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20-MAY-88 OXYGEN/HYDROGEN TECHNOLOGY TEST BED STATUS UPDATE

J. S. Richards
George C. Marshall Space Flight Center
Huntsville, Alabama

This report provides an overview of the Hydrogen/Oxygen Technology Test Bed program. The status of the program, the program direction, plans for testing, and plans for technology implementation within the program are delineated. Test Bed goals and objectives are defined and the current status of the Test Bed engine is provided. A test facility status and a summary of the test facility capabilities are given.

1: TEST BED GOALS AND OBJECTIVES

The Oxygen/Hydrogen Test Bed (TTB) Program is intended to provide a bridge between technology development and technology implementation into current and future rocket engine programs. In order to provide this bridge, the TTB Program has three goals and three specific near-term objectives. These goals and specific objectives define the basis for the overall test program. The technology test bed goals are (1) the assessment of the advances of the Agency's propulsion technology program in the combined environments of an engine systems test, (2) the enhancement of implementation process for emerging technology into the operational program, and (3) the provision of test capability for prototype hardware.

Comprehensive characterization of the internal engine environment for the Space Shuttle Main Engine (SSME) is the first specific objective of the test bed program. Key elements of the RRB Program to support the characterization objective are shown in Figure 1. The environmental data derived from this characterization will be used to validate both existing models and those models emerging from the base technology program. The extensive engine measurement program will also allow a complete description of component interfaces within the engine system. These interface descriptions will allow evaluation of systems effects of alternate components such as the Pratt and Whitney turbopumps in the SSME system. These descriptions will also allow the specification of interface requirements for other alternate components such as the powerhead, nozzle and main combustion chamber. Less costly versions of these components are currently being studied for possible inclusion in the SSME flight system under contract to Marshall.

The second objective is to implement mature technology features and components into test bed hardware and then subject that hardware to the combined environment of an engine. By implementing these mature features and components on the TTB engine, risk to current and future flight programs is reduced and the bridge between technology and implementation for flight is established. Items demonstrated on the test bed can be introduced to the flight program with less perturbation to the on-going activities. Future programs can take advantage of items tested on test bed with a higher degree of confidence that the

expected results for their application will be obtained.

The third objective is the implementation of advanced controls, health monitoring instrumentation, and diagnostic systems. Significant accomplishments in the areas of sensors and diagnostics will be integrated into components and utilized in the overall engine system. With these items integrated in the engine system, new control parameters and improved control methodology will be utilized to control some of the very difficult transient conditions. The evaluation of additional control capability will eventually result in an adaptive control system. Instrumentation and diagnostic systems which do not require integration into the engine system will also be tested in the TTB program. These facility mounted items will generate information pertinent in detection of incipient engine failures and will provide a means to terminate ground tests before occurance of major engine damage.

2: TEST BED ENGINE

In order to accomplish the environmental characterization program objective, the SSME design has been modified to include instrumentation in those areas required. The instrumented engine is designated engine 3001 for tracking purposes. Hardware to support engine 3001 assembly has been selected from the flight and development inventories and instrumentation installation has been initiated. The individual engine components and the total engine system are required to provide a minimum of 25 starts and 3750 seconds of full power level (109% rated thrust) operation. Engine 3001 will be a Phase I flight configuration engine with Test Bed instrumentation and selected Phase II modifications included. The engine will be delivered to Marshall with standard flight high pressure pumps. After the engine start characteristics have been verified, these standard pumps will be replaced with instrumented high pressure pumps for system environmental characterization. The expected delivery date for engine 3001 with standard pumps is late 1988. The instrumented pump delivery is scheduled for early second quarter of calendar year 1989.

The instrumented engine design contains measurements for about six hundred parameters to characterize the environment of the engine system. The instrumentation will permit (1) measurement of interface conditions between all major components, (2) measurement of flow splits in all the engine subsystems, and (3) determination of conditions in the turnaround duct areas and the hot gas manifold upstream of the main injector. In addition, the data from these measurements will provide the environmental loads for the validation of load/life relationships as well as provide verification of scaling techniques from air and water flow simulations to true engine environments. The measurements will provide an adequate data base to refine existing analytical models, including the engine system transient model, the steady state power balance model, major component models (pumps, preburners, turbines, etc.), combustion models, and computational fluid dynamic models. The high pressure turbopump measurement areas of emphasis

include turbine inlet gas temperature profiles, turbine end and pump end bearing environmental characterization, coolant path flow definition downstream of the lift-off seal and rotordynamic characterization.

3: TEST FACILITY STATUS

The test bed testing will be accomplished at the Marshall Space Flight Center. The test facility will utilize the test stand originally built for the booster stage of the Saturn V launch vehicle, and subsequently used for structural tests of the space shuttle external tank. This test stand has been extensively modified to accommodate single engine testing for engines in the Space Shuttle Main Engine class. Modifications to the stand have been completed. Stand activation is progressing with the first firing of a SSME in the facility scheduled for mid to late summer. Cold shock tests of both the liquid oxygen and liquid hydrogen systems have been performed. Engine 2105 (a flight configuration SSME not cabable of hot fire) has been installed in the stand and facility fit and functional checks have been performed using this engine. The Command and Data Simulator (CADS), used to control the SSME, has been installed in the control center. CADS has been integrated with the facility computer and the SSME controller and facility/CADS interfaces have been successfully exercised.

Replacement of engine 2105 with engine 0208 (a hot firable engine) and a dry (no propellants in either propellant tank) count demonstration test (CDDT) are scheduled for early summer. The dry CDDT will demonstrate the readiness of the test procedures and software to support hot fire testing. Tanking tests for both oxygen and hydrogen are scheduled to follow the dry CDDT. These tanking tests are designed to verify cryogenic handling procedures for the facility. After the tanking tests a wet (both propellants tanked as for firing) count down demonstration test will be conducted prior to initial hot fire. This wet CDDT will be the final "dress rehersial" for the first hot fire test. The first hot fire will be a 1.5 second start verification test and will be the first test of the Pathfinder Test Series described in subsequent paragraphs.

4: TEST FACILITY CAPABILITIES

The test facility capabilities are adequate for a test bed, but inadequate for a development program. The test duration is limited to approximately 150 seconds. This limitation is imposed by the liquid oxygen run tank capacity of approximately 23,000 gallons. The test frequency is a maximum of one test per seven working days with the current one-shift operation. However, during the Pathfinder Test Series and engine 3001 testing, twelve to eighteen per year are planned. The engine interface pressures are consistent with the engine interface pressures used in the SSME development program, and encompass the values expected in future engine programs. GH2 is the pressurant used for the hydrogen tank; and GN2 is used for the lox tank. The purge

capability is adequate for all purging and drying requirements. In addition to the engine controller system, the facility is capable of 750 channels of additional digital data and 216 channels of analog data. Flow measurements in the facility feedline can be validated with the level gages in the run tank. The facility does not include altitude simulation, engine gimballing, or engine thrust measurement capabilities. However, engine gimballing and thrust measurement capabilities can be added without redesign.

5: PATHFINDER TEST SERIES

The initial test series for the TTB program is designated the Pathfinder Test Series. This test series will consist of seven baseline tests plus two optional flowmeter calibration tests. The initial test will be a 1.5 second standard start verification test and will be followed by six tests of increasing duration until maximum run duration is demonstrated and other test objectives are achieved. Two additional tests will be performed if required to provide calibration for the facility flowmeters. The test series has been designed to demonstrate the facility capability and to provide crew training.

The purposes of the Pathfinder Test Series are facility verification, crew training, procedure verification, and technology development. The specific objectives of the facility verification are to demonstrate that the engine to facility interface control document requirements can be met and to support technology development. Crew training will include demonstration of standard maintenance and inspection; hardware changeout of such items as turbomachinery, actuators, lines, valves, and controllers as well as the engine system as a whole; and special tests and inspections as called for by hardware conditions. Facility procedures for standard maintenance and inspections, hardware changeout, documentation, hardware tracking, work control, test operations, and test review will be verified during the Pathfinder testing.

The testing will be performed on engine 0208. This engine is a development engine which incorporates several deviations from the baseline flight configurations. The most notable of these deviations are the increased throat diameter in the Main Combustion Chamber (MCC), and the removal of the stability aids (baffles and acoustic cavities). Deviations from the flight configuartion are shown on Figure 2. Engine 0208 is assigned to the SSME Development Project and was designed to provide an option for improving the life of SSME hardware. The engine has been temporarily assigned to the TTB Program for facility activation and technology data collection. Engine 0208 previously has been tested a total of three times at the A-3 test facility in California. These tests were conducted to collect data in support of the external heat exchanger activity as well as characterization of the engine system operation.

Technology item development will be initiated during the Pathfinder series. A prototype Optical Plume Anomaly Detector (OPAD) will be installed on the facility early in the test program. This device is

used to detect incipenent failure of engine components by observation of the plume constituants by spectroscopy. Data will also be gathered to support validation of theoretical models which predict the effects of the large throat Main Combustion Chamber of engine 0208.

6: FUTURE PLANS

The plans for future engine testing are shown in Figure 3. The cross-hatched areas of the schedule indicat uncertainties which result from budget considerations. As shown on Figure 3, Pathfinder testing will be followed by environmental characterization of the SSME system. Baseline environmental characterization will be followed by environmantal characterization of the engine system with the Pratt and Whitney alternate turbopumps. After characterization of the SSME system, the engine will be returned to Rocketdyne for refurbishment into engine 3002. During the refurbishment period, an interim engine will be installed on the TTB facility and mature technology items requiring engine integration will be tested. These items may include the bearing deflectometer, the optical pyrometer, advanced sensor and advanced control devices. Budget projections have been submitted which will allow for integratioin of advanced technology items into engine hardware. Engine 3002 will be a Phase II+ flight configuration and will be used to characterize the environment of this configuration as well as to test mature technology items.

Should engine 3001 devlivery be delayed by either technical or budget problems, the testing of engine 0208 will be extended. A series of seventeen technology support tests has been defined. This test series is designed such that the delivery dates in the cross-hatched area of Figure 3 can be accomodated. These tests provide for a partial environmental characterization using portions of the engine 3001 instrumentation which can be adopted to engine 0208. They also allow for testing of mature technology items which may be come available during the period.

The Technology Test Bed program is progressing toward engine hot fire testing. This activity presents a unique capability for introduction of technology items into the SSME program and to develop technology for use in future engine systems. Technology items which potentially require testing in a TTB engine system level test environment should be identified to the Marshall Research and Technology Office (ER01) at the earliest indication that such testing would be profitable. Early identification of technology items allows for planning and budgeting to support testing.

KEY ELEMENTS
TECHNOLOGY TEST BED

INSTRUMENTED ø I/II ENGINE

- 608 PARAMETERS
- COMPONENT INTERFACE DEFINITION
- COMPONENT OPERATING CHARACTERISTICS

MODEL VALIDATION

- SYSTEM TRANSIENT
- POWER BALANCE
- COMPONENT PERFORMANCE
- COMBUSTION
- CFD

DIRECT EVALUATION OF INTERCHANGEABLE COMPONENTS

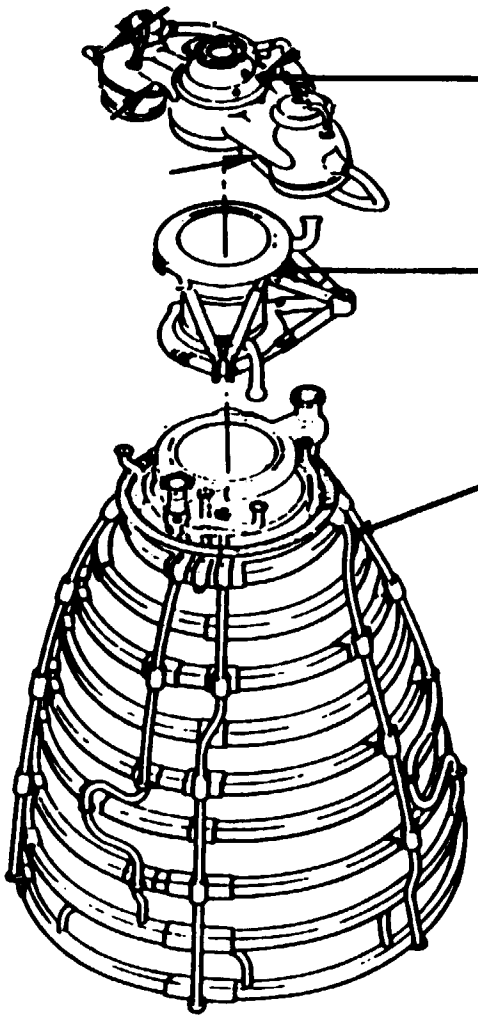
- ALTERNATE TURBOPUMPS (P&W)
- ALTERNATE COMPONENTS
  - -POWERHEAD
  - -MAIN COMBUSTION CHAMBER
  - -NOZZLE
  - -CONTROLLER
  - -EXTERNAL HEAT EXCHANGER

TEST CAPABILITY FOR ADVANCED CONTROLS/DIAGNOSTICS

- ENVIRONMENTAL MODIFICATION
- INTEGRATED CONTROLS
- HEALTH MONITORING
- LEAK DETECTION
- FAILURE TOLERANCE

Figure 1

DIFFERENCES - ENGINE 0208



Main Injector
- "Super" LOX Posts
- No Baffles
- Different H2 Flow Split

Reduced Film Coolant

MCC
- THROAT DIA 10.883 VS 10.305
- L* INCREASED 5.2%
- WALL THICKNESS 0.025 VS 0.028
- CHANNELS 430 VS 390
- PC MEASUREMENT DIFFERENT LOCATION

NOZZLE
- NO CHANGE
- (€ 69.5 VS 77.5)

ENGINE BALANCE & PERFORMANCE

Figure 2

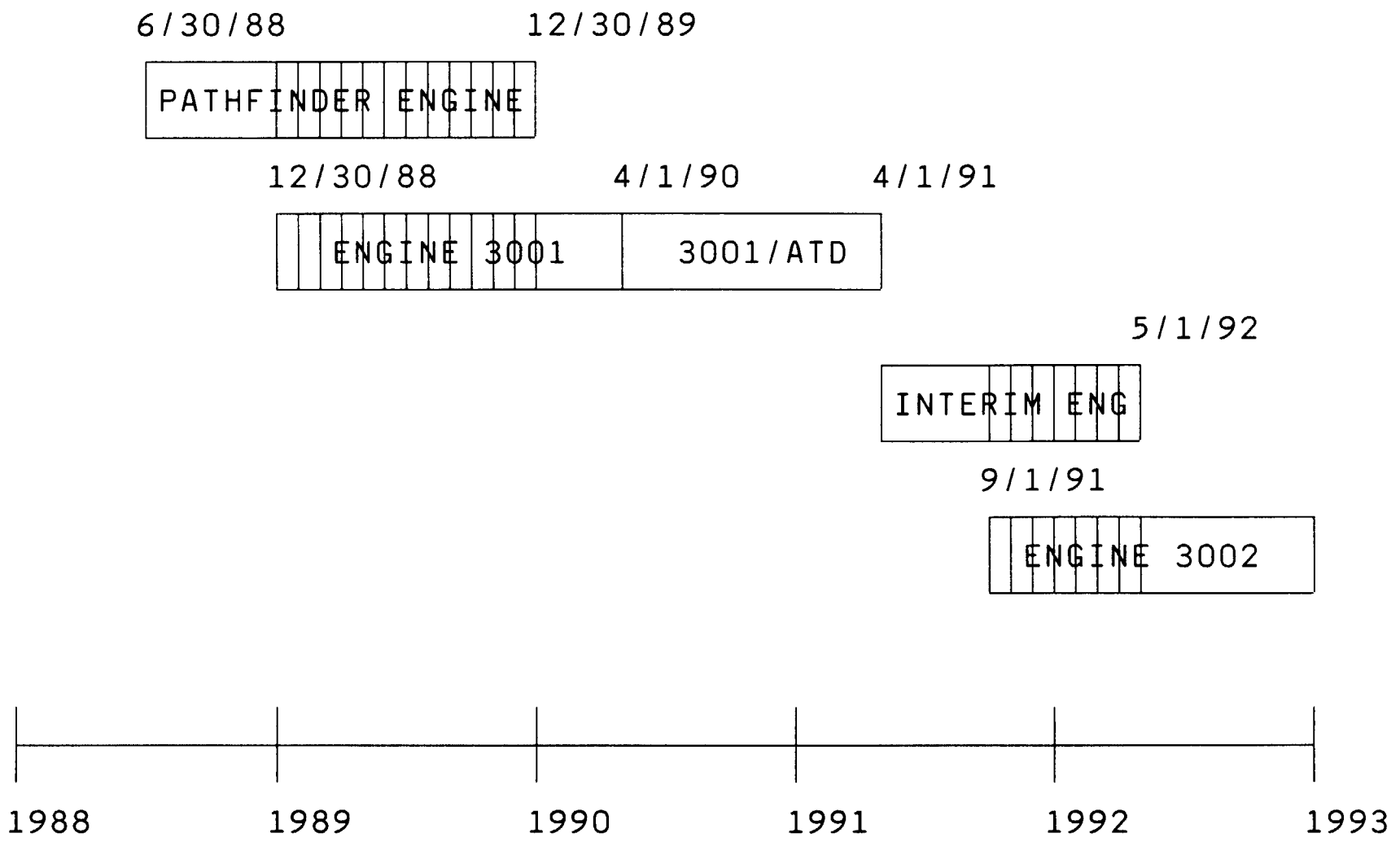


Figure 3

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