

REPORT DOCUMENTATION PAGE

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14. ABSTRACT

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MEMORANDUM FOR PRS (In-House Contractor Publication)

FROM: PROI (STINFO)

17 May 2002

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2002-114**
David Kirtley (ERC) and John Fife (PRSS), "Modeling, Simulation, and Design of an Electrostatic Colloid Thruster" (Viewgraphs only)

29th IEEE International Conference on Plasma Science (Statement A)
(Banfe, Alberta, Canada) (Deadline: 26 May 2002)

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement, b.) military/national critical technology, c.) export controls or distribution restrictions, d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.

Comments: _____

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2. This request has been reviewed by the Public Affairs Office for: a.) appropriateness for public release and/or b) possible higher headquarters review.

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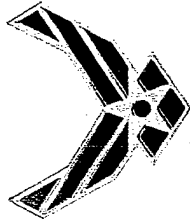
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4. This request has been reviewed by PR for: a.) technical accuracy, b.) appropriateness for audience, c.) appropriateness of distribution statement, d.) technical sensitivity and economic sensitivity, e.) military/national critical technology, and f.) data rights and patentability

Comments: _____

APPROVED/APPROVED AS AMENDED/DISAPPROVED

PHILIP A. KESSEL Date
Technical Advisor
Space and Missile Propulsion Division



Modeling, Simulation, and Design of an Electrostatic Colloid Thruster

David Kirtley

J. M. Fife

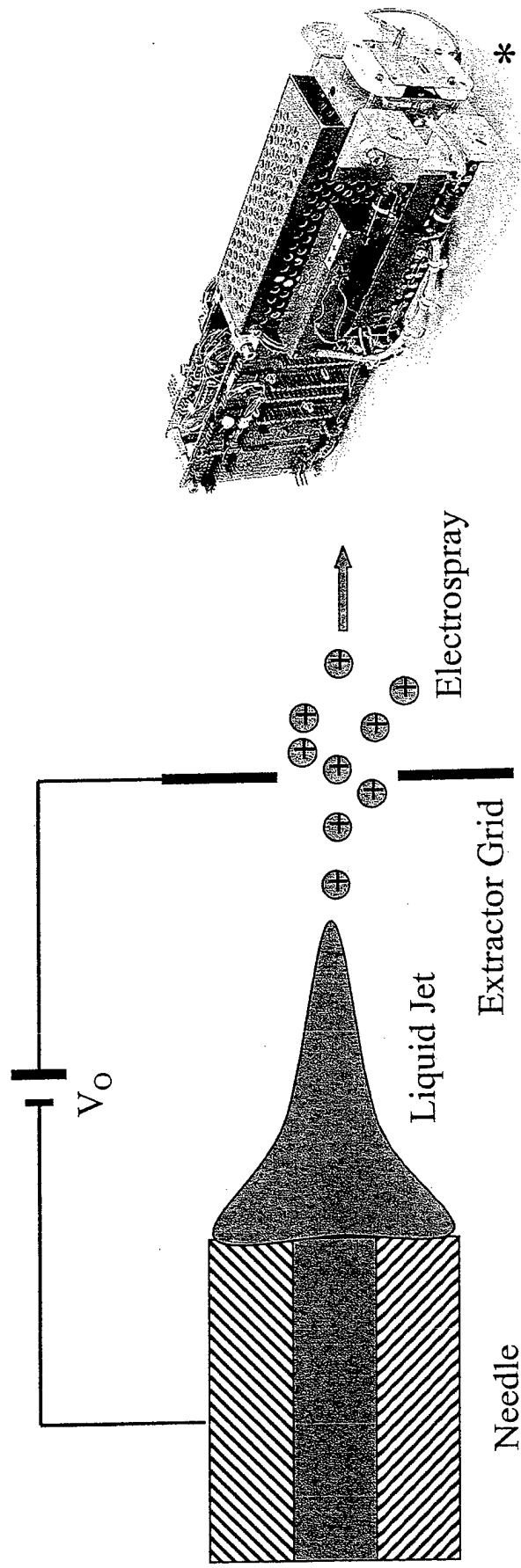
28 May 2002



- Colloid Introduction
- Design Process
 - OTS Modeling, Simulation
- Particle Tracking Analysis
- Non-Ideal Acceleration Voltages
 - Turn-On, Turn-Off, Dispersion, Off-Axis
- Preliminary Extraction Models
- Performance Optimization



Colloid Introduction



•Colloid Engine Theory:

- Particles with Large mass/charge enable higher thrust density Ion (electrostatic) engines
- Use electric fields to extract charged high-conductivity liquid droplets (electro-spray)
- Accelerate particles at high velocities (up to 1500s) and high efficiency (to 90%)
- Arrays of small needles that each provide small thrust ($\mu\text{N}'\text{s}$) with capillary feed systems
- No sheath/ionization losses/complications

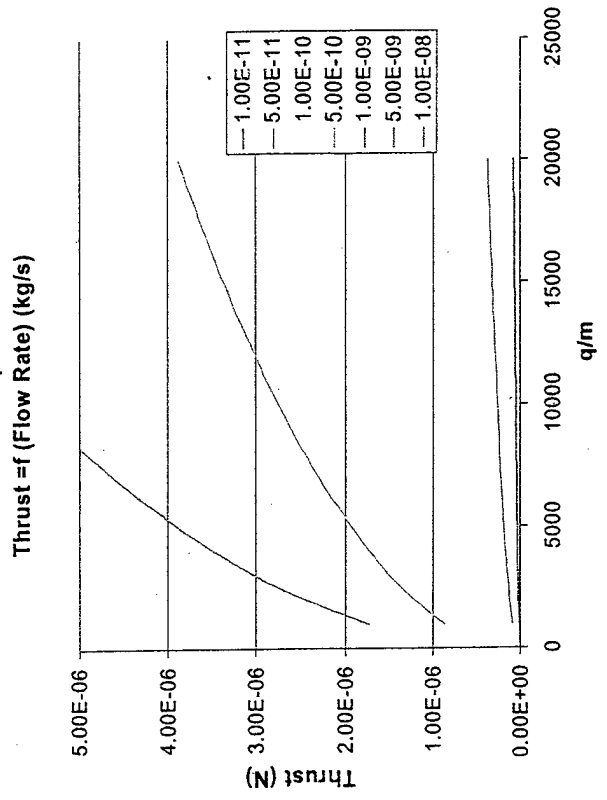
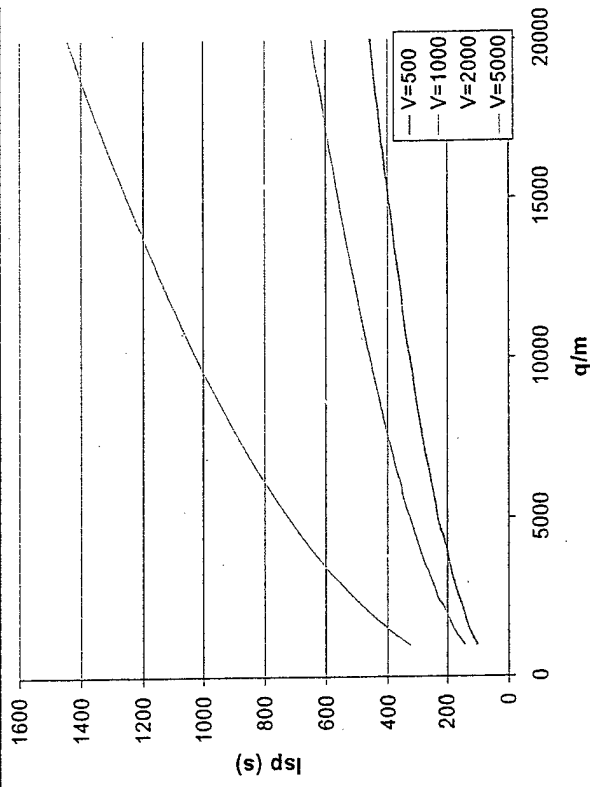


Design Process



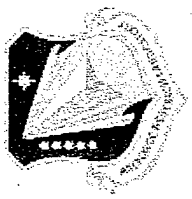
Design Thrusters, Not Electro spray

- Work Backwards
- Locate Missions
 - Performance Characteristics
- Design Acceleration System
 - quantify loss mechanisms
- Design Extraction System
 - Flow system, extraction voltages,
- Optimize design variables

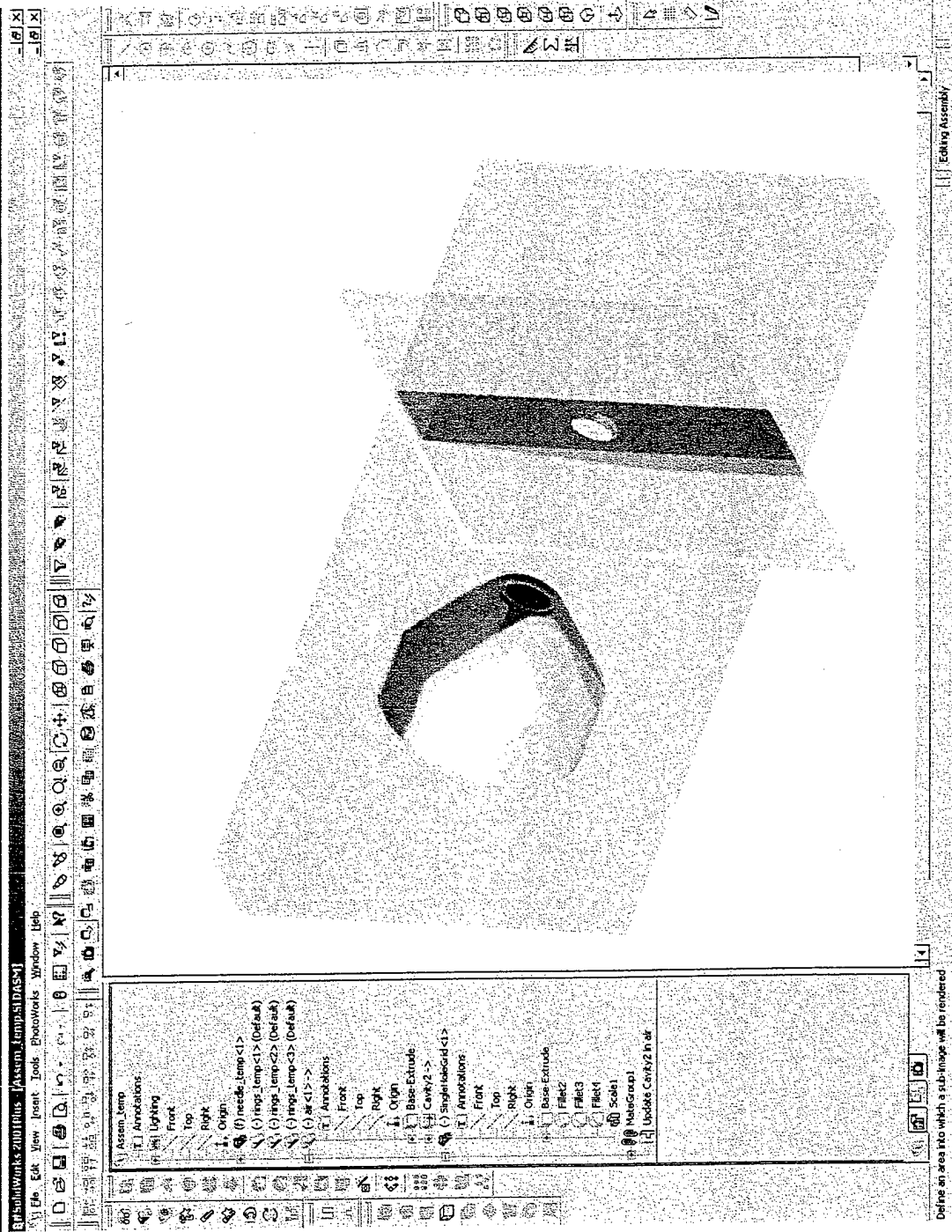




Off-The-Shelf Modeling, Simulation



Use OTS 3D
Modeling, Grid
Generation,
Electrostatic Solvers to
speed/cheapen thruster
design and simulation



Define an area into which a sub-image will be rendered

SOLIDWORKS COLLOID
MODEL



Off-The-Shelf Modeling, Simulation



COSMOSWORKS EMS Gridding

E Resultant	
1	1.173e+005
2	1.075e+005
3	9.774e+004
4	8.797e+004
5	7.819e+004
6	6.842e+004
7	5.865e+004
8	4.887e+004
9	3.910e+004
10	2.932e+004
11	1.955e+004
12	9.774e+003
13	4.450e+003

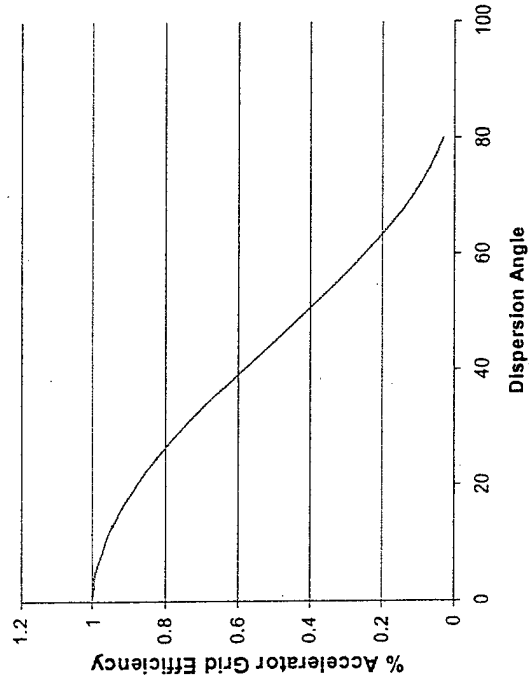
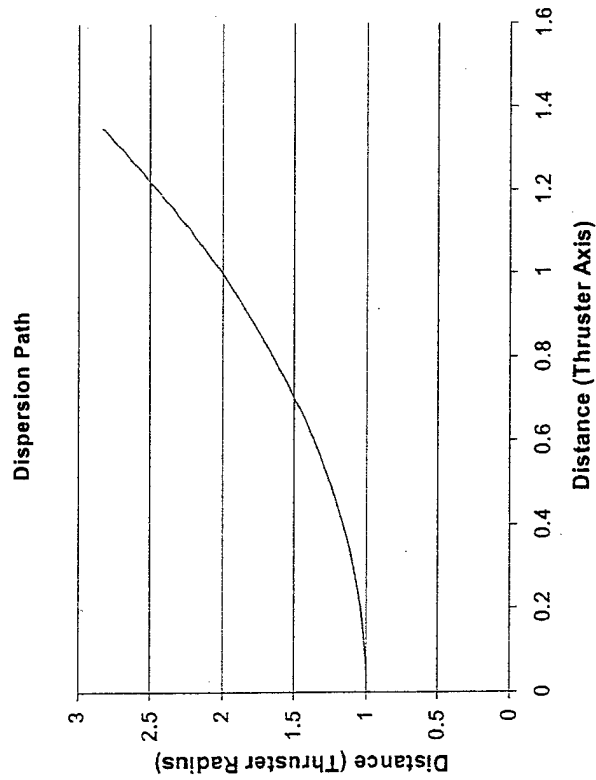
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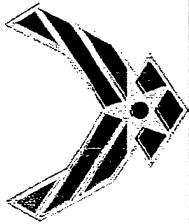


Particle Tracking Analysis



- Straight Dispersion Prediction
- E-field shaping models
- Acceleration/Efficiency losses due to non-uniform E-fields, grids



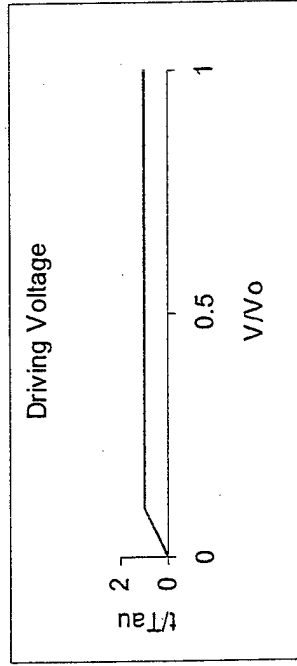


Performance Losses



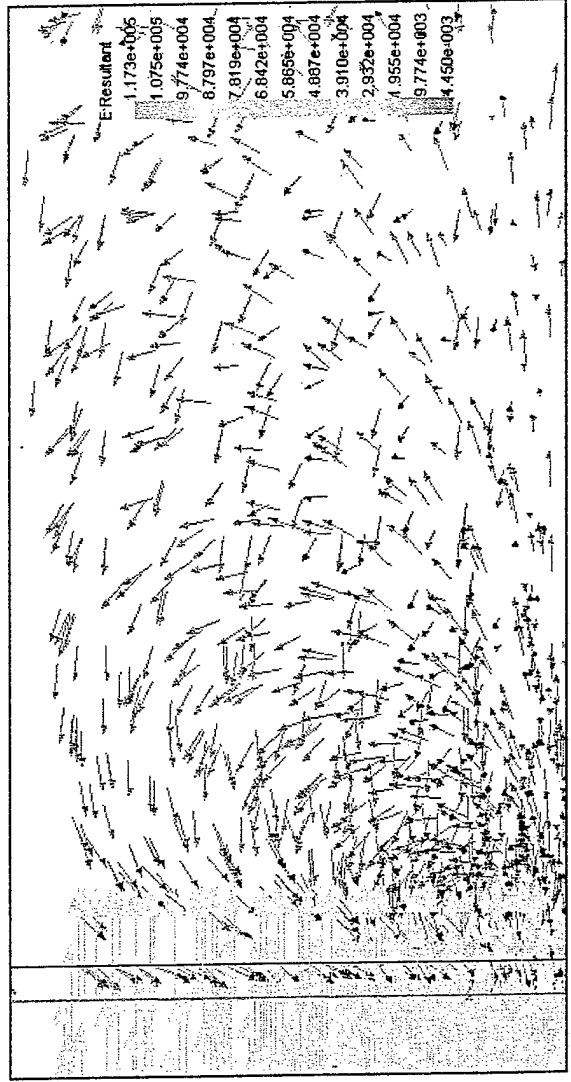
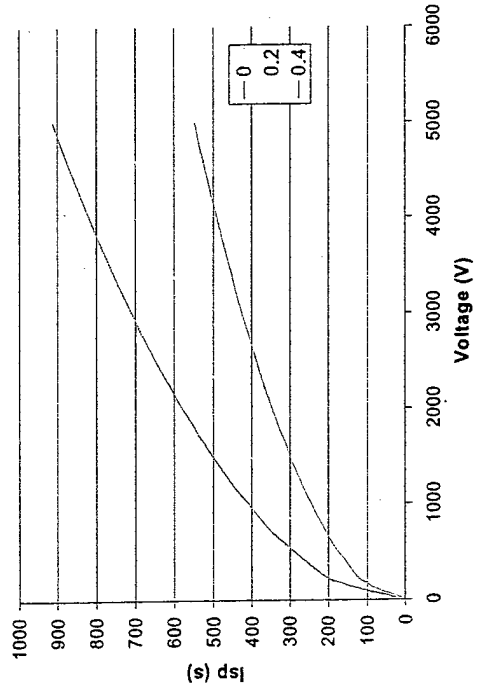
- Turn-On, single droplet
- E-field Incongruities at Interface

- Highly situation dependent
- Developed analysis system for individual cases



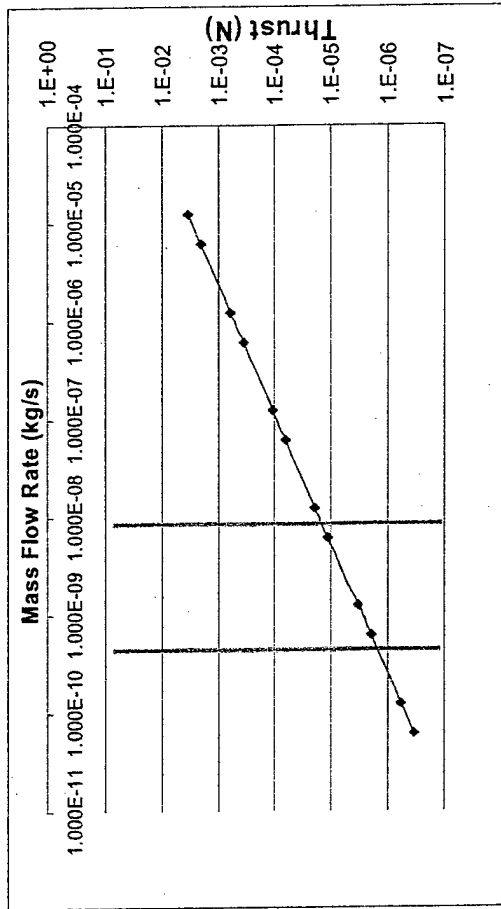
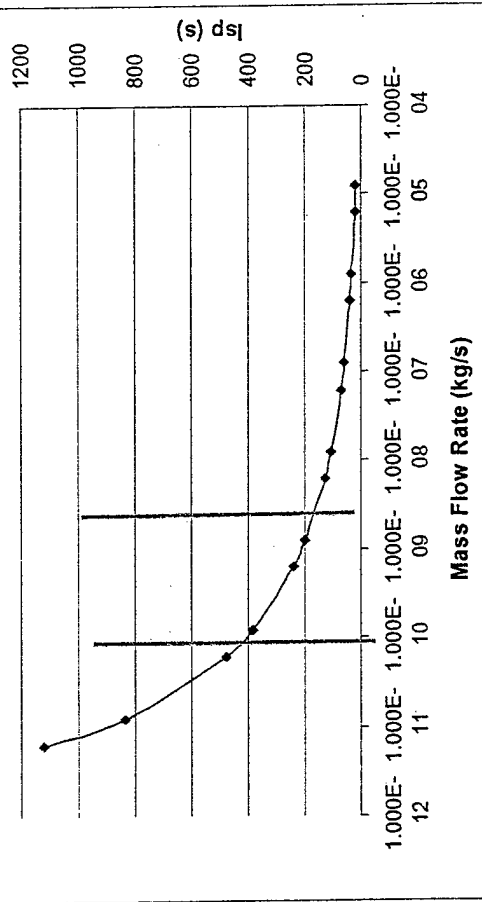
$$x(t) = \frac{q}{m} \Delta x \left(M t_{rise}^2 * t + V \left(\frac{t^2}{2} - t * t_{rise} \right) \right)$$

Isp-V as a function of Rise Time





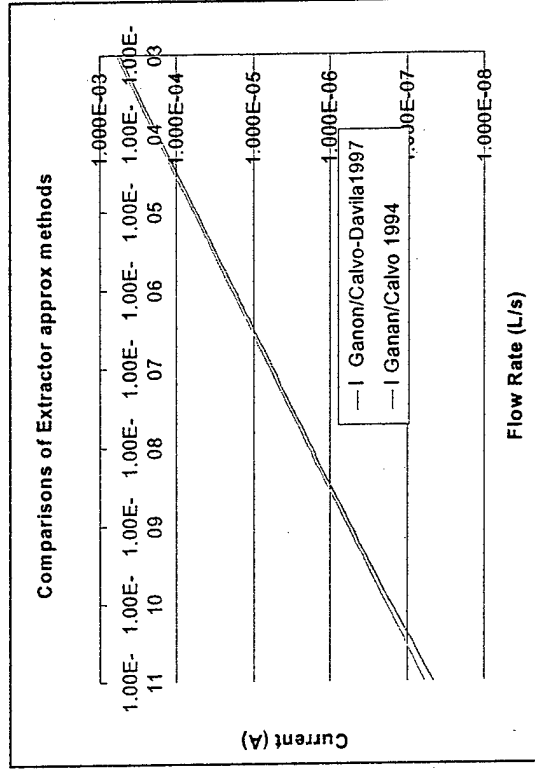
Extractor Modeling



Ganan-Calvo 1997, 1994
 De La Mora and Loscertales 1993

$$\frac{I}{I_0} = 6.2 \left[\frac{Q}{(\beta - 1)^{1/2} Q_0} \right]^{-2.0}$$

$$\frac{d}{d_0(\beta - 1)^{1/3}} = 1.6 \left[\frac{Q}{(\beta - 1)^{1/2} Q_0} \right]^{-1.0}$$





Conclusion



- Presented is a modeling design process for a colloid micro-thruster
- Acceleration Grid Effects
- Extractor Grid Effects
- Performance Predicting, Optimization



References



- *Stanford Colloid Micro-Thrusters, Prof. Mark Cappelli et al.
- Ganan-Calvo, A.M. et al. Current and Droplet size in the Electro spraying of liquids. Scaling laws. 1996
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- Cloupeau and Prunet-Foch. Electrohydrodynamic-spraying functioning modes: a critical review. Journal of Aerosol Sciences, 1994.