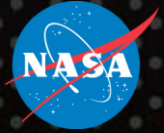


National Aeronautics and
Space Administration



NEXT-C

NASA'S EVOLUTIONARY XENON THRUSTER-COMMERCIAL

New Frontiers Technology Workshop

Matt Dolloff – Project Manager
NASA Glenn Research Center
6/1/16

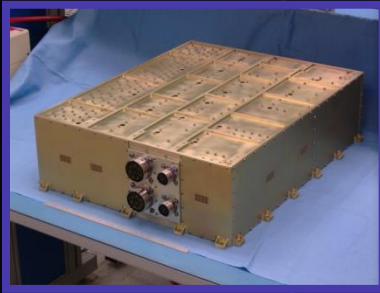
Agenda

- NEXT Technology Program Background
- Transition from NEXT to NEXT-C Flight
- NEXT-C Status
- NEXT-C Hardware Performance Characteristics
- GFE Approach

- NEXT Technology project was NASA's evolutionary development of Ion Propulsion Systems (IPS)
 - Built off the success of the NASA Solar Technology Application Readiness (NSTAR) ion propulsion system that successfully flew on Deep Space 1 (1998 Launch)
 - Work began on NEXT Phase 1 in 2002
 - Project included all components of an ion propulsion system (more on next slide)
 - NSTAR flew again on Dawn (2007 Launch)
 - NEXT Phase 2 completed in 2014

NEXT Technology Project Summary

Power Processing Unit (PPU)
[L-3 Comm, Eng Model]



Gimbal [ATK, Breadboard]

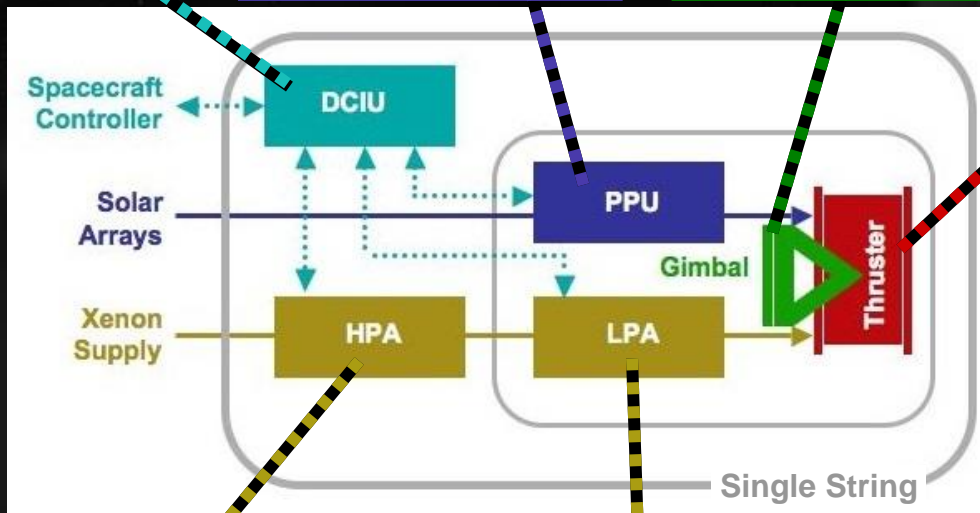


Thruster [Aerojet, Prototype Model]



Digital Control Interface Unit (DCIU)
[Aerojet, Simulator]

NEXT Integrated Propulsion System



Propellant Mgmt System (PMS) [Aerojet, Eng Model]

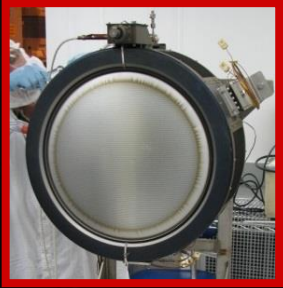
Performance Characteristics

Thruster Power, kW	0.5 – 6.9
Specific Impulse, sec	2500 - 4200
Thrust, mN	25 - 235
Thrust-to-Power, mN/kW	32 - 48
Thruster Efficiency	0.32 – 0.7
Lifetime - Xenon Throughput, kg	> 600

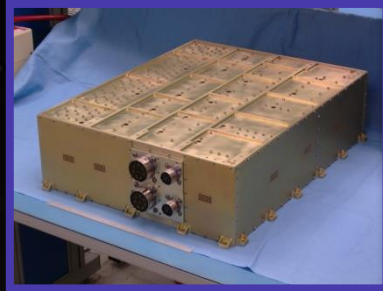
NEXT Thruster Long Duration Test (LDT)

- Initiated on 6/5/2005 as part of thruster service life assessment, which includes:
 - 2,000 h wear test
 - NEXT thruster service life model development
 - Long Duration Test
 - PM1R wear test
- Objectives:
 - Qualify thruster propellant throughput capability to 450 kg
 - Modified to test-to-failure (or until resources exhausted)
 - Validate thruster service life models
 - Characterize performance over duration
 - Measure critical component erosion rates
 - Primary wear out mechanism for thruster is pit and groove erosion of accelerator grid
 - Identify any unanticipated life-limiting mechanisms
- In Feb, 2014, LDT voluntarily terminated
 - Set all lifetime electric propulsion records!
 - Longest duration: 51,184 hours
 - Highest throughput: 918 kg
 - Largest total impulse: 35.5 MN·s
- In 4/2014, thruster vented to atmosphere for post-test inspection
- Currently completing post test destructive evaluation and final LDT report.

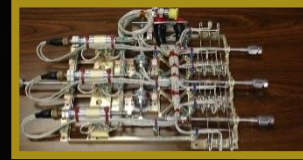
TRL Assessment of NEXT Phase 2



Thruster
TRL6



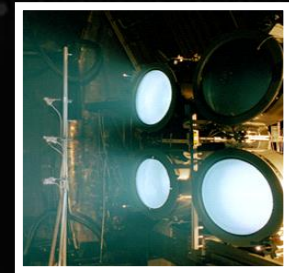
PPU
TRL4



Feed System
TRL6



Gimbal
TRL5



System
TRL4

- TRL assessments performed by GSFC, APL, and JPL
- Integrated system TRL is 4, as system level can be no higher than the lowest component
- Thruster and PMS were ready for mission infusion
- Gimbal could be developed to flight status with minimal risk
- PPU poses biggest technical and programmatic risk
 - Multi-center team (GRC, GSFC, APL) was formed and developed a PPU plan and approach to get to TRL6

NEXT-C

NEXT-C Background

- NEXT-C thruster and PPU offered as GFE for Discovery 14
- RFP issued September, 2014
 - Deliver 2 Thrusters and 2 PPU in time for Discovery mission integration
 - Develop PPU prototype to take PPU to TRL6 prior to flight builds of PPU
- Contract awarded March 1, 2015
 - Aerojet/Rocketdyne selected as prime contractor
 - Overall project management and system responsibility
 - Thruster design, fabrication and test
 - ZIN Technologies is subcontractor for PPU design, fabrication and test

NEXT-C Project Contract Background

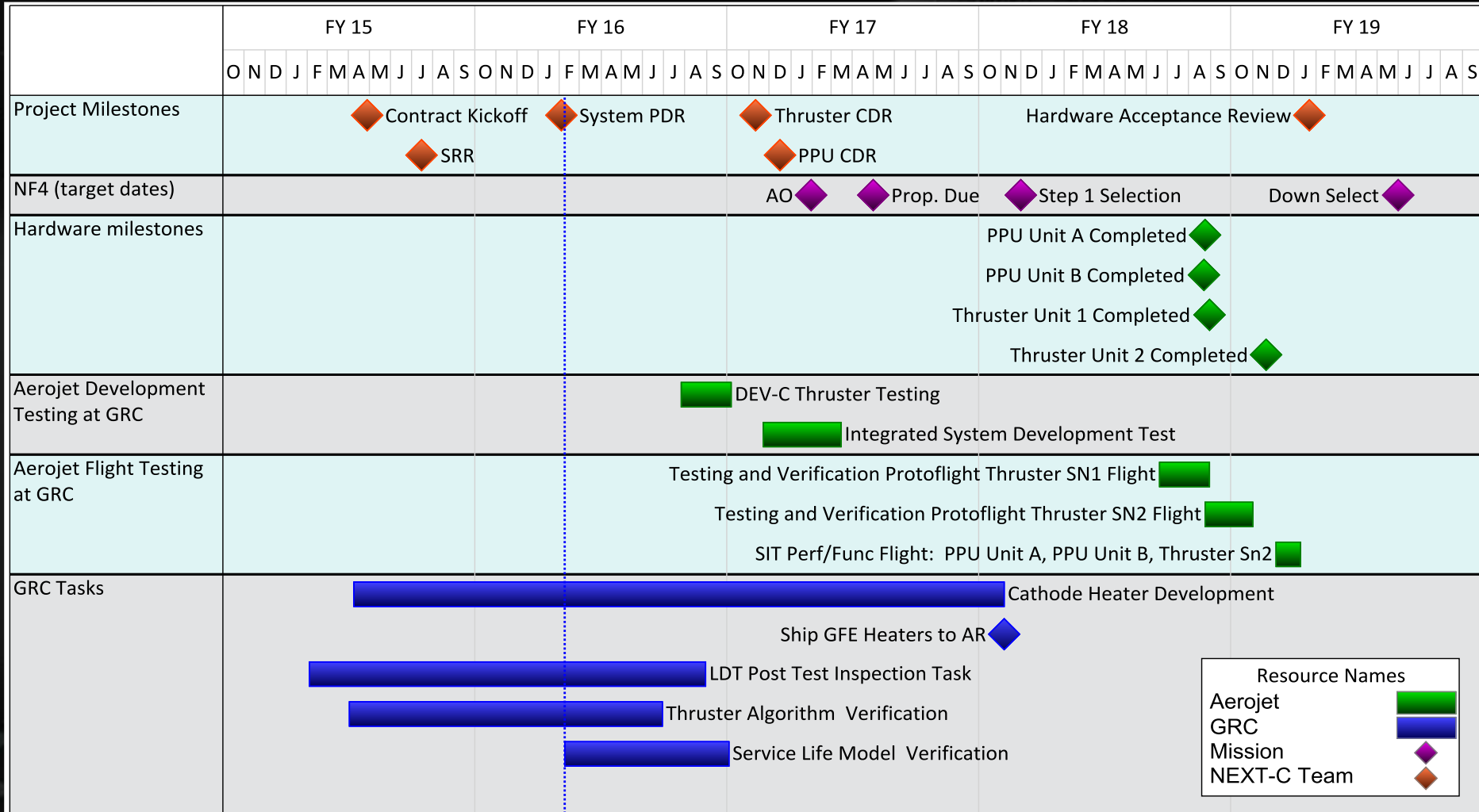
- Products

- PPU: Derivative of design developed during NEXT technology project
 - Design mods to address issues encountered during technology project and lessons learned
 - TRL6 demonstration through high-fidelity prototype unit
- Thruster: Modification and test of existing PM1R thruster
 - Throttle Table 11 performance capability (~0.5kw to ~6.9kw thruster input power)
 - Minor design mods to address technology project and lessons learned
- Currently proto-flight development approach for flight hardware
- Other components of the ion propulsion system are responsibility of mission proposer, but GRC can assist with this development

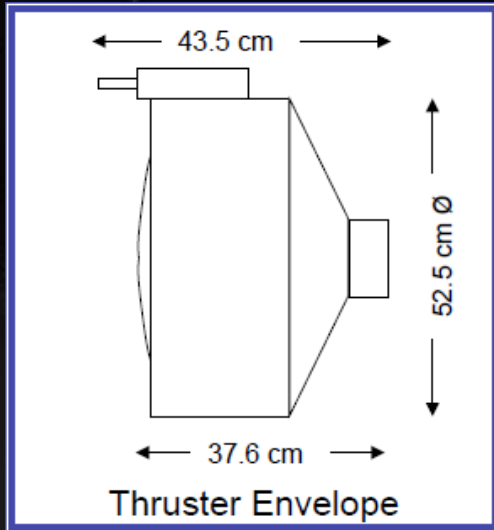


- Successfully completed SRR in July, 2015
- Step 1 Discovery Mission Selection included no missions that utilized NEXT-C
- Completed PDR in February, 2016
- Completed KDP-C in March, 2016
- Thruster Development
 - Minor modifications for flight hardware are in development and will be integrated into engineering model thruster for test in Fall, 2016
- PPU Development
 - Prototype PPU build in progress. PCB population has begun and testing is planned for late 2016
- Flight hardware on track for delivery in early CY2019

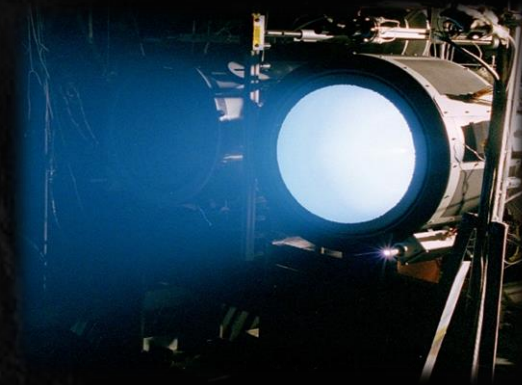
Project Schedule



Thruster Performance



- Thruster characteristics and capabilities established with high-fidelity Prototype Model (PM) unit
- Extended Throttle Levels test-demonstrated and in definition
 - Provides higher thrust-to power capability



Performance Characteristics

Thruster Power Range, kW	0.5-6.9
Max. Specific Impulse, sec	4220
Thrust, mN	25-235
Max. Thruster Efficiency	70%
Beam Diameter, cm	36
Max. Beam Current, A	3.52
Max. Beam Voltage, V	1800
Mass (with harness), kg	<15.0

Lifetime Capability

- Thruster long duration test voluntarily terminated in March 2014, fully functional over throttling range
- Test-demonstrated service life capability exceeding 600 kg xenon throughput and 22.5 MN-s total impulse
- Thruster lifetime margin should be determined through analysis of a specific mission throttle profile

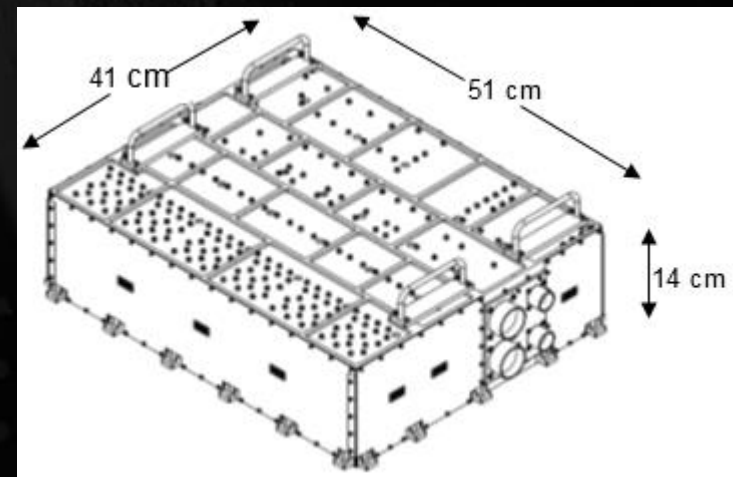
PPU Performance



- Flight PPU based off of NEXT tech program PPU
- Final design numbers will be available after prototype PPU completed

Performance Characteristics

	Existing	Planning
Input Power Range, W	630-7260	640-7360
Peak Efficiency (HV Bus)	95%	> 93.5%
High Power Input Voltage, V	82-160	80-160
Housekeeping Input Bus, V	22-34	22-34
Housekeeping Power, W	16-28	< 40
Mass, kg	33.9	< 36.8



Other NEXT Hardware

- Hardware that could be developed for use in flight but not part of the NEXT-C project (i.e. mission would need to fund development to completion)
 - Xenon Feed System (TRL 6)
 - NEXT Gimbal (TRL 5)



Developments since Discovery A/O

- NEXT-C may transition to a protoflight and qual unit approach from the previous plan of two protoflight units approach
 - This would allow for acceptance testing all future NEXT-C hardware rather than protoflight testing
- Current Mass
 - Thruster
 - Current Requirement: <15.0kg
 - Discovery AO: <14.0kg
 - PPU
 - Current Requirement: <36.8kg
 - Discovery AO: <35.8kg
- NEXT-C is under consideration for flights on other NASA missions so New Frontiers may not be the first flight of NEXT-C hardware

- PSD considering providing 2 NEXT-C thrusters and 2 NEXT-C Power Processing Units (PPU) as GFE to New Frontiers
- NEXT-C project is available for supporting New Frontiers proposers
 - Meetings today
 - Face-to-face meeting at proposers site if requested in the coming weeks/months
 - Ion propulsion system proposal development
 - Etc.

NEXT-C Project

- Delivery of 2 NEXT-C thrusters and 2 NEXT-C PPUs
 - Both tested to protoflight levels
- ICD development for thruster and PPU
- Evaluation of specific mission profile for service life
- Algorithm development for thruster control
- For Thruster and PPU: FMEA, WCA, and thermal and structural models

Mission Proposers

- Mission design
- Remaining IPS components
 - Xenon Feed System
 - Gimbal
 - Digital Control Interface Unit
- Integration testing of end-to-end IPS
- Mission specific testing of thruster and PPU
- Mission specific modeling
- Implementation of thruster algorithms in DCIU

Anticipated AO Library Materials

- Detailed thruster characteristics
- Baseline throttle table
- Extended throttle table and supporting information
- Detailed PPU characteristics
- Thruster and PPU Requirements
- Thruster and PPU ICDs
- Thruster Control Algorithms
- Thruster Envelope Model

*Other materials may be made available as they are generated by the NEXT-C project.

GRC NEXT-C/IPS Capabilities

- Not Part of NEXT-C Project but are GRC capabilities
 - IPS technical expertise
 - Including thruster, PPU, feed system, gimbal, and DCIU
 - IPS system design/integration/test expertise
 - Substantial NEXT-C test facilities and infrastructure
 - IPS test chambers
 - Vibration facilities
 - NEXT and NEXT-C engineering unit hardware for mission specific testing
 - NEXT Feed System and Gimbal

Summary

- NEXT-C is well on its way to delivering flight hardware
 - Successful completion of SRR and PDR
 - Prototype testing planned for late 2016
 - CDR in late 2016/early 2017
 - Hardware Acceptance Review in Early 2019
- PSD is considering 2 thrusters and 2 PPUs as GFE for New Frontiers 4
- NEXT-C Project, NASA GRC, and Aerojet Rocketdyne are ready to assist any New Frontiers proposers wishing to use NEXT-C.

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