

booms which may be extended in various configurations; libration damping is effected by using either an enhanced magnetic damping scheme or a damped gimbaled boom.⁵ The spacecraft, shown in Fig. 7, is 8 feet long, weighs 500 pounds, and has a maximum moment of inertia of 34 slug-ft².

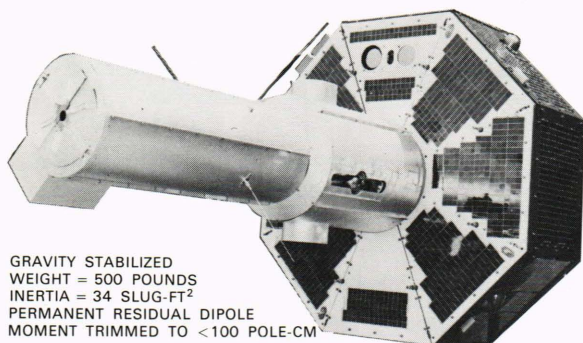


Fig. 7—DODGE Satellite.

DODGE was subjected to magnetics systems testing including pulsed resonance dipole moment measurements at NOL in April 1967. Aerodynamic disturbances were slightly greater on DODGE due to its stack. Additional shrouding was sufficient to reduce angular disturbances to within several seconds of arc. Dipole moment sensitivity on DODGE was of the order of 50 pole-cm.

Components of residual dipole moment in the spacecraft measured at the start of testing were $M_x = +150$, $M_y = -150$, and $M_z = +200$ pole-cm. These components were trimmed to less than 50 pole-cm by the addition of compensating magnets. Figure 5a shows the deflection response record corresponding to 100 pole-cm in the $-Z$ direction. The deflection response sensitivity to a 100 pole-cm di-

pole moment is 12 seconds of arc peak-to-peak in 5 cycles when using a field of ± 600 moe. The deflection response record of a null dipole moment is shown in Fig. 5b. The continuous angular response record was obtained from a Kollmorgan automatic autocollimator.

Pulsed resonance testing was used extensively on DODGE to determine the changes in satellite magnetization caused by the operation of magnetic systems in the spacecraft, as well as the strength of current loops when operating various electrical systems. Changes in the magnetic state were under 50 pole-cm even after exercising the 8.64×10^4 pole-cm electromagnets. Peak variations due to current loops were within 300 pole-cm in battery mode but as high as 1200 pole-cm when operating off the solar array. Compensating current loops were added to the solar bus to alleviate this problem.

Conclusions

To date, pulsed resonance testing has proved to be an excellent technique for determining small dipole moments of large spacecraft. Measurement sensitivity has been of the order of 20 to 50 pole-cm for spacecraft weighing up to 500 pounds. The technique is particularly suited for compensating spacecraft residual permanent dipole moments and confirming the null state. Variations in a null dipole state caused by satellite current loops or changes in magnetization caused by satellite operations are readily detected. Accurate dipole moment determination extends to moments as large as several thousand pole-cm as evidenced by the AE-B attitude performance. Determination of dipole moments in the 10^4 pole-cm range is probably more conveniently accomplished by field measurement techniques. The accuracy and sensitivity of pulsed resonance testing have proved to be quite acceptable for achieving the null magnetic state required by many present near-earth orbiting spacecraft.

⁵ R. E. Fischell, "The DODGE Satellite," Proceedings AIAA/JACC Guidance and Control Conference, Seattle, Wash., August 1966.

ADDRESSES

Principal recent addresses made by APL staff members to groups and organizations outside the Laboratory.

The following three addresses were given at the 14th Annual Meeting of the Society of Nuclear Medicine, Seattle, Wash., June 20-23, 1967:

A. G. Schulz, L. C. Kohlenstein, L. G. Knowles, W. A. Yates, and R. F. Mucci, "Quantitative Assessment of Scanning System Parameters;"

L. C. Kohlenstein, A. G. Schulz, L. G. Knowles, and R. F. Mucci, "The Simulation of Data from Scan Detector Systems;"

A. G. Schulz (APL), F. Rollo (The Johns Hopkins University), and Kurt Fölber (Siemens A.G. WW f. Medizinische

Technik; Erlangen, Germany), "In Vivo Measurement of Absolute Quantities of Radioactivity within an Organ."

F. S. Billig, R. C. Orth, and M. L. Lasky, "Effects of Thermal Compression on the Performance of Estimates of Hypersonic Ramjets," AIAA Third

ADDRESSES (continued)

- Propulsion Joint Specialists Conference*, Washington, D.C., July 17-21, 1967.
- F. J. Adrian and E. L. Cochran, "Methods for Analyzing the ESR Spectra of Fluorine-Containing Radicals" and "Reactions of Fluorine Atoms at 4.2° K," *8th International Symposium on Free Radicals*, Novosibirsk, USSR, July 26-29, 1967.
- V. W. Pidgeon, "Radar Research at Aruba, Netherlands Antilles," *Kiwanis Club of Aruba, Netherlands Antilles*, July 31, 1967.
- D. S. Beall, "The Artificial Electron Belt, October 1963 to October 1965," *Illinois Institute of Technology Advanced Study Institute*, Freising, Germany, July 31 - Aug. 11, 1967.
- B. I. Blum and R. A. Gunter, "Polaris Data Analysis and Retrieval System," *SHARE Meeting*, Miami Beach, Fla., Aug. 17-21, 1967.
- R. C. Moore, "Packaging Flat Pack Integrated Circuits for Earth Satellites," *Eighth International Electronic Circuit Packaging Symposium (WESCON)*, San Francisco, Calif., Aug. 21-22, 1967.
- B. E. Tossman, "Application of Resonance Technique for Measuring Satellite Magnetic Dipole Moments," *Symposium on Magnetic Exploration and Technology*, Reno, Nev., Aug. 28-30, 1967.
- I. Katz, "Radar Detection of Atmospheric Turbulence," *Conference on Atmospheric Microstructure and Its Effects on the Propagation of Optical and Radio Waves*, Breckenridge, Colo., Aug. 29, 1967.
- A. I. Mahan, C. Bitterli, S. M. Cannon, and D. G. Grant, "Ruby as a Macroscopic Maxwellian Fluorescing and Lasing Material," *Colloquium sponsored by the Centre National de la Recherche Scientifique (CNRS) of France and l'Universite Laval*, Quebec, Canada, September 6-8, 1967.
- R. E. Fischell, "A Gravity-Gradient Satellite Experiment at Synchronous Altitude," *International Federation of Automatic Control, Second Symposium on Automatic Control in Space*, Vienna, Austria, Sept. 4-8, 1967.
- T. O. Poehler, "Microwave Emission from Indium Antimonide," *Physics of Solids Colloquium*, Naval Research Laboratory, Washington, D.C., Sept. 11, 1967.
- R. T. Cusick, "A Pressure Commutating System for Use in a Propulsion Research Facility," *22nd Annual Meeting of the Instrument Society of America*, Chicago, Ill., Sept. 11-14, 1967.
- A. G. Carlton, "Estimation of Fixed-Time State Vectors," *1967 International Symposium on Information Theory*, Athens, Greece, Sept. 11-15, 1967.
- L. M. Spetner, "Adaptive Prediction and Random-Process Identification," *1967 International Symposium on Information Theory*, Athens, Greece, Sept. 11-15, 1967.
- R. B. Kershner, "U.S. Navy Navigation Satellite System," *AGARD Avionics Panel Symposium on Advanced Navigational Techniques*, Milan, Italy, Sept. 12-15, 1967.
- V. L. Pisacane, P. P. Pardoe, and J. M. Whisnant, "Simulation of the Attitude Stabilization of the DODGE Spacecraft with Time-Lag Magnetic Damping," *XVIIIth International Astronautical Congress*, Belgrade, Yugoslavia, Sept. 24-29, 1967.
- F. S. Billig, "External Burning in Supersonic Streams," *XVIIIth International Astronautical Congress*, Belgrade, Yugoslavia, Sept. 24-29, 1967.
- The following six addresses were given at the *XIVth General Assembly of International Union of Geodesy and Geophysics*, St. Gall and Zurich, Switzerland, Sept. 25 - Oct. 7, 1967:
- C. O. Bostrom, "Solar Protons Observed at 1100 km During February 1965 and March 1966;"
- F. T. Heuring, A. J. Zmuda, W. E. Radford, and P. Verzariu, "An Evaluation of Geomagnetic Harmonic Series for 1100 km Altitude;"
- R. R. Newton, "On the Inference of Tidal Parameters from Satellite Orbits;"
- T. A. Potemra, A. J. Zmuda, C. R. Haave, and B. W. Shaw, "VLF Phase Perturbations Produced by Solar Protons in the Event of February 5, 1965;"
- A. J. Zmuda, W. E. Radford, F. T. Heuring, and P. Verzariu, "The Scalar Magnetic Intensity at 1100 km in Middle and Low Latitudes;"
- A. J. Zmuda, "A Review and a Recommendation for an International Geomagnetic Reference Field."
- F. T. McClure, "Science, Systems, Students, and Society," *Distinguished Lecturer, Opening the Topic Series 67/68*, Franklin and Marshall College, Lancaster, Pa., Sept. 28, 1967.
- R. M. Fristrom, "Molecular Beams—Tools for Chemical Research," *Department of Chemistry Seminar*, Catholic University of America, Washington, D.C., Oct. 3, 1967.
- T. A. Stansell, "The Navy Navigation Satellite System, Description and Status," *Institute of Navigation National Marine Meeting*, U.S. Naval Academy, Annapolis, Md., Oct. 11-12, 1967.
- F. E. Nathanson and J. P. Reilly, "Clutter Statistics Which Affect Radar Performance Analysis," *IEEE Electronics and Aerospace Systems Technical Convention*, Washington, D.C., Oct. 16-18, 1967.
- T. Thompson and R. C. Beal, "A Slow Scan Television System for Attitude Measurement at Synchronous Altitudes," *IEEE Electronics and Aerospace Systems Technical Convention*, Washington, D.C., Oct. 16-18, 1967.
- G. C. Weiffenbach, "The Navy Navigation Satellite System," *IEEE Electronics and Aerospace Systems Technical Convention*, Washington, D.C., Oct. 16-18, 1967.
- G. R. Valenzuela, "Scattering of Electromagnetic Waves from a Slightly Rough Surface," *1967 Fall Meeting of the International Scientific Radio Union*, University of Michigan, Ann Arbor, Mich., Oct. 16-19, 1967.
- L. B. Piper, "The Role of the Chemical Propulsion Information Agency," *Ninth Liquid Propulsion Symposium*, St. Louis, Mo., Oct. 25-27, 1967.
- V. W. Pidgeon, "Radar, A Research Tool for Oceanography," *New York Academy of Sciences*, New York City, Oct. 26-27, 1967.

PUBLICATIONS

Compilation of recently published books and technical articles written by APL staff members.

- R. R. Newton, "Everyman's Doppler Satellite Navigation System," *IEEE Trans. Aerospace and Electronic Systems*, **AES-3**, No. 3, May 1967, 527-554.
- D. K. Anand and R. E. Jenkins (APL) and A. Z. Dybbs (University of Pennsylvania), "Effects of Condenser Parameters on Heat Pipe Optimization," *J. Spacecraft and Rockets*, **4**, No. 5, May 1967, 695-696.
- F. S. Billig, "Shock-Wave Shapes Around Spherical- and Cylindrical-Nosed Bodies," *J. Spacecraft and Rockets*, **4**, No. 6, June 1967, 822-823.
- D. S. Beall and C. O. Bostrom (APL) and D. J. Williams (Goddard Space Flight Center), "Structure and Decay of the Starfish Radiation Belt, October 1963 to December 1965," *J. Geophys. Research*, **72**, No. 13, July 1, 1967, 3403-3424. •
- V. G. Sigillito (APL) and K. Gustafson (University of Minnesota), "Inequalities for Nonlocal Parabolic and Higher Order Elliptic Equations," *Soc. Ind. Appl. Math., J. Appl. Math.*, **9**, No. 3, July 1967, 531-541.
- V. G. Sigillito, "Pointwise Bounds for Solutions of Semilinear Parabolic Equations," *Soc. Ind. Appl. Math., J. Appl. Math.*, **9**, No. 3, July 1967, 581-585.
- G. R. Valenzuela, "Depolarization of EM Waves by Slightly Rough Surfaces," *IEEE Trans. Antennas and Propagation*, **AP-15**, No. 4, July 1967, 552-557.
- A. N. Jette (APL) and P. Cahill (Columbia University Radiation Laboratory), "The Theory of Magnetic Hyperfine and Zeeman Interactions for Hund's Case (b), Applied to the c^3 II State of H_2 ," *Phys. Rev.* **160**, No. 1, Aug. 5, 1967, 35-44.
- P. Cahill and R. Schwartz (Columbia University Radiation Laboratory) and A. N. Jette (APL), "Polarization of Light Emitted from the Excitation of H_2 by Electron Impact," *Phys. Rev. Letters*, **19**, No. 6, Aug. 7, 1967, 283-284.
- A. A. Westenberg and N. deHaas, "Atom-Molecule Kinetics Using ESR Detection. II. Results for $D + H_2 \rightarrow HD + H$ and $H + D_2 \rightarrow HD + D$," *J. Chem. Phys.*, **47**, No. 4, Aug. 15, 1967, 1393-1405.
- L. Monchick (APL) and E. A. Mason (University of Maryland), "Free-Flight Theory of Gas Mixtures," *Phys. Fluids*, **10**, No. 7, 1967, 1377-1390.
- R. B. Kershner, "Status of the Navy Navigation Satellite System," *Practical Space Applications*, **21**, 1967, 41-59.
- N. W. Bazley (Institut Battelle, Geneva) and D. W. Fox and J. T. Stadter (APL), "Upper and Lower Bounds for the Frequencies of Rectangular Clamped Plates," *Zeitschrift für Angewandte Mathematik und Mechanik (ZAMM)*, **47**, 1967, 191-198.
- N. W. Bazley (Institut Battelle, Geneva) and D. W. Fox and J. T. Stadter (APL), "Upper and Lower Bounds for the Frequencies of Rectangular Free Plates," *J. Appl. Math. Phys. (ZAMP)*, **18**, Fasc. 4, 1967, 445-460.
- W. H. Guier, "Data and Orbit Analysis in Support of the U.S. Navy Satellite Doppler System," *Phil. Trans. Roy. Soc. A., London*, **262**, 1967, 89-99.
- F. S. Billig, "Design of Supersonic Combustors Based on Pressure-Area Fields," *Eleventh Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, Pa.*, 1967, 755-769.
- W. E. Wilson and A. A. Westenberg, "Study of the Reaction of Hydroxyl Radical with Methane by Quantitative ESR," *Eleventh Symposium (International) on Combustion, The Combustion Institute, Pittsburgh, Pa.*, 1967, 1143-1150.

HONORS AND AWARDS

R. B. Kershner, Head of the Space Development Department, was presented the Navy Distinguished Public Service Award by Vice President Hubert H. Humphrey on October 16, 1967, in the Vice President's office. The award was given to Dr. Kershner for his outstanding contributions to the development of the Navy Navigational Satellite System. Dr. Kershner, the only three-time recipient, received the award in 1958 "for his outstanding services to the Department of the Navy . . . in the development of the Terrier guided missile . . ." and in 1961 "for his outstanding contributions to the

successful development of the Fleet Ballistic Missile System . . ."

R. P. Rich, Supervisor of the Data Processing Center, has been elected president of the Maryland Academy of Sciences.

A. G. Schulz, Co-Supervisor of the Excitation Mechanisms Group in the Research Center, has been appointed Associate Professor of Radiological Science with The Johns Hopkins University for a three-year term, beginning July 1, 1967.

S. A. Buckingham, a member of the Satellite Reliability Control Group, has

been selected to serve a second year representing the Laboratory on the Contractor Advisory Board of the Interagency Data Exchange Program.

G. C. Weiffenbach, Supervisor of the Space Physics and Instrumentation Group, is serving as a member of the National Aeronautics and Space Administration Navigation Advisory Subcommittee of the Space Science and Applications Steering Committee during the fiscal year ending June 30, 1968.

The Satellite Spin Rate Device developed by the Applied Physics Laboratory

was selected as one of the "100 most significant new technical products of the year" in the fifth annual I-R 100 Competition, sponsored by the Industrial Research Magazine. The APL spin rate device was first used in the Direct Measurement Explorer Satellite (DME-A) which was launched in November 1965. The purpose of the device has been to measure directly the density and temperature of ions and electrons encountered during satellite orbiting.

APL COLLOQUIA

Oct. 13 "Why the Earth is Slowing Down," by R. R. Newton, Applied Physics Laboratory.

Oct. 20—"The Human Being as a Control Element," by D. McRuer, Systems Technology Incorporated.

Oct. 27—"Possibility of Faster-than-Light Particles," by G. Feinberg, Columbia University.

PATENTS

A. D. Baker—*Proximity Fuze*, Patent No. 3,326,130.

P. R. Schrantz—*Satellite Blade-Retaining Device*, Patent No. 3,327,967.

R. W. Bogle—*Superregenerative Pulse Radar Proximity Fuze*, Patent No. 3,329,952.

R. T. Cusick—*Switch for High-Energy Circuits*, Patent No. 3,344,248.

Editorial Board Changes

Dr. R. E. Gibson, Director of the Applied Physics Laboratory, recently announced changes in the composition of the Editorial Board of the *APL Technical Digest*, as reflected on the inside cover of this issue. Dr. Angus C. Tregidga, an original member of the *Digest* Editorial Board, had expressed a desire to be relieved of this duty, and Mr. Guy Worsley, the other member to leave the Board, has retired from the Laboratory. Dr. Walter A. Good and Dr. George C. Weiffenbach have been named to Board membership.

Dr. Angus C. Tregidga, Assistant to the Director, served on the Editorial Board ever since the inception of the *Digest* in 1961. Born in Burnley, England, Dr. Tregidga received an M.A. degree in Physics from the University of British Columbia in 1935, and a Ph.D. degree in Physics from the California Institute of Technology in 1939. From 1939 to 1941, Dr. Tregidga was an instructor of electrical engineering at Kansas State University. And for the next ten years, prior to his association with APL, he was employed by Motorola, Inc. Dr. Tregidga joined APL in 1951 as a specialist in electronic systems design and development, and systems analysis. His many duties at the Laboratory have included those of being Supervisor of the Bumblebee Homing Systems Group which developed the radar homing guidance system for the Talos missile; consultant to the Bureau of Aeronautics with regard to guidance for the Regulus II missile; consultant to the Office of Naval Research in performing an evaluation of the influence of satellites on Naval operations; and participation in informal studies of ASW problems both for the chief of Naval Operations and for the Bureau of Ships.



As Assistant to the Director of the Laboratory, Dr. Tregidga is closely involved with conducting studies directed toward advising the Navy of ways to perform its mission most effectively, and studies for the Advanced Research Projects Agency of the Department of Defense. Dr. Tregidga is a Senior Member of the Institute of Electrical and Electronics Engineers.

Mr. Guy Worsley, formerly Branch Supervisor, Space Electronics Design Branch of the Space Development Department, was born in Epping, England. He earned B.A. and M.A. degrees in natural science at Cambridge University which he received in 1929 and 1933, respectively. From 1929 to 1942 Mr. Worsley served as Science Master at schools in England and in the United States. He was an instructor and lecturer at Harvard University from 1942 to 1946. A specialist in electronics with particular reference to



missile guidance systems, and satellite tracking and navigation systems, Mr. Worsley joined APL in 1946. In an early position as Supervisor of the Bumblebee Guidance Group he pursued the development of missile beam-riding and homing electronics and missile guidance radars. In his most recent position, before retiring, Mr. Worsley was responsible for the development of systems for satellite instrumentation, tracking, and navigation. He had been a member of the APL Advisory Ad Hoc Committees on counter-countermeasures, and microwave radiation hazards, and Chairman of the Bumblebee Guidance Panel. A member of the *Digest* Editorial Board for two years, Mr. Worsley was also a contributor to its pages, having co-authored "Translocation by Navigation Satellite." Mr. Worsley is a member of the American Association of Physics Teachers and the Institute of Electrical and Electronics Engineers.

WITH THE AUTHORS



H. S. Morton, author of "Scaling the Effects of Air Blast on Typical Targets," is an earlier contributor to the *Digest*, having authored "Unique Bowsprit Assures Greater Control for Sailing Catamaran," in the March-April 1965 issue. Colonel Morton is a native of Minneapolis, Minnesota, and holds an M.E. degree in mechanical engineering which he received in 1913 from the University of Minnesota. A specialist in guided missile warheads, Colonel Morton came to APL in 1946 as Supervisor of the Bumblebee Warhead Group. He determined the

characteristics of Terrier missile warheads, originated techniques for scaling blast damage, and developed rod warheads for guided missiles. Colonel Morton has been a consultant to the Laboratory since his retirement in 1958. During World War II, Colonel Morton was closely associated with the development and eventual world-wide use by the Allied Powers of the proximity fuze that was developed by APL. He is the inventor of the highly successful bombing system known as Toss Bombing. Some of the honors bestowed on him include the Legion of Merit and the U.S. Navy Distinguished Public Service Award. He is an Honorary Officer of the Most Excellent Order of the British Empire. Colonel Morton is a member of the American Society of Mechanical Engineers, the American Society of Heating and Ventilating Engineers, and the American Ordnance Association.

B. E. Tossman, author of "Resonance Technique for Measuring Satellite Magnetic Dipole Moment," was born in Baltimore, Maryland. He holds B.S. and M.S. degrees in mechanical engineering which he received from the University of Maryland in 1961 and 1964, respectively. A specialist in spacecraft attitude control



systems, Mr. Tossman joined the Laboratory in 1961. His first assignment, in the Satellite Systems Engineering Group, involved structural vibration and stress analysis, design of shock mounts for spacecraft components, and despin and separation dynamic analysis. Presently, as a member of the Space Power, Thermal, and Attitude Control Systems Group, Mr. Tossman is concerned with attitude control systems and the analysis of attitude dynamics, design of attitude stabilizing devices, spacecraft magnetic systems, testing, and post-launch attitude operations.