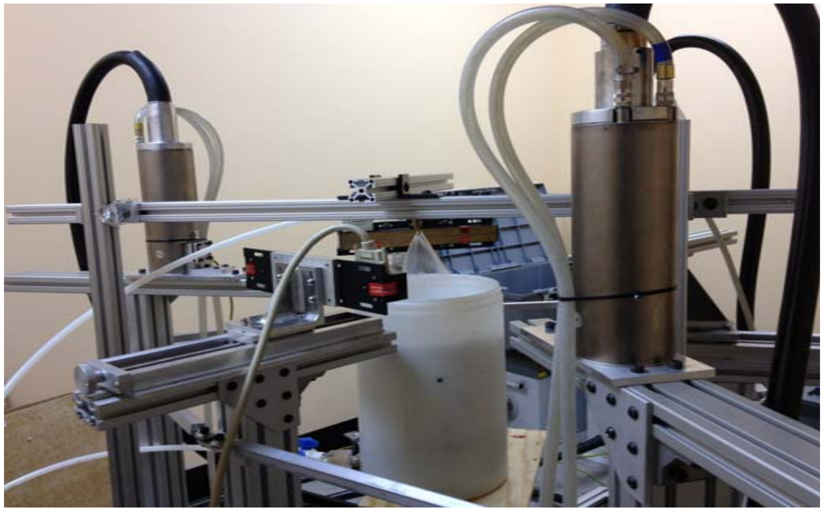
Contract No. FA9300-12-M-1012

Mapping Liquid Mass Fractions in Optically Dense Rocket Combustion Chambers



En'Urga Inc.

Final Report Presentation

1291 Cumberland Avenue, West Lafayette, IN 47906

innovations in quality control

Outline

- **Phase I Objectives**
- **Phase I Results**
- **Phase I Conclusions**
- **Phase II plans**

Phase I Objectives

Objectives

- Establish the feasibility of utilizing X-Ray tomography for studying the near injector structure of dense sprays
- Specific Questions

1) Is it feasible to obtain spatially and temporally resolved X-Ray extinction measurements in high flow rate nozzles?
2) Is it possible to determine the local mass fraction of liquids near the exit plane of the high flow rate injector from these extinction measurements?

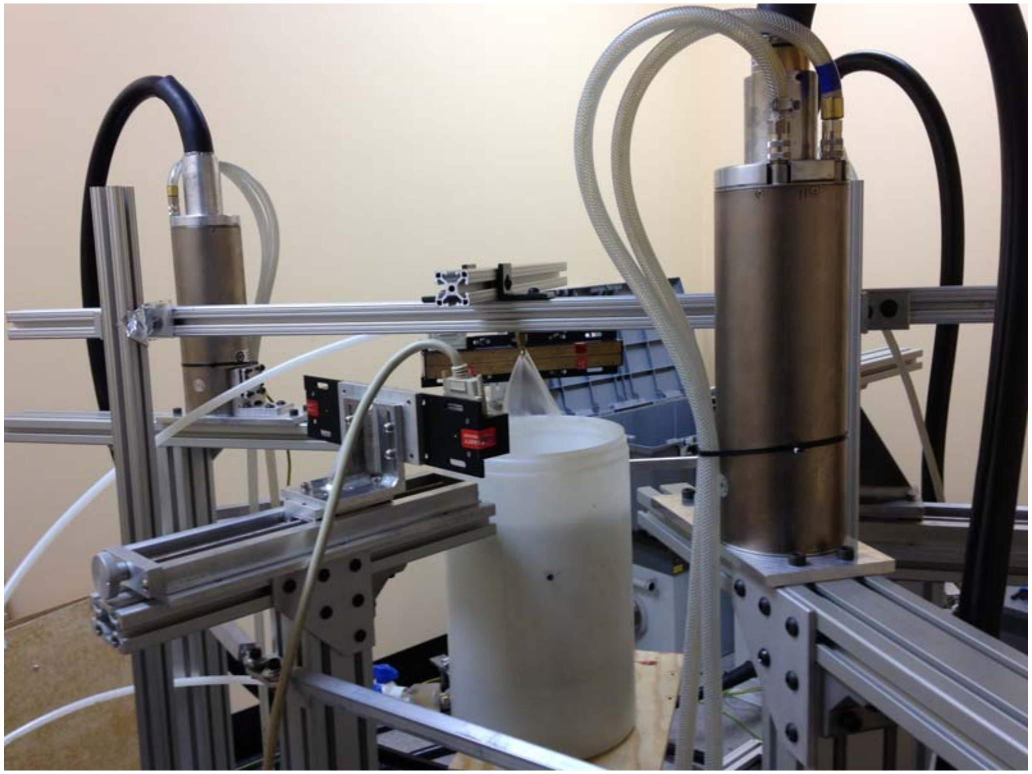
Work Task

- Develop X-Ray system
- Develop the deconvolution
- Evaluate system using a high flow rate industrial nozzle
- Develop concept design for a prototype Phase II

Phase I Results

Experimental Arrangement

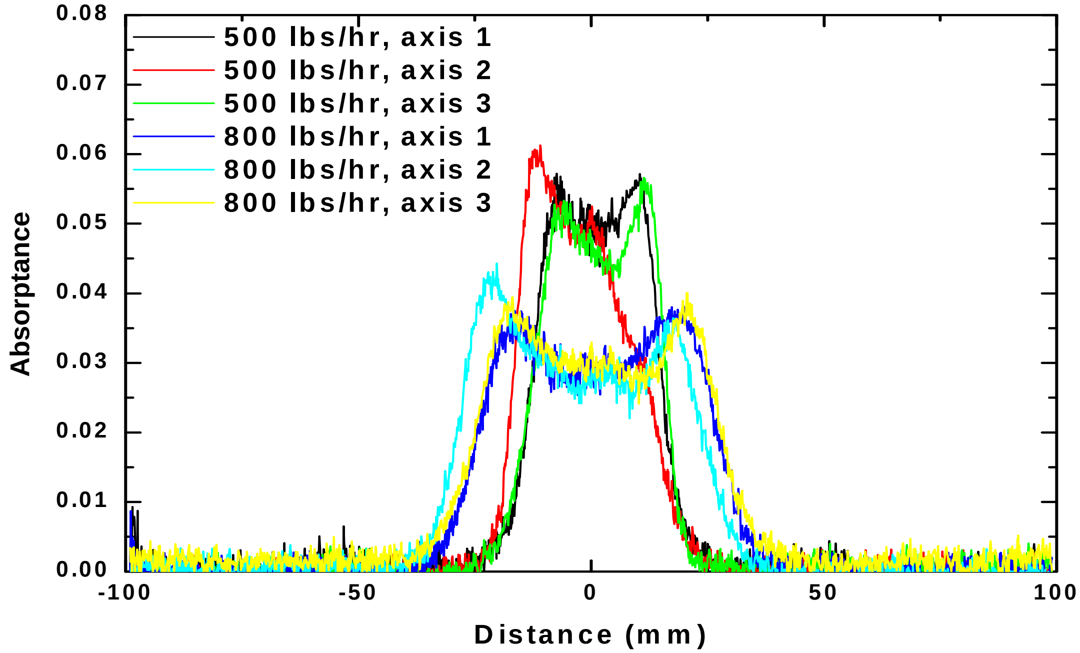
- Fan beam arrangement of 3 sources and 3 arrays



En'Urga Inc.

1291 Cumberland Avenue, West Lafayette, IN 47906

Absorptance Measurements

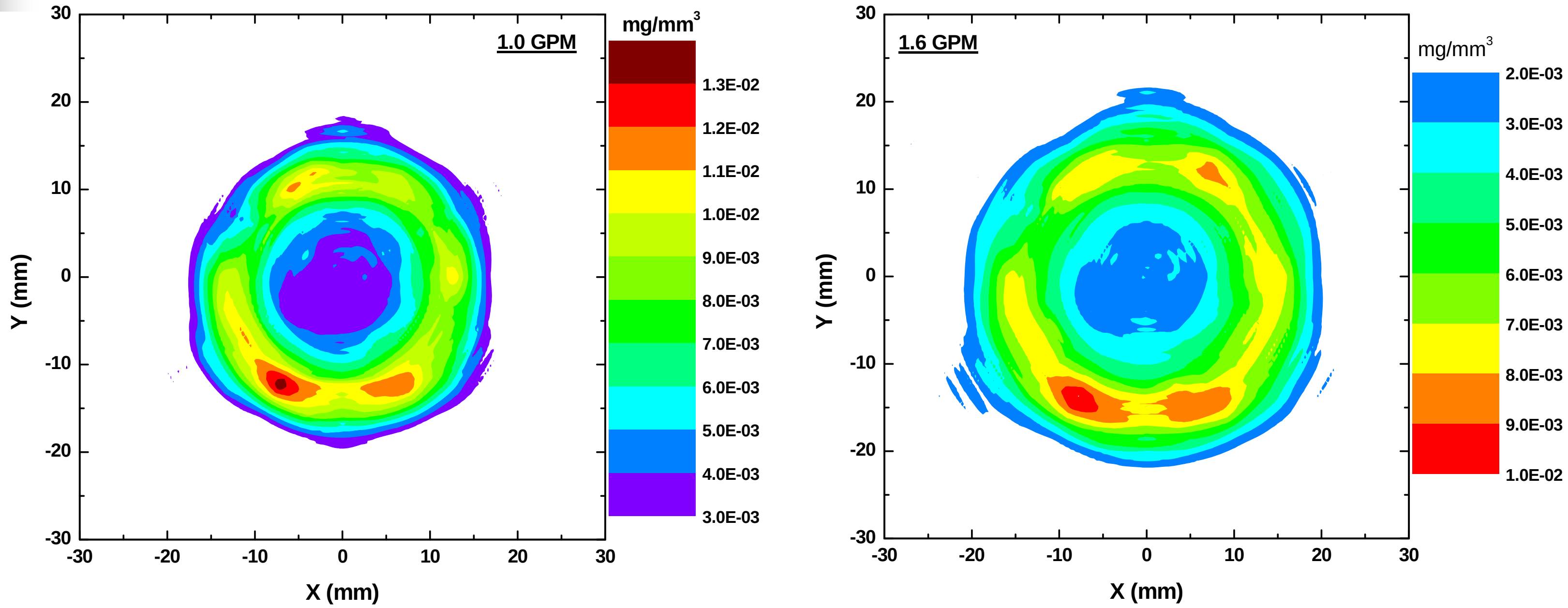


- Peak absorptance < 10%
- Larger flow rate has wider spread

En'Urga Inc.
1291 Cumberland Avenue, West Lafayette, IN 47906

innovations in quality control

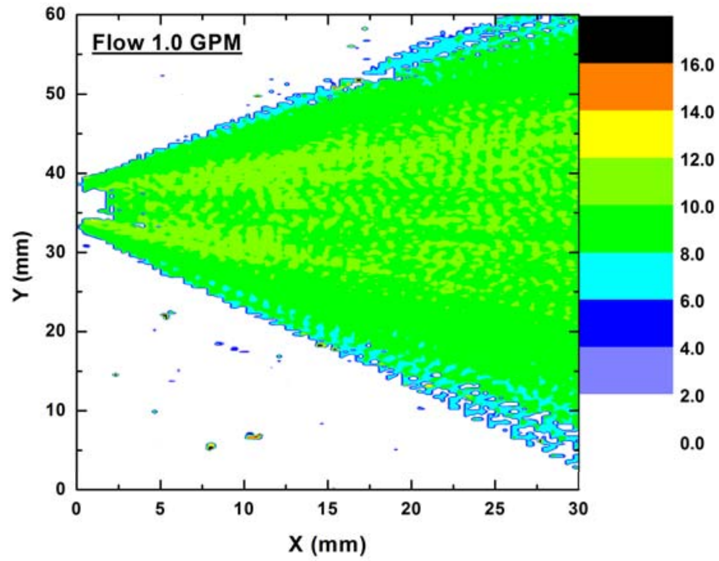
Concentration Maps

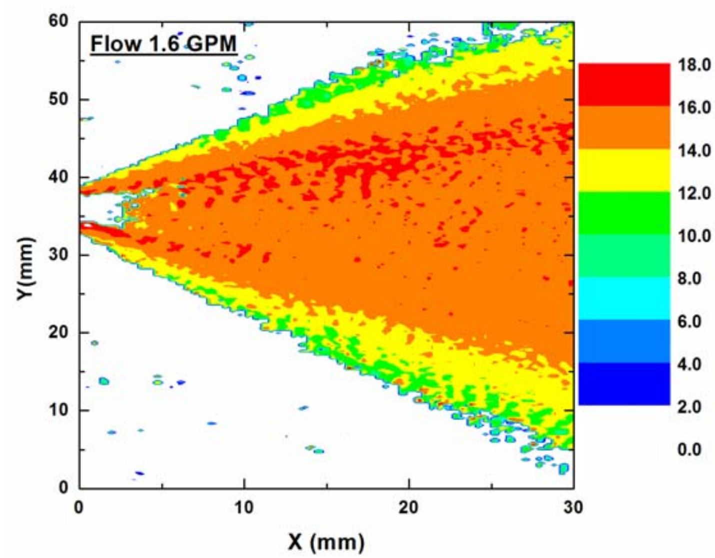


- Deconvoluted results of mass fraction of water
- Lower flow rate has higher local concentration
- High flow rate had larger footprint

Velocity Measurements

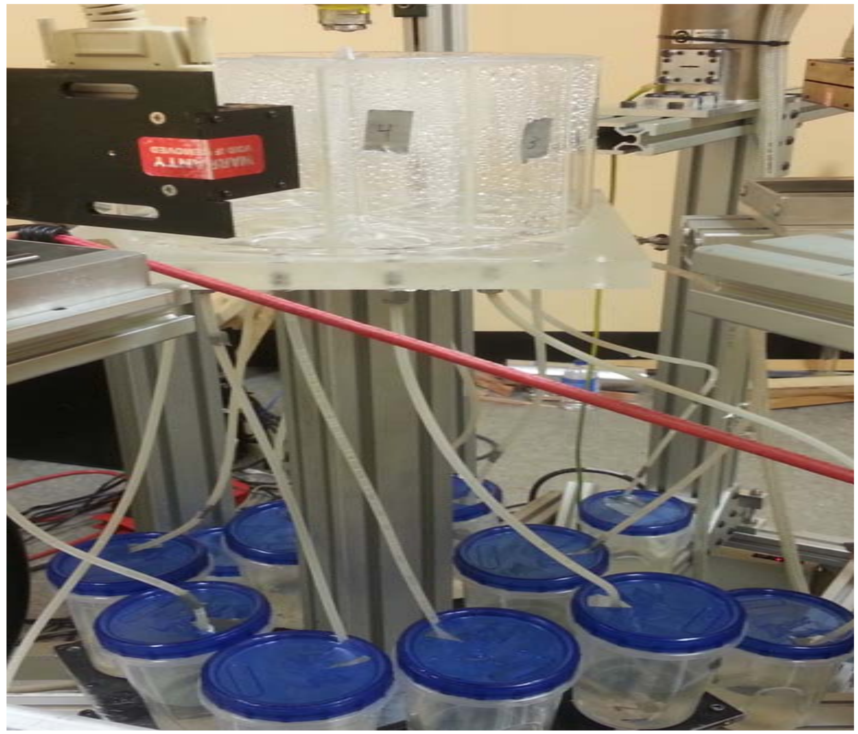
- Velocity required to obtain mass flux for validation
- Statistical Image Correlation Velocimetry used
- Mean velocities much higher at higher flow rate





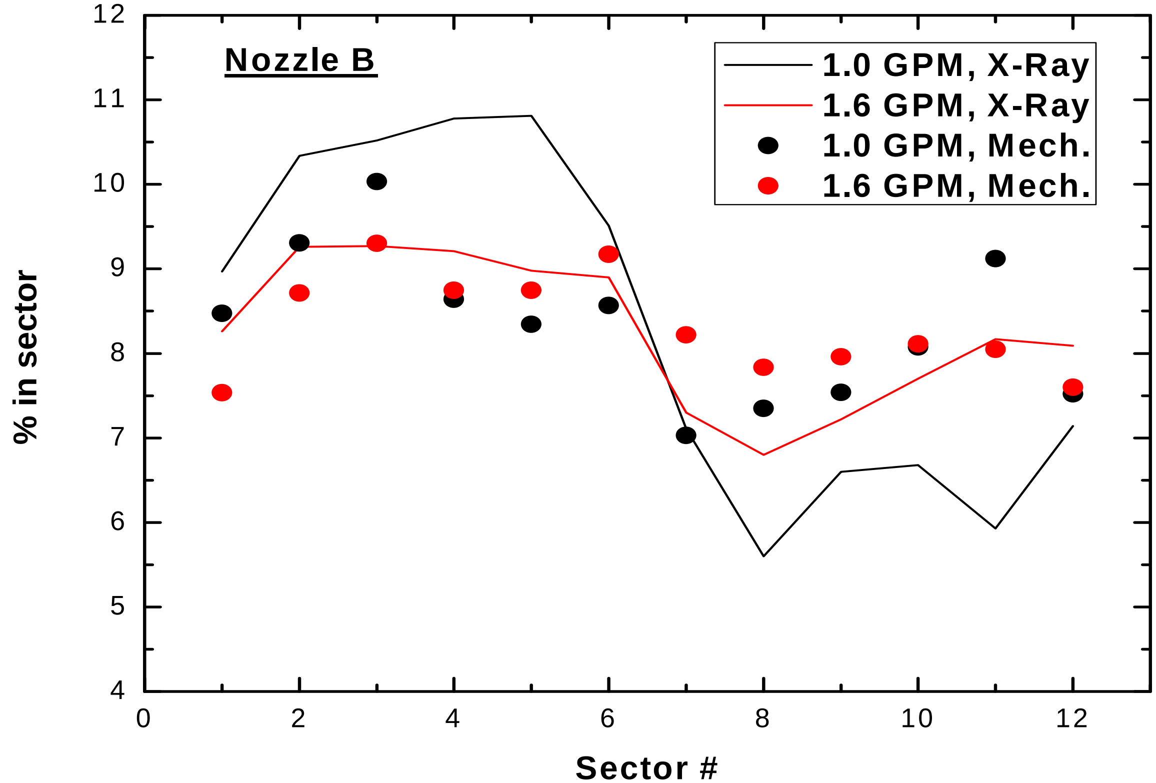
En'Urga Inc.
1291 Cumberland Avenue, West Lafayette, IN 47906

Mechanical Patternator



12 sector patternator, commonly used by nozzle manufacturers

Validation (Mechanical Patternation)



- Similar trends with flow rates and angle
- Results agree with uncertainty of mechanical patternator

En'Urga Inc.
1291 Cumberland Avenue, West Lafayette, IN 47906

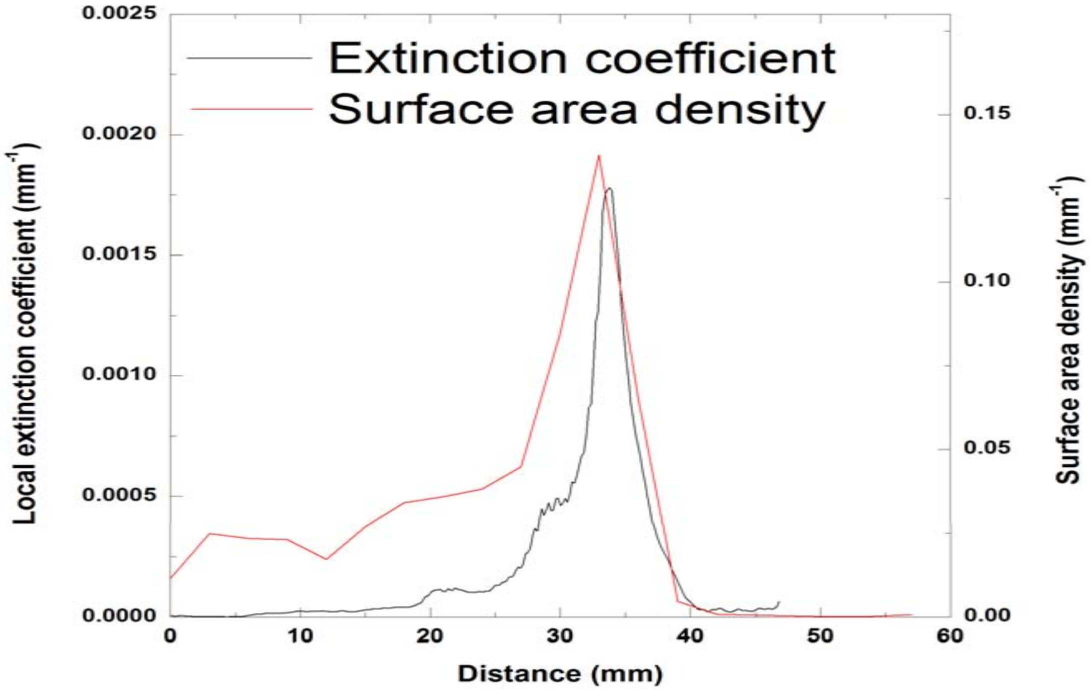
innovations in quality control

Validation (Total flow)

Nozzle	Input Flow (kg/hr)	Total planar mass (mg/mm)	Mean velocity (m/s)	Planar mass flux (kg/hr)
A	227	10.2	5.72	211
A	363	11.1	8.86	353
B	227	7.20	9.44	245
B	363	7.52	14.5	392

- Nozzle A results match flow meter to within 5%
- Nozzle B results match flow meter to within 10%
- Results validate X-Ray measurements within the uncertainty band of the flow meter and the velocimeter

Validation (Optical patternator)



- Only one condition was possible with optical patternator
- Radial peak location very similar

En'Urga Inc.
1291 Cumberland Avenue, West Lafayette, IN 47906

innovations in quality control

Conclusions

- Feasibility of obtaining local mass extinction coefficients was completely demonstrated using two nozzles
- Provides local mass density information in optically dense flows with sufficient spatial and temporal resolution
- With Statistical Image Correlation Velocimetry, the X-Ray tomography system can provide the local mass flux in optically dense sprays
- In conjunction with Optical patternator, provides full planar SMD in sprays