Pulsed Inductive Thruster Using Martian Atmosphere as Propellant

presented at ***Concepts and Approaches for Mars Exploration***

12-14 June 2012

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Pulsed Inductive Thruster (PIT)

Inductive Pulsed Plasma Thrusters Demonstrated

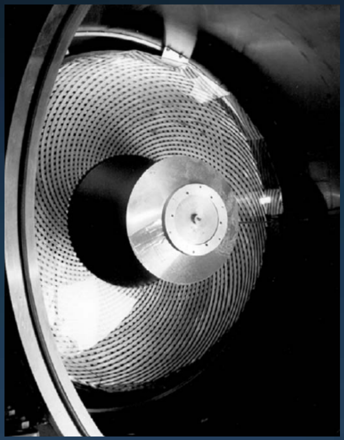
– High, relatively constant η_t over an I_{sp} range

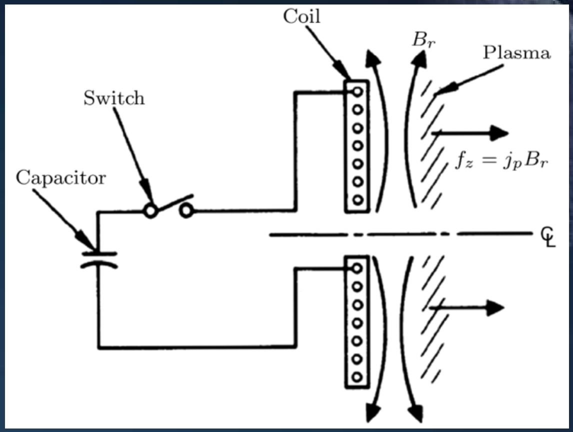
– Operate on arbitrary power level while maintaining constant performance

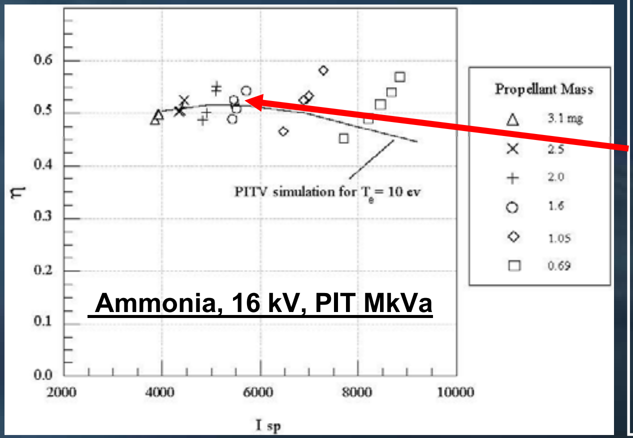
– Increase pulse rate to process significant levels of power in a single thruster unit

– Electrodeless, operates on range of propellants: Ammonia, Hydrazine, Hydrocarbons, Water

Pulsed Inductive Thruster







Energy = 4.6 kJ/pulse

Impulse = 0.1 N-s

Isp = 5,000 s

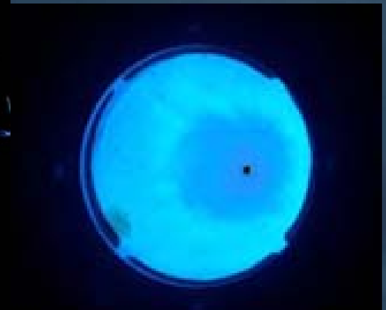
η = 50% (or better)

→ Thrust = 3 N
(f_{rep} = 30 hz)

P_{Jet} = 75 kW

Other Inductive PPT Variants

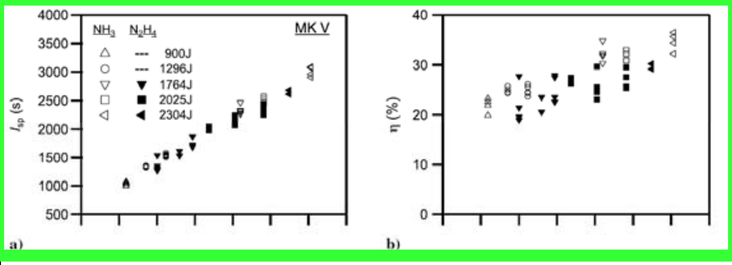

Field-Reversed Configuration

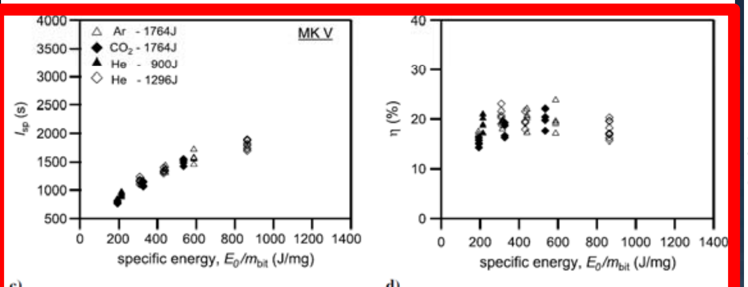

Conical Theta-Pinch

From C.L. Dailey and R.H. Lovberg, NASA CR-191155 (1993)

Performance of PIT on Various Propellants

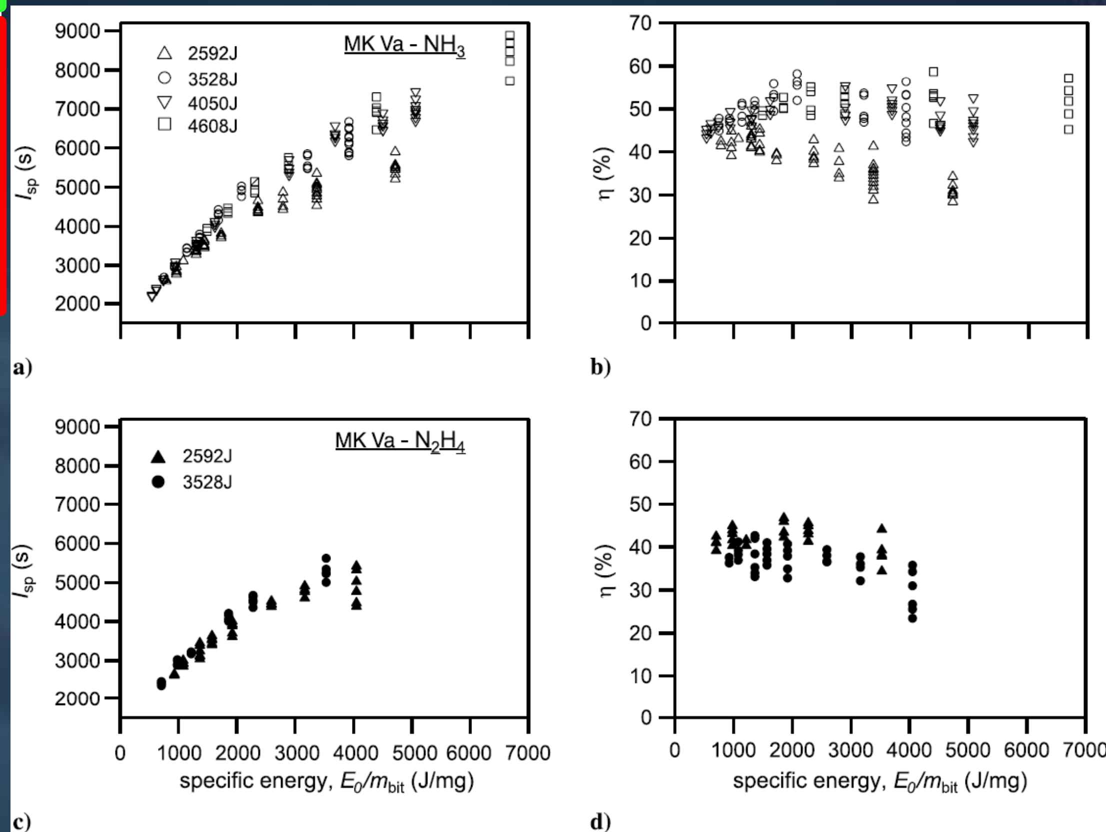
PIT MK V – 4.5 μF , PIT MK Va – 9 μF





Demonstration of significant advancement in operation capability from MK V to MK Va

- Due to better dynamic impedance matching
- Further advances possible



Expect all other atomic / molecular propellants to follow suit in terms of performance trends and improvements

Data from K.A. Polzin, *Journal of Propulsion and Power*, **27**:513 (2011)

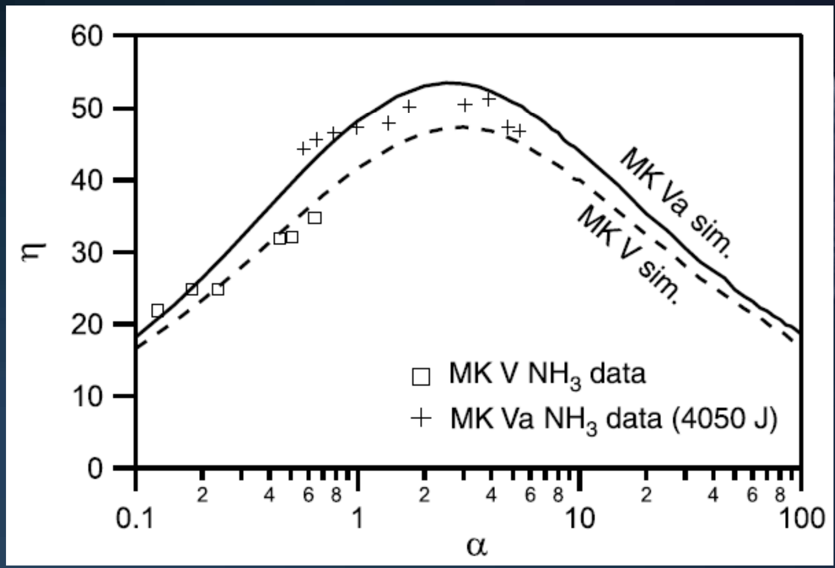
Performance of PIT

MK V performance

- NH_3, N_2H_4 – η_t ~ 20-30%
- Ar, He, CO_2 – η_t ~ 15-20%
- Dynamic Impedance not optimum

MK Va performance

- NH_3, – η_t ~ 40-50%
- N_2H_4 – η_t ~ 35-40%
- Dynamic Impedance spans optimum



From K.A. Polzin, *Journal of Propulsion and Power*, **27**:513 (2011)

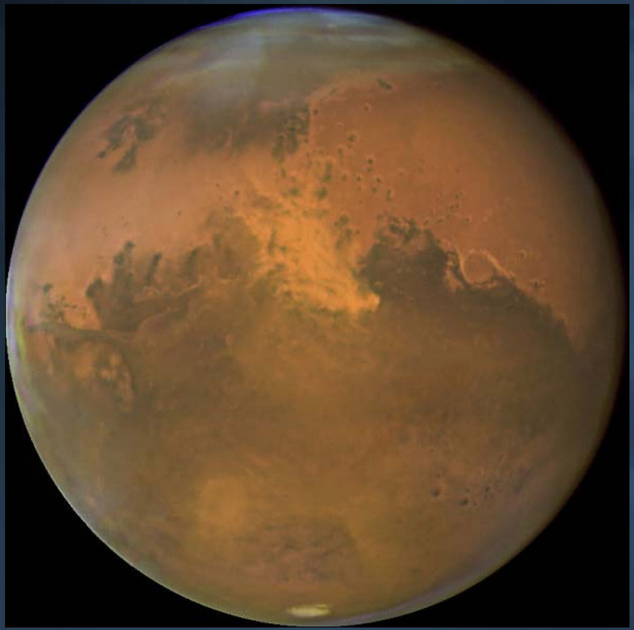
Takeaways

- PIT will operate on many propellant options
  - Provides consistent performance and flexibility for a mission
- Variations in efficiency across various propellants, but performance likely better for all options with improved dynamic impedance match
- Higher efficiency possible with inductive energy recapture
  - Electrical / Power System challenge : Independent of propellant choice

The Martian Atmosphere as Propellant

Propulsion Systems Department

Chemical Species	Mole fraction
Carbon Dioxide	95.32%
Nitrogen	2.7%
Argon	1.6%
Oxygen	0.13%
Carbon Monoxide	0.07%



Concept

- If an EP system can operate on CO_2 (as PIT can), Mars atmosphere is a simple ISRU option
- Only need to carry propellant for one way trip (mass and systems advantages)
- Can produce propellant at Mars by compressing atmosphere and filling a COPV tank
- Variation in η_t with propellant (but still fairly close)
  - Analysis of system and mission concept required to quantify effects
  - Testing will be conducted at NASA-MSFC using a PIT thruster on simulated Martian atmosphere.
- Spacecraft could also leave Mars and go to a different destination (other than returning to Earth)
- Potentially permits *in situ* refueling at any other destination where the atmosphere is accessible