Books & Reports

These reports, studies, and handbooks are available from NASA as Technical Support Packages (TSPs) when a Request Card number is cited; otherwise they are available from the NASA Center for Aerospace Information.

Electronic Components and Circuits

Milliwatt Electric Power Sources Would Last for Years

A report discusses the design of proposed radioisotope thermoelectric generators, each of which would produce about 30 mW of electric power for decades, would fit in a package about the size of a D cell, and would have a mass of only 70 g. These small sources could be distributed around a small spacecraft to replace a centralized power plant. They could also energize the new generation of smaller, cheaper autonomous instruments, landers and microrovers.

This work was done by Arthur Chmielewski, Alexander Borshchevsky, and Cronin Vining of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Milliwatt Isotope Power Source for Microspacecraft,"* ***write in 12*** *on the TSP Request Card. NPO-19042.*

Mathematics and Information Sciences

Normalization of Thermal-Radiation Form-Factor Matrix

A report describes an algorithm that adjusts the form-factor matrix in the TRASYS computer program, which calculates intraspacecraft radiative interchange among the various surfaces and environmental heat loading from sources such as the sun. The adjustments performed by the algorithm are intended to compensate for errors in the form factors, which are computed from simplified geometric models and used in computing fluxes of heat between nodes in simplified thermal mathematical models.

This work was done by Glenn T. Tsuyuki of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "TRASYS Form Factor Matrix Normalization,"* ***write in 25*** *on the TSP Request Card. NPO-18921.*

Materials

Fingerprinting of Materials

A collection of three reports surveys the emerging technology of chemical fingerprinting, which can be defined, loosely, as the systematic application of modern methods of analysis to determine the elemental or molecular compositions of materials, measure the relative amounts of constituents of materials, and/or measure other relevant properties of materials. Chemical fingerprinting can include, for example, (1) the use of such instrumental chemical-analysis techniques as Fourier-transform infrared spectroscopy, high-performance liquid chromatography, nuclear magnetic resonance, and x-ray fluorescence spectroscopy; (2) the use of statistical techniques to optimize the acquisition and interpretation of data from instruments; and (3) the use of data-base-management techniques to store the acquired data and to identify the material under study by comparison of the acquired data with "signature" data on file.

This work was done by Gary L. Workman of the University of Alabama in Huntsville for **Marshall Space Flight Center**. *To obtain copies of the reports, "Fingerprinting of Materials," "Chemical Fingerprinting — An Important TQM Tool for Control of Materials," and "Fingerprinting of Materials Technical Supplement,"* ***write in 58*** *on the TSP Request Card. MFS-27311.*

Mechanics

Recent Developments in Theory of Balanced Linear Systems

A report presents a theoretical study of some issues of controllability and observability of a system represented by a linear, time-invariant mathematical model of the form

$x = Ax + Bu$, $y = Cx + Du$, $x(0) = xo$

where x is an n-dimensional vector that represents the state of the system; u is a p-dimensional vector that represents the control input to the system; y is a q-dimensional vector that represents the output of the system; n,p, and q are integers; x(0) is the initial (zero-time) state vector; and the set of matrices (A,B,C,D) is said to constitute the state-space representation of the system. One example of such a system is a structure that can vibrate and that is equipped with vibration sensors and/or actuators that could be connected with a control system to measure and/or suppress vibrations.

This work was done by Wodek Gawronski of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Reduction and Assignment of Systems and Structures,"* ***write in 85*** *on the TSP Request Card. NPO-18753.*

Fabrication Technology

Magnetic Subassembly for Directional-Solidification Furnace

A report describes the initial phase of development of a directional-solidification furnace that would grow nearly perfect single-crystal ingots of semiconductor materials in microgravity. The furnace assembly would include magnets: Lorentz force caused by the interaction between the magnetic field and convection currents in the electrically conductive melt would suppress the convection currents. (Even the minute accelerations of a spacecraft in adjustments of its orbit and attitude can give rise to residual convection, which adversely affects the homogeneity and structure of a solidifying crystal.)

The report discusses primarily the magnetic subassembly, which would be built with permanent magnets instead of electromagnets to keep the weight and power consumption as low as possible.

This work was done by Bill R. Aldrich of Microgravity Systems, Inc., for **Marshall Space Flight Center**. *To obtain a copy of the report, "High Field Low Mass Permanent Magnet Furnace and Shielding Development for Applications in Space,"* ***write in 52*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to: Microgravity Systems, Inc.; c/o TBG; Bill R. Aldrich, President; P. O. Box 07007, MS #150; Huntsville, AL 35807. Refer to MFS-26253, volume and number of this NASA Tech Briefs *issue, and the page number.*

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JPL

September 13, 1994
Refer to: 892-WRS:mb

Mr. Cronin B Vining
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91109

Ref: NASA Tech Brief NPO-19042
MILLIWATT ELECTRIC POWER SOURCES WOULD LAST FOR YEARS

Dear Mr. Vining:

Congratulations on your Tech Brief which was published in the August 94 issue of the "NASA Tech Briefs" journal. We appreciate your collaboration with the Technology Utilization Program; please continue to support the program and encourage others to participate.

The enclosed Technical Support Package was prepared by this office to send to those individuals who request additional information on your Tech Brief. Please inform this office of any additional material which you want added to this package to help industry create new products, processes or services based on your work.

Very truly yours,

Wayne R Schober

Wayne R. Schober
Manager
Technology Utilization

Enclosures: a/s

xc: (w/Tech Brief only)
C. P. Bankston, Section Manager
Employee Records, 291-208

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONTRACT NO. NAS 7-918

TECHNICAL SUPPORT PACKAGE

on

MILLIWATT ELECTRIC POWER SOURCES WOULD LAST FOR YEARS

for AUGUST 1994

NASA TECH BRIEF Vol. 18, No. 8, Item #12

from

JPL NEW TECHNOLOGY REPORT NPO-19042

Inventor(s): A. Borshchevsky
A. B. Chmielewski
C. B. Vining

New Technology Report
Prepared by: R. L. Klein

TSP assembled by:
JPL Technology Utilization Office

pp. i, 1-2, 1a-6a

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

AUGUST 1994

Milliwatt Electric Power Sources Would Last for Years

A report discusses the design of proposed radioisotope thermoelectric generators, each of which would produce about 30 mW of electric power for decades, would fit in a package about the size of a D cell, and would have a mass of only 70 g. These small sources could be distributed around a small spacecraft to replace a centralized power plant. They could also energize the new generation of smaller, cheaper autonomous instruments, landers and microrovers.

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NPO-19042.

Jet Propulsion Laboratory

NEW TECHNOLOGY REPORT

JPL & NASA Case No. NPO-19042

JPL Log No. 8630

MILLIWATT ISOTOPE POWER SOURCE FOR MICROSPACECRAFT

I. Novelty

Spacecraft radioisotope power sources provide power in the 100-1000 watt range. Terrestrial radioisotope power sources have been built with power output levels as low as a few microwatts, but are too heavy for space applications. The instant invention discloses a small, lightweight, reliable power source suitable for microspacecraft. More specifically, the Milliwatt Isotope Power Source (MIPS) is a D-cell size battery capable of delivering about 30 milliwatts of electrical power for several decades and weighing only 70 grams.

II. Complete Technical Disclosure

Problem

Microspacecraft and miniature instruments are expected to be widely used in future space exploration efforts. These missions will require much lower power levels. Suitable space quality power sources are not currently available.

MILLIWATT ISOTOPE POWER SOURCE FOR MICROSPACECRAFT

Arthur B. Chmielewski, Alexander Borshchevsky, and Cronin B. Vining
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Abstract

Miniature spacecraft offer the potential to greatly reduce mission costs, but today there is no flight qualified power source that could operate a microspacecraft during a journey to the outer planets. This paper describes the Milliwatt Isotope Power Source (MIPS), a concept capable of reliable, long term electrical power generation in the milliwatt range. Utilizing existing Radioisotope Heater Unit (RHU) heat source technology and proven thermoelectric energy conversion module technology, a MIPS package about the size of a D-cell battery could deliver about 30 milliwatts of electrical power for several decades and weigh 70 grams. Such a power source could be used to power miniature instruments such as seismometers, propel a microrover or provide decentralized power aboard a more conventional spacecraft. Also, reliance on flight-qualified heat source technology and the small radioisotope inventory required are attractive safety considerations.

INTRODUCTION

Advances in modern electronics, very large scale integration (VLSI) and miniaturization will significantly benefit spacecraft design. Miniature spacecraft can be launched on small rockets, as opposed to more expensive Shuttle or Titan-Centaur launchers. Because of their small mass they can be sent on more direct trajectories, reducing mission duration time and operations costs. Microinstruments such as X-ray telescopes, imaging spectrometers, seismometers, and scanning calorimeters are all under consideration for microspacecraft as well as deployable microstations. Missions such as Asteroid Investigation with a Microspacecraft (AIM), Mars Environment Survey (MESUR) and microrover in particular are expected to benefit from these advances.

The technology to make microinstruments is rapidly advancing, but the availability of power may be a limiting factor. This paper describes miniature thermoelectric conversion technology suitable for power generation in the milliwatt range. Modern thin film techniques are also discussed as a possible alternative for microwatt range devices consistent with the voltage levels needed. Similar techniques have been developed in the former Soviet Union which allow, for example, 100 or more thermocouples to be packed into an array of 1mm x 1mm. An additional benefit of the MIPS may be the possibility of using other, less toxic isotopes. Such an approach would substantially reduce the manufacturing and launch approval costs of a MIPS.

APPLICATIONS

The MIPS could be utilized in a variety of autonomous science packages. For example, a microseismometer is being developed that requires less than 1 watt to operate. The next generation of seismometers is expected to consume no more than 0.1 W. Seismometers require power sources that can last for years due to sporadic nature of seismic events. An alpha-proton-x-ray spectrometer that is being developed for small rovers to investigate rock composition would require about one third of a watt of power, which again is within the range of a MIPS. The next generation of cameras using principles of active pixel sensors could operate on only a fraction of a watt.

There is also a number of microspacecraft instruments and subsystems that could operate using distributed instead of centralized power. Instruments such as magnetometers that must be located on extended booms are perfect candidates for distributed power.

NASA Resident Office
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

National
Aeronautics and
Space
Administration

Reply to Attn of: SJT (180-801)

May 7, 1993

Cronin B. Vining
11738 Moorpark Street #J
Studio City, CA 91604

SUBJECT: NPO-19042 / MILLIWATT ISOTOPE POWER SOURCE FOR MICROSPACECRAFT

I am pleased to inform you that the subject New Technology disclosure has been selected as a Class I NASA Tech Brief to be published in the NASA Tech Briefs Journal. All innovators of Class I Tech Briefs are entitled to receive a $150 Award and Certificate.

In order to facilitate early processing and minimize errors in personal data, please complete the enclosed form and return the form to me AS SOON AS POSSIBLE. All forms NOT returned to me will prohibit the submission of this information to the NASA Headquarters Inventions and Contributions Board. Please note that the submission and approval cycle takes several months.

For your convenience, I have also enclosed a return mailing envelope. Innovators employed at JPL, please use internal mail system to return attached form. Send to Mail Stop 180-801.

If you should have any questions regarding the above Tech Brief, please feel free to call me at (818) 354-4862.

Arif Husain
Technology Utilization Officer

Enclosures (2)

NTR NO./TITLE: NPO-19042 / MILLIWATT ISOTOPE POWER SOURCE FOR MICROSPACECRAFT

SOCIAL SECURITY NO: 231-82-7442 *INNOV CODE:* VINCB

☐Dr. ☐Mr. ☐Mrs. ☐Ms.

NAME: (First MI Last)

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Please print correct address only if address above is incorrect:	EMPLOYER
	* Company * Mail Stop
Street	** Street
City	** City
State Zip Code	** State ** Zip Code

* *Info required for all innovators*
** *Info **not** required for innovators located at JPL*

PRIVACY ACT:

Certain personal information, including your social security number is being requested under the authority of the National Aeronautics and Space Act, 42 U.S.C. 2454; the Privacy Act, 5 U.S.C. 552a; the Tax Code, 26 U.S.C. 3401 et seq.; the Civil Service pay laws, 5 U.S.C. 5301 et seq. and 5 U.S.C. 6301 et seq; Treasury Fiscal Requirements Manual; Federal Personnel Manual; and the NASA Financial Management Manual, sections 9300 and 9600. This information will be provided to the NASA Financial Management Division to process the awards. It is also forwarded by NASA to the U.S. Treasury for the issuance of the check. This information may be supplied by you on a voluntary basis; however, a monetary award cannot be made unless all of the requested information is included.

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Cronin B. Vining

(Please sign here)

National Aeronautics and
Space Administration

Certificate of Recognition

Presents this Certificate to:

CRONIN B. VINING

For the creative development of a technical innovation which has been proposed for publication as a NASA Tech Brief entitled...

MILLIWATT ISOTOPE POWER
SOURCE FOR MICROSPACECRAFT

Sylvia T. Kraemer
Chairperson, Inventions and Contributions Board

SEP 9 1993
Date

JET PROPULSION LABORATORY INTEROFFICE MEMORANDUM

April 19, 1993

TO: Distribution

FROM: Norman L. Chalfin (x46833) MS 122-116
Technology Utilization Office

SUBJECT: NASA Tech Brief publication recommendation for NPO-19042, entitled "Milliwatt Isotope Power Source for Microspacecraft"

As one of the procedures of the Technology Utilization Office, New Technology Reports (NTRs) forwarded by the Office of Patents & New Technology (OPANT) (after 1-1-93) are reviewed by an in-house JPL Committee for NASA Tech Brief publication.

The following criteria are considered in this review:

- **Novelty**: Does the report describe an innovation, discovery, modification or improvement regardless of patentability?
- **Technical Significance**: Does the report add to the general body of knowledge in the subject area? Will it interest an audience in a related area?
- **Utility**: Are there any **commercial** (aerospace or consumer) applications?

The committee assigned the following classification to NPO-19042:

☒ Class 1: Publication is recommended. You will receive a draft of the Tech Brief to approve in the future. You will also receive a letter from Arif Husain, NASA Resident Office-JPL, verifying your home address and social security number in order to process your $150.00 award.

☐ Class 3: Publication is not recommended.

☐ Class 4: Additional information is needed to enable a thorough evaluation.

Only Class 1 recommendations result in NASA Tech Brief publication.

Class 3 and 4 recommendations may be upgraded to Class 1.0 based on your comments. Your response (verbal or written) is necessary in order for the committee's recommendation to be reconsidered.

Distribution:
Artur Chmielewski
Alexander Borshchevsky
Cronin Vining