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Extended Abstract

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Funded under Stennis Work Request TH430UTG00
NASA Contract Number NNS04AB62C
November 9, 2007

for

John C. Stennis Space Center
National Aeronautics and Space Administration
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Extended Abstract

John C. Stennis Space Center (SSC) is the premier test facility for liquid rocket engine development and certification for the National Aeronautics and Space Administration (NASA). Therefore, it is no surprise that the SSC will play the most prominent role in the engine development testing and certification for the J-2X engine. The Pratt & Whitney Rocketdyne J-2X engine has been selected by the Constellation Program to power the Ares I Upper Stage Element and the Ares V Earth Departure Stage in NASA's strategy of risk mitigation for hardware development by building on the Apollo program and other lessons learned to deliver a human-rated engine that is on an aggressive development schedule, with first demonstration flight in 2010 and human test flights in 2012.

Accordingly, J-2X engine design, development, test, and evaluation is to build upon heritage hardware and apply valuable experience gained from past development and testing efforts. In order to leverage SSC's successful and innovative expertise in the plume diagnostics for the space shuttle main engine (SSME) health monitoring,[1-10] this paper will present a blueprint for plume diagnostics for various proposed ground testing activities for J-2X at SSC.

Complete description of the SSC's test facilities, supporting infrastructure, and test facilities is available in Ref. 11. The A-1 Test Stand is currently being prepared for testing the J-2X engine at sea level conditions. The A-2 Test Stand is currently being used for testing the SSME and may also be used for testing the J-2X engine at sea level conditions in the future. Very recently, groundbreaking ceremony for the new A-3 rocket engine test stand took place at SSC on August 23, 2007. A-3 is the first large - scale test stand to be built at the SSC since the A and B stands were constructed in the 1960s. The A-3 Test Stand will be used for testing J-2X engines under vacuum conditions simulating high altitude operation at approximately 30,480 m (100,000 ft). To achieve the simulated altitude environment, chemical steam generators using isopropyl alcohol, LOX, and

water would run for the duration of the test and would generate approximately 2096 Kg/s of steam to reduce pressure in the test cell and downstream of the engine. The testing at the A-3 Test Stand is projected to begin in late 2010, meanwhile the J-2X component testing on A-1 is scheduled to begin later this year.

Since the propellants used for J-2X engines are the same as the SSME propellants LOX and LH, technology development for the J-2X engine health monitoring would be fairly straight forward especially for the sea level testing of the full scale engine. In particular, the same ten elements Ni, Fe, Cr, Co, Mn, Cu, Ag, Al, Ca, and Pd will be identified and quantified in the plume by means of their atomic emission lines.[1] However, new lookup tables[1,2] will have to be generated based on the line-of-sight (LOS) flowfield properties obtained from the CFD results. The Engine Diagnostics Console (EDC)[5] software will naturally be specific for J-2X engine taking into account its hot gas path components and materials database. Further details including the information on the spectroscopic instrumentation will be given in the conference paper.

Plume diagnostics for the J-2X engines at the A-3 Test Stand faces several technological challenges. Assuming that the LOS issues can be worked out satisfactorily, lower temperatures rule out the emission spectroscopic methods, just as in the case of the SSME altitude simulation testing.[7] Furthermore, SSME testing experience has shown that the detection sensitivity with the atomic absorption is not very good due to extremely low free atomic factors at lower plume temperatures. We need to look into the feasibility of molecular absorption techniques with or without laser sources. The second issue to consider is the process of steam generation for the altitude simulation. The altitude simulation calls for a 2-stage ejector system with chemical steam generators. Steam is generated by combusting isopropyl alcohol. Main combustion products are H_2O, CO_2, O_2, CO, and N_2. However, several hydrocarbons are also produced. These are methane, ethylene, acetylene, ethane, propylene, propane, and isopropanol. At higher temperatures present at the nozzle exit, where the spectroscopic system is mounted, these hydrocarbons will react and produce many more species such as CH, C_2, CN, and NO. Presence of all these species in the plume LOS will complicate the spectral analysis. Therefore we plan to utilize the recently developed and implemented rocket plume spectroscopy simulation code (RPSSC) at SSC for hydrocarbon-fueled rocket engines[12] for J-2X engine plume diagnostics at the A-3 Test Stand. Complete strategy for plume diagnostics at A-3 Test Stand will be provided in the paper.

J-2X engine powerpack testing will take place soon at the A-1 Test Stand. The nature of this testing precludes plume diagnostics. However, plume diagnostics, if feasible, will provide very useful information for additional component testing at A-1 or E Test Stands. Application of plume diagnostics to the component testing will also be discussed in the paper.

REFERENCES

1. G. D. Tejwani, F. E. Bircher, D. B. Van Dyke, G. P. McVay, C. D. Stewart, L. A. Langford, and C. C. Thurman, “Space Shuttle Main Engine Exhaust-Plume Spectroscopy”, Spectroscopy 11 (9), 31-43, 1996.

2. G. D. Tejwani and C. C. Thurman, “Rocket Engine Plume Spectral Simulation and Quantitative Analysis”, Advanced Earth-to-Orbit Propulsion Technology 1994, NASA conference Publication 3282, Vol. I (NASA, MSFC, AL, 1994). pp. 200-214.

3. F. E. Bircher, G. D. Tejwani, E. L. Valenti, and C. C. Thurman, “Recent Results in the Development of the Engine Diagnostic Console”, Advanced Earth-to-Orbit Propulsion Technology 1994, NASA Conference Publication 3282, Vol. I (NASA, MSFC, AL, 1994). pp 190-199.

4. G. D. Tejwani, F. E. Bircher, D. B. Van Dyke and C. C. Thurman, “Space Shuttle Main Engine Health Monitoring with Exhaust Plume Emission Spectroscopy”, Journal of Spacecraft and Rockets 35 (3), 387-394, 1998.

5. F. E. Bircher, G. D. Tejwani, D. B. Van Dyke, and C. C. Thurman, “Engine Diagnostic Console: Recent Development and Test Results with SSME Data,” AIAA 95-2785, 31st AIAA/ASME/SAE/ASEE Joint Propulsion Conference, San Diego, CA, July 10-12, 1995.

6. G. D. Tejwani, D. B. Van Dyke, F. E. Bircher, and C. C. Thurman, “SSME Exhaust Plume Emission Spectroscopy at SSC: Recent Analytical Developments and Test Results,” AIAA 95-2786, 31st AIAA/ASME/SAE/ASEE Joint Propulsion Conference, San Diego, CA, July 10-12, 1995.

7. G. P. McVay, F. E. Bircher, G. D. Tejwani, and C. C. Thurman, “Development of an Atomic Absorption System for the Space Shuttle Main Engine”, AIAA 97-2665, 33rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Seattle, WA, July 6-9, 1997.

8. G. D. Tejwani, F. E. Bircher, D. B. Van Dyke, and C. C. Thurman, “SSME Health Monitoring at SSC with Exhaust Plume Emission Spectroscopy,” AIAA 97-2666, 33rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Seattle, WA, July 6-9, 1997.

9. G. D. Tejwani, D. B. Van Dyke, G. P. McVay, C. D. Stewart, L. A. Langford, and C. C. Thurman, “Engine Plume Diagnostics,” Technology 2007 Conference, NASA Tech Brief and Technology Utilization Foundation, Boston, MA September 22-24, 1997.

10. G. D. Tejwani, L. A. Langford, D. B. Van Dyke, G. P. McVay and C. C. Thurman, "Rocket Engine Plume Diagnostics at Stennis Space Center", 27th JANNAF Exhaust Plume Technology Subcommittee Meeting, NASA Stennis Space Center, MS, May 5-9, 2003.

11. P. Hensarling, "Test Facilities Capability Handbook: Volume 1- Stennis Space Center (SSC); Volume 2- Marshall Space Flight Center (MSFC), NASA SSTI-8080-0013, January 2007.

12. G. D. Tejwani, G. P. McVay, L. A. Langford, and W. W. St. Cyr, "Hydrocarbon-Fueled Rocket Engine Plume Diagnostics: Analytical Developments & Experimental Results", AIAA 2006-4407, 42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Sacramento, CA, July 9-12, 2006.