REPORT DOCUMENTATION PAGE

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE Technical Papers	3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE

(See attached)

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

(See attached)

5d. PROJECT NUMBER 3058
5e. TASK NUMBER RF9A
5f. WORK UNIT NUMBER 346055

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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

8. PERFORMING ORGANIZATION REPORT

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

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

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S NUMBER(S)
AFRL-PR-ED-AB-2002-276

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

20030116 078

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Leilani Richardson
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified	A	5	19b. TELEPHONE NUMBER (include area code) (661) 275-5015

MEMORANDUM FOR PRS (In-House/Contractor Publication)

FROM: PROI (STINFO)   07 Nov 2002

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-AB-2002-276**
　　　　　Mark Archambault (PRSA); Oshin Peroomian (Metacomp), "Three-Dimensional Simulations of a
　　　　　Gas/Gas, Hydrogen/Oxygen Engine" (abstract only)

　　16th AIAA Computational Fluid Dynamics Conference　　　　　　　　　　**(Statement A)**
　　(Orlando, FL, 23-26 June 2003)

Three-Dimensional Simulations of a Gas/Gas, Hydrogen/Oxygen Engine

Mark Archambault

Air Force Research Laboratory
Propulsion Directorate
Space and Missile Propulsion Division
Edwards AFB, CA 93524

Oshin Peroomian

Metacomp Technologies
Westlake Village, CA 91361

The overall objective of this research is to establish a design methodology for gas/gas injectors. This paper, however, focuses on a computational methodology to efficiently, accurately, and robustly obtain high-fidelity solutions of combusting rocket engine flows to gain a knowledge and understanding of their features. To that end, simulations of a single-element, shear-coaxial, H_2/O_2 engine are being performed to characterize its flowfield and to validate the CFD++ flow solver for this class of problems. Previous work has focused on obtaining solutions on a grid three to four times finer than those reported by other researchers and resolving numerical issues that reduce the computational efficiency of this inherently unsteady flow.[1-4] Comparisons of steady and averaged time-accurate solutions have also shown that a steady solution may not provide an accurate depiction of the combusting flow field over time (Fig. 1).

Other simulations have shown[5] that flow features unique to an experimental configuration, such as a nitrogen curtain purge used to cool the optical access, can influence both the experimental and computational results. Figure 2 shows that when the nitrogen curtain purge present in the experiment is modeled, the predicted hydrogen profile more closely matches the data. This is due to the fact that when the nitrogen is present, the hydrogen is unable to radially diffuse to the engine walls as quickly as when the nitrogen is absent. It is clear that the nitrogen has had an influence on the experimental data and both the experimenter and the modeler should take care when interpreting their results.

Finally, a comparison of turbulence models has provided evidence that the simulation is sensitive to which turbulence model is employed.[5] Figure 3 shows profiles of hydrogen mole fraction and mean axial velocity generated by various turbulence models. It is clear from the figures that the results are sensitive to the selection of the model. In this case, we've found that a linear k-epsilon model best predicts the data. This is likely caused by higher values of turbulent viscosity produced by the linear k-epsilon model, allowing for increased mixing with the oxygen.

The current work continues these studies by examining the results of three-dimensional calculations on this same configuration. The first simulation will determine whether there exists a three-dimensional flow structure, such as a helical shear layer, when using the axisymmetric geometry. Steady and time-averaged results (including the nitrogen curtain purge) will be discussed and compared with experimental data. Additional simulations will focus on biasing the GOX post such that it is either non-concentric with the hydrogen annulus, or non-parallel with the hydrogen stream. The purpose of these calculations will be to determine if manufacturing errors of this type could have a significant impact on the flow, and thus the efficiency of the engine. In addition, this will also provide us an initial step in investigating whether intentional GOX post biasing could be used as a means to control propellant mixing.

References

1. Archambault, M. R., Talley, D. G., & Peroomian, O., "Computational Analysis of a Single-Element, Shear-Coaxial, GH_2/GO_2 Engine," AIAA 2002-1088, 40th AIAA Aerospace Sciences Meeting & Exhibit, Reno, NV, Jan. 2002.

2. Moser, M. D., Merenich, J. J., Pal. S., & Santoro, R. J., "OH-Radical Imaging and Velocity Field Measurements in a Gaseous Hydrogen/Oxygen Rocket," AIAA 93-2036, 29th AIAA/SAE/ASME/ASEE Joint Propulsion Conference & Exhibit, Monterey, CA, June 1993.

3. Foust, M. J., Deshpande, M., Pal, S., Ni, T., Merkle, C. L., & Santoro, R. J., "Experimental and Analytical Characterization of a Shear Coaxial Combusting GO_2/GH_2 Flowfield," AIAA 96-0646, AIAA 34th Aerospace Sciences Meeting & Exhibit, Reno, NV, Jan. 1996.

4. Schley, C. –A., Gagemann, G., Tucker, P. K., Venkateswaran, S., & Merkle, C. L., "Comparison of Computational Codes for Modeling Hydrogen-Oxygen Injectors," AIAA 97-3302, 33rd AIAA/ASME/ SAE/ASEE Joint Propulsion Conference & Exhibit, Seattle, WA, July 1997.

5. Archambault, M. R., & Peroomian, O., "Characterization of a Gas/Gas, Hydrogen/Oxygen Engine," AIAA 2002-3594, 38th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Indianapolis, IN, July 2002.
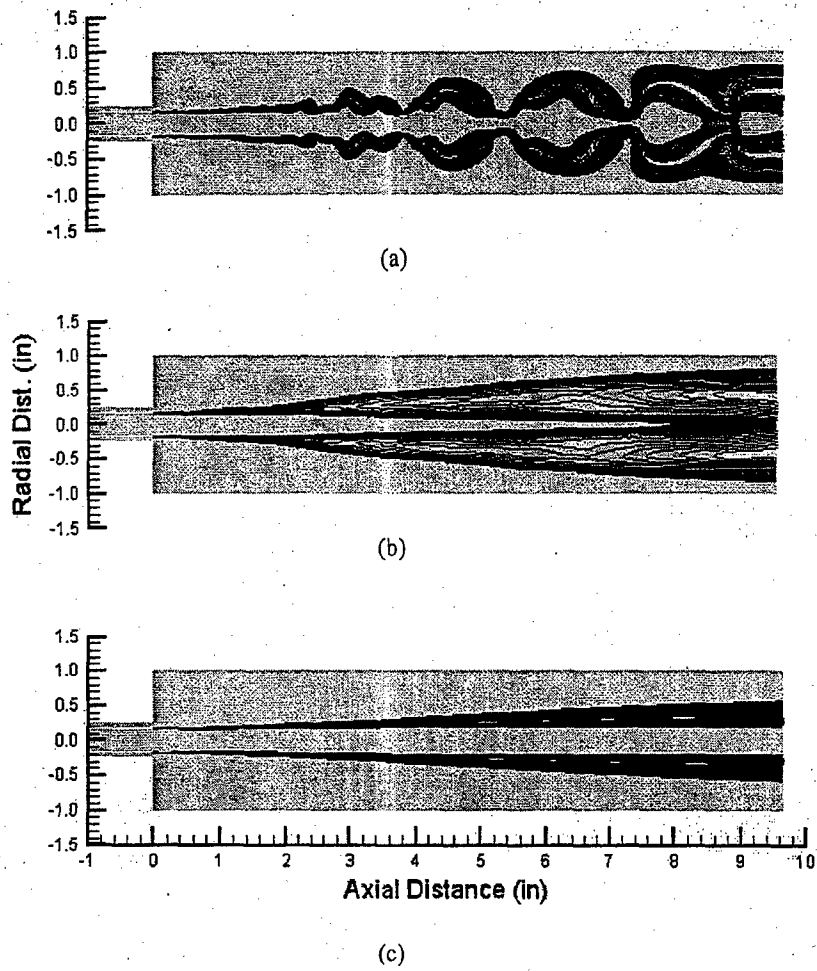
Figure 1. OH concentration contours from (a) instantaneous, (b) averaged time-accurate, and (c) "quasi-steady" solutions.
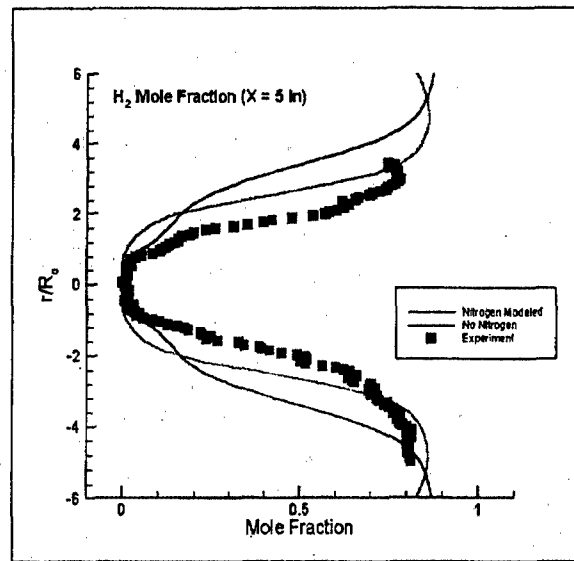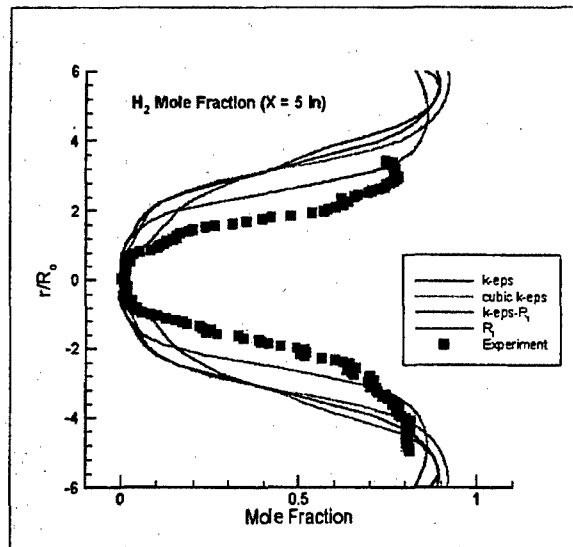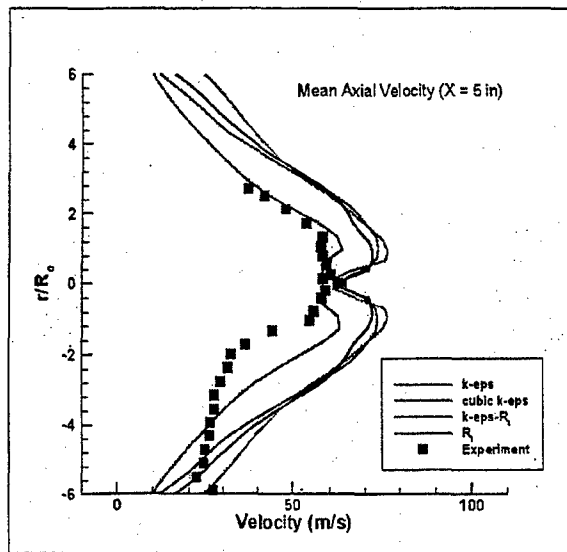
Figure 2. Hydrogen profiles comparing the difference with
and without the experimental nitrogen curtain purge.

(a)

Mean Axial Velocity (X = 5 in)

(b)

Figure 3. Profiles of (a) hydrogen mole fraction and (b) mean velocity with various turbulence models.

[This page is intentionally left blank.]