of 6 km/sec was completed at NRL. Some proof tests have been made, but optimization of loading parameters has not been completed. A maximum velocity of 7.82 km/sec has been reached with a 5 gm mass.

400. THE PERFORMANCE OF THE ARDE HYPER-VELOCITY LAUNCHERS.
Winter, D. F. T. and C. R. Wall. Armament Research and Development Establishment, Fort Halstead, England. In Advances in Hypervelocity Techniques: Proceedings of the Second Symposium on Hypervelocity Techniques. Plenum Press, New York, 1962.

The development of light-gas guns for launching hypervelocity models is reviewed. The ARDE helium-operated two-stage launchers are described, with their associated range equipment. This includes spark shadowgraph stations with photoelectric trigger units, and a passive telemetry system. Examples of aerodynamic and impact tests are presented.

401. PERFORMANCE OF A HIGH-VELOCITY PROPELLANT GUN CONTROLLED IMPACTS.
Graham, R. A. November 1961, Sandia Corp., Albuquerque, N. M. Report No. SC-4652 (RR).

The performance of an extensively modified U. S. Army 40 mm gun for producing controlled impacts is described. Various projectiles in the range of 200 ft/sec to 3200 ft/sec are achieved by varying the amount of a fast-burning propellant. The desired velocity may be varied in small increments. Impact occurs while the projectile is being guided by the bore of the gun, thus facilitating precise alignment between the impacting surface of the projectile and the target specimen. Evacuating the barrel between the projectile and target eliminates undesired air cushioning to insure a step function impact. Projectile velocity measurements are made just prior to impact.

402. PERFORMANCE OF A TWO-STAGE LAUNCHER USING HYDROGEN.
Stephenson, W. B. and R. E. Knapp. March 1962, Arnold Engineering Development Center, Arnold Air Force Station, Tenn. AEDC-TDR-62-32.

A procedure is outlined for computing the performance of two-stage, light-gas launchers using hydrogen as a propellant. A method in general dimensionless terms is developed by which the launch velocity for this type of launcher may be computed. The effects of piston weight and velocity, as well as preheating of the pump tube gas, are determined. Experimental results using both unheated and heated hydrogen are compared with theoretical calculations of velocity. Since the important physical variables - piston mass, velocity, pump tube geometry, initial pump tube pressure, piston reversal, initial projectile movement, and heat losses - are included, a design optimization has been made, and limits to the launch velocity have been estimated.

403. PHOTOGRAPHIC METHOD FOR HYPERVELOCITY MEASUREMENTS. Hall, Donald A. In Journal of the SMPTE, Vol. 62, No. 3, pp. 149-151, March 1959.

A slit camera has been designed to permit reliable velocity measurements in low-pressure chambers too small for ballistic pendulums. At two or more viewing ports along a horizontal trajectory, the shadow of the projectile is cast upon a vertical slit. A reduced image of each slit is focused on a film transported in a standard high-speed camera. Timing marks also are put on the film by means of a flashing strobe light. These, together with the measured displacement between projectile images, permit computation of the velocity. The system appears to be the most satisfactory means of attaining accurate hypervelocity measurements. It has been operated with excellent results over a variety of base lengths and gun sizes.

404. PRACTICAL LOW-COST LIGHT-GAS GUN. Hegge, Edward N. and J. P. McDonough. Watertown Arsenal, Watertown, Mass. In 4th HVIS, Vol. III.

Given is a detailed discussion of operating factors influencing gun performance, but no data on the interactions of projectiles and targets. To measure velocity, the shock from the projectile is allowed to displace a very lightweight bar (soda straw) thereby breaking a circuit. An oscilloscope is used to measure the time between breaking of successive circuits.

405. A SEQUENTIAL ELECTRICAL DISCHARGE-LIGHT GAS GUN. Volpe, Vincent F. and Frank J. Zimmerman. Armour Research Foundation, Chicago, Ill. In 4th HVIS, Vol. III.

This paper describes an experimental light-gas hypervelocity launcher which utilizes electrical discharges to raise the energy level of the propelling gases. The system is unique because the heating occurs during the expansion cycle, thus avoiding many of the problems associated with heating during compression. The addition of energy raises the temperature and, consequently, the pressure, and produces increased velocity.

406. SHAPED-CHARGE HYPERVELOCITY FRAGMENT PROJECTOR STUDY. DEVELOPMENT OF FRAGMENT PROJECTIVE AND INSTRUMENTATION TECHNIQUE. Squier, J. L. September 1961, Aerojet General Corp., Azusa, Calif. Aerojet-0377-01(15)FP; APGC TR-61-42; Contract AF-08(635)975.

Shaped-charge hypervelocity fragment projectors and instrumentation techniques were developed and tested which will permit the gathering of terminal ballistics data for fragments one grain larger in size when they impact targets at velocities between 30,000 to 40,000 ft/sec.

The fragment projectors developed were shaped charges with liners of small apex angle (42°, 30°, 25°, 20°).

This report describes the projectors and their performance, the instrumentation and its operation, and briefly reviews the problems encountered and solutions provided during the development program.

407. SOME CONSIDERATION ON THE PERFORMANCE OF HIGHLY COMPRESSED GASES IN HYPERVELOCITY PROJECTION. Orr, William R., William G. Harrach, Eugene S. Grubin and Arthur M. Krill. Denver Research Institute, University of Denver, Colo. In 4th HVIS, Vol. III.

Studies of equations of state, equations of motion and other related thermodynamic and hydrodynamic phenomena are used to predict the limiting velocity attainable with a light-gas gun to approach 50,000 ft/sec for projectiles of mass approximately 25 grains.

408. STUDY OF ELECTROMAGNETIC GUN. Miller, K. W. and R. M. Bergslien. Armour Research Foundation, Chicago, Ill. In 2nd HVIS, Vol. I.

The three basic types of guns - induction, repulsion and DC parallel rail - are described. Straight acceleration paths are deemed preferable, as opposed to circular paths. Theoretically, electromagnetic fields are capable of accelerating large masses to velocities approaching that of light, but the practical limitations of power supply, structural materials, arcing and skin proximity effects, solenoid timing and sliding contact behavior in DC rail guns set much smaller limits. The homopolar generator and the inverse gun, capacitive electromagnetic energy converters, have promise as possible power sources for the electric gun.

409. STUDY OF METHODS OF PRODUCING HIGH-SPEED PARTICLES. FINAL REPORT. Bergstralh, T., David Meyer Krucoff and J. J. Worcester. November 1959, Aeronutronic Systems, Inc., Glendale, Calif. Publication No. U-698; AFOSR TR 59-181; ASTIA AD-229,718; Contract AF-49(638)366.

Methods were investigated for accelerating, measuring the size and velocity, and measuring the effects of impacts of small particles with diameters in the range of 1 to 100 to velocities of 5 to 10 km/sec. The primary interest in meteoritic impact effect is on missiles, satellites, and space vehicles. The experimental efforts were limited to electromagnetic and light gas gun techniques since the particles involved in meteoritic impact have diameters greater than 1 micron. Two methods of electromagnetic acceleration were studied: (1) the single coil, repulsion solenoid, employing a thin disc as the sabot; and (2) a variant of the exploding wire technique. An adaptation of the single-chamber, directly heated, light gas gun was undertaken.

410. A TECHNIQUE FOR OBTAINING HYPERVELOCITY IMPACT DATA BY USING THE RELATIVE VELOCITIES OF TWO PROJECTILES. Kinard, William H. and Rufus D. Collins, Jr. February 1961, NASA, Langley Research Center, Langley Field, Va. NASA TN D-724; ASTIA AD-251,187.

A facility which uses the relative velocity of projectiles from two facing guns to obtain hypervelocity impact data is described. A 22-caliber light-gas gun is used to launch projectiles toward targets fired from a 37-millimeter powder gun. Results of several preliminary firings are included for an impact-velocity range from 12,050 feet per second to 21,850 feet per second.

411. THE TRAVELING CHARGE GUN AS A HYPERVELOCITY LAUNCHING DEVICE. Baer, Paul G. Ballistic Research Labs., Aberdeen Proving Ground, Md. In 4th HVIS, Vol. II.

The author attempts to demonstrate possibility of launching projectiles without subjecting them to severe acceleration forces (i.e., sufficient to break them up by using a system in which the propellant is attached to the projectile instead of remaining in the gun). With this system, there is no theoretical limit to the velocities which can be achieved.

However, the program is still in the development phases and no workable system has been devised.

412. A TWO-MILLION VOLT ELECTROSTATIC ACCELERATOR FOR HYPERVELOCITY RESEARCH. Friichtenicht, J. F. September 8, 1961, Space Technology Lab., Inc., Canoga Park, Calif. STL Report 9844-00090RU-RO-1.

A two million volt Van de Graaf positive ion accelerator has been modified to accelerate micron-sized charged particles for studies of high speed impact and for micrometeoroid simulation. Modification was accomplished by replacing the ion source by a particle charging and injection system. The particles are contact charged to values resulting in electric field strengths at the surface of the particle of about 2.5 x 10^9 volts/meter. Using iron spheres, final velocities up to 14 km/sec have been observed. Techniques for measurement of particle parameters have been developed and measurements of the focusing properties of the modified accelerator are discussed.

413. THE UTAH LIGHT-GAS GUN. Boyd, W. A., William S. Partridge and Emerson T. Cannon. Utah Research and Development Co., Inc., Salt Lake City and University of Utah, Salt Lake City. In 3rd HVIS.

The University of Utah light gas gun facility is described. No test data are given.

414. WATERTOWN ARSENAL LIGHT-GAS GUN. Hegge, Edward N. and J. P. McDonough. December 1960, Watertown Arsenal Labs., Watertown, Mass. WAL TR 761/64.

A simple, practical, low-cost light gas gun has been developed by the Watertown Arsenal Laboratories to conduct terminal-ballistic studies in the velocity range of 6,000 to 13,000 ft/sec. Standard cartridge cases and propellants are used to propel a lightweight plastic piston to compress the light gas (helium). The light gas is shaped to flow uniformly behind the projectile through the launching tube or rifled barrel by a disposable cone of plastic material which also serves as a buffer to decelerate the piston without appreciable damage to any major structural component. Either full-caliber conventional shear-type projectiles or sub-caliber projectiles, fragments and other irregularly shaped missiles can be fired, the latter by means of plastic-discarding-carrier techniques, in either smoothbored launching tubes or rifled barrels. Firing rates up to 20 rounds per day are easily attained.

SECTION VI. PROCEEDINGS OF SYMPOSIA

415. ADVANCES IN HYPERVELOCITY TECHNIQUES. Krill, Arthur M., Editor. Proceedings of the Second Symposium on Hypervelocity Techniques. Sponsored by University of Denver, Denver Research Institute, March 20 and 21, 1962. Plenum Press, New York, 1962.

This volume contains the proceedings of the Second Symposium on Hypervelocity Techniques, sponsored by the University of Denver, and held March 20 and 21, 1962 at the Cosmopolitan Hotel in Denver, Colorado. Of the thirty-six excellent papers on new developments in the production of hypervelocity environments and on associated instrumentation presented, twenty-eight are included here; others are available as unbound addenda.

Research and development in the hypervelocity regime are significant to so many major scientific and engineering undertakings that the techniques area continues to be a dynamic and expanding one. Every eighteen months it is possible to report an important body of new and exciting advances in the state-of-the-art. It is the object of "Advances in Hypervelocity Techniques" to document suitably this progress.

416. HYPERVELOCITY IMPACT. FOURTH SYMPOSIUM. VOL. I. Held at Air Proving Ground Center, Eglin Air Force Base, Fla., April 26-28, 1960. September 1960, Sponsored by U. S. Army, Navy and Air Force. APGC-TR-60-39 (I); ASTIA AD-244,475.

Contents:

- Hypervelocity Gun for Micrometeorite Impact Simulation Employing Capacitor Discharge in a Condensed Phase.
- An Exploding Wire Hypervelocity Projector.
- Acceleration of Projectiles with the Sequenced High Explosive Impulse Launcher.
- A Multi-State Hypervelocity Projector.
- Electroballistic Techniques.
- Experimental Production of Hypervelocity Pellets by Means of Condenser Discharges in Hydrogen
- The Addition of Electrical Energy to Helium.
- The Flexitron - a New, Short Pulse, High Intensity X-Ray Tube.
- Studies of Hypervelocity Impact on Lead.
- An Experimental Study of Crater Formation in Metallic Targets.
- Hypervelocity Penetration Studies.
- Mechanics of Hypervelocity Impact of Solids.
- Cratering; Experiment and Theory.
- Effects of Target Temperature on Hypervelocity Cratering
- (See also AD 244,276, Vol. II, and AD 244,477, Vol. III).

417. HYPERVELOCITY IMPACT. FOURTH SYMPOSIUM. VOL. II. Held at Air Proving Ground Center, Eglin Air Force Base, Fla., April 26-28, 1960. September 1960, Sponsored by U. S. Army, Navy and Air Force. APGC TR-60-39 (II); ASTIA AD-244,476.

Contents:

A High Explosive Gun Test Range.
The Traveling Charge Gun as a Hypervelocity Launching Device.
Some Considerations on the Performance of Highly Compressed Gases in Hypervelocity Projection.
Effects of Intermolecular Interactions on Thermodynamic Properties of Gases at High Temperatures and Pressures.
The Application of Interior Ballistic Theory in Predicting the Performance of Light Gas Hypervelocity Launchers.
The Comparison Between ORDVAC Predictions for the Performance of a WSL/BRL Light-Gas Gun and Some Experimental Firings.
Interior Ballistics of the NRL Light-Gas Gun.
Practical Low-Cost Light-Gas Gun.
A Hypervelocity Impact System Using the Relative Velocity of Two Projectile Accelerators.
Metallurgical Observations of High Speed Impact.
An Experimental Investigation in Lead of the Whipple "Meteor Bumper."
Volume-Energy Relation from Shaped Charge Jet Penetrations.
The Re-Entry Simulation Range.
Studies of Surface Pitting Due to Alloy Formation at Elevated Temperatures.
Observations of the Phenomena of Hypervelocity Impact.

418. HYPERVELOCITY IMPACT. FOURTH SYMPOSIUM. VOL. III. Held at Air Proving Ground Center, Eglin Air Force Base, Fla., April 26-28, 1960. September 1960, Sponsored by U. S. Army, Navy and Air Force. APGC-TR-60-39 (III); ASTIA AD-244,477.

Contents:

Framing Camera Observations of Ultra-High Velocity Penetration in Transparent Targets and a Mechanism for Crater Expansion.
An Analytical Approach to Hypervelocity Impact Mechanics.
Impact Crater Formation in Rock.
A Model of Oblique Impact.
Further Studies of Micro-Particle Cratering in a Variety of Target Materials.
A Metallurgical Approach to the Hypervelocity Problem.
High-Velocity-Projectile Drag Determination.
Experimental Investigation of Spray Particles Producing the Impact Flash.
An Investigation of Spalling and Crater Formation by Hypervelocity Projectiles.
Ballistic Impacts by Microscopic Projectiles.
The Penetration of Thin Rods in Aluminum.
A Sequential Electrical Discharge-Light Gas Gun.

419. MATERIALS IN SPACE ENVIRONMENT. PROCEEDINGS OF THE FIFTH SAGAMORE ORDNANCE MATERIALS RESEARCH CONFERENCE. Conducted at Sagamore Conference Center, Racquette Lake, N. Y. September 16, 17, 18 and 19, 1958. Co-sponsored by Army Ballistic Missile Agency and the Office of Ordnance Research of the Army. Arrangements by Syracuse University Research Institute, Syracuse, N. Y. SURI MET 597-596; ASTIA AD-205,880.

The papers and proceedings assembled in this report were presented at the Fifth (1958) Sagamore Ordnance Materials Research Conference which was held at Syracuse University's Sagamore Conference Center near Racquette Lake, New York, on Sept. 16, 17, 18, and 19, 1958. The papers presented dealt with the problems of materials in space environments such as may be encountered by space vehicles or orbiting satellites.

420. PROCEEDINGS OF THE FIFTH SYMPOSIUM ON HYPERVELOCITY IMPACT. VOL. I. PART 1 AND PART 2. Held at Denver, Colo., October 30-31-November 1, 1961. April, 1962. Sponsored by the U. S. Army, Navy and Air Force.

Pertinent papers are included in various sections of the Bibliography by title.

421. PROCEEDINGS OF THE FIFTH SYMPOSIUM ON HYPERVELOCITY IMPACT. VOL. II. (U). Held at Denver, Colo. October 30-31-November 1, 1961. April 1962, Sponsored by the U. S. Army, Navy and Air Force. Report SECRET. Abstract SECRET.

422. PROCEEDINGS OF THE NATIONAL SYMPOSIUM ON HYPERVELOCITY TECHNIQUES. Held at Denver, Colo., October 20-21, 1960. Co-sponsored by University of Denver-Denver Research Institute and Institute of Aeronautical Sciences. Institute of Aeronautical Sciences, New York, 1960. For Second Symposium, 1962, see Advances in Hypervelocity Techniques.

423. PROCEEDINGS OF THE RAND SYMPOSIUM ON HIGH SPEED IMPACT (U). Huth, J. H., R. D. Holbrook and H. M. Dye, Editors. May 1955. Held at The RAND Corp., Santa Monica, Calif., 1955. Jointly sponsored by the RAND Corp. and the OSR of the Air Research and Development Command. RAND Report S-34; ASTIA AD-205,808; Contract AF-33(038)6413. Report CONFIDENTIAL. Abstract CONFIDENTIAL.

AUTHOR	REFERENCE

A BIBLIOGRAPHY CONCERNING ASPECTS OF THE METEOROID HAZARD

PART B

SECTION I. FLUX DETERMINATION

1. ALL-SKY METEOR RATES IN THE SOUTHERN HEMISPHERE. Ellyett, C. D. and C. S. L. Keay. In Journal of Geophysical Research, Vol. 66, No. 8, August 1961.

   An extensive experiment has just been completed at Christchurch, New Zealand (43°37'S, 172°24'E), to determine meteor rates over the visible sky, using radar equipment with all parameters maintained at constant values throughout the experiment. Results have been obtained for an unbroken year between February 1, 1960, and January 31, 1961.

2. AN ANALYSIS OF ROCKET AND EARTH SATELLITE MEASUREMENTS OF MICROMETEORITE INFLUX. ACOUSTIC DETECTION OF METEORIC PARTICLES, Volume II, Appendix B. Final Report (Master's Thesis). McCracken, Curtis W. April 14, 1960, Oklahoma State University, Research Foundation, Stillwater. AFCRC TR 60-272, ASTIA AD-240,260; Contract AF 19(604)1908.

   An analysis is presented of the data obtained through the use of micrometeor detection systems mounted on high-altitude rockets and an earth satellite. The analysis is presented as an indication of a major deviation from the results expected on the basis of extrapolations of visual and radar meteor data. Other known data on meteoric influx are introduced to support the micrometeor data and to provide a framework onto which the micrometeor data can be added. The micrometeor data and some of the other available data on meteoric influx are plotted together as particle influx versus particle momentum to get a tentatively revised mass distribution curve.

3. AN ANNOTATED BIBLIOGRAPHY ON INTERPLANETARY DUST. Hodge, Paul W., Frances W. Wright and Dorrit Hoffleit, Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. Smithsonian Contributions to Astrophysics, Vol. 5, No. 8, 1961.

   Three types of dust have been considered as meteoritic dust particles that enter the upper atmosphere as minute dust particles (the zodiacal light may be a source of such); dust products of the disintegration of larger meteoroidal masses during their passage through the atmosphere; and possible pulverized remnants of meteorite impacts. Papers are also included relating to interplanetary dust outside the earth's atmosphere.

4. ARTIFICIAL EARTH SATELLITES AND METEORIC BODIES. Levin, B. Yu. Translation from Meteoritika, Akad. Nauk SSSR, Vol. 18, pp. 20-25, 1960.

This article discusses frequency of recurrence of meteoroids in some detail and disagrees in part with Whipple. The author attempts to take into account effect of earth shielding and other factors on meteor observation data.

5. ASTRONAUTICAL NOTES ON THE PLANETARY SYSTEM. Straly, Warren H., NASA, Marshall Space Flight Center, Huntsville, Ala. Report No. NASA MM-S&M-F-1-60.

This report is intended to be an aid to personnel in the field of astronautics. It is a handbook, compiled from extensive sources, providing pertinent astrophysical and astronautical data about the sun, planets and their satellites, the asteroids, meteorites, comets, and interplanetary and interstellar space. Information about surface intensities, meteoric fluxes, etc. is given for each planet. The text is augmented by 17 tables and 41 figures showing astrophysical data, surface features, opposition and conjunction dates, and plotted velocities and periods.

6. AUTHOR'S REPLY TO THE PRECEDING DISCUSSION ON THE ARTICLE, "THE DISTRIBUTION OF MICROMETEORITES NEAR THE EARTH." Hibbs, A. R., Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. In Journal of Geophysical Research, Letters to the Editor, Vol. 66, No. 8, pp. 2595-2596, August, 1961.

The author says he is making an attempt to clarify some of the misimpressions generated by Mr. Dubin's letter.

7. BETWEEN THE PLANETS. Watson, Fletcher G. Harvard University Press, Cambridge, Mass., 1956.

An excellent basic text which covers the asteroid belt, comets, meteor showers, and meteoritics. Brief discussions of optical and radar meteor observation methods are included.

8. A BIBLIOGRAPHY ON METEORITES. Brown, Harrison. University of Chicago Press, Illinois, 1953.

Approximately 8,600 major reference listings of world literature on meteorites and related subjects published between the years 1941 and 1950 are given. All references are listed chronologically and alphabetically by author, with an author index. A subject index is not included.

9. BOMBARDMENT OF THE EARTH BY METEORS. In Nature, Vol. 179, No. 4551, pp. 121-124, January 19, 1957.

A review is made of the papers presented during the geophysical discussion on "The Bombardment of the Earth by Meteors and Meteorites," held at the Royal Astronomical Society, 15 Nov. 1956. Discussed are meteorites and the results of impacts therefrom (terrestrial and lunar), tektites, and the accretion of meteors and meteorites by the earth.

10. BOMBARDMENT OF THE EARTH BY MICROMETEORITES. In Bulletin de la Societé Astronomique de France, Paris, Vol. 67, pp. 36, 1953 (in French).

11. THE BRIGHTNESS OF THE ZODIACAL BAND AND THE TOTAL MASS OF ASTEROIDAL MATTER. Fesenkov, V. G., September 14, 1949. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC-241939; Translation F-TS-8869/III of Doklady Akademii Nauk SSSR, Vol. 69, pp. 149-152, 1949. ASTIA AD-11,048.

Meteoric matter as it can be observed in the earth's atmosphere is distinguished by the peculiarity that its mass is apparently a constant quantity in each interval of stellar magnitudes. The reduction in the brightness of meteors is entirely compensated by the increase in their number. By adopting this regularity, it will be possible to find the distribution of meteoric particles by size.

12. CATALOG OF HOURLY METEOR RATES. Olivier, Charles P., Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. Smithsonian Contributions to Astrophysics, Vol. 4, No. 1, 1960.

This catalog presents the average hourly rates of visual meteors for each night of the year, based on data for a period of 58 years, from 1901 to 1958 inclusive. About 60 percent of the data summarized here has appeared elsewhere.

13. CATALOGS OF METEOR RADIANTS. Hawkins, Gerald S., Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. Smithsonian Contributions to Astrophysics, Vol. 3, No. 2, 1958.

Denning's historic catalog of 3,035 radiant points has been examined in the light of modern knowledge. The catalogued radiant points show the expected concentration toward the plane of the ecliptic and in addition show a concentration at the declination corresponding to the zenith of the observer. This second concentration is spurious and indicates the percentage of fictitious radiants that have been included, in error, in the catalog. The visual work of Öpik and McIntosh shows more clearly the concentration in the plane of the ecliptic, and the percentage of spurious radiants is considerably reduced. The material had previously been presented as the Concentration of Meteor Orbits in the Plane of the Ecliptic, Interim Report 14, Contract AF 19(122)458. Subcontract 57. Harvard College Observatory, Cambridge Mass., November 1956.

14. A CLASSIFICATION CATALOG OF THE METEORITIC FALLS OF THE WORLD. Leonard, F. C. and de Violini, R. University of California Press, Berkeley, Calif., 1956.

Meteorites are classified into one each of 3 divisions, 7 classes, and 30 subclasses, according to their internal structure and mineral composition. The falls are listed by class and include the name, coordinate number, total known weight, number of known masses, and date.

15. THE CLASSIFICATION OF METEORITES. Leonard, F. C. In Sky and Telescope, Vol. 16, pp. 370-373, June 1957.

Meteorites are classified by composition.

16. COMETS, METEORS, AND MINOR PLANETS. Candy, M. P. In Discovery, pp. 31-35, January 1960.

A summary of orbital data on comets, meteors and minor planets as gathered by means of observations from Earth is presented. The need for rocket research to help determine the hazards from impact with interplanetary material is suggested.

17. A COMPLEX PERSEID SPECTRUM. Millman, Peter M. Publications of the Dominion Observatory, Ottawa, Vol. XV, No. 6. In Sky and Telescope, Vol. XV, No. 10, August 1956.

The Perseid Meteor shower of August 1952 was observed and photographed. A chart was made to provide a key to the photograph.

18. COSMIC SPHERULES AND METEORITIC DUST. Pettersson, Hans. In Scientific American, Vol. 202, No. 2, pp. 123-128, 130, 132, February 1960.

Tiny magnetic spherules found in air and in the ocean beds are thought to be produced when meteors plunge into the atmosphere. Studies of ocean cores indicate that the meteoritic influx has been increasing over the past tens of thousands of years and presently is about five million tons a year.

19. THE DENSITY AND MASS DISTRIBUTION OF METEORITIC BODIES IN THE NEIGHBORHOOD OF THE EARTH'S ORBIT. Brown, Harrison. In Journal of Geophysical Research, Vol. 65, pp. 1679-1683, 1960. Also in Space Research: Proceedings of the First International Space Science Symposium, Nice, France. January 11-16-1960. Kallman Bijl, Hilde, Editor. North-Holland Publishing Co., Amsterdam, 1960.

The author estimated the frequency of meteorite impact upon the earth and moon on the basis of the numbers of observed falls over a period of a century in Japan, India, and Western Europe. All of these areas have had high rural population densities during the entire period. It was recognized, however, that the estimated fall density of 0.32 falls/year/10^6/km^2 was probably low.

Using the term "fall" to denote a meteorite that passes through the atmosphere and, after landing, is large enough to be found and picked up, the total rate of fall upon the earth appears to be about 560 meteorites per year.

20. DENSITY AND MASS DISTRIBUTION OF METEORITIC BODIES IN THE NEIGHBORHOOD OF THE EARTH'S ORBIT. ADDENDUM. Brown, Harrison. California Institute of Technology, Pasadena, Calif. Report No. NSG-56-60. In Journal of Geophysical Research, Vol. 66, No. 4, pp. 1316-1317, April 1961.

21. A DETERMINATION OF THE MEAN-SQUARE DEVIATION OF THE TIME-RATE OF METEORS. Bel'kovich, O. I. In Soviet Astronomy (AJ), Vol. 5, No. 3, pp. 396-398, November-December 1961.

A formula for the mean-square deviation of the observed meteor time-rate is derived and verified experimentally. A method based on dispersion analysis for making a preliminary selection of activity maxima in order to detect possible meteor showers is considered.

22. DIRECT MEASUREMENTS OF INTERPLANETARY DUST PARTICLES IN THE VICINITY OF EARTH. McCracken, Curtis W., W. M. Alexander and Maurice Dubin. December 1961, NASA, Goddard Space Flight Center, Greenbelt, Md. NASA TN D-1174; ASTIA AD 268,455; also in Nature, Vol. 192, No. 4801, pp. 441-442, November 6, 1961 (abridged version).

The direct measurements made by the Explorer VIII satellite provide the first sound basis for analyzing all available direct measurements of the distribution of interplanetary dust particles. The model average distribution curve established by such an analysis departs significantly from that predicted by the (uncertain) extrapolation of results from meteor observations. A consequence of this difference is that the daily accretion of interplanetary particulate matter by the earth is now considered to be mainly dust particles of the direct measurements range of particle size. Almost all the available direct measurements obtained with microphone systems on rockets, satellites, and spacecraft fit directly on the distribution curve defined by Explorer VIII data. The lack of reliable datum points departing significantly from the model average distribution curve means that available direct measurements show no discernible evidence of an appreciable geocentric concentration of interplanetary dust particles.

23. THE DISTRIBUTION OF MICROMETEORITES NEAR THE EARTH. Hibbs, A. R., Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. In Journal of Geophysical Research, Vol. 66, No. 2, pp. 371-377, February 1961; also in IGY Satellite Report No. 14, pp. 187-193, National Academy of Science, Washington, D. C. IGY World Data Center A: Rockets and Satellites, July 1961.

Impacts of micrometeorites recorded by the artificial satellite Explorer I in February 1958 have been examined statistically to determine their distribution with latitude, altitude, and longitude relative to the Satellite-Earth-Sun angle (satellite local time). The latitude distribution shows an interesting peak near the equator, which is, however, not statistically significant. The distribution in longitude relative to the Satellite-Earth-Sun angle corresponds to an altitude distribution and apparently contains no information that is not better shown in this latter distribution. With suitable analysis, the altitude distribution yields information on the velocity of the particles relative to the center of the earth. The conclusion is that the average particle measured by Explorer I was in a closed orbit around the earth rather than an impact trajectory from a great distance to the surface of the earth.

24. THE DISTRIBUTION OF THE ORBITS OF SPORADIC METEORS. Weiss, A. A. In Australian Journal of Physics, Vol. 10, No. 1, pp. 77-102, March 1957.

The directions of the reflection points of sporadic meteor trails for March and September 1953, and the hourly echo rates of sporadic meteors obtained from the Adelaide radio survey of meteor activity over 1952-1956 are analyzed. Diurnal and annual variations in the sporadic echo rate are predicted from contemporary theory on the reflection of radiowaves from meteor trails for several model distributions. A sporadic distribution is derived which consists of a concentration of direct short-period orbits to the plane of the ecliptic superimposed upon a more uniform distribution of near-parabolic orbits. This distribution is consistent with the results of radar, visual, and telescopic surveys in the northern hemisphere. The density of sporadic meteors around the earth's orbit is also derived.

25. DIURNAL VARIATIONS IN THE NUMBER OF SHOWER METEORS DETECTED BY THE FORWARD-SCATTERING OF RADIO WAVES: PART III. ELLIPSOIDAL THEORY. Hines, C. O. In Canadian Journal of Physics, Vol. 36, No. 117, 1958.

A theory of meteor "observability" relating to forward-scatter radio experiments was developed in Part I of this series with the use of a simplifying "cylindrical approximation." The application of the theory to data obtained during meteor showers provides a promising new method for studying the intrinsic strengths of the showers. The principal limitation of the method is due to the inaccuracies of the cylindrical approximation. In the present paper, these inaccuracies are removed by a full development of the ellipsoidal geometry inherent in the forward-scatter process. The more rigorous results are compared with the approximate results at various stages throughout the analysis.

26. DUST AND METEORITES. Whipple, Fred L., Smithsonian Astrophysical and Harvard College Observatories. ARS Preprint 2253-61, American Rocket Society, New York. Also in Astronautics, Vol. 7, No. 8, pp. 40-42, August 1962.

With considerable assurance we may now visualize the small, particulate matter of the solar system as originating primarily in comets, distributed originally from typical comet orbits, with a considerable concentration toward the plane of the ecliptic. At the time of injection from the nuclei of comets, the particles are highly concentrated near the orbits of the comets. A quasi-equilibrium condition is maintained by the occurrence of new comets and the dissipation of the particles by a number of effects including small injection velocities from the cometary nuclei, light pressure, Poynting-Robertson effect (solar-radiation drag), planetary perturbations and encounters, sputtering effects, sublimation effects from solar radiation, and a major effect of breakage, disruption and some vaporization by mutual collisions among the small particles themselves. The Zodiacal Light testifies to the existence of this stream of particles and is one of our major sources of information concerning the fine dust.

27. THE EARTH AND ITS ATMOSPHERE. Bates, David Robert, Editor. Basic Books, Inc., Publishers, New York, July 1957.

Some general discussion is included on micrometeorites. Chapter 15 by A. C. B. Lovell entitled "Meteors" is of special interest.

28. ENLARGED SESSION OF THE BUREAU OF THE COMMITTEE ON METEORS AND COMETS OF THE ASTRONOMIC COUNCIL AND SSSR. Fedinskiy, V. V. May 18, 1952, Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC-242103, Translation F-TS-8834/III from Astronomicheskii Zhurnal, Vol. 30, pp. 115-116, 1953; ASTIA AD-111,024.

At this session it was shown that systematic visual observations of the spectra of meteors had been initiated for the first time. The visual observations and photographs obtained in the preceding years are now being systematically worked up.

29. THE ENVIRONMENT OF A SATELLITE. National Aeronautics and Space Administration, Washington, D. C. Report No. NASA, 15 September, 1959.

This report summarizes the present state of knowledge about the upper atmosphere from the data gathered by rockets and satellites that were sent up during and after the IGY. The authors concern themselves only with what is incident to the outer skin of a satellite and its vehicle. Included in this report are sections on atmospheric structure, atmospheric composition, and the electromagnetic spectrum.

30. THE ENVIRONMENT OF AN EARTH SATELLITE. Griffith, R., W. Nordberg and W. G. Stroud. March 30, 1956. Revised November 15, 1956. Signal Corps Engineering Lab., Fort Monmouth, N. J. Report No. Technical M-1747; ASTIA AD-121,408.

Contents:

- I. Mechanical-Thermal Considerations
  - A. Aerodynamics of the object
  - B. Vibration, acceleration, and spin
  - C. Radiative equilibrium temperature of the satellite
- II. Composition of the Atmosphere
- III. Properties of the Ionosphere
- IV. Radiation at High Altitudes
  - A. Solar X-rays
  - B. Ultraviolet (far and near ultraviolet)
  - C. Infrared and visible spectrum
  - D. Airglow intensities
  - E. Cosmic rays
  - F. Variation of g with height
  - G. The earth's magnetic field
  - H. Temperature, pressures, densities, and wind
  - I. Micrometeorites and meteorites.

31. THE FALLOUT OF METEORIC IRON PARTICLES. Freiken, E. A., Ankara University, Astronomical Institute, Ankara, Turkey. In Planetary and Space Science, Vol. 2, No. 1, pp. 38-48, October 1949.

This paper is a survey of the attempts made at the Astronomical Institute of the Ankara University to determine the daily amounts of the fall-out of iron particles of meteoric origin, to study the seasonal variations of the fall-out, and to compare the curve representing these seasonal variations in meteoric activity. The results obtained are critically discussed and possibilities for improving the method of observations are indicated.

32. A FEW PROBLEMS OF METEORITICS. Fesenkov, V. G. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Translation F-TS-8940/III, 1955, from Meteoritika, Akad. Nauk SSSR, Vol. 8, pp. 38-54, 1950. ASTIA AD-120,698.

The problems of meteoritics are closely associated with meteoric astronomy, which stands today before the possibilities of most exceptional development due to the introduction of a new technique based on the use of radar.

Although certain investigators abroad continue to maintain that considerable portions of all observed meteors are streams of cosmic meteors passing at hyperbolic velocities through the solar system, these cosmic streams are without doubt fictitious. The meteors observed by us move along elliptical orbits and belong to the solar system.

33. THE FREQUENCY OF FAINT METEORS. In Journal of Royal Astronomical Society of Canada, Vol. 50, No. 2, pp. 90, 1956.

A rate of 12-25 per hour for non-shower nights of meteors of magnitude ~12.5 (limit of visibility) is reported.

34. FREQUENCY OF METEORITE FALLS THROUGHOUT THE AGES. Gallant, R., London, England. In Nature, Vol. 193, No. 4822, pp. 1273-1274, March 31, 1962.

A controversy is described which exists between several astronomers as to whether or not meteorites fell on the earth before the pre-late Quaternary period.

35. GEOPHYSICAL DISCUSSION ON "BOMBARDMENT OF THE EARTH BY METEORS AND METEORITES." From Proceedings of the Royal Astronomical Society Meeting, November 1956. Speakers: Bardi, H., J. G. Davies and H. H. Hey. In Observatory, Vol. 76, pp. 219-225, 1956.

Various aspects of micrometeorite accretion are considered. Among them are the catching of dust particles in trays and study of the oceanic sediments (suggesting a deposition of 10^{6} tons per year for the whole earth).

36. THE HARVARD PHOTOGRAPHIC METEOR PROGRAM. Whipple, Fred L. In Sky and Telescope, Vol. VIII, No. 4, February 7, 1949.

The program will give information on the radiance, velocity and deceleration of individual meteors down to the 12th magnitude. A short resumé of the plans at Harvard College Observatory, Cambridge, is given.

37. THE HARVARD RADIO-METEOR PROGRAM. Hawkins, Gerald S., Curtis L. Hemenway and Fred L. Whipple. In Astronomical Journal, Vol. 61, No. 1233, pp. 179, May 1956.

The program will give information on the radiance, velocity, and deceleration of individual meteors down to 12th magnitude. A short resumé of the plans at Harvard College Observatory, Cambridge, is given.

38. HAZARDS OF METEOROID STREAMS. Blizard, Jane B., Martin-Marietta Corp., Denver, Colo.

39. IMPACT EFFECTS AND TEKTITES. Rinehart, John S. October 30, 1957, Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. Air Force Office of Scientific Research, ARDC, Washington D. C. Report No. AFOSR TN-57-659; ASTIA AD-136,652; Contract AF 18(600)1596.

Data on the composition, form, and distribution of tektites are examined in the light of our knowledge of high speed impact phenomena to see how strong the evidence is for an impact origin. It is concluded that tektites could be of impact origin, but the arguments are inconclusive. A strong argument against such an origin is the lack of nickel-ferrous materials within the tektite.

40. THE INCIDENCE OF METEOR PARTICLES UPON THE EARTH. Weiss, A. A. In Australian Journal of Physics, Vol. 10, No. 3, pp. 397-411, September 1957.

The incident flux of meteors above limiting brightness of $M_r < 7.5$ is calculated. Mass and density relations are also considered, and the total amount of meteoric matter falling on the earth per day within mass limits of 10^{-1} to 10^{-4} g is estimated.

41. THE INFLUX RATE OF METEORS IN THE EARTH'S ATMOSPHERE.
Hawkins, Gerald S. and Edward K. L. Upton, June 18, 1958. In The Astrophysical Journal, Vol. 128, No. 3, pp. 727-735, November 1958.

Photographic observations obtained with Super-Schmidt cameras are used to determine the rate of incidence of meteoric particles on the earth's upper atmosphere. The rate is expressed as a function of the photographic and visual magnitude of the meteor, the electron line density of the trail, and the mass of the original meteoroid. It is shown that the number of the meteors increased by a factor of 3.4 ± 0.2 per magnitude. The total number of meteors brighter than a visual magnitude of +5 which enter the atmosphere in 24 hours is 20 million.

42. INTER-PLANETARY DUST AND TERRESTRIAL ACCRETION OF METEORIC MATTER.
Öpik, Ernst J. In Irish Astronomical Journal, Vol. 4, No. 3/4, pp. 84-135, 1956.

The properties, amount, and terrestrial accretion of interplanetary dust are critically reviewed. Solid particles in interplanetary space will carry an electrostatic charge of the order of 200 volts, caused by the photo-electric effect of the solar corona. The inferior limit of radius for metallic particles in interplanetary space is 7.2×10^{-6} cm as determined by radiation pressure, and 1.9×10^{-5} cm for compact stone fragments as depending upon the disruptive force of electrostatic charge. "Dustballs" or "stone-flakes," such as prevail among meteors of the visual range, cannot have radii of less than 1.9×10^{-3} cm, for the same reason. The actual radii of dustball grains are probably about 0.02-0.03 cm.

43. INTERPLANETARY DUST NEAR THE EARTH. Singer, S. Fred, Maryland University, College Park. In Nature, Vol. 192, No. 4300, pp. 321-323, October 28, 1961.

The problem of gravitational accretion of interplanetary dust by a planet has recently been the subject of renewed attention. In particular, the possibility of observing dust impacts experimentally at various distances from the center of the earth by means of rockets, satellites and space probes has stimulated an inquiry into the concentration of dust around the earth.

44. INTERPLANETARY MATTER. Hoffmeister, C. In Naturwissenschaften, Vol. 38, No. 10, pp. 227-234, 1951 (in German).

Interplanetary material may be broadly classified according to the phenomena associated with each of 6 classes of bodies, whose sizes range from 10^7 to 10^{-6} cm, viz., class I (particle size, 10^7-10^5 cm), comprises the minor planets; class II (10° - 10^{-2} cm), planetary meteorites; class III (10^{-1} - 10^{-3} cm), the zodiacal light; class IV (~ 10^{-2}), the solar corona; class V (< 10^{-2} cm), striated structure of the night sky; class VI (10^{-6} cm), luminous night clouds. Compared with the mean density of interstellar matter (10^{-25} to 10^{-26} g cm^{-3}), interplanetary material attains densities of 10^{-21} g cm^{-3} in the neighborhood of the earth's orbit, and 10^{-17} g cm between the orbits of Mars and Jupiter.

45. INVESTIGATION OF METEORIC PARTICLES ON THE THIRD SOVIET SATELLITE. Nazarova, T. N. In American Rocket Society Journal, Vol. 31, No. 9, pp. 1314-1344, September 1961; and in Planetary and Space Science, Vol. 8, No. 9, pp. 82-85, November 1961. Translated from Artificial Earth Satellites, No. 4, pp. 165-170, Academy of Sciences, USSR, Moscow, 1960.

Brief review of the article states that it is generally conceded that measurements of meteoric particles are among the most difficult and uncertain of satellite experiments. Much more research is needed.

46. INVESTIGATION OF THE SOLID COMPONENTS OF INTERPLANETARY SPACE BY MEANS OF ROCKETS AND ARTIFICIAL SATELLITES. Poloskov, S. M. and T. N. Nazarova. In Uspekhi Fizicheskikh Nauk SSSR, Vol. 63, No. 1B, pp. 263-265, September 1957 (in Russian). Also in AEC TR-3973, Part 1, 1960.

Review article concerned particularly with the determination of the flux of meteorite particles and with the determination of their kinetic energy or momentum.

47. THE LUNAR SURFACE OF AN IMPACT COUNTER. Öpik, Ernst J. In Monthly Notices of Royal Astronautical Society, Vol. 120, No. 5, pp. 404-411, July 1, 1960.

The dust cover of the moon sticks to mountain slopes and cannot possess any degree of fluidity. It is probable that only a limited migration of the dust from the slopes into adjacent valleys takes place, caused by meteor bombardment. The material of the micrometeors cannot escape from the moon and is expected to form a layer of the order of 40 gr/cm^2, accumulating over the maria and protecting them from further erosion by small meteors.

Large meteorites are not stopped by the dust and produce meteor craters. At a velocity of 20 km/sec the ratio of crater to projectile diameter estimated to be about 20.812 crater diameters, measured over an area of 465,000 km^2 in Western Mare Imbrium, shows a frequency distribution which is close to that predicted from the present population of interplanetary space and time interval of 4.5×10^9 years. It is concluded that since the formation of Mare Imbrium the population of interplanetary space has not changed appreciably; a tentative explanation is given.

48. THE MASS OF THE ATMOSPHERIC TRACE OF THE SIKHOTE´ALIN METEORITE. Fesenkov, V. G. Translated by E. R. Hope, June 8, 1954. Defense Scientific Information Service, DRB, Canada. Translation T-133R from Doklady Akad. Nauk SSSR, Vol. 66, No. 3, pp. 359-360, 1949. ASTIA AD-50,270.

A study was made of the details of the Sikhote´Alin Meteorite's motion in the atmosphere. The following data was considered: the particles of the trace consisted practically of pure iron, the volume of the trace amounted to about 70 km^3, the width of the trace in its middle part was 1.5 km, and the diameter of the incandescent head of the meteorite was about 630 m.

49. METEOR ANALYSIS PROJECT AT THE HARVARD COLLEGE OBSERVATORY. Jacchia, Luigi G. June 15, 1954, Harvard College Observatory. Cambridge, Mass., Status Report 5, March 1-May 31, 1954; ASTIA AD-34,111; Contract DA 19-020-ORD-2556.

Geometric reductions were completed for 95 meteors. There is evidence that faint meteors break up into fragments of comparable size almost as soon as they become bright enough to be photographed. A theory is proposed which appears to explain the following features peculiar to faint meteors: the anomalous decelerations; anomalous light curves; irregularities in light curves; sudden appearance and attainment of maximum brightness, followed by slow fading to invisibility; progressive elongation of the exposed segments of the meteor trail; and the fact that not all faint meteors show anomalous decelerations and yet have normal durations and light curves. Photographic meteor observations can be employed to derive empirical corrections to account for progressive fragmentation.

50. METEOR ANALYSIS PROJECT AT THE HARVARD COLLEGE OBSERVATORY. Jacchia, Luigi G. September 15, 1954, Harvard College Observatory, Cambridge, Mass. Status Report No. 6, June 1, 1954-August 31, 1954; ASTIA AD-51-269; Contract DA-19-020-ORD-2556.

Geometric reductions were completed for 115 meteors. Sixteen additional meteors are being processed through the steps of measurement and amputation. The possibilities of mechanizing part of the meteor reductions through the use of punched-card calculating machines are being studied. A considerable gain in out-put is expected. Basic data for 75 Super-Schmidt meteors have been collected for publication.

51. METEOR OBSERVATIONS WITH AN IMAGE ORTHICON. Spalding, I. John and Curtis L. Hemenway. In Astronomical Journal, Vol. 66, No. 2, pp. 54, 1961.

52. METEOR SCIENCE AND ENGINEERING. McKinley, D. W. R. McGraw-Hill Book Co., Inc., New York, 1961.

This is a summarization of the major observational theoretical developments in meteor science and includes a historical survey of meteors, astronomical aspects of meteors and good discussions of the visual photographic and radar observation methods.

53. METEORIC DUST EROSION PROBLEM AND ITS EFFECT ON THE EARTH SATELLITE. Hoenig, S. A. In Aeronautical Engineering Review, Vol. 16, pp. 37-40, July 1957.

The problem is presented and previous work done is reviewed. The effects of meteoric impact and recent experiments on penetration are discussed. It is indicated that for short-lived vehicles the hazard is negligible.

54. METEORIC EFFECTS ON LONG RANGE AND ORBITAL VEHICLES. Naumann, Robert J. September 27, 1957, Army Ballistic Missile Agency, Redstone Arsenal, Ala. ABMA DS TN-94.

There is much speculation on meteoric effects on space and orbital vehicles. However, due to the uncertainty of theoretical assumptions, the problem cannot be accurately evaluated. On the other hand, by employing the most pessimistic reasonable assumptions, an upper limit on the problem can be set until more accurate information is available from actual satellite experiments. It is the purpose of this report to compare work by Whipple (1957) with earlier estimates and to derive analytical expressions and procedures whereby these estimates may be applied to various satellites.

55. METEORIC HAZARDS TO SPACE FLIGHT. Langton, N. H. In Engineering, Vol. 185, pp. 164, February 7, 1958.

This brief summary entitled "Collisions in Space," reviews the article "Meteoric Hazards to Space Flight," a talk delivered by Dr. Langton at a meeting of the British Interplanetary Society in 1958. See also entry 186 in Part A of the Bibliography.

56. METEORIC MATTER AND SOME GEOPHYSICAL PROBLEMS OF THE UPPER ATMOSPHERE. Mirtov, B. A. In American Rocket Society Journal Supplement, Vol. 32, No. 1, pp. 143-151, January 1962. Translated from Artificial Earth Satellites, No. 4, pp. 118-134, Academy of Sciences, USSR, Moscow, 1960.

In this paper an attempt is made to connect the occurrence of certain phenomena in the upper atmosphere with the presence in the atmosphere of fast-flying particles of meteoric origin. It should be noted that the part played by meteoric matter in the existence of the upper atmospheric layers has not been sufficiently studied. The reason for this has been the great difficulty of investigating the finely dispersed meteoric substance entering into the relatively dense layers of earth's atmosphere (100 km and higher). Consequently, the experiments conducted by the artificial earth satellites (1, 2, 3) carried out over an extended period of time should provide, together with the usual meteoric observation methods (photography) and radiosonde, very important data for an understanding of the relationship between meteoric material and earth's atmosphere.

57. METEORIC RADIO ECHOES. Manning, Laurence A. July 15, 1953, Stanford University, Electronics Research Lab., Stanford, Calif. Technical Report No. 66; ASTIA AD-16,402.

Study of meteoric effects by radio methods has resulted in gain of three fields - astronomy, upper atmosphere physics, and radio propagation. In each of these fields progress is surveyed, and some of the more important unsolved problems are pointed out.

58. METEORITE ENVIRONMENT. Frost, V. C. November 1, 1960, Northrop Corp., Norair Div., Hawthorne, Calif. Report No. RAS-139.

59. THE METEORITE ENVIRONMENT. Mustain, R. W. In Proceedings of Institute of Environmental Sciences, National Meeting, Los Angeles, Calif., April 6-8, 1960.

This paper summarizes the potential hazards of extraterrestrial materials to a space vehicle traveling within the solar system. The problem encompasses two categories of "space debris": puncture type elements and dust particles. Information needed concerns origin, distribution, size, composition, velocity and daily influx of particles. With this data the probability that these materials will impinge upon interplanetary rockets and the concomitant probability of structural and/or puncture type damage can be considered.

60. I. METEORITI. Timpone, Francesco. In Rivista Aeronautica, Vol. 36, No. 9, pp. 1423-1431, Sept. 1960 (in Italian).

A general description of macro- and micrometeorites in terms of size, composition, distribution in space, and impact effects is given.

61. METEORITIC DUST. Hoffleit, Dorrit. In Sky and Telescope, Vol. 10, No. 115, pp. 173, 1951.

This is a review of the book, "Meteoritic Dust," by John Davis Buddhue. See entry number 207, in Part B of the Bibliography.

62. METEORITIC DUST AND GROUND SIMULATION OF IMPACT ON SPACE VEHICLES. Robey, Donald H. General Dynamics/Astronautics, San Diego, Calif. In Journal of the British Interplanetary Society, Vol. 17, No. 1, pp. 21-30, January-February 1959.

A general discussion of meteoritic dust is presented, and deductions pertaining to the physical properties and probable speeds are given. It is believed that a large portion of atmospheric dust is generated in the atmosphere by the disintegration and ablation of meteors. Thus, the siliceous and magnetic spherules, which are found on the ground, are believed to originate at meteor altitudes from vaporized meteorites. A large quantity of smaller sized dust is believed to be cometary, either arriving directly from comets, etc., per se, or indirectly from exploding or disintegrating meteoroids. The possibility that a portion of the flux of meteoroids may contain a sizeable percentage of frozen molecular fragments has influenced the results. For example, from this hypothesis, the possibility of a dust cloud surrounding the earth and extending out for several thousand miles has been suggested. Also, the correlation between prominent meteor showers and excessive rainfall, snow cover and cirrus cloud, can be explained on this basis. Finally a proposal for accelerating dust particles to speeds of 10 miles per sec and possibly up to 10 miles per sec in vacuo, is presented.

63. THE METEORITIC HAZARD OF THE ENVIRONMENT OF A SATELLITE. Duberg, John E. May 1962, NASA, Langley Research Center, Langley Field, Va. NASA TN D-1248.

A review of the current knowledge of meteorites, their composition, and frequency of occurrence is presented. A meteoroid flux as a function of mass that has been proposed by Whipple is compared with the direct measurements obtained to date by rockets, satellites, and space probes. On the assumption of a Poisson distribution for the probability of impacts and a penetration law which represents a mean of those proposed for high-velocity impact, the probability of penetration of earth-satellite surfaces is obtained.

64. METEORITIC PHENOMENA AND METEORITES. Whipple, Fred L. In Physics and Medicine of the Upper Atmosphere: Proceedings of a Symposium on the Physics and Medicine of the Upper Atmosphere, San Antonio, Tex., 6-8 November, 1951. University of New Mexico Press, Albuquerque, N. M., 1952.

Given is a thorough discussion of: (1) the contents of interplanetary space; (2) meteors and the upper atmosphere; and (3) meteoritic penetration of high-altitude vehicles. Generally speaking, the hazards from meteoritic penetration to vehicles and occupants at extremely high attitudes are minor in comparison with other recognized hazards.

65. THE METEOROID HAZARD AND ITS SIMULATION. Hopkins, Alan K. March 15, 1962, Air Force Systems Command, Aeronautical Systems Div., Wright-Patterson AFB, Ohio.

One of the hazards encountered by vehicles operating in space is the presence of solid particles having velocities ranging from zero to ninety kilometers per second with respect to the vehicle. Outlined herein is the research completed to date, including recent meteoroid distribution data and probabilities of vehicle skin penetration.

The nature of the problem is presented, as well as methods so far developed and proposed for accelerating particles to the super-velocities desirable for experimentation. The most significant breakthrough in accelerating macro-particles to above twenty kilometers per second is discussed. The observations and analyses of particle impact effects are covered including energy partition, penetration and spallation.

66. THE METEOROID HAZARD TO SPACE TRAVEL. Martin, Henry L. August 5, 1959, Army Ballistic Missile Agency, Huntsville, Ala. Report No. ABMA DV-TN-22-59.

This report discusses the nature and distribution of meteoroids in space, satellite meteoroid data, the effects of meteoroid impact on space vehicles, laboratory simulation of the effects of meteoroid impact, and protective measures against meteoroids.

67. METEOROIDS. Barton, J. A., Boeing Airplane Co., Aero-Space Div., Seattle, Wash. Report Memo 2-5475-60.

A summary of the whole field of the meteoritic environment of space and the problem of hypervelocity impact is contained in the memorandum.

68. METEOROIDS AND THEIR INFLUENCE ON MATERIALS. Atkins, J. H., R. L. Bisplinghoff, J. L. Ham, E. G. Jackson and J. C. Simons, Jr., National Research Corporation, Cambridge, Mass. In Effects of Space Environment on Materials, December 1960. WADD TR 60-721; ASTIA AD-254,075; Contract AF 33(616)6288.

The nature of the meteoroid environment and the effects of this environment on materials are briefly discussed. Suggestions are made for future research projects.

69. METEOROIDS AS A HAZARD IN SPACE FLIGHT. A SURVEY OF PRESENT INFORMATION. Thompson, A. B. and Charles F. Gell. 1961, Astronautics Div., Chance Vought Corp., Dallas, Tex. American Rocket Society, N. Y. ARS Paper 2138-61.

This is a review of present knowledge of meteoritic material in space, based on satellite, rocket, radio and visual sources. Results of hypervelocity impact tests are analyzed to better define penetration relationships for development of a meteoroid risk probability. The effects of meteoroid penetration into manned space cabins are deduced, based on animal tests, and a brief review is made of the effectiveness of various wall structures for reducing possible penetration.

70. METEOROIDS, METEORITES, AND HYPERBOLIC METEORITIC VELOCITIES. LaPaz, Lincoln. In Physics and Medicine of the Upper Atmosphere. Proceedings of Symposium on the Physics and Medicine of the Upper Atmosphere, San Antonio, Tex., 6-9 November 1951. University of New Mexico Press, Albuquerque, 1952.

Contents:

- Introduction: Summary of Results
- The Inverse Acceleration Problem in Meteoritics.
- The Extra-Atmospheric Velocity of Meteoroid No. 660.
- The Velocity of the Prambachkirchen (Austria) Aerolite.
- The Velocity of the Pultusk (Poland) Meteorite.
- The Velocity of the Treysa (Germany) Meteorite.
- The Velocity of the Kybunga (Australia) Meteorite.
- Classification and Ballistic Potential of the Cosmia Material Encountered by the Earth.
- Investigation of Impact Damage and Other Aspects of Meteorite Falls.

71. METEOROIDS VERSUS SPACE VEHICLES. Bjork, Robert L. April 4, 1960, The RAND Corp., Santa Monica, Calif. Presented at the Semi-Annual Meeting and Astronautical Exposition of the American Rocket Society Meeting held in Los Angeles, Calif., May 9-12, 1960. RAND Report P-1963. Also in American Rocket Society Journal, Vol. 31, No. 6, pp. 803-807, June 1961. See entry 409 in Part B of the Bibliography.

This is a discussion of the effects that meteoroids are expected to have on space vehicles. Current knowledge of meteoroid flux rate, mass, velocity, density, and impact effects is summarized. The preliminary designs of space power station radiators, as well as the examples given, indicate that the weight penalty imposed by estimates of the meteoroid hazard is large enough to warrant research on its reduction. Several promising areas of research that may lead to lighter-weight designs are investigated.

72. METEOROLOGICAL ABSTRACTS AND BIBLIOGRAPHY. Rigsby, M., Editor. American Meteorological Society, Boston, Mass., Vol. 8, No. 8, August 1957. ASTIA AD-161,864; Contract AF 19(604)2062. Available from American Meteorological Society. Special Feature; Recent Literature of Meteors and Zodiacal Light by Mary L. Rice.

73. 294,000 METEORS. Olivier, Charles P. In Sky and Telescope (News Notes) Vol. 20, No. 4, pp. 189, October 1960.

This is a brief reference to meteor counts made from 1901 to 1958 by C. P. Olivier and to his catalog. For Basic see entry 12 in Part B of Bibliography, "Catalog of Hourly Meteor Rates," by C. P. Olivier.

74. METEORS. Kaiser, T. R., Editor. In Proceedings of Symposium on Meteor Physics, Jodrell Bank Experimental Station, July 1954. Special Supplement (Vol. II) to Journal of Atmospheric and Terrestrial Physics. Pergamon Press, New York, 1955.

This book contains a collection of 30 papers which were read at the symposium on meteor physics held at Jodrell Bank Experimental Station in July 1954. The subjects treated include meteor ablation, luminosity, ionization, spectra collision processes, radio echoes, masses, space density drift, zodiacal dust cloud and orbits as determined photographically or by radio. Effects on ionosphere and upper air data are obtained from meteors, pressure, winds, and height.

75. METEORS AND METEORITES. In Transactions of the International Astronomical Union. Vol. 10. Meeting held at Moscow, August 13-20, 1958. Sadler, D. H., Editor. Cambridge University Press, London, 1958.

Great progress has been made in the physical theory of meteors, although many unknown parameters permit different interpretations of the new theories. I.G.Y. measurement directly in the meteor surroundings (artificial satellites and meteors) will contribute to the removal of the fundamental discrepancies which exist today. We shall then know even better the interaction between the atmosphere and meteors.

A detailed description of results obtained is presented.

76. METEORS AND SPACE FLIGHT. Langton, N. H. In Spaceflight, Vol. I, No. 3, pp. 92-100, April 1957.

Approximately 75 x 10^{16} meteors are consumed in our atmosphere daily, the great majority of which are of negligible size and mass; however, they are capable of erosive effects when their velocities are considered. The chance of a collision taking place with a meteorite larger than a grain of sand during space journeys of a few weeks duration is very small. However, the number of collisions with small particles would be large, and after several hours the accumulation of damage might become serious. In order to properly protect the space vehicle, it will be necessary to utilize meteor bumper screens, preferably fabricated from chrome steel. Protection against larger meteorites (with which the chance of collision is very small) is not presently feasible due to extreme weight penalties imposed by thickened hulls or bumper screens.

77. METEORS AND SPACE TRAVEL. Ovenden, Michael W. In Journal of the British Interplanetary Society, Vol. 10, pp. 175-180, July 1951.

After discussion of meteor and interstellar dust observations, the statement is made "that as far as present observation can tell us, dangers to an interstellar rocket of collision with interstellar dust particles are negligible."

78. METEORS AS PROBES OF UPPER ATMOSPHERE. Whipple, Fred L., Harvard College Observatory, Cambridge, Mass. In Compendium of Meteorology. Malone, Thomas F., Editor. American Meteorological Society, Boston, Mass., 1951. ASTIA AD-22,102.

A survey is presented of atmospheric research based on visual observations, photographic meteor studies, and radio meteor studies.

Average visual meteors, which become observable at about 100 to 110 km with a large scatter and persist to 90 km or lower, indicate an annual fluctuation of the height of the atmosphere, which roughly corresponds to the annual temperature curve, of a 3.7 ± 0.7 km total amplitude. From a study of meteor trains, the average wind velocity was calculated as 203 km/hr. 182 km/hr for night trains whose heights were assumed, and 173 km/hr for day or twilight trains. Preferential directions of drift appeared for various areas of the earth. A comparison of atmospheric densities, as derived from photographic meteors with densities of the NACA atmosphere, revealed residuals with a strong seasonal correlation. This effect appeared to decrease with increasing height, and became quite small and uncertain around 100 km. A method of observing high-altitude winds by radio meteors indicated that an important fraction of sporadic-E ionization arises from other than meteoric sources, and that the ionization normally produced by meteors is trivial compared to normal daytime E-layer ionization.

79. METEORS IN THE UPPER ATMOSPHERE. DeJager, C. In Nederlands Tijdschrift voor Natuurkunda, Vol. 15, pp. 193-202, August 1949 (in Dutch).

A brief survey of the theory of meteoric phenomena is followed by a discussion of methods of observation and the conclusions derivable as to the constitution of the upper atmosphere. A description is also given of certain electronic techniques for the observations of meteors, and of results which have been obtained.

80. METEORSTROME. Hoffmeister, C. Weimer, Germany, 1948.

This book covers valuable experimental data of artificial meteors from which observational errors in position, magnitude, and velocity are derived. A major attempt is made towards a separation of the chief statistical components of the meteoric phenomenon - the elliptical, the cometary, and the interstellar meteors.

81. MICROMETEORITE DISTRIBUTION NEAR THE EARTH. Martin, Henry L. February 1, 1961, NASA, Marshall Space Flight Center, Huntsville, Ala. Report NASA MTP-M-RP-61-2.

This report discusses the concentration or impact frequency of micrometeorites in space near the earth, their minimum mass distribution, their penetration into aluminum and steel, the 95% probability of no penetrations, and erosion depths.

82. MICROMETEOROITES. Vedder, J. F. In Satellite Environment Handbook, Johnson, Francis S., Editor. Missile and Space Div., Lockheed Aircraft Corp., Sunnyvale, Calif., 1960. LMSD-8950006; ASTIA AD-249,473 and Satellite Environment Handbook, Stanford University Press, Stanford, Calif., 1961.

This short survey concentrates on micrometeorites. Some early satellite data are presented and a table of micrometeorite parameters developed by Whipple in 1958 are given.

Dust particles in interplanetary space consist mainly of micrometeorites. The data presented in this chapter are considered to be the most reliable estimates presently available concerning the size, mass, spatial distribution, velocities and number densities of the particles.

83. MICROMETEORITES, HIGH VELOCITY IMPACT STUDIES, AND PROBLEMS OF SPACE TRAVEL RELATING TO PARTICLE IMPACT. Barber, Edda and Dorothy I. Sweitzer, Editors. 15 October 1959, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. JPL-A1-LS-143; ASTIA AD-231,586; Contract NASW-6.

Information is reviewed concerning the existence of micrometeorites, interplanetary dust and other small particles in space and their possible influence on interplanetary flight. To facilitate the use of this search, the material is divided into the following sections: general material (including books) that would be of interest for background research; composition of meteorites, as well as of smaller particles, as a possible indication of the type of matter in space; properties, such as mass, size, thermal constants; kinematics, such as velocities, orbits, and distributions of meteoric particles; meteorological effects including astronomical lighting and effects on weather; impact studies; particle acceleration; and space travel problems. An author index is included.

84. NATURAL ENVIRONMENT OF INTERPLANETARY SPACE. Shaw, John H. January 1960, Ohio State University, Research Foundation, Columbus, Ohio. WADD Phase Technical Note No. 4; ASTIA AD-250,230; Contract AF 33(616)5914.

A brief account of some of the phenomena which may be encountered in interplanetary space is given. An attempt has been made to give numerical values where such data are available.

85. NEW INVESTIGATIONS OF THE ALLEGED METEORITE FROM IGAST, ESTONIA. O'Keefe, John A. and Paul D. Lowman, Jr. December 1961, NASA, Goddard Space Flight Center, Greenbelt, Va. NASA-TN-D-1151; ASTIA AD-268,740.

This paper presents the results of a re-investigation of the object which allegedly fell at Igast, Estonia, in 1855, and which may be the only example of a meteorite with the chemical composition of a tektite. It is concluded that generally quoted opinions of the artificial nature of this object are based on spurious samples, specifically, melted brick and quartz basalt porphyry distributed by a Russian collector. Possibly genuine specimens from this observed fall are in the British Museum, the Paris Museum, and perhaps the University of Dorpat, Estonia. It is recommended that these specimens be re-examined and that a search for similar objects be made.

86. NOTES ON COMETS, METEORS AND PLANETARY EVOLUTION. Whipple, Fred L. In Astronomical Society of the Pacific, Vol. 70, No. 416, pp. 485-488, October 1958.

The cometary origin of meteors is discussed, and the icy model of a cometary nucleus from H, C, N, and O and heavier meteoritic elements is considered. The collection of micrometeorite dust at 50,000 ft by Hodge and Rinehart is reported, and properties of the dust mentioned. Laboratory growth of high-density sub-micron grains is recommended for testing.

87. OBSERVATIONS OF NICKEL-BEARING COSMIC DUST COLLECTED IN THE STRATOSPHERE. Yagoda, H. March 1959, Cambridge Research Center, Bedford, Mass. Report No. Research Notes 9; ASTIA AD-212,422.

Stratospheric dust particles collected on plastic surfaces have been examined microchemically for nickel, using dimethylglyoxine as a specific developing reagent. Samples collected from four balloon flights at elevations from 77,000 to 112,000 ft indicate deposition of 0.17 to 0.36 nickel-bearing particles per cm^2 per day. Some dust particles as small as 1 or 2 microns diameter have given positive reactions. The experimental technique is described.

88. ON THE COMETARY NATURE OF THE TUNGUSKA METEORITE. Fesenkov, V. G., Astrophysical Institute, Kazakh Academy of Sciences. In Soviet Astronomy (AJ), Vol. 5, pp. 441-451, Jan-Feb. 1962. Translated from Astronomicheskii/Zhurnal, Vol. 38, No. 4, pp. 557-592, July-August 1961.

The Tunguska meteorite which appeared on June 30, 1908, in central Siberia did not produce any craters or even meteoritic fragments, but was followed by quite enormous fall of the forest having a clearly radial character at least at a certain distance from the central area. According to all evidence, this meteorite moved around the sun in a retrograde direction, which is impossible for typical meteorites which are the products of asteroidal disintegration.

89. ON THE ICY CONGLOMERATE MODEL FOR COMETS. Whipple, Fred L. In Physics of Comets, Papers presented at the 4th International Colloquium on Astrophysics. Part V. Physical Processes Concerned with Formation and Evaluation of Atmospheres, Liége, Belgium, 12-21 September 1952. Mémoires de la Societé Royal des Sciences de Liége, 4th Series, Vol. 13, Nos. 1/2, 1953.

A progress report is made on the various investigations being undertaken at the Harvard College Observatory, Cambridge, Mass., and dealing specifically with problems of the nature of comets, their development and their relationships with interplanetary (meteoritic) material.

90. ON THE NON-CONSERVATIVE PROPERTY OF THE PHOTO-GRAVITATIONAL FIELD AND ON A POSSIBLE MECHANISM OF CAPTURE OF COSMIC DUST BY THE SUN. Radzievskii, V. V. In Doklady Akademii Nauk, (SSSR), Vol. 72, No. 5, pp. 861-864, 1950 (in Russian).

91. ON THE VELOCITIES AND ORBITS OF METEORS, FIREBALLS, AND METEORITES. Whipple, Fred L. and Robert F. Hughes, Harvard College Observatory, Cambridge, Mass. In Meteors (A Symposium on Meteor Physics): Special Supplement, (Vol. 2, pp. 149-156) to Journal of Atmospheric Terrestrial Physics, 1955. ASTIA AD-92,422; Contract N5-ori-07647.

Extraterrestrial material falling upon the earth can be arranged according to mass in the following sequence: radio meteors, visual meteors, photographic meteors, fainter fireballs, great fireballs, detonating bolides, and meteorite falls. Precise velocities have been measured only for radio meteors, meteors of cometary streams, and photographic meteors. These velocities and the elongation of the apparent radiants from the apex of the earth's motion indicated that in the sequence beginning with photographic meteors the distribution of geocentric velocities shifts progressively toward the low-velocity limit. That is, the orbits become less inclined, smaller, and more circular. The relative cometary contribution is probably a maximum for the smallest masses and decreases steadily to zero for meteorite falls. Meteorites move largely in small, low-eccentricity orbits of small inclination. We find that their root-mean-square atmospheric velocity is about 17 km/sec.

92. THE ORIGIN OF METEORITES. Mason, Brian. The American Museum of Natural History, New York. In Journal of Geophysical Research, Vol. 65, No. 9, pp. 2965-2970, September 1960.

Chondritic meteorites are not fragments of disrupted planets, but have always been independent and individual objects; they can have been produced by recrystallization of material now represented by carbonaceous chondrites. Composition is such that if they are heated above 600°C they would give a mixture of olivine, orthopyroxene, and nickel-iron similar to that of chondrite meteorites.

93. THE ORIGIN OF METEORITES. Singer, S. Fred. In Scientific American, Vol. 191, No. 5, pp. 36-41, November 1954.

There seems to be little doubt that meteorites are small asteroids. Chemical and metallographic studies of the meteorites gave a general outline of the history of the planets of which they were presumably a part. Before they crash to earth, these objects are exposed to cosmic rays. Helium produced by this bombardment provides a new clue to the planetary catastrophes of the past.

94. THE ORIGIN OF TEKTITES. O'Keefe, John A. November 1960, National Aeronautics and Space Administration, Washington, D. C. NASA TN D-490; ASTIA AD-245,682. Also in Space Research: Proceedings of the First International Space Science Symposium, Nice, France. Jan. 11-16, 1960. Kallman-Bijl, Hilde, Editor. North-Holland Pub. Co., Amsterdam, 1960.

The composition and distribution of tektites, with the fact of apparent ablation in flight, strongly suggest extraterrestrial origin. Thermodynamic considerations suggest their arrival in orbits nearly parallel with the earth's surface, resulting from the decay of a natural satellite orbit. Comparison of the great meteor procession of 1913 with the re-entry of artificial satellite 1957 Beta suggests that the meteor procession resulted from the ablation of such a single body. It is shown that the ultimate source of the original tektite-producing body probably is the moon, and it is suggested that the Igast object alleged to have fallen in 1855 is genuine and is an unmelted portion of the lunar crust.

95. ORIGIN OF TEKTITES. O'Keefe, John A. In Nature, Vol. 181, No. 4503, pp. 172-173, January 18, 1958. Also in Science, Vol. 130, pp. 97-98, July 10, 1959.

Tektites are postulated as being lunar ejecta with a period in orbit on the order of 10^7 years, the orbit becoming very circular with respect to the earth. It is shown that eventually this material will be about 11 mi. nearer the surface of the earth at the equator than at the poles, and will be subjected to about 15 times as much air resistance; it will thus nearly always come to earth in latitudes near the equator, in accordance with the distribution found for tektites.

96. PARTICULATE CONTENTS OF SPACE. Whipple, Fred L. Presented at the Third Symposium on the Medical and Biological Aspects of the Energies of Space, at the U. S. School of Aviation, Brooks AFB, Tex., October 24, 1960. In Medical and Biological Aspects of the Energies of Space, Campbell, P., Editor. Columbia University Press, New York, 1961.

Rockets, satellites and space probes have by now provided considerable observational data concerning the acoustical impact rates of meteoritic particles at altitudes from 10^2 to 10^5 km above the earth's surface. The calibration in terms of momentum appears to be fairly satisfactory. The minimum masses are in the range 10^{-10} - 10^{-8} gm. At great distances the frequency of impact appears to be in good agreement with the older data obtained from the optical observations and theory of the zodiacal cloud.

97. PHYSICAL FACTORS IN SPACE FLIGHT - 13 METEOR HAZARDS TO SPACE STATIONS. Ovenden, Michael W. In Realities of Space Travel (Selected papers of the British Interplanetary Society). Putnam, London, 1957.

A summary of the meteoroid environment and its hazard to space flight up until 1959 is given.

98. THE PHYSICAL THEORY OF METEORS. VIII. FRAGMENTATION AS CAUSE OF THE FAINT-METEOR ANOMALY. Jacchia, Luigi G. August 26, 1954, Harvard College Observatory, Cambridge Mass. Technical Report No. 1; ASTIA AD-92,428; Contract DA 19-020-ORD-2556.

The observed decelerations and light-curves of bright meteors are in good agreement with the simple ballistic theory, while fainter meteors photographed with the Super-Schmidt camera in New Mexico show startling anomalies. In particular, the durations of faint meteors are shorter and the decelerations increase faster than predicted by the theory when the mass is computed from the integration of the luminous-intensity-curve in the same fashion as for bright meteors. Extreme fragility and progressive fragmentation seem to account for these and other anomalies. The concept of pellet-like meteors must be replaced with that of a cluster of breaking fragments in the case of most smaller bodies.

99. PHYSICS AND MEDICINE OF THE UPPER ATMOSPHERE. PROCEEDINGS OF A SYMPOSIUM OF THE PHYSICS AND MEDICINE OF THE UPPER ATMOSPHERE, SAN ANTONIO, TEXAS, 6-9 November 1951. White, Clayton S. and Otis O. Benson, Jr., Editors. University of New Mexico Press, Albuquerque, N. M., 1952.

100. PHYSICS AND MEDICINE OF THE UPPER ATMOSPHERE. PROCEEDINGS OF SECOND INTERNATIONAL SYMPOSIUM ON THE PHYSICS AND MEDICINE OF THE ATMOSPHERE AND SPACE, SAN ANTONIO, TEXAS, 10-12 NOVEMBER 1959. Benson, Otis O. Jr., and Hubertus Strughold, Editors. John Wiley & Sons, New York, 1960.

101. PHYSICS OF THE ATMOSPHERE AND SPACE. Friedman, Herbert, Naval Research Lab., Washington, D. C. In Astronautics, Vol. 6, No. 12, on pages 45, 92, 93, 94 and 96.

Space physics was characterized during the past year by the broad range of problems from aeronomy to astrophysics which came under investigation. The items mentioned below are a sampling of some of the more important accomplishments: Aeronomy, Solar Spectroscopy, Interplanetary Gas and Dust, Gamma Ray and Ultraviolet Astronomy, and VLF Propagation.

102. PHYSICS OF THE UPPER ATMOSPHERE. Ratcliffe, J. A., Editor. Academic Press, New York, 1960. The article "The Upper Atmosphere and Meteors," by J. S. Greenhow and A. C. B. Lovell, pp. 513-548 is of special interest.

103. PRECISION ORBITS OF 413 PHOTOGRAPHIC METEORS. Jacchia, Luigi G. and Fred L. Whipple, Smithsonian Institution, Washington, D. C. Smithsonian Contributions to Astrophysics, Vol. 4, No. 4, 1961.

Orbital results are presented for 413 long-trail meteors doubly photographed with the Baker Super-Schmidt cameras in New Mexico and reduced by precise methods. The error in velocity probably does not exceed 0.1 percent for 173 meteors, or 0.4 percent for 181 others.

With such exact material it is now possible to determine definitively the source of meteors in the visual range. The obvious possibilities are interstellar, cometary, asteroidal, and secondary lunar sources.

Meteors of interstellar origin would move in hyperbolic orbits about the sun. The 251 orbits of precision 0.2 percent in velocity include no hyperbolic cases; for 7 hyperbolic orbits among the less precise cases, a long-period solution exists within the possible range of each. Hence, more than 99 percent, if not all, must have been gravitational members of the solar system. The orbital data alone indicate that more than 90 percent of these, probably more than 99 percent, must be cometary in origin, while the physical data from decelerations and light curves show no unusual characteristics for the remainder. The number of meteoroids produced by the encounter of meteorites with the moon cannot exceed 1 percent level of probability among the current selection. Thus, comets seem to supply essentially all the visual meteors and probably also smaller meteoroids.

A number of statistical correlations among meteor orbital elements are shown and commented on. Also a preliminary study of meteor streams and associations is made. Several new cometary associations with meteor streams are suggested.

104. A PRELIMINARY COMMENT OF MICROMETEORITES. Whipple, Fred L. In Science, Vol. 110, pp. 438, October 28, 1949.

The term micrometeorite is here defined as an extraterrestrial body that is sufficiently small to enter the earth's atmosphere without being damaged by encounter with the atmosphere. The limiting circumstances arise when the micrometeorite radiates energy rapidly enough that its temperature remains below its melting point as its motion is retarded by atmospheric resistance. The theory of the maximum direction for such a particle with prescribed geocentric velocity and physical characteristics is developed.

105. PRELIMINARY SURVEY OF METEOROID EFFECTS ON SPACE VEHICLES. Caylor, G. H. 10 April 1962, North American Aviation, Inc., Space and Information Systems Div., Downey, Calif. Report NAA-SID-62-519.

The Space and Information Systems Division of North American Aviation has been conducting a number of studies related to the selection of a suitable structure for use in manned space vehicles which remain in orbit for long periods of time. Of particular concern are the meteoroid environment in space and its effect on the structural design. Since there are several conflicting theories on both the environment and the meteoroid penetration, an effort was initiated to establish which of these were most reasonable. Most of the existing literature concerning meteoroid flux and penetration has been considered in the preparation of this paper. The resulting equations were derived for use in the design of spacecraft structures that will resist meteoroid penetration.

106. PROBABILITY THAT A METEORITE WILL HIT OR PENETRATE A BODY SITUATED IN THE VICINITY OF THE EARTH. Grimminger, George. April 22, 1948, The RAND Corp., Santa Monica, Calif. Rand Report P-18; also in Journal of Applied Physics, Vol. 19, No. 10, pp. 947-956, October 1948. ASTIA AD-267,751.

When a body is situated at sufficiently great altitudes (about 200 km or above) it is exposed to impact by the meteorites which enter the earth's atmosphere. A preliminary attempt is made to estimate the probability that a body situated in the vicinity of the earth will be hit by a meteorite and, when hit does occur, to estimate the metal plate thickness necessary to prevent perforation by the impact of meteorites of different sizes. For stainless steel skin thicknesses ranging from 0.05 to 0.02 inch, it is necessary to consider meteorites as small as those corresponding to magnitude 8 to 11, respectively. In general, however, it is found that for meteorites which are large enough to present a perforation hazard the probability of a hit is negligibly small, particularly if the body is not exposed to meteoritic impact for excessively long periods of time.

107. PROGRESS OF METEORITICS DURING 1950. Fesenkov, V. G. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC-249342, Translation F-TS-8861/III from Meteoritika, Akad. Nauk SSSR, Vol. 10, pp. 26-36, 1952. ASTIA AD-111,050.

The paper reviews in rather full detail the progress made in meteorics during the year 1950. The most significant problems posed and solved are discussed.

108. REFERENCE LIST OF METEOR ARTICLES WITH PARTICULAR EMPHASIS ON RADIO-METEORS. Ellyett, C. D. February 5, 1958, National Bureau of Standards, Boulder, Colo. NBS Report 5531; ASTIA AD-156,910.

This list includes all references which could be found in the published literature relating to the radio investigation of meteors. These include:

(a) all back-scatter investigations;
(b) forward-scatter, except a few articles which are of a communications nature, and merely assume the presence of meteors, without making any special mention or study of their behavior or influence.

All references relating to the radio study of meteors as probes of the upper atmosphere - including density and temperature profiles, winds, and similar studies.

Most references to visual, photographic and telescopic studies of meteors, and phenomena of the upper atmosphere emerging from such studies.

Some articles have been referenced on meteor-comet relationships, and on dust in the vicinity of the solar system, but in this field articles of marginal interest to other than the pure astronomer have not been included.

109. THE RELATION BETWEEN RAINFALL AND METEOR SHOWERS. Bowen, E. G. In Journal of Meteorology, Vol. 13, pp. 142, 1956.

The rainfall peaks occur approximately 30 days after prominent meteor showers. It is suggested that they are due to the nucleating effect of meteoric dust falling into cloud systems in the lower atmosphere, the time difference being accounted for by the rate of fall of the material through the atmosphere.

110. RESEARCHES IN THE FIELD OF METEORITES. (Seventh Meteorite Conference). Krinov, Ye. L., May 1957. A translation, 15 April 1959. ASTIA AD-204,505.

This report gives a brief review of the papers read at the Seventh Meteorite Conference, held in Moscow from the 14 to the 17th of November 1956. Specialists in the study of meteorites were brought together from the different cities and research establishment of the USSR; also guests abroad attended.

111. RESEARCHES ON METEORITES. Moore, Carleton B., Editor. John Wiley & Sons, Inc., New York, 1962.

Twelve papers presented at the 1961 Arizona State University symposium on meteorites are collected here. Among the subjects are the radiochemistry of iron meteorites, metallurgical and mineralogical studies, and the origin of meteorites. A bibliography is included.

112. ROCKET AND SATELLITE METEORIC DUST INVESTIGATIONS. Nazarova, T. N. Presented at the 12th International Astronautical Congress, Washington, D. C., October 1-7, 1961.

113. SATELLITE ENVIRONMENT HANDBOOK. Johnson, Francis S., Editor. Stanford University Press, Stanford, Calif., 1961.

The book's title accurately describes its content-data on the main aspects of a satellite's environment: the upper atmosphere, the ionosphere, cosmic rays, meteor particles, the earth's magnetic field, and soft X-rays. The authors have skillfully combined ground observations with recent results obtained from both American and Soviet satellites.

114. SECOND CONFERENCE ON METEORITES. Krinov, Ye. L. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC-242119; Translation F-TS-8850/III of Priroda, Vol. 12, pp. 70-75, 1950. ASTIA AD-111,037.

A review is made of the papers given at the Second Conference on Meteorites held March 21-23, 1950, in Moscow by the Committee on Meteorites.

115. SIDERITE METEORITES AND THEIR CHEMISTRY. Graham, R. P. In Journal of the Royal Astronomical Society, Canada, Vol. 41, pp. 129-143, 177-187, 1947.

Author discusses the chemical analysis, structure and origin of meteorites.

116. SILICATE METEORITE STRUCTURES AND THE ORIGIN OF THE METEORITES. Wood, J. A., Jr. June 19, 1958, Astrophysical Observatory Smithsonian Institution, Cambridge, Mass. Technical Report 10; AFOSR TN-58-547; ASTIA AD-158,364; Contract AF 18(600)1596.

The petrography (particularly textures) and petrology of stony meteorites were studied as a key to the origin, evolution, and constitution at depth of the earth. Classifications, textures and mineralogy, and chemical compositions of numerous meteorites are given as well as 19 microphotographs. Discussions on the solar system evolution and the condensation of the chondrules included topics on (1) currently considered hypotheses for the formation of the solar system, (2) stellar temperatures and pressures, (3) effect of rotations, (4) phase equilibria, (5) adiabatic cooling, (6) condensation processes, (7) chondrule-dust fractionation, (8) optical measurements of Fe content of olivine in chondrites, and (9) accretion. The classification, mineralogy, textures, and chemical compositions of nonchondrites are presented, and the relation of nonchondrites to chondrites is discussed. The topics covered in a discussion of parent meteorite planets encompassed: (1) a review of the central-melting model; (2) enstatite chondrites and aubrites, (3) the stony-irons, ureilites; (4) howardites and breccias, (5) sherghottites, (6) mesosiderites, (7) occluded gases and the carbonaceous chondrites, and (8) amphoterites.

117. SOLID INTERPLANETARY MATTER. Beard, David B., University of California, Davis. Sandia Corp., Albuquerque, N. Mex. Sandia Corporation Research Colloquium Paper. Report No. SC-R-252.

The Research Colloquium Series includes transcripts of talks originating either as formal colloquia or formal research and development seminars. This paper was a research colloquium given in December 1960. Specific topics included are comets, comet size, meteors, zodiacal light, and dust and space vehicles.

118. SPACE DEBRIS HAZARD EVALUATION. Davison, E. H. and Paul C. Winslow, Jr. December 1961, NASA, Lewis Research Center, Cleveland, Ohio. NASA TN-D1105; ASTIA AD-268,737. Also in IAS Annual Meeting, 30th, New York, January 22-24, 1962. Paper 62-7.

A survey of the available information pertinent to this problem is presented. The magnitude of the hazard and the problems involved in making direct measurements are discussed. It is concluded that a definite hazard exists but that it can only be poorly assessed on the basis of present information.

119. THE SPACE ENVIRONMENT. Neugebauer, Marcia. 13 December 1960, Jet Propulsion Lab., California Institute of Technology, Pasadena. Technical Release No. 34-229; ASTIA AD-250,885; Contract NASW-6.

The space environment is described in this report by means of a listing of one or more key references for each type of radiation or particle found in space. This is not intended as a complete bibliography. Whenever possible, review articles have been chosen, that is, articles which give the reader the broad outlines of the subject and then list references for more detailed study.

120. SPACE RESEARCH. Fellows, R., J. E. Jackson, H. E. Newell, Jr. and M. Stroller. In AGARD Proceedings of the Ninth General Assembly. Part II. pp. 37-70. The German AGARD Conference 24-25 September, 1959, held at Aachen, Germany. Advisory Group for Aeronautical Research and Development, Paris France, 1960.

Space research is concerned with the atmospheres of the earth and planets; their ionospheres; their electric, magnetic, and gravitational fields; the earth-moon system; the planets, comets, meteors, and other bodies of the solar system; the sun, stars, and galazies; the particles, plasmas, electromagnetic radiation and other phenomena of interplanetary, galactic, and intergalactic space. It includes the search for forms of extra-terrestrial life and the study of the behavior of terrestrial life forms under the conditions of space and space flight. Its ultimate and most exciting quest is for an understanding of the origin and fundamental nature of the universe.

121. SPACE RESEARCH. Proceedings of the First International Space Science Symposium, Nice, France. January 11-16, 1960. Kallman Bijl, Hilde, Editor. North-Holland Publishing Co., Amsterdam, 1960.

The hundred papers presented in this book are organized into seven sections according to the subject area of interest as follows: The Earth's Atmosphere, The Ionosphere, Tracking and Telemetering, Solar Radiation, Interplanetary Dust, The Moon and Planets. Effort was concentrated on the results achieved in the two years following the launching of the first Sputnik, October 4, 1957. Detailed data obtained by Explorer VI and the Russian moon probes launched in the second half of 1959 are included.

122. SPACE RESEARCH. Proceedings of the Second International Space Science Symposium, Florence, Italy. April 1961. Van de Hulst, Hendrik Christoffel, C. deJager and A. F. Moose, Editors. North-Holland Publishing Co., Amsterdam, 1961.

The proceedings of the second International Space Science Symposium, organized by COSPAR and the Consiglio Nazionale delle Ricerche and held at Florence, Italy, in April of 1961, constitute the more than 100 technical papers in the present volume. Topics include optical and radio tracking, telemetry, instrumented spacecraft, world magnetic survey, and atmospheric studies. Almost all the papers are in English, a few in French, and each is introduced with an abstract in English and in Russian.

123. SPACE VEHICLE ENVIRONMENT. Gazley, Carl, Jr., William W. Kellogg and E. H. Vestine. June 15, 1959, The RAND Corp., Santa Monica, Calif. RAND Report P-1335. In Journal of the Aero/Space Sciences, Vol. 26, pp. 770-782, December 1959.

Various physical space attributes of the natural environment in the solar system are estimated and discussed. In particular, the discussion is concerned with a survey of the characteristics of solar radiation, the earth's magnetic fields, the earth's exosphere, the solar corona, cosmic rays and meteoroids.

124. STUDIES OF RATE OF ACCRETION OF INTERPLANETARY MATTER BY THE EARTH. Whipple, Fred L., Paul W. Hodge and Hai Chin Rhee. March 1960, Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. Report SAO SR 1.

An exhaustive survey of the soil around the Arizona Meteorite Crater was made. In the soil, numerous tiny meteoritic particles were found (about 100 microns in diameter). The total mass of the original meteoritic material which these particles represented was estimated to be 12,300 short tons. Another problem involved the collection of atmospheric dust by various types of high-flying vehicles, and the search for the meteoritic component of this material. Preliminary results indicate that the amount of terrestrial dust at heights of 50,000 ft and more is somewhat greater than many investigators supposed and that the probable influx of meteoritic particles into the earth's atmosphere is smaller than the values generally quoted. This latter conclusion agrees with the preliminary results from rockets and satellites, results which also indicate somewhat smaller space densities of small particles near the earth than were predicted by some scientists. Other activities involved the development of highly sensitive techniques for determining the physical structure and chemical composition of particles of only a few microns diameter.

125. STUDY OF ATMOSPHERIC ENTRY AND IMPACT OF HIGH VELOCITY METEORITES. Riggs, Behn F., Jr. and Fred L. Whipple. 31 August 1960, Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. Quarterly Status Report No. 18 [for period] 1 April-30 June, 1960. ASTIA AD-242,417; Contract AF 18(600)1596.

This report is a continuation of the study previously described in Report No. 17. A description of the two spectrometers employed and a statement regarding the results of their use are presented.

126. THE STUDY OF METEOR VELOCITIES. Porter, J. G. In Journal of the British Astronomical Association, Vol. 60, pp. 1-18, December 1949.

A survey of methods of measurement and conclusions of the statistical analysis of results is presented.

127. A SUMMARY OF LITERATURE PERTAINING TO RADIO STUDIES OF METEORS AND METEOR TRAILS. FINAL REPORT. Vincent, W. R. and Frances H. Smith. January 1960, Stanford Research Institute, Menlo Park, Calif. SRI Project 1422; AFCRC TR 59-367; ASTIA AD-231,809; Contract AF-19(604)1517. Prepared for the Air Force Cambridge Research Center, Hanscom Field, Bedford, Mass.

A comprehensive survey of the literature pertinent to radio studies of meteors is presented. An abstract is given of each article, paper, report or book that is available in English. A separate list without abstracts is given of material published in the Soviet Union and in Eastern European countries.

128. A SURVEY OF ASTEROIDS. Kuiper, Gerald Peter, Y. Fujita, T. Gehrels, I. Groeneveld, J. Kent, G. van Biesbroeck and C. J. van Houten. In Astrophysical Journal Suppl. Ser., Vol. III, Suppl. No. 32, pp. 289-428, July 1958.

A systematic survey of asteroids down to photographic magnitude 16.5 is described. The measures resulting from the survey are contained in a 93-page table; the accuracy of the measured positions is about ±3". The asteroids found were measured for position, daily motion, and magnitude; the subsequent identification work with the Ephemeris asteroids and objects having provisional designations was done with great care. Six new objects are probably Trojans; for 33 new objects circular orbits can be computed; for 4 additional asteroids such orbits were computed. Because of the rapid increase of faint asteroids, it is not possible at this time to estimate the total mass of the asteroid ring.

129. A SYMPOSIUM ON METEOR PHYSICS AT JODRELL BANK (Summary). Kaiser, T. R. In Observatory, Vol. 74, pp. 195-209, October 1954.

Dr. E. Öpik presented a paper on masses of meteors, which was summarized by Dr. F. L. Whipple. Dr. Öpik is reported as concluding that meteors fainter than magnitude 0 consist of fragile dust balls. Dr. Whipple presented results of deceleration measurements made at Harvard. The mass of a 0 magnitude meteor with velocity 31 km sec^{-1} is found to be about 0.04 g assuming density of 1 g cm^{-3}. Mention is made of meteor fragmentation by Dr. L. G. Jacchia. Two papers by Dr. F. Link were read by Dr. Brown. The first dealt with scale height distribution; the second was entitled "Contribution of Meteoritic Material to the Atmospheric Absorption." A paper by Dr. Z. Ceplecha on "Atmospheric Corrections to Meteor Velocities and Atmospheric Density Gradients" was read by D. Vl. Guth.

130. SYMPOSIUM ON THE ASTRONOMY AND PHYSICS OF METEORS, A PROGRAM. August 28-September 1, 1961. Held at Cambridge, Mass. Sponsored by Smithsonian Astrophysical Observatory and Geophysical Research Directorate, AFRL, Office of Aerospace Research, Hanscom Field, Bedford, Mass.

131. TEKTITE. Cohen, Alvin J., Mellon Institute of Industrial Research, Pittsburgh, Pa. Reprint from McGraw-Hill Yearbook of Science and Technology. McGraw-Hill Book Co., Inc., New York, 1962.

The composition, occurrence and origin of tektites are discussed. A tektite is defined as a natural silica-glass of unusual composition; high in aluminum, calcium, potassium and silicon oxides, and low in iron, magnesium and sodium oxides. Dating of tektites by the potassium-argon method has indicated that tektites are of at least three different ages, although all of the North American tektites found (in Georgia, Texas, and Mass.) have the same approxiamte age of 33,000,000 years. The shapes and colors of the various tektites, and the country and strata in which they were found are discussed.

132. TEKTITE PROJECT ANNUAL REPORT. MAY 1960-MAY 1961. Hawkins, Gerald S. and S. H. Wolfson. Boston University Observatory. NASA Grant NSG 21-59.

Given is a review of the second experiment in the solar furnace series. Evidence obtained from the experiments has virtually eliminated the possibility of a terrestrial origin for tektites. Two plasma jet experiments have indicated that tektite material is well able to survive entry into the earth's atmosphere.

133. TEKTITE PROJECT SEMI-ANNUAL REPORT. MAY 1961-NOVEMBER 1961. Hawkins, Gerald S. and S. H. Wolfson. Boston University Observatory. NASA Grant NSG 21-59.

This is a review of work carried on for six months on the tektite project. A revision of the computer program permitted interpretration of data more accurately with a saving in time and money. Reports prepared during the period are listed.

134. TEKTITES AND THE CYRILLID SHOWER. O'Keefe, John A., NASA Goddard Space Flight Center, Greenbelt, Md. In Sky and Telescope, Vol. XXI, No. 1, pp. 4-8, January 1961. ASTIA AD-256,995.

The orbital flight path of the cyrillid shower is discussed. The Cyrillid shower was a group of meteorites which passed close to the earth in the year 1913. The flight path and composition of the shower are reconstructed from popular accounts of the passing. The study of the shower offers the possibility of explaining the origin of tektites, a glassy object found in many parts of the world.

135. TEKTITES AS NATURAL EARTH SATELLITES. O'Keefe, John A., NASA Goddard Space Flight Center, Greenbelt, Md. In Science, Vol. 133, No. 3452, pp. 562-566, February 24, 1961. ASTIA AD-256,996.

A study has been made of the great meteor procession of 9 February 1913, for which the name Cyrillids is proposed (after St. Cyril's day, 9 February). It was found that the theory of a lunar origin for tektites can be reconciled with the criticisms of Urey and Barnes (Nature 181:1498, 1958) with respect to the distribution, but that to reconcile them requires us to assume, first, that the orbits are measurably eccentric, second, that the glassy form of the tektites is the result of atmospheric ablation, and third, that lunar material also reaches the earth in considerable quantity in some other, probably inconspicuous, form. The conclusion of Kopal, that some source nearer than the moon is required to account for the narrow distribution of the tektites, is valid in the sense that the breakup into separate bodies takes place in the earth's atmosphere.

136. THE UNIVERSE DISCLOSES ITS MYSTERIES. THE INVESTIGATION OF COSMIC SPACE WITH HELP OF ROCKETS AND SATELLITES. Zygielbaum, Joseph L., translator, from Pravda, July 15, 1959. Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. Report No. JPL AI-Trans. 3. Contract NASW-6. Also in Royal Aircraft Establishment, Farnborough, Hants, England, Report No. RAE-LIB-TRANS-834.

The two translations of a Pravda article dated July 15, 1959, give popular science treatment of Russian experiments. One portion deals with micrometeorites.

137. UPPER ATMOSPHERE RESEARCH. FINAL REPORT. Kaplan, J. and H. Korff Kallmann. 30 June 1957, Institute of Geophysics, University of California, Los Angeles. Report No. AF CRC-TR-57-213; ASTIA AD-133,688; Contract AF 19(604)111.

Various means of investigating the physical state of the upper atmosphere of the earth are discussed. They are classified according to the sources of information, e.g., rocket flights, meteor observations, sound propagation, etc. Each method is described briefly, and typical results concerning temperatures, pressure, density, composition, and winds, etc., are given. A distinction is made between the physical quantities which can be measured directly and those which can only be deduced from observations and theories. Tables, graphs, and literature references are part of each chapter.

138. VISTAS IN ASTRONAUTICS. VOL. I. Alperin, Morton and Marvin Stern, Editors. First Annual Air Force Office of Scientific Research Astronautics Symposium, Co-sponsored with Convair Div., General Dynamics Corp. Held in San Diego, Calif. February 1957. Pergamon Press, New York, 1958.

The meeting had two objectives: to survey the scientific progress of astronautics and to indicate the lines of research which need to be emphasized to facilitate further space exploration.

This book brings into one cover, for the first time, papers representing the entire field of original technical research, ranging from the theoretical to the experimental.

139. VISTAS IN ASTRONAUTICS. VOL. II. Alperin, Morton and Hollingsworth, Editors. Proceedings of the Second Annual Astronautics Symposium. Held in Denver, 1958. Co-sponsors Air Force Office of Scientific Research and Institute of Aeronautical Sciences. Pergamon Press, New York, 1959.

Papers included the following subjects: Space Environment and Vacuum Research, Control and Propulsion of Vehicles Outside the Atmosphere, Departure, Space Navigation and Re-Entry Problems. The Earth's Moon and a Miscellaneous Panel Discussion.

140. YOU DON'T WORRY ABOUT THE BIG ONES. Hopkins, Alan K. Air Force Systems Command, Aeronautical Systems Div., Wright-Patterson AFB, Ohio. In Machine Design, Vol. 34, No. 23, pp. 142-145, September 27, 1962.

The seriousness of the meteoroid hazard in space is considered. Known facts concerning meteoroids are reviewed, including composition, origin, velocity, and distribution. The probable consequences of impact are deduced from these facts and from hypervelocity impact studies. In such studies, depth of penetration is the unknown factor, and it is not known whether it is dependent on incident particle kinetic energy v^2 or momentum v. High-speed experiments such as the shaped-charge acceleration technique, and electrostatic accelerator being developed by NASA, and a novel hypervelocity particle-accelerator system developed by Technical Operation, Inc. are described.

SECTION II. EXPERIMENTS AND INSTRUMENTATION

141. ACOUSTIC DETECTION OF METEORIC PARTICLES. FINAL REPORT. Harrington, H. E. and Richard F. Buck. 14 April 1960, Research Foundation, Oklahoma State University, Stillwater. AFCRC-TR-60-272; ASTIA AD-240,259; Contract AF 19(604)1908.

An investigation is progressing for detecting the influx of micrometeoritic material. The technique is based on the acoustic activation of suitable devices by the impact of such meteoric material upon the metallic surfaces carried by high altitude rockets. The development of this technique is traced from the early discovery to a definite program of rocket instrumentation. This technique is exploited to an electronic system for installation in satellite and space probe vehicles. Laboratory investigations were concerned with two general aspects: (1) the establishment of a working technique and verification of information, and (2) the establishment of the specific electronic rocket flights. A discussion of the problem of interpretation of the information acquired from each specific rocket experiment station accompanies the data.

142. ACOUSTIC METHOD OF MEASURING THE DYNAMICAL PARAMETERS OF METEORITES. Isakovich, M. A. and N. A. Roy. In Annals of the International Geophysical Year, Vol. XII, Part II, pp. 484-486. Pergamon Press, New York, 1961.

For several years, attempts have been made to detect meteorites directly by the aid of an acoustic apparatus installed in rockets. However, the apparatus used permitted only a count of the particles and in the main did not offer the possibility of measuring their dynamical parameters, for example, the momentum and energy of the particles. Among these types of apparatus are the piezo-pickups in the form of a piezo-crystal, an electrical potential being created in its output by the incidence of a meteorite on its surface. Such instruments as use piezo-elements are characterized by light weight, simplicity, and a sufficiently high sensitivity, but they do not give a single-valued relation between the dynamical parameters of the meteorites and the electrical signal. Therefore, such a pickup cannot serve as a measuring device. In particular, the incidence of particles on different parts of the pickup surface leads to the formation of elastic waves of varying form: the deformation of the crystal and its progress with time, and, consequently, the electric potential determined by it will be different for identical meteorites falling on different points of the pickup.

143. ARTIFICIAL EARTH SATELLITES. Kurnsova, L. V., Editor. In 6 Vols. (Translated from Russian). Plenum Press, Inc. New York, 1959.

Results of the investigations carried out according to the IGY program with help of the first and second artificial earth satellites are given.

144. ARTIFICIAL EARTH SATELLITES OF 1959. Stafford, Walter H. May 25, 1960, Army Ballistic Missile Agency, Redstone Arsenal, Ala. Report No. ABMA DSP TM-6-60.

EXPLORER VI: The satellite counted one dust particle for every one hundred million cubic feet of space. Dust distribution is apparently uniform to an altitude of 22,000 miles.

VANGUARD III: Two hermetically sealed pressure zones girdling the interior walls of the satellite were designed to record the impact of micrometeorites large enough to pierce the satellite shell. Erosion of the satellite shell through bombardment was recorded by three chromium-strip erosion gauges on the satellite surface and by a photosensitive detector.

EXPLORER VII: For this experiment a cadmium sulphide photoconductor was covered with an optically opaque film. An impact of a micrometeorite larger than about 10 inches in diameter will damage the film and permit sunlight to enter the cell.

145. BIBLIOGRAPHY, SCIENTIFIC INVESTIGATIONS BY MEANS OF SOUNDING ROCKETS. 8 April 1960, NASA, Office of Satellite and Sounding Rocket Program, Washington, D. C.

This subject bibliography is arranged by author and country. Subjects include: atmosphere, astronomy, aurorae and airglows, electric and magnetic fields, energetic particles, gravity, meteorology and meteors.

146. CALIBRATION OF MICROMETEORITIC DETECTORS USED IN SATELLITES AND ROCKETS. Cohen, Herbert A., Arthur Corman, and Maurice Dubin. In 3rd HVIS, Vol. 1.

This paper discusses the calibration procedures for Explorer I micrometeorite experiment. The microphone was calibrated by dropping small glass beads a known height, bouncing particles with a known period, and ejecting particles into an air stream for a known velocity. These techniqves allowed recording the output signal produced by the air input of known momentum. It was found that output was proportional to momentum for the velocity used for calibration, and it was assumed that the relation holds at meteoroid velocities. The threshold momentum was 1.7×10^{-3} gm cm sec^{-1} directly over the microphone and falls to 2.5×10^{-3} gm cm sec^{-1} twelve inches away from the microphone.

The wire grids were calibrated by use of a shaped charge. It was found that wires would be broken by 50 micron diameter particles at velocities between 10 and 14 km/sec.

147. CALIBRATION RECORD FOR THE IGY EARTH SATELLITE 1958 ALPHA. Randolph, R. W. and R. L. Choate. February 5, 1960, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. JPL Pub. No. 130.

This report has temperature calibration graphs for the micrometeorite microphone (freq. vs T) and erosion gage (No. of wire gages broken vs freq. for 3 T's). Also has diagram of micrometeorite microphone position and table of calibrations for different locations on the cylinder.

148. CALIBRATION OF MICROMETEORITIC DETECTORS USED IN SATELLITE AND ROCKETS. Cohen, Herbert A., Arthur Corman and Maurice Dubin. Air Force Cambridge Research Center, Bedford, Mass. In 3rd HVIS, Vol. 1.

Paper describes wind tunnel tests, using sand, used to calibrate AFCRC's micrometeorite detectors. No test data are given other than momenta necessary to break wire grids and activate microphones.

149. CALIBRATION RECORDS FOR THE IGY EARTH SATELLITE 1958 GAMMA. Choate, R. L. 1958, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. JPL Pub. No. 126.

The micrometeorite erosion gauge consists of a set of twelve wire grid detectors placed in a ring around the fourth stage motor. Each grid is one square centimeter in area and is composed of fine wire approximately 17μ in diameter. The twelve grids are connected in parallel with each other and with a 60,000 ohm resistor. This combination forms part of the RCO in Channel 4. If a wire grid is severed, the frequency of the sub-carrier oscillator is given a step increase.

150. THE CAPTURE OF ZODIACAL DUST BY THE EARTH. deJager, C. In Mémoires de la Société Royale des Sciences de Liége, Vol. 15, pp. 174-182, 1955 (Special Number).

To account for the excess observed deposit of extraterrestrial dust on the earth (factor, 10^3) over that expected on the basis of meteor frequencies, it is suggested that zodiacal dust is captured also over an effective diameter of about 8 x 10^6 km, as the result of in-spiralling of matter under the influence of the solar Poynting-Robertson effect. Taking this process into account, the computed fall between 1.6 and 9 x 10^9 g/day is in satisfactory agreement with the observed amount. This implies that the assumed model of the zodiacal dust-cloud, with particles moving in circular orbits around the sum, must be correct.

151. CAPTURING MICRO-METEORITES. In The Aeroplane and Astronautics, Vol. 97, No. 2508, pp. 491, November 13, 1959.

Experiments are being made at White Sands, New Mexico, to capture micrometeorites and bring them to earth. The capture device will be pierced by the first micrometeorites traveling at six to seven miles per second, but will resist other particles.

152. COLLECTION AND ANALYSIS OF MICROMETEORITES. Hemenway, Curtis L., Herbert A. Cohen, and R. E. Coon, Dudley Observatory, Albany, N. Y. NASA Grant NsG 155-61.

During the period covered by this report, work was begun on two phases: the detection of cobalt in meteoric sources by neutronactivation and γ-ray scintillation spectrometry and the design and construction of a micrometeorite particle collector to be flown on top of balloons. A breakdown of expenses incurred and a derivation of a formula limiting mass detectability are appended.

153. COSMIC DEBRIS OF INTERPLANETARY SPACE. Dubin, Maurice, Air Force Cambridge Research Center. In Vistas in Astronautics, Vol. II. Second Annual Astronautics Symposium held in Denver, Colorado, 28 April 1958. Co-sponsors Air Force Office of Scientific Research and Institute of Aeronautical Sciences. Pergamon Press, New York, 1959.

The environment of vehicles in the interplanetary space and in satellite orbits contains debris of asteroidal and cometary origin. Such particulate material moving at heliocentric velocities interacts at very high-energy densities upon collision with planetary atmospheres and space vehicles. Direct measurements of the dust component of this cosmic debris have been undertaken with rocket and satellite vehicles. These measurements involve the determination of the spatial density and size distribution of cosmic dust, as well as the impact damage to space vehicles. Various experimental techniques used on high altitude vehicles are described, in particular, the experimental equipment used on Aerobee rockets and on the IGY satellite, Alpha 1958.

154. COSMIC DUST IN THE ATMOSPHERE. Parkin, D. W. and W. Hunter. In Nature, Vol. 183, No. 4663, pp. 732-734, 14 March 1959.

On occasions during the summer months, aircraft of the Meteorological Research Flight have been collecting samples of dust over southern England at 10,000 ft., while flying at a speed of about 200 mph. A slotted "Perspex" slide of effective collecting area 10 sq. cm. was thinly coated with gelatine. Each slide, held in an aluminum frame, was exposed from the side of the fuselage, for exactly 30 min. The results of flights carried out on August 11 and 20, 1958, are of particular interest. Three slides were exposed during each flight.

155. COSMIC-RAY INSTRUMENTATION IN THE FIRST U. S. EARTH SATELLITE. Ludwig, George H., State University of Iowa, Iowa City. In the Review of Scientific Instruments, Vol. 30, No. 4, pp. 223-229, April 1959.

The first U. S. Satellite, 1958 Alpha (Explorer I) carried instrumentation to measure cosmic-ray intensity, micrometeorite impacts, and temperatures within the satellite. The instrumentation was designed with emphasis on conservation of electrical power, on stable and reliable operation, on operation over a wide range of temperatures, and on compactness and mechanical ruggedness.

The cosmic-ray instrumentation in Alpha 1958 operated according to expectations providing several hundred recordings of data received during transits over ground stations. These data led to the discovery of a belt of high intensity radiation around the earth.

156. DESCRIPTION OF IONOSPHERE DIRECT MEASUREMENTS SATELLITE S-30, JUNO II, PAYLOAD 19D. (Explorer VIII). February 2, 1960, NASA, Goddard Space Flight Center, Greenbelt, Md.

The major objective of the S-30 satellite is the study of the temporal and spatial distribution of ionospheric parameters at altitudes between 200 and 1200 kilometers. The ionization which will be investigated consists of particles with low or thermal energies, a group which exerts the greatest influence on communications.

The ionospheric parameters which will be studied include the concentrations of electrons and positive ions, the electron temperature and the mass distribution of the positive ions. Simultaneous measurements of electron and ion concentration will resolve the question of the neutrality of the medium.

157. DISCOVERY OF METEORIC DUST AT THE PLACE OF FALL OF THE SIKHOTE-ALIN SHOWER OF IRON METEORITES. Krinov, E. L. and S. S. Fonton, American Meteorological Society, Boston, Mass. Translated by D. Kraus from Doklady Akad. Nauk, SSSR, Vol. 85, pp. 1127-1230, 1952. ASTIA AD-118,436; Contract AF 19(604)1364.

A systematic study was made of the meteoritic dust in the soil at the place of fall of the Sikhote-Alin shower of iron meteorites. The authors use the term meteoric dust for the product of blow-off into the atmosphere from meteoric bodies moving in the atmosphere with cosmic velocity and for the product of the condensation of the evaporating substance of meteoric bodies. Thus, it is rational to call the produce of the disintegration of meteorites that fall to the earth meteoritic dust.

158. DISTRIBUTION OF METEORITIC DUST ABOUT THE ARIZONA METEORITE CRATER. Rinehart, John S., Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. In Smithsonian Contributions to Astrophysics, Vol. 2, No. 7, 1958. AFCRC-TN 58-272; ASTIA AD-248,118.

Seven hundred soil samples were collected from various depths in the vicinity of Barringer Crater at one-half mile intervals using a grid system with the crater at the center. The amount of meteoritic debris obtained by magnetic separation indicates that the total amount of finely divided material in the soil mantle surrounding the crater is approximately 10,500 tons, a considerably greater quantity than the 20 to 30 tons of meteorites that have been picked up over the years. The distribution of finely divided debris closely corresponds to the distribution of large meteoritic fragments and indicated that all the meteoritic material fell to its present location shortly before, just at, or shortly after the instant of the meteor's impact.

159. THE DISTRIBUTION OF SMALL INTERPLANETARY DUST PARTICLES IN THE VICINITY OF EARTH. McCracken, Curtis W. and W. M. Alexander. NASA, Goddard Space Flight Center, Greenbelt, Md. Presented at the International Symposium on the Astronomy and Physics of Meteors, Cambridge, Mass., August 28-September 1, 1961. NASA TN-D-1349.

This report is primarily devoted to the micrometeorite experiment on the Explorer VIII (1960 ξ) but there are tables of data obtained from other satellites and rockets.

160. DO METEORITES REVEAL LIFE ON OTHER WORLDS? Gaskell, Tom, British Petroleum, Ltd. In New Scientist, No. 289, pp. 458-460, May 31, 1961.

The discovery last year of microscopic "organized elements" in carbon-bearing meteorites has stimulated a great deal of analysis and speculation about the possibility that they are fossil micro-organisms from another planet. Many questions are still unanswered, but the principal observations and the attempts to explain them are here reviewed.

161. EARTH SATELLITE INSTRUMENTATION. Matthews, Whitney, Naval Research Lab., Washington, D. C. January 1957. In Electrical Engineering Vol. 76, No. 7, pp. 562-567, July 1957.

This article discusses the use of an instrumented satellite wherein measurements made in the vehicle are transmitted to ground recording stations by means of a radio telemetering system. The design requirements of a unique telemetering encoder system are examined in the light of the limitations imposed by the overall satellite program.

162. EARTH SATELLITES--SOME CHARACTERISTICS AND PROBLEMS. Peterson, N. V. In Sperry Engineering Review, Vol. 9, No. 2, pp. 3-11, March-April 1956.

This paper presents a general study of earth satellites, their characteristics, and some of the problems involved in launching and controlling such vehicles. The properties of upper atmosphere are outlined and the factors governing satellite lifetimes discussed. Limitations in observation of satellites are surveyed, and some of the possible applications projected.

163. EVASION OF HAZARDOUS OBJECTS IN SPACE. PART II. THE APPARATUS FOR EVASION. Proell, Wayne. In The Journal of Space Flight, Vol. 3, No. 5, pp. 1-9, May 1951. For Part I, see entry 29 in Part A of the Bibliography.

In the previous section, certain conditions for "missing" were established, and it was indicated that each condition had certain special advantages. Here one condition is explored and apparatus developed to apply it and achieve evasion.

164. EVIDENCE ON THE NATURE OF AIRFLOW AROUND STONY METEORITES IN FLIGHT. Henderson, E. P. and D. T. Williams. 29 April 1958, Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. Technical Report No. 9; AFOSR TN-58-436; Contract AF 18(600)1596; ASTIA AD-185,240.

The flow markings on the surface of a series of stony meteorites were photographed and rationalized in the light of simple aerodynamic theory. Complete agreement between theory and experiment was demonstrated as relating to the orientation of the objects during flight, and separation of flow from fluff objects near the edges. The pits which are universally observed characteristics of meteorites showed flow lines inside. Some of the meteorites showing no flow lines were identified as being oriented in flight by other characteristics, leading to the conclusion that flow lines are not a unique indicator of nontumbling flight.

165. EXPERIMENTAL PHYSICS USING SPACE VEHICLES. Sonett, Charles P. In Advances in Space Science (And Technology), Vol. 2, Chapter 1, Section 6: Micrometeorites, pp. 1-111. Ordway, Frederick I., III, Editor. Academic Press, New York, 1960.

166. EXPERIMENTS FOR MEASURING TEMPERATURE, METEOR PENETRATION, AND SURFACE EROSION OF A SATELLITE VEHICLE. LaGow, Herman E. and J. A. Van Allen, Editors. In Scientific Uses of Earth Satellites, University of Michigan Press, Ann Arbor, Mich., 1956.

Importance of miniaturization in relation to environment including temperature extremes, surface erosion and surface penetration is assessed.

167. EXPLORATION OF SPACE. Clarke, Arthur C. Temple Press Ltd., London, 1951.

The book was written for the benefit of all those who are interested in the "why" and "how" of astronautics, yet do not wish to go into too many scientific details. Questions regarding space exploration were anticipated, and an attempt was made to show how astronautics may contribute to the program of civilization and the ultimate happiness of mankind.

Chapter 9, "Life in the Spaceship," discusses cosmic rays, meteors, meteoritic dust, space medicine, and life in the capsule during flight.

168. EXPLORATION OF SPACE. Jastrow, Robert. The MacMillian Co., New York, 1960.

A dozen authors survey developments in space research and delineate the major problems to be considered in future work. Descriptions of American space rockets, both in existence and under development, are included with data on their payloads, estimated completion dates, and suitability for specific lunar planetary exploration missions. In addition to detailed discussion of the properties of the moon and planets, material is presented on such subjects as plasma and magnetic fields in the solar system, solar wind, low-energy cosmic ray events associated with solar flares, outer atmospheres of the earth and planets, and ages and origins of the meteorites and rocket astronomy.

169. EXPLORATION OF THE UPPER ATMOSPHERE BY METEORITIC TECHNIQUES. Whipple, Fred L. In Advances in Geophysics, Vol. 1. Landsberg, H. E., Editor. Academic Press, Inc., New York, 1952.

A discussion of the conclusions that can be drawn concerning the nature of the upper atmosphere by observation of the effects of particles from space which encounter the earth's atmosphere is given. Discussed are: (1) techniques of observations and astronomical results, (2) theory of the meteoric process, (3) results concerning the upper atmosphere, and (4) circulation in the upper atmosphere.

170. EXPLORER I. February 28, 1958, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. JPL External Pub. No. 461; Contract DA-04-495-ORD-18.

This paper presents the results of one phase of research carried out at JPL, California Institute of Technology under Contract DA-04-495-ORD-18, sponsored by the Department of the Army, Ordnance Corps. Included in the paper are: historical review of the Explorer I, a description of the launching system, the satellite and the launching, some tables and figures.

171. EXPLORER I AND II INSTRUMENTATION. Pilkinton, William C. April 10, 1958, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. JPL External Pub. No. 483; Contract DA-04-495-ORD-18.

This paper discusses briefly what data were transmitted from Explorer I and III, how it was encoded, transmitted, received, recorded and finally reduced.

172. THE EXPLORER REPORT RESEARCH PROGRAM. Robillard, G. October 31, 1958, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. JPL Pub. No. 145; ARS Reprint 718-58; JPL External Pub. No. 631.

Since September of 1956, nine Jupiter-C missiles have been launched from the firing pad at Cape Canaveral. The first Jupiter-C firing tested the propulsion system, air frame, and guidance components of the missile, and second and third firings tested a model of the Jupiter nose cone under realistic re-entry conditions. The remaining six Jupiter-C missiles were used as the launching vehicles for Explorer satellites I through VI. Of the six satellite firings, Explorers I, III, and IV achieved satisfactory orbits. This paper describes the design and firing sequence of Jupiter and discusses payloads and orbits of the Explorers along with scientific data which were obtained.

173. EXPLORER SATELLITE ELECTRONICS. Victor, W. K., H. L. Richter, Jr. and J. P. Eyraud, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. Technical Release No. 34-12, January 29, 1960. In IRE Transactions on Military Electronics, Vol. MIL 4, No. 2-3, April-July 1960.

A discussion is presented of the design restrictions and the philosophy which enabled the Explorer satellites to be first during the IGY to reveal the presence of a belt of intense cosmic radiation encircling the earth's equator. In addition, an indication of the amount and momentum of cosmic dust in the solar system was obtained from the Explorers. Methods used to obtain reliability in the transducing and communications system are described, together with interpretations of space-environment information as deduced from the narrow-band telemetry.

174. FUNDAMENTAL GEOCHEMICAL RESEARCH OF TEKTITES, STONY METEORITES, AND RADIATION DAMAGE IN RELATED SILICATE MATERIALS. Quarterly Report (Two Quarters), July 1, 1960-December 31, 1960. Cohen, Alvin J., Mellon Institute, Pittsburgh, Pa. Fundamental Research No. FR 217A.

This is a survey of work completed on the Fundamental Research Project 217A during the biannum.

175. GEOPHYSICAL RESEARCH WITH ARTIFICIAL EARTH SATELLITES. In Advances in Geophysics, Vol. 3. Landsberg, H. E., Editor. Academic Press, New York, 1956.

A review is made of experiments which have been suggested for a satellite, a geophysical tool whose scope extends further than any other known technique.

176. GEOPHYSICAL RESEARCH WITH THE AID OF ROCKETS AND ARTIFICIAL SATELLITES. Blagonravov, A. A. and M. G. Kroshkin. February 1961, National Aeronautics and Space Administration, Washington, D. C. Report No. NASA TT-F-57, from Akademiia Nauk SSSR, Vestnik, No. 7, pp. 7-20, 1960. Available from Department of Commerce, OTS, Wash., D. C.

This paper presents a summarization of the accomplishments in geophysical research realized in recent years by use of rockets and artificial satellites and a review of the primary unsolved geophysical problems relating to space. Fifteen micrometeorite experiments were launched: 7 in the morning, 6 in the afternoon, 1 in the evening, and one at night. A determination of the electron concentration in the ionosphere including the region above the main maximum (100-470 km) was made.

177. GROUND SIMULATION OF METEORITIC DUST IMPACT ON HIGH FLYING VEHICLES. Robey, Donald H. June 1957, General Dynamics/Convair, San Diego, Calif. ARS Preprint 465-57.

A general discussion of meteoritic dust is presented, and deductions pertaining to the physical properties and probable speeds are given. An hypothesis to explain the rainfall correlation with meteor showers is also included. Finally a proposal for accelerating dust particles to speeds of 30 kilometers per second is discussed.

178. HANDBOOK OF SPACE FLIGHT. Proell, Wayne and N. J. Bowman. Perastadion Press, Chicago, Ill., 1950.

This is a reference book bringing together data and ideas from divergent disciplines which are pertinent to space flight. In addition to many tables, formulas, equations and diagrams, there are listed companies which build rockets, notable space flight research men, known societies devoted to rockets and space flight, glossary of rocketry and astronautics terms and a bibliography.

179. HIGH ALTITUDE RESEARCH. Burgess, Eric. In British Interplanetary Society Journal, Vol. 15, No. 5, pp. 261-279, September-October 1956.

A brief review is given of the development of vehicles for the exploration of the upper atmosphere, together with the peculiarities connected with rocket experiment in this field. Attempts were also made to detect the presence of micrometeorites by the use of polished plates and specially sensitive microphones mounted on the skin of the missile. Although there were indications that a number of small bodies had impinged on the plates and microphones, there seemed to be no altitude dependence. The results are not conclusive as to whether or not the observed impact represented micrometeorites or merely particles present in the terrestrial atmosphere and arising from terrestrial sources.

180. HIGH VELOCITY IMPACT STUDIES DIRECTED TOWARDS THE DETERMINATION OF THE SPATIAL DENSITY, MASS AND VELOCITY OF MICROMETEORITES AT HIGH ALTITUDES. Bohn, J. Lloyd and Otto P. Fuchs. January 31, 1958. Temple University, Philadelphia, Pa. Science Report No. 1; AFCRC TN 58-243; ASTIA AD-243,106; Contract AF-19(604)894.

The particular problem of the development of analytical expressions describing micrometeorite impact processes is studied. Observations suggest an hypothesis about the microstructure of impact processes which takes into consideration all physical magnitudes inherent to the process. This hypothesis is described and should provide an interpretation of the responses of various kinds of transducers. The credibility of this hypothesis is established by comparison of experimental results obtained from the hypothesis in question. The experiments were conducted at a shooting range constructed at Temple University in the velocity range of between 100 and 200 m sec^{-1}, at the shooting range at Kunnersdorf with a velocity of 700 m sec^{-1} and as far as extremely high velocities are concerned a previous published result has been used with the velocity of 45 km sec^{-1}. The comparison shows that the hypothesis adopted approximates fairly well the experimental results.

181. HOW SATELLITE MEASURES MICROMETEOROIDS. In Electronics, Vol. 34, No. 34, pp. 24, August 25, 1961.

The S-55 satellite was designed to send back information about micrometeoroids 240 mi to 620 mi above the earth. The 187.23-lb satellite will give a direct measure of the puncture hazard of micrometeoroids in spacecraft structural skin samples and will measure micrometeoroid flux rates.

182. IGY MICROMETEORITE MEASUREMENTS. Dubin, Maurice. In Space Research: Proceedings of the First International Space Science Symposium, Nice, France, January 11-16, 1960. Kallman Bijl, Hilde, Editor. Interscience Publishers, Inc., New York, 1960 and IGY Satellites Report No. 14. IGY World Data Center A: Rockets and Satellites, National Academy of Sciences, Washington, D. C., July 1961.

Direct measurements of micrometeorites were obtained during the International Geophysical Year by monitoring the impacts of cosmic dust on satellites and deep space probes. The largest data sample resulted from an experiment using crystal transducers to direct impacts upon the exposed sensitive area. The impact rate of Alpha 1958 was 8.0×10^{-3} meters^{-2} sec^{-1} for cosmic particles of mass greater than 8×10^{-10} g based upon the calibration and an impact velocity of 30 km/sec. The density of cosmic material in space at one astronomical unit is 5×10^{-22} g cm^{-3} for this component of cosmic dust, or approximately 10^{-20} g cm^{-3} based on a mass distribution assumption. The density of cosmic material measured from Pioneer I is less by more than an order of magnitude than that measured on Alpha 1958; the impact rate was 4.0×10^{-3} meters^{-2} sec^{-1} for particles of mass greater than 10^{-10} grams for similar impact conditions. These measurements are compared in relation to daily and diurnal variations.

183. IGY SATELLITE 1959 ETA. In IGY Bulletin No. 28, October 1959. National Academy of Sciences, Washington, D. C.

Erosion of the satellite shell through bombardment by dust, micrometeorites, ions, molecules, and atoms is recorded by three chromium-strip erosion gauges on the satellite surface and by a photosensitive detector. Electrical resistances of the gauges change as their surfaces are changed by erosion. The photosensitive detector, a cadmium-sulphide cell protected by an opaque covering of Mylar plastic and deposited aluminum, also shows a resistance change as the covering is eroded or penetrated. As with the pressure zones, erosion measurements are telemetered as channel lengths, but in this case permitting estimates of the erosion rates. In addition, four barium-titanate-type microphones record micrometeorite impacts on the sphere's surface. The microphone output is amplified, shaped, and fed into a magnetic counter unit. This unit provided continuously, in three-decimal digits, the cumulative count of impacts. It counts up to 1000 and then resets to zero.

184. INSTRUMENTATION AND CONTROLS. Friedman, Herbert. Naval Research Lab., Washington, D. C. In Astronautics, Vol. 4, No. 11, pp. 36, 114-115, 117-118, 120, November 1959.

In the field of instrumentation we are concerned with apparatus and techniques applied to the detection, measurement, evaluation, transformation, and display of information, and the conversion of information to control operations. Rocket engineering and space research have generated such unique requirements for performance testing, controls, and payloads that instrumentation has come to represent one of the most important aspects of Space Age technology.

Advances in instruments have made it possible for both the researcher in basic science and the design engineer to obtain more data more rapidly and to extend the scope of his experimentation by virtue of increased sensitivity and reliability.

185. INTERPLANETARY DUST PARTICLES OF MICRON SIZE PROBABLY ASSOCIATED WITH THE LEONID METEOR STREAM. Alexander, W. M., Curtis W. McCracken and Herman E. LeGow. December 1961, NASA, Goddard Space Flight Center, Greenbelt, Md. Report NASA TN D-1154, also in Journal of Geophysical Research, Vol. 66, No. 11, pp. 3970-3973, November 1951; ASTIA AD 268,741.

An interplanetary dust particle event, concident with the Leonid meteor shower and lasting approximately 70 hours, was recorded by a sensor on the Vanguard III satellite. During this interval the satellite's microphone system registered impacts of approximately 2800 dust particles with momentums exceeding 10^{-2} dyne-second. The impact rate varied by as much as two orders of magnitude within a few hours. The microphone system was almost omnidirectional, so the radiants of the dust particles cannot be defined. Association of these dust particles with the Leonid meteor stream is suggested by the coincidence in time and by the location of the satellite. Vanguard III traversed five major meteor streams, but the impact rates significantly exceeded the background rate only during this one interval. This is the first case in which a significant increase in the directly measured impact rate of dust particles possibly can be associated with a major meteor stream.

186. INVESTIGATION OF MICROMETEORITES WITH THE AID OF ROCKETS AND SATELLITES. Komissarov, O. D., T. N. Nazarova, L. N. Neugodov, S. M. Poloskov, and L. Z. Rusadov. In American Rocket Society Journal Supplement, Vol. 29, No. 10, pp. 724-744, October 1959.

This article describes the type of piezoelectric-micrometeorite detection system used on board the third Soviet satellite. Preliminary results from that experiment are included.

187. IONIZATION IN THE TRAIL OF HIGH-VELOCITY PELLETS. Partridge, William S. and L. Dale Harris. In Journal of Applied Physics, Vol. 28, No. 11, pp. 1269-1271, November 1957.

Aluminum, magnesium, and lithium-magnesium pellets were accelerated to velocities as high as 4/5 km/sec by means of an explosive. The ionization in the trails of these pellets was determined by measuring the reflection of a microwave signal from the trail. It was found that the ion density in the trail is an increasing function of the velocity and for the velocity range between 1 and 4.5 km/sec lies between 10^{10} and 10^{15} electrons per cm of path. It was observed that aluminum pellets do not produce ionization at velocities below approximately 2.9 km/sec, while magnesium leaves an ionized trail at velocities down to approximately 1.6 km/sec and lithium-magnesium alloy down to approximately 1.3 km/sec.

188. THE LATITUDE DEPENDENCE OF RADAR METEOR SHOWER OBSERVATIONS Keay, C. S. L. and C. D. Ellyett, University of Canterbury, Christchurch, New Zealand. In Journal of Geophysical Research, Vol. 66, No. 8, pp. 2337-2343. August 1961.

A simplified method of assessing the relative significance of meteor showers is discussed. The bias inherent in single-station rate measurements is largely eliminated and the importance of short-range echoes is emphasized. Comparison of results obtained from both hemispheres reveals a considerable measure of agreement between various surveys.

189. THE "LIGHT BLUE" TRAINS OF METEORS AND LUNAR TIDES FROM METEOR OBSERVATIONS 1942-1945. Astapovich, Igor and A. P. Savrukhin. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report No. ATIC 262977; Translation No. F-TS-8985/3 of Ashkhabad Astrophysical Lab. Report No. 121, pp. 4-5 and 11-12, 1951; ASTIA AD-128,660.

The observation in September 1947, carried out by the author from the grounds of the high mountain station of the Astrophysical Laboratory, discovered a new phenomenon which had been previously unknown in meteoric astronomy. Sometimes, in the hours before dawn, a faint light-bluish luminescence preceded the ordinary appearance of a meteor. The phenomenon reminded one of the flight of a meteor forming a very pale ionized train. The meteor itself remained invisible and appeared in its usual form only a few degrees below the point of disappearance of the "light blue train." We propose that the term "pale blue meteor train" be applied, for brevity, to this phenomenon.

190. THE LIGHT POWER FUNCTION OF METEOR STREAMS AND THE DISTRIBUTION OF METEORIC BODIES BY MASS. In Berichte (Doklady) der Akademii der Wissenschaften der UdSSR, Vol. 90, pp. 513-516, 1953 (in Russian).

191. LISTENING TO METEORS ON SHORT WAVE. Setteducati, Arthur F., Berkeley, Calif. In Sky and Telescope, Vol. 19, No. 6, pp. 363, 365, April 1960.

Author describes home made radio equipment used to observe radio reflections from meteor trails and makes suggestions for studies to be carried out by use of equipment described.

192. LUMINOSITY STUDIES OF HIGH VELOCITY IMPACT, FINAL REPORT. Keough, Douglas D. October 12, 1960, Stanford Research Institute, Menlo Park, Calif. AFCRL TR 60-415; ASTIA AD-247,074; Contract AF-19(604)5572.

An experimental investigation of the light associated with the impact of high velocity microparticles is described. A system capable of producing velocities in the range of 4-5 mm/μsec and of observing the impact effects by means other than terminal observations has been achieved. Multiplier phototube results indicating the energy associated with the phenomenon at varying pressures are reported. A short duration pulse consisting of a fast rise portion followed by an appropriately exponential decay is observed. All work was performed in an air atmosphere ranging in pressure from atmospheric to ~ 16μ. A possible source of luminosity is discussed briefly.

The velocity range of calibration of a micrometeorite detector has been extended, with the result that the impinging particle momentum versus detector microphone output is found to be linear.

193. MAGNETIC CORE EVENT COUNTER FOR EARTH SATELLITE MEMORY. Schaefer, D. H. In Electrical Engineering, Vol. 77, pp. 52-56, January 1958.

This is a description of the counter circuitry being developed to record micrometeorite bombardment of artificial earth satellites.

194. MEASUREMENT OF MICROMETEORITE SHOWER FROM AN IRBM. Geophysics Research Directorate, Air Force Cambridge Research Center, ARDC, Hanscom Field, Bedford, Mass.

There is good evidence that 8 grid detectors on an IRBM were destroyed during a micrometeorite shower.

195. MEASUREMENTS OF DISTRIBUTION OF INTERPLANETARY DUST. Dubin, Maurice and Curtis W. McCracken. NASA, Goddard Space Flight Center, Greenbelt, Md. Presented at the Symposium on Small Meteoric Particles in the Earth's Neighborhood, 110th Meeting of the American Astronomical Society, Cambridge, Mass., April 2, 1962.

Of the various methods for investigating the distributions and properties of interplanetary dust, direct measurements with satellites and probes are the most effective for studying the characteristics of particles with radii less than 100 microns. Since 1958, more than a dozen major space vehicles have included such instrumentation. At the present time, a significant amount of data has been accumulated and several characteristics of the interplanetary dust in the vicinity of the earth may be described.

196. MEASUREMENTS OF FLUX OF SMALL EXTRA-TERRESTRIAL PARTICLES. Cohen, Herbert A. January 1960, Geophysic Research Directorate, AF Cambridge Research Center, Bedford, Mass. Also in AFBMD/STL Symposium on Advances in Ballistic Missile & Space Technology, 4th, Los Angeles, Calif., August 27-24, 1959. And in Planetary & Space Science, Vol. 7, pp. 417-422, July 1961.

Through use of wire grids and highly sensitive microphones, direct measurements of micrometeorite influx and their damaging effects have been made from satellites and rockets. These measurements indicate that 10^{-3} particles/(m^3sec) is the order of magnitude of flux into the earth's atmosphere of extra-terrestrial particles several microns in size; they also indicate shower periods.

197. METEOR ASTRONOMY. Lovell, Alfred Charles Bernard. Oxford University Press, New York, 1954.

This book is a general text on meteor astronomy. The subject of meteor physics is being reserved for a future text. Observational methods and techniques are described, and information gathered from observations is presented. Radio techniques for measuring meteor velocities and radiants have been concentrated on the problem of the spatial orbits of the shower and sporadic meteors. Öpik's work, among others, on the velocity distribution of sporadic meteors is dealt with in particular detail. Also considered is the use of meteor photography in studying the movement of meteors in the solar system. The problem of cosmical origin of meteors is set forth for further study. Neither meteorites nor micrometeorites are dealt with in this text.

198. METEOR CORRELATION STUDY. Schley, Dewey R. August 1960, Rome Air Development Center, Griffiss AFB, New York. RADC TR 60-160.

The study of meteor trails, their cause and re-occurrence has presented many problems to astronomers and scientists; however, many of these have been solved with the use of modern radio echo techniques and optical recording equipment. This report presents the results of experiments conducted to correlate radar observations of meteor trails with simultaneous observations by visual methods. Radar set AN/FPS-17(XW-2) was used for collection of the radar data, and precision cameras located in the White Sands Proving Ground area were used for the collection of optical data.

199. METEOR DISTRIBUTION AND CRATERING. Rinehart, John S. October 28, 1957. Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. Technical Report 3; AFOSR TN 57-700; ASTIA AD-136,693; Contract AF 18(600)1596.

Three classes of extraterrestrial material that reaches the earth are discussed. These include (1) interplanetary dust, (2) debris from comets, and (3) meteorites or fragments of planets which once resided between Mars and Jupiter. Estimates of the quantity of material falling to the earth vary from 1 to 10,000 tons per day. The concepts of energy, momentum, and the quality of failure which are considered basic to terminal ballistics are defined. Some practical problems are outlined with concern: (1) the possible penetration of the hulls of spaceships, satellites and intercontinental ballistic missiles by meteoric particles, (2) the effects of surface erosions, and (3) possible damage to equipment. Suggestions for future experimentation include an increase in efforts to detect, identify, and describe meteoric material, an extension of impact studies to higher and higher velocities, and an investigation of the physical processes that operate during meteoric impact.

200. METEOR HEIGHT DISTRIBUTIONS AND THE FRAGMENTATION HYPOTHESIS. Weiss, A. A. University of Adelaide, Division of Radiophysics, South Australia. In Australian Journal of Physics, Vol. 13, No. 3, pp. 532-549, September 1960.

This paper is concerned with a comparative study of the incidence of fragmentation amongst bright and faint meteors, as disclosed by photographic measurements of heights and light curves of brighter meteors (visual magnitudes $<$ +4), and by measured radio-echo height distributions of faint meteors (visual magnitudes ~ +6). The discussion is based on photometric and height data for sporadic and shower meteors obtained by Harvard and Canadian observers, and on radio-echo height distributions measured at Jodrell Bank. Mean photographic light curves are shorter than predicted by evaporation theory, and there is a large residual scatter in the heights of maximum brightness after reduction to standard meteor velocity and brightness. Trail length is independent of reduced height, and also of velocity if this exceeds 25 km/sec; for slower meteors, trail lengths shorten rapidly. The radio-echo height distribution as a function of trail length is calculated for a simple model which incorporates these features of the ablation process for brighter meteors. Comparison with radio height measurements indicates that meteors below the photographic threshold show a closer approach to the prediction of the evaporation theory than meteors bright enough to record photographically.

201. METEOR SCIENCE AND ENGINEERING. McKinley, D. W. R. McGraw-Hill Series in Engineering Science. McGraw-Hill Book Co., Inc., New York, 1961.

Part of the McGraw-Hill "Series in Engineering Sciences," this work summarizes the major observational and theoretical developments in Meteor Science. The book aims primarily at the man who has not specialized in meteor research. One chapter is on Astronomical Aspects of Meteors.

202. METEORIC ABRASION STUDIES PROPOSED FOR VANGUARD. Swetnick, M. J. In Advances in the Astronautical Sciences, Vol. 1, Proceedings of the American Astronautical Society, 3rd Annual Meeting, December 6-7, 1956, pp. 59-64. Plenum Press, Inc., New York, 1961.

Two Vanguard methods approved for inclusion in the satellite program, for studying of meteoric abrasion of satellite skins are discussed.

203. METEORIC BOMBARDMENT. Dubin, Maurice. In Scientific Uses of Earth Satellites, Van Allen, J. A., Editor. University of Michigan Press, Ann Arbor, 1956.

An experiment for the detection of meteoric particles entering the earth's atmosphere is proposed for an earth satellite.

204. THE METEORIC INFLUX. Whipple, Fred L. and Gerald S. Hawkins. In Materials in Space Environment. Proceedings of the Fifth Sagamore Ordnance Materials Research Conference. Conducted at Sagamore Conference Center, Racquette Lake, N. Y., September 16, 17, 18 and 19, 1958. Syracuse University Research Center, N. Y. SURI MET-597-596; ASTIA AD-205,880.

Results obtained by visual, photographic and radio observations of meteors are given, and extrapolations are made to the smaller meteoroids.

205. METEORIC IONIZATION. Millman, Peter M. Dominion Observatory, Ottawa, Canada. In Journal of the Royal Astronomical Society of Canada, Vol. 47, No. 1, Whole No. 400, pp. 29-33, January-February 1953.

The most detailed observational evidence of meteoric ionization is obtained by radio methods. It has been demonstrated that the ionization produced by individual meteors acts as a radio target and can be detected on frequencies between 3 and 200 Mc/s. Since 1944, extensive radio observations of meteors have been carried out in England, Japan, the United States and Canada. These have produced valuable data concerning meteors as astronomical bodies and as physical phenomena in the ionosphere. We deal here with the latter phase of the subject.

206. METEORITE IMPACTS TO ALTITUDE OF 103 KILOMETERS. Berg, Otto E. and L. H. Meredith, Naval Research Lab., Washington, D. C. In Journal of Geophysical Research, Vol. 61, No. 4, pp. 751-754, December 1956.

A discussion is given of the micrometeorite impact-type detector flown in an Aerobee rocket on 17 November 1955 and results of data therefrom. Of 114 impacts registered upon the 75 cm^2 detector, 101 occurred during the 84 seconds when the rocket was above 85 km.

207. METEORITIC DUST. Buddhue, John Davis. University of New Mexico Publications in Meteoritics, No. 2. University of New Mexico Press, Albuquerque, N. Mex., 1950. Reviews found in Popular Astronomy, Vol. 59, pp. 213-214, 1951 and Sky and Telescope, Vol. 10, No. 115, pp. 173, 1951.

Contents:
- Introduction and Historical Review
- Methods of Collecting Dust
- Types and Size of Particles
- Physical and Chemical Tests
- The Annual Deposit
- Dust in Hail and Snow
- Interstellar Matter
- The Origin of Meteoritic Dust
- The Rate of Fall of Meteoritic Dust
- Annual Variation and Other Problems
- Details Concerning Orionid Particles
- Localities Where Deep-Sea Spheres Have Been Found.

208. METEORITIC DUST. Gustavson, John. In Jet Propulsion, Vol. 27, No. 2, Part 1, pp. 207-208, February 1957.

Meteoroids, probably of cometary origin, are porous, fragile materials with bulk densities of less than one. They are composed of compacted dust and ices (H_2O, NH_4, CO_2). Upon heating, the meteoroid gives off its frozen gases and is left as a fragile structure which easily disintegrates into micrometeoroids. About 90% of the meteor trails are formed either by the meteoroids or by the shattered product, the micrometeoroids.

Meteorites, asteroidal fragments, are solid, high density materials, which may penetrate the atmosphere and strike the ground. Magnetic or siliceous spherules and grains are formed by a vaporized meteorite, or portions thereof and are termed micrometeorites. The total accretion of meteoroids and meteorites is estimated to be 1,000 tons/day.

209. METEORITIC DUST MEASURED FROM EXPLORER I. Dubin, Maurice. Air Force Cambridge Research Center, Bedford, Mass. July 1959. Report No. NASA-CN-78424Y. In Annals of the International Geophysical Year, Vol. XII, Part II. Pergamon Press, New York, 1961; also in Journal of Planetary and Space Science, Vol. 2, (2/3) pp. 121-129.

The impacts of micrometeorites upon the cylindrical shell of the satellite 1958 Alpha were monitored by a calibrated piezoelectric detector. Results of these measurements are presented, including a description of the instrumentation, the calibration procedure, and the amount and type of data recorded at the ground stations. The total data sample over a period of twelve days of telemetering consisted of 78,890 sec of telemetered data with an excellent signal-to-noise ratio. During this time 153 signals denoting impacts by micrometeorites were recorded. This is equivalent to 1.7×10^{-2} impacts/m^2/sec on the earth. The calibration indicates that for a mean impact velocity of 30 km/s the particles striking the satellite had a mass of 8×10^{-10} g or larger if no large deviations in momentum transfer occur during the formation of hypervelocity craters. Thus, the accretion rate of extraterrestrial dust upon the earth may be estimated at 10,000 tons per day during the month of February 1958. A variation from day to day of the influx rate as large as an order of magnitude is evident from the data. A "shower" of dust particles has been found for the third day in orbit. A variation of the influx of particles may also be attributed to a diurnal effect from the earth's rotation and its heliocentric velocity.

210. THE METEORITIC ENVIRONMENT FROM DIRECT MEASUREMENTS. Dubin, Maurice. In Tenth International Astronautical Congress, London, 1959, Vol. 2. Springer-Verlag, Vienna, 1960.

A summary is given of data obtained in micrometeoritic measurements made with sounding rockets, satellites and space probes over the period 1949-1958. There are still discrepancies that require classification, and much work remains to be done on both the calibration of sensor systems and the acquisition of data for mapping the distribution of matter in interplanetary space.

211. METEORITIC MATERIAL IN SPACE. Whipple, Fred L., Smithsonian Astrophysical Observatory and Harvard College Observatory, Cambridge Mass. In Physics and Medicine of the Atmosphere and Space: Proceedings of the Second International Symposium, San Antonio, Tex. November 10-12, 1959, Chapter III. Benson, Otis C. and H. Strughold, Editors. John Wiley & Sons, Inc., New York, 1960.

This chapter outlines the type of information required in astronautics and briefly discusses possible effects of meteoritic material; second, it discusses the sources of our information and the nature of our knowledge concerning meteoritic material in space; and it deals with methods for increasing both our basic and our engineering knowledge through experimental and theoretical developments that will utilize both astronautical and earth-based tools of research.

212. THE METEOROID AND COSMIC-RAY ENVIRONMENT OF SPACE VEHICLES AND TECHNIQUES FOR MEASURING PARAMETERS AFFECTING THEM. REPORT FOR 15 FEB-15 NOV 1960. Goettelman, R. C., S. D. Softky, J. S. Arnold and W. B. Farrand. February 1961, Stanford Research Institute, Menlo Park, Calif. Wright Air Development Division, Flight Dynamics Lab., Wright-Patterson AFB, Ohio. WADD TR 60-846; ASTIA AD-262,013; Contract AF 33(616)7015.

This study incorporates terrestrial observations of the secondary effects of mechanisms that operate above the earth's atmosphere and the data obtained from in situ measurements by rocket and satellite borne detectors.

Techniques for measuring the meteoroid and cosmic-ray environments are reviewed, and some new approaches for detector developments are presented. The methods for measuring the effects of the environment on vehicle structures incorporated the same operating principles as these detector systems. Specific methods are reviewed, and areas requiring further development are noted. Several general methods for monitoring space-vehicle integrity are presented.

213. METEOROIDAL PARAMETERS TO BE MEASURED BY SATELLITE-BORNE EXPERIMENTS. A MEMORANDUM. Schaffer, F. B. 18 July 1962, Northrop Space Labs., Northrop Corp., Hawthorne, Calif. Report No. 550-FBS-106.

Parameter description of the flux of meteoroids which might be measured by one or more experiments aboard a satellite or satellites is discussed. The author shows that with an exposed area of 25 to 50 square meters a significant number of meteoroids of sufficient size to be dangerous to spaceships could be observed within a year using a Langley transducer aboard a comparatively simple payload. The capabilities of variations of the basic Langley transducers are discussed.

214. METEORS AND THE EARTH'S UPPER ATMOSPHERE. Whipple, Fred L., Harvard College Observatory, Cambridge, Mass. In Reviews of Modern Physics, Vol. 15, No. 4, pp. 246-264, October 1943.

This paper describes photographic observation by two cameras with one or two hours exposure. A rotating shutter chopped exposure so velocities could be measured. Brightness was estimated from velocity and comparison with stars. The author corrects for non-reciprocity of emulsion, but correction is small. He derives an equation for deceleration due to air resistance, and loss of mass due to varporization. Luminosity is calculated.

An equation is calculated for air density in terms of velocity, deceleration, and luminosity. He gives densities of atmosphere consistent with meteor behavior.

215. METEORS IN THE IONOSPHERE. Manning, Laurence A. and Von R. Eshleman. In Proceedings of the IRE, Vol. 47, No. 2, pp. 186-199, February 1959.

When meteors enter the lower E region of the ionosphere, they produce trails of ionization. Sensitive radio systems at frequencies of 3 to 300 mc can record echoes from these ionized trails at rates of thousands per hour. Study of these echoes has benefited astronomy, the physics of the upper atmosphere, and radio communication. This paper presents a review of the nature of meteoric echoes, and describes the principal uses of meteors as research tools. Some of the directions in which further meteoric research may prove profitable are suggested as well. When the results of the IGY programs are correlated, we may expect the knowledge gained from the study of meteors to play an important role.

216. A METHOD FOR STUDYING THE DISTRIBUTION OF MASS OF METEORIC BODIES. Fialko, E. I., Tomsk Polytechnic Institute. In Soviet Astronomy (AJ), Vol. 3, No. 6, May-June 1960, pp. 970-974. Translated from Astronomicheskii Zhurnal, Vol. 36, No. 6, pp. 1058-1060, November-December 1959.

The method outlined may be used to study the mass-wise distribution pattern of meteoric bodies, by utilizing the distribution by duration of persistent radio echoes returned from meteor trails.

Experimental results from the application of this method to the Perseid shower are presented.

217. MICROMERITICS: THE TECHNOLOGY OF FINE PARTICLES. Dalla Valle, Joseph M. Pitman Publishing Corp., New York, 1948.

This book is intended as a guide to the general subject of the behavior and characteristics of small particles. It brings together a mass of widely scattered information on methods of particle-measurements, size-distributions, packing arrangements and a general theory concerning the physical properties of finely divided substances. A lengthy bibliography is included.

218. MICROMETEORITE COLLECTION FROM A RECOVERABLE SOUNDING ROCKET. Soberman, Robert K., Editor. November 1961, Geophysics Research Directorate, AFCRL, Bedford, Mass. GRD Research Notes No. 71; AFC RL-1049.

This report contains three articles regarding the "Venus Flytrap" collector rocket. The first article discusses the experimental details and rocket performance. The second and third articles present the results obtained to date and an interpretation of these results, respectively.

219. MICROMETEORITE DISTRIBUTION MEASURED BY SEVERAL ROCKETS AND SATELLITES. Martin, Henry L. 29 February 1960, Army Ballistic Missile Agency, Redstone Arsenal, Ala.

This report summarizes the results of micrometeorite detecting experiments carried by several recent rockets and satellites. The types of instruments used, effective experimental time periods and micrometeorite frequency rates are discussed.

220. MICROMETEORITE IMPACT MEASUREMENTS ON A 20 INCH DIAMETER SPHERE AT 700 TO 2500 KM ALTITUDE. LaGow, Herman E., D. H. Schaefer and J. C. Schaffert. Report NAS-NRC-F.13. In Annals of the International Geophysical Year, Vol. XII, Pt. II, pp. 465, 472. Pergamon Press, New York, 1961. Presented at CSAGI General Assembly, Moscow, July 1958, Rev. May 1959.

Crystal microphones were used to detect the impacts of micrometeorites on a 20 inch diameter sphere during an attempted launching of an earth satellite. This IGY satellite was carried on a Vanguard launching vehicle to altitudes above 2500 km on 27 May 1958. A total of 17 impacts was recorded during a 590 sec period after the satellite was separated from the launching vehicle. This gave an average period between counts of 35 sec and an average flux 3.6×10^{-2} impacts/m^2/sec. Laboratory calibrations indicated that the system was sensitive enough to detect all micrometeorites large enough to stay in the solar radiation field.

221. MICROMETEORITE IMPACTS TO AN ALTITUDE OF 135 KM. Lovering, J. F. Australian National University, Canberra, Australia. In Planetary and Space Science, Vol. 2, No. 1, pp. 75-77, October 1959.

In view of the discrepancy between the rate of impact reported by satellites and that reported by the Berg and Meredith dectector, it was decided to repeat the latter experiment, using a Longton two-stage rocket. The rocket was fired from the Woomera Rocket Range, Australia, as part of the IGY Upper Atmosphere Research Program. The present note gives the details of the experiment and discusses the results. The round was fired at night and reached an altitude of 135 km. During the entire duration no impacts were recorded although according to Berg and Meredith 276 impacts should have been recorded. An upper limit to the influx rate, consistent with the satellite rate, is given.

222. MICROMETEORITE MEASUREMENTS FOR THE MIDAS II (1960 Zeta 1) SATELLITE. Soberman, Robert K. and Lois Della Lucca. November 1961, Geophysics Research Directorate, AF Cambridge Research Labs., Hanscom Field, Bedford, Mass. GRD Research Notes No. 72; AFCRL-1053; ASTIA AD-268,556.

This report discusses micrometeorite data accumulated by the Midas II satellite which was launched 24 May 1960 into an approximately 500 km circular equatorial orbit. Data were obtained by three acoustic detectors and two wire-grid detectors, and the discrepancy between acoustic and wire-grid data is discussed. Results are compared with preliminary results from Samos II (1961 α I) and other satellites.

223. MICROMETEORITE MEASUREMENTS FROM 1958 ALPHA AND GAMMA SATELLITES. Manring, Edward R., Geophysics Research Directorate, AFCRC, Bedford, Mass. In Planetary and Space Science, Vol. 1, No. 1, pp. 27-31, January 1959.

Grid abrasion micrometeorite detectors mounted on 1958 Alpha and Gamma satellites give a maximum influx rate of particles 10 microns in diameter or larger for the period 1 February to 7 May 1958. On 7 May 1958 two detectors appeared to indicate impacts on 1958 Gamma. The failure within a few days of all electronics on the satellite opens the possibility that a shower was encountered with meteor damage subsequently destroying electronics, or of an electronics failure which first manifested itself in the meteorite detection gear.

224. MICROMETEORITE MEASUREMENTS. SATELLITE AND GROUND LEVEL DATA COMPARED. Crozier, W. D., New Mexico Institute of Mining and Technology, Socorro, N. Mex. In Journal of Geophysical Research, Vol. 66, No. 9, pp. 2793-2795, September 1961.

Comparison is made between an annual mass accretion to the earth (3.9×10^5 metric tons) calculated on the basis of micrometeorite counts by satellites 1958 and 1959, and an annual mass accretion of magnetic spherules (0.9×10^5 metric tons) determined by collections made at ground level by the Airborne Particle Study of the New Mexico Institute of Mining and Technology.

Both measurements apply to the particle mass interval 3.3×10^{10} g to 1.2×10^{-8}g. On the basis of the theory of E. J. Öpik, the ratio of the two amounts is quite reasonable, but the entire interpretation becomes uncertain because of the possibility that many of the particles encountered by the satellites may be in orbit around the earth.

225. THE MICROMETEORITE PENETRATION EXPERIMENT. LaGow, Herman E. and L. Secretan. In Juno II Summary Report, Vol. I: Explorer VII Satellite, Chapter 10, July 1961. NASA, Marshall Space Flight Center, Huntsville, Ala. NASA TN D-608.

This report describes the first satellite flight unit lifted by a Juno II in an orbital attempt, the Explorer VII. The evaluation of the potential experiments and the selection of those which were carried aloft by the Explorer VII are discussed, and details of the launching and orbital flight are provided. Also included are the final results of the micrometeorite experiment.

226. MICROMETEORITES. Vedder, J. F. In Satellite Environment Handbook. Johnson, Francis S., Editor. December 1960, Missile and Space Div., Lockheed Aircraft Corp., Sunnyvale, Calif. Report LMSD-895006; ASTIA AD-249,473.

The existence of dust in interplanetary space has been well established. The dust particles, which range in size down to a few microns in diameter, consist mainly of micrometeorites. The size, mass, spatial distribution, velocities and number densities of the particles are not well known; however, the data presented are considered to be the most reliable estimates currently available.

227. THE NASA MICROMETEORITE DETECTOR CARRIED BY JUPITER AM-28. Martin, Henry L. NASA, Marshall Space Flight Center, Huntsville, Ala.

This report covers the background and history of the micrometeorite detector carried by Jupiter AM-28.

228. THE NATURE AND DISTRIBUTION OF METEORIC MATTER. Ovenden, Michael W. In British Interplanetary Society Journal, Vol. 6, pp. 157-173, September 1947.

The purpose of this paper is to give a brief but fairly comprehensive survey of the methods of observing or detecting meteors and meteoric matter, and our knowledge of the nature and distribution of such matter obtained therefrom. Some of the topics discussed may appear to have little relevance, but in the light of further knowledge such irrelevances disappear. For example, the physical nature of meteor phenomena, discussed at some length, combined with the study of meteor light curves, may yield valuable information of conditions of temperature and pressure in the upper atmosphere.

229. A NEW METHOD FOR DETERMINING THE RADIANT OF A METEOR STREAM USING AN ANTENNA OF LOW DIRECTIVITY. Fialko, E. I. In Soviet Astronomy (AJ), Vol. 3, pp. 136-138, 1960.

The possibility of measuring the coordinates of a meteor stream using an antenna of low directivity is considered.

230. OBSERVATIONS OF SIMULATED METEORS. McCrosky, Richard E. Smithsonian Institute, Washington, D. C. In Smithsonian Contributions to Astrophysics, Vol. 5, No. 4, 1961.

An attempt has been made to simulate meteor phenomena by the high-speed ejection of shaped-charge liners at an altitude of 80 kilometers. Photographs of two of the three charges flown in an Aerobee rocket have supplied sufficient information to specify, with degree of probability, which charges were responsible for the observed meteors.

Laboratory tests of one charge give an upper limit to the mass ejected at significant velocities. This limit, together with the observed velocity and integrated intensity, is used to compute a lower limit on the luminous efficiency of aluminum in the meteoric process. The relative efficiencies of aluminum and natural meteoric materials are estimated, and a lower limit is derived for the luminous efficiency of this latter material, assumed to have the composition of stony meteorites. This lower limit is comparable to an upper limit determined by Cook and Whipple from meteor train data. An upper limit on the luminous efficiency has not been well defined by this experiment, and a value 10^2 times larger, as has been suggested by Öpik, cannot be excluded.

231. OBSERVATIONS OF THE ZODIACAL LIGHT AT JUNGFRAUJOCH AND THEORETICAL COMMENTS. Siedentopf, H. In Mémoires de la Société Royale des Sciences de Liége, Vol. 15, pp. 96-99, 1955 (Special Number).

Recent photoelectric measures of brightness and polarization of the Z. L. indicate asymmetry in the distribution of light-intensity with respect to the ecliptic, and a symmetrical distribution of the degree of polarization. Calculations of back-diffraction from low-albedo particles, with a distribution function of the radii with exponent between 2 and 3, yield brightness and diameter commensurate with those observed for the counterglow, thus suggesting its origin in a pure diffraction effect.

232. ON THE STRUCTURE OF THE GEMINID METEOR SHOWER. B. L. Kashcheev and V. N. Lebedinets. In Soviet Astronomy, (AJ), Vol. 3, pp. 615-625, 1960. Translated from Astronomicheskii Zhurnal, Vol. 36, No. 4, pp. 629-640, July-August, 1959.

Measurements were made of meteor activity during the epoch of the Geminid meteor stream, from December 10 to December 19, 1958.

The distribution by mass of sporadics was found to be $N = N_O/m^2$. The maximum of the shower was observed during the night of December 13-14. The maximum hourly rate of occurrence of meteors was 945. At the moment of maximum activity, the distribution of meteoric bodies according to mass changed abruptly, and an increase in the number of large particles was observed. The central condensation has a cross section measuring over $5 \cdot 10^5$ km across. Distribution according to mass in the middle of the stream is $N = N_O/m^{1.3}$ at $m > 0.02$ g and $N = N_O/m^{2.2}$ at $m < 0.02$ g.

On December 12, from 0^h to 2^h, the earth passed through a condensation of large meteoric bodies in the stream. A maximum was observed for the large particles only. The transverse section of the condensation is estimated at $2 \cdot 10^5$ or at $5 \cdot 10^4$ km.

233. PAPERS ON REDUCTION METHODS FOR PHOTOGRAPHIC METEORS. Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. Smithsonian Contributions to Astrophysics Vol. 6, No. 2, 1962.

Contents:
Reduction Methods for Photographic Meteor Trails: Fred L. Whipple and Luigi G. Jacchia. The Method of Reduction of Short Trail Meteors: Gerald S. Hawkins. A Rapid Graphical Method of Meteor Trail Reduction: Richard E. McCrosky. A Reduction Method for the Motions of Persistent Meteor Trains: Allan F. Cook and Robert F. Hughes, and Methods for the Study of Shower Radiants from Photographic Meteor Trails: Fred L. Whipple and Frances W. Wright.

234. PHOTOELECTRIC OBSERVATIONS OF THE ZODIACAL LIGHT. Siedentopf, H., A. Behr and H. Elsässer. Letter in Nature, Vol. 171, pp. 1066-1067, June 13, 1953.

Records of brightness and polarization of the zodiacal light were obtained with a 1-P 21-multiplier during February-March and October, 1952, and in the winter, 1952-1953, on the Jungfraujoch (3600 m). Spatial densities of electrons and dust particles were deduced from these results on the basis of Mie scattering theory. Electron distribution is symmetric, and dust distribution asymmetric, with respect to the ecliptic, the observed densities of electrons and dust-particles near the earth's orbit being ~600 per cm^3, and $\sim 10^{-23}$ g cm^{-3}, respectively. Brightness of gegenschein corresponds to that of a dust cloud, 20° diameter distance 0.01 A. U. from earth.

235. THE PHYSICAL THEORY OF METEORS. V. THE MASSES OF METEOR-FLARE FRAGMENTS. Smith, H. J. In Astrophysical Journal, Vol. 119, pp. 438-442, March 1954.

The masses of particles contributing to meteor flares have been computed from their observed durations by applying the classical equations of meteor ballistics. The flare masses determined in this way are of the order of 10^{-5} g. This value is 10^{-3} - 10^{-4} times smaller than the flare masses computed by Jacchia from the total light generated by the flare. It is concluded that a typical meteor flare consists of the simultaneous emission of several thousand microscopic particles rather than the fracture of the parent-body into a few larger pieces.

236. PIONEER V: MICROMETEORITE MEASUREMENTS PROGRESS REPORT. National Aeronautics and Space Administration, Washington, D. C. Release No. 60-180, dated April 29, 1960.

237. PROBLEMS OF SPACECRAFT SCIENTIFIC-INSTRUMENT CALIBRATION AND SYSTEMS TESTS. Heacock, Raymond L. 1961, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. ARS Preprint 1672-61, American Rocket Society, New York.

This is a general presentation of equipment for Rangers 1 and 2, mostly concerning ground equipment. "The micrometeorite experiment will measure the number, size, and energy level of the interplanetary dust impinging upon the instrument's detector. The instrument consists of a scintillation system using a photomultiplier tube in conjunction with a microphone." Experiment will be on both vehicles.

238. PROGRESS IN DESIGN AND IMPLEMENTATION OF SCIENTIFIC SPACECRAFT. Lundquist, Charles A. Army Ballistic Missile Agency, Huntsville, Ala. Report ABMA DV-December 31, 1959.

The section on micrometeorite experiments is of special interest.

239. A PROPOSED SATELLITE PAYLOAD FOR DETECTING METEOROIDS. A MEMORANDUM. Shaffer, J. B. 13 July 1962, Northrop Space Labs., Northrop Corp., Hawthorne, Calif. Report No. 550-F BS-107.

The author proposes a satellite payload which could be used to measure the diameter of individual meteoroids. Among the advantages of this satellite payload is the capability of providing exact measurements of velocity and direction of arrival of meteoroids.

240. RADAR OBSERVATIONS OF METEORS ACCORDING TO THE INTERNATIONAL GEOPHYSICAL YEAR PROGRAM. Kascheyev, B. L. Aug. 1961, National Aeronautics and Space Administration, Washington, D. C. NASA TT-F-68.

An apparatus used in the investigation of meteor activity, which employs a system of protection against pulse interference, is described. Preliminary results of the measurement of meteor velocities obtained by Russian observation stations during the first 12 months of the International Geophysical Year are presented, and a study of the physical properties of the atmosphere at altitudes of 80 to 100 kilometers is made.

241. RADAR OBSERVATIONS OF THE PERSEIDS DURING 1957. Fialko, E. I. In Soviet Astronomy (AJ), Vol. 3, 1960, pp. 306-309.

During twenty-four hour radio-echo observation on $\lambda = 10$ m made during August 11-12, 1957, in Tomsk, two maxima (a daytime and nighttime) in the number of radio-echoes were registered.

The daytime maximum (as well as the nighttime) is due to the Perseid stream.

242. RADIO ECHO DETERMINATIONS OF ORBITS OF INDIVIDUAL METEORS. Kashcheev, B. L., V. N. Lebedinets and M. F. Lagutin, Khar'kov Polytechnical Institute. In Soviet Astronomy (AJ), Vol. 5, pp. 517-525, January 1962. Translated from Astronomicheskii Zhurnal, Vol. 38, No. 4, pp. 681-689, July-August 1961.

Radar measurements of radiants and meteor velocity by the method whereby a reflected signal is observed at three points are described. The radiants and velocities of 298 meteors of the

Geminid stream were measured during December 9-14, 1959. The accuracy of one determination of the coordinates of the radiant is $\pm 2^{\circ}.5$, that of the velocity of one meteor ± 1.8 km/sec.

The orbits of all observed meteors are computed. A systematic increase in the semi-major axis and eccentricity of the orbits during the period of observation is noted, the results being in good agreement with those of photographic observations [1, 14]. An attempt is made to explain these results theoretically.

243. RATE OF ACCRETION OF COSMIC DUST ON THE EARTH. Pettersson, Hans. In Nature, Vol. 181, p. 330, February 1, 1958.

Nickel content of air at 11,000 ft in Hawaii was 14.3 $\mu g/100\ m^3$, and Fe content 1577 $\mu g/1000\ m^3$. For an average Ni content of meteorites of 2.5%, this gives 28.6×10^6 tons of cosmic dust below the 100 km level. If this is renewed every two years, the rate of accretion is about four times larger than the highest previous estimates.

244. RECENT DIRECT MEASUREMENTS BY SATELLITES OF COSMIC DUST IN THE VICINITY OF THE EARTH. LaGow, Herman E. and W. M. Alexander. September 1960, National Aeronautics and Space Administration, Washington, D. C. NASA TN D-488. Also in Space Research: Proceedings of the First International Space Science Symposium, Nice, France, January 11-16, 1960. Kallman Bijl, Hilde, Editor. North-Holland Publishing Co., 1960 and IGY World Data Center A: Rockets and Satellites - National Academy of Sciences, Washington, D. C. IGY Satellite Report No. 14.

Direct measurements of the space density of cosmic dust particles in the vicinity of the earth have been made from rockets, satellites, and space probes. The largest data samples have been obtained from crystal transducer sensors that detect the impact impulses occurring from the collision of dust particles on sensitive surfaces of space vehicles. Preliminary results from satellite 1959 Eta show: (1) over 1500 impacts and an area-time product greater than $10^{10}\ cm^2$-sec, and (2) a daily variation in the dust particle density near the earth. The dust particle instrumentation of 1959 Eta and sensor calibration techniques are discussed in this paper. The results of direct measurements from space vehicles prior to 1959 Eta are summarized with respect to 1959 Eta information.

245. THE REGRESSION OF THE NODE OF THE QUADRANTID. Hawkins, Gerald S. and Richard B. Southworth, Smithsonian Astrophysical Observatory, Cambridge, Mass. In Smithsonian Contributions to Astrophysics, Vol. 3, No. 1, 1958.

Observations of the longitude of the descending node of the Quadrantid meteor stream from 1838 to 1954 are assembled and discussed. It is concluded that the majority of the older observations were made in years of unusually high activity. The descending node of the observed stream has regressed 0.6 per century.

246. RESEARCH DIRECTED TOWARD THE DEVELOPMENT OF PHOTO-OPTICAL, ELECTRONIC, AND CALIBRATION APPARATUS. FINAL TECHNICAL REPORT. Nardone, Louis J. March 31, 1961, Northeastern University, Boston, Mass. Prepared for Geophysics Research Directorate, AFCRC, Bedford, Mass. AFCRC-TR-60-234; ASTIA AD-234,043; Contract AF 19(604)1749.

In support of the upper-air research program, activities conducted by this organization were primarily concerned with direct and indirect support of projects dealing with micrometeorite detection measurement of day air-glow, and the installation of a data reduction facility. In conjunction with these projects, programs involving the development and construction of equipment, and various activities supporting programs at AFCRC were conducted.

247. RESEARCH DIRECTED TOWARDS THE STUDY OF TRANSDUCING METEORIC IMPACTS. FINAL REPORT. Bohn, J. Lloyd, Otto P. Fuchs et al. December 1, 1960, Temple University, Philadelphia, Pa. AFCRL TR-60-436; ASTIA AD-249,949.

Contents:

- Transistor micrometeorite amplifier
  - Preliminary investigation (1956)
    - Transistors
    - Audio amplifiers
  - The equivalent circuit of the 2N94 transistor
    - Transport factor Beta and short circuit current-transfer ratio Alpha
  - Tuned sub-radio frequency amplifier circuit
  - Extended range amplifier
  - Double output and special amplifiers
  - Block diagram of the three pulse system
- Dual output amplifiers
- Report on micrometeorites.

248. RESEARCH ON STONE DROPPING METEORS. FINAL REPORT. THE DETERMINATION OF PATHS, VELOCITIES, AND ORBITS OF DETONATING AND STONE-DROPPING METEORS. Wylie, C. C. 23 August 1954, State University of Iowa, Iowa City. ASTIA AD-38,866; Contract DA-11-022-ORD-1038.

A discussion is presented of research conducted on paths and velocities of stone-dropping meteors. A program of measurements based on interviews with eye witnesses was inaugrated and carried out. To minimize systematic errors, these measurements were used instead of estimates, and only observers with the apparent path well marked and close to the real path were selected. The apparent paths were plotted on a stereographic projection of convergence. By this method all apparent paths could be used in the plotting. Another advantage was that each plotted apparent path could be extended forward to the horizon projection and the indicated azimuth of the ground point for that observer read off. The velocity was determined by using with each observer's duration the portion of the path he saw. The greatest uncertainty in this method is in the velocity, which in turn depends on the duration of visibility. All orbits computed were found to be direct and of moderate eccentricity and inclination. These orbits indicate that before entering the gravitational field of the earth, the meteors dropping meteorites were permanent, and fairly regular, members of our solar system.

249. RESONANCE EFFECTS IN THE THEORY OF METEOR OBSERVABILITY. Moorcroft, D. R. and C. O. Hines. In Canadian Journal of Physics, Vol. 36, No. 134, 1958.

The theory of forward-scattering of radio waves from meteor trails, initiated by Eshleman and Manning has been applied to determining the "observability" of meteor showers as a function of radiant position. This theory showed qualitative agreement with preliminary data obtained for four showers (Forsyth, Hines, and Vogan 1955), and more recently has led to a quantitative analysis of the 1956 Quadrantid shower (Hines and Vogan 1957). The latter comparison revealed the forward-scattering technique as a valuable tool for the study of meteor showers. The further development of this technique will require some improvement on the approximations implicit in the original observability theory.

250. RESULTS OF INVESTIGATION OF THE METEORIC MATTER BY MEANS OF INSTRUMENTS INSTALLED ON COSMIC ROCKETS. Nazarova, T. N. In American Rocket Society Journal Supplement, Vol. 31, No. 5, pp. 713-715, May 1961. Translated from Artificial Earth Satellites, No. 5, pp. 38-40, Academy of Sciences, USSR, Moscow, 1960.

A comparison of the results obtained by the use of micrometeorite detectors installed on the satellite and three cosmic rockets indicates that the density of meteoric matter in the vicinity of the earth is not constant but changes both in time and space. During the flights of the second and third cosmic rockets, the largest number of "ejection impulse" recorded applied not to minimal impulses, which could have been recorded by the instrument, but to impulses of larger value.

251. RESULTS OF MICROMETEORITE EXPERIMENTS FLOWN ON MISSILES DURING 1959. Cohen, Herbert A. Geophysics Research Directorate, Air Force Cambridge Research Center, Bedford, Mass.

A discussion of the 13 separate micrometeorite detecting experiments flown on missiles during 1959 is given. Four separate techniques were used: microphone, grid, thin film and photoflash.

252. RESULTS OF PIONEER I FLIGHT. Sonett, Charles P., Space Technology Labs., Inc., Los Angeles, Calif. In Proceedings of Lunar and Planetary Exploration Colloquium, January 12, 1959, Vol. 1, No. 4. North American Aviation Inc., Downey, Calif. Report NAA 12 Jan 59, Vol. I.

A detailed description of Pioneer I and an account of the flight with references to changes made in Pioneer II is presented. Illustrations consist of a number of figures.

253. RESULTS OF ROCKET AND METEOR RESEARCH. Whipple, Fred L. In Bulletin of the American Meteorological Society, Vol. 33, pp. 13-25, January 1952.

Results are presented of rocket and meteor research in the upper atmosphere during the past three years. Both methods have been valuable in determining the pressures, densities and temperatures in the upper atmosphere and variations with time and place above an altitude of 30 km. The basic atmospheric data are now rather well determined to 130 km over New Mexico. Knowledge of the composition of the atmosphere to 72 km depends solely upon rocket sampling techniques. A great deal of information has been obtained from the rocket measures concerning radiation from the sun in the far ultraviolet to wavelength about 800 Å and in the soft X-ray region below 20 Å. A considerable section of the paper is devoted to the question of micrometeorites, their existence and effect on the upper atmosphere.

254. RESULTS OF SCIENTIFIC INVESTIGATIONS MADE BY SOVIET SPUTNIKS AND COSMIC ROCKETS. Krassovsky, V. I. In Astronautica Acta, Vol. VI, No. 1, pp. 32-47, 1960.

A survey is given of the results of Soviet investigations carried out by means of cosmic rockets and artificial satellites of the earth, and, in connection with it, hitherto unpublished information is given on measurements in the upper atmosphere and in the cosmic space.

255. THE RESULTS OF STUDIES OF METEORIC DUST BY MEANS OF SPUTNIK III AND SPACE ROCKETS. Nazarova, T. N., Academy of Sciences, Moscow, USSR. In Space Research: Proceedings of the First International Space Science Symposium, Nice, France. January 11-16, 1960. Kallman Bijl, Hilde, Editor. North-Holland Publishing Co., Amsterdam, 1960.

Meteoric impacts have been studied by means of instruments carried in Sputnik III and Space Rockets I, II, and III. It has been found that density of meteoric matter in the vicinity of the earth is not constant and does vary with time and in space. Within mass ranges from 10^{-9} and above, the number of impactions did not exceed 2×10^{-3} $m^{-2}sec^{-1}$ but was sometimes below 5×10^{-5} m^{-2}/sec^{-1}. Instruments carried in Sputnik III registered an increase in impacts by four orders of magnitude on 15 May 1958.

256. RESULTS OF THE IGY SATELLITE PROGRAM. Pickering, W. H. October 1958, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. External Pub. 574. In Proceedings of the National Electronics Conference, October 13, 14, 15, 1958.

Instrumentation of the Explorer satellites is discussed. A brief description of the Microlock telemetry systems is given, as well as some results of ionization, particle, and temperature measurements in the satellite orbits.

257. REVIEW OF DIRECT MEASUREMENTS OF INTERPLANETARY DUST FROM SATELLITES AND PROBES. Alexander, W. M., Curtis W. McCracken, L. Secretan and Otto E. Berg, NASA, Goddard Space Flight Center, Greenbelt, Md. Report NASA-X-613-62-25 (Preprint). A paper presented at the COSPAR meeting May 1962.

A number of interplanetary dust particle experiments have been flown on various types of spacecraft. Measurements of dust particle momentum, kinetic energy, and impact damage have been obtained from a variety of sensors.

More than 10,000 dust particle impacts have been measured from the acoustical and light flash detectors. A cumulative mass distribution curve valid for average conditions in the vicinity of the earth has been derived from the direct measurements for dust particles with masses between about 10^{-13}gm and 10^{-6}gm.

The distribution curve obtained with the direct measurements differs from that expected from extrapolations of meteor observations. The small dust particles dominate the accretion by the earth of interplanetary matter; the accretion rate is of the order of 10^{4} tons per day.

258. ROCKET AND SATELLITE INVESTIGATION OF METEORS. Nazarova, T. N., National Academy of Sciences-National Research Council, Washington, D. C. Report No. NAS-NRC-F. 14.

This paper was presented at the Rocket and Satellite Symposium during the Fifth Reunion of the Comité Special Annee Géophysique Internationale held in Moscow July 30-August 9, 1958. It has been reproduced by the National Academy of Science for use by the USNC/IGY Technical Panel on the Earth Satellite Program and the Space Science Board.

Also identified by Title -- "Study of Meteors on Rockets and Satellites."

259. S-55 TO EXPLORE THREAT OF PUNCTURES FROM "SPACE DUST." Gettings, Hal. In Missiles and Rockets, Vol. 8, No. 24, pp. 14-15, 12 June 1961.

NASA is preparing an extensive investigation into the micrometeoroid puncture hazard to manned spacecraft beginning with the launch of an S-55 satellite - probably this month - aboard a Scout. Proposals are being considered concerning the problems of stabilizing and orienting micrometeoroid data-gathering satellites, optimum orbits and building vehicles with larger surface-area collectors. Some of the later satellites in the program will be launched into polar orbits.

260. SAMPLING DUST FROM THE STRATOSPHERE. Hodge, Paul W. Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. Smithsonian Contributions to Astrophysics, Vol. 5, No. 10, 1961.

Airborne particles have been obtained from stratospheric air by collectors mounted on high-flying jet aircraft. The estimated density of particles in the 10μ size range is found to vary widely, with an average value of about 30 particles larger than 6μ in diameter per cubic meter at 45,000 feet. Only a very small number of these particles are possibly meteoritic in origin.

261. A SATELLITE METEOR TRAP. Hawkins, Gerald S. Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. SAO Special Report 19, 6 December 1958.

A method is suggested for determining speed and radiant distribution of meteorites by means of two concentric rotating cylinders with slits. Only particles in a certain velocity range could pass through both slits and strike a microphone. The radiant distribution would be measured by a second microphone. Mass would be estimated. The spin rate of the satellite would have to be known. From this information the orbits of the meteorites could be found.

262. SATELLITE MICROMETEORITE MEASUREMENTS. Manring, Edward R. and Maurice Dubin. May 12, 1958, Geophysics Research Directorate, ARDC, Cambridge Research Center, Mass. IGY World Data Center A: Rockets & Satellites, IGY Satellite Report No. 3, pp. 25-30, May 1, 1958. National Academy of Sciences, Washington, D. C.

Numerous meteorite and micrometeorite detectors were devised for satellite testing. The gauges developed present a total of about 2 sq. in. of sensitive area, and each is sensitive to the impact of a single micrometeorite of 5 to 10 microns in diameter. The individual gauges are 1 cm^2 in area and are wound with 17-micron-diameter enameled wire in two layers. An impact upon one of the gauges destroys its electrical continuity, and this is reported back by telemetry. The microphone detector detects the acoustical energy generated by particles which impact the skin and charges the frequency of a subcarrier generator. With about 10% of the microphone data and perhaps 50% of the gauge data from Explorer I available, it is possible to provide the following information: (1) seven hits have been detected by the microphone, and (2) after 32 days not more than one gauge has registered an impact.

263. SCIENTIFIC REPORTS RESULTING FROM THE FIRST EIGHT U. S. SCIENTIFIC SATELLITES AND SPACE PROBES. March 1960, National Aeronautics and Space Administration, Washington, D. C.

In this listing, primary references are those reports which directly describe the scientific results from the payload. Secondary references include all other papers closely associated with the particular satellite or space probe.

264. SCIENTIFIC REPORTS RESULTING FROM U. S. SCIENTIFIC SATELLITES AND SPACE PROBES LAUNCHED BETWEEN MARCH 4, 1959 AND APRIL 8, 1960. National Aeronautics and Space Administration, Office of Satellite and Sounding Rocket Programs, Washington, D. C.

A listing of reports associated with results from the payload of these satellites is given.

265. SCIENTIFIC RESULTS FROM THE EXPLORER SATELLITES. Hibbs, A. R. June 2, 1958, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. JPL Ext. Pub. 514. Also in IXth International Astronomical Congress Proceedings, Amsterdam, 1958. Vol. II, pp. 680-697, Springer-Verlag, Vienna, 1959.

A brief history of Explorer satellite launchings together with a description of payload information is given. Summary is presented of results of experiments made in the following areas: temperatures of both case and internal instrumentation, micrometeorite activity, and cosmic ray intensity. The results of preliminary analyses of these various measurements as carried out by the responsible institutions are given together with a discussion of the implications for future measurements of this type.

266. THE SCIENTIFIC RESULTS OF THE PIONEER V SPACE PROBE. Linder, John W. January 1961, Space Technology Labs., Inc., Los Angeles, Calif. Report STL/TR-61-0000-02014. Presented at the 7th Annual Meeting of the American Astronautical Society, Dallas, Tex., January 16-18, 1961.

The Pioneer V space probe was launched from Cape Canaveral on March 11, 1960, inwards towards the orbit of Venus. The scientific instrumentation included a spin coil magnetometer, two radiation experiments, and a micrometeorite detector. Data were obtained for distances up to 40 million kilometers from the earth. The most significant results of these experiments are summarized in this paper.

267. A SEARCH FOR METEORITIC MATTER IN ATMOSPHERIC DUST. Norris, D. K. and F. S. Hogg. In Astronomical Journal, Vol. 54, No. 7, pp. 192-193, September 1949.

Spectrochemical analysis of the material collected at the southern stations gave positive evidence for the presence of nickel, as well as abundant iron, magnesium and silicon from samples from the observatory and from Haliburton.

268. THE SEARCH FOR SMALL NATURAL EARTH SATELLITES. Tombaugh, C. W., J. C. Robinson, B. A. Smith and A. S. Murrell. 30 June 1959, New Mexico State University, University Park, N. Mex.

The authors describe the entire search for small natural earth satellites from its inception, through the development of various procedures, to the statistical conclusions.

Systematic observations were conducted on approximately 80 percent of all clear, moonless nights from December 1953 to October 1958. A total of 15,567 photographs was taken, in which the various cameras were driven at angular speeds to match those of possible revolving satellites. This could only be achieved by dividing the two principal planes, the equator and the ecliptic, into 281 concentric zones, each requiring its own drive rate. An equally important equivalent was performed in visual patrols, where geometrical circumstances rendered photography impractical.

An effective search for possible satellites revolving around the moon was made when a successful series of special photographs was obtained of the satellite regions around the moon during a long total eclipse of the moon on 18 November 1956.

269. SOLID PARTICLES IN SOLAR SYSTEM. Whipple, Fred L., Smithsonian Astrophysical Observatory and Harvard College Observatory, Cambridge, Mass. In Journal of Geophysical Research, Vol. 64, No. 1, pp. 1653-1664, November 1959.

Solid particles in the solar system are briefly discussed. To date the rocket and satellite work has not added definitive information on solid particles in interplanetary space. The best information comes primarily from studies of optical meteors, radio meteors, the zodiacal cloud, and meteorite analysis.

The analysis of argon spallation products from cosmic rays in meteorites indicates an upper limit to the rate of erosion of iron meteorites in space, 2×10^{-7} cm/year. Deductions based on study of the zodiacal light and the Fraunhofer corona remain today the best source for estimates of the quantity of fine dust in the solar system.

A study is presented of vitally needed meteoritical research, from space and from observations on the ground, to be supplemented by proposed ground-based experiments. The writer concludes that 70 to 90 percent of the expected results can be obtained from the ground. Both types of research should be supported because unanticipated results may be obtained from space and because ground-based research cannot give us good information concerning the solid particles in space much beyond the earth's distance from the sun. Ground-based information may be unreliable at the distance of Mars or beyond. Comparable investments for space-based and ground-based meteoritical research are strongly recommended.

270. SOME FACTORS AFFECTING THE RADIO DETERMINATION OF METEORIC VELOCITIES. McKinley, D. W. R., National Research Council, Ottawa, Canada. In Naturwissenschaften, Vol. 43, No. 10, pp. 21-22, 1956.

Consideration is given to the question as to whether or not some delaying effect in the reflection of radio waves from the ionized path of a meteor might account for a discrepancy between the observed mean value of the velocity of the Delta Aquarid shower meteors as determined by radio techniques and the mean photographic value corrected for deceleration as reported by Whipple.

271. SOME PHYSICAL AND STATISTICAL STUDIES OF METEOR FRAGMENTATION. McCrosky, Richard E. November 1955, Harvard College Observatory, Cambridge, Mass. Doctoral Thesis. ASTIA AD-93,444; Contract N5ori-07647.

Small meteors were investigated whose maximum intensities range from 3 to 0 in magnitude. The analyzed data were derived almost entirely from double-station photographs obtained with 4 Baker Super-Schmidt meteor cameras operated by the Harvard Meteor Project at Soledad Canyon and Dona Ana Stations in New Mexico. A rapid graphical method of meteor-trail reduction was developed to acquire a large amount of data with which to study the statistical aspects of the faint-meteor phenomena. Results are presented from about 1000 meteors which represent a homogeneous group with respect to apparent maximum magnitude.

272. SOME PROPERTIES OF COSMIC DUST. Krasovskii, V. I. In Doklady Akademii Nauk (SSSR), Vol. 89, No. 5, pp. 805-808, 1953 (in Russian).

This article discusses the charges and other properties of dust particles and concludes that (1) the effective section of the charged cosmic-dust particles for their collisions with the clouds of ionized gas is greater than their gas-kinetic (geometrical) section, (2) condensation of the interstellar ionized gas near the stars on positively charged particles is little probable, (3) condensation of the interstellar ionized gas occurs more readily on neutral and negatively charged particles, i.e., in regions of the cosmic space characterized by a small density of ultraviolet radiation, and (4) condensation of neutral interstellar gas is possible on both positive and negative particles. Collisions of particles among themselves and possibilities of change of charge are also discussed.

273. SOME RESULTS OF PRELIMINARY OBSERVATIONS OF RESONANCE OF RADIO WAVES BY METEOR TRAILS. Nemirova, E. K., Tomsk Polytechnical Institute. In Soviet Astronomy (AJ), Vol. 3, pp. 371-373, 1960.

Special observations for an experimental investigation of the influence of resonance, during the scattering of radio waves by meteor trails, on the accuracy of the determination of some meteor characteristics are being made at the Tomsk Polytechnical Institute. In the present paper some results of Tomsk preliminary observations are given.

274. A SPACE DUST SATELLITE. In The Aeroplane and Astronautics, Vol. 101, No. 2603, pp. 338-339, September 1961.

After radiation, probably the greatest environmental hazard affecting the future astronaut are the dust particles which exist in space. The main source of these particles is the asteroid belt, which may be the remains of an unformed planet or one which destroyed itself at an early stage of its evolution. Most of the "debris" is confined to the region of space between Mars and Jupiter, but some particles in eccentric orbits periodically cross the earth's path and impact on the earth and the moon.

When in space, the particles are known as micrometeoroids. To investigate the micrometeoroids more fully, NASA has a well-defined program of experiments employing different techniques. A system of some novelty is the S-55 satellite in which the attempt is made to assess the penetrative energy of the dust particles.

275. SPATIAL MICROMETEORITE DISTRIBUTION MEASURED BY SEVERAL EARTH SATELLITES. Martin, Henry L. April 5, 1959, Army Ballistic Missile Agency, Redstone Arsenal, Ala. Report ABMA DV-TN-15-59.

This report summarizes the results of experiments carried on earth satellites which were designed to measure the distribution of micrometeorites in space. It covers the results obtained by the satellites Explorer I, Explorer III, Sputnik III, and an attempted Vanguard satellite launching.

276. "SPORADIC SHOWER" PROPERTIES OF VERY SMALL METEORS. Gallagher, P. B. and Von R. Eshleman. In Journal of Geophysical Research, Vol. 65, No. 6, pp. 1846-1947, June 1960.

A long-term radar study of meteors as faint as 15th magnitude has led to the conclusion that these particles are grouped into millions of small showers of only a few hours duration. Because of the large number of these showers and their rare encounters with the earth it would be practically impossible to predict future occurrence of a given shower.

277. THE STATISTICS OF METEORS IN THE EARTH'S ATMOSPHERE. Hawkins, Gerald S. and Richard B. Southworth. In Smithsonian Contributions to Astrophysics, Vol. II, No. 11, 1958, Smithsonian Institution, Washington, D. C.

A random sample of 360 of the meteors doubly photographed by the Baker Super-Schmidt cameras has been taken. These meteors are fainter than those previously reduced, reaching a limiting photographic magnitude of +4. Their heights, velocities, radiants, and magnitudes have been accurately computed and are tabulated. Current meteor theory is briefly outlined, and certain of its predictions compared with statistics of the observed sample of meteors. The observed length of trail is less than that predicted by the single-body theory.

278. SYMPOSIUM ON PROBLEMS IN SPACE EXPLORATION. Ace Reporting Company, (Stenographic Transcript) April 29, 1959.

Included in the symposium is a report by Fred L. Whipple entitled "Solid Particles in the Solar System." The various experiments tried, or in progress, and the need for further and new instrumentation are summarized. This report also appears in Journal of Geophysical Research, Vol. 64, No. 11, November 1959.

279. THEORY OF THE RADIO DETECTION OF METEORS. Manning, Laurence A., In Journal of Applied Physics, Vol. 19, No. 8, August 19, 1948.

The methods of observation are described both for "bursts" of signal strength and "whistles" caused by reflection of radio waves from meteoric ionization. Consideration is given to the geometry of reflection, and it is shown that meteoric velocity and range can be accurately determined by combined pulse and whistle observations. The possibility of determining the direction and position of a meteor path by observations at three receiving locations is examined, and a method for interpreting such data is developed. An investigation is made of the fraction of meteors capable of producing bursts, and the important effect of the meteoric radiant is emphasized.

280. TIME LAG BETWEEN HIGH-SPEED PELLETS AND THE IONIZATION IN THEIR TRAILS. Davidson, R. A. and William S. Partridge, University of Utah, Salt Lake City. In Journal of Applied Physics, Vol. 28, No. 11, pp. 1304-1308, November 1957.

An investigation of the spatial relation between high-speed projectiles fired at velocities of from 1 to 2.5 km per sec shows that the ionization and light in their trail do not occur at a point along the projectile path at the same instant the projectile passes. The time lag has been measured by letting the projectile and ionization in its trail obstruct the transmission of microwaves through a short length of wave guide. The time lag between the pellet and the ionization was observed for magnesium, aluminum, and titanium projectiles, but attempts to obtain the same data for copper, steel, and zinc were unsuccessful because these materials did not seem to produce ionization in their flight at the velocities being investigated. Time lags of up to 100μ sec were measured at the lower velocities for aluminum projectiles. At velocities of 2.5 km per sec, no time lag was observed. That is, the ionization occurred immediately as the pellet passed. Measurements of the luminosity associated with these pellets by means of photocells indicated that the ionization and the luminous region occurred simultaneously. The variations of this time lag as a function of velocity are explained by some thermodynamic properties of the metal in the pellet.

281. TRANSLATED ARTICLES. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC-242110; Translation F-TS-8838/III from Biul. Vsesoyuz. Astron.-Geod. Obshchestov, Vol. 16, (23) 1955. ASTIA AD-120-627.

Contents:

"Determination of the Trajectories of Meteors in the Earth's Atmosphere," by K. P. Stanyukovich; "Installation for Meteor Photometry," by D. L. Astavin-Ruzumin; "Problems of the Number and Mass of Telemeteors of Various Brightness," by A. M. Bakharev; and "Problem of the Study of Telescopic Meteors," by V. Ye. Shtepan.

282. TRANSLATED ARTICLES. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC-242106; Translation F-TS-8837/III from Biul. Vsesoyuz. Astron.-Geod. Obschestvo, No. 10, pp. 19-27, 37-38, 42-44, 55-56, 1951. ASTIA AD-111,027.

Contents:
"Photographic Study of Meteors by the Moscow Section of the All-Union Astronomical Geodetic Society in 1949-1950," by N. I. Grishin and K. A. Mansurova; "Effect of the Passage of Bright Meteors on Radio-Reception," by Yu. N. Khlystov; "Attenuation of the Photographic Image of a Meteor as a Function of Its Angular Velocity," by D. L. Astavin-Razumin; "Expanded Plenum of the Committee on Comets and Meteors, of the Astronomical Council of the Academy of Sciences of the USSR," by B. Yu. Levin.

283. TRANSLATED ARTICLES. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC-249344; Translation F-TS-8863/III from Trudy Akademii Nauk Tadzhik SSR, Vol. 20, 1954 and Trudy Stalinabadskoi Astronomicheskoi Observatorii, Vol. 4, pp. 42-112, 125-151, 1954. ASTIA AD-111,051.

Contents:
"Results of the Photographic Study of Meteors at Stalinabad Observatory," by L. A. Katadev and A. K. Sonsnova; "Study of Meteors from Photographic Data (preliminary communication)," by A. P. Savrukhin; "The Curvature of the Path of a Photographic Meteor," by K. Kh. Saidov; "Heights of Telescopic Meteors from Observation at Stalinabad Astronomic Observatory of Tadzhik SSSR Academy of Sciences," by A. M. Bakharev; "Heights of Telemeteors by Ashkhabad Observations," by Igor S. Astapovich; "Influence of Meteors on the Nature of Planets and Satellites of the Solar System," by N. N. Sytinskaya; "Basic Achievements of Soviet Meteoritics," by Ye. L. Krinov; "Meteorologic Conditions of the Appearance of Silvery Clouds," by N. I. Grishin; "Some Results of the Study of Silvery Clouds," by O. V. Deminev; "Study of Meteors at the Simferopol' Meteor Station Imeni, and Prospects for Future Development," by K. A. Lyubarskiy and G. O. Zateyshchikov.

284. TRANSLATED ARTICLES. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC 262885; Translation F-TS-8939/V from Meteoritika Akademiya Nauk SSSR, Vol. 7, 1950. ASTIA AD-120,697.

Contents:
"Elements of the Physical Theory of Meteors and Crater-Forming Meteorites," by K. P. Stanyukovich; "Results of 12-year Studies of Telescopic Meteors at the Stalinabad Astronomical Observatory,"

by A. M. Bakharev; "A Few Questions of the Motion of Meteors in the Earth's Atmosphere," by B. Yu. Levin; "A Few Physical Phenomena Accompanying the Passage of Meteorites Through the Earth's Atmosphere," by Igor S. Astapovich.

285. U. S. SPACE EXPLORER SATELLITES. Victor, W. K. May 1, 1958, Jet Propulsion Lab., California Institute of Technology, Pasadena, Calif. JPL Ext Pub No. 491.

A chronological history of the development leading to Explorer I is presented. Objectives of Explorers I and III are listed, and agencies sharing in development of instrumentation for the experiments are mentioned. The Jupiter-C vehicle is described briefly; instrumentation for the Explorers is described more fully, and the calibration of components is explained. A brief report of telemetered information and the effectiveness of the communication system is also given. A short discussion of orbits is included.

286. VANGUARD. Stedfeld, R. L. In Machine Design, Vol. 28, pp. 82-86, November 1, 1956.

Some instrumentation is listed. A relatively unconventional item is an erosion gauge, consisting of a Nichrome film evaporated into a glass strip in the outer surface of the satellite. As the film becomes eroded by dust and micrometeorites, its resistance will increase. Another is the collision microphone, which is used to record the noise produced on a metal diaphragm in the skin by impact of small meteoric particles.

287. VANGUARD GEAR IN EXPLORER. ARMY'S GLOBE-CIRCLING SATELLITE CARRIES NAVY CIRCUITS. In Electronics (English Edition), Vol. 31, No. 8, February 14, 1958.

Explorer I is investigating three areas: cosmic rays, density and size of micrometeorites, and temperatures both inside and outside the satellite's shell.

Vanguard I is primarily concerned with ultraviolet radiation.

288. THE VARIATION OF IONIZATION ALONG A METEOR TRAIL. Greenhow, J. S. and E. L. Neufeld. In Monthly Notices of Royal Astronomical Society, Vol. 117, No. 4, pp. 359-369, 1957.

The ionized trails of faint meteors have been investigated by observations of radio echoes at two spaced receiving stations. The mean ionization curve is much shorter than predicted by present theory, and in particular the rise to maximum electron line density is more rapid than expected. Occasional meteors appear almost instantaneously with maximum electron density, and in many cases, irregularities in the ionization considerably distort the diffraction effects during trail formation. Evidence for the fragmentation of meteors is also presented. These effects are considered in relation to Jacchia's photographic observations of the light curves of faint visual meteors.

SECTION III. THEORETICAL STUDIES

289. ABNORMAL FREEZING NUCLEI IN THE ATMOSPHERE. Cwilong, B. M., Letter in Nature, Vol. 176, pp. 129-130, July 16, 1955.

At Panama during the period January 13 to February 17, 1955, nuclei were present in the atmosphere which caused the water drops to freeze at temperatures above those normally recorded; the abnormal nuclei were large and were also associated with abnormal rainfall. A similar phenomenon was observed in May and it is suggested that this is striking confirmation of Bowen's meteoritic hypothesis as both periods correspond with dates of meteoric showers.

290. THE ABSORPTION OF COSMIC RADIATION IN METEORITES. Bauer, C. A., Letter in Physical Review, Vol. 74, pp. 225-226, July 15, 1948.

The He content of meteorites formed at the absorption of primary cosmic ray particles in them is shown theoretically to be a function of the meteorite dimensions. Observations are consistent with this, and with the conclusion that it is possible for the whole He content of meteorites to have arisen from cosmic ray bombardment.

291. ABUNDANCES OF METEORIC LEAD ISOTOPES. Russell, R. D. In Nature, Vol. 179, p. 92, January 12, 1957.

The article compares the meteorite lead isotope ratios with the observed ratios in terrestrial minerals, and suggests that the isotopic data of Patterson could be interpreted as indicating recent chemical alteration of some stone meteorites.

292. THE ABUNDANCES OF THE CHEMICAL ELEMENTS IN THE GALAXIES AND THE THEORY OF THEIR ORIGIN. Greenstein, J. L. In Publication of the Astronomical Society of the Pacific, Vol. 68, No. 402, pp. 185-202, June 1956.

Although this work deals mostly with the structure of stars, there is considerable discussion on the properties of meteorites.

293. THE ABUNDANCES OF THE ELEMENTS. Urey, Harold Clayton. In Physical Review, Vol. 88, pp. 248-253, October 15, 1952.

The cosmic abundances of the elements were estimated by Goldschmidt (1937) from a study of terrestrial and meteoritic abundances and a comparison of these with Russell's data on the sun. More recently Brown has prepared a table weighting the proportions of the iron and silicate phases according to an estimated proportion of these phases in the earth. The writer has recently proposed that chondritic meteorites themselves may represent an average sample, and has shown that this assumption is consistent with the density of the moon, which on the basis of his recent discussion in regard to the origin of the solar system should also be approximately a sample of non-volatile materials. A table of abundances is prepared assuming that these meteorites do represent such a mean sample. This table does not differ markedly from Goldschmidt's, but is distinctly different from Brown's, both because of a different weighting of the phases in meteorites and because of a different choice of data from the literature. Iron is much less abundant than estimated by Brown and somewhat less abundant than Goldschmidt's estimate. There is some indication for markedly low abundances of Se and Te and Br and I, which may indicate some escape of these elements during the formation of the meteorites. Hg is low, almost certainly because of its loss as a volatile substance during the formation of the meteorites.

294. ACCRETION AND THE ORIGIN OF COMETS. Gething, P. J. D. In Monthly Notices of the Royal Astronomical Society, Vol. 111, No. 5, pp. 468-477, 1951.

The effect of small density asymmetries in an interstellar dust cloud on the process of accretion by the sun in its passage through the cloud is considered, with particular reference to Lyttleton's theory of the origin of comets. Such variations in density can give the accreted material a velocity component perpendicular to the axis of accretion sufficient to prevent the material falling into the sun. Nuclei which might form as a result of the disruption of the accreted material into separate segments can be deflected into periodic orbits, thus apparently removing one of the difficulties of Lyttleton's theory. It appears to be unlikely, however, that the steady state considered by Bondi and Hoyle in earlier papers concerning accretion problems would be reached in the presence of asymmetries. Thus, their estimates of the rate at which the sun can gain in mass might need to be considerably reduced. It is also shown that the influence of random magnetic fields on charged particles will tend to reduce the rate of accretion.

295. THE ACCRETION OF METEORITIC MATERIAL BY THE EARTH. Best, G. T. In Space Research: Proceedings of the First International Space Science Symposium, Nice, France, January 11-16, 1960. Kallman Bijl, Hilde, Editor. North-Holland Publishing Co., Amsterdam, 1960.

The various methods used for the detection of meteoric material are discussed, including those used in rockets and satellites, as well as the indirect methods such as studies of the zodiacal light and deep sea deposits.

The considerable scatter in the results of these investigations is reviewed and a possible explanation sought. Due to the Poynting-Robertson effect, and the barrier presented by Jupiter to larger particles, it is unlikely that micrometeorites should have the same origin, and consequently the same mass-distribution law, as meteors. Possible sources of the micrometeorite component are considered.

296. AERODYNAMIC EFFECTS OF METEORITES. A SPECIFIC CASE. Stanyukovich, K. P., National Astronautics and Space Administration, Washington D. C. NASA TT-F-70, August 1961, from Izvestiya Akademii Nauk SSSR, Otdeleniye Tekhnicheskikh Nauk, Mekhanika i Mashinostroyeniye, No. 5, pp. 3-8, 1960. ASTIA AD-261,101.

Presented is a study of atmosphere molecule collisions on a meteor body. For velocity impacts, the magnitude cx is found to be greater than theory predicts. For the given deceleration, the density of the atmosphere is thought to be several times lower than previously calculated by means of meteor data.

297. AERODYNAMIC EVIDENCE PERTAINING TO THE ENTRY OF TEKTITES INTO THE EARTH'S ATMOSPHERE. Chapman, Dean R., Howard K. Larson and Lewis A. Anderson. 1962, NASA, Ames Research Center, Moffett Field, Calif. Report NASA TR-134.

The authors personally studied actual tektites in eleven museums around the world. They then conducted a series of tests to determine if the configurations of tektites could have been the result of aerodynamic forces and heating. They concluded that aerodynamic factors are the most important.

The authors also made an analytical analysis of ablation.

298. AERODYNAMICS OF THE UPPER ATMOSPHERE. Masson, David J., Compiler. 10 June 1959, The RAND Corp., Santa Monica, Calif. Rand Report R-339.

The meteoroid deceleration, mass loss, and luminosity are formulated in general terms, and in such a form so as to allow direct comparison with observation. The purpose of this comparison was to deduce the applicability of conventional aerodynamic drag and heating relations to the meteor case. An attempt was made to use only the most reliable measurements - such as velocity and heights of appearance, maximum luminosity, and disappearance. Observations of deceleration, absolute luminosity, and variation of luminosity were not used.

299. AGE DETERMINATION OF STONE METEORITES BY THE RUDIDIUMSTRONTIUM METHOD. Schumacher, E. In Zeitschrift für Naturforschung, Vol. 11a, No. 3, pp. 206-212, 1956 (in German).

By comparison of the present measurements on two types of meteors with others made by different methods, an age value of $4.7 \pm 0.4 \times 10^9$ years was obtained, and a value of $6.75 \pm 0.03\%$ for the primordial abundance of Sr^{87}.

300. AGE OF METEORITES BY THE A^{40}/K^{40} METHOD. Wasserburg, G. J. and R. J. Hayden. In Physical Review, Vol. 97, No. 1, pp. 86-87, January 1955.

The ages of two stony meteorites were determined by measuring the A^{40}/K^{40} ratio using an isotopic dilution technique. With a branching ratio $\lambda_e/\lambda_\beta = 0.085$ and a decay constant $\lambda = 0.55 \times 10^{-9} yr^{-1}$, the ages obtained were $(4.82 \pm 0.20) \times 10^9$ and $(4.58 \pm 0.20) \times 10^9$ years.

301. THE AGES AND ORIGIN OF METEORITES. Reasbeck, P. and K. I. Mayne. In Nature, Vol. 176, No. 4474, pp. 186-188, July 30, 1955.

Ages of some stone meteorites determined by the helium method are shown to be in substantial agreement with the ages of the same meteorites determined by the argon-potassium method, indicating that diffusive loss of helium is unimportant. The ages are within the range 0.5-4×10^9 years, in general agreement with ages derived for stones by the isotopic lead content. The ages of iron meteorites derived by the helium method are less (2-4×10^8 years). This difference is believed to be significant, and its relevance to the problem of the origin of meteorites is discussed. A planetary origin for all meteorites seems attractive, the planet having undergone a cataclysmic break-up after the solidification of the bulk of the iron phase.

302. THE ALIGNMENT OF GALACTIC DUST. Gold, T. In Monthly Notices of the Royal Astronomical Society, Vol. 112, No. 2, pp. 215-218, 1952.

It is shown that the dynamic interaction between galactic gas and those dust particles which are elongated will, in certain circumstances, lead to a partial alignment of those particles. The direction which is preferred by the long dimension of the particles is that of the relative velocity between gas and dust. The possible relation between this effect and the observed polarization of starlight is discussed.

303. ANALYSIS OF LOW ENERGY SPUTTERING. Langberg, Edwin, RCA Labs., Princeton, N. J. In Physics Review, Vol. 111, No. 1, pp. 91-97, 1 July 1958.

A two-collision sputtering mechanism near the threshold is described. (Based on a dissertation submitted to the Department of Electrical Engineering at Princeton University in partial fulfillment for the requirement for the Ph. D. degree.)

304. APPLICATION OF ABLATION ANALYSIS TO STONY METEORITES AND THE TEKTITE PROBLEM. Adams, E. W. and R. M. Huffaker. In Nature, Vol. 193, No. 4822, pp. 1249-1251, March 31, 1962.

Since sufficient information is available about the initial and the final shapes of the button-type australites, their final descent can be analyzed by ablation and trajectory equations, the validity for missile heat protection shields of which is well established. Details are given of the investigated tektite model, the calculation method and the result of the calculation.

305. AN APPROXIMATE ESTIMATION OF THE PROBABILITY OF METEORIC IONIZATION. Fialko, E. I. In Soviet Astronomy (AJ), Vol. 3, pp. 479-483, 1960.

An appropriate estimation is made of the exponent n, which characterizes the relation of the probability of ionization to meteor velocity.

306. ARGON AND HELIUM DETERMINATION IN IRON METEORITES. Gentner, W. and J. Zahringer. Note in Zeitschrift für Naturforschung, Vol. 10a, No. 6, pp. 498-499, 1955 (in German).

A mass spectrographic determination of the isotopic abundances of argon and helium in four iron meteorites is given. It was found that the ratio A^{36}/He^{3} was constant over a concentration range of two powers of 10, and this is briefly discussed.

307. ASTROCHEMICAL PROBLEMS IN THE FORMATION OF THE EARTH. Latimer, W. M. In Science, Vol. 112, pp. 101-104, July 28, 1950.

Consequences of the assumption that the earth was formed by the condensation of a cold cosmic cloud are discussed in relation to the chemical composition of terrestrial matter and meteorites. The formation of water and the atmosphere is also considered.

308. THE ATTENUATION OF LIGHT BY METEORIC DUST IN THE UPPER ATMOSPHERE. Giovanelli, R. G. In Australian Journal of Physics, Vol. 7, No. 4, pp. 641-648, December 1954.

An examination of Zacharov's results on the wavelength variation of attenuation of solar radiation following the Perseid meteor shower shows that the effects could be produced either by absorbing particles of diameter about 10^{-5} cm or less, or by transparent particles of diameter in the range 5×10^{-5} to 10^{-4} cm. The rapid disappearance of attenuation, however, can be explained only if the particles evaporate on falling, and it is concluded that they are ice crystals formed on nuclei of meteoric origin at a height of about 80 km where there is a temperature minimum. From estimates of the light scattered by these ice crystals, it is deduced that they would be visible as noctilucent clouds.

309. BASIC PHYSICS OF THE SOLAR SYSTEM. Blanco, V. M. and S. W. McCuskey, Addison-Wesley Publishing Co., Inc., Reading, Mass., 1961.

The aim of this book is to present in a concise way some of the basic physical and dynamical aspects of the solar system. The book is an outgrowth of lectures given by the staff of the Department of Astronomy, Case Institute of Technology. Emphasis is placed on the methods used by astronomers and on the degree of precision with which various astronomical data have been determined.

310. BIBLIOGRAPHY OF LUNAR AND PLANETARY SEARCH - 1960 (WITH ANNOTATIONS). Salisbury, J. W. and L. T. Salisbury. July 1961, Geophysics Research Directorate,AFCRL, Bedford, Mass. GRD Res. Notes No. 62; AFCRL-684; ASTIA AD-265,171.

A checklist of lunar and planetary research articles published in 1960 is provided, plus a convenient starting place for a literature search on Astrobiology, Meteors and Meteorites, Moon, Origin of the Solar System, Planets and Tektites. In some cases 1959 articles have been included to present a more well-rounded reference list.

311. BIBLIOGRAPHY ON METEORITIC DUST WITH BRIEF ABSTRACTS (INCLUDING COMPILATION BY THE LATE WILLARD J. FISHER). Hoffleit, Dorrit. Harvard College Observatory Tech. Report 9, 1952; ASTIA AD-5,639.

A bibliography on meteoritic dust and closely allied topics, consisting of some 500 references, has been compiled from sources available at Harvard Observatory. For most of the references an abstract of a sentence or two has been added to enhance their usefulness. The nucleus of the bibliography was a card catalogue prepared twenty years ago by the late Willard J. Fisher. Arrangements of the bibliography is by senior author rather than by subject or date.

312. CALCULATION OF EROSION IN SPACE FROM THE COSMIC RAY EXPOSURE AGES OF METEORITES. Whipple, Fred L. and E. L. Fireman. April 1958, Smithsonian Astrophysical and Harvard College Observatories. In Nature, Vol. 183, No. 4671, pp. 1315, May 9, 1959.

A cosmic ray exposure age is obtained from the measurement of one radioactive and one staple spallation isotope produced in a meteorite by cosmic rys. A new interpretation of this age indicates that it sets an upper limit to the erosion rate of a meteorite in space. The more obvious interpretations in terms of meteorite break-up and planetary pertubational effects may remain valid.

313. COLLOQUIUM ON METEORIC ASTRONOMY. IV. Astapovich, Igor S. et al. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC-262979. Translation F-TS-8987/III from Biul. Vsesoyuz. Astron.-Geod. Obshchestvo, Vol. 2, No. 9, pp. 13-18, 1947. ASTIA AD-128,662.

On 9 November 1946 at Moscow for the first time after the end of World War II, a colloquium was held on meteoric astronomy, organized by the Moscow Section of the All-Union Astronomical and Geodetic Society. The object of the colloquium was a preliminary exchange of opinions on scientific and organizational questions. Before the war such colloquia were held three times and were of definite advantage in the development of Soviet meteoric astronomy.

314. A COMET MODEL. II. PHYSICAL RELATIONS FOR COMETS AND METEORS. Whipple, Fred L. In Astrophysical Journal, Vol. 113, pp. 464-474, May 1951.

It is shown that the icy conglomerate model for comets explains the anomalous accelerations of certain comets and also possible reductions in the effective attraction by the sun. These effects depend upon a moderate loss of matter, $\Delta M/M$ per period. This loss measures the loss of radius, $\Delta R/R$ while the solar radiation determines the maximum loss of radius by sublimation. By this means an upper limit of radius for 7 comets has been determined. The model predicts a large excess of unobserved hydrides, H_2O, NH_3 and CH_4 molecules, as compared to the observed CO^+, C_2 and CN. For Halley's comet, using Wurm's calculations for the rate of loss of CO^+ and C_2 and using the total loss of ices calculated from solar radiation for a nucleus of radius 10 km, the relative abundances of CO^+ and C_2 to the combined hydrides are 10^{-5} and 10^{-3}, respectively. These abundances are roughly consistent with certain of ter Haar's calculations for molecules formed from interstellar atoms. Calculations show that the predicted excess of hydrides will produce no appreciable Rayleigh scattering in comets and also little electron scattering, should all atoms become singly ionized by photo-ionization.

315. A COMET MODEL III. THE ZODIACAL LIGHT. Whipple, Fred L., Harvard College Observatory, Cambridge, Mass. In The Astrophysical Journal, Vol. 121, No. 3, pp. 750-770, May 1955. ASTIA AD-92,427.

The Poynting-Robertson effect is shown to require about 1 ton/sec of small particles to maintain the zodiacal cloud irrespective of particle shape, density, or dimension within the range of 10^{-4} to 1.0 cm. The zodiacal cloud is assumed to be of the nature deduced by Vạn de Hulst and Allen from their studies of the Fraunhofer corona and the zodiacal light. The probable cometary contribution to the zodiacal cloud is here considered on the basis of the icy-comet model. Some 30 tons/sec of meteoritic material contributed continuously in typical comet orbits are mostly lost by the action of the following physical forces or processes as the particles spiral inward toward the sun by the Poynting-Robertson effect: (a) interstellar wind, (b) Jupiter's random perturbations, (c) the Jupiter perturbational barrier, and (d) collisional destruction. Of these, b and d are found to be the most important. The final calculated contribution is about the required amount.

Collisions among the particles appear to be largely responsible for the cutoff in zodiacal particle size above about 0.03 cm, as found by Van de Hulst. Corpuscular radiation from the sun will simulate the Poynting-Robertson effect but will simultaneously tend to destroy the particles. No allowance for this effect is included in the calculations because of uncertainties in the numerical quantities involved. Corpuscular radiation, however, if sufficiently powerful, may exceed the Poynting-Robertson effect in importance and may also demand a larger source of material for the zodiacal cloud. If so, the corpuscular radiation will also increase the critical cutoff dimension.

316. COMETS AND METEOR STREAMS. Porter, J. G. International Astrophysics Series, Vol. 2, Chapmann and Hall, London, 1952. See a review of the book in Nature, Vol. 172, pp. 883, November 14, 1953.

In 1947 when the Physical Society conference was held in Manchester to discuss radar methods of investigating meteors, Dr. Porter gave a lecture which is expanded in this book. The last three chapters deal with meteors, Chapter 5, on meteor streams, giving a general survey on such matters as visual observations (including photography and radar), perturbations of meteor streams and the effect on the elements of their orbits. In the next chapter is shown how the orbit of a meteor stream is computed when the position of the radiant is known and also how corrections are made in this position when the earth's attraction and the aberrational effects due to the diurnal rotation are taken into account. The reverse problem, the determination of the radiant of a stream associated with a comet, is also dealt with. Chapter 7 deals with meteor velocities.

317. THE COMETS AND THEIR ORIGIN. Lyttleton, R. A. Cambridge University Press, Cambridge, Mass., 1953.

Contents:

Dynamical Properties of Comets.
Physical Properties of Comets.
Origin and Formulation of Comets.
Relation of the Present Theory to Earlier Ideas.

318. A COMPARATIVE ANALYSIS OF ATMOSPHERIC DENSITIES FROM METEOR DECELERATIONS OBSERVED IN MASSACHUSETTS AND NEW MEXICO. Jacchia, Luigi G. 1952, Massachusetts Institute of Tech., Numerical Analysis Lab., Cambridge. Tech. Rept. No. 10; ASTIA AD-6,809; Contract DA 19-020-ORD-1093, in co-operation with Harvard College Observatory.

Velocities, accelerations, and integrated luminosities were determined on photographic plates for 46 Massachusetts meteors and 73 New Mexico meteors. Atmospheric densities computed from the New Mexico meteors in the same general fashion as in Technical Report No. 2 (Harvard Preprint Series 11, no. 26) are in good agreement with the slope of the density profile derived from V-2 rockets; however, in analogy with the previous results for Massachusetts meteors, the residuals from the rocket curve are strongly dependent on velocity. A change of one full power in V in the fundamental equation is needed to make the residuals independent of velocity, but then the slope of the density curve diverges considerably from the rocket profile. The introduction of an empirical scale factor R reduces the velocity-free densities back again in the rocket profile. These final densities show only a slight seasonal effect, if any. Mass observations were reduced by using the same constants as for New Mexico. The final densities are in good agreement with the New Mexico densities up to 75 km, but above that height the Massachusetts densities are systematically higher. The seasonal effect was more than twice as large for the Massachusetts observations as for New Mexico. The bad distribution of the Massachusetts meteors with regard to seasons, velocities, and heights should, however, suggest some caution in interpreting this last result.

319. A COMPARISON OF THEORY AND OBSERVATION OF THE ECHO I SATELLITE. Bryant, R. W., December 1961, NASA, Goddard Space Flight Center, Greenbelt, Md. Report NASA TN D-1124.

Observations of the Echo I balloon satellite have been compared with a theory including the following perturbing effects: (1) solar radiation pressure; (2) lunar and solar gravitation; (3) second, third, and fourth harmonics of the earth's gravitational potential; and (4) atmospheric drag. With a set of orbital elements at the 26th day of the lifetime of the satellite, it was possible to match the observational data to 180 days with root mean square residuals as follows: $\Delta a = 17.9$ km, $\Delta e = 0.002$, $\Delta i = 0.0177°$, $\Delta w = 1.1231°$, $\Delta\Omega = 0.4821°$, Δ perigee height = 7.50 km. No differential correction has been applied as yet.

320. THE COMPOSITION OF METEORIC MATTER AND THE ORIGIN OF METEORITES. Brown, Harrison. In Science, Vol. 109, pp. 251-254, March 11, 1949.

Much chemical data must be accumulated before one can say definitely that meteorites did or did not have their origin in a planet. It is difficult to believe that, on the basis of existing data, the hypothesis can be refuted. However, with the development of new methods for studying meteorites, the time should not be too far distant when precise distribution coefficients are available together with adequate information on distribution coefficients as a function of temperature.

321. CONCENTRATION OF URANIUM AND LEAD AND THE ISOTOPIC COMPOSITION OF LEAD IN METEORITE MATERIAL. Patterson, C. C., Harrison Brown, G. R. Tilton and M. Inghram. In Physical Review, Vol. 92, No. 5, pp. 1234-1235, December 1, 1953.

The cosmic abundance of lead and uranium has been determined by studying the lead and uranium contents of meteoritic materials. Lead is found to be present to 8 x 10^{-3} atom/10,000 atoms of silicon, and uranium to 1 x 10^{-4} atom/10,000 atoms of silicon. The new value for lead removes the hump in the cosmic abundance curve in the 206-208 mass region. The relative primordial abundances of lead isotopes of mass 204, 206, 207 and 208 are found to be 1:9.4:10.3:29.2, respectively.

322. CONCERNING A CERTAIN EFFECT IN THE FIELD OF METEOR AERODYNAMICS. Stanyukovich, K. P. Translated by Joy B. Gazley, January 1962, The RAND Corp., Santa Monica, Calif. From Akademii Nauk SSSR, Otdeleniye Tekknicheskikh Nauk. Izvestia: Mekhanika i Mashinostroenie, Issue 5, 1960. Report RAND RM-2932 PR; ASTIA AD-270,232.

The study analyzes meteoric ablation resulting in expressions for the variation of mass and velocity during entry into the atmosphere. The results allow the use of meteor data to deduce the properties of the upper atmosphere.

323. CONFIRMATION OF OUTER ATMOSPHERIC ASYMMETRY POSTULATED TO EXPLAIN THE FALSE ZODIACAL LIGHT. Hope, E. R, Defense Research Board, Ottawa, Canada. In Nature, Vol. 192, pp. 742, November 25, 1961.

In 1952 and afterwards, the author suggested that the false zodiacal light, an early morning pyramid of light above the western horizon, resembling the zodiacal light which at that time would be on the opposite side of the sky might be explained if earth's gaseous tail were driven off mainly from the western twilight rim of the globe. In the article he points to some recent findings that support the idea.

324. A CONJECTURE ON THE NATURE OF SOME METEORIC MATTER. Anyzeski, Vincent. In Popular Astronomy, Vol. 55, pp. 169-171, 1947.

It is suggested that some meteors may be solid hydrogen, or ice, or such, with ordinary meteoritic material inclusions. Some bolides might on entering the atmosphere have a thick coating of H which might account for some trains. Nebulous meteors might be explained if they were considered to be of solid hydrogen.

325. A CONSIDERATION OF RADIO STAR SCINTILLATIONS AS CAUSED BY INTERSTELLAR PARTICLES ENTERING THE IONOSPHERE. I. DAILY AND SEASONAL VARIATION OF THE SCINTILLATION OF A RADIO STAR. Harrower, G. A. In Canadian Journal of Physics, Vol. 35, No. 5, pp. 512-521, May 1957.

Given is an analysis of measurements of the scintillations of the radio source in Cassiopeia recorded at Ottawa during 1954 at a frequency of 50 Mc/s. After removal of the effect of the altitude of the source, the data show certain daily maxima occurring at solar times dependent on the date of the year. The maxima are found to comprise five separate groupings, two being present roughly from September 13 to March 30, and the other three for the remainder of the year. The obvious lack of circular symmetry suggests a cause external to the solar system, such as the infall of interstellar particles. The apparent directions of arrival of these particles are derived from the scintillation measurements.

326. A CONSIDERATION OF RADIO STAR SCINTILLATIONS AS CAUSED BY INTERSTELLAR PARTICLES ENTERING THE IONOSPHERE. II. THE ACCRETION OF INTERSTELLAR PARTICLES AS A CAUSE OF RADIO STAR SCINTILLATIONS. Harrower, G. A. In Canadian Journal of Physics, Vol. 35, No. 5, pp. 522-535, May 1957.

The analysis of measurements of radio star scintillations is interpreted to be the result of the accretion of interstellar particles by the sun's gravitational field. After a brief general discussion of the accretion process, the measurements are examined in an attempt to provide an explanation on that basis. Five distinct features exhibited by the scintillation data are interpreted as resulting from particles arriving at the earth as follows: directly from interstellar space, from a collision region behind the sun (both directly and after having crossed the earth's orbit), and from the collision region by a process of accretion in the gravitational field of the earth. The collision region is calculated to be located a radial distance of 200 million miles from the sun.

327. A CONSIDERATION OF RADIO STAR SCINTILLATIONS AS CAUSED BY INTERSTELLAR PARTICLES ENTERING THE IONOSPHERE. III. THE KIND, NUMBER, AND APPARENT RADIANT OF THE INCOMING PARTICLES. Harrower, G. A. In Canadian Journal of Physics, Vol. 35, No. 7, pp. 792-798, July 1957.

It is suggested that interstellar particles, captured by the gravitational field of the sun, contribute to the observed features. Arguments presented here lead to the conclusion that such particles must be hydrogen atoms. The number of hydrogen atoms reaching the earth is estimated to be 6 x $10^{16}/m^2/sec$. Their energy averages 9 or 22 electron volts, depending on whether or not they are ionized. It is concluded that the effect of this fall on the earth's ionosphere would more than adequately produce scintillations. The location of the radiant, subject to the possibility of some considerable error, is judged to be right ascension 17 hours, declination -30°. Based on this position of the radiant, the velocity of the interstellar hydrogen atoms in the vicinity of the sun is found to have the components: tangential 28 x 10^4m/sec radial 2 x 10^4m/sec, and transverse 0.2 x 10^4m/sec, with respect to the plane of our galaxy.

328. THE COSMIC ABUNDANCES OF POTASSIUM, URANIUM AND THORIUM, AND THE HEAT BALANCES OF THE EARTH, THE MOON AND MARS. Urey, Harold Clayton. In Proceedings of the National Academy of Sciences, Vol. 41, No. 3, pp. 127-144, March 55.

Abundances of radioactive K, U and Th in representative chondritic meteorites appear to be higher by a factor of about 3.19 than in planetary bodies. Since the known thermal properties of the earth's mantle, the permanent anomaly in the shape of the moon, and the absence of a Martian core can all be accounted for on the basis of a decreased abundance for the above three elements, it is difficult to account for the present heat-balance of the earth without rejecting the hypothesis of radioactive heating in the initial stages of the melting of meteoritic matter. On the basis of the terrestrial abundances, the amount of heat available would be insufficient, but Al^{26} may have provided the additional thermal energy. Alternatively, a depletion of these radioactive nuclides in the planetary bodies considered could account for the required lower abundance values, if this occurred during this formation.

329. COSMIC DUST AND THE ORIGIN OF STARS. Lebedinsky, A. I. In Mémoires de la Societe Royale des Sciences de Liege, Vol. 15, pp. 678-681, 1955 (Special Number).

A theoretical discussion of the process of star formation in relation to the balance of interstellar gas, and dust in diffuse nebulae is given. Dwarf stars originate by gravitational condensation to form bodies of mass up to 5 $M_{\odot}$, and hot, giant stars derive from these dwarf stars in cold nebulae by an accretion process. Diffuse matter is continually used up in these concurrent processes, but the loss is offset by ejection of fresh material during the evolution of each star as the result of corpuscular radiation. A certain average concentration of discrete matter, denoted by the critical density value, is thus maintained automatically.

330. COSMIC RADIATION AND THE K^{40} - A^{40} AGES OF IRON METEORITES. Marshall, R. R. August 10, 1961, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif. Report JPL TR 32-147; ASTIA AD-271,649; Contract NASW-6.

The potassium-argon data of Stoenner and Zachringer are consistent with an age for the iron meteorites of 5.0 ± 0.5 aeons. For iron meteorites with moderate to high concentrations of He-3, the A-40 which has been produced by nuclear spallation and the A-40 produced by the decay of primordial K-40 can be calculated accurately (provided that the radiation age of the meteorite is known) and their sum compared to the measured A-40. Cosmogenic neon and argon predominate in inclusions of troilite and schreibersite in large ion meteorites. The enhanced yield of these elements seems to be due to the interaction of cosmic rays with elements below iron in atomic mass, such as chlorine, sulfur, and phosphorus. The K-39/K-41 ratio of some potassium recovered from the Canyon Diablo iron meteorite differed by less than 2% from the ratio in terrestrial potassium, but was consistent with the low radiation age of 0.145 aeon calculated by Fisher and Schaeffer for this meteorite.

331. COSMIC RADIATION EFFECTS IN METEORITES. Reasbeck, P. and K. I. Mayne. In Nature, Vol. 176, pp. 733-734, October 15, 1955.

Measurements are reported on the neon content of iron meteorites. The quantities observed agree well with the theory that they are residual nuclei left after evaporation due to cosmic radiation.

332. COSMIC-RAY-INDUCED RADIOACTIVITIES IN METEORITES AND TEKTITES. Ehmann, William D. 3 June 1957, Carnegie Institute of Technology, Pittsburgh, Pa. Doctoral Thesis. Report No. NYO-6634; Contract AT(30-1)884.

This thesis is concerned with the search for cosmic-ray-induced radioactivities in meteorites, tektites and some terrestrial materials. Several longlived radio activities which may be produced in meteorites by cosmic-ray bombardment are searched for by use of very low background counting techniques. This work has resulted in the detection of Al^{26}, Be^{10} and Co^{60} activities in several meteorites and Al^{26} and Be^{10} activities in several tektites and Libyan Desert glass.

333. COSMIC SOURCES OF DEEP-SEA DEPOSITS. Öpik, Ernst J. In Nature, Vol. 176, No. 4489, pp. 926-927, November 1955.

The author states that the black magnet spherules found in deep-sea deposits are micrometeors, and the general nickel excess may be due to amorphous cosmic matter.

334. THE CRATER CONTRIBUTION TO SURFACE ROUGHNESS OF THE MOON. Kornhauser, Murray, General Electric Co., Missile and Space Vehicle Dept., Philadelphia, Pa. Presented at the AAS 8th Annual National Meeting, Washington, D. C., January 16-18, 1962. Report No. AAS 62-23, American Astronautical Society, New York.

By plotting numbers of craters vs size and extrapolating below the size limit of telescopic resolution, it is found that less than ten percent of the moon's surface is covered by craters. In local areas, however, the surface is covered by craters. Slopes inside the craters are an inverse function of size, the 10,000 ft. diameter crater having a maximum slope of 46 deg. It is concluded that some areas of the moon should be easy to traverse, while others must be impassable.

The crater size distribution on the moon does not correlate well with the size distribution of sporadic meteoroids currently existing in earth-moon space, indicating that this may be a function of geologic time.

335. CRITICAL ANALYSIS OF SOLID DEBRIS IN SPACE. Jonah, Fred C. Vought Astronautics, Div. of Chance Vought Aircraft, Inc., Dallas, Tex. Paper presented at the I. A. S. National Summer Meeting, Los Angeles, Calif., June 28 - July 1, 1960. IAS paper 60-73. Institute of Aeronautical Sciences, New York.

A critical analysis is made of a number of the physical properties of the solid debris in space that are considered important for the design of space vehicles. The mass, density, and total number of this debris are considered in terms of the best available data on atmospheric properties, IGY meteor observation programs, high altitude rocket probes, satellite impact counts and many other sources. It is shown that there is a remarkably close agreement between the different estimates of the number of particles within the orbit of the earth when we consider the visual meteor magnitude range from 9 to 30.

336. CRITICISM OF DR. B. MASON'S PAPER ON "THE ORIGIN OF METEORITES." Urey, Harold Clayton. In Journal of Geophysical Research, Vol. 66, No. 6, pp. 1988-1991, June 1961.

The author points out many reasons why there are misunderstandings of this problem. He states "It seems likely that meteorites are produced by collisions in the asteroidal belt and that the stone meteorites are destroyed by further collisions in some tens of millions of years as has been suggested by Eberhardt and Urey, 1959, and Eberhardt and Hess, 1960."

337. DENSITY AND TEMPERATURE OF THE UPPER ATMOSPHERE. Jastrow, Robert. In Astronautics, Vol. 4, No. 7, July 1959, pp. 24-25, 108-109.

Analysis of IGY rocket and satellite data leads to the surprising picture of density in the auroral zone controlled by the Great Radiation Belt, and relatively independent of latitude outside this zone.

338. DENSITY OF THE LUNAR ATMOSPHERE. Öpik, Ernst J. and S. Fred Singer. University of Maryland, College Park, Md. In Science, Vol. 133, No. 3463, pp. 1419-1420, May 5, 1961. NASA Grant NsG-58-60.

The consequences of a model are worked out in which the lunar atmosphere is formed by gravitational accretion of interplanetary gas. The results differ from those of Firsoff and of Brandt, partly because of the inapplicability of the barometric equation to the case of an exosphere.

339. DETECTION OF ATMOSPHERIC DUST AND TEMPERATURE INVERSIONS BY TWILIGHT SCATTERING. Bigg, E. K. Commonwealth Scientific and Industrial Research Organization, Sydney, Australia. In Nature, Vol. 177, pp. 77-79, 1956.

Experiments for detection of atmospheric dust and temperature inversions by twilight scattering are described. The observations so far made are consistent with Bowen's rainfall-meteor dust hypothesis but provide no conclusive evidence to support it.

340. THE DEVELOPMENT OF PLANETARY COSMOGONY. Levin, B. Yu. and O. Yu. Shimdt. Translated by Z. Jakubski of Space Technology Labs., Inc., Los Angeles, Calif., from Priroda, No. 10, pp. 19-26. Report STL-TR-61-5110-37; ASTIA AD-264,161. Available from Department of Commerce, OTS, Washington, D. C.

All contemporary investigators in the field of planetary cosmogony consider that the planets were formed from a cold cloud of gas and dust in the vicinity of the sun. However, the opinions of scientists differ as to the origin of the cloud itself and the process of formation of planets from it. The majority consider that the principal process in planet formation was the accumulation of cold solid particles. Only the American astronomer G. P. Kuiper and Academician V. G. Fesenkov assume the disintegration of a protoplanetary cloud into large, massive protoplanets which subsequently, by decreasing their masses, became the present-day planets. In addition all scientists except V. G. Fesenkov hold that the earth was formed as a cold body and only after its formation was heated by the accumulation of radioactively generated heat.

341. DIAMONDS, METEORITES, AND THE ORIGIN OF THE SOLAR SYSTEM. Urey, Harold Clayton. In Astrophysical Journal, Vol. 124, No. 3, pp. 623-637, November 1956.

In order to explain the chemical composition and physical structures of meteorites, it is proposed that two sets of objects of asteroidal and lunar size were accumulated and destroyed during the history of the solar system. These are referred to as the "primary" and "secondary" objects. Since diamonds occur in meteorites, some of the objects must have been of lunar mass or greater, but it is not possible to be certain as to whether this occurred in the primary or secondary objects. The ages of the meteorites require that the primary objects accumulated about 4.5×10^9 years ago were heated by some means to the melting point of silicates and iron, were then cooled to 500°C for 10^7 - 10^8 years and, subsequent to this, were broken into fragments of less than centimeter and millimeter sizes. The secondary objects accumulated from these fragments about 4.3×10^9 years ago, and were of asteroidal size. These objects were broken up at some time or times during the last 4.5×10^9 years, and the fragments are the meteorites.

342. DISTRIBUTION OF ELEMENTS IN THE METEORITES AND THE EARTH, AND THE ORIGIN OF HEAT IN THE EARTH'S CORE. Urey, Harold Clayton. In Annals of Geophysics, Vol. 11, No. 1, pp. 65-72, 1955.

Thermochemical calculations relating to the distribution of various elements in the silicate, troilite and metallic phases of meteorites assuming equilibrium conditions at 2000°K, and comparison with observed concentrations, indicate that the concentrations of the radioactive elements uranium, thorium and potassium in meteorites are no guide to their concentration in the earth's core. Further considerations suggest that uranium and thorium cannot be present in sufficient concentration to maintain an abiadatic gradient and produce convection currents, but potassium might be. Alternatively, convection currents might arise from the progressive differentiation of earth material from a more to a less uniform chemical composition.

343. DISTRIBUTION OF METEOR RADIO ECHOES BY DURATION. I. REFLECTION FROM STABLE TRAILS. Fialko, E. E., Tomsk Polytechnic Institute. Translated from Astronomicheskii Zhurnal, Vol. 36, No. 5, pp. 867-873, September-October, 1959. In Soviet Astronomy (AJ), Vol. 3, pp. 842-843, 1960.

The distribution of meteor radio echoes intercepted from a sector is considered with respect to the duration of the reflections. Analytical expressions are derived for the general case and two particular cases. The experiments, on the whole, confirm the results obtained.

344. DISTRIBUTION OF RADIO FREQUENCY BRIGHTNESS ACROSS THE SOLAR DISK AND THE DERIVATION OF A MODEL CORONA. O'Brien, P. A. and C. J. Bell. Letter in Nature, Vol. 173, pp. 219, January 30, 1954.

From observations of the distribution of brightness across the solar disk on 1.4, 3.7, and 7.9 meters, the following expressions for electron density N and temperature T at radial distance (from the solar centre) R in the corona have been derived empirically: $N = 16 \times 10^8 R^{-5}$ cm^{-3} and $T = 2 \times 10^6 R^{-3}$ °K. These formulae give the best fit to the observations over the range of 1.2 to 3 times the photospheric radius. A slight defect of observed intensity at small radii over the predictions of the above model on 1.4 and 3.7 meters is attributed to scattering of irregularities of electron density in the corona.

345. DISTRIBUTIONS OF HELIUM-3 IN THE CARBO-METEORITE. Fireman, E. L. In Nature, Vol. 181, No. 4625, p. 1725, June 21, 1958.

The distribution of He^3 throughout a section of this meteorite was measured by neutron activation. These results are discussed in relation to the original shape of the meteorite and to the energy of cosmic ray protons responsible for this He^3.

346. DUST AND GAS IN INTERSTELLAR SPACE. Lebedinskii, A. I. In Doklady Akademii Nauk SSSR, Vol. 92, No. 3, pp. 507-510, 1953 (in Russian).

The part played by the heat of chemical reaction (causing the "local rise of temperature") generated when atoms of interstellar gas are absorbed by dust particles is emphasized. The main cause of these local rises of temperature is the formation of H_2 and H atoms. The total number of molecules of the dust particle evaporating when energy ϵ is liberated is calculated to be $\cong 0.026\ \epsilon/U$, where U is the average heat of evaporation of 1 molecule. Values of U and of T^* (absolute temperature at which the density of saturating vapors is 1 molecule/cm^3) are tabulated for H_2 and 8 simple components. If the temperature of the cosmic dust is 10°K, H_2 cannot solidify on dust particles. For the range 10-30°K, the value of U is 0.1-0.15 ev; owing, however, to the local rises of temperature, there remain in these particles only molecules with U $\cong$ 0.5 ev. With the exception of H_2, the evaporated molecules undergo photodissociation.

347. DUST AND STAR FORMATION IN SUPERNOVA EXPLOSIONS. Öpik, Ernst J. In Mémoires de la Société Royale des Sciences de Liège, Vol. 5, pp. 634-637, 1955 (Special Number).

The radiation pressure of a cataclysmic outburst like that of a supernova, acting on the interstellar dust, will produce thin, dense shells, the sheet of dust concentration moving gradually outwards. When overtaken by the gaseous envelope from parent star, the sheet will act as a center for nucleation, with the formation of an expanding association of discrete stars.

348. THE DUST CLOUD ABOUT THE EARTH. Whipple, Fred L. In Nature, Vol. 189, No. 4759. pp. 127-128, January 14, 1961.

The author gives the rocket, satellite and space probe observations of acoustical impact which have assisted in demonstrating the existence of a high concentration of interplanetary dust near the earth. Four possible explanations for the dust concentration are discussed. The author suggests that the dust and droplets originate from the moon by meteoritic crater formation into temporary cislunar orbits.

349. DYNAMICAL EFFECTS OF RADIATION IN THE SOLAR SYSTEM. Robertson, H. P. In Monthly Notices of the Royal Aeronautical Society, Vol. 97, pp. 423-438, April 1937.

The article investigates the motion of a small spherical body in a beam of radiation, under the supposition that it absorbs all the energy falling upon it, and that it re-emits this energy at the same rate isotropically with respect to a reference system in which it is instantaneously at rest.

350. DYNAMICAL LIMITS ON A LUNAR ORIGIN FOR TEKTITES. Varsavsky, Carlos M. 20 November 1957, Harvard College Observatory, Cambridge, Mass. Air Force Office of Scientific Research, ARDC, Washington, D. C. AFOSR-TN-57-697; ASTIA AD-136,690.

Theories regarding the origin of tektites are reviewed; it is proposed that the moon is the most likely source for these objects. Detailed calculations show that the Whipple-Rinehart model for the ejection of tektites from the moon makes it possible to reproduce their observed distribution over the earth's surface.

351. THE EARTH'S DUST BELT. Whipple, Fred L. Paper presented at the 7th Annual Meeting of the American Astronautical Society. January 16-18, 1961, Dallas, Tex. AAS Reprint 61-46. Also _in_ Astronautical Sciences Review, Vol. 3, pp. 17-20, February 1961.

Evidence for a dust belt around the earth is presented. Various theories on why it exists are discussed. In particular the likelihood of its originating from material ejected from the lunar surface as a result of meteoritic impact is emphasized.

352. EFFECT OF MAJOR METEORIC SHOWERS ON THE DENSITIES OF THE UPPER ATMOSPHERE. Rasool, S. I. _In_ Science, Vol. 134, No. 3476, pp. 385-386, August 11, 1961.

A study was made to show that the amount of meteoric dust entering the earth's atmosphere is quite significant. A first analysis of the density data inferred from the satellite measurements is consistent with the expected density increases during the major meteor shower. More data will be required to confirm this hypothesis.

353. THE EFFECT OF RADAR WAVELENGTH ON METEOR ECHO RATE. Eshleman, Von R. February 1, 1953, Stanford University, Electronics Research Lab., Stanford, Calif. SU-ERL-TR-59; ASTIA AD-3,549.

A new theory is given for the way in which the number of echoes received from sporadic meteor ionization trails varies with radar wavelength and other system parameters. Previously published explanations of the echo rate dependence on wave-length are critically examined. The present explanation of echo rate variation is based on a more complete analysis of the radio reflection process than is afforded by the Lovell-Clegg theory. A number of apparent conflicts in earlier investigations are reconciled by the new theory.

354. THE EFFECTS OF METEORITES UPON THE EARTH (INCLUDING ITS INHABITANTS, ATMOSPHERE, AND SATELLITES). LaPaz, Lincoln. In Advances in Geophysics, Vol. 4, Edited by H. E. Landsberg and J. Van Mieghem. Academic Press, New York, 1958.

A detailed survey paper in which the following subjects are discussed: The Effects of Typical Falls; Number, Classification and Weights of Recovered Meteoritic Accretion; the Hyperbolic Meteorite Velocity Program I and II and Crater-Producing Meteorite Falls. A list of 202 references to the literature is included.

355. ELEMENTS OF THE PHYSICAL THEORY OF METEORS. Levin, B. Yu. 1955, Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC-262874; Translation F-TS-8928/V; from Astronomicheskii Zhurnal, Vol. 17, pp. 12-37, 1940. ASTIA AD-120,689.

The phenomenon of meteors, arising in the upper layers of the atmosphere, is undoubtedly intimately connected with the structure of these layers. For a comprehensive utilization of the results of meteor observations to study the stratosphere, a physical theory of meteors must first be established. This theory must take account not only of the general course of the phenomenon but also of the elementary physical processes that occur during that course.

356. ELEMENTS OF THE PHYSICAL THEORY OF METEORS. PART II. Levin, B. Yu. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio, Report ATIC-262875; Translation F-TS-8929/V; from Astronomicheskii Zhurnal, Vol. 18, pp. 331-340, 1941. ASTIA AD-142,690.

The problems of the evaporation of molecules from the meteor surface and its effect in screening the meteor and retarding into motion in the atmosphere are discussed.

357. ELEMENTS OF THE PHYSICAL THEORY OF METEORS AND CRATER-FORMING METEORITES. Stanyukovich, K. P., A. M. Bakharve et al. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC 262885; Translation No. F-TS-8939/V; from Meteoritika, Akademiya Nauk, SSSR, Vol. 7, pp. 36-62, 1950. ASTIA AD-120,697.

Contents:

1. Results of 12 year studies of telescopic meteors at the Stalinabad Astronomical Observatory.
2. A few questions of the motion of meteors in the earth's atmosphere.
3. A few physical phenomena accompanying the passage of meteorites through the earth's atmosphere.

358. EMPTY SPACE. Van de Hulst, Hendrik Christoffel. In Scientific American, Vol. 193, No. 1, November 1955.

The vast reaches between stars contain about one atom per cubic centimeter, perhaps a quarter of the matter in our galaxy. This substance is made visible by the ultra-violet radiation of stars. Interstellar space contains almost as much matter as comprises the stars.

359. EPHEMERAL NATURAL SATELLITES OF THE EARTH. Baker, Robert M. L., Jr., Aeronutronic Systems, Glendale, Calif. In Science, Vol. 128, No. 333, pp. 1211-1213, November 14, 1958.

A discussion is presented of transient or short-lived natural satellites of the earth, which result from meteorites that only graze our atmosphere. Preliminary calculations show that only about 0.2 percent of the total number of the porous, stony meteorites which strike the earth will result in natural satellites. It is noted that such satellites also would be difficult to detect observationally.

360. THE EROSION OF METEORS AND HIGH SPEED VEHICLES IN THE UPPER ATMOSPHERE. Hansen, C. F. March 1957, NASA, Ames Aeronautical Lab., Moffett Field, Calif. NACA TN-3962; ASTIA AD-125,284.

A simple inelastic collision model of meteor-atmosphere interaction is used and analytic relations for velocity, deceleration, size, and relative luminous magnitude of meteors are derived and expressed in dimensionless parametric form. The analysis is compared with available quantitative observations of meteor behavior, and it is indicated that a large fraction of the atmospheric bombardment energy is used in eroding meteoric material. The erosion from large, high-speed vehicles as they traverse the high-altitude, free-molecule portion of the atmosphere is calculated on the assumption that the vaporization process is similar to that which occurs for meteors. The maximum possible erosion does not create significant mass loss. The minimum and maximum velocity of meteors and the heating of meteors and radiation losses are discussed in two appendices.

361. THE EVAPORATION OF CARBON. Goldfinger, P. In Mémoires de la Société Royal de Sciences de Liège. Vol. 15, pp. 378-385, 1955 (Special Number).

It is shown that recent results of evaporation measurements on graphite are compatible with the thermodynamic properties of C, C_2, and C_3 and C_5 provided that their respective heats of evaporation are taken to be 170, 200, 200 and 230 kcal/mole. Consideration is given to the exothermic bimolecular exchange reaction which leads to the formation of C atoms in flames, and in stars, $2CH = C + CH_2$, and also reactions of the form $C_x + CH = C_{x+1} + H$, which lead to soot formation.

362. AN EXAMINATION OF THE ZODIACAL LIGHT AND GEGENSCHEIN FROM PHOTOELECTRIC MEASUREMENTS AT THE JUNGFRAUJOCH. Behr, A. and H. Siedentopf. In Zietschrift für Astrophysik, Vol. 32, No. 1, pp. 19-50, 1953 (in German).

The brightness and polarization of the evening zodiacal light and gegenschein have been recorded in blue and yellow light using a photo-multiplier (1P21) and tuned amplifier, in conjunction with color-filters and a rotating "Polaroid" analyzer. The polarized component of the zodiacal light exhibits a symmetrical elliptical intensity distribution with respect to the ecliptic, the isophotic axes having ratio 2:1. The unpolarized component shows marked asymmetry, with a strong concentration along the ecliptic. The surface brightness of the gegenschein exceeds the sky background by an amount equal to about 30 x 10 magnitude stars/sq degree. The observed zodiacal polarization (19% at 60° from $\odot$) is supposed due to free electrons, the dust component of the zodiacal matter causing inappreciable polarization, the particle radii being $> 10^{-4}$ cm.

363. FACTORS AFFECTING LIFETIME OF EARTH SATELLITES. Petersen, N. V. In Aeronautical Digest, Vol. 73, No. 1, pp. 74-76, July 1956.

The utility of earth satellites is strongly related to their orbit stability, as influenced by the several perturbing forces acting on the satellite mass. Primary perturbations of the orbit path will be caused by (1) nonsphericity of the earth (oblateness caused by the earth's rotation about polar axis), (2) anomalies in the earth's crust (nonuniform distribution of the earth's mass, for example, mountain ranges, oceans and land masses) and (3) drag, due to immersion of the satellite in the earth's atmospheric envelope.

Secondary perturbations will be due to the variable, combined gravitational field of the earth-moon-sun system. However, this influence will be negligible with respect to the earth's oblateness and atmospheric drag.

364. A FEW PROBLEMS OF METEORITICS. Fesenkov, V. G. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Translation F-TS-8940/III, from Meteoritika Akademiya Nauk SSSR, Vol. 8, pp. 38-54, 1950. ASTIA AD-120,698.

365. FIRST SYMPOSIUM: SURFACE EFFECTS ON SPACECRAFT MATERIALS. Clauss, F. J., Editor. Held at Palo Alto, Calif., May 12-13, 1959. Sponsored by Air Research Development Command, U. S. Air Force and Missile Space Division, Lockheed Aircraft Corp. John Wiley and Sons, Inc., New York, 1960.

Of special interest is the article "Interplanetary Dust Distribution and Erosion Effects," by Beard, pp. 378-404.

366. THE FITTING OF TRUNCATED TYPE III CURVES TO DAILY RAINFALL DATA. Das, S. C. In Australian Journal of Physics, Vol. 8, No. 2, pp. 298-304, June 1955.

The method of maximum likelihood has been used to fit a truncated type III (Gamma) distribution to daily rainfall data for Sydney over the period 1859 to 1952. An approximate test of the hypothesis that there is a singularity at the origin is suggested. This test is based on a comparison of the expected frequency in the truncated part, when the observed frequency in this part is taken into account in the fit, with the expected frequency when these observations are neglected. For Sydney the test shows that there is no evidence in the rainfall data for a singularity at the origin.

367. FOUSSIERES METEORIQUES DANA L'ATMOSPHERE TERRESTRE. Link F. In Bulletin of the Astronomical Institutes of Czechoslovakia, Vol. 4, pp. 158-161, 1953.

Due to atmospheric dust, a layer is formed in the earth's atmosphere which shows itself through the fading of light. There exists a relation between the fading and the density of the meteoric materials, which only recently has been discovered.

368. FRAUNHOFER CORONA AND ZODIACAL LIGHT. Elsässer, H. In Zeitschrift für Astrophysik, Vol. 37, No. 2, pp. 114-124, 1955 (in German).

Using the zodiacal light measures of Behr and Siedentopf (1953), and the usual model of dust distribution in the planetary system, the brightness of the F-corona is computed, and a value of 5 x 10^{15} cm^{-3} is obtained for the number density of dust particles. Computation of the color-excesses of the F-corona, and of an interpolated distribution between that of the zodiacal light and that of a solar corona, using successive electron-density values for the outer coronal regions, leads to a mean value close to that observed by Blackwell (1952).

369. GAS-DUST INTERACTION IN THE ACCRETION OF INTERSTELLAR DUST BY THE SUN. Stephenson, C. B. February 14, 1957. In Astrophysical Journal, Vol. 126, pp. 195-201, July-November 1957.

" . . . Approximate calculations have been made to ascertain the behavior of dust particles of the order of 10^{-5} cm in diameter, for which $p \sim 1.0$, in the radiation field of the sun and subject to viscosity effects in the interstellar gas . . ." Velocities of the order of 5 km/sec are considered.

370. GAS HYDRATES IN COMETARY NUCLEI AND INTERSTELLAR GRAINS. Delsemma, A. H. and P. Swings. In Annales d'Astrophysique, Vol. 15, pp. 1-6, January-February 1962 (in French).

Solid hydrates of CH_4, CO_2, . . . may be present in cometary nuclei and interstellar grains. The vapour pressures (hence, the rates of sublimation) of the various hydrates are of the same order of magnitude while the vapour pressures of solid CH_4, H_2O, . . . differ by very large factors. The relative abundances of the radicals which are observed in comets would be explained more satisfactorily by assuming the presence of solid hydrates.

371. GEOLOGICAL AGE OF METEORITES. Paneth, F. A., University of Durham, England. Letter in Nature, Vol. 165, No. 4194, pp. 454, March 18, 1950.

Reference is made to author's joint survey of radiochemical and astronomical results on the age of the universal comments concerning the "surprisingly wide range of values' for the dates of solidification of meteoritic material. Further studies on meteorites are being conducted.

372. GEOPHYSICAL ASPECTS OF METEORS. Lovell, Alfred Charles Bernard. In Handbuch der Physik (Encyclopedia of Physics), Band XLVIII, Geophysik II. Flügge, S., Editor. Springer-Verlag, Berlin, 1957.

373. HELIUM AND NEON AS REACTION PRODUCTS OF COSMIC RADIATION IN IRON METEORITES. Wanke, H. and J. Hintenberger. In Zeitschrift für Naturforschung, Vol. 13A, pp. 895-897, October 1958 (in German).

The helium and neon content of several iron meteorites was accurately measured. The rare gases were absorbed on activated carbon at the temperature of boiling nitrogen, and the quantity obtained was determined with a Pirani manometer. A mass spectrographic analysis was then made of the sample. The results are tabulated and show a neon isotopic ratio different from atmospheric neon.

374. IGY ROCKETS AND SATELLITES: A REPORT ON THE MOSCOW MEETINGS, AUGUST 1958. Kellogg, William W. September 15, 1958, The RAND Corp., Santa Monica, Calif. Rand Report P-1501. In Planetary and Space Science, Vol. 1, pp. 71-84, 1959.

The report is a summarization of 77 papers presented at the Technical Symposia on Rockets and Satellites during the Fifth meeting of the Committee Spéciale de l'Année Géophysique Internationale at Moscow, July 31 to August 9, 1958. Such topics are reviewed as atmospheric structure, electromagnetic properties of the ionosphere, cosmic and auroral particles, solar and stellar ultraviolet and X-ray radiation, micrometeorites, biological experiments, rocket and satellite instrumentation, and rocket and satellite programs.

375. THE IMPACT OF COSMIC RADIATION IN METEORITES. Geiss, J. and H. Oeschger. In Space Research: Proceedings of the First International Space Science Symposium, Nice, France. January 11-16, 1960. Kallman Bijl, Hilde, Editor. North Holland Pub. Co., Amsterdam, 1960.

From tritium contents in small stony meteorites, a primary cosmic flux of 0.6 - 0.8 particles/cm^2 sec sr with Ekin $>$ 300 MeV is calculated. Intensity variations of the cosmic radiation with time can be detected by comparison of cosmic ray produced radioisotopes in meteorites. Radiation ages (exposure ages) of meteorites from He^3/tritium contents and from isotopes are discussed. The oldest observed radiation ages lead to an upper limit of 2×10^{-7} g/cm^2 year for the space erosion rate of iron meteorites. From this figure an upper limit of 3×10^{-22}g/cm^3 for the dust density along the path of the iron meteorites in space may be evaluated. It is shown that radiation ages of the order of 10^7 years or younger are not affected appreciably by space erosion, but rather give the time of the creation of the meteorite by a break-up process from a larger object.

376. IMPACTITE SLAG AT BARRINGER CRATER. Mininger, H. H. In American Journal of Science, Vol. 252, No. 5, pp. 277-290, May 1954.

The material found is composed of dolomite, silica, calcium carbonate, and particles of metallic nickel-iron.

377. THE INFLUENCE OF METEORIC DUST ON RAINFALL. Bowen, E. G. In Australian Journal of Physics, Vol. 6, No. 4, pp. 489-497, December 1953.

A correlation is shown between peak rainfall and the passage of meteor streams. A log of approximately 30 days is observed. The relation between meteoric dust and noctilucent clouds is explained.

378. INTERACTION OF DUSTY AND GASEOUS INTERSTELLAR MATTER. Krasovskii, V. I. In Doklady Akademii Nauk, SSSR, Vol. 92, No. 5, pp. 907-910, 1953 (in Russian).

The author discusses the effect of the concentration of interstellar dust on the ionization and dissociation of interstellar gas. The neutralization of H II can occur as a result of collision either with electrons or with (neutral or charged) dust particles. These particles in a heated ionized interstellar gas, which consist, e.g., of Si or Fe oxides, are probably covered with a thin layer of the reduced element, owing to the (chemical) adsorption of atomic H. In the conditions of interstellar space, each collision between H and a dust particle carrying adsorbed H atoms will result either in formation and evaporation of H_2 or in adsorption of H in the holes of the monatomic Si(Fe) film. In cold interstellar gas (~ 100°K), a recombination of this kind will only occur with very few atoms whose energy E exceeds 10 k/T. Hence, a relatively large-scale formation of molecules on dust particles is possible only in regions with a high-density or high-temperature gas, but it is not possible in cold and rarefied gas. The energy of each dust particle is probably higher than the mean kinetic energy of molecules of the surrounding gas. In the vicinity of hot stars, where there is little dust matter, it is the electrons that are mainly responsible for the neutralization of H II, and the radio-temperature of H I can be higher than in regions with much dust. The distribution and composition of interstellar dust should vary in the cosmic space according to differences in the light and electron pressures.

379. INTERNATIONAL ASTRONAUTICAL CONGRESS PROCEEDINGS, XIth, VOL. I, MAIN SESSIONS. Held in Stockholm 1960. Reuterswärd, Carl W. P., Editor. Springer-Verlag, Wien, 1961.

The papers are on the following subjects: Planetary Atmosphere Environments; Interplanetary Environment; Medicine; Navigation and Space Communications; Guidance Control; Propulsion; Space Projects; Trajectories; Vehicles and Power Supplies and Economics.

380. INTERNATIONAL GEOPHYSICAL YEAR INFORMATION BULLETIN NO. 7. November 1960. National Aeronautics and Space Administration, Washington, D. C. Report NASA TT F-50.

Presented are articles on the dependence of the frequency of appearance of noctilucent clouds upon the date and the geographical latitude, on the control of permanency of airglow transparency, on the study of movements of winds in the F2 layer, which were made by the phase method, and on foreign methods of observations carried out with rockets and artificial earth satellites.

381. INTERPLANETARY DUST DISTRIBUTION. Beard, David B. In General Research in Flight Sciences. Vol. III. Fluid Mechanics-Gas Dynamics. January 1959, Lockheed Aircraft Corp., Missiles and Space Division, Sunnyvale, Calif. Report LMSD-48381; ASTIA AD-210,403. The paper is a reprint of LMSD-2393, 25 April 1958. Also in Astrophysical Journal, Vol. 64, pp. 496-506, 1959.

A detailed calculation of the dust-scattered light at very small elongations from the sun (2-10 solar radii) reveals (1) that the dust is distributed as $\gamma^{-\nu}$, where γ is the distance from the sun and ν is some number possibly less than, but most probably equal to, 1.5; (2) that the minimum radius of the dust particles is a few microns; (3) that the particle concentration depends on the particle radius, a, as a^{-p} where p is a number possibly equal to, but most probably greater than, 2.5; (4) that the scattered light should depend linearly on the square root of the wave length of the light; (5) that the concentration of dust at the earth's orbit is, to a good approximation, 10-14-10-15 particle/cc; but (6) that, because of the earth's gravitational field, the concentration at the earth's surface may be increased to as much as 10^{-1C}-10^{-11} particle/cc.

382. INTERPLANETARY DUST DISTRIBUTION AND EROSION EFFECTS. Beard, David B. Presented at the Western Regional Meeting, American Astronautical Society, Stanford University, Palo Alto, Calif., August 18-19, 1958. AAS Preprint No. 58-23. Also in Advances in Astronautical Science, Vol. 3. Plenum Press Inc., New York, 1958, and First Symposium: Surface Effects on Spacecraft Materials, held at Palo Alto, Calif., May 12 and 13, 1959. Clauss, Francis J., Editor.

The presence and extent of minute material distributed throughout the solar system are inferred from observations of the outer solar corona and the brightness of the night sky. Calculations based on the observations show, in an unambiguous way, that the dust concentration decreases with increasing solar distance as about $r^{-1.5}$ where r is the solar distance. The density of particles depends inversely on the particle radius to roughly the 3.5 power. Considerations of the orbits of particles in the combined gravitational fields of the sun and the planets and the observations themselves show concentrations of the dust in the plane of ecliptic and in the region of the planets. Roughly 10^{-5} to 10^{-6} particles larger than 4 microns should impact cm^2/sec on a satellite skin. This figure is in agreement with the direct observations made with Explorer I.

383. INTERPLANETARY DUST AND PHYSICAL PROCESSES IN THE EARTH'S UPPER ATMOSPHERE. Kaiser, T. R. and M. J. Seaton. In Mémoires de la Société Royale des Sciences de Liége, Vol. 15, pp. 48-45, 1955 (Special Number).

The density of interplanetary matter entering the earth's upper atmosphere is too low for the individual particles to play a major role in most problems of atmospheric physics, though they are probably important in ionospheric nocturnal E-ionization, and the thermal balance.

384. INTERPLANETARY MATTER AND THE IONOSPHERIC DISTURBANCES CAUSING SCINTILLATION OF RADIO STARS. Ginzburg, V. L. Translated by Hope, E. R. January 24, 1953, Defense Scientific Information Service, Canada. Translation T82R from Doklady Akademii Nauk, SSSR, Vol. 84, pp. 245-248, 1952. ASTIA AD-4,233.

A discussion is presented of the hypothesis of Ryle and Hewish (Monthly Notices of the Royal Astronomical Society, v. 110, p. 381, 1960) regarding the agency responsible for the scintillation of radio stars which are produced by interplanetary matter in the earth's atmosphere. Direct testing of the hypothesis is believed possible by observation of changes in the nature of the scintillation of radio stars while the moon eclipses. During this time the stream of cosmic particles precipitating onto the earth is screened by the moon.

385. INTERPRETATION OF MICROMETEORIC DATA. Fuchs, Otto P. February 1961, Temple University, Physics Dept., Philadelphia Pa.

386. INTRODUCTION TO ASTRONOMY. Gaposchkin, Cecilia Helena (Payne). Prentice-Hall, Inc., New York, June 1954.

387. INVESTIGATION CONCERNING FUNDAMENTAL PROBLEMS OF METEORIC ASTRONOMY. Hoffmeister, C. In Observatory, Vol. 70, pp. 70-76, April 1960.

This is a contracted report on the investigations of methods of observations of meteoric astronomy. In the August 1950 issue a letter to the editor amends a statement on the velocity of meteors made in the above article, and there is comparison made of velocity with mass of meteor.

388. ISOTOPIC ANOMALIES OF MOLYBDENUM IN SOME IRON METEORITES. Murthy, V. Rama, University of California, La Jolla. In Journal of Geophysical Research, Vol. 67, No. 2, pp. 905-907, February 1962.

The anomalous molybdenum found in some iron meteorites (Aroos, Santa Luzia, Odessa and Deep Springs) cannot be attributed either to any contamination effects or to fractionization in the mass spectrometer. The anomaly for the 92/100 ratio in Aroos is as large as 6 to 7 percent relative to terrestrial molybdenum. It is believed tentatively that these isotopic anomalies are real; they are all the more puzzling because they seem to be restricted only to some meteorites.

389. ISOTOPIC COMPOSITION OF METEORITIC HYDROGEN. Edwards, G. In Nature, Vol. 176, pp. 109-111, July 16, 1955.

Measurements have been made on iron meteorites, and it has been found that the D/H ratio is different for the surface rust and for the interior, which leads to the view that the latter is the same as for the original hydrogen incorporated during the formation of the meteorite. The ratio is 12.9% less than for average sea water. The agreement of these figures with data for carbonaceous chondrites is discussed.

390. THE ISOTOPIC COMPOSITION OF POTASSIUM FROM METEORITES. Rik, G. R. and Yu. A. Shukoliukov. Translated by Hope, E. R. February 23, 1956. Directorate of Scientific Information Service, Canada. Translation F167R from Doklady Akademii Nauk, SSSR, Vol. 94, pp. 667-669, 1954; ASTIA AD-106,681.

A study was made of the isotopic composition of potassium extracted from three meteorites, and also potassium of terrestrial origin. The Padvarninkiai meteorite which fell in 1929 was studied; it belongs to the eucrite type. The isotopic composition of potassium extracted from a mixture compounded of two meteorites of identical type was also studied. The findings are additional confirmation of the thesis that meteoric and terrestrial matter have a common origin and evolution.

391. ISOTOPIC CONSTITUTION OF SULPHUR IN METEORITES AND TERRESTRIAL OBJECTS. Trofimov, A. In Doklady Akademii Nauk, SSSR, Vol. 66, No. 2, pp. 181-184, 1949 (in Russian).

Since the work of Aston, who first established the complex composition of sulphur, and the work of Nier, who determined the isotopic composition of sulphur with much greater precision and completeness, no new data have been published on the isotopic composition of this element.

Up to the present time, comparative studies have been made, by various methods of a number of meteoritic elements, Fe, Ni, Cl, Si, C, O, K^{40}, Cu, Ga.

In the present paper the first results secured in a mass-spectroscopic investigation of the isotopic composition of natural sulphur compounds, mainly of meteoritic origin, are being communicated.

392. A LABORATORY INVESTIGATION OF METEOR PHYSICS. Jensen, James R. and E. P. Palmer. October 15, 1961, University of Utah, Salt Lake City. Technical Report No. 22; AFOSR 1938; ASTIA AD-270,181; Contract AF-49(638)462.

Equations of motion for a single particle traveling in a constant density atmosphere are derived. The aerodynamic drag on the particle and the atmosphere-particle energy transfer resulting in loss of particle mass are considered. It is assumed as an initial condition that steady-state ablation is occurring. Emphasis is placed on determining particle size and absolute luminosity from measurements of distance versus time. Micron-size particles, which travel at velocities in lower meteor range of 10 to 20 km/sec, are produced by impact of spherical steel pellets on a steel target. The leading edge of a cloud of particles was detected and velocities to 15 km/sec were measured. By applying the theory to deceleration measurements, the size of the particles was estimated at approximately 1.0 micron diameter. An improved vacuum firing range was designed to correct for the vacuum and size limitations.

393. LUNAR DUST AND THE GEGENSCHEIN. Brandt, J. C. and Paul W. Hodge. In Nature, Vol. 192, No. 4806, pp. 957, December 9, 1961.

Review is made of some possible explanations for the gegenschein. The dust trail hypothesis in conjunction with Whipple's supposition that the moon might be the source of the earth's dust layer is considered to be the most likely explanation. Possible methods of testing the hypothesis are proposed.

394. THE MASSES OF METEORS. Öpik, Ernst J. In Armagh Observatory Contribution No. 14, 1955. Also in Mémoires de la Société Royale des Sciences Liége, 4th Ser., No. 15, pp. 125-146, 1955.

Observational data indicate that meteors (as a whole) are of the spongy, dust-ball type of a much lower average density than that of the minerals of which they consist. They seem to decompose (pulverize) from aerodynamic pressure, on the order of 10 cm of water. The masses of meteors cannot therefore be calculated simply from considerations of liquefaction or vaporization at the expense of the aerodynamic work of resistance. The only method at present available for the calculation of masses is still that based on radiation data; formulae are given to enable determination of meteor masses.

395. MEAN HOURLY RATE OF METEORS RECORDED BY RADAR. I. METEOR STREAM. Fialko, E. I., Tomsk Polytechnic Institute. Translated from Astronomicheskii Zhurnal, Vol. 36, No. 4, pp. 626-628, July-August, 1959. In Soviet Astronomy, (AJ), Vol. 3, pp. 12-614, 1960.

A general expression is derived for the number of meteors detected by radar under conditions of normal reflection (scattering) of radio waves by ionized trail in the case of a meteor stream.

A simplified formula for calculations was deduced.

396. MEASUREMENTS OF INTERPLANETARY DUST. Singer, S. Fred., University of Maryland, College Park. In Scientific Uses of Earth Satellites, Proceedings of 10th Anniversary Meeting of Upper Atmosphere Rocket Research Panel, Ann Arbor, Mich., 26-27 January 1956. Van Allen, James A., Editor. University of Michigan Press, Ann Arbor, 1956.

A simple theory is developed for the motion of charged interplanetary dust particles in the vicinity of the earth. These considerations are then applied to possible experimental tests in rockets or satellites. Some suggestions are made for resolving the discrepancy between meteor data and optical measurements of interplanetary dust-particle densities. The problem of dust-particle accretion is briefly considered.

397. THE MECHANICAL PENETRATION OF BUMPER SCREENS. Langton, N. H. In British Interplanetary Society Journal, Vol. 13, No. 5, pp. 283-294, September 1954.

The mechanical penetration of bumper screens of different materials by an iron or stone meteorite is investigated theoretically; tables and graphs showing the penetrations for different sized meteorites at varying impact velocities are given. These values are compared with those for the thermal penetrations, and conclusions about the design of bumper screens and spaceship hulls are thereby obtained.

398. METEOR HAZARDS BEYOND THE ATMOSPHERE. Ovenden, Michael W. In Space Research and Exploration. Bates, David Robert and P. More, Editors. Eyre & Spottiswoode, London, 1957.

A discussion of the effect of meteors on the lifetime of artificial satellites is given.

399. METEOR HAZARDS TO SPACE STATIONS. Ovenden, Michael W. In British Interplanetary Society Journal, Vol. 10, No. 6, pp. 275-286, November 1951 also in The Artificial Satellite: Proceedings of the 2nd International Congress on Astronautics, London 1951 and in Realities of Space Travel. Crater, J. L., Editor. Putnam, London, 1957.

The analysis of Grimminger is summarized, and possible astronomical factors affecting its validity are examined. The existence of iron meteors is shown to require a reduction in Grimminger's collision times by a factor of about 2. Radar observations provide direct evidence for the assumed number of meteors/magnitude relationship down to magnitude 7; extrapolation beyond this limit is uncertain because of the removal of smaller meteors by the Poynting-Robertson effect.

400. METEORIC DUST IN THE EARTH'S ATMOSPHERE. Link, F. In Bulletin of the Astronomical Institutes of Czechoslovakia, Vol. 4, pp. 158-161 (in French).

The author considers the possibility that a high altitude layer of meteoritic dust would cause absorption of light that could be observed during lunar eclipses. For the effective diameter of particles that produce the greatest absorption, he obtains values of the order of one μ. A systematic, extensive collection of meteoric dust could provide data on the nature of the particles and their total mass. However, particles that enter the earth's atmosphere simultaneously are not collected simultaneously on the surface of the earth, since the time required to fall depends on their diameter. During a long time of fall, fine iron particles may be oxidized and therefore would not be found in magnetic material collected.

401. METEORIC EFFECTS ON ATTITUDE CONTROL OF SPACE VEHICLES. White, J. B., NASA, Marshall Space Flight Center, Huntsville, Ala. In American Rocket Society Journal, Vol. 32, No. 1, pp. 75-78, January 1962.

To design adequately an attitude control system for an orbital vehicle, it is necessary to know the magnitudes of the disturbances acting on the vehicle. Numerous papers are available dealing with disturbances resulting from earth's gravitational, magnetic and electric fields, aerodynamic drag, and solar radiation pressure, but little has been done to determine attitude disturbance due to meteoric bombardment. The purpose of this paper is to develop general methods for determining meteoric disturbances for any known vehicle configuration; the methods are then applied to the 24-hour communication satellite for illustrative purposes. Probable disturbance is in the order of 10^{-3} deg/sec. Calculated impact density agrees favorably with that measured by Explorer I and a Vanguard.

402. METEORIC EROSION. Miksch, Ed, Amherst, Mass. In British Interplanetary Society Journal, Vol. 16, pp. 246, 1957.

This letter which pertains to the article by Singer in Jet Propulsion (V. 26, p. 1071, December 1956) states that the estimated rate of 10 microns loss in 1600 seconds of sandblasting seems too high. At this rate, meteoric dust should erode meteors as well as spaceships, and a moon the size of Phobos would become minute in 1.6×10^{12} sec. Since meteors and moons do exist, it is believed this figure is too high.

403. THE METEORITE DANGER ON EARTH. Kornhauser, Murray. Paper presented at 4th Western Regional A. A. S. Meeting, San Francisco, Calif., 1-3 August 1961. American Astronautical Society, New York. AAS Preprint 61-80.

Because of the present state of international tensions, there is a high likelihood that the impact of a large meteorite in the vicinity of a populated area, with attendant phenomena very similar to those of a re-entering and exploding ballistic missile war-head could cause very serious political repercussions. The similarities in appearance are presented as well as the probability that a large meteorite will impact during this period of tension. A simple means of distinguishing the difference in effects is presented.

404. METEORITES AND SPACE TRAVEL. Whipple, Fred L., Harvard College Observatory, Cambridge, Mass. In Astronomical Journal, Vol. 52, pp. 131, February 1947.

This one-page article discusses the probability of puncture by a meteor. The probability is once in 50 years for a 1-milligram meteor and a satellite of a 12 ft. diameter and a 1/4 in. steel skin.

405. METEORITES, SATELLITES, AND CERAMICS. Rinehart, John S., Smithsonian Institution Astrophysical Observatory, Cambridge, Mass. In American Ceramic Society Bulletin, Vol. 37, No. 11, pp. 461-467, November 15.

Studies of meteorites and their related phenomena can give clues to satellite design and behavior. Discussed are (1) the nature of meteoritic material, (2) general aspects of meteorites, (3) phenomena attending flight, (4) ablation effects and (5) conclusion.

406. METEORITIC IMPACT. Beard, David B. In American Rocket Society Journal, Vol. 31, No. 1, pp. 87-88, January 1961.

The impact of meteoroids on a space vehicle skin is examined from a consideration of the different physical processes by which energy transfer can occur. It is shown that only evaporation is significant, that erosion is negligible, and that puncture is less likely than previously thought by many authorities, the threshold thickness in centimeters being only 0.6 cm for one puncture per year per $100m^2$ of surface.

407. METEORITIC PHENOMENA AND METEORITES. Whipple, Fred L. In Physics and Medicine of the Upper Atmosphere: A Study of Aeropause. University of New Mexico Press, Albuquerque, 1952.

A discussion of the possibility of meteoritic penetration of high altitude vehicles is presented.

408. METEORITIC RISK TO SPACE VEHICLES. Whipple, Fred L., Smithsonian Astrophysical Observatory and Harvard College Observatory, Cambridge, Mass. In Vistas in Astronautics, Vol. 1, Pergamon Press, New York, 1958; also in Proceedings of the VIIIth Astronautical Congress, Barcelona, Spain, October 1957. Springer-Verlag, Vienna, 1958 and American Rocket Society Preprint ARS 499-57.

Consideration is given to the distribution of meteoritic material and its rate of fall on the earth as functions of mass and velocity. With a simple theory, the probabilities are calculated that surfaces in space in the neighborhood of the earth may be punctured by meteoric action. A table of data and probabilities is given. It is calculated that a near-earth satellite of radius 20 inches and skin thickness of 0.5 mm Al will be punctured on the average of once in five days.

Upper limits to the effects of skin erosion on a space-exposed surface are calculated on the basis of erosion by meteoritic dust, by corpuscular radiation from the sun and by gases of the extended solar corona. The erosive effect from meteoritic dust is comparable to the combined effects from the other two causes and gives a rate of skin (Al) erosion of the order of 2×10^{-13} gm/cm^2/sec or less. Optical surfaces exposed to space should not be affected functionally by erosion over periods less than about a year. Attention is given to the expected degree of accuracy of the observed data and the conclusions, particularly for the meteoritic material. The uncertainties arise from combined theoretical and observational limitations.

409. METEOROID HAZARD TO NUCLEAR POWER STATIONS IN SPACE. Bjork, Robert L. December 21, 1960, The RAND Corp., Santa Monica, Calif. Rand Report P-2172. See also entry 72 in Part B of the Bibliography.

This report is an assessment of the meteoroid hazard to a nuclear power station operating in the vacuum of space. Such a station will require a radiator of large area. The radiator is the component shown to be most vulnerable to meteoroids in the sense that more weight is required to armor it properly than any other portion of the station. The radiator is indispensable, since the station must constantly rid itself of the heat created within it or else suffer the consequence of a continual temperature rise until intolerable levels are reached. This report, a condensed version of P-1963, was published in Nucleonics, April 1961.

410. METEORS. Whipple, Fred L., Smithsonian Astrophysical Observatory and Harvard College Observatory, Cambridge, Mass. In New Horizons in Astronomy. Smithsonian Contributions to Astrophysics, Vol. 1, No. 1, pp. 83-86, 1956. Same title in Publications of the Astronomical Society of the Pacific, Vol. 67, No. 399, pp. 367-386, December 1955.

The author outlines the problems confronting the observers of meteors and calls for a study of the relation that exists between the orbits of comets and meteors, the distribution of particle orbits to produce the observed zodiacal light, the nature of the

Gegenschein, the development of meteor streams of great diffusion or low population, and a number of problems relating to orbits of comets, meteors, meteorites and asteroids.

411. METEORS. Whipple, Fred L. and Gerald S. Hawkins. In Handbuch der Physik (Encyclopedia of Physics), Vol 52, Astrophysics III, The Solar System. Flügge, S., Editor. Springer-Verlag, Berlin, 1959.

Basic theory of meteors, their origin, spectra, dynamics, orbits, visual photographic and radio observations, masses and densities, showers, sporadic meteors, total influx, meteorites, their chemical compositions, distribution in space, ablation, ionization, etc. are discussed in review fashion with ample data and illustration.

412. METEORS AND SPACE TRAVEL. Von Pirquet, I. G. In British Interplanetary Society Journal, Vol. 9, pp. 153-154, July 1950.

Some further calculations are given for the limiting value of the dangerous particle size. The conclusion is that interstellar flight is completely impracticable.

413. METEORS AS A DANGER TO SPACE-FLIGHT. Clarke, Arthur, C. In British Interplanetary Society Journal, Vol. 8, pp. 157-162, July 1950. Based on "Probability that a Meteorite Will Hit or Penetrate a Body Situated in the Vicinity of the Earth," by George Grimminger, which appeared in Journal of Applied Physics, Vol. 19, No. 10, pp. 947-956, October 1948. See entry number 107 in Part B of the Bibliography.

A detailed analysis of the problem is given for meteors with the following dimensions: Visual magnitude from -3 to 30; number 28,000 to 45 x 10^{16}, mass from 4 to 2.5 x 10^{-13} gram; and a diameter from 1.3 to 0.00005 cm. Charts and tables are included.

414. MOTION OF COSMIC DUST IN INTERPLANETARY SPACE. Fesenkov, V. G. 1955, Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC-262878, Translation F-TS-8932/III from Astronomicheskii Zhurnal, Vol. 23, No. 6, pp. 353-366, 1946. ASTIA AD-120,693.

The problem of the variation in the elliptic elements of the orbit of an individual dust particle moving under combined action of solar attraction and of light repulsion is considered. Interest is centered on the secular variation of the elements of the dust particles.

415. ON METEOR MASSES AND DENSITIES. Whipple, Fred L. In Astronomical Journal, Vol. 57, pp. 28-29, April 1952.

This paper discusses meteors of various densities and meteoroids of cometary origin.

416. ON THE FREQUENCY DISTRIBUTION OF THE ELEMENTS OF ORBIT FOR INTERPLANETARY DUST PARTICLES. Haug, H. In Zeitschrift für Astrophysik, Vol. 44, No. 2, 1958 (in German).

The space density of dust particles and the rate of capture of particles by the earth, are expressed as integrals involving the frequency distribution N (a,e,i,) of the elements of particle orbits.

417. ON THE OPTICAL INTERPRETATION OF THE GEGENSCHEIN. Siedentopf, H. In Zeitschrift für Astrophysik, Vol. 36, No. 3, pp. 240-244, 1955 (in German).

An analogy is drawn between the gegenschein and the optical-meteorological phenomenon of the halo. This interpretation leads to estimates of the distribution function of the radii, of the albedo and of the number density of the interplanetary dust particles which are in good agreement with the other estimates of these quantities.

418. ON THE SIZE OF METEORIC DUST IN THE TERRESTRIAL ATMOSPHERE. Bulletin of the Astronomical Institutes of Czechoslovakia, Vol. 7, pp. 69-75, 1956.

A number of reasons are given against the theory presented by Svestka of the existence of meteoric dust in the atmosphere with diameters in the range of 10^{-6} to 10^{-3} cm.

419. ORIGIN, EVOLUTION, AND STRUCTURE OF METEOR SWARMS. Levin, B. Yu. 1958, Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Translation F-TS-9228/V, of Physical Theories of Meteors and Meteoric Material in the Solar System, Chapter IV, pp. 147-190, 1956. ASTIA AD-153,381.

The meteor bodies that originate from the disintegration of comets remain for a long time in swarms, stretched out along the orbit of the parent comet, and often having the form of closed elliptical rings. The meteor bodies making up each swarm are not gravitationally bound to each other, and therefore the existence of a swarm is merely due to the fact that the relative velocities of these bodies are very small by comparison with the velocity of their orbital motion, so that motion takes place along almost "parellel" orbits. The evolution and gradual dispersion of each meteor swarm is due to three factors; first, the initial velocities of "expulsion" of particles from the comet, thus producing (with the different radiation pressure of the sun on particles of different size) an initial dispersion of their orbits, and, in particular, of their periods of revolution, leading to the stretching of the swarm into a closed ring; second, by planetary perturbations which act differently on different parts of the swarm and ultimately lead to increasing thickness; third, by the bremsstrahlung of the sun, leading to a very slow widening of the swarm in its orbital plane.

420. PERIODIC INFLUX OF INTERPLANETARY DUST PARTICLES INTO THE TERRESTRIAL ATMOSPHERE. Sen Gupta, Prabhat K. In Indian Journal of Meteorological Geophysics, Vol. 5, No. 3, pp. 272-276, July 1954.

A brief account is given of available evidence on the influx of interplanetary dust particles into the terrestrial atmosphere, viz., presence of sodium at high altitudes, appearance of noctilucent clouds, pitting of polished surfaces during high altitude rocket flights, high nickel content in deep sea sediments and periodic occurrence of heavy rainfall in association with meteor showers. These dust particles have sizes of the same order as of those which account for the outer corona of the sun, but terrestrial evidences suggest a higher concentration in the vicinity of the earth. Discussing the processes which are responsible for the high concentration of dust particles, it has been suggested that solar corpuscular streams push interplanetary dust particles towards the earth by repeated impacts. This mechanism is expected to give rise to an accumulation of dust particles near the earth, as well as in the plane of ecliptic.

421. THE PHYSICAL THEORY OF METEORS. VIII. FRAGMENTATION AS THE CAUSE OF THE FAINT METEOR ANOMALY. Jacchia, Luigi G. In Astrophysical Journal, Vol. 121, No. 2, pp. 521, March 1955.

The observed decelerations and light-curves of bright meteors are in good agreement with the simple ballistic theory, while fainter meteors photographed with the Super-Schmidt cameras in New Mexico show startling anomalies. In particular, the durations of faint meteors are shorter and the deceleration increases faster than predicted by the theory, when the mass is computed from the integration of the luminous-intensity-curve, in the same fashion as for bright meteors. Extreme fragility and progressive fragmentation seem to account for these and other anomalies. The concept of pellet-like meteors must be replaced with that of a cluster of breaking fragments in the case of smaller bodies.

422. PHYSICAL THEORY OF METEORS AND METEORIC MATTER IN THE SOLAR SYSTEM. Levin, B. Yu. Academy of Sciences, USSR, Moscow, 1956 (in Russian).

423. THE PHYSICAL THEORY OF METEORS AND THE STUDY OF SPACE DENSITY OF METEORIC MATTER. Levin, B. Yu. In Bulletin of the Astronomical Institutes of Czechoslovakia, Vol. 7, pp. 45-49, 1956.

It is concluded that the preponderant part of the sporadic meteor moves to the right, and the average density amounts to 1.1×10^{-2} cm^{-3}.

424. PHYSICS OF METEOR FLIGHT IN THE ATMOSPHERE. Öpik, Ernst J. Interscience Tracts on Physics and Astronomy, No. 6. Interscience Publishers, Inc., New York, 1958.

The book is a mathematical treatise including discussions of energy transfer, meteor radiation and ablation.

425. PHYSIOLOGICAL ASPECTS OF INTERPLANETARY TRAVEL. Germain, A. V. In American Helicopter, Vol. 21, No. 2, pp. 10-12, 19 January 1951.

The danger of collision with meteorites is calculated, and ways to cope with pressure losses arising from the collision are discussed.

426. THE POYNTING-ROBERTSON EFFECT ON METEOR ORBITS. Wyatt, Stanley P., Jr. and Fred L. Whipple. In Astrophysical Journal, Vol. III, pp. 134-141, January 1950.

The Poynting-Robertson effect will operate to sweep small particles of the solar system into the sun at a cosmically rapid rate. Robertson derived an expression for the times of fall from inertially circular orbits. Since, if other parameters are equal, the times are less for orbits of high eccentricity, tables are given to enable simple calculation of the times of fall in terms of initial orbit elements, q and e, and particle radius and density.

427. PRINCIPLES OF METEORITICS. Krinov, E. L. Pergamon Press, New York, 1960.

An English translation of a Russian book concerned mainly with morphology and meteorology of meteorites.

428. PROBABILITY OF SATELLITES BEING HIT BY PELLETS. Knothe, Herbert. October 1961, Directorate of Research Analysis, Holloman AFB, N. Mex. Report AFORS/DRA-61-2.

A great number of N pellets ($N > 10^3$) is assumed to rotate about the earth at a distance r, $r_o \leq r \leq r_1$, from the center of the earth. The inclination of i_p of their orbits with respect to the equator may lie in the interval $i_o \leq i_p \leq i_1$. The question discussed is probability that one or several satellites will be hit by one of these pellets during a certain number of rotations.

429. THE PROBLEM OF A METEORIC DUST LAYER IN THE EARTH'S ATMOSPHERE. Svestka, Z. In Bulletin of the Astronomical Institutes of Czechoslovakia, Vol. 5, pp. 91-98, 1954.

The author discusses again the evidence for a high atmosphere dust layer, as deduced from lunar eclipse observations. He calculates that only particles of radius 10^{-3} or 10^{-6} cm are consistent with the observations. Such small particles would have to be carried to the lower parts of the atmosphere much faster than the rate computed for a quiet atmosphere. The author believes that turbulence could do this.

430. PROBLEMS IN THE PHYSICS OF METEORS. Öpik, Ernst J. In American Journal of Physics, Vol. 26, No. 2, pp. 70-79, February 1958.

Some basic notions of the physics of meteors are illustrated and recent developments mentioned. Values of the efficiency of meteor radiation are visible light, formulae for the calculation of meteor masses, tables for the ionizing efficiency, depth of penetration of the ions, and the selectivity of radar observations with respect to velocity are given. The importance of initial penetration of the high velocity ions in determining the radius of the ionizing column, and the selectivity of radar observations, biased against velocities exceeding 50 km/s, are pointed out. The dust ball nature of visual meteors is described. The significant share of nickel-iron in meteoric populations is stressed. Systematic errors in correlating meteor decelerations with atmospheric densities are discussed.

431. PROBLEMS OF SPACE DEBRIS WITH THE SATELLITE STATION. Proell, Wayne. In Journal of Space Flight, Vol. 7, pp. 1-4, December 1955.

The discussion is directed toward calculating the mathematical probability of impact with debris.

432. QUANTITATIVE ESTIMATE OF FREQUENCY AND MASS DISTRIBUTION OF DUST PARTICLES CAUSING THE ZODIACAL LIGHT EFFECT. Kallman, H. Korff. In Mémoires de la Société Royale des Sciences de Liége, Vol. 15, pp. 100-113, 1955 (Special Number).

From an estimate of the number of meteors, and amount of meteoric dust entering the earth's atmosphere per day, and the Van de Hulst-numbered distribution as a function of radii for the Z. L., a comparison is made of the two types of dust, between 1 and 250 micron particle-size. The differences are found to be so large as to imply that interstellar space must contain two different types of particles of similar density, but of different origin.

433. THE RELATION BETWEEN ASTEROIDS, FIREBALLS, AND METEORITES. Hawkins, Gerald S. In The Astronomical Journal, Vol. 64, No. 10, pp. 450-454, December 1959.

Asteroids, meteorites and fireballs with visual magnitude $M < -5$ are shown to have the same mass distribution. Bright fireballs are therefore asteroidal debris, whereas the fainter meteors originate in the nuclei of comets. The influx of cometary meteors equals the influx of asteroidal meteors at a visual magnitude of -3. The percentage of asteroidal meteors varies from 90 percent at magnitude = -10 to 7 percent at magnitude = +5. A fireball of magnitude -10 travelling with a velocity of 17 km sec^{-1} has a mass of 40 kg on entering the earth's atmosphere and produces a meteorite weighing approximately 10 kg. The earth on the average encounters 3.3 fireballs per day with magnitude ≤ -10 and collects an asteroidal fragment with mass $\gtrsim$ 4,000 tons every hundred years.

434. REMARKS ON THE ARTICLE BY A. R. HIBBS, "THE DISTRIBUTION OF MICROMETEORITES NEAR THE EARTH." Dubin, Maurice, National Aeronautical and Space Administration, Washington, D. C. In Journal of Geophysical Research, Vol. 66, No. 8, pp. 2592-2594, November 1961.

This letter is addressed to the question whether the data from the Explorer I micrometeorite experiment is indicative of an altitude dependence of the impact rate of micrometeorites, and the attendant implication that perhaps a very large fraction of the particles measured on Explorer I were moving in closed orbits about the earth, as hypothesized in the paper by Hibbs (1961).

435. RESEARCHES ON THE PHYSICAL THEORY OF METEOR PHENOMENA. I. THEORY OF THE FORMATION OF METEOR CRATERS. Öpik, Ernst J. In Acta et Comm., University of Tartu., 1936; Tartu. Obs. Publ. 28, No. 6, 1936.

436. SATELLITE PRESSURE LOSSES CAUSED BY METEOROID IMPACTS. Kornhauser, Murray, General Electric Co., Philadelphia, Pa. In American Rocket Society Journal, Vol. 30, No. 5, pp. 475-479, May 1960.

In order to predict the frequency of hull penetration of a satellite capsule by meteoroids, estimates are made of the frequency of encounters with meteoroids, and the cratering effect of each impact. The cratering effects are based on the correlation of recent laboratory experimentation using hypervelocity particles, and very conservative estimates of impact frequency are employed. The resulting calculations of percentage of hull area covered by holes, and loss of internal pressure vs time, are expected to be conservative for design purposes.

437. SIZE AND MASS DISTRIBUTION OF COSMIC DUST. Laevastu, Taivo and Otto Mellis. In Journal of Geophysical Research, Vol. 66, No. 8, August 1961.

The size distribution of the cosmic spherules found in sediments shows that the total mass of particles in equal size (diameter) intervals remains constant. The size distribution of cosmic dust in space, as computed from the data obtained by impact measurements by artificial satellites, shows the same distribution in the interval of particle diameters approximately 5μ and 15μ, and as determined by extrapolation, the distribution is probably valid for larger particles.

438. SOLID PARTICLES IN THE STARS. In Memoires de la Société Royale des Sciences de Liége, Vol. 15, Special Number 687, 1954.

Communications presented at the Sixth International Colloquium of Astrophysics, held in Liége, July 1954. Subjects included: Dust in Interplanetary Space, Dust and Associated Molecules in Stellar Atmospheres, Experimental Researches on Graphic Particles and on Certain Cometary Molecules, Interstellar Dust in the Galaxies and the Role of Dust in the Formation and Evolution of Stars.

439. SOVIET SPACE SCIENCE. Shternfel'd, Airo Abramovich. Technical Documents Liaison Office, Wright-Patterson AFB, Ohio. Translated from Iskusstvennye Sputniki, 2nd Rev. Ed. Basic Books, New York, 1959.

This article discusses meteor hazard based on U. S. data obtained from satellites. In conclusion the author notes that the most convincing evidence of the harmlessness of the collision of micrometeorites with the skin of an artificial satellite is the experience of the first and the second artificial satellites.

440. SPACE AND PLANETARY ENVIRONMENTS. Valley, Shea L., Editor. January 1962, Geophysics Research Directorate, Air Force Cambridge Research Labs., Hanscom Field, Bedford, Mass. AF Surveys in Geophysics; AFCRL-62-270.

This report surveys most of the aerospace environment, presenting information on interplanetary gas and magnetic fields, terrestrial magnetic field, external terrestrial gravity field, corpuscular radiation in the vicinity of earth, solar electromagnetic radiation, lunar environment, planetary environments, and space environment of the solar system.

441. THE SPACE DISTRIBUTION OF ZODIACAL-LIGHT MATERIAL. Elsässer, H. In Zeitschrift für Astrophysik, Vol. 33, No. 4, pp. 274-285, 1954 (in German).

The distribution of material is deduced from observations of the brightness and polarization of the zodiacal light. The surfaces of constant electron density in interplanetary space can be represented by ellipsoids with axes of rotation through the sun and perpendicular to the ecliptic plane. Distribution curves of particle density with distance from the ecliptic plane are also given.

442. SPACECRAFT MATERIALS PROBED BY SYMPOSIUM. McGuire, Frank G. In Missiles and Rockets, Vol. 5, pp. 56-59, May 25, 1959.

Technical aspects of temperature, erosion, sputtering, lubrication and vacuum effects on materials were thoroughly discussed at the first symposium on "Surface Effects on Spacecraft Materials," co-sponsored by Lockheed and ARDC. The action of particles of varying sizes in space on the surface of a spacecraft was looked at from a number of angles: micrometeorites, dust and individual atoms and molecules. Results of a collision with a full-scale meteor were so obvious as to eliminate need for discussion.

443. SPUTTERING AS IT IS RELATED TO HYPERBOLIC METEORITES. Baker, Robert M. L., Jr., Aeronutronic Systems, Inc., Newport Beach, Calif. In Journal of Applied Physics, Vol. 30, No. 4, pp. 550-555, April 1959.

A theoretical discussion is presented of the phenomenon of cathode sputtering as it is related to high-speed meteorites, i.e., to meteorites whose speeds are high enough to have reached the earth from interstellar space. The drag and heat transfer are found to be markedly affected by sputtering, even when the most conservative estimates of sputtering yield and energy-transfer efficiency are employed. It is shown that theoretically sputtering can account in part, at least, for the discrepancy between meteor photographs, which show no extra-solar meteorites, and certain visual-telescopic data which, on the contrary, show a significant number of meteorites to have an extra-solar origin.

444. SUR LE DANGER MÉTÉORITIQUE EN ASTRONAUTIQUE. (2^{me} partie) (The Meteoritic Danger in Astronautics). Boneff, N. In Proceeding of the 10th International Astronautical Congress, London, 1959. Springer-Verlag, Vienna, 1960 (in French).

The hypothesis that the circular sphere of the planet Mercury is an indication that space is relatively free from meteoritic matter is advanced.

445. THE THEORY OF MICRO-METEORITES. Part I. IN AN ISOTHERMAL ATMOSPHERE. Whipple, Fred L. In Proceedings of the National Academy of Sciences, Washington, D. C. Vol. 36, No. 12, pp. 687-695, December 1950.

The discovery in 1946 by H. E. Landsberg of a small magnetic particle, named the micrometeorite, demands theoretical questioning into what conditions are necessary to stop such meteors in the atmosphere without their being heated beyond the melting point. This promotes a relation between temperature, velocity and time, inasmuch as the density of the atmosphere as a function of time can be calculated and illustrated in an isothermal atmosphere by the study of the effects of size, velocity, and melting point of particles of various forms.

446. THE THEORY OF MICROMETEORITES. Part II. IN HETEROTHERMAL ATMOSPHERES. Whipple, Fred L. In Proceedings of the National Academy of Sciences, Washington, D. C. Vol. 37, No. 1, pp. 19-20, January 1951.

The maximum diameter of an undisturbed micrometeorite appears at vertical descent to be 0.01 cm or smaller. Further observations are reported for various zenith distances and meteor velocities.

447. THE UNEARTHLY VISITORS. Mason, Brian. In Natural History, Vol. 70, No. 4, pp. 18-25, April 1961.

A brief historical survey of meteoritics is given, including a discussion of some well known falls and derivation of classificational terminology. A discussion of the numerous theories on the origin of meteorites is included. The extraterrestrial origin of tektites is considered uncertain.

448. VELOCITIES, ORBITS AND MASSES OF METEORITES. Levin, B. Yu. Air Technical Intelligence Center, Wright-Patterson AFB, Ohio. Report ATIC 262877, Translation F-TS-8931/V from Astronomicheskii Zhurnal, Vol. 23, No. 2, pp. 83-95, 1946. ASTIA AD-120,692.

In modern astronomical literature the view is widespread that, of the various meteoric bodies entering the earth's atmosphere, the small bodies are disintegrated in the upper layers, yielding the phenomenon of meteors, the somewhat larger bodies penetrate to the lower layers and are perceived as bolides, while the large bodies penetrate the entire atmosphere and fall on the earth's surface. Usually nothing is said of the velocity in this case, and consequently a secondary role is attributed to it. Yet the physical theory of meteors as well as the observational data shows that the velocity does not play a smaller part than the mass, but, if anything, a more important part. Allowance for the role of the velocity permits characterizing the typical properties of the orbits of meteoric bodies able to yield meteorite falls, and, on the other hand, estimating the part of meteoric matter that is vaporized during its flight through the atmosphere.

449. THE ZODIACAL LIGHT AND THE NATURE OF INTERPLANETARY GAS. Blackwell, D. E. In Observatory, Vol. 77, No. 900, pp. 187-191, 1957.

An attempt is made to determine the relation between electron and dust components.

450. ZODIACAL LIGHT IN THE SOLAR CORONA. Van de Hulst, Hendrik Christoffel. Astrophysical Journal, Vol. 1-5, pp. 471-488, 1947.

A theory for the scattering in planetary space is given. The problem of interstellar matter is reviewed including a table of the number and mass of particles in interplanetary space.

SECTION IV. AUTHOR INDEX

APPROVAL

A BIBLIOGRAPHY CONCERNING ASPECTS OF THE METEOROID HAZARD

by

The Meteoroid Damage Working Group

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

W. A. Mrazek

W. A. MRAZEK
Director, Propulsion & Vehicle Engineering Division

Geissler

E. D. GEISSLER
Director, Aerobalistics Division

Gerhard Heller

for ERNST STUHLINGER
Director, Research Projects Division

INTERNAL DISTRIBUTION

M-MS-IP

M-MS-IPL (8)

M-DEP-R&D

M-CP, Mr. Maus

M-SPA-LLV, Mr. Herbert Schaeffer
-LLV, Mr. Ernest Wells

M-REL, Mr. Nicholas Babakitis

M-FPO, Mr. Louis H. Ball

M-FPO-DIR

M-SAT-DIR

M-TEST-DIR

M-QUAL-DIR

M-P&VE-DIR, Dr. Mrazek
-DIR, Mr. Weidner
-F, Mr. Conrad Swanson
-F, Dr. Helmut G. Krause
-F
-TS
-V
-P
-REL
-S
-E
-M, Shannon/Zoller/Gray
-MA
-MC
-ME
-MM
-MR
-MG (12)
-MG, Dr. Gayle
-MG, Dr. Pschera

M-AERO-DIR
-TS
-TS, Mr. Murphree (40)
-PS
-A
-G, Mr. Vaughan
-G, Mr. Dalton
-GS, Mr. D'Arcangelo
-GT, Mr. Daniels
-D
-E
-F
-P
-PF, Mr. H. L. Hooper

M-ASTR-DIR
-TSA
-A
-R

M-RP-DIR
-N, Dr. Shelton
-T, Miss Smith
-R
-S, Mr. Williams
-S, Mr. Southerland
-S, Mr. Epsy
-M, Dr. Johnson
-P, Dr. Hudson
-P, Miss Smith
-P, Mr. Bensko
-A, Mr. Graham
-A, Mr. Thompson
-PCA, Mr. Mathis
-PCA, Mrs. Christopher

EXTERNAL DISTRIBUTION

Melvin S. Day
Office of Technical Information & Education
National Aeronautics and Space Administration
1512 H. Street, N. W.
Washington 25, D. C.

Scientific & Technical Information Facility
Attn: NASA Rep.
(S-AK/RKT)
P. O. Box 5700
Bethesda, Md.

Dr. Leo Werner
Office of Flight Systems
OMSF-Code MEF
NASA
801 19th Street, N. W.
Washington 25, D. C.

Mr. John R. Davidson, Code SRD
National Aeronautics and Space Administration
Langley Research Center
Langley Station,
Hampton, Virginia

Mr. Elmer Davison, Code 2323
National Aeronautics and Space Administration
Lewis Research Center
21,000 Brookpark Road
Cleveland 35, Ohio

Mr. James J. Kramer, Code 9510
National Aeronautics and Space Administration
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio

Mr. Thomas N. Canning, Code HBR
National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California

EXTERNAL DISTRIBUTION (Cont'd)

Mr. James L. Summers, Code HBR
National Aeronautics & Space Administration
Ames Research Center
Moffett Field, California

Mr. Burton Cour Palais
National Aeronautics and Space Administration
Structures Branch
Manned Spacecraft Center
Houston, Texas

Mr. Paige Burbank
National Aeronautics & Space Administration
Structures Branch
Manned Spacecraft Center
Houston, Texas

Mr. Mason Charak, RV-1
Office of Advanced Research & Technology, NASA
1512 H Street
Washington 25, D. C.

Mr. Charles T. D'Aiutolo, RV-1
Office of Advanced Research & Technology, NASA
1512 H Street
Washington 25, D. C.

Mr. Warren J. Keller, RV-1
Office of Advanced Research & Technology, NASA
1512 H Street
Washington 25, D. C.

Mr. Maurice Dubin
Headquarters, National Aeronautics and Space Administration
Code SG
Washington 25, D. C.

Dr. Curtis W. McCracken
National Aeronautics & Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

Mr. Richard J. Wisniewski
Project Officer for Apollo, Code MSA
National Aeronautics & Space Administration
Washington 25, D. C.

EXTERNAL DISTRIBUTION (Cont'd)

Dr. Richard W. Shorthill, Staff Member
Geo-Astrophysics Laboratory
Boeing Scientific Research Laboratories
P. O. Box 3981
Seattle 24, Washington

Mr. Goerge Derderian, Research Engineer
Sperry Gyroscope Company
Garden City, New York

Dr. J. Gordon Stipe, Jr.
Dept. of Physics and Astronomy
Boston University
Boston 15, Mass.

Mr. Frank Dachille, Research Associate
Pennsylvanie State University
University Park, Pennsylvania

Mr. Francis B. Schaffer, Org. 550-62
Northrop Space Labs.
1111 East Broadway
Hawthorne, California

Mr. Russel J. Bowen
Arthur D. Little, Inc.
Acorn Park
Cambridge 40, Massachusetts

Mr. R. L. Shannon
Chief, Technical Information Extension
Atomic Energy Commission
P. O. Box 62
Oak Ridge, Tennessee

Mr. Glenn R. Maynard
Librarian, University of California
Radiation Lab
Box 808
Livermore, California

Redstone Scientific Information Center (20)
Redstone Arsenal, Ala.
Attn: AMSMI-RBLD

EXTERNAL DISTRIBUTION (Cont'd)

Redstone Scientific Information Center
Redstone Arsenal, Ala.
Attn: Charlotte F. Shenk (10)

Commander
Armed Services Technical Information Agency
Arlington Hall Station
Arlington 12, Virginia
Attn: TIPCR

Chief, Air Defense Division
Office, Chief of Research and Development
Department of the Army
The Pentagon, Room 3E 371
Washington 25, D. C.

Director
Air University Library
Maxwell Air Force Base, Alabama
Attn: AUL3T

Operations Analysis
Headquarters, Strategic Air Command
Offutt Air Force Base, Nebraska

Director
Marine Corps Landing Force Development Center
Marine Corps Schools
Quantico, Virginia

Commander
Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio
Attn: ASAPRD-Dist.

Commander
Rome Air Development Center (RAALD)
Griffiss Air Force Base, New York
Attn: Documents Library

Commander
Air Force Flight Test Center
Edwards Air Force Base, California
Attn: FTOOT

Director, Research Analyses
Holloman Air Force Base, New Mexico
Attn: Technical Library (SRAT)

EXTERNAL DISTRIBUTION (Cont'd)

Commander
Air Proving Ground Center
Eglin Air Force Base, Florida
Attn: PGAPI

Commanding Officer
U. S. Army Engineer Research and Development Laboratories
Fort Belvoir, Virginia

Commanding Officer (AD-5)
U. S. Naval Air Development Center
Johnsville, Pennsylvania
Attn: NADC Library

University of California
Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, New Mexico
Attn: Report Library

Commanding Officer
U. S. Army Chemical Research and Development Laboratories
Edgewood, Maryland
Attn: Librarian

Commander

EXTERNAL DISTRIBUTION (Cont'd)

Research Analysis Corporation
6935 Arlington Road
Bethesda, Maryland

Office, Assistant Secretary of the Army (R&D)
Room 3E 390, The Pentagon
Washington 25, D. C.

Commander
U. S. Naval Missile Center
Point Mugu, California
Attn: Code 3022

Commandant
U. S. Army Air Defense School
Fort Bliss 16, Texas
Attn: AKBAAS-DP-R

Commanding Officer
U. S. Army Electronics Research Unit
P. O. Box 205
Mountain View, California

EXTERNAL DISTRIBUTION (Cont'd)

President
U. S. Army Air Defense Board
Fort Bliss, Texas

Superintendent
U. S. Naval Postgraduate School
Monterey, California
Attn: Code 0384

Scientific and Technical Information Facility
P. O. Box 5700
Bethesda, Maryland
Attn: NASA Representative (S-AK/DL)

Director
National Security Agency
Fort George G. Meade, Maryland
Attn: C3/TDL (Room 2C087)

Commanding Officer
Diamond Ordnance Fuze Laboratories
Washington 25, D. C.
Attn: Technical Reference Branch

Director, Guided Missile Department
U. S. Army Artillery and Missile School
Fort Sill, Oklahoma

Commanding Officer
U. S. Naval Propellant Plant
Indian Head, Maryland
Attn: Technical Library - Code T2

Commanding Officer
U. S. Army Office of Special Weapons Development
U. S. Army Combat Developments Command
Fort Bliss 16, Texas

Director, Air Force Cambridge Research Laboratories
L. G. Hanscom Field
Bedford, Massachusetts
Attn: CRXLT-1 Stop 29

EXTERNAL DISTRIBUTION (Cont'd)

Air Force Logistics Command
Wright-Patterson Air Force Base, Ohio
Attn: MCMTA

Commander
Operational Test and Evaluation Force
U. S. Naval Base
Norfolk 11, Virginia

Commanding Officer
Nuclear Weapons Training Center, Atlantic
Nuclear Warfare School
Norfolk 11, Virginia

Commandant
U. S. Army Command and General Staff College
Fort Leavenworth, Kansas
Attn: Archives

Director
U. S. Naval Research Laboratory
Washington 25, D. C.
Attn: Code 2027

U. S. Army Air Defense Engineering Agency
Fort Gecrge G. Meade, Maryland
Attn: SELAD-6B

Sandia Corporation
Livermore Laboratory
P. O. Box 969
Livermore, California
Attn: Technical Library

Commander
U. S. Naval Ordnance Laboratory
White Oak
Silver Spring, Maryland
Attn: Librarian

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California
Attn: Library Supervisor

EXTERNAL DISTRIBUTION (Cont'd)

Technical Library
Naval Weapons Laboratory
Dahlgren, Virginia

Commanding Officer
U. S. Army Air Defense Combat Developments Agency
Fort Bliss, Texas

Commanding Officer
U. S. Army Artillery Combat Developments Agency
Fort Sill, Oklahoma

Commanding Officer
U. S. Army Chemical Research and Development Laboratories
Edgewood Arsenal, Maryland
Attn: Chief, Munitions Development Division
Directorate of Weapons Systems

Commanding General
U. S. Army Materiel Command
Washington 25, D. C.
Attn: AMCCG
AMCRD

Central Intelligence Agency
Washington 25, D. C.
Attn: OCR - Standard Distribution

Commanding General
U. S. Army Combined Arms Group
Fort Leavenworth, Kansas

Commanding Officer
U. S. Army Combat Service Support Group
Fort Lee, Virginia

Commanding General
U. S. Army Air Defense Command
Ent Air Force Base
Colorado Springs, Colorado

EXTERNAL DISTRIBUTION (Cont'd)

Headquarters
U. S. Army Test and Evaluation Command
Aberdeen Proving Ground, Maryland
Attn: AMSTE

Director
Missile Division
U. S. Army Artillery Board
Fort Sill, Oklahoma

Commanding General
U. S. Army Missile Command
Redstone Arsenal, Alabama
Attn: USACDC LnO