Solar Electric Propulsion Nasa

KEITH KRISTA

Solar Power System Options for the Radiation and Technology Demonstration Spacecraft Createspace Independent Publishing Platform
This second edition of Spacecraft Power Systems is a comprehensive coverage of the fundamentals, design trades, components, controls, and operations of spacecraft power systems based on the real-world design and operations of spacecraft that have successfully flown for decades. It also includes emerging high-voltage, high-power systems for in-space propulsion for interplanetary travel. With new and updated chapters, sections, and discussions, the second edition covers up-to-date high-voltage, MW-scale electric propulsion, updated PV and battery systems, spacecraft power components, power electronics, and their architectures and operations. This book also presents the latest in spacecraft design processes and trades, controls, operations, and protection. This book is intended for senior undergraduate and graduate students in mechanical, aerospace, and electrical engineering taking courses in Space Systems, Space Engineering, and Spacecraft Power Systems, as well as for practicing aerospace and power engineers and managers who are designing, developing, and operating spacecraft power systems.
NASA Technical Paper Elsevier
Power limited, low-thrust trajectories were assessed for missions to Jupiter, Saturn, and Neptune utilizing a single Venus Gravity Assist (VGA) and a primary propulsion system based on either a 3-kW high voltage Hall thruster, of the type being developed by the NASA In-Space Propulsion Technology Program, or an 8-kW variant of this thruster. These Hall thrusters operate with specific impulses below 3,000 seconds. A trade study was conducted to examine mission parameters that include: net delivered mass (NDM), beginning-of-life (BOL) solar array power, heliocentric transfer time, required launch vehicle, number of operating thrusters, and throttle profile. The top performing spacecraft configuration was defined to be the one that delivered the highest mass for a range of transfer times. In order to evaluate the potential future benefit of using next generation Hall thrusters as the primary propulsion system, comparisons were made with the advanced state-of-the-art (ASOA), 7-kW, 4,100 second NASA's Evolutionary Xenon Thruster (NEXT) for the same mission scenarios. For the BOL array powers considered in this study (less than 30 kW), the results show that the performance of the Hall thrusters, relative to NEXT, is largely dependant on the performance capability of the launch vehicle, and that at least a 10 percent performance gain, equating to at least an additional 200 kg dry mass at each target planet, is achieved over the higher specific impulse NEXT when launched on an Atlas 551.Witzberger, Kevin E. and Manzella, DavidGlenn Research CenterHALL THRUSTERS; SOLAR ELECTRIC PROPULSION; DEEP SPACE 1 MISSION; SPACECRAFT CONFIGURATIONS; NASA SPACE PROGRAMS; SOLAR ARRAYS; POWER CONDITIONING; MATHEMATICAL MODELS; SPECIFIC IMPULSE; HIGH VOLTAGES; NEPTUNE (PLANET); SATURN (PLANET); LAUNCH VEHICLES
Space Nuclear Power and Propulsion Independently Published
The sun tower concept of collecting solar energy in space and beaming it down for commercial use will require very affordable in-space as well as

earth-to-orbit transportation. Advanced electric propulsion using a 200 kW power and propulsion system added to the sun tower nodes can provide a factor of two reduction in the required number of launch vehicles when compared to in-space cryogenic chemical systems. In addition, the total time required to launch and deliver the complete sun tower system is of the same order of magnitude using high power electric propulsion or cryogenic chemical propulsion: around one year. Advanced electric propulsion can also be used to minimize the stationkeeping propulsion system mass for this unique space platform. 50 to 100 kW class Hall, ion, magnetoplasmadynamic, and pulsed inductive thrusters are compared. High power Hall thruster technology provides the best mix of launches saved and shortest ground to Geosynchronous Earth Orbital Environment (GEO) delivery time of all the systems, including chemical. More detailed studies comparing launch vehicle costs, transfer operations costs, and propulsion system costs and complexities must be made to down-select a technology. The concept of adding electric propulsion to the sun tower nodes was compared to a concept using re-useable electric propulsion tugs for Low Earth Orbital Environment (LEO) to GEO transfer. While the tug concept would reduce the total number of required propulsion systems, more launchers and notably longer LEO to GEO and complete sun tower ground to GEO times would be required. The tugs would also need more complex, longer life propulsion systems and the ability to dock with sun tower nodes. Oleson, Steve Glenn Research Center NASA/TM-1999-209307, E-11833, NAS 1.15:209307, AIAA Paper 99-2872

NASA Technical Memorandum National Academies Press

Solar Electric Propulsion (SEP) when used for station keeping and final orbit insertion has been shown to increase a geostationary satellite's payload when launched by existing expendable launch vehicles. In the case of reusable launch vehicles or expendable launch vehicles where an upper stage is an expensive option, this methodology can be modified by using the existing on-board apogee chemical system to perform a perigee burn and then letting the electric propulsion system complete the transfer to geostationary orbit. The elimination of upper stages using on-board chemical and electric propulsion systems was thus examined for GEO spacecraft. Launch vehicle step-down from an Atlas IIAR to a Delta 7920 (no upper stage) was achieved using expanded on-board chemical tanks, 40 kW payload power for electric propulsion, and a 60 day elliptical to GEO SEP orbit insertion. Optimal combined chemical and electric trajectories were found using SEPSPOT. While Hall and ion thrusters provided launch vehicle step-down and even more payload for longer insertion times, NH3 arcjets had insufficient performance to allow launch vehicle step-down. Degradation levels were only 5% to 7% for launch step-down cases using advanced solar arrays. Results were parameterized to allow comparisons for future reusable launch vehicles. Results showed that for an 8 W/kg initial power/launch mass power density spacecraft, 50% to 100% more payload can be launched using this method. Oleson, Steven Glenn Research Center NASA/TM-1999-209646, NAS 1.15:209646, IEPC-99-185, E-11994

Advanced Space Propulsion Systems John Wiley & Sons

In March 2000, NASA's Office of Space Flight asked the Aeronautics and Space Engineering Board of the National Research Council to perform an independent assessment of the space solar power program's technology investment strategy to determine its technical soundness and its contribution to the roadmap that NASA has developed for this program. The program's investment strategy was to be evaluated in the context of its likely effectiveness in meeting the program's technical and economic objectives.

Solar Electric Propulsion Vehicle Design Study for Cargo Transfer to Earth-Moon L1 National Academies Press

Solar electric propulsion (SEP) technology is already being used for geostationary satellite stationkeeping to increase payload mass. By using this same technology to perform part of the orbit transfer additional increases in payload mass can be achieved. Advanced chemical and N2H4 arcjet systems are used to increase the payload mass by performing stationkeeping and part of the orbit transfer. Four mission options are analyzed which show the impact of either sharing the orbit transfer between chemical and SEP systems or having either complete the transfer alone. Results show that for an Atlas 2AS payload increases in net mass (geostationary satellite mass less wet propulsion system mass) of up to 100 kg can be achieved using advanced chemical for the transfer and advanced N2H4 arcjets for stationkeeping. An additional 100 kg can be added using advanced N2H4 arcjets for part of a 40 day orbit transfer. Oleson, Steven R. and Curran, Francis M. and Myers, Roger M. Glenn Research Center NASA-TM-106942, E-9671, NAS 1.15:106942 NAS3-27186; RTOP 564-09-20...

Electric Propulsion Concepts Enabled by High Power Systems for Space Exploration Independently Published

This extensive and completely comprehensive proceedings volume offers the most in-depth examination available today of nuclear power for applications in space.

Performance of Solar Electric Powered Deep Space Missions Using Hall Thruster Propulsion Createspace Independent Publishing Platform

The NASA Office of the Chief Technologist Game Changing Division is sponsoring the development and testing of enabling technologies to achieve efficient and reliable human space exploration. High-power solar electric propulsion has been proposed by NASA's Human Exploration Framework Team as an option to achieve these ambitious missions to near Earth objects. NASA Glenn Research Center (NASA Glenn) is leading the development of mission concepts for a solar electric propulsion Technical Demonstration Mission. The mission concepts are highlighted in this paper but are detailed in a companion paper. There are also multiple projects that are developing technologies to support a demonstration mission and are also extensible to NASA's goals of human space exploration. Specifically, the In-Space Propulsion technology development project at NASA Glenn has a number of tasks related to high-power Hall thrusters including performance evaluation of existing Hall thrusters; performing detailed internal discharge chamber, near-field, and far-field plasma measurements; performing detailed physics-based modeling with the NASA Jet Propulsion Laboratory's Hall2De code; performing thermal and structural modeling; and developing high-power efficient discharge modules for power processing. This paper summarizes the various technology development tasks and progress made to date Kamhawi, Hani and Manzella, David H. and Smith, Timothy D. and Schmidt, George R. Glenn Research Center WBS 182603.01.04.02

NASA Space Systems Technology Model Springer

The NACA and aircraft propulsion, 1915-1958 -- NASA gets to work, 1958-1975 -- The shift toward commercial aviation, 1966-1975 -- The quest for propulsive efficiency, 1976-1989 -- Propulsion control enters the computer era, 1976-1998 -- Transiting to a new century, 1990-2008 -- Toward the future

High-Power Hall Propulsion Development at NASA Glenn Research Center National Academies Press

After the completion of the National Research Council (NRC) report, Maintaining U.S. Leadership in Aeronautics: Scenario-Based Strategic Planning for NASA's Aeronautics Enterprise (1997), the National Aeronautics and Space Administration (NASA) Office of Aeronautics and Space Transportation Technology requested that the NRC remain involved in its strategic planning process by conducting a study to identify a short list of revolutionary or breakthrough technologies that could be critical to the 20 to 25 year future of aeronautics and space transportation. These technologies were to address the areas of need and opportunity identified in the above mentioned NRC report, which have been characterized by NASA's 10 goals (see Box ES-1) in "Aeronautics & Space Transportation Technology: Three Pillars for Success" (NASA, 1997). The present study would also examine the 10 goals to determine if they are likely to be achievable, either through evolutionary steps in technology or through the identification and application of breakthrough ideas, concepts, and technologies.

Laying the Foundation for Space Solar Power Createspace Independent Publishing Platform

Space propulsion systems have a great influence on our ability to travel to other planets or how cheap a satellite can provide TV programs. This book provides an up-to-date overview of all kinds of propulsion systems ranging from classical rocket technology, nuclear propulsion to electric propulsion systems, and further to micro-, propellantless and even breakthrough propulsion, which is a new program under development at NASA. The author shows the limitations of the present concepts and how they could look like in the future. Starting from historical developments, the reader is taken on a journey showing the amazing technology that has been put on hold for decades to be rediscovered in the near future for questions like how we can even reach other stars within a human lifetime. The author is actively involved in advanced propulsion research and contributes with his own experience to many of the presented topics. The book is written for anyone who is interested in how space travel can be revolutionized.

Technology for Small Spacecraft Createspace Independent Publishing Platform

This paper describes the latest development in electric propulsion systems being planned for the new Space Exploration initiative. Missions to the Moon and Mars will require these new thrusters to deliver the large quantities of supplies that would be needed to support permanent bases on other worlds. The new thrusters are also being used for unmanned exploration missions that will go to the far reaches of the solar system. This paper is intended to give the reader some insight into several electric propulsion concepts their operating principles and capabilities, as well as an overview of some mission applications that would benefit from these propulsion systems, and their accompanying advanced power systems. Gilland, James and Fiehler, Douglas and Lyons, Valerie Glenn Research Center NASA/TM-2005-213371, AIAA Paper 2004?5690, E-14840

Maintaining U.S. Leadership in Aeronautics Elsevier

The results of the NASA Glenn Research Center (GRC) COllaborative Modeling and Parametric Assessment of Space Systems (COMPASS) internal Solar Electric Propulsion (SEP) stage design are documented in this report (Figure 1.1). The SEP Stage was designed to deliver a science probe to Saturn (the probe design was performed separately by the NASA Goddard Space Flight Center s (GSFC) Integrated Mission Design Center (IMDC)). The SEP Stage delivers the 2444 kg probe on a Saturn trajectory with a hyperbolic arrival velocity of 5.4 km/s. The design carried 30 percent mass, 10 percent power, and 6 percent propellant margins. The SEP Stage relies on the probe for substantial guidance, navigation and control (GN&C), command and data handling (C&DH), and Communications functions. The stage is configured to carry the probe and to minimize the packaging interference between the probe and the stage. The propulsion system consisted of a 1+1 (one active, one spare) configuration of gimbaled 7 kW NASA Evolutionary Xenon Thruster (NEXT) ion propulsion thrusters with a throughput of 309 kg Xe propellant. Two 9350 W GaAs triple junction (at 1 Astronomical Unit (AU), includes 10 percent margin) ultra-flex solar arrays provided power to the stage, with Li-ion batteries for launch and contingency operations power. The base structure was an Al-Li hexagonal skin-stringer frame built to withstand launch loads. A passive thermal control system consisted of heat pipes to north and south radiator panels, multilayer insulation (MLI) and heaters for the Xe tank. All systems except tanks and solar arrays were designed to be single fault tolerant. Oleson, Steven R. and McGuire, Melissa L. Glenn Research Center SOLAR ARRAYS; PROPELLANTS; PACKAGING; MISSION PLANNING; SOLAR ELECTRIC PROPULSION; ELECTRIC BATTERIES; SPACECRAFT LAUNCHING; DATA TRANSMISSION; GALLIUM ARSENIDES; PANELS

Advanced Electric Propulsion for Rlv Launched Geosynchronous Spacecraft Springer Nature

The NASA Solar Electric Propulsion Technology Applications Readiness Program (NSTAR) will provide a single-string primary propulsion system to NASA's New Millennium Deep Space 1 Mission which will perform comet and asteroid flybys in the years 1999 and 2000. The propulsion system includes a 30-cm diameter ion thruster, a xenon feed system, a power processing unit, and a digital control and interface unit. A total of four engineering model ion thrusters, three breadboard power processors, and a controller have been built, integrated, and tested. An extensive set of development tests has been completed along with thruster design verification tests of 2000 h and 1000 h. An 8000 h Life Demonstration Test is ongoing and has successfully demonstrated more than 6000 h of operation. In situ measurements of accelerator grid wear are consistent with grid lifetimes well in excess of the 12,000 h qualification test requirement. Flight hardware is now being assembled in preparation for integration, functional, and acceptance tests. Sovey, James S. and Hamley, John A. and Haag, Thomas W. and Patterson, Michael J. and Pencil, Eric J. and Peterson, Todd T. and Pinero, Luis R. and Power, John L. and Rawlin, Vincent K. and Sarmiento, Charles J. and Anderson, John R. and Bond, Thomas A. and Cardwell, G. I. and Christensen, Jon A. Glenn Research Center; Jet Propulsion Laboratory RTOP 242-70-01...

Primitive Meteorites and Asteroids National Academies Press

Current technology for solar-electric propulsion is used to assess the potential performance advantages of low-thrust propulsion for an out-of-the-ecliptic mission. Simple normal-to-the-orbit thrust steering is assumed with coast subarcs permitted. The electric spacecraft is launched onto an Earth escape trajectory by an Atlas (SLV3C)-Centaur or a Titan IIIC. Comparisons with a similarly launched uprated Burner II stage reveal that significant performance gains are possible using the electric stage with 250- to 475-day flight times.

Space Solar Power Satellite Technology Development at the Glenn Research Center Government Printing Office

A preliminary investigation of a lunar-comet rendezvous mission using a solar electric propulsion (SEP) spacecraft was performed in two phases.The first phase involved exploration of the moon and the second involved rendezvous with a comet. The initial phase began with a chemical propulsion translunar injection and chemical insertion into a lunar orbit, followed by a low thrust SEP transfer to a circular, polar, low-lunar orbit. After collecting scientific data at the moon, the SEP spacecraft performed a spiral lunar escape maneuver to begin the interplanetary leg of the mission. After escape from the Earth-moon system, the SEP spacecraft maneuvered in interplanetary space and performed a rendezvous with a comet.The immediate goal of this study was to demonstrate the feasibility of using a low-thrust SEP spacecraft for orbit transfer to both the moon and a comet. Another primary goal was to develop a computer optimization code which would be robust enough to obtain minimum-fuel rendezvous trajectories for a wide range of comets. Kluever, Craig A. Unspecified Center NAG3-1581...

Solar Cell Array Design Handbook Createspace Independent Publishing Platform

Space Power Systems covers systems based on the three primary sources of energy of practical value, namely, solar, nuclear, and chemical sources. This book is organized into four parts encompassing 32 chapters that also explore the requirements for space power. Part A presents the general aspects of solar cell power systems based on the work performed for US space vehicles that are to be placed in orbit. This part specifically considers a graph showing the variation of characteristic parameters of the solar cell battery storage system as a function of flight altitude. Considerable chapters in this part are devoted to the solar cell power plant for the space vehicles ADVENT, RANGER, TIROS, and TRANSIT. The remaining chapters provide a detailed analysis of the physics and engineering of solar panel and solar mirror design. Part B contains a series of papers involving the various aspects of the Atomic Energy Commission SNAP (Systems for Nuclear Auxiliary Power) program. Many details are presented for the 3 kw, liquid metal, turbo-machinery SNAP II power systems covering subjects from the basic concept through vehicle integration and safety aspects. Significant chapters in this part discuss the compact and apparently highly reliable radioisotope thermoelectric generator. Part C highlights the methods of storing and expelling high energy cryogenic fuels, which can provide from two to five times more energy per unit weight than the silver-zinc primary battery. Part D provides an interesting and useful estimation of the many requirements that are likely to become firm for space vehicles. Space vehicle engineers, designers, and researchers will find this book invaluable.

Compass Final Report Independently Published

The success of the NASA Deep Space I spacecraft has demonstrated that ion propulsion is a viable option for deep space science missions. More aggressive missions such as Comet Nuclear Sample Return and Europa lander will require higher power, higher propellant throughput and longer thruster lifetime than the NASA Solar Electric Propulsion Technology Application Readiness (NSTAR) engine. Presented here are thruster plume and discharge plasma measurements of an NSTAR-type thruster operated from 0.5 kW to 5 kW. From Faraday plume sweeps, beam divergence was determined. From Langmuir probe plume measurements on centerline, low energy ion production on axis due to charge-exchange and direct ionization was assessed. Additionally, plume plasma potential measurements made on axis were used to determine the upper energy limits at which ions created on centerline could be radially accelerated. Wall probes flush-mounted to the thruster discharge chamber anode were used to assess plasma conditions. Langmuir probe measurements at the wall indicated significant differences in the electron temperature in the cylindrical and conical sections of the discharge chamber. Foster, John E and Soulas, George C. and Patterson, Michael J. Glenn Research Center NASA/TM-2000-210382, E-12438, AIAA Paper 2000-3812, NAS 1.15:210382

The Power for Flight Springer Science & Business Media

A design study for a cargo transfer vehicle using solar electric propulsion was performed for NASA's Revolutionary Aerospace Systems Concepts program. Targeted for 2016, the solar electric propulsion (SEP) transfer vehicle is required to deliver a propellant supply module with a mass of approximately 36 metric tons from Low Earth Orbit to the first Earth-Moon libration point (LL1) within 270 days. Following an examination of propulsion and power technology options, a SEP transfer vehicle design was selected that incorporated large-area (approx. 2700 sq m) thin film solar arrays and a clustered engine configuration of eight 50 kW gridded ion thrusters mounted on an articulated boom. Refinement of the SEP vehicle design was performed iteratively to properly estimate the required xenon propellant load for the out-bound orbit transfer. The SEP vehicle performance, including the xenon propellant estimation, was verified via the SNAP trajectory code. Further efforts are underway to extend this system model to other orbit transfer missions. Sarver-Verhey, Timothy R. and Kerslake, Thomas W. and Rawlin, Vincent K. and Falck, Robert D. and Dudzinski, Leonard J. and Oleson, Steven R. Glenn Research Center NASA/TM-2002-211970, E-13613, NAS 1.15:211970, AIAA Paper 2002-3971

Electric Propulsion for Geostationary Orbit Insertion Createspace Independent Publishing Platform

In 2003, NASA began an R&D effort to develop nuclear power and propulsion systems for solar system exploration. This activity, renamed Project Prometheus in 2004, was initiated because of the inherent limitations in photovoltaic and chemical propulsion systems in reaching many solar system objectives. To help determine appropriate missions for a nuclear power and propulsion capability, NASA asked the NRC for an independent assessment of potentially highly meritorious missions that may be enabled if space nuclear systems became operational. This report provides a series of space science objectives and missions that could be so enabled in the period beyond 2015 in the areas of astronomy and astrophysics, solar system exploration, and solar and space physics. It is based on but does not reprioritize the findings of previous NRC decadal surveys in those three areas.