

PREPARATION FOR HOLLOW CATHODE TESTING FOR THE ADVANCED ELECTRIC PROPULSION SYSTEM AT NASA GLENN RESEARCH CENTER

Scott J. Hall

Vantage Partners, LLC, NASA Glenn Research Center, Cleveland, OH

**Timothy R. Sarver-Verhey, Jason D.
Frieman, and Hani Kamhawi**

NASA Glenn Research Center, Cleveland, OH

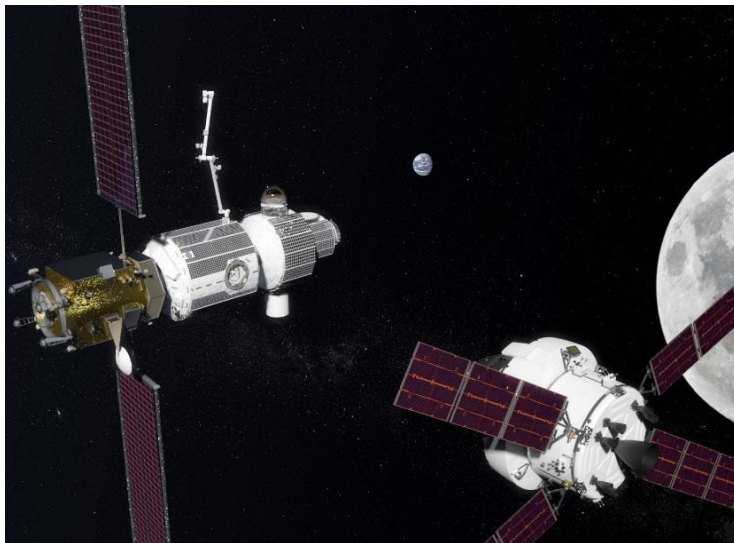
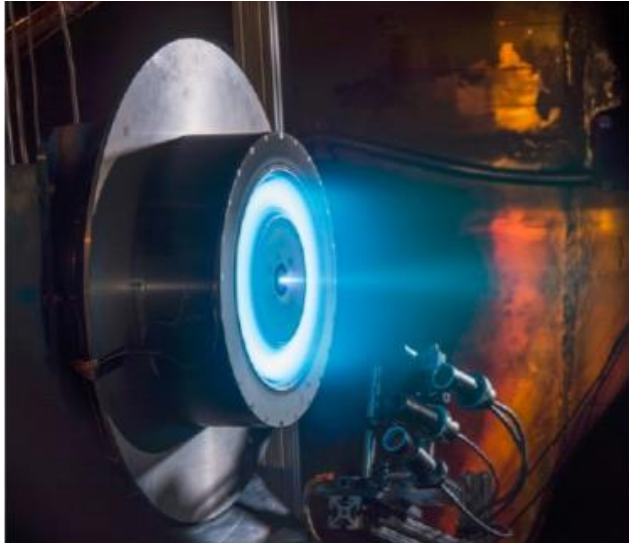
James Myers

Vantage Partners, LLC, NASA Glenn Research Center, Cleveland, OH





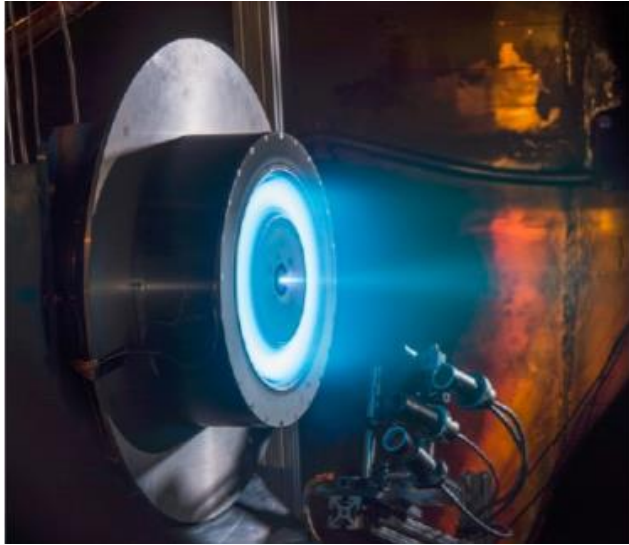
Long-life Hall thrusters need long-life cathodes



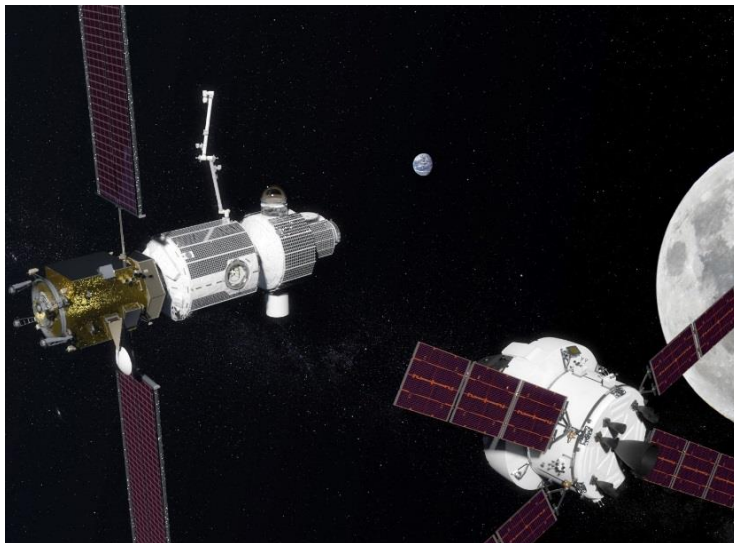
- NASA developing the Hall Effect Rocket with Magnetic Shielding (HERMeS) to serve as high-power EP capability for future missions
 - 12.5 kW magnetically-shielded Hall thruster
 - Example mission: Power and Propulsion Element of NASA's Gateway
- Aerojet Rocketdyne (AR) developing Advanced Electric Propulsion System (AEPS)
 - Leverages HERMeS thruster and cathode development



Long-life Hall thrusters need long-life cathodes

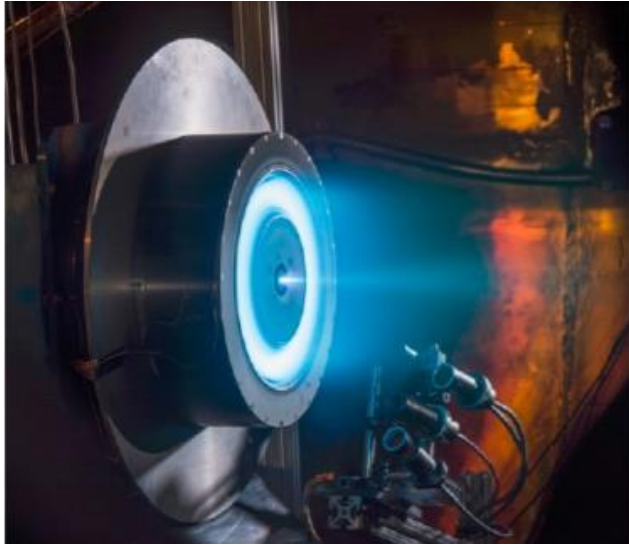


- Targeting system lifetimes of >23 khrs
- Thruster discharge channel lifetime enabled by magnetic shielding



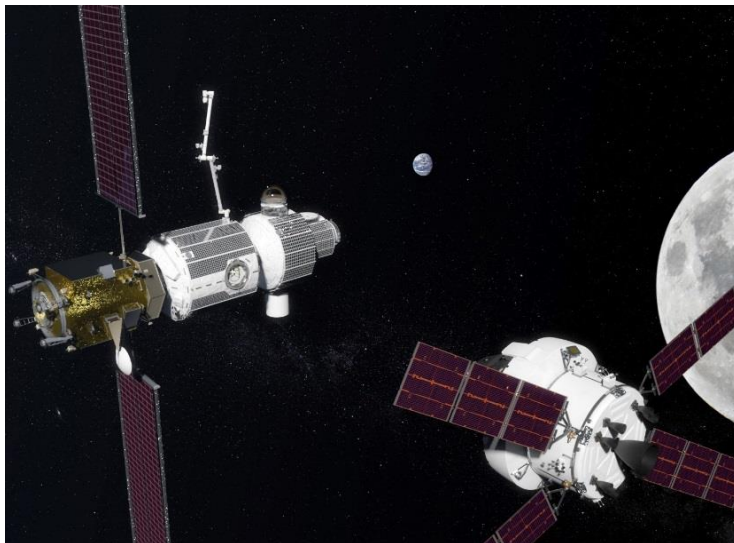


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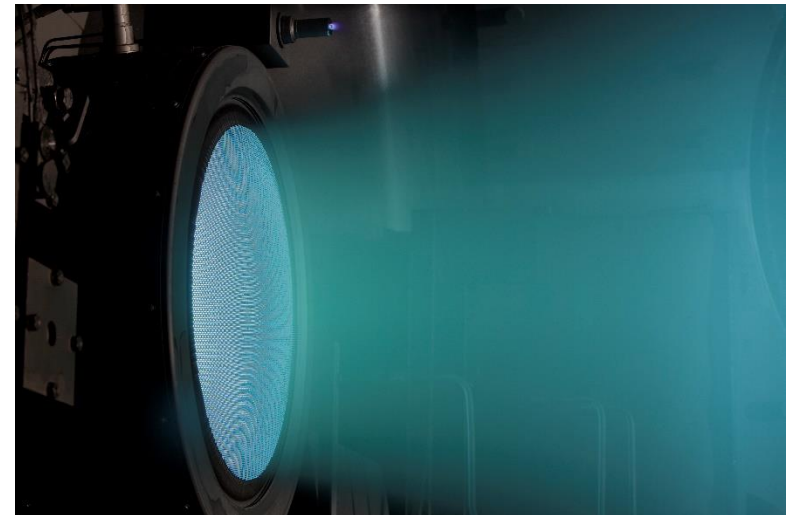
Cathode needs to provide same lifetime, too!





Hollow cathode technology has demonstrated necessary lifetime before

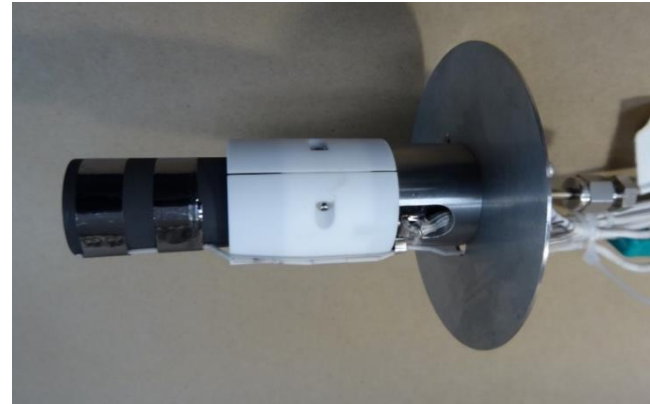
- ISS plasma contactor laboratory model: 28,000 hours (ground)
- NSTAR: 30,000 hours (ground); 46,000 hours (Dawn)
- NEXT: 50,000 hours (ground)





Significant cathode accomplishments during HERMeS development

- Developed two cathode options:
 - BaO (led by GRC)
 - Heritage to ISS PCU, NSTAR
 - Directly based on NEXT DCA
 - LaB₆ (led by JPL)
 - Heritage to H6 and high-current cathode development
- Substantial stand-alone testing of both cathodes:
 - 1800 and 2000 hour wear tests at JPL
 - 2000 hour wear test at GRC



BaO TDU cathode developed by GRC.

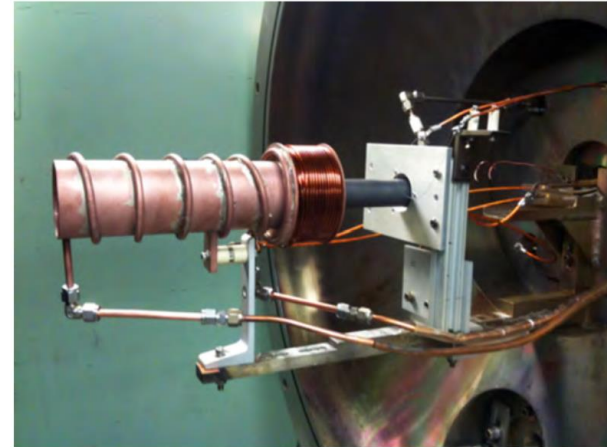


LaB₆ TDU cathode developed by JPL.

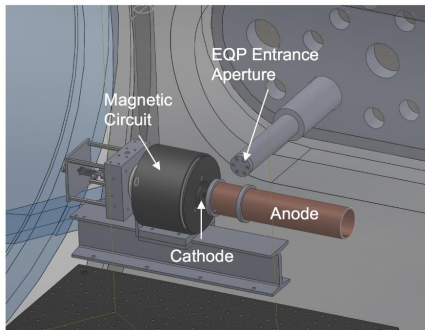


Significant cathode accomplishments during HERMeS development

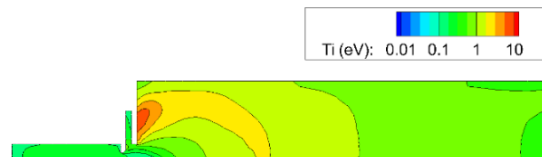
- Cathodes also used during TDU thruster testing:
 - 1700 hours in TDU 1 (GRC)
 - Risk-reduction testing with TDU 2 (JPL)
 - 3000+ hours in TDU 3 (GRC)
- Other risk reduction activities:
 - Cathode ion energy measurements (JPL)
 - Continued refinement of OrCa2D plasma simulations
- AR down-selected to BaO cathode design



Standalone cathode testing at JPL.



Cathode ion energy measurements at JPL



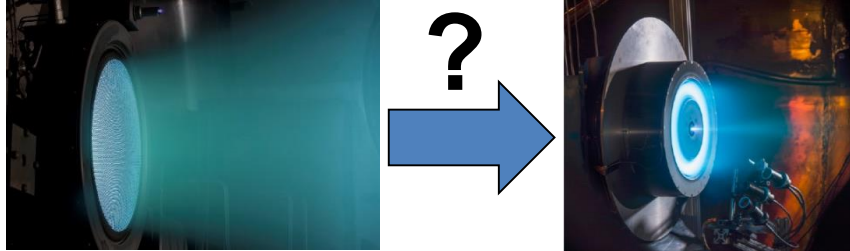
Plasma modeling results from JPL's OrCa2D code.



TDU-3 testing in VF-6 at GRC.



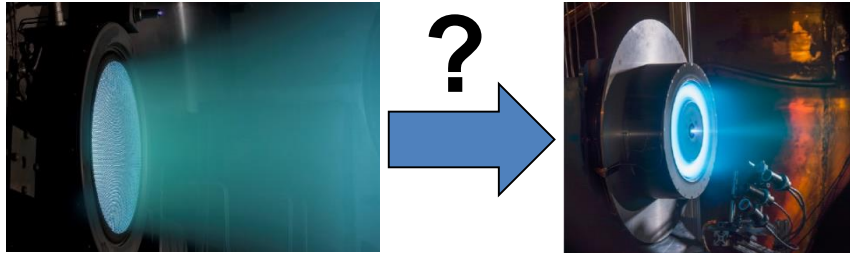
Still, some questions linger about hollow cathode lifetime



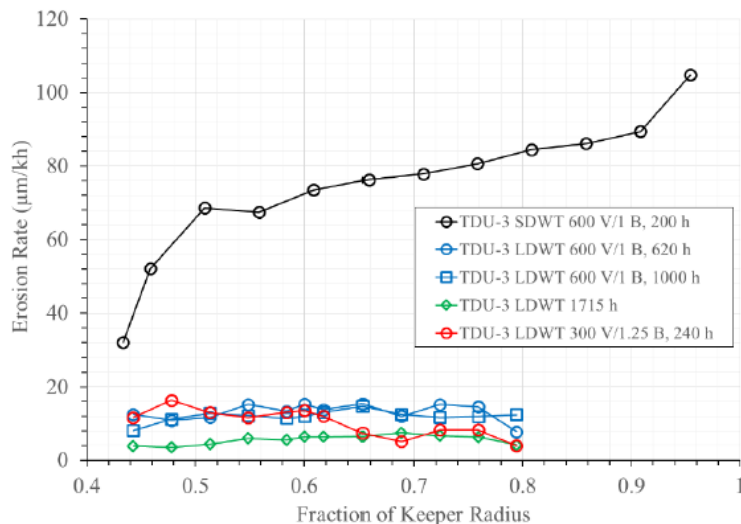
- For AEPS, cathode is centrally mounted
 - Operation environment is different from previous development efforts



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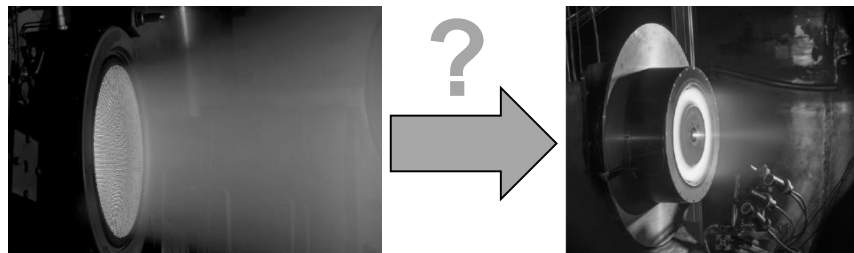


- For AEPS, cathode is centrally mounted
 - Operation environment is different from previous development efforts
- Ongoing work includes:
 - Confirming emitter lifetime
 - Understanding oscillation mechanisms
 - Can we replicate without thruster?
 - Understanding cathode environment in thruster
 - Small change in cathode position in thruster resulted in significant change in keeper erosion!



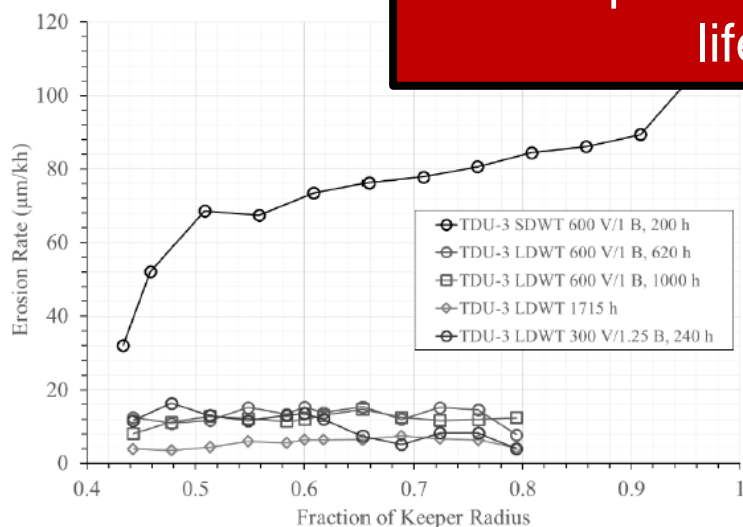


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Long-duration testing is still an important part of cathode development to demonstrate lifetime.



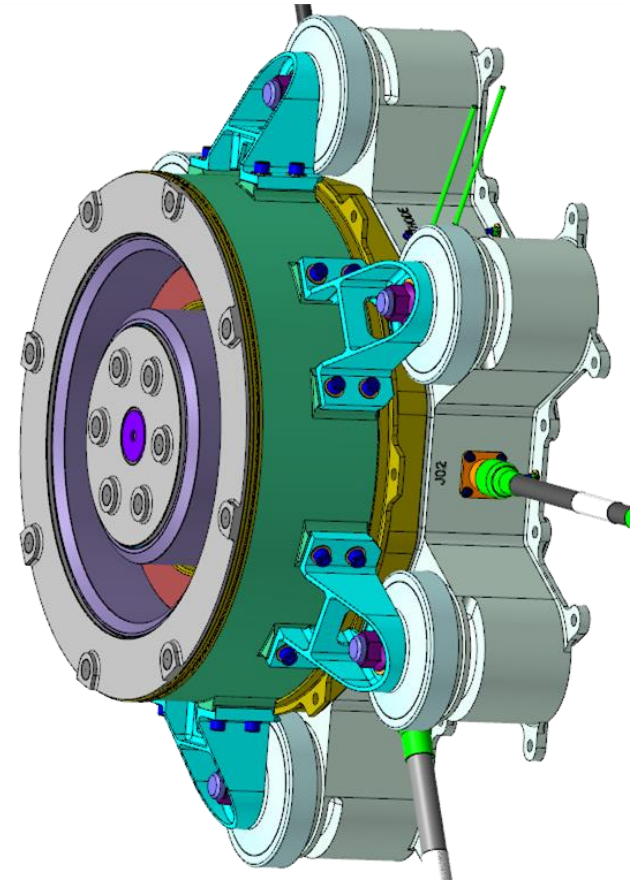
emitter lifetime
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EDU testing will include long-duration testing of both thruster and stand-alone cathode

- Under the AEPS project, long-duration wear testing will be performed on EDU thruster (with EDU cathode assembly)
 - Testing in VF-5
 - Targeting 23 khrs in duration
- Two standalone cathode assemblies (units 3 and 4) will undergo separate long-duration testing:
 - Part of a set of risk-reduction component-level testing
 - EDU-3 will undergo long-duration wear testing (GRC)
 - EDU-4 will undergo long-duration cold-cycle testing (JPL)





GRC preparing for EDU cathode arrival



GRC preparing for EDU cathode arrival

Facility buildup

- Three additional facilities for cathode testing:
 - VF-67
 - VF-17
 - VF-1
- Development of new hardware:
 - Thruster-like magnetic field simulator
 - Cold plate for LN2 cold cycling





GRC preparing for EDU cathode arrival

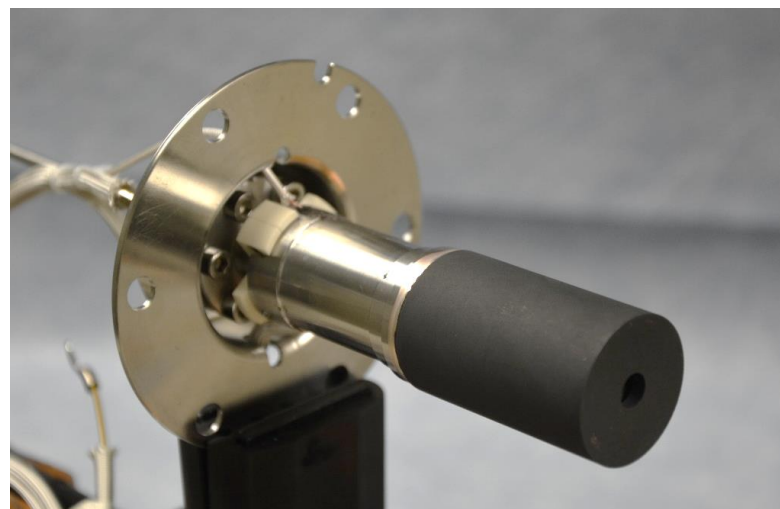
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GRC cathode design evolution

- Updates to TDU cathode design:
 - Brazed joints
 - Design simplification
 - Improved emitter retention
 - Keeper assembly geometry match
- New cathode: “Mark II”

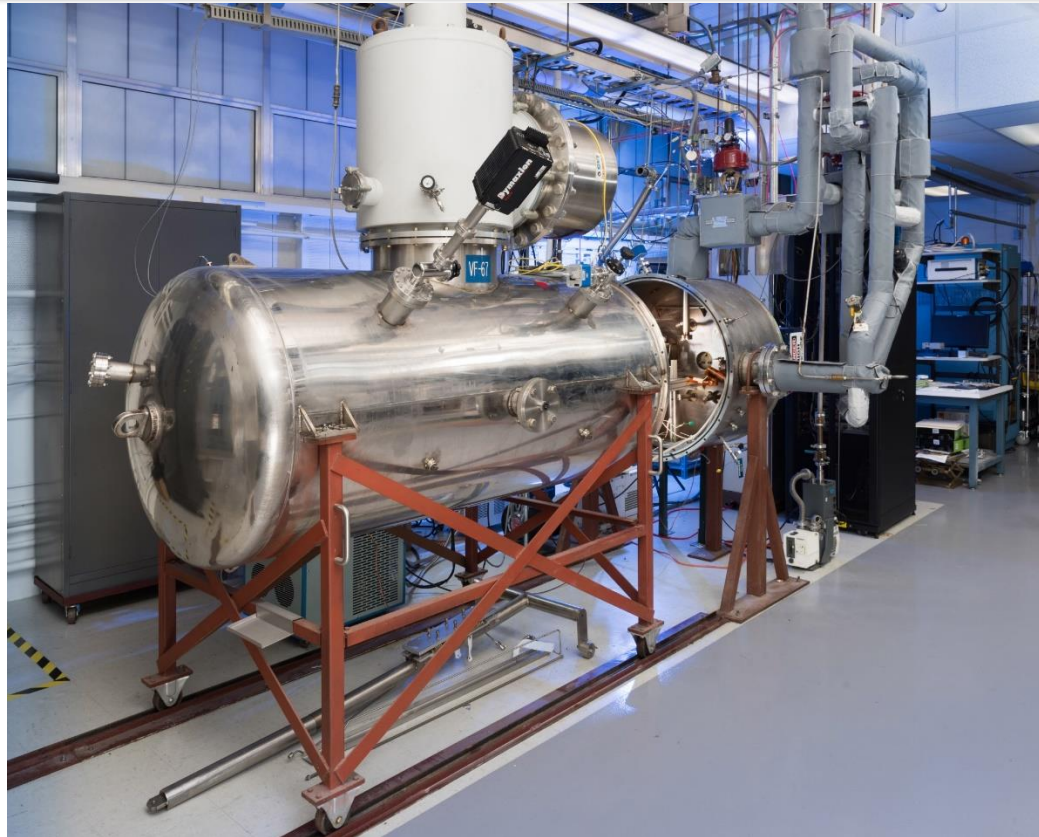




FACILITY BUILDUP



VF-67: Long Duration Test Facility



- VF-67:
 - EDU cathode wear and thermal cycle test facility
 - 2.7 m x 0.9 m
 - 8×10^{-5} torr-Xe at cathode



VF-17: Short Duration/Diagnostics Test Facility



- VF-17:
 - EDU cathode characterization and diagnostics
 - 2.1 m x 0.9 m
 - 9.5×10^{-5} torr-Xe at cathode



VF-1: Cathode Development Facility



- VF-1:
 - Cathode development testbed
 - Plasma diagnostics array
 - 4.5 m x 1.5 m
 - 3×10^{-5} torr-Xe at cathode



Even with different applications, facilities feature similar test infrastructure

- All three facilities are being built up with commonality
- Hardware shares heritage to TDU thruster infrastructure
- Each facility will have:



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Power Console





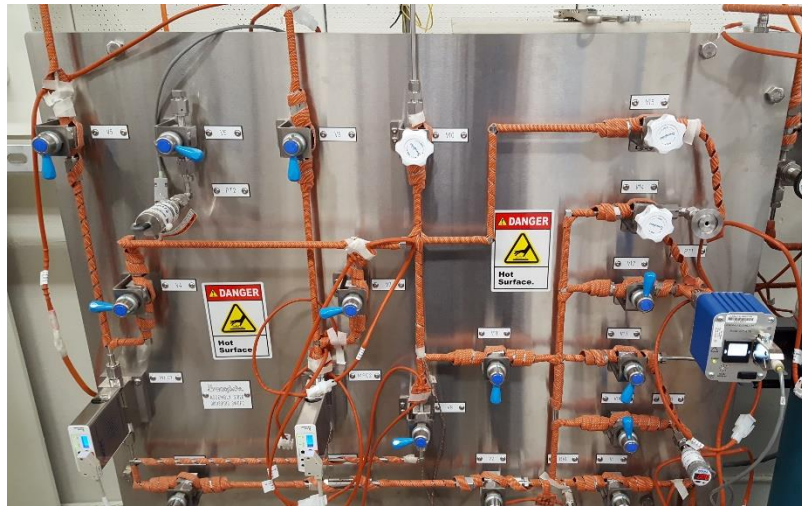
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Xenon Feed System





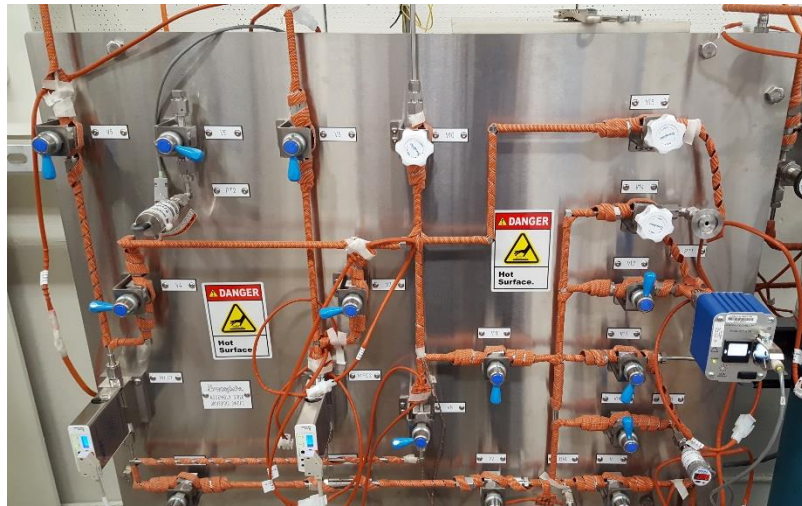
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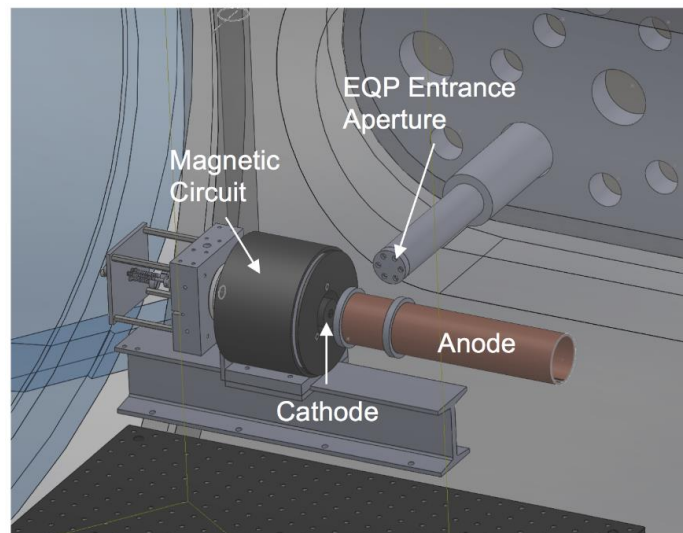
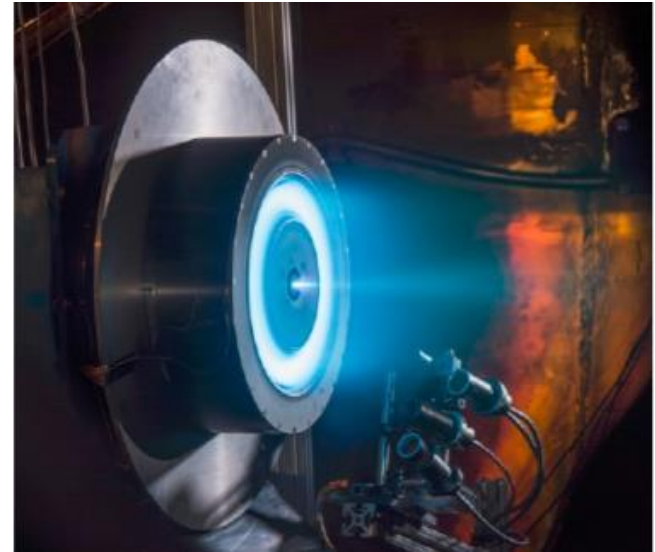
Breakout Box





Thruster magnetic field simulator

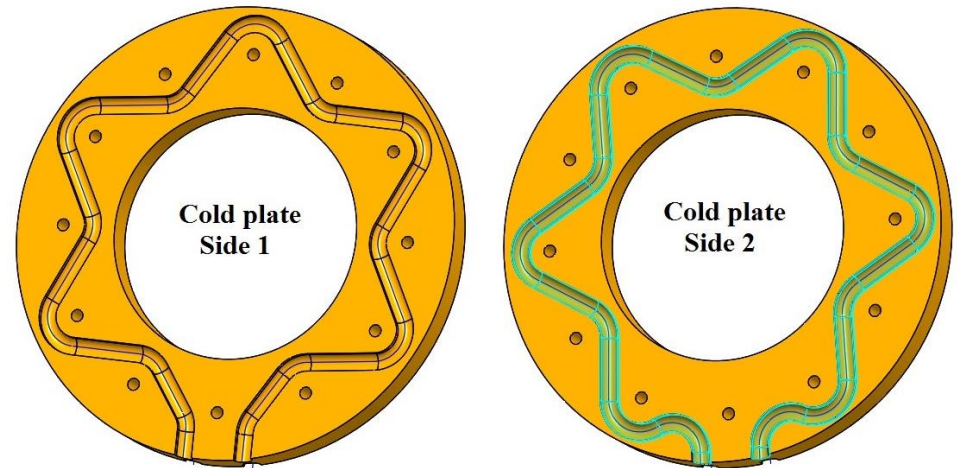
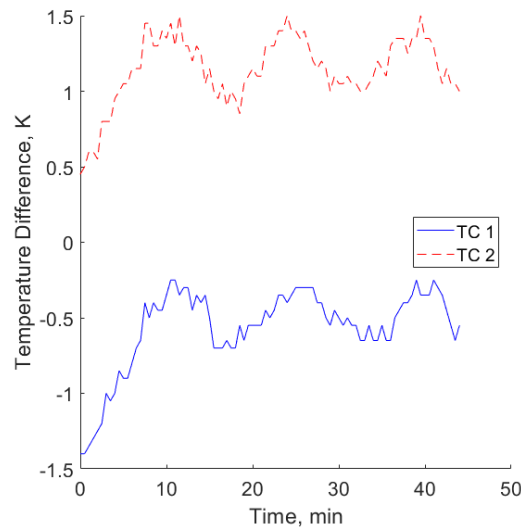
- Developing thruster magnetic field simulator
 - Replicates EDU thruster magnetic field topology in cathode region
 - Similar effort for TDU at JPL
- Magnetic field simulator will be implemented in all cathode tests





Liquid nitrogen cold plate

- Cold-cycling periodically during long-duration cathode test
- Plate features counter-flow design to provide even temperature
- Will perform thermal cycling of cathode assembly
- LN2 system checkouts are underway in VF-67
 - LN2 valve (bang-bang) was able to hold target temperature to within ± 3 K





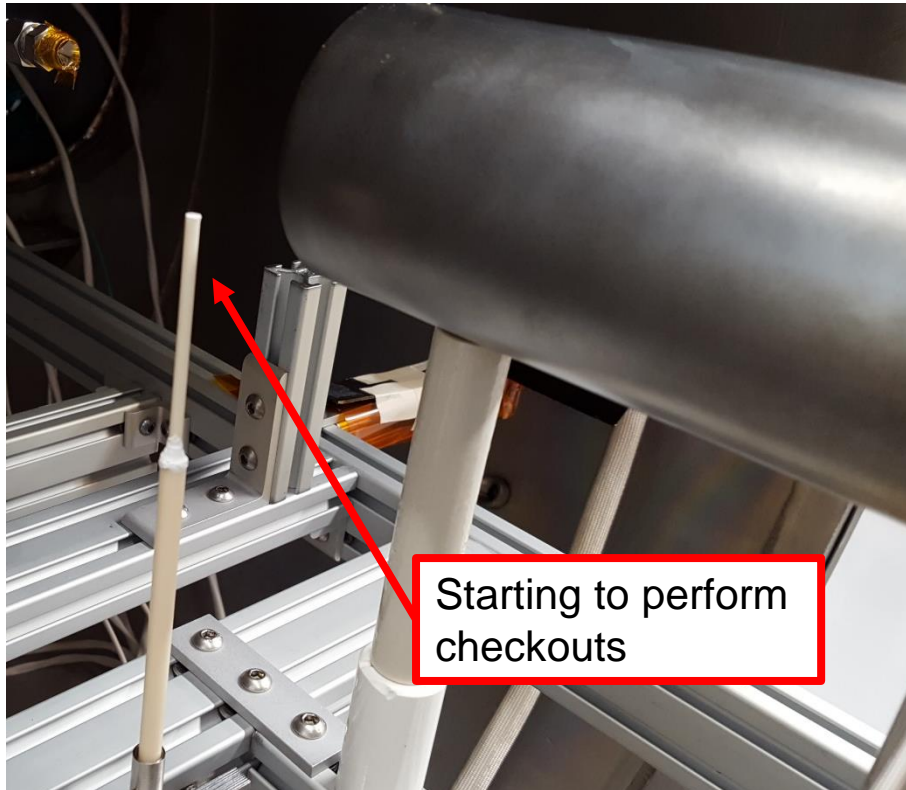
Plasma diagnostics array



- Electrostatic plasma probes:
 - RPA
 - LP
 - Emissive probe
- Fast internal temperature measurement
 - Based on JPL diagnostic
 - Fast stage with fiberoptic sensor; ratio pyrometry
- Exploring other capabilities as well:
 - Optical emission spectroscopy
 - Fast LP
 - Small RPA



Plasma diagnostics array

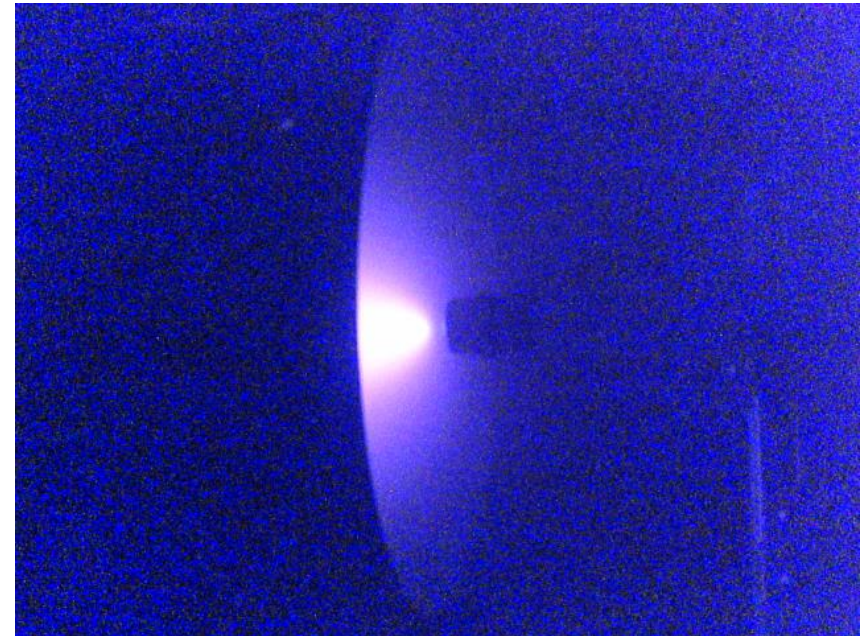


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Cathode test facility status

- VF-67:
 - Operational. Accumulated approximately 400 hrs of cathode operation.
 - Left to do:
 - Cold plate installation and checkout
- VF-1 & VF-17:
 - VF-1 facility upgrade underway
 - Research equipment buildup ongoing
 - Targeting August for first fire in both facilities



First hot fire of TDU cathode in VF-67

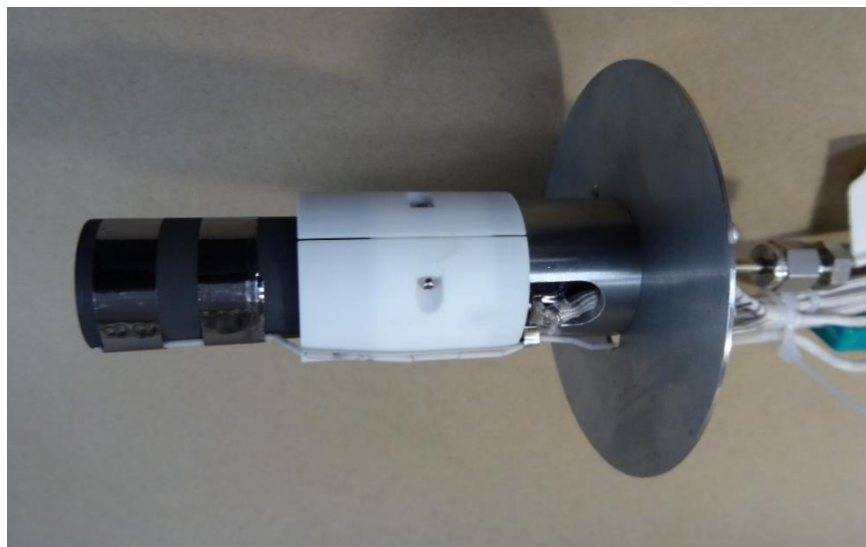


MARK II CATHODE

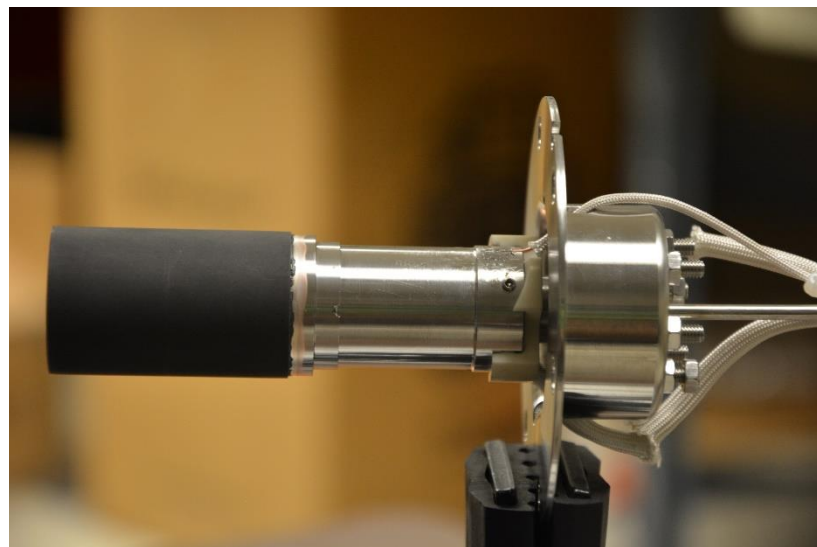


Mark II cathode evolved from TDU design

TDU lab cathode

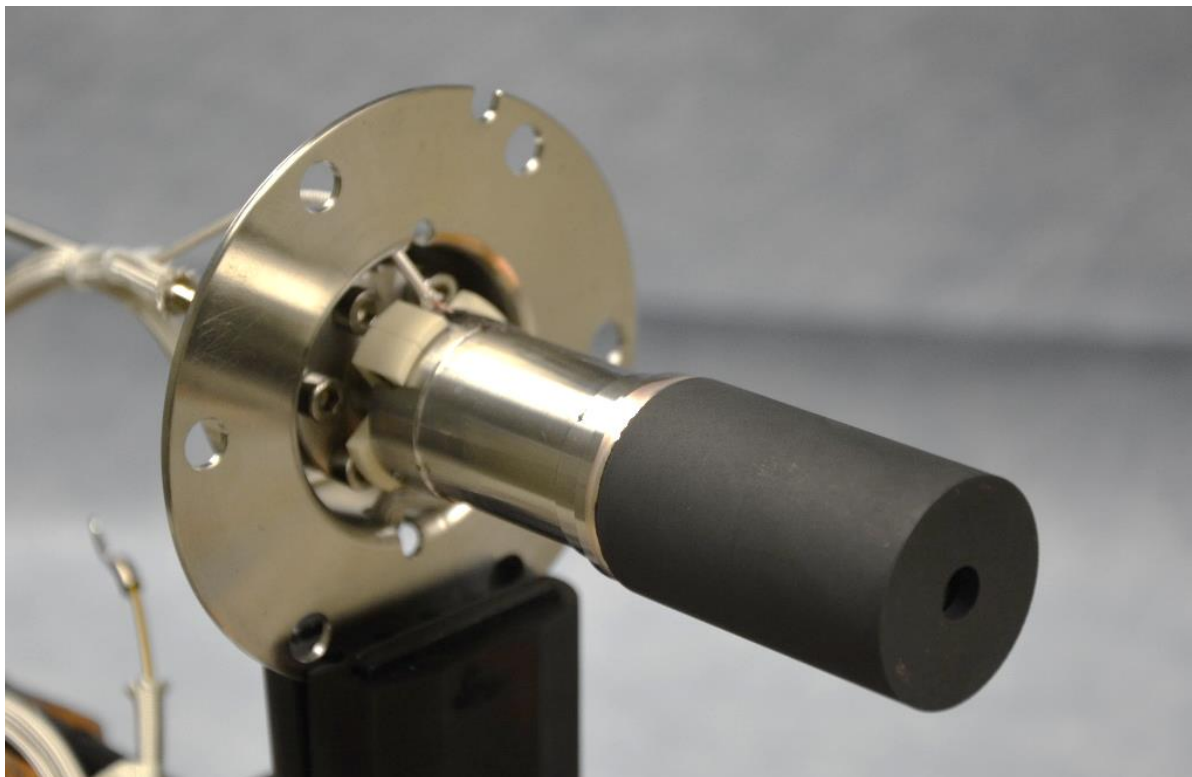


Mark II cathode



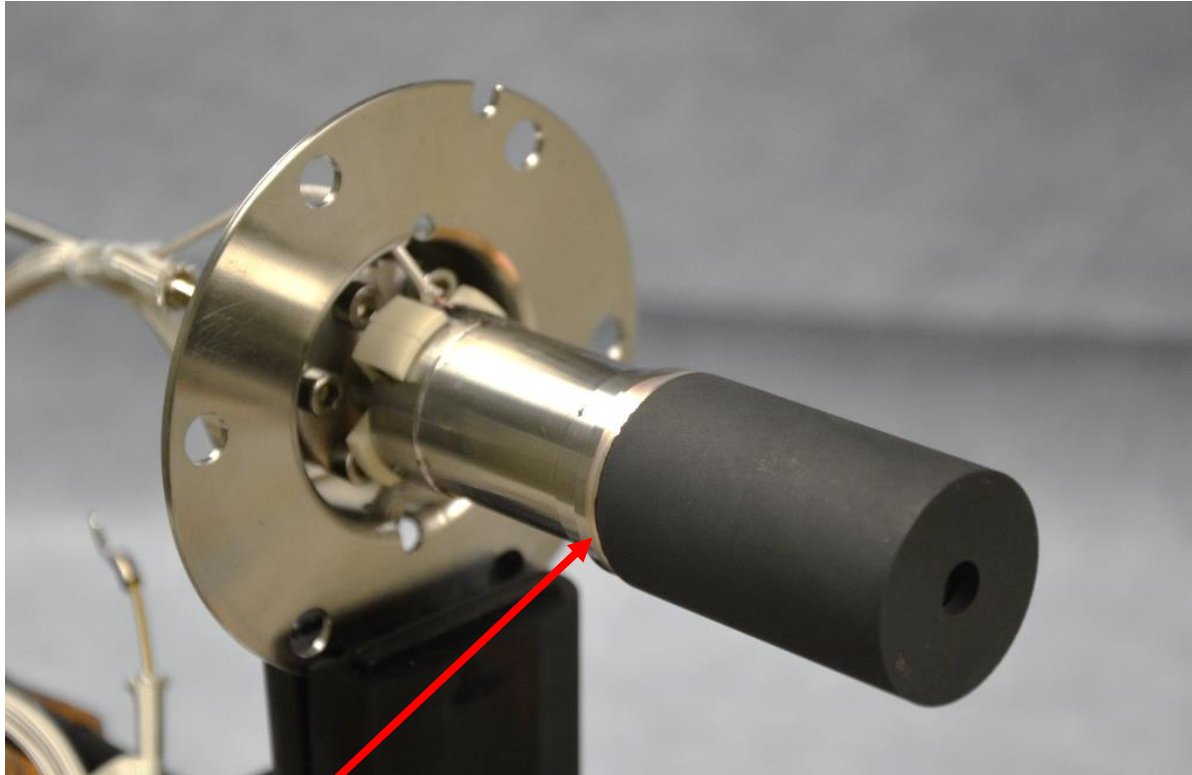


Key design changes of Mark II cathode





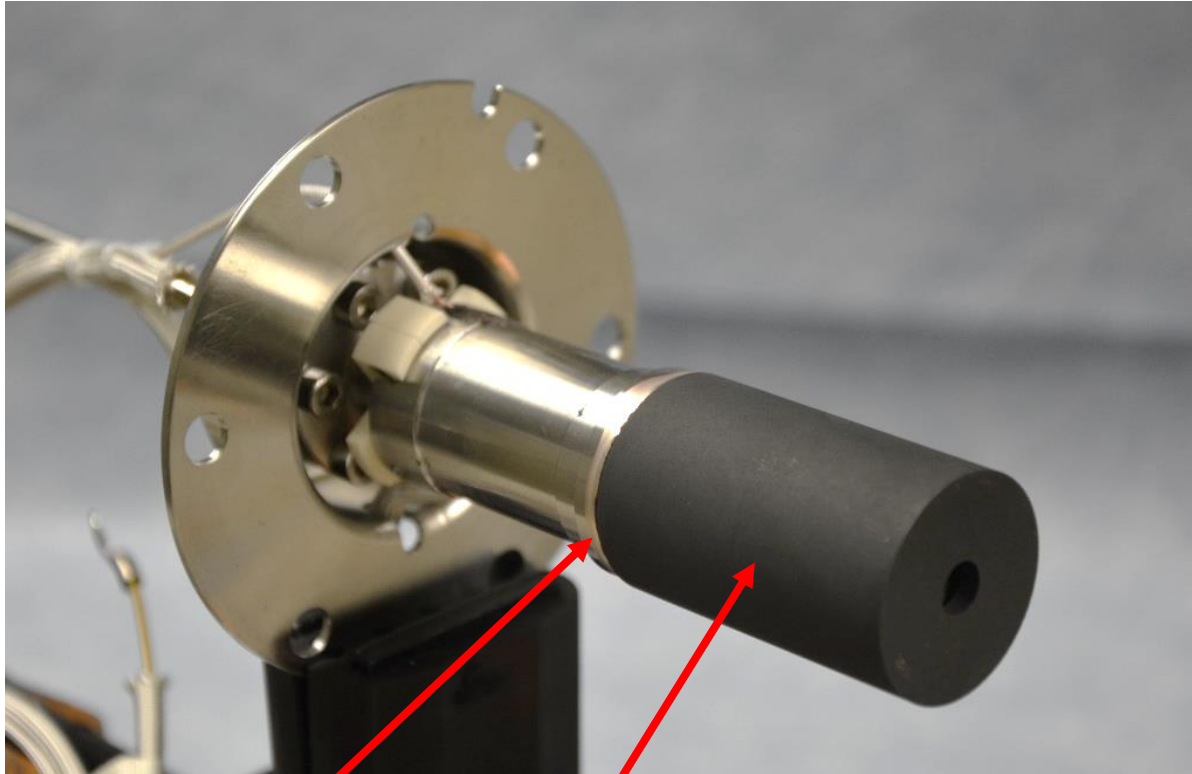
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Brazed joints



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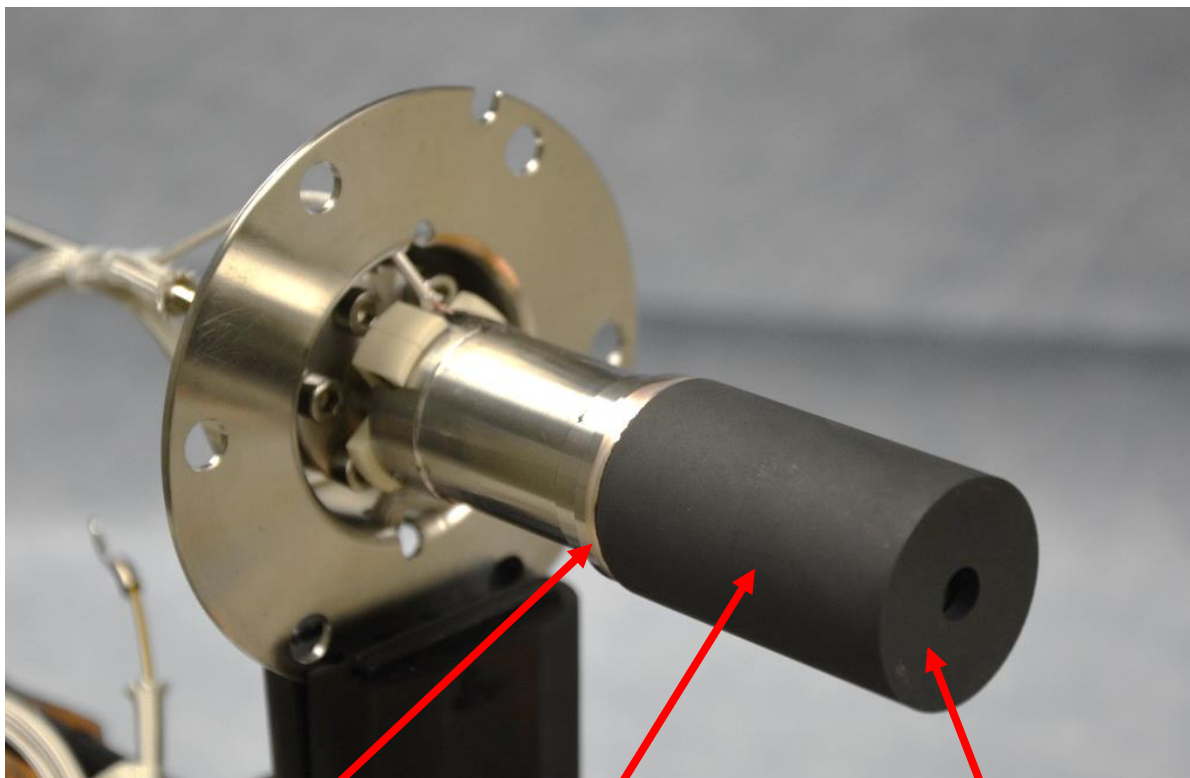


Brazed joints

New emitter
holder design



Key design changes of Mark II cathode



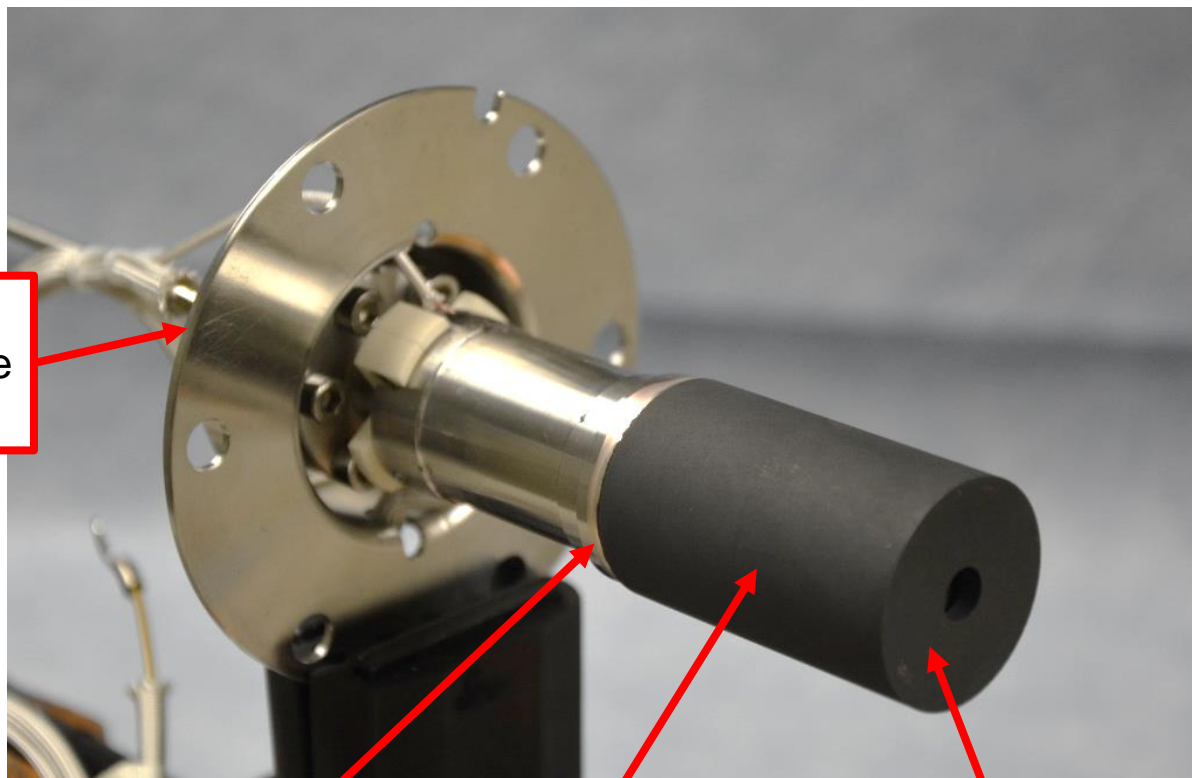
Brazed joints

New emitter
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EDU-like keeper
configuration



Key design changes of Mark II cathode



Improved
propellant tube
attachment

Brazed joints

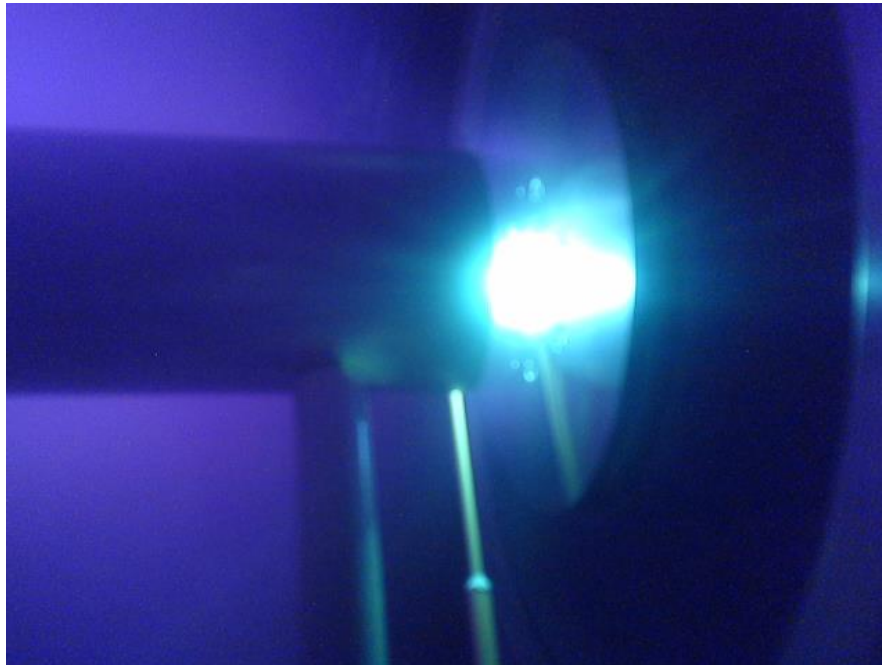
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Mark II cathode status

- Three Mark II cathodes are being assembled
- Initial characterization of first cathode has been completed
- Next, continued diagnostic work:
 - Plasma plume measurements
 - Temperature mapping



First fire of Mark II cathode in VF-67.



Conclusions

- EDU cathode hardware delivery upcoming
- GRC will be performing cathode testing on EDU units



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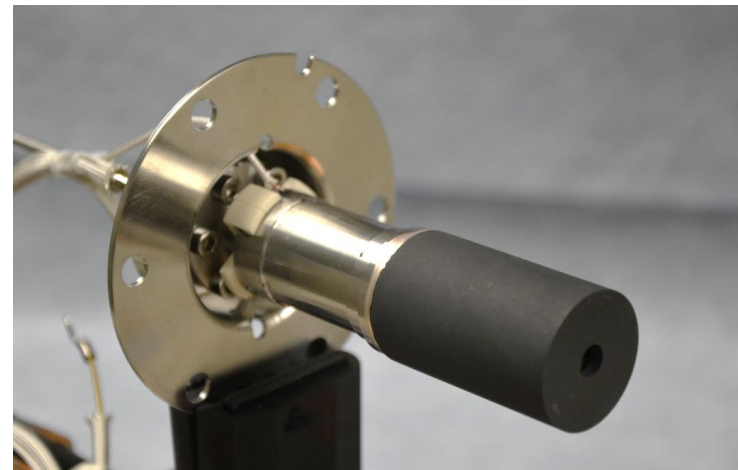
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- GRC will be performing cathode testing on EDU units
- Three new facilities for cathode development work
 - VF-67: long-duration wear test (online now)
 - VF-17: short-duration testing (first fire in Aug)
 - VF-1: diagnostics test bed (first fire in Aug)
- New cathode design developed
 - First unit complete; assembly of units 2 and 3 in progress
 - Will be used for continued checkouts of all three facilities
 - Plasma plume probing and temperature mapping planned





QUESTIONS