



Propulsion Systems Department

# ***Pulsed Inductive Thruster Using Martian Atmosphere as Propellant***

*presented at **Concepts and Approaches for Mars Exploration**  
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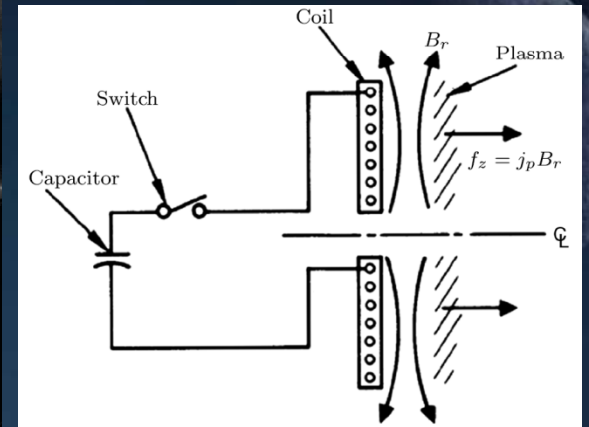
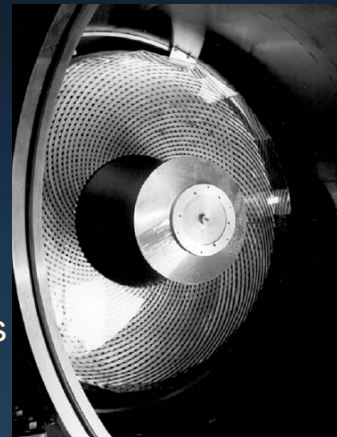
# Pulsed Inductive Thruster (PIT)

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## Inductive Pulsed Plasma Thrusters Demonstrated

- High, relatively constant  $\eta_t$  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

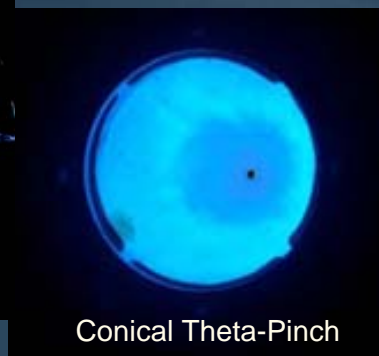
Pulsed Inductive Thruster



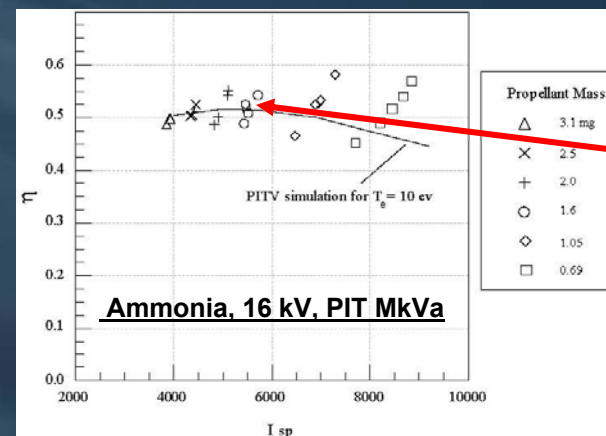
Other Inductive PPT Variants



Field-Reversed Configuration



Conical Theta-Pinch



**Energy = 4.6 kJ/pulse**

**Impulse = 0.1 N-s**

**$I_{sp} = 5,000$  s**

**$\eta = 50\%$  (or better)**

**→ Thrust = 3 N**  
( $f_{rep} = 30$  hz)

**$P_{jet} = 75$  kW**

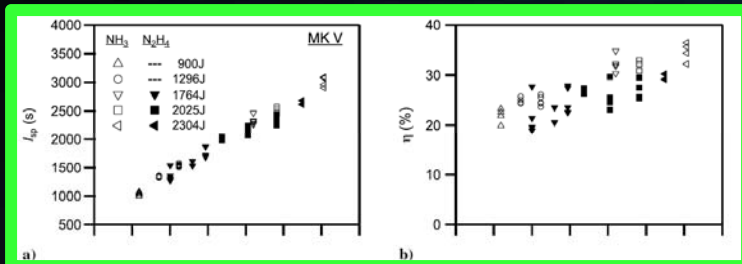
From C.L. Dailey and R.H. Lovberg, NASA CR-191155 (1993)



# Performance of PIT on Various Propellants

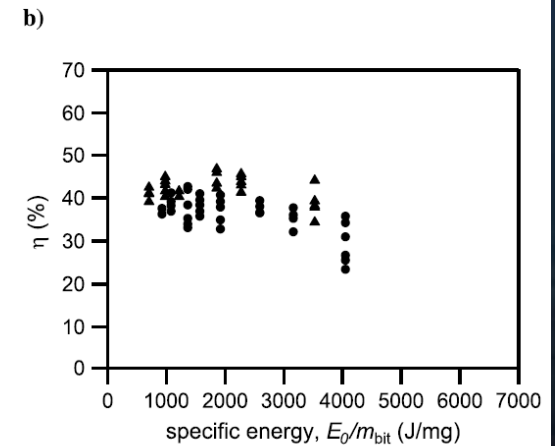
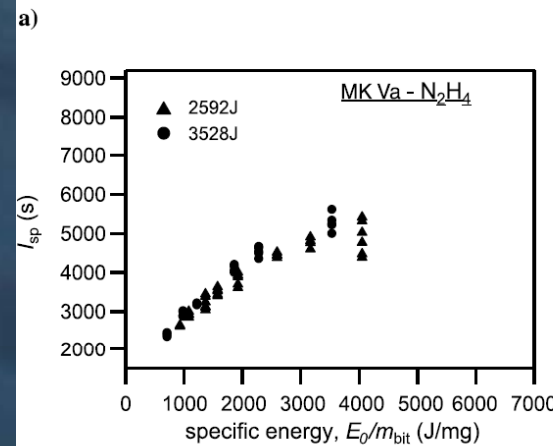
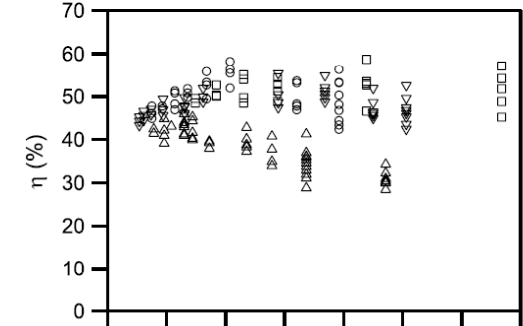
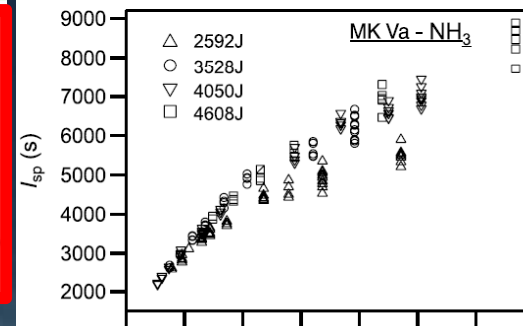
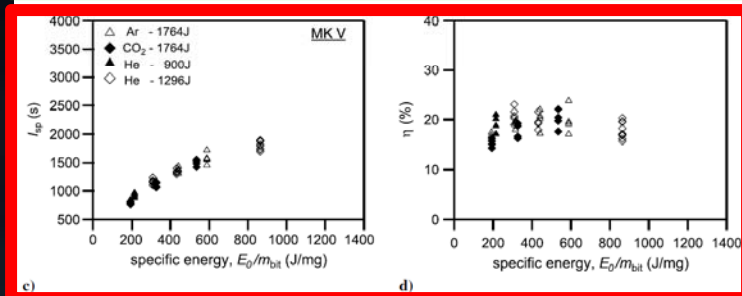
## PIT MK V – 4.5 $\mu\text{F}$ , PIT MK Va – 9 $\mu\text{F}$

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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



# Performance of PIT

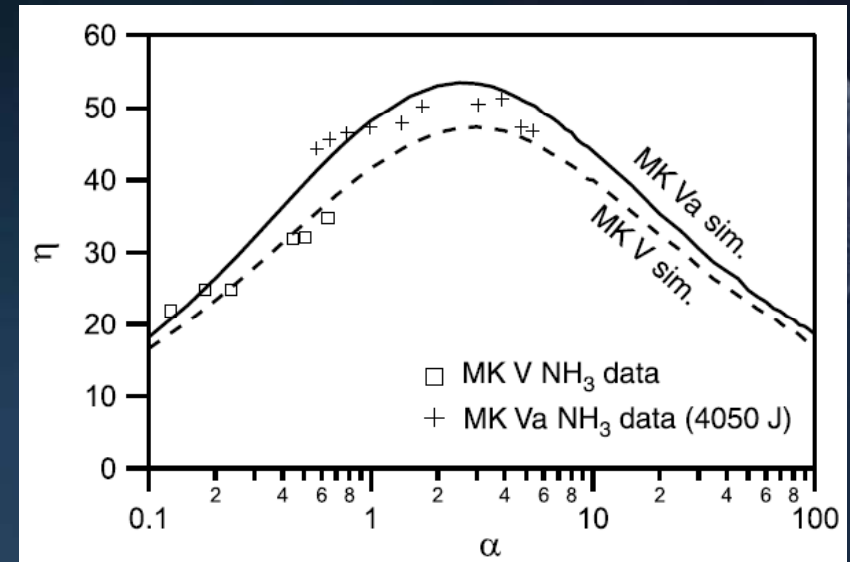
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## MK V performance

- $\text{NH}_3, \text{N}_2\text{H}_4 - \eta_t \sim 20\text{-}30\%$
- $\text{Ar}, \text{He}, \text{CO}_2 - \eta_t \sim 15\text{-}20\%$
- Dynamic Impedance not optimum

## MK Va performance

- $\text{NH}_3, - \eta_t \sim 40\text{-}50\%$
- $\text{N}_2\text{H}_4 - \eta_t \sim 35\text{-}40\%$
- Dynamic Impedance spans optimum



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

## Takeaways

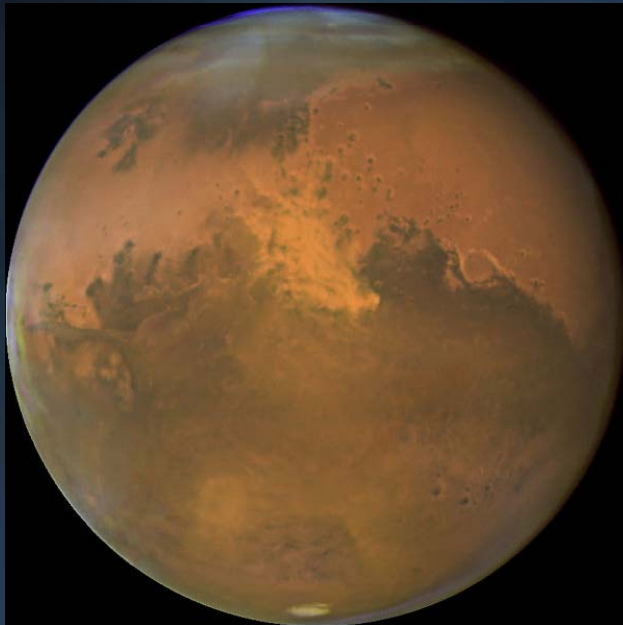
- PIT will operate on many propellant options
  - Provides consistent performance and flexibility for a mission
- Variations in efficiency across various propellants, but performance likely better for all options with improved dynamic impedance match
- Higher efficiency possible with inductive energy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



# The Martian Atmosphere as Propellant

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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<sub>2</sub> (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  $\eta_t$  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