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Direct Drive Solar-Powered Arcjet Thruster

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Sponsoring Program(s)

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Project Description

Electric thrusters typically require a power processing unit (PPU) to convert the spacecraft-provided power to the voltage and current that a thruster needs for operation. NASA Marshall Space Flight Center has initiated fundamental studies on whether an arcjet thruster can be operated directly with the power produced by solar arrays without any additional conversion. Elimination of the PPU significantly reduces system-level complexity of the propulsion system, and lowers developmental cost and risk. The proposed work will aim to refine the proof-of-concept presently being assembled and begin to identify and address technical questions related to power conditioning and noise suppression in the system, and heating of the thruster in long-duration operation. The apparatus proposed for investigation has a target power level of 400 to 1,000 W. The proposed direct-drive arcjet is potentially a highly scalable concept, applicable to spacecraft with up to hundreds of kilowatts and beyond.

The design of the arcjet built for this effort was based on previous low power (1 kW class) arcjets.[1–3] It has a precision machined 99.95% pure tungsten anode that also serves as the nozzle with a 0.040-in- (1-mm-) diameter, 0.040-in-long constrictor region. An additional anode with a 0.020-in- (0.5-mm-) diameter, 0.020-in-long constrictor region was purchased, but has not yet been used. The cathode is a 0.125-in-diameter tungsten welding electrode doped with lanthum-oxygen; its tip was precision ground to a 308° angle and terminates in a blunt end. The two electrodes are separated by a boron-nitride insulator that also serves as the propellant manifold; it ends in six small holes which introduce the propellant gas in the diverging section of the nozzle, directly adjacent to the cathode. The electrodes and insulator are housed in a stainless-steel outer body, with a Macor insulator at the mid-plane to provide thermal isolation between the front and back halves of the device. The gas seals were made using Grafoil gaskets. Figure 1(a) shows the assembled thruster; figure 1(b) shows the thruster in the vacuum chamber with electrical and propellant connections.

(a)

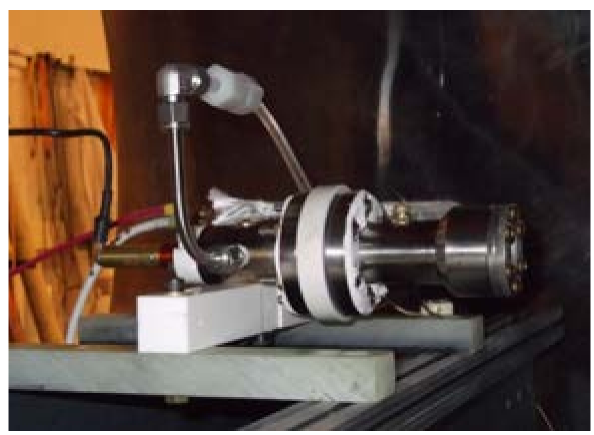

(b)


Figure 1: Direct drive arcjet: (a) In the vacuum chamber and (b) in operation.

Anticipated Benefits

Direct drive of an electric propulsion system confers the advantage of reducing or eliminating the PPU that is typically needed to convert the spacecraft-provided power to the voltage and current needed for thruster operation. Since the PPU is typically the most expensive piece of an electric thruster system, from both a fabrication and qualification standpoint, its elimination offers the potential for major reductions in system cost and risk.

Potential Applications

Arcjets are widely used for station keeping of satellites and, in higher power incarnations, may be used for orbit raising. A direct-drive electric propulsion system would be comprised of a thruster that operates with the power supplied directly from the power source (typically solar arrays) with no further power conditioning needed between those two components. Arcjets are best suited for direct drive, as the voltage and current levels they require are close to the output levels of photovoltaic arrays. Demonstration of direct-drive operation would significantly reduce cost and lead time in the deployment of these systems.

Notable Accomplishments

Initial testing was conducted in a 3.5-ft-diameter vacuum chamber (see fig. 2); the ultimate pressure reached during quasi-steady operation of the thruster was about 330 millitorr. The thruster was powered with a high current, 15-kW power supply. The discharge was initiated with a high-voltage (~10 kV) spark initiator that was isolated from the supply by a stack of diodes. Initial testing indicated that an operating point exists within the I-V characteristics that is typical of solar arrays; for a flow rate of 20 mg/s (argon), the arc could be sustained at a voltage of about 20 V and a current of 25 A (500 W).

Figure 2: The direct drive arcjet in operation.

References

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2. Yamada, T.; Shimizu, Y.; Toki, K.; and Kuriki, K.: "Thrust Performance of a Regeneratively Cooled Low-Power Arcjet Thruster," *Journal of Propulsion and Power*, Vol. 8, No. 3, pp. 650–544, 1992.

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