NEXT-C Flight Ion Propulsion System Development Status

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Abstract: The NASA's Evolutionary Xenon Thruster – Commercial (NEXT-C) gridded ion thruster system provides a combination of performance and spacecraft integration capabilities that make it uniquely suited for deep space robotic missions. Aerojet Rocketdyne's flight hardware development program of the 7.4kW NEXT ion thruster system will deliver the first flight hardware in 2019. The NEXT-C project will deliver two flight thrusters and two flight Power Processing Units (PPU) to NASA for use on the Applied Physics Laboratory's Double Asteroid Redirection Test (DART) mission, a New Frontiers, or other NASA science mission project. The NEXT system was developed to TRL 6 at Aerojet Rocketdyne and L3, followed by characterization and long duration testing at NASA Glenn Research Center. The original NEXT effort culminated in a long duration life test of 50,000 hours on a NASA Engineering Model (EM) thruster with Aerojet Rocketdyne high fidelity optics. The thruster is throttleable across a thrust range of approximately 25-235mN. Thruster specific impulse ranges from 1400 – 4200sec, depending on the throttle condition. Each NEXT-C thruster is powered by a PPU with an input power of up to 7.4kW. The PPU converts spacecraft power, over an unregulated input voltage range from 80 to 160 volts, to the conditions required to operate the thruster, and also utilizes spacecraft 28 volt power to operate the PPU's control circuitry. On the NEXT-C program, the component designs have matured to include design updates to increase capability and incorporate lessons learned. Aerojet Rocketdyne has completed the system requirements review, preliminary design review, and an early system integration test on development hardware that includes most of these changes. The thruster and PPU component development testing is currently ongoing. Performance of the system is nominal with no significant issues identified. Flight hardware procurements have been initiated, and design of ground test equipment for the flight hardware is complete with all necessary flight controls defined. This paper will present the flight system capabilities, latest test results, and flight hardware development status for the NEXT-C ion engine system.

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Nomenclature

AR	=	Aerojet Rocketdyne
ARTEMIS	=	Acceleration, Reconnection, Turbulence & Electrodynamics of the moon's Interaction w/ the Sun
CDR	=	Critical Design Review
DART	=	Double Asteroid Redirection Test
DCIU	=	Digital Control Interface Unit
DS-1	=	Deep Space 1
EEE	=	Electrical, Electronic and Electromechanical
EP	=	Electric Propulsion
EM	=	Engineering Model
EMC	=	Electromagnetic Interference
EMI	=	Electromagnetic Compatibility
FM	=	Flight Model
FT	=	Flight Thruster
GEO	=	Geosynchronous
GRC	=	Glenn Research Center
JPL	=	Jet Propulsion Laboratory
LDT	=	Long Duration Test
NEXT	=	NASA's Evolutionary Xenon Thruster
NEXT-C	=	NASA's Evolutionary Xenon Thruster – Commercial
NSTAR	=	NASA Solar Electric Propulsion Technology Applications Readiness
PDR	=	Preliminary Design Review
PM1R	=	Prototype Model #1 Revised
PMS	=	Propellant Management System
PPU	=	Power Processing Unit
SEP	=	Solar Electric Propulsion
SIT	=	System Integration Test
TRL	=	Technology Readiness Level
TVAC	=	Thermal Vacuum
VF	=	Vacuum Facility
WCA	=	Worst Case Analysis

I. Introduction

The gridded ion thruster remains the highest performance (specific impulse) electric propulsion technology in use, especially suited for ambitious, high ΔV missions requiring high specific impulse and long life. The 7.4kW NASA Evolutionary Xenon Thruster (NEXT) system independently controls power and flow parameters enabling throttling by an order of magnitude in thrust and required input power, which is critical for solar powered missions traveling large distances from the sun. Additionally, the relatively simple acceleration physics of the gridded ion engine allows for excellent correlation between ground test and in space performance. Finally, the highly collimated beam allows greater flexibility in locating the thruster on the spacecraft to avoid impingement of the exhaust on spacecraft surfaces, reduce communications impacts, and allowing a reduction of the off-axis pointing and associated thrust loss for geosynchronous (GEO) satellite orbit-raising.

Challenging NASA science missions that would greatly benefit or be enabled by the NEXT system have emerged in recent years. The NEXT system has been proposed for multiple Discovery and New Frontiers missions and included in small body mission studies, such as a Comet Surface Sample Return. A 2008 study of the Titan Explorer flagship class mission showed significant mass and transit time advantages from avoiding gravity assists by using the NEXT system.[1] Large, deep space observatories such as SHOE-EZE and New Worlds Observer were enabled by using the NEXT system to position these large platforms at great distances from Earth.[2] Mars Sample Return mission studies have long taken advantage of the NEXT system's performance, especially for the sample return vehicle. The launch of such a vehicle in the late 2020s has been discussed.[3]

In addition to the NASA missions, national security space missions with very high ΔV requirements have been identified as potential applications for NEXT systems. Finally, the use of NEXT systems on Comsats for GEO orbit acquisition is under continued investigation. Challenges include reducing the recurring cost of the flight hardware without sacrificing extensive test heritage, increasing the thrust/power ratio to reduce transit times, and providing a closer to "drop-in replacement" physical configuration at the gimbal footprint.

The most immediate application for the NEXT system is NASA's Double Asteroid Redirection Test (DART) mission,[4] which will use a single NEXT thruster and PPU for primary propulsion and is already in Phase B development. This mission involves impacting the smaller of a co-orbiting binary asteroid, Didymos, in 2022 with a >300 kg spacecraft. The goal is to demonstrate and characterize the deflection of a hazardous asteroid with the momentum transfer from a very high speed impact by the spacecraft. By impacting the smaller, 150m asteroid and monitoring the change in its orbit around the 800m partner, it will be possible to characterize the deflection much more precisely than to detect the change in the heliocentric orbit of a single asteroid. This mission will launch as early as late 2020 and navigate to the binary asteroid using a single flight thruster and PPU resulting from final maturation of the design developed on the NEXT program.

II. Ion Thruster System Background

Gridded Ion Engine systems have already been used successfully on several notable missions. The 2.5 kW NASA Solar Electric Propulsion Technology Applications Readiness (NSTAR) system was launched in 1998 on the Deep Space-1 mission to flyby asteroid Braille and comet Borrelly.[5] In 2001, the 500W RIT-10 thruster rescued the ARTEMIS mission, stranded in a low orbit, demonstrating the use of ion engines for GEO orbit acquisition.[6] The XIPS-13 and XIPS-25 systems, produced by L3, have been used successfully on many Boeing 601 and 702 GEO Comsats for orbit acquisition and station-keeping since 1997.[7] From 2009-2013, the atmosphere skimming GOCE mission, used QinetiQ's 700W T5 ion propulsion system for drag compensation.[8] The celebrated Japanese Hayabusa mission was rescued from multiple system failures by its 400W ion engines to return the first samples from an asteroid in 2010.[9] In 2015, the world's first all-electric satellite, a Boeing 702SP spacecraft, demonstrated complete orbit raising with a gridded ion engine system.[10] NSTAR is in use today on the Dawn mission to study two of the largest proto-planets in the solar system, first Vesta and now Ceres, which it is orbiting today.[11]

From the success of NSTAR, NASA studies in 2001 showed that development of a higher power ion engine was enabling for many of NASA's future planetary science missions. In 2002, NASA's Science Mission Directorate awarded NASA's Evolutionary Xenon Thruster (NEXT) program under the In-Space Propulsion Technology project to a team led by NASA Glenn Research Center (GRC). The goal of the program was to develop a 7 kW class Ion Propulsion System, including thruster, Power Processing Unit (PPU), Propellant Management System (PMS), Digital Control Interface Unit (DCIU) and gimbal. The team included JPL, which was responsible for some of the testing and analysis and the gimbal development; L-3 Communications, which was responsible for PPU development; and Aerojet Rocketdyne (AR), which was responsible for thruster, PMS and DCIU development.[12,13]

AR significantly upgraded the NASA Engineering Model (EM) thruster design to a more robust, flight weight EM design, dubbed the "Prototype Model" or "PM" thruster. Following delivery of hardware by L-3 and AR in 2006, NASA GRC and JPL conducted comprehensive testing, both as individual components and as integrated combinations, of the NEXT ion propulsion system. These included detailed performance characterization, vibration, and thermal vacuum testing at qualification levels, as well as a 2,000 hour test of the thruster. Table 1 gives a partial performance table for the thruster/PPU system. Additionally, NASA GRC conducted a Long Duration Test (LDT) of a GRC-built EM thruster with AR-built PM design optics that was operated a record breaking 50,000 hours and consumed 900 kg of Xe.[14,15] The total impulse of 35 MN-s is over three times the total impulse demonstrated on any other electric propulsion thruster. Under the program the L-3 Engineering Model (EM) PPU achieved Technology Readiness Level (TRL) 4/5, falling short of TRL 6 due to component failures in elevated temperature vacuum testing for which root causes and corrective actions were identified in failure investigations at GRC. The AR "PM" thruster and EM PMS both achieved TRL 6 by the end of the NEXT program.[16]

Table 1. Selected NEXT-C Throttle Points

Beam Voltage V	Beam Current A	PPU Input Power kW	System Efficiency	Thrust mN	Specific Impulse s	Thrust / Power mN/kW
1800	3.52	7.33	0.70	235	4155	32
1800	2.70	5.65	0.68	178	4082	32
1800	1.20	2.61	0.61	78	3882	30
1396	3.52	5.84	0.69	208	3683	36
1396	2.70	4.51	0.67	159	3626	35
1396	1.20	2.15	0.59	69	3432	32
1021	3.52	4.50	0.66	177	3169	39
1021*	2.70	3.48	0.66	137	3137	39
1021	1.20	1.70	0.57	59	2953	35
679	2.70	2.55	0.60	111	2565	43
275	1.00	0.64	0.32	25	1395	39

* Throttle point to be used by DART[17]

III. NEXT-C Program Overview

While there was interest in the NEXT system for multiple NASA science programs, a barrier to infusion was the cost and risk of completing development, qualifying the system, and building the first flight units, all of which must be borne by the first mission. In order to facilitate the incorporation of NEXT for use in NASA missions, NASA decided to fund this effort. A lesson learned from the NSTAR program was that the decade between uses of the system on DS-1 and Dawn led to significant risk and cost growth on the Dawn program, despite the system having been successfully demonstrated on DS-1.

A solution to this problem was to create an industrial partner who would be able to offer the NEXT system as a commercial offering after the first flight units were manufactured, marketing it to multiple applications and customers with minimal non-recurring engineering for each program. The greater cadence of use of the NEXT system would greatly reduce the risk of and provide a lower and more consistent cost for subsequent flight units. In order to ensure that the industrial partner was committed to wide marketing of the NEXT system and making it competitive, the program was created as a cost-shared partnership, which also offset some of NASA's development cost.

The program is focused only on the thruster and PPU because those are the key components specific to the NEXT system. Other system component options with flight heritage already exist for the DCIU, propellant feed system and gimbal. Different missions may have different needs and approaches to these components. The overall approach of the development phase of the program was to address known issues with the current PPU and thruster designs, meet any updates to the requirements, and make design changes that would reduce cost while maintaining the validity of the testing to date, in particular the 50,000 long duration test, which would not be feasible to repeat.

The NEXT-C program was awarded to Aerojet Rocketdyne in March of 2015 with the goal of completing flight system development and delivery of two sets of flight PPUs and thrusters. There is close collaboration with NASA GRC and the industry NEXT team, comprised of Aerojet Rocketdyne, who is responsible for system integration, thruster development and manufacture, and PPU development oversight, and AR's subcontractor, ZIN Technologies, who is responsible for PPU development and manufacture. The xenon flow control element of the system is not part of this contract since there are a sufficient number of mature options already available. The NEXT-C program objectives are to mature the thruster and PPU elements from the NEXT Program from TRL 4 (PPU)/TRL 6 (thruster) to TRL 8. The program will provide two flight fidelity thrusters and PPUs for use on a future NASA science mission. Aerojet Rocketdyne (AR) will establish a commercial platform for a high-power ion thruster engine system by updating the NEXT thruster with identified design changes to allow it to sustain flight structural loads and key manufacturability enhancements; as well as implement PPU design improvements.

The most recent NASA ion thruster design was the baseline for the NEXT-C thruster. The NEXT-C thruster design implements some updates for manufacturability and for increased structural capability. The design of propellant wetted surfaces which dictate thruster performance were not changed in order to ensure heritage to the extensive testing and performance that has been previously demonstrated by NASA. The accumulated operation at NASA is over 50,000 hours and over 900 kg of throughput with minimal degradation.[14,15,18]

The PPU design is baselined from the previous test bed design which has successfully operated the NASA ion thrusters for many years. The NEXT-C PPU has incorporated several lessons learned from the previous testing as well as incorporated solutions to issues uncovered from recent testing. Additionally, parts have been upgraded to take advantage of current technology where applicable and to address obsolescence.

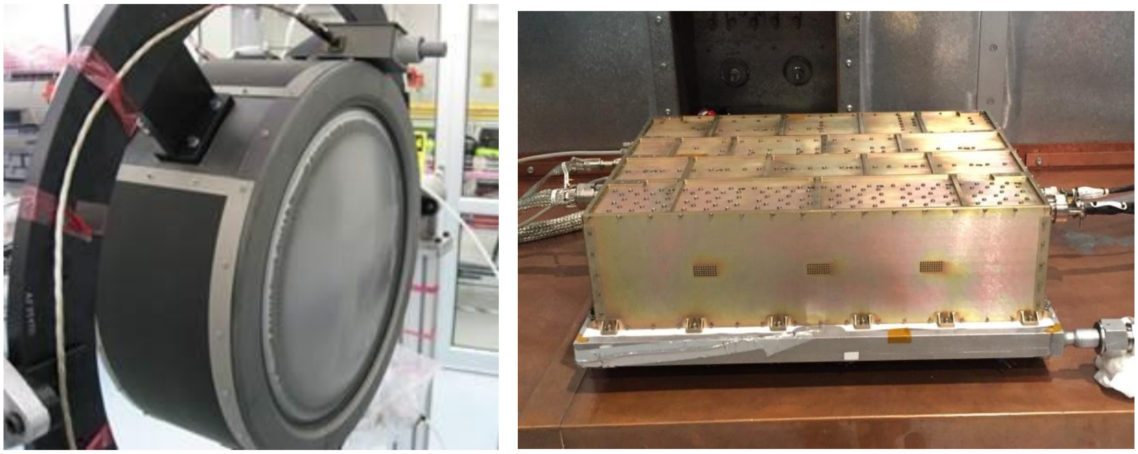

Figure 1. NEXT-C Thruster and Power Processing Unit

Both thruster and PPU are completing development testing. This testing will verify operation of each component as well as mitigate risk of failures during testing of the flight hardware. Because there is no qualification unit or the associated qualification testing, the flight hardware will be tested to protoflight levels.

This paper summarizes the status of the NEXT-C program, including updates to the thruster and power processor, as well as the results of recent integrated system testing that verified successful operation of an EP string and identified necessary design updates that will be incorporated prior to the Critical Design Review in early 2018.

IV. Thruster

The NEXT-C thruster is an evolution of the flight proven NSTAR thruster providing a wider throttle range, higher power, better efficiency and higher thrust and specific impulse than the previous thruster. Similar to the NSTAR thruster, NEXT-C is a two grid, ring-cusp thruster utilizing xenon as the propellant. However, in contrast to the previous generation thruster, NEXT-C produced a slightly larger 36 cm diameter ion beam with a more uniform beam current density. The highest and lowest operating points listed in Table 1 show that the NEXT-C thruster has an almost 10 to 1 throttle range (235:25 mN) which increases the applicability of the thruster to future NASA near-Earth and planetary missions.

In addition to increased throttling capabilities of NEXT-C, NASA increased both the operating time and throughput of the thruster. Due to the large throttling capabilites, the operating time and throughput vary as a function of the operating point. Previously demonstrated life of over 50,000 hours was for the specific duty cycles tested which were not all at the most life-limiting levels. At the highest operating power of 6.9 kW and 4,200 seconds, the primary wear-out mechanism is structural failure of the accelerator grid, which is predicted to occur at approximately 36,000 hours and 770 kg of xenon.[19] At the lowest power setting for the thruster, the primary wear out mechanism is still structural failure of the accelerator grid, which is predicted to occur at approximately 45,000 hours of operation and 330 kg of xenon throughput.[19] It should be noted that the throughput and operating times for the highest and lowest power settings above are for operation at those specific throttle levels. By combining throttle levels, as will be required by most missions, the throughput and operating times will vary and will have to be predicted for each mission.

As stated earlier in this paper, the development of the NEXT-C thruster began over 10 years ago when NASA created several engineering model versions of the thruster. These designs help to refine and solidify the design of the discharge chamber as well as the ion optics. Once the design had matured, Aerojet Rocketdyne competed for and was awarded a contract to further refine the NASA engineering model thruster into a version capable of surviving the extreme operating environments associated with NASA planetary missions. The result of this effort was a prototype design from which the piece parts for two thrusters were manufactured and delivered to NASA GRC for testing in 2005. Subsequently, NASA performed a significant number of tests to fully characterize the PM1R thruster performance over the entire throttle range; as well as conduct thermal vacuum testing and vibration testing. The objective of the NEXT-C program was to explore opportunities to reduce the cost of the thruster to potential mission users, mature the design to TRL 8, and produce two flight thrusters that could be provided as government furnished equipment to the first mission users. To support this effort, Aerojet Rocketdyne has examined the prototype thruster designs for cost reduction while not affecting the performance or life capabilites of the original design.

Figure 2. NEXT-C Development Thruster

Aerojet Rocketdyne has incorporated several improvements to the thruster design. These changes address mission concerns with both the neutralizer and thruster wiring harnesses, manufacturing issues experienced with the plasma screens, structural issues with the discharge cathode, and configuration issues with the neutralizer. The key changes are listed below:

- Configuration & locations of the propellant connections were changed for ease of manufacturing and access
- Some of the materials used to construct the harnesses have been changed to both increase the temperature capabilities and mitigate the bending radius concern.
- Features were added to the gimbal and neutralizer mounting pads to address manufacturing concerns
- Mounting hardware design was modified to increase the strength and stiffness to meet structural requirements.
- Propellant connections were changed to tube stubs which will be welded into the spacecraft during assembly to facilitate the integration of the thruster.

Most of the above changes were implemented on the NASA PM1R thruster, shown in Figure 2, which was provided to the program for risk reduction purposes. Thruster development testing is underway with performance testing, early integrated system testing, and random vibration testing complete. The remaining thruster development testing includes qualification level shock testing and post-structural performance testing. The development thruster will also be used to conduct integrated system testing which includes hot-fire and EMI/EMC characterization. This testing will verify operation of each component as well as mitigate risk of failures during testing of the flight hardware. Flight hardware will be tested to protoflight levels.

Design updates will result in a gridded ion thruster that is more structurally capable and improve manufacturability and spacecraft integration. Flight hardware will be tested to protoflight levels and will include performance testing, vibration testing, and thermal vacuum testing. Flight thrusters are planned to be completed and available for integrated system testing in November 2018.

V. Power Processing Unit

The NEXT-C Power Processing Unit (PPU) provides the electrical power to the thruster and reports the telemetry of the thruster system. The PPU powers a 7 kW class gridded-ion thruster as shown in Figure 3 and consists of:

- Beam Supply (~85% Total Power)
    - Positive Grid Electrostatic Field with regulated voltage up to 1,800V
- Discharge Supply (~10% Power)
    - Ionizes Xenon and is current regulated
- Quad Supply (~5% Total Power)
    - Accelerator (Negative) Grid, Neutralizer, Discharge and Neutralizer Heaters
- Communicates via an RS-485 serial link
    - Command and Telemetry is configurable; fully redundant A and B channels or can send on channel A and receive on channel B for compatibility with older equipment.

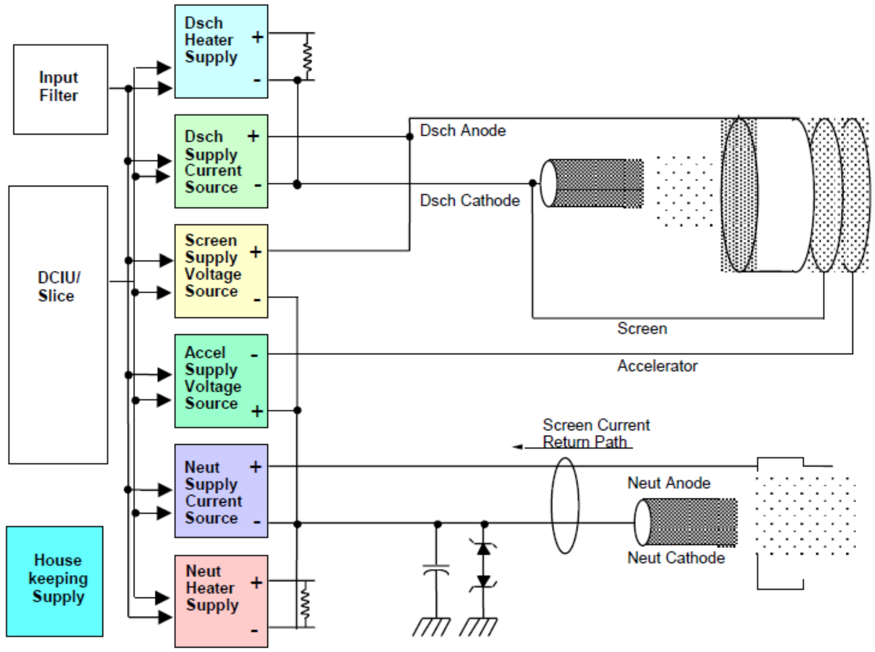

Figure 3. PPU subcomponents in the NEXT-C System

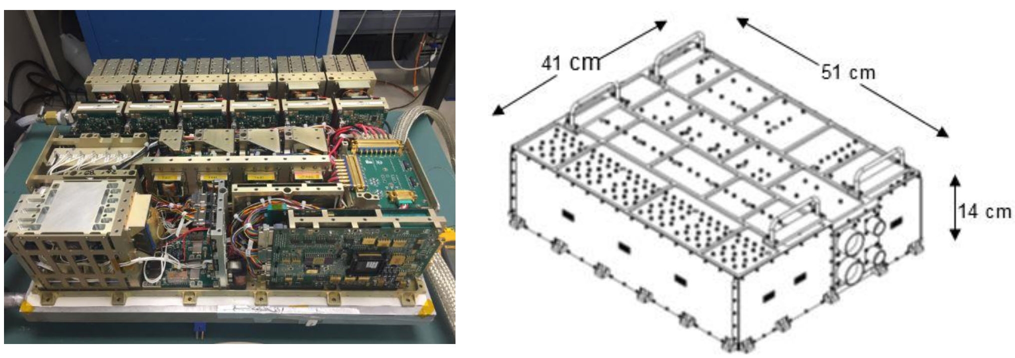

Figure 4. Photo of PPU prototype unit (left) and PPU dimensions (right)

During the redesign phase and subsequent testing, several improvements have been made to the design;

- The PPU is capable of autonomously recycling the power supply in case of a high current event and has the capability of going in to a grid clearing mode to burn off debris from the grid
- The RS-485 communication bus is configurable from half to full duplex
- The RS-485 device address is also configurable
- The telemetry was improved to report individual module health, status, and specific fault information.
- EEE Parts were selected with consideration of EEE-INST-002 compliance, obsolescence and radiation survivability
- Some custom magnetics were replaced with MIL-STD-981-compliant readily available parts
- Several improvements were made to resolve test anomalies observed during PPU EMI/EMC testing
- The PPU sub-assemblies were connectorized to simplify manufacturing
- During environmental testing of vibration and shock, two mechanical issues were discovered and resolved
- During TVAC testing, especially at elevated temperature, some thermal issues were noted and corrected
- The transition between pulse width and phase shift mode in the beam supply was improved
- The beam supply modules are able to be switched independently, which provides mission flexibility.
- Worst Case Analysis (WCA) was performed to verify the design's stability and telemetry/setpoint accuracy.
- Added a thruster plume mode detection circuit, which was verified during integrated testing.

The PPU weighs less than 35kg and is conductively cooled through the base plate. At base plate temperatures between -29°C to 50°C, PPU efficiencies exceed the design requirements with over 90% efficiency at most power levels. At full output power, the PPU efficiency is up to 95%.

The prototype PPU is currently completing environmental testing including EMI/EMC, shock, vibration and thermal-vacuum testing. Figure 5 shows a photo of the PPU installed adjacent to the thruster vacuum chamber for functional testing prior to system hot-fire and as installed in the PPU thermal vacuum chamber. An analysis is ongoing to validate the cycling capability to 10,000 on/off cycles in support of some of the mission profiles.

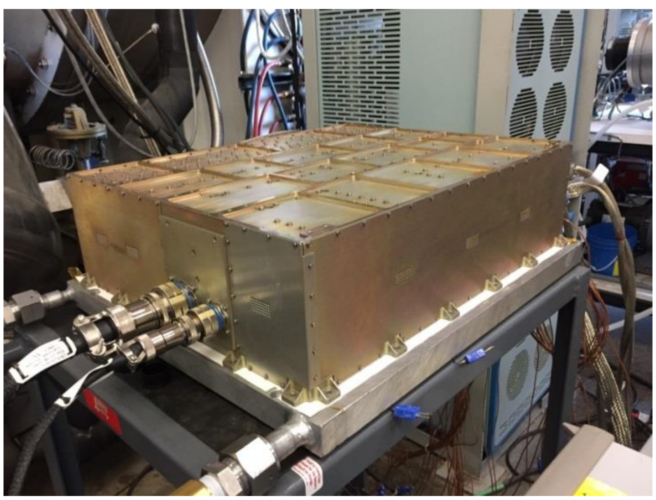

Figure 5. PPU installed for functional testing (above) and in TVAC chamber for temperature testing under vacuum (right).

As expected the testing identified issues to be resolved for flight. All the issues to date are well understood and changes are being made and verified prior to the Critical Design Review (CDR) and flight build early in 2018. Most of the anomalies have already been verified through extensive analysis and bench testing.

Design updates have produced a more robust PPU that will meet all the mission requirements, including all EMI/EMC requirements and mechanical loads (shock and vibration). Flight hardware will be tested to protoflight levels and will include performance testing, vibration testing, EMI/EMC, and thermal vacuum testing. Flight PPUs are planned to be completed and available for integrated system testing in October 2018.

VI. Early Integrated System Test

In August of 2017, an early System Integration Test (SIT) was successfully performed with the NEXT-C prototype hardware at NASA's Glenn Research Center. This test involved the efforts of a multidisciplinary team of Aerojet Rocketdyne, NASA, and ZIN Technologies personnel. The test consisted of using the prototype PPU to power the development thruster. It was the first opportunity to operate the PPU and thruster as a system. It is referred to as the early SIT or risk mitigation SIT in contrast to the more exhaustive, development SIT, which will be performed later in the test series when the hardware has completed component-level testing.

The purpose of this early test was to determine any potential performance problems with the PPU, which may not have been found through testing with only a resistive load. Thruster performance metrics were also measured and recorded for comparison to operation with Special Test Equipment (STE) power supplies. It was important that this test was performed early in the series so that any anomalies arising from the test could be adequately resolved prior to the final SIT, mitigating the risk of potential delays to the program.

For this test, the prototype thruster was installed in NASA's Vacuum Facility (VF) 16. VF-16 is 2.75 meters in diameter by 4.5m long. Utilizing ten 48" diameter cryopumps, it's capable of achieving a base pressure of 7×10^{-8} torr with no load and has a pumping speed of 500,000 l/s air at 10^{-6} torr. For this testing, the chamber was equipped with several plasma-diagnostic tools, including a thrust vector probe, a Faraday probe, an ExB probe, and a computer system for controlling these probes. The facility also provided ion gauge pressure measurements, a xenon feed system with digital flowrate controllers and xenon propellant, a data acquisition system, a thruster breakout box, and multimeters for real-time data display.

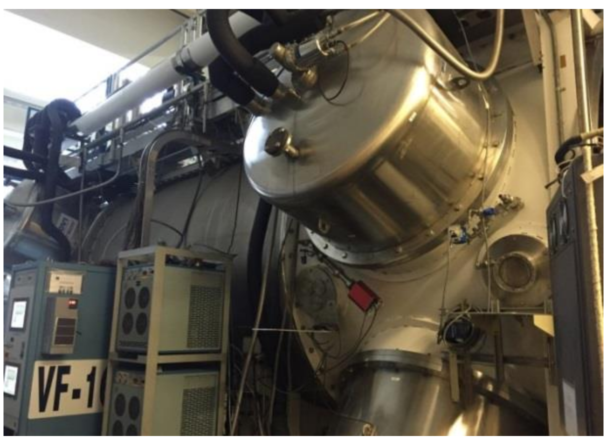

Figure 6. Side view of VF-16. ***The facility's controller can be seen in the bottom left of this photo, alongside 2 compressors for the 4' diameter cryopumps.***

Figure 7. DEV-C thruster during stable operation. ***Photo taken in VF-16 at a beam current of 2.00A and beam voltage of 1179V. Photo taken by George Soulas.***

The PPU was set up adjacent to the vacuum chamber on a cold-plate, which was maintained at 25^{o}C for the duration of the test. The PPU was exposed to ambient pressure. Thermal and vacuum behavior of the PPU was demonstrated in a previous test and was outside the scope of this test. The PPU received power from two supplies: a low voltage, nominally 28V supply and a high voltage 80-160V supply. The PPU provided two output lines to the thruster, one for the neutralizer and one for the discharge. Control and telemetry for the PPU, and therefore the thruster, was provided by a laptop computer.

The test started with checkouts of the hardware. The thruster was already installed in the chamber under vacuum following hot-fire testing, so the first step was to perform insulation resistance checks of the various thruster inputs. In parallel with this, the PPU was successfully verified to be functioning nominally by simulating the thruster using a resistive load. This included simulating control of the thruster's two hollow cathode heaters and recycle recovery capability. Following component checkouts, the PPU was disconnected from the resistive load and the two components were electrically connected in series via their breakout boxes.

The system was operated at seven throttle levels ranging from minimum to maximum system power. At each throttle level, the PPU's low and high voltage inputs were swept through their operating ranges. This was both to ensure the PPU could operate over its full required range and to exercise the PPU beam module Pulse Width Modulation (PWM) to phase shift mode transition functionality. Collected data included PPU telemetry, verification of telemetry from the PPU breakout box multimeters, thruster voltages, vacuum chamber pressure, neutralizer voltage and current ripple, neutralizer spot-plume mode transition flowrate, electron back streaming voltage, and Faraday and ExB probe data. Additionally, recycles were forced at each throttle point to ensure the system could recover from recycle events. The system successfully demonstrated recovery from forced recycle events. At specific throttle levels, the number of active PPU beam modules was reduced by one to demonstrate the ability to operate at these levels in the event of a single module failure. The test spanned several days, and at the conclusion of each test day the system's operation was terminated by triggering one of several limits meant to force safe shutdown of the PPU in the event of limit violation.

As stated earlier in this section, the purpose of this test was to determine any issues with the PPU that otherwise would not be discovered until the final SIT late in the development cycle. A few minor issues with the PPU were identified as a result of this testing, all of which will be resolved prior to the final development SIT. This early SIT successfully demonstrated the development NEXT-C thruster and PPU's ability to operate as an integrated system.

VII. Conclusions

The NEXT ion propulsion system has been shown to be ideally suited for a wide range of NASA robotic science missions as well as several national and commercial orbit raising missions. The NEXT-C program has completed the first phase of the development process through the Preliminary Design Review and successfully completed an early system integration test demonstrating the required control and throttling capabilities of the thruster and PPU. The thruster and PPU component teams are performing component level testing and addressing issues as they arise. The flight designs are nearly complete, incorporating lessons learned and resolutions to anomalies uncovered during development testing. The program will complete the required component testing including environments demonstration. CDR is planned for early 2018 with delivery of the flight NEXT-C strings by early 2019.

VIII. Acknowledgments

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