Pulsed Cathodic Arc Thruster Development and Applications

An overview of the technology and introduction to our future plans

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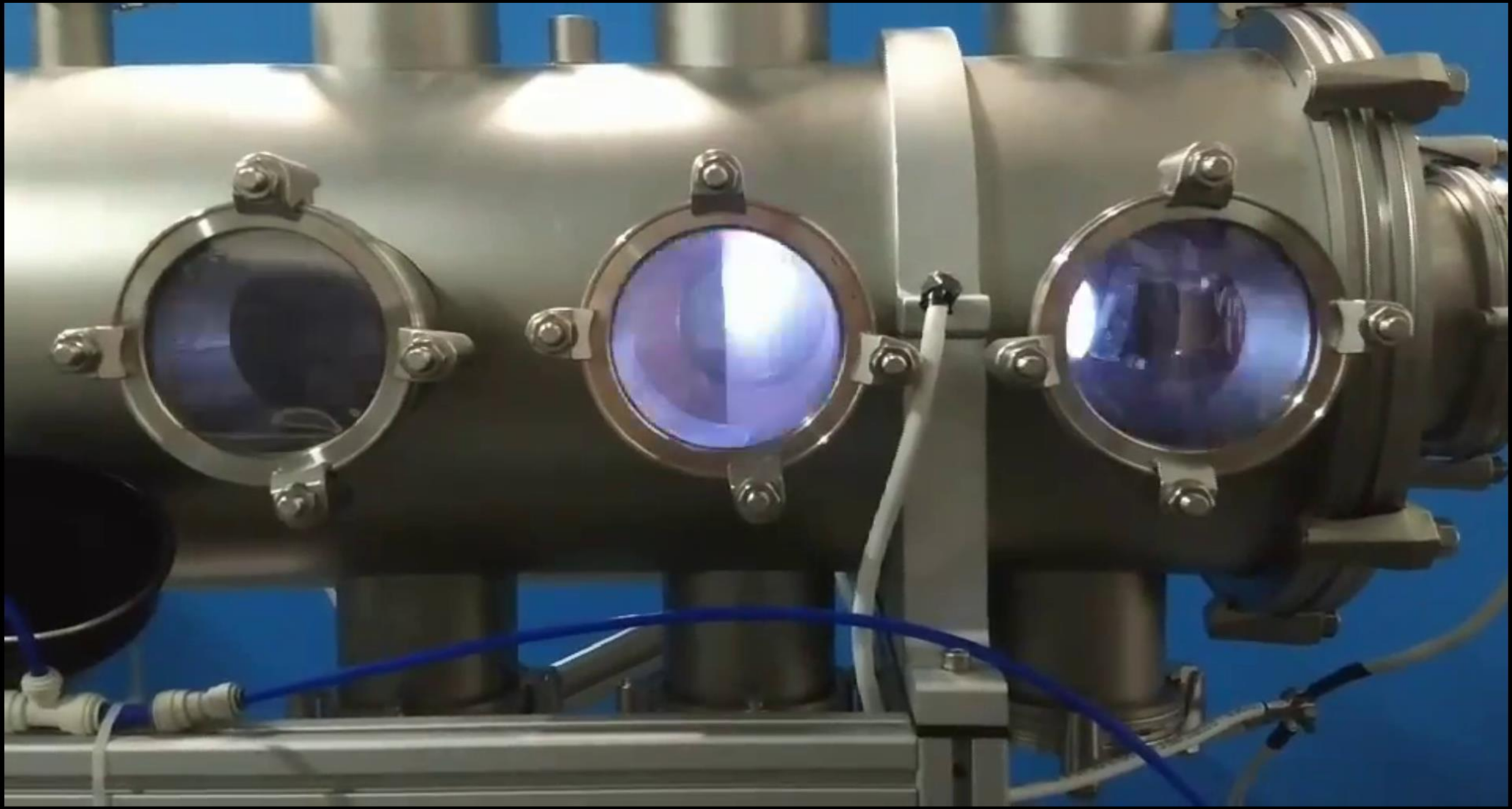

Introduction

- Space is inspiring, fascinating, and important
- But is challenging to reach
- And more so to navigate
  - Since you must bring the propellants with you
  - And pump/push it about
  - In micro-g and with limited power/pressurant
- Additionally, no propulsion system is perfect
  - Nothing ever is
  - But there is always room to improve…

Motivation – Pulsed Cathodic Arcs

- Previous work suggests PCA systems
- High measured ion velocities, no grid, neutral exhaust
- Solid reaction mass; no pipes/valves/pumps
- Need to determine efficiencies to compare with other techs
  - PhD @ USyd measured thrust, mass flow of 11 materials
  - Derive specific impulse and thrust-to-power ratio, compare

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Pulsed Cathodic Arc Plasma Sources

- Source of highly ionised plasma
- Plasma eroded from cathode
- Cathode can be made from most conductors
- Narrow plasma plume
- Source of industrial coatings for decades

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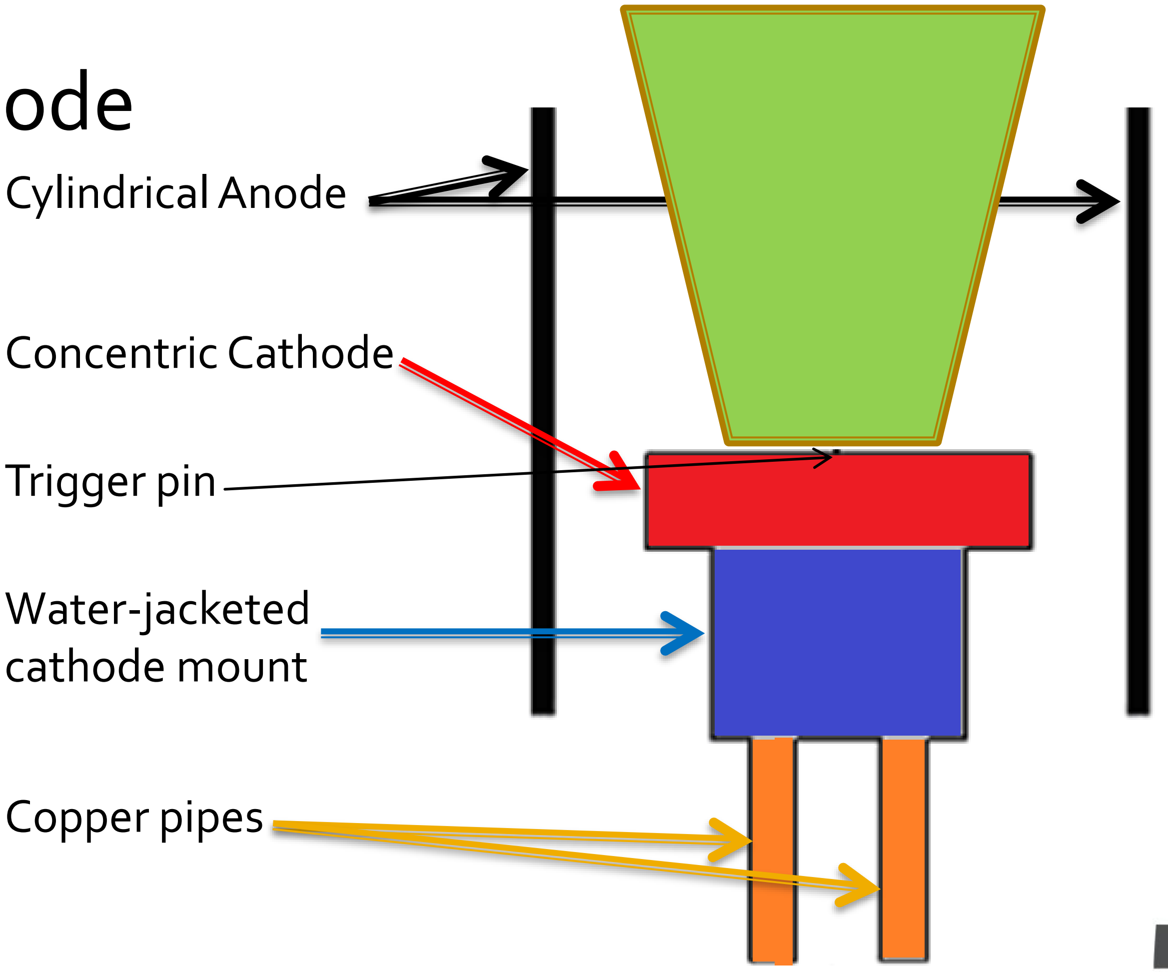
Structure and Operation

- Electric field from cathode charging
- Flashover to trigger
- Cathode spots and erosion



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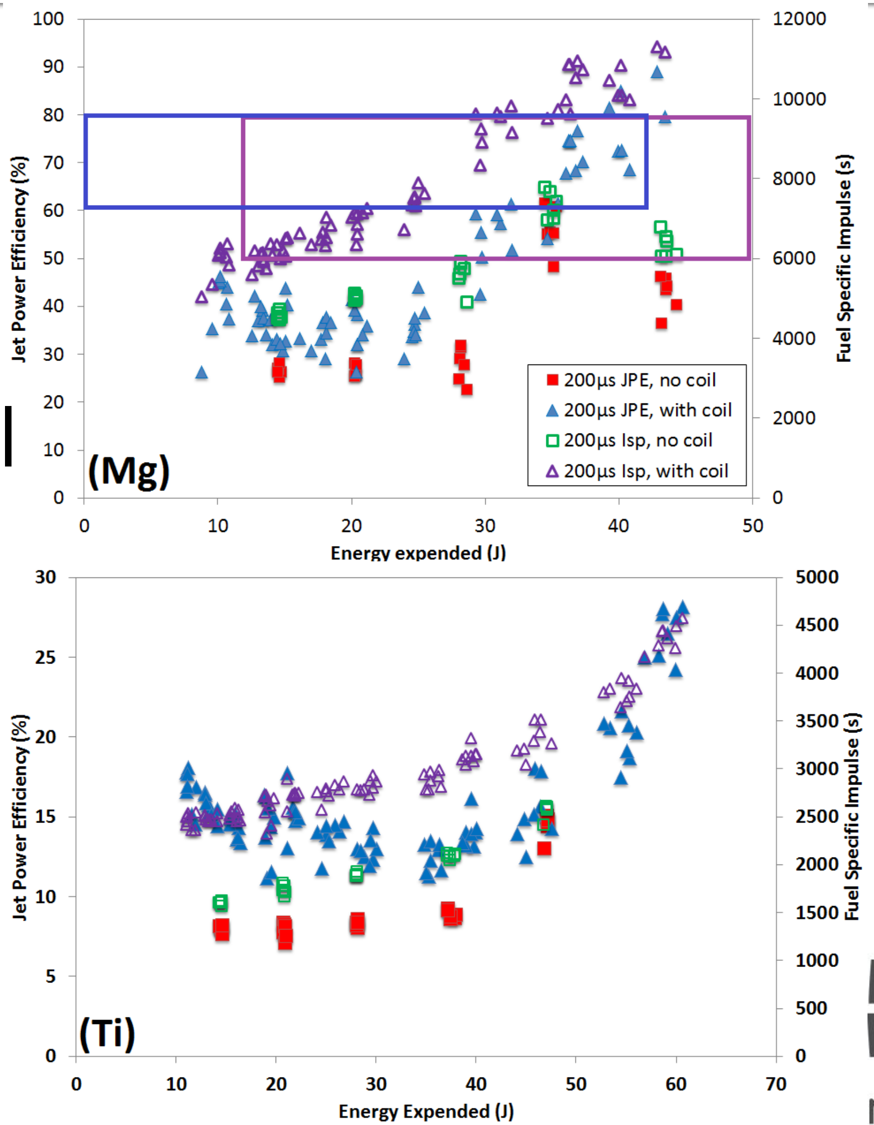
Nozzle data – APL 2016

- Mg at top, Ti at bottom, non-eroded surfaces
- Measurable improvement at all settings
- Mg Isp best in class



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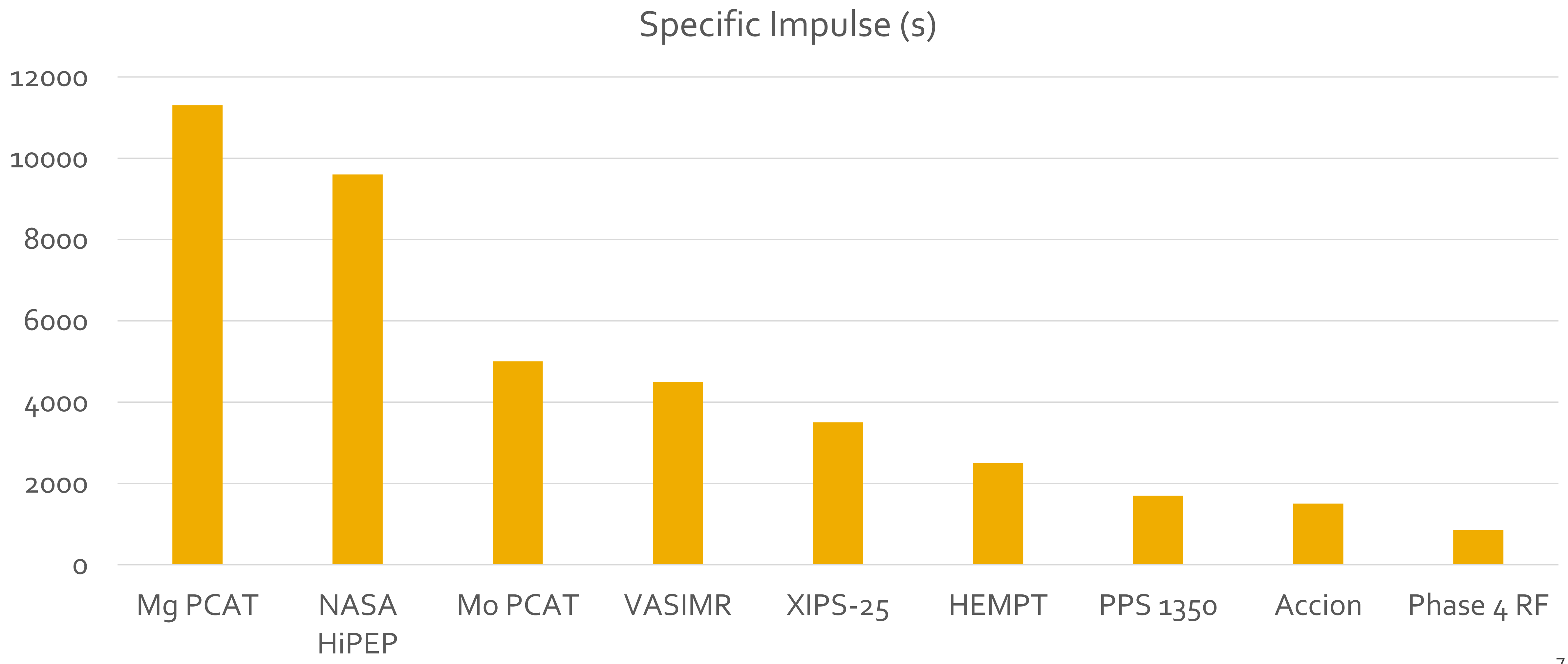
Specific Impulse Comparison



Logistics and Tugs, Chemical Fuel

- Space tugs fill the niche of car transporters
- For a 1t tug, 4t payload, 400km ELEO to GEO, 320s Isp
  - ~3.5t of tug +fuel for the return, thus
  - ~7.5t reaching GEO, thus
  - ~26.4t min wet mass in ELEO, thus
  - ~21.5t of propellant and pressurant in ELEO
- Each mission requires HLLV for refuelling
- Cheapest is Falcon 9 @62M USD for ~22.3t
- Uneconomical.

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Tugs using HETs

- For a 1t tug, 4t payload, 400km ELEO to GEO, 1700s Isp
  - ~1.3t of tug +Xe for the return, thus
  - ~5.3t reaching GEO, thus
  - ~7t min wet mass in ELEO, thus
  - ~2.1t of propellant and pressurant in ELEO
- Airbus DS Toulouse studies suggest 4.5t of Xe
- Bulk aerospace Xe @ ~1200USD/kg, per NASA
- Falcon 9 could launch 4 Airbus tug fuel loads
- ~20M USD/mission for fuel – still bad

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Tugs, Mo propelled PCA

- For a 1t tug, 4t payload, 400km ELEO to GEO, 5000s Isp
  - ~1.1t of tug + Mo for the return, thus
  - ~5.1t reaching GEO, thus
  - ~5.6t min wet mass in ELEO, thus
  - ~650kg of propellant in ELEO
- Scrap 99.9% Mo @ ~20USD/kg
- Falcon 9 could launch 30 Mo tug fuel loads
- ~2M USD/mission for fuel
- Sounds better, could be economical
- Power budget? Timeframes?

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Mo PCA Orbit Raising Tug (ORT)

- Needs short transfer time to be attractive
  - Boeing 702SP 6mths GTO-GEO, Eurostar E3000e in 4mths
  - ORT constrained to 9 mths ELEO-GEO
  - 1.3N of thrust required for Mo ORT
  - 274d transfer out, including time in eclipse
- Requires min 65kWe to thruster
  - 327kg of flight rated solar panels needed (Spectrolab ITJ)
  - Increase to 375kg to allow for degradation, increased strut mass; ~200m^2 will need bracing
- Complete mission evolution in ~330d

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Phobos and Deimos – Mo PCA

- Let's assume ORT, return 100kg from each of Phobos and Deimos
- 263 days to Deimos, another 36 to Phobos
  - Well timed spiral transfer
  - Minimise eclipse @ Earth, unavoidable @ Mars
- 270 days return from Phobos
- 950kg Mo fuel required; allocate 50kg extra
- 2t in LEO for Martian lunar sample return

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Current Activities

- Neumann Space Pty Ltd formed May 2015
  - Relocate to Adelaide Dec. 2016
  - Develop hardware for on-orbit verification and MVP
- FAST: Bartolomeo payload slot reserved Sep. 2016
  - 100kg total mass to ISS; thruster ~10-20kg, structure ~10-15kg
  - Power and data via ISS resources
  - Can on-sell excess capacity
  - First customer SA DECD for SA Schools Space Mission

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Conclusion

- Pulsed cathodic arc thrusters solve many mission problems
- And could open up the inner system to humanity
- But will need to be tested in space first.
- We have secured the facilities to do this
- And can offer this to others, thus growing an ecosystem.

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