N STARK

NS TRAK is the embodiment of a revolutionary new philosophy of work, a key ingredient in the advancement of technology and national security.

The program is designed to provide the next generation of professionals with the skills and knowledge necessary to succeed in the rapidly changing technological landscape.

In 1997, the NS TRAK program was established to address the critical need for highly skilled professionals in the fields of national security and technology.

The program is administered by the National Aeronautics and Space Administration (NASA) and is supported by various federal agencies.

In addition to providing advanced training and education, the program also includes opportunities for students to work on cutting-edge projects and research.

The NS TRAK program is open to students from a variety of backgrounds, including those with degrees in engineering, computer science, and other related fields.

For more information on the NS TRAK program, please visit the National Aeronautics and Space Administration (NASA) website or contact your local campus representative.

INTER UCTION

OVERVIEW AND STATUS OF NASA'S PROGRAM
In this section, we also describe the links and products made by the IEE to develop the implications for population

<table>
<thead>
<tr>
<th>Population</th>
<th>43</th>
<th>Percentage, mean</th>
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</thead>
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<td>Year 5</td>
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A new, population-specific program that will not be released to commercial practice.

The population-specific program is associated with the NSTR/AV-validated performance model. The confidence that the error term is due to the correction in the mean model is due to the correction in the population-specific program. The confidence that the error term is due to the correction in the mean model is due to the correction in the population-specific program.

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**Approach**

1. Verify that the data are described in function of

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**References**

The new NSTR/AV validation program was began with no objectives.
The potential users of ion propulsion technology surveyed included project managers, spacecraft manufacturers, propulsion system vendors, purchasers of communications services, and designers of planetary missions. Their requirements were prioritized using a Quality Function Deployment (QFD) methodology. Subsequently, NSTAR program personnel, working with ion propulsion technologists, selected a subset of the user-identified requirements as the validation requirements to which the NSTAR program would be directed. These validation requirements met several criteria: first, if successfully satisfied they would yield an ion propulsion system that would offer the performance needed to provide a significant improvement when compared to the systems-level performance offered by chemical propulsion systems; second, the validation requirements were requirements that were within our technical ability to satisfy; and third, they were validation requirements that could be met within the funding constraints of the NSTAR program. The NSTAR validation requirements are shown in Table 1.

The NSTAR Program's approach to achieving its objectives began with its thrust selection. The 30-cm ion thruster had been under development by NASA's LeRC for several years. It was derived from the J-Series thruster that had first been tested with mercury in the late 1970s. The 30-cm ion thruster to be used as the basis for the NSTAR flight thruster's design was originally designed to operate at 10 kW for 10,000 hours using xenon as propellant. Because lifetime is a critical technical requirement, this thruster was devoted for its operation on NSTAR to a maximum power of 2.5 kW and a service lifetime of 8,000 hours. This derating was intended to minimize the risk of failure during the NSTAR validation process while validating an ion thruster design that had significant growth potential.

Validation requirements fell naturally into a group that could be validated in tests in vacuum chambers on Earth and a second group that could only be addressed with operation in space. Those that could be addressed with ground testing were those tests to validate lifetime and performance. Those tests that could only be performed in space consisted of tests that would measure the interactions of an ion propulsion system with the spacecraft on which it was integrated, and its interactions with the surrounding space plasma. In addition to the validation tests planned for ground tests, a series of development tests were anticipated. These development tests would address detailed design issues, obtaining data that would contribute to the design of the flight thruster and power processing unit.

To ensure an effective transfer of the expertise developed by NASA to industry, the opportunity to design and fabricate the ion thruster, power processing unit (PPU), and digital control interface unit (DCIU) was competitively awarded to the Hughes/Eltron Dynamics Division (HEDD), Torrance, CA. Similarly, a partnership with Moog Inc. of East Aurora, NY was established for the design and fabrication of the propellant control portion of the Propellant Storage and Control (PSCS).

Requirements

Analyses of the missions for which ion propulsion would yield a significant cost advantage led to a set of validation requirements, shown in Table 1, to which NSTAR would be directed. To address these requirements, the NSTAR Program selected the NASA 30-cm, ring-cusp, electron-bombardment ion thruster as the thrust producing device it would use to validate ion propulsion technology. To accommodate the reduction in available power concomitant to the increasing distance to the sun for many deep-space missions, the thruster is required to operate over an available power range of 0.5 kW to 2.5 kW with an input voltage between 80 V and 160 V and to be able to process 83 kg of xenon.

Ground Tests

NSTAR's formal ground test program consists of two tests:

- A test of an engineering model thruster with a bread board power processing unit (BBPPU) (both designed and fabricated by the government) for 8,000 hours at full power. The purpose of this test was the validation of the performance and lifetime of the functional design of the ion thruster. Operation of the ion thruster at full power is the most stressful operating condition for the ion thruster. Thus, operation for 8,000 hours at full power, consuming 83 kg of propellant, demonstrates the ability of the ion thruster to process 83 kg of propellant at any power level within the thruster's operating range. As of October 1, 1996, 1,600 hours of the planned 8,000 hours had been completed with no significant problems encountered.
• A Mission Profile test intended to demonstrate the ability of the NSTAR ion propulsion system to process 83 kg of xenon (equivalent to the concept of a service lifetime) with a power profile intended to simulate a "typical" outward bound deep space mission. The test is also intended to demonstrate a 50% lifetime margin on the 83 kg service lifetime requirement, resulting in a test during which 125 kg of xenon will be consumed. The power profile to which the ion propulsion system will be operated will provide operation for significant periods of time at each of the system throttle points from minimum to maximum.

The test hardware for the mission profile test will consist of:

• One thruster (fabricated by ITT Interpower Corporation).
• One flight Power Processing Unit and controller from Jet Propulsion Laboratory.
• One engineering model propellant storage and control system.

In addition to these major ground tests, the ground test program includes an extensive series of tests termed development tests. The development tests are intended to provide specialized information to aid in the design of the ion thruster, power processor, or the propellant storage and control system.

Prior to the start of the 8,000-hour, full-power test, two tests of the ion thruster were conducted: the first one, which was intended to identify life-limiting mechanisms operating in the ion thruster and to quantify their rates. This first test was to last for 100 hours during which the government-designed engineering model ion thruster was to operate at full power. Prior to this test, erosion of the ion thruster's accelerator grid by charge-exchange ions was expected to be the principal life-limiting mechanism. Following the test four observations were made:

• Accelerator grid erosion was less than anticipated.
• Discharge cathode erosion was severe.
• Screen grid erosion was significant.
• Loose flakes of sputtered material were found in the discharge chamber.

The engineering model ion thruster was reworked by incorporating a new discharge cathode having an enclosed keeper, by maintaining the screen grid at cathode common potential instead of allowing it to "float" electrically, and by surface texturing and adding fine wire mesh to the interior surface of the discharge chamber.

A subsequent 1,000-hour, full-power test of the ion thruster indicated that the problems observed following the completion of the 2,000-hour, full-power test had been successfully corrected. These changes to the original design were then incorporated in a new engineering model thruster built for the 8,000-hour test.

Thermal development tests have been and are being used to define the thermal environment in which the ion thruster will operate, to assess its thermal performance in that environment, to define the qualification requirements to which the ion thruster must be designed, and to normalize the thermal model of the ion thruster. Recent tests of the ion thruster determined that the lowest temperature to which the ion thruster could be conditioned, non-operating, in the vacuum chamber was -105°C. This test then set the lower, non-operating qualification temperature limit for the ion thruster. These data, when combined with the thermal margin requirements, then set the temperature at or above which the thermal design of the spacecraft would be required to maintain the non-operating ion thruster. This minimum allowable flight temperature is -90°C.

Vibration development tests were and are being used to provide the data needed for the structural design of the ion thruster. These tests have been used to assess the accuracy of the structural model of the ion thruster and to evaluate candidate designs.
IN-SPACE DEMONSTRATION

The NSTAR ion propulsion system is hosted as an advanced technology to be validated (in part), on the first technology demonstration mission (referred to as “DS1”) of the New Millennium Program. On DS1 the NSTAR ion propulsion system consists of one ion thruster, a PPU, a DCIU, a xenon PSCS, and a diagnostics system to measure the effect of the operation of the ion propulsion system on the DS1 spacecraft and the surrounding space plasma. The ion thruster ionizes xenon, accelerates it electrostatically to 31 km/sec, and neutralizes the departing plasma. The PPU conditions the power provided by the SCARE/T solar array to the voltages and currents required by the ion thruster. The PPU accepts DC input power in a voltage range of 80V to 160V and requires a small amount of 28V housekeeping power. The DDU (Figure 1) interfaces the ion thruster system with the spacecraft, accepting high level commands from the spacecraft (e.g. thrust on, thrust off, power level, etc.) and in turn causing the PPU J and the propellant storage and control system to execute the correct sequence of operations to effect those commands. The DCIU also provides NSTAR’s telemetry to the spacecraft for transmission to Earth. For the DS1 spacecraft the NSTAR ion propulsion system serves as the spacecraft’s primary propulsion system, providing the impulse needed to effect an asteroid flyby followed by a comet flyby from the escape trajectory on which the DS1 spacecraft is placed by the Delta launch vehicle.

Figure 1. NSTAR DCIU

HDLD, of the Hughes Telecommunication and Space Company was competitively selected to provide the ion thruster, PPU and DCIU for the DS1 spacecraft. HDLD will also provide the ion thruster, PPU, and DCIU for the Mission Profile Test. LeRC is the contracting organization working with HDLD to transfer NASA’s knowledge and experience to U.S. industry. The critical design reviews (CDR) for the ion thruster, PPU, and DCIU were completed on October 3, 1996.

The schematic for the xenon PSCS is shown in Figure 2. Flow rate control is effected by maintaining the pressure in the xenon tanks at an appropriate level as determined by the calibration of the flow control devices. Pressure control is done by the DCIU, which compares the measured pressure in the xenon tanks to a preprogrammed set point and actuates the solenoid valves, admitting xenon from the storage tank to maintain that set point. The PSCS is designed and fabricated jointly by JPL and their competitively selected industry partner, the Space Products Division of Moog, Inc., East Aurora, NY. JPL provides the propellant storage and xenon tanks and the calibrated flow resistance devices for flow rate control; Moog provides the remainder of the components. Testing of an engineering model of the PSCS was started in September, 1996. The CDR for the PSCS was completed on September 19, 1996.

Figure 2. Schematic of the NSTAR Propellant Storage and Control System
**SUMMARY**

The key points of the summary are as follows:

- The NSRV mission is to achieve the highest mission fidelity using a proven propulsion system. The STP propulsion system is designed to meet the highest mission requirements.

![Image](image.png)

**Figure 1.** The predicted mission envelope of the NSRV operating points during the mission.

- The NSRV mission is to achieve the highest mission fidelity using a proven propulsion system. The STP propulsion system is designed to meet the highest mission requirements.

Table I. Schedule of the NSRV Propulsion System and Performance

<table>
<thead>
<tr>
<th>NSRV Required</th>
<th>IST Propulsion System</th>
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<td><strong>Engine Type</strong></td>
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<td><strong>Environmental Impact</strong></td>
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**Diagram:**

- The NSRV mission is to achieve the highest mission fidelity using a proven propulsion system. The STP propulsion system is designed to meet the highest mission requirements.

![Diagram](diagram.png)
spur the rise and development of creative enterprises, for a wide spectrum of firms, tangible and deep-space spectrums.

The two sets of television programs, the immediate success of the NSFAR evaluation of ion propulsion will

versions of the NSFAR 30-in cluster, the ion thrusters success of the NSFAR evaluation of ion propulsion will

water yield of carbon-cathode grids. For example, is expected to show dramatically longer hours, higher powers.

path to these improvements has been identified as a result of NASA's advanced technology program. The next task

depth in response to competitive pressure. A

But we also know that NSFAR is just the beginning. Future evolution of the NSFAR hardness, reaching higher

