

Japanese Aerospace Literature

This month: *Spacecraft Power Supplies*

A92-55869 ISY-METS rocket experiment and its preparatory airplane experiment (Microwave Energy Transfer in Space). H. MATSUMOTO and N. KAYA, et al., 43rd IAF International Astronautical Congress, Washington, Aug. 28–Sept. 5, 1992. 5pp.

It is very important and indispensable for power supplying in space as well as to the ground to develop technologies of the microwave energy transmission. We are planning a rocket experiment (METS: Microwave Energy Transmission in Space) and its preparatory airplane experiment called MILAX (Microwave Lifted Aircraft eXperiment) in the International Space Year. The METS aims to verify a newly developed microwave energy transmission system for space use and to study nonlinear effects of the microwave energy beam in the space plasma environment. We will also perform a ground-based energy transmission test of the developed system by using a small airplane as a target before the launch. In this paper, we describe the newly developed active phased-array antenna in detail. (Author)

A92-53771 Development of the solar Stirling engine alternator for space experiments. MASAFUMI NOGAWA, TAKANORI HAMAJIMA, HIROKI ISHIKAWA, YUTAKA MOMOSE, and NOBUHIRO TANATSUGU, *Proceedings of the 17th International Symposium on Space Technology and Science*, Vol. 2, Tokyo, Japan, May 20–25, 1990, (A92-53451 23-12). Tokyo, AGNE Publishing, Inc., 1990, pp. 2255–2260.

The IAS-200 prototype Stirling engine alternator is a subscale, but otherwise identical version of the flight design that is to be carried by the Japanese Space Flyer Unit. This free-piston Stirling engine uses He as the working gas and employs a displacer and two power pistons that are arranged in opposing configuration in order to minimize vibration. This linear alternator furnishes high efficiency over a wide operating range, and has successfully operated for over 200 hrs.

A92-53767 Space experiment of High Voltage Solar Array onboard SFU. H. KUNINAKA, K. TAKASHI, A. USHIROKAWA, and K. KURIKI, *Proceedings of the 17th International Symposium on Space Technology and Science*, Vol. 2, Tokyo, Japan, May 20–25, 1990, (A92-53451 23-12). Tokyo, AGNE Publishing, Inc., 1990, pp. 2231–2236.

The High Voltage Solar Array (HVSA) experiment to be carried into orbit aboard Japan's Space Flyer Unit in 1994 will demonstrate the safe and stable operation of such a power source in LEO, as well as the novel capability of optimal bus voltage power generation through changes in solar-cell series-parallel connections. The HVSA encompasses a solar array module and a 'versatile power control unit' (VPCU) that can call for the generation of up to 280 V in 70-V increments. The VPCU can also count plasma-induced discharges and measure their duration.

A92-53656 Development status of ETS-VI. S. TANAKA, T. KATAGI, H. KITAHARA, Y. YAMAMOTO, T. ITAKURA, K. ITO, and M. SUENAGA, *Proceedings of the 17th International Symposium on Space Technology and Science*, Vol. 2, Tokyo, Japan, May 20–25, 1990, (A92-53451 23-12). Tokyo, AGNE Publishing, Inc., 1990, pp. 1477–1488.

Japan's Engineering Test Satellite (ETS) VI has been devised to probe the basic technology required for future operational communications and broadcasting satellites in the 1990s. An account is presently given of major design features, enabling technologies, and the current development status of ETS-VI, with a view to the extension of payload capabilities in future applications through the adoption of Ni-H₂ batteries, an ion-propulsion system, and lighter solar-array substrates with higher conversion-efficiency cells.

A92-53627 Thermodynamic performance of Space Stirling engine—NALSEM 125. SACHIO OGIWARA, TSUTOMU FUJIWARA, KUNIHISA EGUCHI, and YOSHIHIRO NAKAMURA, *Proceedings of the 17th International Symposium on Space Technology and Science*, Vol. 2, Tokyo, Japan, May 20–25, 1990, (A92-53451 23-12). Tokyo, AGNE Publishing, Inc., 1990, pp. 1261–1268.

The NAL of Japan has developed the SEM-125 free-piston research engine, which is configured with an integral linear alternator, with a view to solar dynamic spacecraft solar power system applications. An effort has been made to define the dynamic and thermodynamic characteristics of the engine by accurately measuring the time-varying movement of the piston-stroke on the basis of readings from a laser-optics gap sensor. These measurements are in qualitative agreement with the results of a simple coupling analysis that is based on a Schmidt-cycle model and a linear oscillation mode.

A92-12490 JEM Electrical Power System architecture. TAKEHIKO KATO, 42nd IAF International Astronautical Congress, Montreal, Canada, Oct. 5–11, 1991. 9 pp.

The architecture of the Japanese Experiment Module Electrical Power System (JEM EPS) designed for the Space Station Freedom is described and its requirements are documented. The relationship between the physical and functional aspects of the EPS are explained using a specially designed matrix representation. Special attention is given to the relationship between the EPS architecture to other subsystems of the Space Station Manned Base.

A92-53587 A high-efficiency and light-weight TWT power supply for ETS-VI. KATSUHIKO YAMAMOTO, SATOSHI OHTSU, and TAKASHI YAMASHITA, *Proceedings of the 17th International Symposium on Space Technology and Science*, Vol. 1, Tokyo, Japan, May 20–25, 1990, (A92-53451 23-12). Tokyo, ACNE Publishing, Inc., 1990, pp. 977–982.

The paper describes a high-efficiency lightweight traveling-wave tube (TWT) power supply with a switching frequency of 200 kHz, developed for the Engineering Test Satellite VI. Special attention is given to the new techniques and devices that were developed to realize this power supply. These include a new high-voltage diode, a MOSFET, a newly developed high-voltage transformer, and high-efficiency circuits. A diagram of the TWT power supply circuit configuration is presented along with the results of TWT power supply efficiency.

A92-53586 Engineering model design of electrical power subsystem for the Space Flyer Unit. AKIO USHIROKAWA, KEIJI TAKAHASHI, NOBORU WAKASUGI, SHINOBU MATSUOKA, TAKEO KATSUKI, MITSUO HOMMA, and HIROKI KARASAWA, *Proceedings of the 17th International Symposium on Space Technology and Science*, Vol. 1, Tokyo, Japan, May 20–25, 1990, (A92-53451 23-12). Tokyo, ACNE Publishing, Inc., 1990, pp. 965–976. Research supported by New Energy Development Organization.

The Space Flyer Unit (SFU) is an unmanned, automated, and reusable space platform. The development of the SFU has entered on its engineering model phase. Its electrical power subsystem has four batteries consisting of 19AH Ni-Cd cells to supply 1.4kW power to all subsystems and experiment payloads during eclipse. As a result of thermal analysis, it is predicted that the temperature of shunt dissipators rises up to 70 C and cools down to 40 C. Retrieval by the space transportation system is the highest priority mission of the SFU, so that the reliability and safety design should be the most important matter. In this paper an EM design of the electrical power subsystem from the point of view described above is presented. (Author)

A92-53585 Prevention of high voltage breakdown by using paraxylene conformal coating for scientific satellites. II. YASUOHARU TSUNEOKA, TSUTOMU OHSHIMA, MASASHI HASHIMOTO, and TOMONAU HAYASHI, *Proceedings of the 17th International Symposium on Space Technology and Science*, Vol. 1, Tokyo, Japan, May 20–25, 1990, (A92-53451 23-12). Tokyo, ACNE Publishing, Inc., 1990, pp. 957–963.

The study demonstrates the effectiveness of the conformal coating of poly-paraxylene (parylene) in preventing electrical breakdown in high voltage electronics. The parylene is a dielectric material with high dielectric strength and high melting temperature, and is shown to provide a pinhole-free conformal insulation film, which is very effective in preventing high-voltage breakdown. To promote adhesion of parylene films on various substrates, a pretreatment procedure with silicone coupling agents was studied, and the procedure established was applied to 16 high-voltage power supplies on the Akebono scientific satellite. From the start of observations in orbit up to the time of writing—more than one year—no trouble caused by high voltage breakdown occurred, this proving the present coating technique's effectiveness for application to high-voltage power supplies in spacecraft.

A92-53206 High efficiency silicon solar cells for space use. M. UESUGI, T. NOGUCHI, T. KATSU, Y. TONOMURA, T. HISAMATSU, T. SAGA, and A. SUZUKI, 22nd IEEE Photovoltaic Specialists Conference, Las Vegas, NV, Oct. 7–11, 1991, Conference Record. Vol. 2 (A92-53126 22-44)

High-efficiency silicon solar cells for space use were developed, and the manufacturing process was established. The maximum size of these cells is 4 x 6 cm. The cells have fine grid patterns formed by photolithography and lift-off technique. Obtained AMO efficiencies of 50-, 70- and 100-micron-thick 4 x 6 cm BSFR cells at 28 C were 14.3 percent, 14.5 percent, and 14.8 percent, respectively. Those of 200-micron BSR cells with 10-Ohm-cm substrate and 2-Ohm-cm substrate were 12.7 percent and 13.6 percent, respectively. Work to increase the electrical output of these cells is discussed. At present non-texturized 100-micron cells show 16.1 percent and texturized 200-micron cells show 17.3 percent.

A92-37819 High performance battery and its computer simulation technology. KIYONAMI TAKANO, KATSUHIKO KANARI, KEN NOZAKI, TOSHIHISA MASUDA, KAZUO ONDA, and MASAYUKI KAMIMOTO, *Electrotechnical Laboratory, Circulars* (ISSN 0366-9084), No. 222, Aug. 1991, 117 pp.

The current status of advanced high-performance batteries and their simulation technology is reviewed in a systematic manner. In particular, attention is given to the energy, power density, efficiency, life, and capacity requirements; battery evaluations; and computer simulation studies. Results of evaluation studies are reported for some typical batteries, and it is suggested that the lithium secondary battery is particularly promising for high-density power systems. Results of simulations are presented for different types of batteries, including lead-acid, sodium-sulfur, lithium-iron sulfate, lithium, and zinc-bromine cells. Various battery applications are discussed, including electric vehicle propulsion.

A92-50572 Test facility of thermal storage equipment for space power generation. T. INOUE, M. NAKAGAWA, Y. MOCHIDA, F. OHTOMO, K. SHIMIZU, K. TANAKA, Y. ABE, O. NOMURA, and M. KAMIMOTO, IECEC '91; Proceedings of the 26th Intersociety Energy Conversion Engineering Conference, Boston, MA, Aug. 4-9, 1991. Vol. 1 (A92-50526 21-20). La Grange Park, IL, American Nuclear Society, 1991, pp. 308-312.

A thermal storage equipment test facility has been built in connection with developing solar dynamic power systems (SDPSs). The test facility consists of a recuperative closed Brayton cycle system (CBC), with a mixture of helium and xenon with a molecular weight of 39.9 serving as the working fluid. CBC has been shown to be the most attractive power generation system among several types of SDPSs because of its ability to meet the required high power demand and its thermal efficiency, about 30 percent. The authors present a description of this test facility and give results of the preliminary test and the first-stage test with heat storage equipment.

A92-50569 Development of advanced space solar dynamic receiver. YOSHIIYUKI ABE, KOTARO TANAKA, OSAMI NOMURA, KATSUHIKO KANARI, YOSHIO TAKAHASHI, and MASAYUKI KAMIMOTO, IECEC '91; Proceedings of the 26th Intersociety Energy Conversion Engineering Conference, Boston, MA, Aug. 4-9, 1991. Vol. 1 (A92-50526 21-20). La Grange Park, IL, American Nuclear Society, 1991, pp. 291-296.

Work on an advanced solar dynamic receiver is reviewed. The authors first describe the component test of the receiver tube with LiF in metallic containers, which was performed in a closed high-temperature He-Xe loop. They then give the details of the development of composite phase change materials, such as ceramic/molten salts or carbon/molten salts for advanced receiver concepts. As for SiC/LiF composites, the performance test of the receiver component will soon be ready to begin.

A92-44756 A light and high-efficiency TWT power supply for a communications satellite. TAKASHI YAMASHITA, SATOSHI OHTSU, KATSUHIKO YAMAMOTO, and TOSHIYUKI SUGIURA, NTT Review (ISSN 0915-2334), Vol. 4, No. 3, May 1992, pp. 56-62.

A new technique for designing high-voltage transformers and choke coils to reduce power loss by transformer stray capacitance is presented. A heater inverter is simplified, and surface mount technology is applied to a control circuit and the heater inverter. The efficiency of the new TWT power supply is increased to 82 percent at a switching frequency of 200 kHz and the power supply weighs approximately 70 percent of the conventional power supply.

A92-47800 Numerical analysis of charge and discharge characteristics of advanced energy storage systems. KATSUHIKO KANARI, *Electrotechnical Laboratory, Researches* (ISSN 0366-9106), No. 936, Jan. 1992, 123 pp.

A thermal energy storage system using phase-change materials and flow batteries was investigated, and computer simulation models were developed for estimating charge and discharge characteristics of latent thermal energy storage units using high-density polyethylene, pentaerithritol, and molten salts. These models are useful for evaluating the charge and discharge characteristics of the energy storage system, conducting feasibility studies for new applications, and for optimizing thermal-energy storage units. Computer simulation models were also developed for the analysis of shunt current flowing in redox flow and Zn/Br batteries. These models can be used for estimating the round-trip efficiencies, the state of charge, the terminal voltage, and, in case of Zn/Br battery, for the distribution of zinc metal deposited in the cells in a stack.

A92-47113 Surface modification of metal hydride negative electrodes and their charge/discharge performance. CHIAKI IWAKURA, MASAO MATSUOKA, KATSUHIKO ASAI, and TATSUOKI KOHNO, *Journal of Power Sources* (ISSN 0378-7753), Vol. 38, No. 3, May 1992, pp. 335-343.

Negative electrodes consisting of a multicomponent alloy, $\text{MmNi}_{0.36}\text{Mn}_{0.4}\text{Al}_{0.3}\text{Co}_{0.7}$, in a porous nickel substrate were modified by using different kinds of electroless plating baths or alkaline solutions containing hypophosphite as a reducing agent. Electrochemical properties of the negative electrodes such as discharged capacity, electrocatalytic activity for the hydrogen electrode reaction, and high-rate dischargeability were examined in a 6 M KOH solution. It was found that such simple surface modifications as described here improved the performance of negative electrodes. (Author)

A92-40446 An evolutionary satellite power system for international demonstration in developing nations. N. NAGATOMO and KIYOHICO ITOH, SPS 91—Power from space; Proceedings of the 2nd International Symposium, Gif-sur-Yvette, France, Aug. 27-30, 1991 (A92-40401 16-44). Paris, Societe des Electriciens et des Electroniciens and Societe des Ingenieurs et Scientifiques de France, 1991, pp. 356-363.

The ISAS solar power satellite working group is working on a concept of an SPS strawman model for demonstration of electric power supply to customers at the earliest opportunity. The SPS is modularized, so that each unit can be launched by a commercial launcher to an equatorial low earth orbit where it is assembled automatically. The satellite can supply electric power by microwave to rectennas at every pass. Based on this model, technological and programmatic characteristics of a small SPS are discussed. (Author)

A92-40448 A feasibility study of power supplying satellite (PSS). H. MATSUMOTO, N. KAYA, S. KINAI, T. FUJIWARA, and J. KOCHIYAMA, SPS 91—Power from space; Proceedings of the 2nd International Symposium, Gif-sur-Yvette, France, Aug. 27-30, 1991 (A92-40401 16-44). Paris, Societe des Electriciens et des Electroniciens and Societe des Ingenieurs et Scientifiques de France, 1991, pp. 375-380.

A feasibility study is given on a new type of orbiting power station which supplies a power of the order of 100 kw to orbiting customers (satellites or space stations). This power supplying satellite (PSS) is composed of three main parts: a power generator, a power transmitter and a satellite bus system. The unique feature of the proposed PSS is the usage of a module which has a solar-cell array on one side and a microwave transmitting antenna array driven by FET-amplifiers on the other side. These autonomous transmitter modules are used to form a large disk-structured active phased array of 40 m diameter which transmits a 100 kw energy beam of 24 GHz microwave. The frequency of 24 GHz is chosen to reduce the size and volume of the transmitting antenna. dc electric power generated by the solar cells on the top plane of the module is fed directly to the semiconductor FET amplifiers located under the solar-cells, converted to 24 GHz microwave, and then transmitted from the antenna arrays on the bottom plane of the module. These autonomous solar-cell-transmitter modules make it possible to eliminate the rotary joint and the dc power collecting network from the design of the PSS and SPS system. The PSS provides the following advantages: (1) availability of high power electricity to orbiting customer satellites or stations; (2) reduction of weight and volume of power system on customer space vehicles; and (3) technical go-forward for the future SPS. (Author)

A92-35608 Outline of the electric power and communication control systems of the exposed facility in the Japanese Experiment Module (JEM). KAZUHIKO KAMESAKI, M. TAKAI, TADASHI M. ORIYA, KENJI HONDA, T. KIKUCHI, and S. NISHIDA, *Proceedings of the 7th Space Station Conference*, Tokyo, Japan, Apr. 16, 17, 1991, (A92-35601 14-12). Tokyo, Japan Society for Aeronautical and Space Sciences, 1991, pp. 11, 12.

The configurations of the communication control system of the exposed facility (EF) in the Japanese Experiment Module (JEM) are presented. The electric power supply system of EF-JEM is given and the payload interface unit is discussed.

A92-12581 Orbit demonstration of two-dimensional deployable array including high voltage photovoltaic power generation. HITOSHI KUNINAKA, MICHIOHITO NATORI, YOSHIHARU KAWAI, and SHINGO IKEGAMI, IAF, 42nd International Astronautical Congress, Montreal, Canada, Oct. 5-11, 1991, 10 pp.

The development of a 2D deployable high voltage (2D/HV) solar array experiment to demonstrate repetitive deployment/retraction of a plane structure and high voltage photovoltaic power generation in space is presented. Flight objective of 2D/HV is to demonstrate fundamental technologies on a high power solar array in LEO. The 2D experiment will advance the space membrane structure from line to plane and the HV experiment will conduct high voltage power generation utilizing solar cells in a space environment.

A91-41981 Space proven GaAs solar cells—Main power generation for CS-3. N. TAKATA, H. KURAKATA, S. MATSUDA, T. OKUNO, S. YOSHIDA et al., 21st IEEE Photovoltaic Specialists Conference, Kissimmee, FL, May 21-25, 1990, Conference Record, Vol. 2 (A91-41876 17-44). New York, Institute of Electrical and Electronics Engineers, Inc., 1990, pp. 1219-1225.

GaAs solar cells were used for the main solar array to satisfy the power requirement for the Japanese domestic communications satellite-3 (CS-3). The authors review the GaAs solar cell performance, reliability, and array assembly for CS-3 and present the on-orbit performance of CS-3 after launch in 1988. The annual radiation degradation rate of the CS03 GaAs solar array was found to be one fourth or one fifth that of the ETS-V and BS-2b Si solar arrays. It was clear from the flight data that the radiation hardness of GaAs solar cells was excellent in comparison with that of Si solar cells.

A91-41887 A GaAs-on-Si solar cell for space use. YOSHIRO OHMACHI, TAKAHIKO OHARA, and YOSHIKI KADOTA, 21st IEEE Photovoltaic Specialists Conference, Kissimmee, FL, May 21-25, 1990, Conference Record, Vol. 1 (A91-41876 17-44). New York, Institute of Electrical and Electronics Engineers, Inc., 1990, pp. 89-94.

Efforts to grow high-quality GaAs films on Si substrates and improvements in the efficiency of GaAs-on-Si solar cells are reported. The epitaxial growth of GaAs on Si was studied using metalorganic chemical vapor deposition (MOCVD). The dislocation density in the active layer of the GaAs solar cell is significantly reduced by combining cyclic thermal annealing and the insertion of buffers such as InGaAs/GaAs and AlGaAs/GaAs . This minimal dislocation density allowed a large-size and high conversion efficiency GaAs-on-Si solar cell to be fabricated with a total area of 2 sq cm and an efficiency of 18.3 percent under AM0 and one-sun illumination. After 1-MeV electron beam irradiation at 1×10 to the 15th/sq cm, the GaAs-on-Si cells show a normalized efficiency of 0.83, which is larger than the 0.71 of a GaAs-on-GaAs cell. The use of GaAs-on-Si solar cells as the power source for satellites now looks feasible because this material is highly efficient, lightweight, inexpensive, and highly radiation resistant.