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| Air Force Research Laboratory (AFMC)  
AFRL/PRS  
5 Pollux Drive  
Edwards AFB CA 93524-7048 |

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<th>NAME OF RESPONSIBLE PERSON</th>
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<tr>
<td>Leilani Richardson</td>
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<th>TELEPHONE NUMBER (include area code)</th>
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<td>(661) 275-5015</td>
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MEMORANDUM FOR PR (In-House Publication)

FROM: PROI (TI) (STINFO) 24 January 2000

Levine, J., Wysong, I., "Coordinated Development of DSMC Plume & Contamination Models"

AFOSR Meeting (plus Russian Scientists) (Deadline: 25 Jan 2000) (Statement A)

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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Signature ____________________________ Date ____________________________

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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3. This request has been reviewed by the STINFO for: a.) changes if approved as amended, b.) appropriateness of distribution statement, c.) military/national critical technology, d.) economic sensitivity, e.) parallel review completed if required, and f.) format and completion of meeting clearance form if required
Comments:

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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:

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Signature ____________________________ Date ____________________________

APPROVED/APPROVED AS AMENDED/DISAPPROVED

ROBERT C. CORLEY (Date)
Senior Scientist (Propulsion)
Propulsion Directorate
Coordinated Development, Validation and Transition of DSMC-based Plume and Contamination Models

Jay Levine and Ingrid Wysong
AFRL/PRSA
Edwards AFB, CA

27 January, 2000
Air Force Office of Scientific Research
Outline / Introduction

Still working on this...
## DSMC Simulation Tool: Applications, Payoffs

<table>
<thead>
<tr>
<th>DoD Application</th>
<th>Scientific/Technical Challenges</th>
<th>Payoff</th>
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<tbody>
<tr>
<td>High Altitude Rocket Plume Radiation – BMDO, AF, Navy</td>
<td>Chemically reacting flow, trace species, spatial resolution</td>
<td>National Defense</td>
</tr>
<tr>
<td>Plume / Spacecraft Interactions – AF TechSat21</td>
<td>Surface collisions, complex 3D geometries</td>
<td>Increased orbit lifetime, decreased sensor, array degradation</td>
</tr>
<tr>
<td>MEMS – AF, DARPA</td>
<td>Surface dominated effects, unsteady highly viscous flows</td>
<td>Optimized microsatellite propulsion systems, embedded sensors</td>
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<tr>
<td>Hypersonic Flight, Re-entry – AF HyTech, Military Aerospace Vehicle</td>
<td>Shock layer, trace species chemistry, aerodynamics</td>
<td>Improved aerodynamic performance, vehicle/propulsion integration</td>
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CHSSI Project: $1.5 million, 3 years, AFRL, NRL, outside experts: ITAM, Boyd, Bird
Leverages the extensive 6.1 research from AFOSR
Leverages SMILE code (ITAM) for test-bed
First DSMC code for non-expert users tailored to DoD applications
AFRL/PRSA is a key player in all three facets of this effort; our ongoing research and application work facilitates coordination and technology transition
All three facets benefit from substantial international participation
AFRL/PRSA DSMC Research and Transition

Plumes: Wysong, Wadsworth

Twice awarded AFOSR Star Team for excellence in basic research

DSMC Research: -- Chemical models, Validation (Boyd, Ivanov, Levin, Rich, Dressler)

DSMC Transition: CHSSI Project (NRL, Ivanov, Boyd, Bird)

DSMC Transition: Cooperation with Plume Phenomenology BMDO group -- transition research results to users. Join realistic engine/nozzle CFD results to DSMC plume simulations (Levine, Smith)

MirEx Steering Group: Potential DSMC validation; AFRL input and cooperation (AEDC, Tsniiimash, Levin)

Chemical Kinetics: Vaghjiani, Alfano -- experimental research on combustion, plume radiation kinetic mechanisms and rates
DSMC Chemistry Model Research

Working on this...

Example of results

On-going: Current work with AFRL/VSBS uses recently measured dissociation cross sections for more extensive validation
Free Molecule Micro-Resistojet (FMMR) -- basic research (surface models) and transition (MicroSat propulsion flight test) (USC, NASA JPL)

Application areas: Plume/Spacecraft Interaction for Constellations (TechSat21), MEMS

Micronozzle flow -- effect of boundary layer, important for performance, spacecraft interaction (ITAM)

Microvalves -- key for micropropulsion systems (NASA JPL)
6.1 Transition to 6.2/6.3
Free Molecule Micro-Resistojet (FMMR)
  - AFRL Patent Pending
MEMS Fabricated Micropropulsion System
  - Low Cost, Robust MEMS Structure
Transition Effort Builds on 6.1 Basic Research
Free Launch on AFOSR/DARPA University Microsat Flight Experiment (ASU)
Partners: JPL, ASU, USC
AFRL/PRSA DSMC Research and Transition

*Spacecraft Interaction: Key*

CHAFF Collaborative High Altitude Facility
AFRL/PRSA, USC
AFOSR DURIP and ARO funded

A unique, world-class space simulation to assess thruster/spacecraft interactions

- Apply DSMC code to contamination predictions
- Improve surface physics models
- Validate results: lab measurements / space experiments
- Identify chamber effects on contamination models
- Transition to microspacecraft cluster contamination potential - unknown effects
- Coordinated expt and modeling, AFRL/PRR,
Collaborative Research Opportunities

On-going projects have demonstrated the feasibility and value of US/Russian collaborations in:

• Combined Ground test data, Modeling and Simulation, Flight expt. Data

Previous Case: ESEX EP Flight Expt. -- AFOSR-supported research allowed DSMC simulation for pre-flight prediction of thruster contamination measurement

Nov. 4 workshop organized by Dr. Birkan gathered input from experts
Proposed Areas

Hall Effect Thruster:
• Flight data -- Tsnimash, AEDC
• Ground data -- Michigan (Gallimore), AFRL/PRR, CHAFF, AEDC, Tsnimash
• Simulation -- Michigan (Boyd), AFRL/VS

Pulsed Plasma Thruster:
• Flight data -- TechSat21 AFRL/VS, AFRL/PRR
• Simulation -- Michigan (Boyd), GWU (Levin)
• Ground data -- CHAFF (AFRL/PRSA, USC), AFRL/PRR

Chemical Thruster:
• Simulation: ITAM, AFRL/PRSA, GWU, Michigan (Boyd), AFRL/VS
• Ground data -- CHAFF (AFRL/PRSA, USC)

Micropropulsion:
• Simulation -- ITAM, AFRL/PRSA
• Ground, Flight data -- TechSat21, AFRL/PRR
High Altitude Plume and Contamination Program

• High quality, productive basic research program

• Strong focus on technology transfer

• Effective collaboration among Government agencies, University, International partners

• Initiative possibilities being explored for further cost-effective data and simulation effort on plume/spacecraft interactions