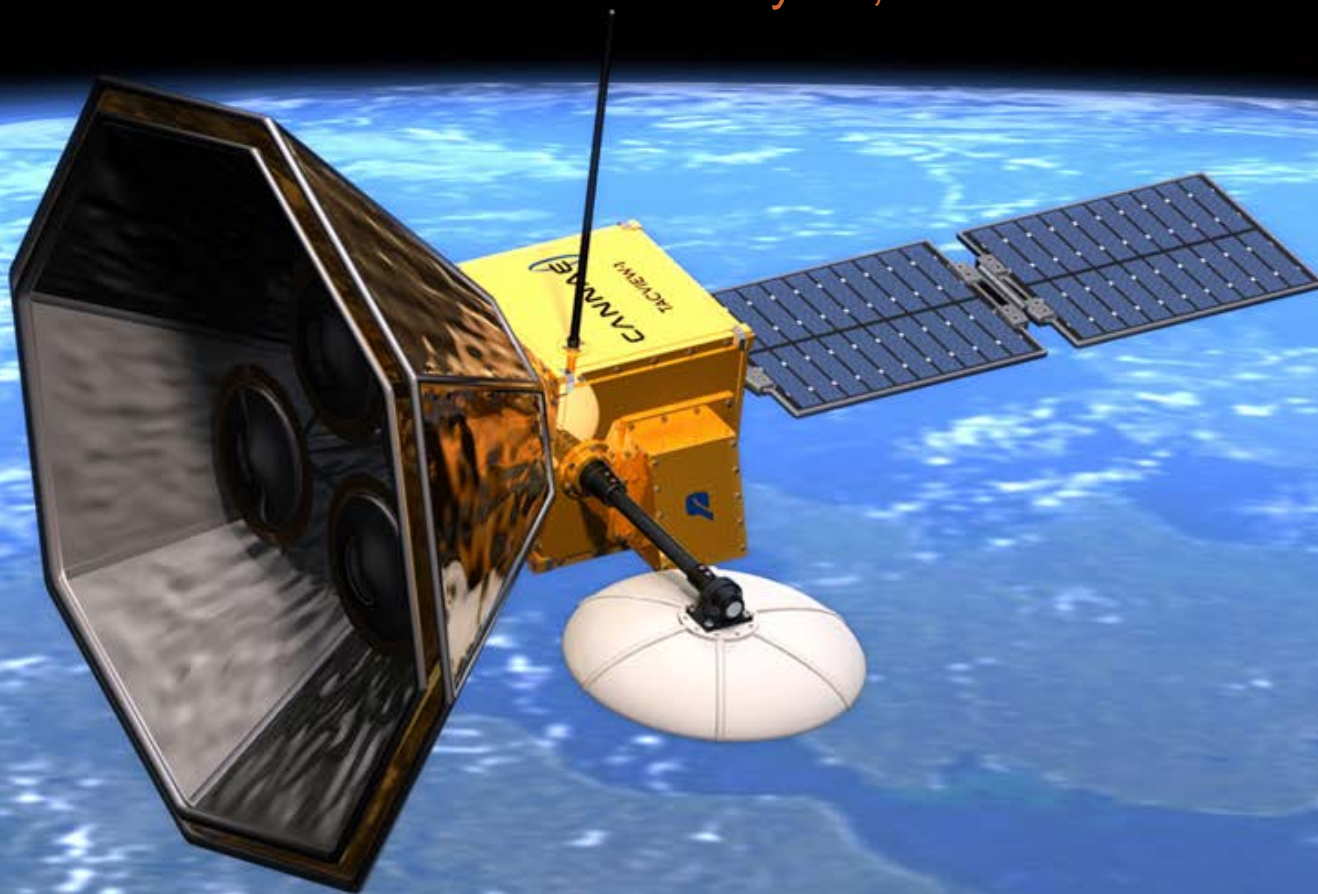


# CANNAE

AIAA Presentation July 30, 2014



# AGENDA

- Intro and Background
- Proof-of-Concept Thruster Design
- Numerical Results
- Experimental results
- Dielectric Drive
- Q & A

# CANNAE BREAKTHROUGH

## **Imagine a space program with:**

- No on-board propellant requirements
- Reduced weight of launches
- Increased satellite life cycles and sustainment
- Reduced costs to achieve GEO
- Significantly reduced material failure due to limited moving parts
- Persistent ISR

## **Imagine the ability to meet key DoD and USG challenges:**

- Stealth
- Self-Healing satellite systems
- Constellation operations
- Maneuver and Freighter between LEO and GEO
- Significant reduction in space travel times ( i.e., Mars in 30 days)

**Cannae technology represents  
a next-generation breakthrough**

# BOTTOM LINE

## Cannae has developed 2 breakthrough thruster designs

- Cannae I:
  - A POC Type I Drive developed 7-10  $\mu\text{N}$  sustained thrust using 10.5 watts of input power
  - Numerical modeling indicates thrusts  $> 10 \text{ N}$  using less than 10 watts of RF power (in high Q structures)
  - Larger satellite operations
- Cannae II: Precision satellite movement
  - sustained 30-40  $\mu\text{N}$  in NASA tests

## Key Take Away(s):

- Requires NO on-board propellant
  - Limitless thrust capability
  - Reduces signature – no off-gassing
- Delta V is only limited by available power
- Ability to change orbit and inclination at will
- Ability to scale from cube sat to large satellites and deep-space missions

# TYPE I CANNAE DRIVE

- Uses a modified superconducting radio frequency (SRF) resonating cavity
- Similar to design of an SRF particle accelerator resonant cavity
- Generates imbalance in radiation pressure to create thrust

Type I Cannae Drive technology is based on SRF LINAC technology

# SRF LINEAR ACCELERATOR



The Type I Drive is based on existing SRF cavity technology

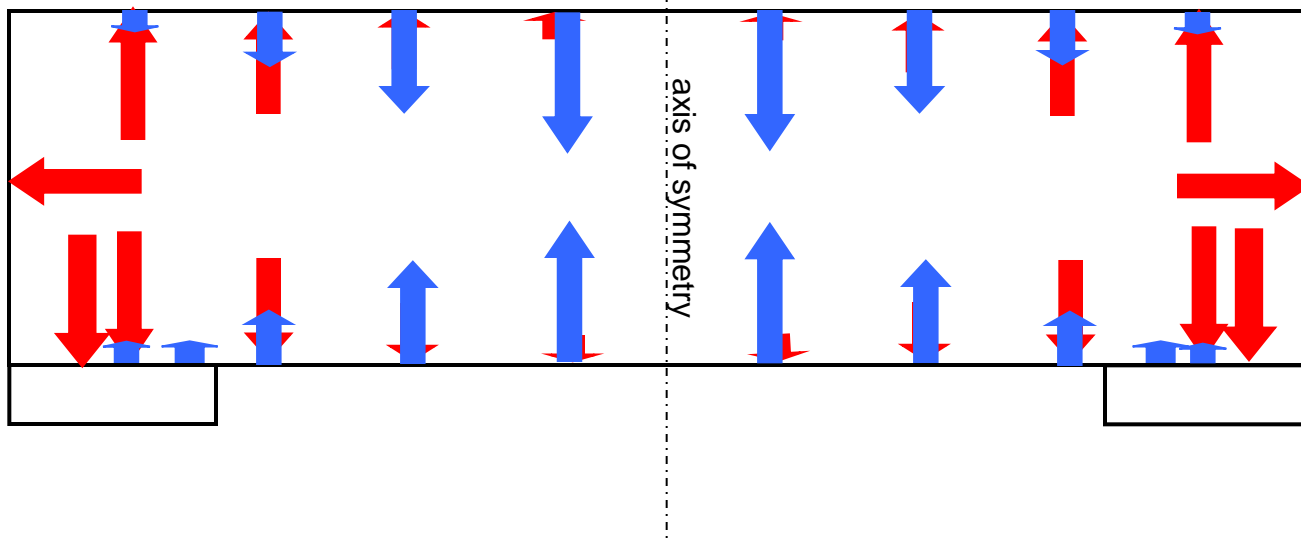
## CANNAE DRIVE PROOF-OF-CONCEPT (POC) CAVITY



The Type I Drive cavity is based on LINAC cavity design but has several significant design distinctions

# LORENTZ FORCES ON A $TM_{010}$ RESONATING CAVITY

$$F = q (E + v \times B)$$



Slots are located in areas of high H-field and low E-field



The slots of the Type I POC cavity induce a radiation pressure imbalance on the cavity when operated with a  $TM_{010}$  wave

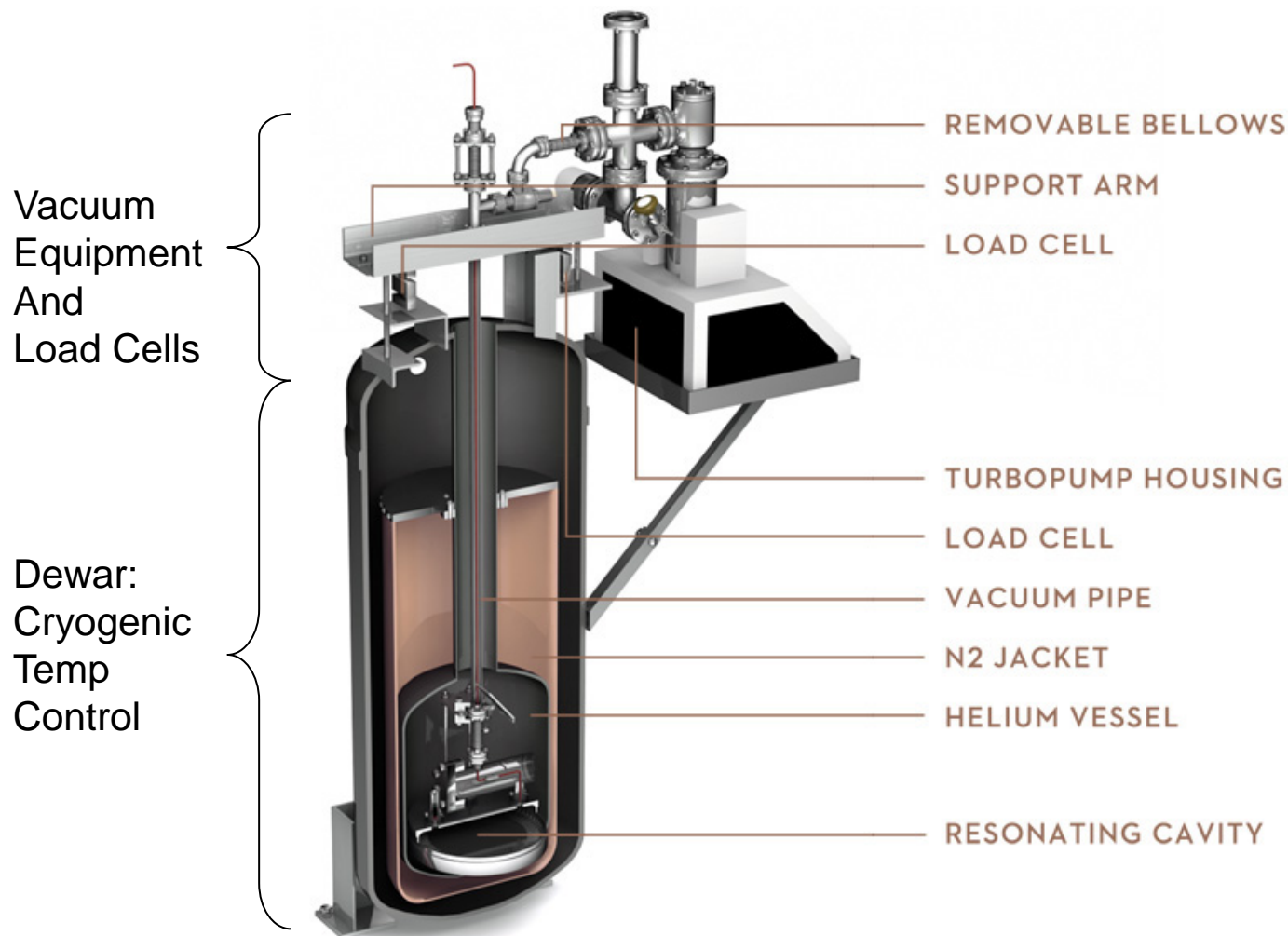


## TYPE I PROOF-OF-CONCEPT EXPERIMENTAL RESULTS

- A superconducting proof-of-concept (POC) cavity was tested in January 2011
- Niowave, Inc. (Lansing, MI) was prime subcontractor
- Force generation of 7-10 mN was measured in numerous runs over 3 test days
- Extensive procedures designed to rule-out potential false positives were used in tests

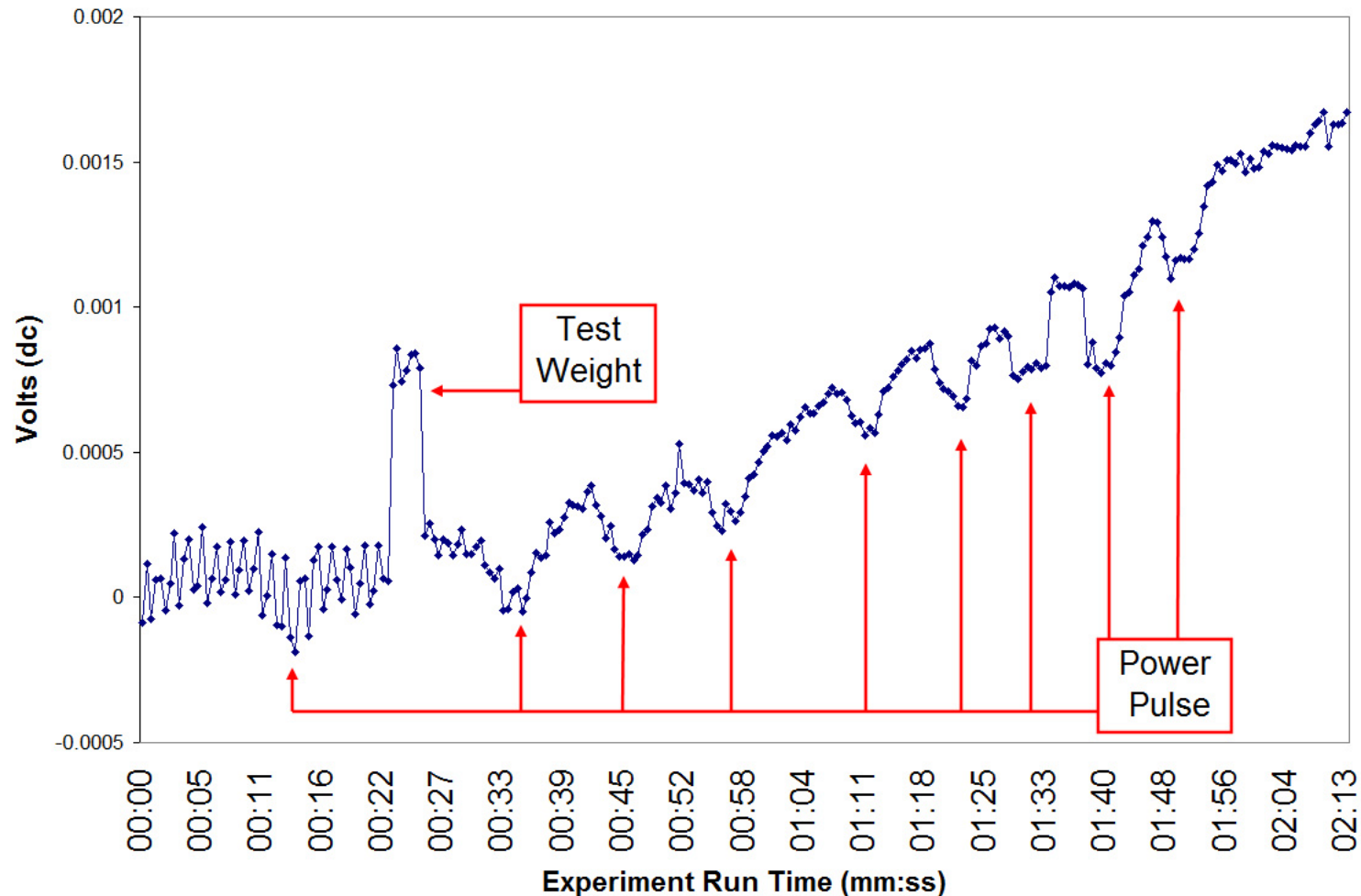
A superconducting Type I POC prototype demonstrated force generation

# TYPE I ASSEMBLED POC EXPERIMENT



POC experiment performed using  
standard SRF LINAC practices

# EXPERIMENTAL RESULTS at NIOWAVE



Experimental results indicate the POC cavity generates a radiation pressure imbalance

## TYPE I CANNAE DRIVE SUMMARY

- A POC Type I Drive developed 7-10 mN sustained thrust using 10.5 watts of input power
- Numerical modeling indicates thrusts  $> 10$  N using less than 10 watts of RF power
- Cannae plans for a superconducting test of an improved Type 1 prototype
- Cannae has patent-pending status on the enabling technology used by the Type I Drive

The Type I Drive has numerical and experimental results demonstrating the technology

## TYPE II CANNAE DRIVE

- Is a dielectrically-loaded coaxial waveguide which is operated with a TEM wave
- Interactions of the TEM wave with the Type I Drive create a force on the system
- Prototype was demonstrated at NASA's Johnson Space Center, Houston, TX in August 2013
- Cannae continues to develop the Type II Cannae Drive

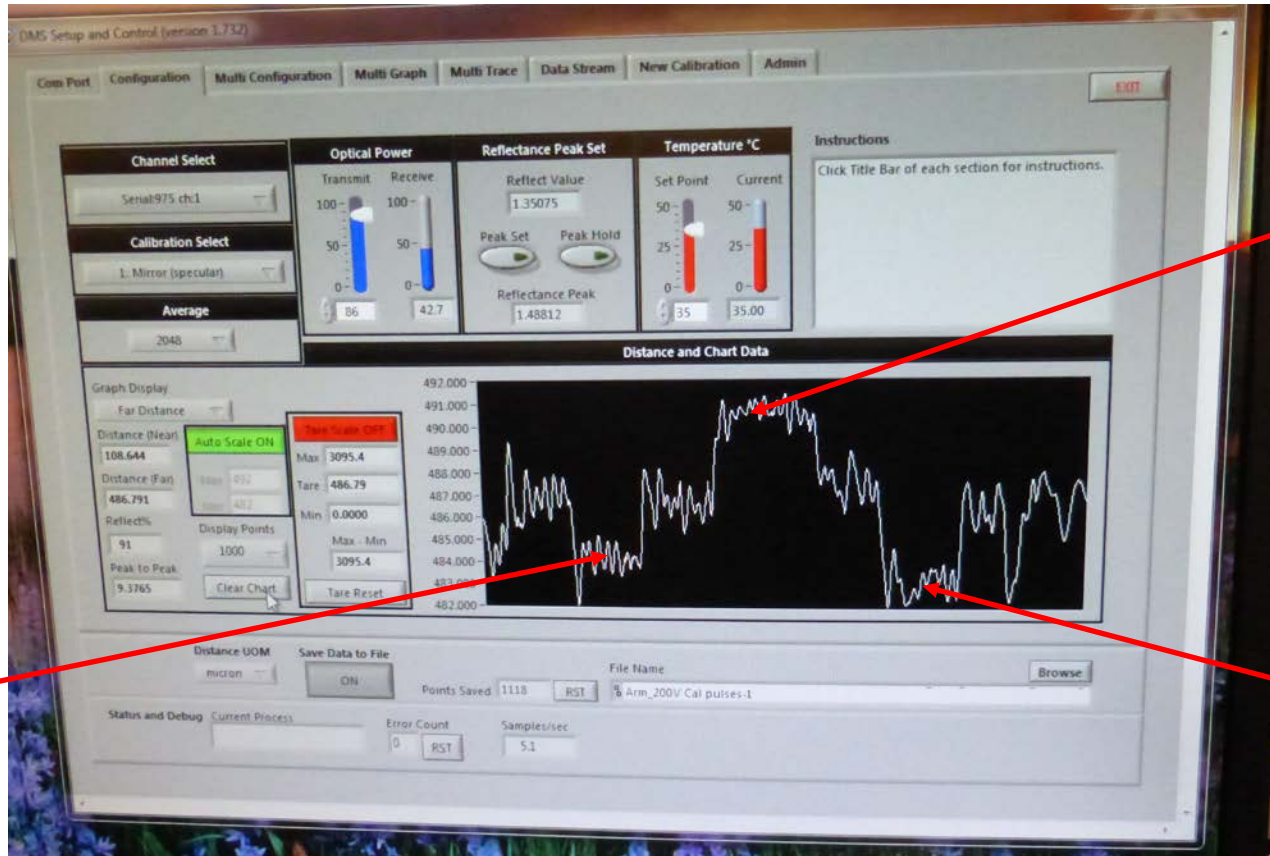
The Type II Drive has developed force sufficient to provide 100 m/s/yr  $\Delta V$  for a 10 kg satellite

# THE TYPE II DRIVE AT NASA JSC



The torsion pendulum isolates the test article from outside forces

# A SUCCESSFUL TEST PULSE AT JSC



Calibration Pulse

Test Pulse

Calibration Pulse

The test pulses show sustained force generation for duration of power pulse to the test cavity



## TYPE II SUMMARY

- A POC Type II Drive developed 30-40  $\mu\text{N}$  sustained thrust, sufficient force to maintain the LEO orbit of a small (10 kg) LEO satellite
- Cannae continues developing the Type II technology
- Cannae has patent-pending status on Type II Drive technology

Type II Drive has already demonstrated sufficient force to be useful in space propulsion apps

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