1999

ELECTRIC PROPULSION

Oscar Biblarz, Professor
Department of Aeronautics and Astronautics
Sponsor: Unfunded

OBJECTIVE: The goal of this project is to arrive at a specific procedure suitable for preliminary design of space missions where electric propulsion is more attractive than chemical propulsion.

SUMMARY: Electric Propulsion has shown to be advantageous over chemical propulsion in a majority of space missions of interest. We extended the Langmuir-Irving payload mass-fraction formulation to a "dual optimum" condition to yield a minimum overall mass for a specified mission/payload which is consistent with minimum propulsion time. This dual optimum allows for the unambiguous selection of one or more electric engines based on their advertised specific impulse, efficiency and a specific power parameter (α in Watts/kg) which represents the power plant. Values of α are tabulated for the present inventory of engines. Examples are worked out for various missions of interest.

PUBLICATIONS: None

THESIS DIRECTED: De Bellis, John J., "Optimization Procedure for Electric Propulsion Engines, " Master of Science Thesis, Naval Postgraduate School, December 1999.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Space Propulsion, Electric Propulsion, Ion Engines, Hall Thrusters, Optimum Specific Impulse, Minimum Thrusting Time

1997

SPACE PROPULSION AND THERMAL CONTROL

O. Biblarz, Professor of Aeronautics and Astronautics

Sponsor: Unsponsored

OBJECTIVE: The effort here represents activity in applications of importance to space. The arc-jet is used for electric propulsion and PANSAT is an NPS satellite which is undergoing thermal analysis.

SUMMARY: The anode of the arc jet is usually the first component to fail in such thrustors. The anode region is defined as a highly nonequilibrium region which is composed of a nonneutral region or sheath and of an ambipolar region. A continuum description of the anode region for steady state, isothermal conditions with two- and three-body recombination has been sought in conjunction with Professor C. L. Frenzen of the Mathematics Department. We have looked at a one dimensional description which is has so far eluded any satisfactory solution. With respect to PANSAT, a thermal model of the spacecraft has been used to simulate its behavior under given thermal environments and boundary conditions so that temperature predictions can be made. This effort was undertaken in conjunction with Professor Ashock Gopinath of Mechanical Engineering and Mr. Dan Sakoda of SSAG.

1996

JSOW UNITARY CAPTIVE AIR TRAINING MISSILE (CATM) CONCEPTUAL DESIGN STUDIES

Gerald Lindsey, Professor
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Sandra Scrivener, Assistant Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Air Systems Command PMA-301

OBJECTIVE: To perform conceptual design studies on a Captive Air training Missile to be used by F-18 pilots in training for use of the JSOW Unitary missile.

SUMMARY: A detailed concept for operational employment of the JSOW CATM has been written, from which functional requirements for the CATM have been derived. These include all operational, performance, compatibility, communications and electro-mechanical requirements and constraints.

Detailed studies have been made in four areas: (1) overall configuration studies (2) airframe structural weight, strength and fatigue studies, (3) configuration drag studies of the missile and pylon while in the captive position, and (4) flight simulation studies of the missile in flight after release.

Configuration studies have led to a preferred size and carry position to accommodate weight limitations and constraints created by requirements to communicate with the GPS satellites and the control aircraft. Weight, strength and fatigue studies have shown that a gross weight of 300 pounds may be possible, but will be a difficult challenge to achieve. Drag studies have resulted in new insights into the process of tailoring the aft area distribution of the CATM for minimum drag and have led to a promising approach to optimizing the configuration design. Flight simulation studies have been completed for the missile itself, and work is now continuing by modeling the F-18 to fly as the JSOW in the carry mode as the training aircraft and determining the best suite of pilot cues to accomplish it.

The project began October 1, 1995 and was continued for a second year October 1, 1996.

MEASUREMENT OF SOOT EMISSIONS

O. Biblarz and D.W. Netzer
Department of Aeronautics and Astronautics
Sponsor: Unsponsored

OBJECTIVE: Adapt an existing three-wavelength laser extinction measurement system for use with a phase conjugate crystal to minimize atmospheric and beam steering effects on soot mass concentration measurements. Use the instrument in conjunction with a recently NPS developed soot mass concentration measurement technique to measure the soot concentration in simulated engine plumes.

SUMMARY: An instrument is under development and calibration capable of on-line determination of soot concentration in plumes. The instrument utilizes an argon-ion laser and two passes through the exhaust plume using a phase conjugate crystal to correct for aberrations in the transmitted beam and to increase accuracy when used in low opacity plumes. Several aspects of instrument layout and performance have been investigated, and an initial calibration was performed using an ethylene-air combustor. The method requires further development, but shows significant promise for use in a jet engine test cell.

ALTERNATE PROPELLANTS FOR NUCLEAR ELECTRIC PROPULSION

O. Biblarz, Professor
Department of Aeronautics and Astronautics
Sponsor: Unsponsored

OBJECTIVE: The original goal of this project was to relate to the Nuclear Electric Propulsion (NEP) space test mission of the AF Phillips Laboratory. Now it is broadened to electrical power generation by direct conversion together with electric propulsion, including space nuclear reactor utilization.

SUMMARY: The Space Power and Thermal Management Division of the AF Phillips Labs has run a number of programs for which the Naval Postgraduate School has been able to contribute expertise. One of these is the TOPAZ II thermionic power generator, purchased from the former USSR and being tested and evaluated by the TOPAZ International Program (TIP). Prior to propulsion applications, the thermionic power generator thermal and electric characteristics as well as the system start-up are being studied and these efforts comprised the effort during this reporting period. It was found that useful power can be produced by the thermionic fuel elements at low heating levels. The test stand for single cell elements (TFE) was investigated and critical thermal resistances identified. Work on a control system to be designed to US standards would benefit from the theory and design presented in LT Astrin's thesis. In electric propulsion, "thermionic arcing" is proposed as an improvement over present ionization chamber for ion engines.

1995

ALTERNATE PROPELLANTS FOR NUCLEAR ELECLTRIC PROPULSION

O. Biblarz, Professor of Aeronautics and Astronautics

Sponsor: Phillips Labs, Kirkland AFB

OBJECTIVE: The goal of this project is to relate to the Nuclear Electric Propulsion (NEP) space test mission of the AF Phillips Laboratory. Electrical power generation by direction conversion together with electric propulsion are included a bimodal concept for space nuclear reactor utilization.

SUMMARY: The Space Power and Thermal Management Division of the AF Phillips Labs runs a number of programs in which the Naval Postgraduate School is able to contribute expertise. One of these is the TOPAZ II thermionic power generator, purchased from the former USSR and being tested and evaluated by the TOPAZ International Program (TIP). Prior to propulsion applications, the thermionic power generator thermal and electric characteristics as well as the system start-up are being studied and these efforts comprised the effort during this reporting period. It was found that useful power can be produced by the thermionic fuel elements at low heating levels. The test stand for single cell elements (TFE) was investigated and critical thermal resistances identified. Work on a control system to be designed to US standards would benefit from the theory and design presented in LT Astrin's thesis.

MEASUREMENT OF SOOT EMISSIONS

O. Biblarz and D.W. Netzer
Department of Aeronautics and Astronautics

Sponsor: Naval Air Warfare Center Aircraft Division

OBJECTIVE: Adapt an existing three-wavelength laser extinction measurement system for use with a phase conjugate crystal to minimize atmospheric and beam steering effects on soot mass concentration measurements. Use the instrument in conjunction with a recently NPS developed soot mass concentration measurement technique to measure the soot concentration in simulated engine plumes.

SUMMARY: An instrument was developed and calibrated which is capable of on-line determination of soot concentration in plumes. The instrument utilizes an argon-ion laser, four passes through the exhaust plume using a retroreflector and a phase conjugate crystal to correct for aberrations in the transmitted beam and to increase accuracy when used in low opacity plumes. Several aspects of instrument layout and performance were investigated, and an initial calibration was performed using an ethylene-air combustor. The method requires further development, but shows significant promise for use in a jet engine test cell.

1994

MEASUREMENT OF SOOT EMISSIONS FROM GAS TURBINE ENGINES

D.W. Netzer, Professor of Aeronautics and Astronautics
O. Biblarz, Professor of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center Aircraft Division

OBJECTIVE: To adapt a three-wavelength laser extinction measurement system with a retroreflector or equivalent for measurements of plume soot size and concentration. To compare results from a newly developed direct soot concentration measurement technique to those obtained using assumed soot optical properties.

SUMMARY: An apparatus was developed for determining soot particle densities by measuring laser light extinction through an exhaust plume. A two-pass technique with both a retroreflector and an optical phase conjugator crystal has been utilized. Although the conjugator returned the laser beam, showing proof of principle, a portion of the beam was not received back at the photodetector.

ALTERNATE PROPELLANTS FOR NUCLEAR ELECTRIC PROPULSION

O. Biblarz, Professor of Aeronautics and Astronautics
Sponsor: Phillips Labs, Kirkland AFB

OBJECTIVE: The goal of this project is to relate to the Nuclear Electric Propulsion (NEP) space test mission of the AF Phillips Laboratory. Electrical power generation by direct conversion together with electric propulsion are included a bimodal concept for space nuclear reactor utilization.

SUMMARY: The Space Power and Thermal Management Division of the AF Phillips Labs runs a number of programs in which the Naval Postgraduate School is able to contribute expertise. One of these is the TOPAZ II thermionic power generator, purchased from the former USSR and being tested and evaluated by the TOPAZ International Program (TIP). Prior to propulsion applications, the thermionic power generator thermal and electric characteristics are being studied and these studies comprised the effort during this reporting period. It was found that useful power can be produced by the thermionic fuel elements at low heating levels. The test stand for single cell elements (TFEs) was investigated and critical thermal resistances identified.

EFFECTS OF BOUND CLUSTERS ON THE OPTICAL AND THERMAL PROPERTIES OF HIGH-ENERGY LASER MIRRORS

Oscar Biblarz, Professor of Aeronautics and astronautics

Sponsor: NAWC Physics Division, China Lake
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to investigate possible cluster contributions to mirror damage and to the operation of uncooled optics in high energy laser applications.

SUMMARY: High energy laser mirrors exhibit damage of as yet unknown origin. Bound clusters from the substrate have the same chemical elements as the rest of the surface but manifest a different structure. They have, therefore, different properties, both optical and thermal. The existence of these clusters is predicted from equilibrium relationships. The study of melting has yielded some interesting insights in that they coatings with the highest melting point are the least susceptible to damage. Melting of refractory metals such as tungsten are scrutinized with the model of intrinsic clusters permeating the crystalline matrix and representing a "molten fraction" at any temperature.

EVALUATION OF UTSI PROGRAM ON OPTICAL MEASUREMENTS OF TURBINE EXHAUST PARTICULATES

O. Biblarz, Professor of Aeronautics and Astronautics
D.W. Netzer, Professor of Aeronautics and Astronautics

Sponsor: Naval Air Warfare Center Aircraft Division

OBJECTIVE: To provide an independent evaluation of the theoretical and experimental approaches which have been used by the University of Tennessee Space Institute's Center for Laser Applications for the measurement of soot size and optical properties in gas turbine engine exhausts.

SUMMARY: An evaluation was made based upon the published literature of UTSI-CLA. Specific conclusions and recommendations were included in the final report submitted to the NAWCAD. A new, simple technique for measuring the concentration of soot in gas turbine exhaust plumes was proposed.

1992

EFFECTS OF BOUND CLUSTERS ON THE OPTICAL AND THERMAL PROPERTIES…

Oscar Biblarz, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: NAWC Physics Division, China Lake
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to investigate possible cluster contributions to mirror damage and to the operation of uncooled optics in high energy laser applications. This is a new project.

SUMMARY: High energy laser mirrors exhibit damage of unknown origin. We are studying possible contributions from intrinsic clusters to this damage. Bound clusters which originate from the substrate have the same chemical elements as the rest of the surface but manifest a different structure. They have, therefore, different properties, both optical and thermal. The existence of these clusters is predicted from equilibrium relationships. By studying damage and relating it known cluster characteristics, we would anticipate improving damage thresholds.

LOW-VOLTAGE, THERMIONIC BREAKDOWN FOR XENON ION ENGINES

Oscar Biblarz, Associate Professor
Department of Aeronautics and Astronautics
Sponsor: Naval Research Laboratories
Funding: Naval Postgraduate School

OBJECTIVE: To better understand low-voltage thermionic discharges so that they may be implemented to ionization chambers. The advantages of low voltage operation may translate into less demand from power-conditioning equipment as well as less sputtering from energetic ions. These discharges are also of interest to many other arc devices. This is a continuing project.

SUMMARY: We have arrived at an equivalent form of Paschen's law which applies to low-voltage, thermionic discharges. The key element is that there be a source of electrons at the cathode sheath prior to the formation of the arc. The small voltages observed require very small gaps so that the implementation of the scheme requires an auxiliary device such as an incandescent fillament across the electrodes. NASA's work with the ionization xenon for ion engines has been scrutinized. Some preliminary modifications to this ionizer have been looked at.

IMPROVEMENT OF THE ALTITUDE MEASUREMENT CAPABILITY OF THE SAIP

Oscar Biblarz
Associate Professor
Department of Aeronautics and Astronautics
Sponsor: PMTC, Point Mugu, CA
Funding: UNFUNDED

OBJECTIVE: The goal of this project is to identify the sources of error in the measurement of barometric-pressure altitude in the Navy's Service Aircraft Instrumentation Package (SAIP). Errors have been observed beyond those standard for this technique. In the long term we had hoped to influence new designs. This is a continuing project.

SUMMARY: Altitude measurements with the SAIP do not conform with the specifications for the probe. Errors seem to worsen with aircraft speed and altitude and, therefore, appear to be of aerodynamic origin. Our work with a second-generation SAIP [model # NCA S/N 0040, P/N 2111940-001] indicated that there is a grounding problem arising from an ambiguous specification. After correcting this, however, the probe continues to read above the static value of the pressure and we have identified the 5"-body of the SAIP as the culprit along with the aircraft mounting location. We have refined a computer description and are presently looking very closely at the way the data are reduced in order to define parameter sensitivity.