MEMS Technology for Jet Fuel Atomization

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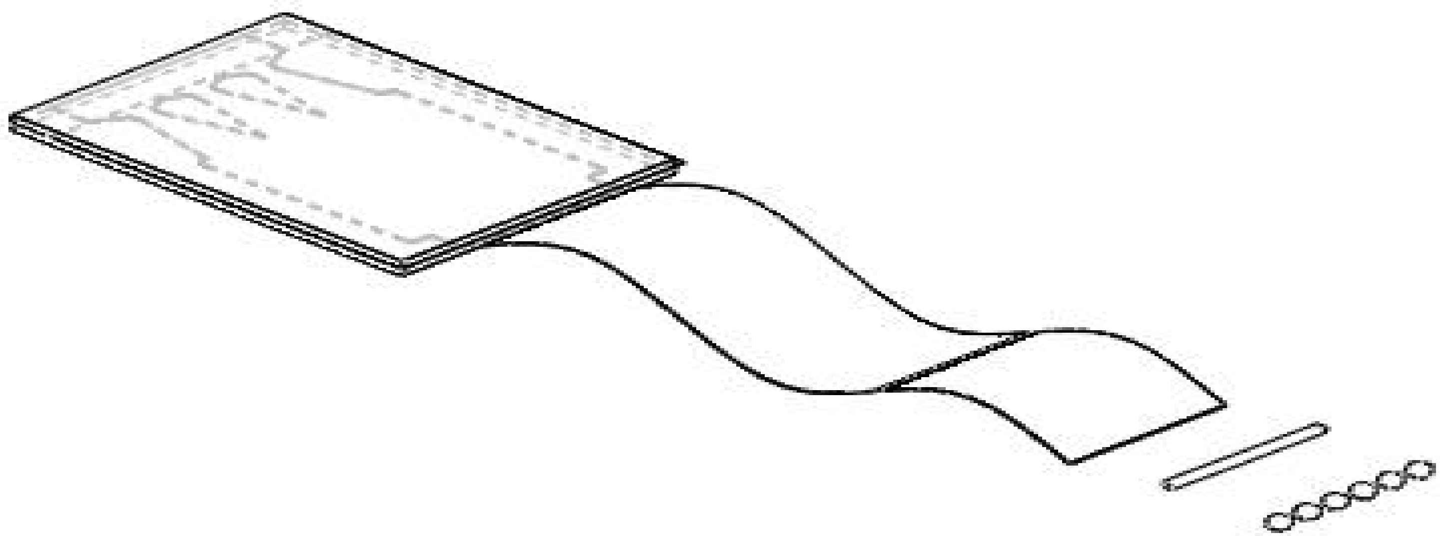
TDA Research, Inc



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Outline

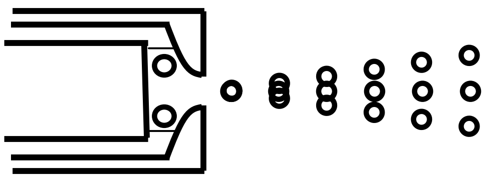
- Objective
- Atomizer technologies
- MEMS atomizer
- Approach to design, build and test
- Conclusions

Objective

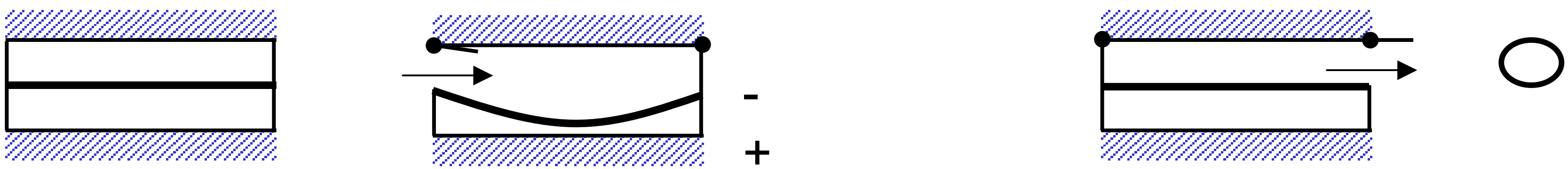
- Develop a MEMS atomizer to produce small (<50μm) droplets
  - improve gas turbine flameholding
  - reduce emissions

Baseline Technologies

- Air blast / air assist (Many types; internal mixed type shown here)



- Others: Simple Orifice, Poppet Orifice, Ultrasonic, Electrostatic Charge, **Inkjet**



Initial state

Applied DC voltage draws down the pressure plate or diaphragm

Remove voltage to release diaphragm and eject droplet

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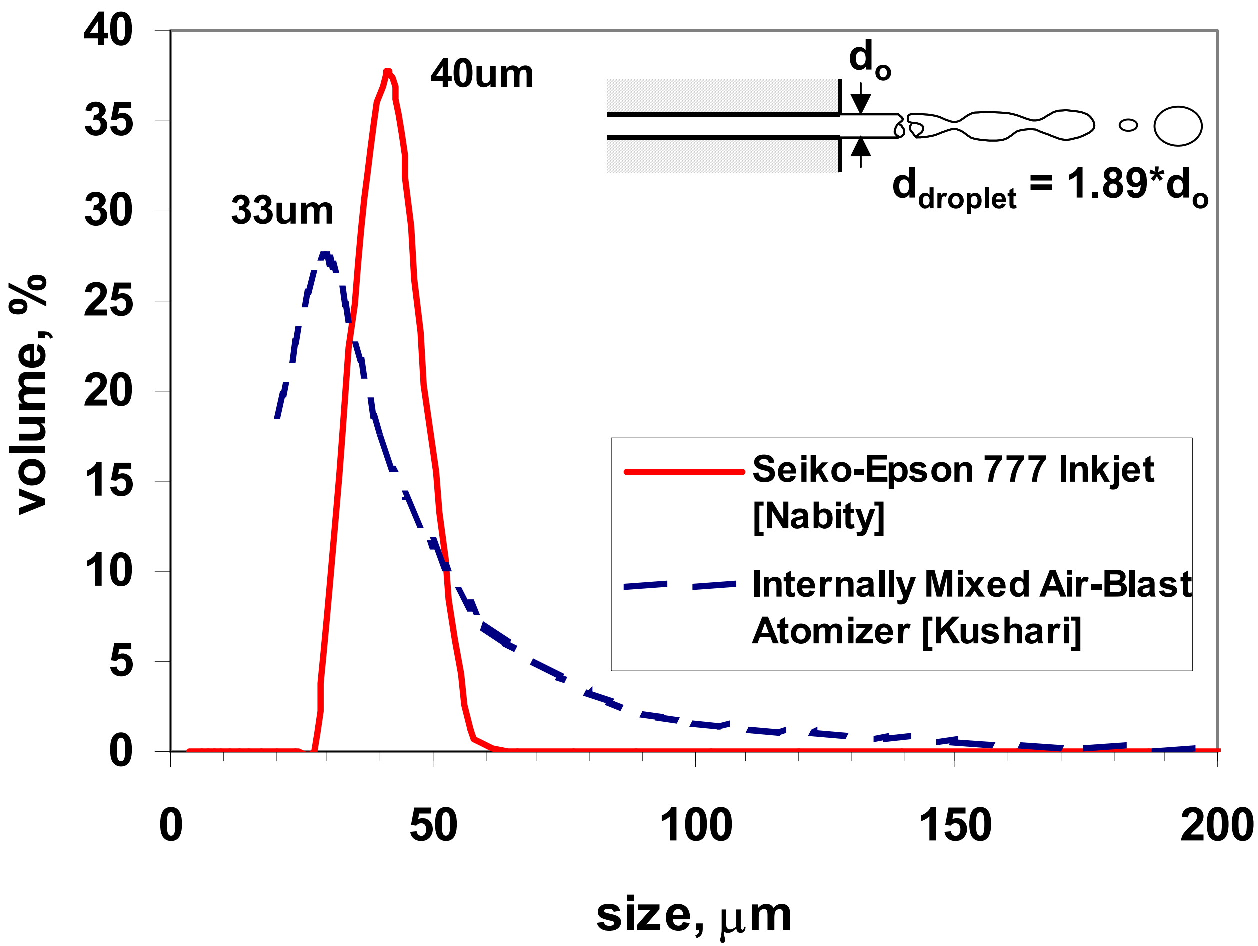
Droplet Size Measurements



A. Kushari, Y. Neumeier, O. Israeli, E. Lubarsky, and B.T. Zinn, "Internally Mixed Liquid Injector for Active Control of Atomization Process," Journal of Propulsion and Power, Vol. 17, No. 4, July-August 2001.

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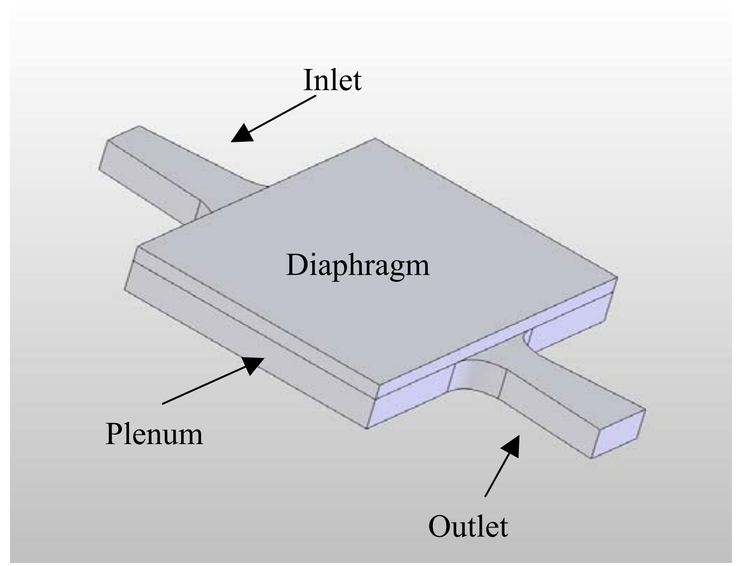
The Basic Design

- Electrostatically actuated diaphragm pump with passive valves:

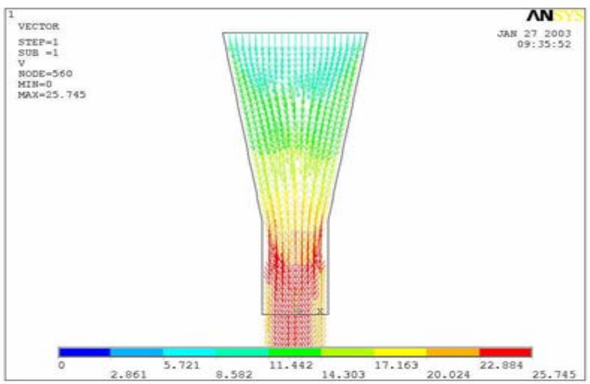
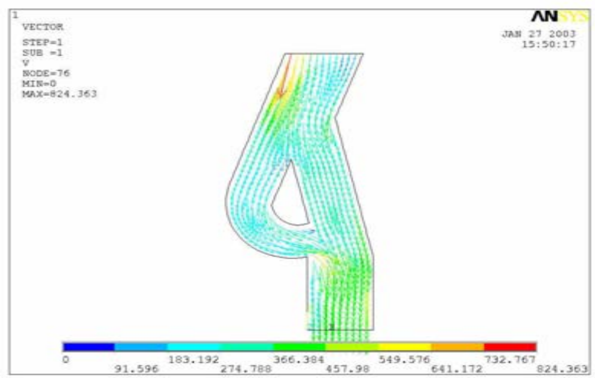
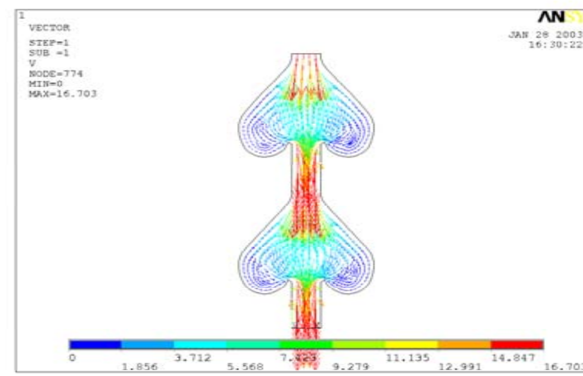
  •Electrostatic for high displacement/low power.

  •Passive valves for simplicity.



What is Important?

- Need high pump efficiency: $\eta = \dfrac{Q_{net}}{Q_{ideal}}$
- Valves are critical

- Dielectric – cleanliness is everything

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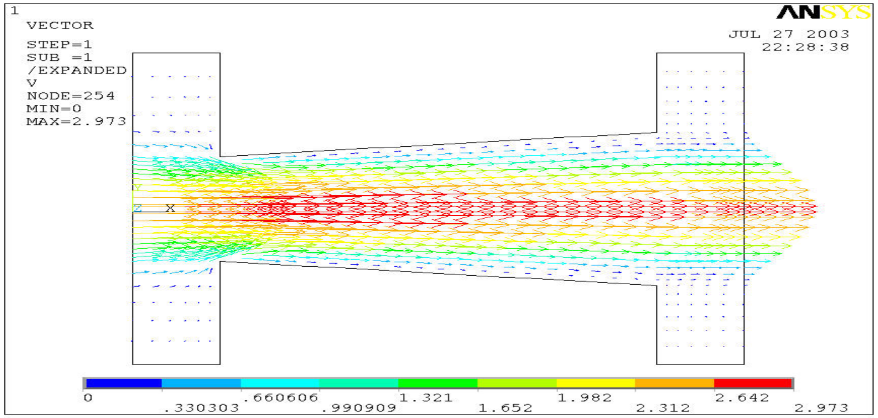
Research

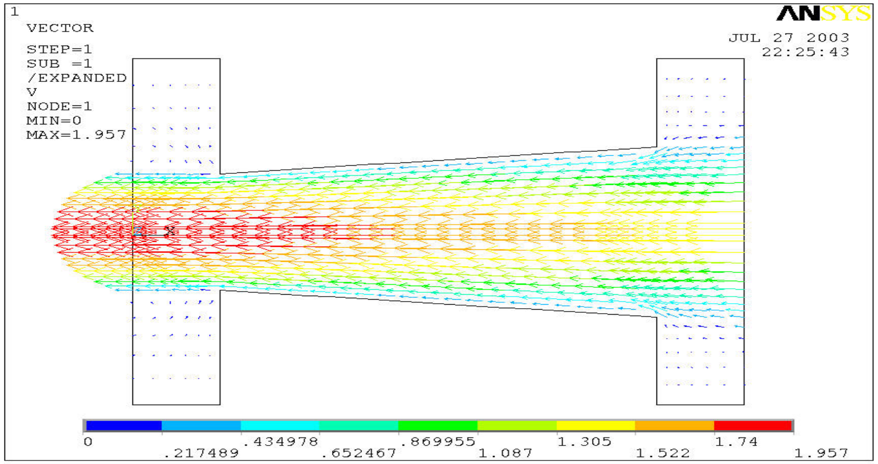
Approach

- Analytical & numerical performance modeling
  - Fuel ejection & droplet formation
  - Micropump operation (especially, the valving)
  - Stiction
- Fabrication
  - Materials, processes and assembly
- Engine integration
- Testing

Fluidic Valve Performance Evaluation



forward



reverse

<u>Flow rectification</u>

Steady	2.2
Periodic	1.4

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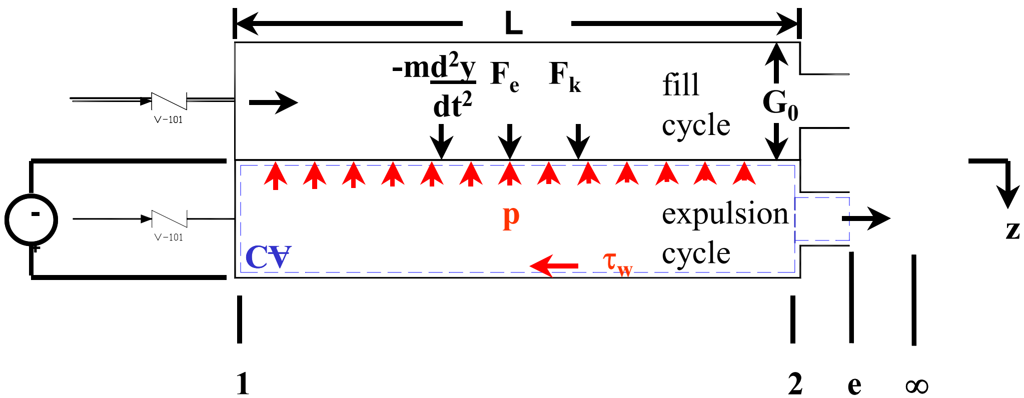
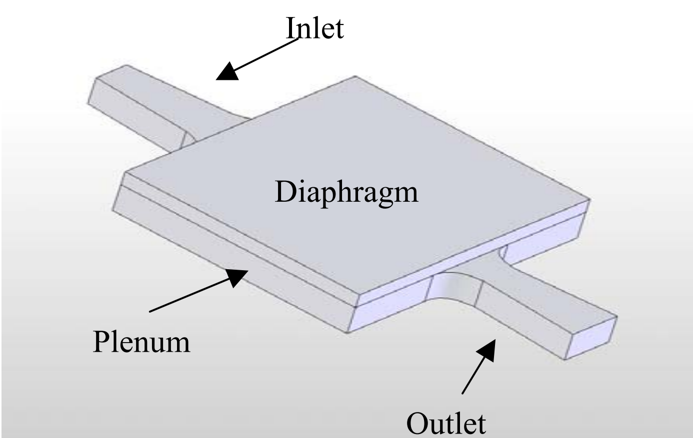
Performance Modeling

- TDA's Quasi 1-D Micropump Model



- ANSYS fully coupled modeling



$L_{diaph} = 1000\ \mu m$

$t_{diaph} = 10\ \mu m$

$t_{plenum} = 100\ \mu m$

$t_{passages} = 100\ \mu m$

$L_{passages} = 330\ \mu m$

$W_{inpassages} = 66.7\ \mu m$

$\alpha_{valve} = 5$ degrees

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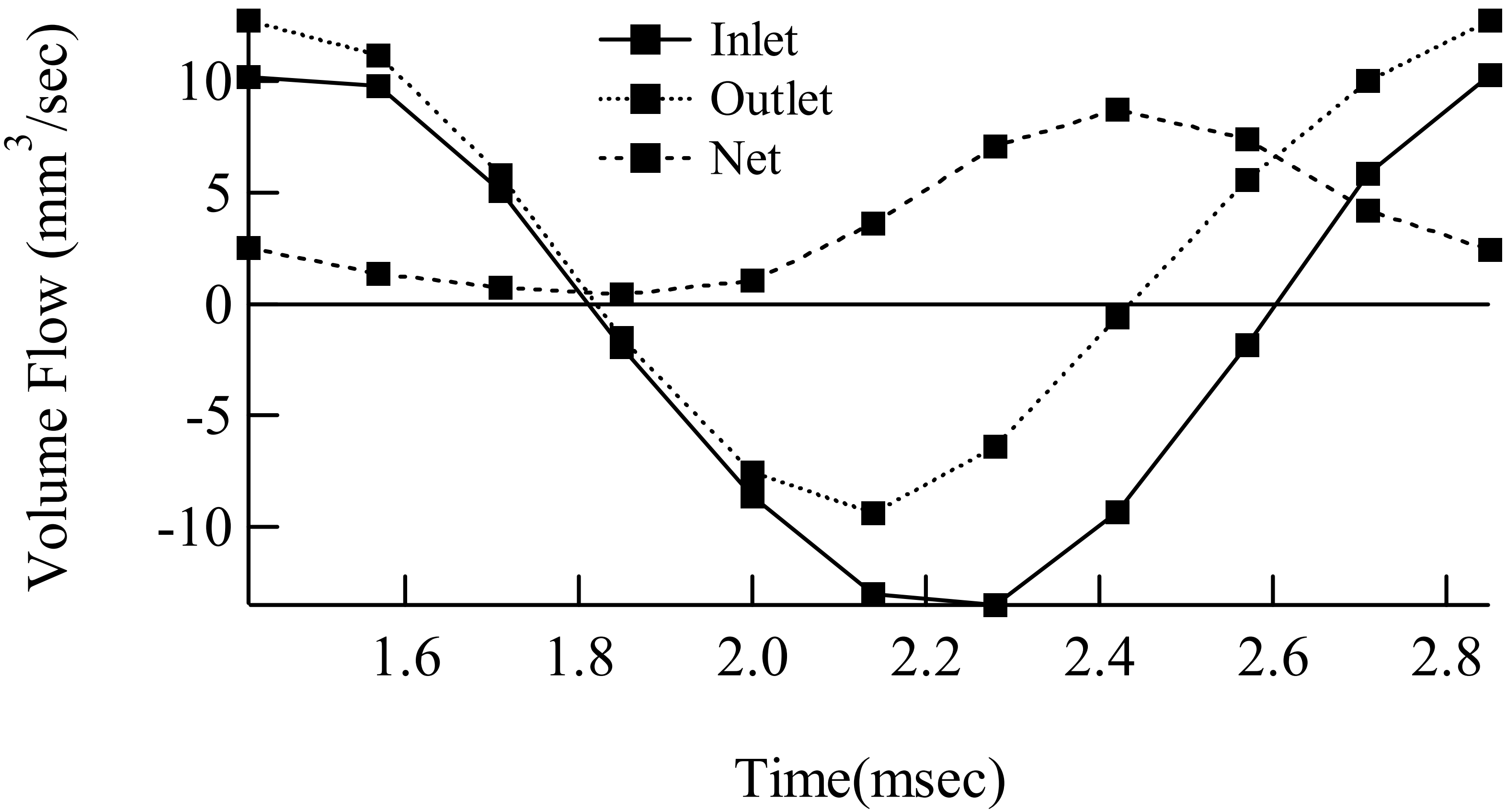
ANSYS Results
(30um sinusoidal deflection at 700 Hz)



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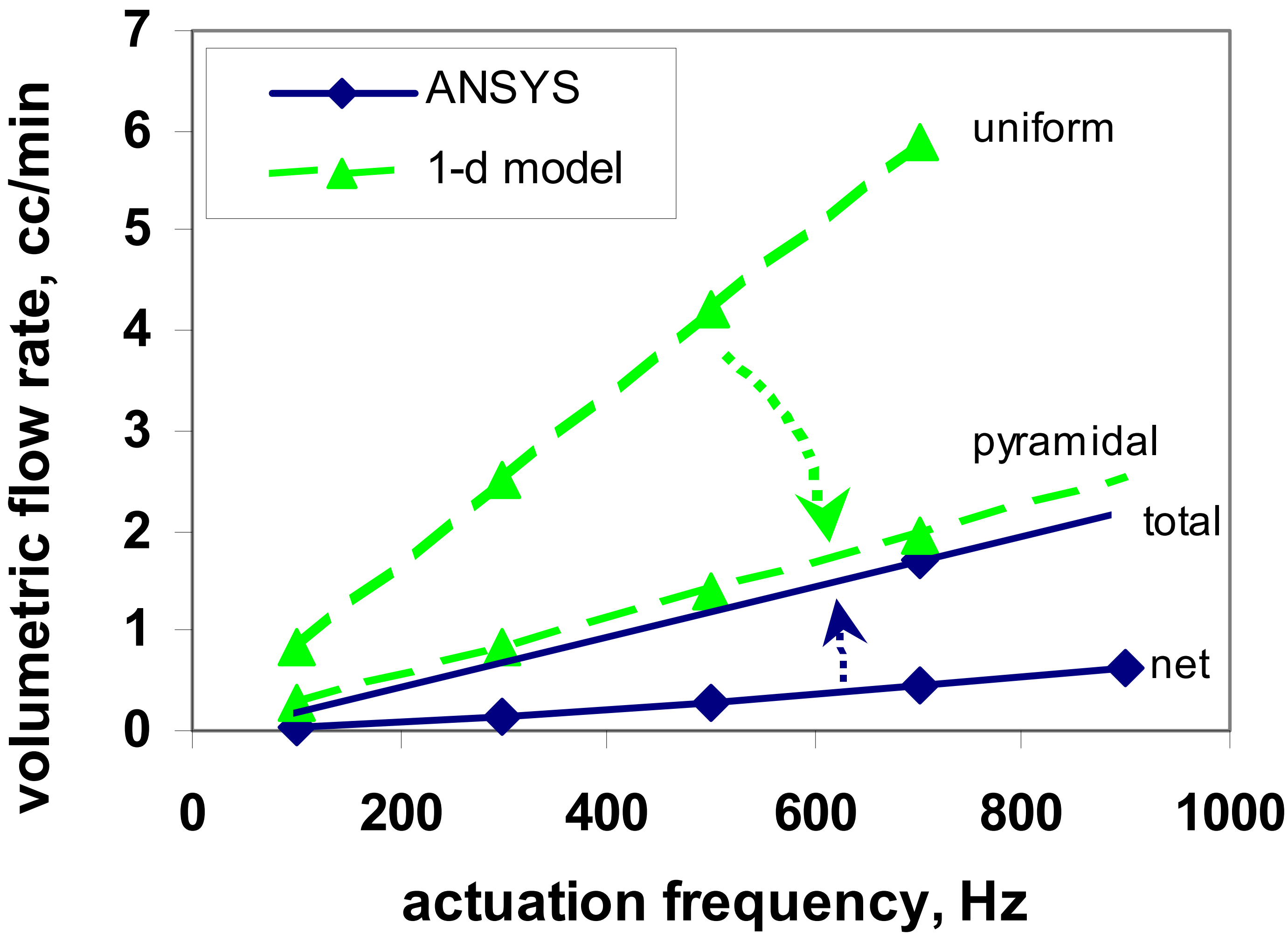
Model Performance Predictions



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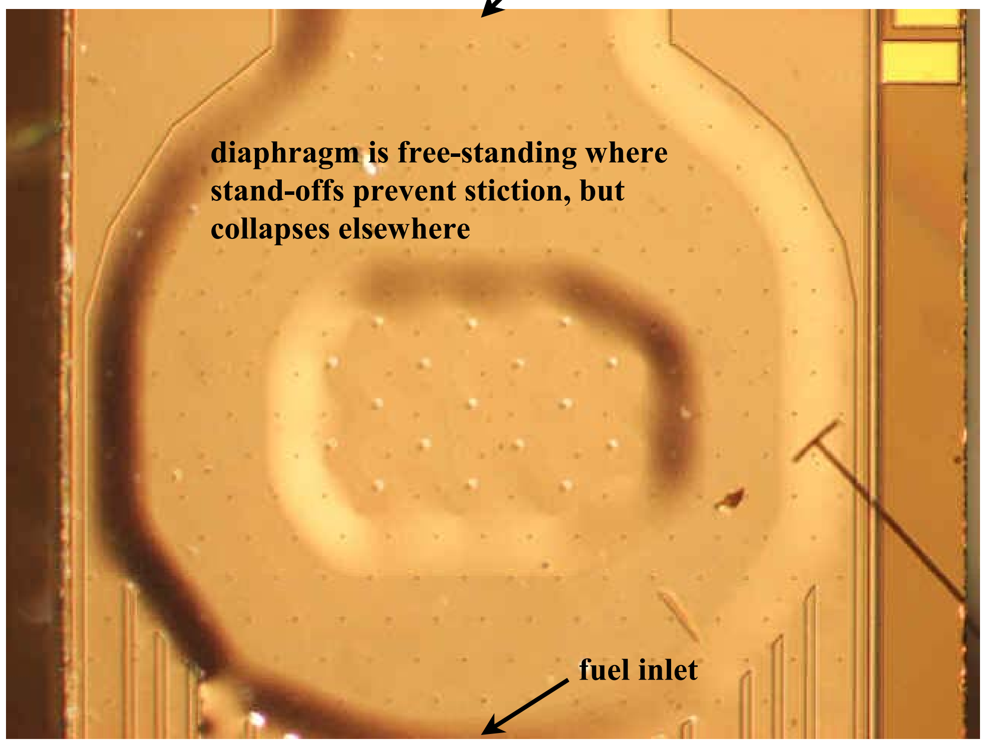
Stiction

- Nemesis to MEMS



- Therefore, use Mastrangelo elastocapillary & peel numbers

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Materials

- Silicon – most commonly used material
  - 3-inch SSP wafer costs about $10
  - <1800°F
- Silicon carbide – 20X the cost, but good to 2900°F
- Silicon carbide nitride – also expensive, but highest temperature and strength

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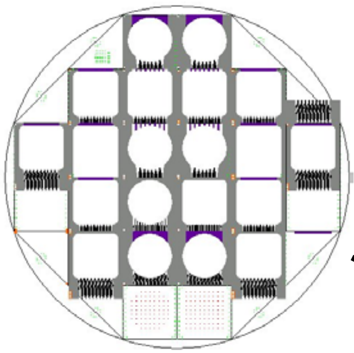
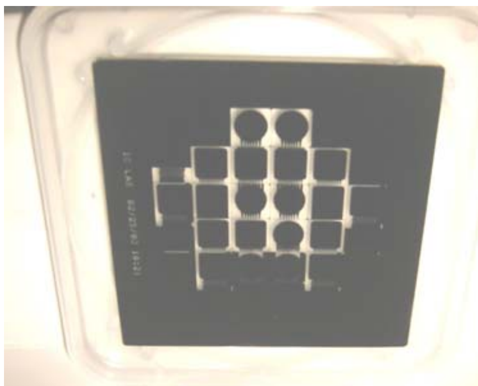
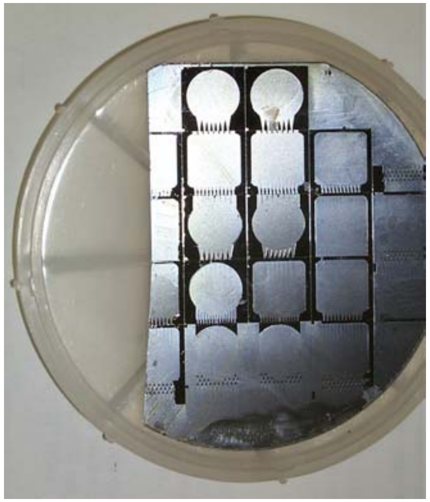
Wafer Level Microprocessing



CAD drawing



Mask



Pattern & etch

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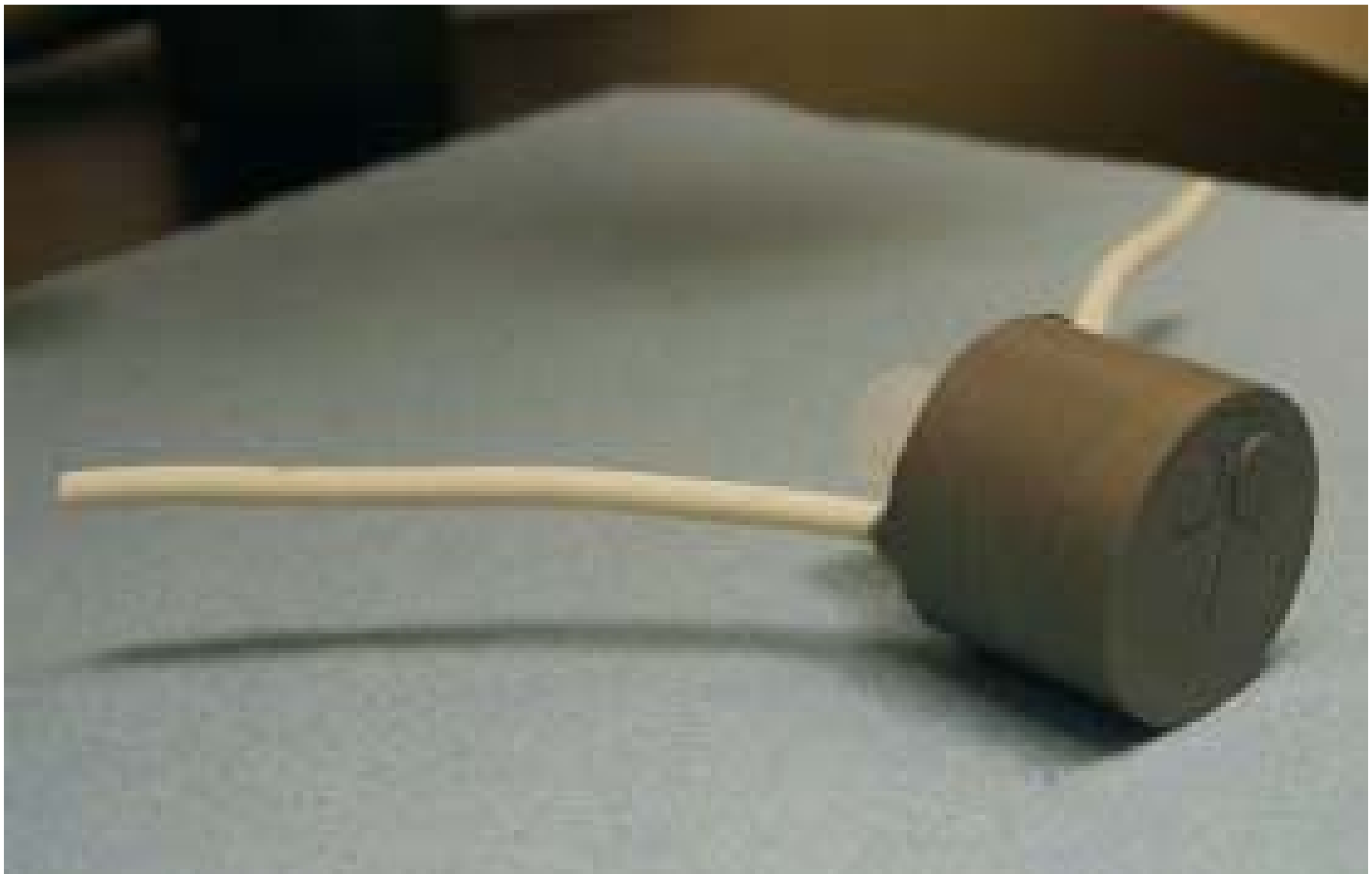
Assembly & Packaging



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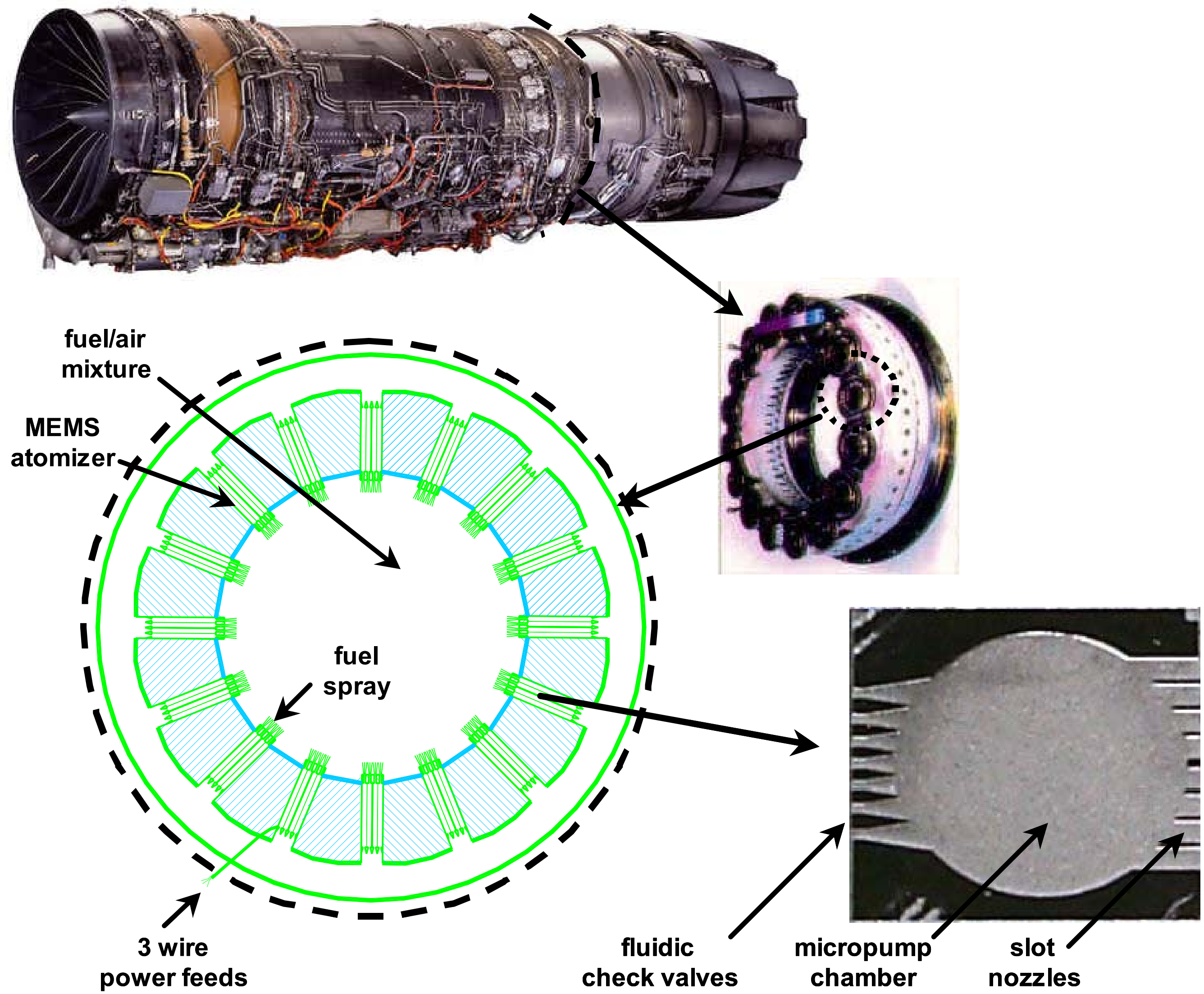
Gas Turbine



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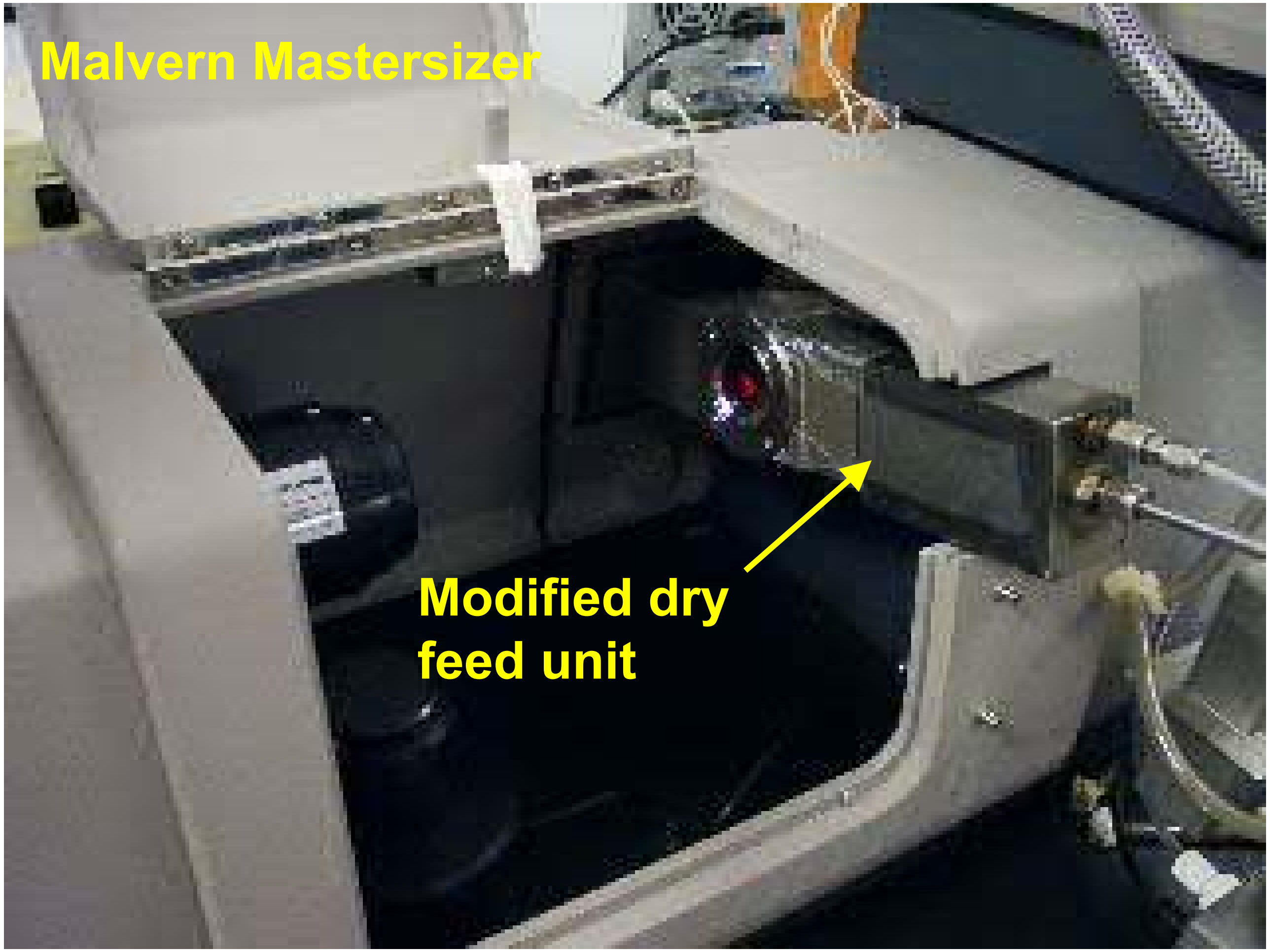
Test Setup



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Conclusions

- Analytical & computational tools Developed
- Design completed
- MEMS fabrication processes defined
- Atomizers built
- Testing underway

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