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A Scale Model Investigation of Rocket Exhaust Effects on an Improved Saturn V Booster Utilizing Solid Propellant Strap-Ons

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ABSTRACT

A SCALE MODEL INVESTIGATION OF ROCKET EXHAUST EFFECTS ON AN IMPROVED SATURN V BOOSTER UTILIZING SOLID PROPELLANT STRAP-ONS*

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Background

Missions currently being considered by NASA beyond the Apollo manned lunar landing will require a larger payload capability than is available with the current generation of Saturn boosters. An attractive method of achieving the desired payload increase consists of adding large solid propellant rocket motors (strap-ons) to existing boosters to augment the thrust from the basic booster liquid-propellant engines. The soundness of this approach has already been demonstrated by such vehicles as the Titan III-C and Thrust Augmented Thor/Delta, where significant performance increases have been obtained within current state of the art and at minimum cost, while simultaneously retaining the proven reliability characteristics of the previously developed basic booster.

The possibility of increasing the performance of the Saturn V booster through the addition of previously developed 120-inch solid-propellant rocket motor strap-ons to the S-IC first stage is currently being evaluated by the Marshall Space Flight Center of NASA. One of the items of concern with such a configuration is the possibility of a detrimental alteration in the base environment of the S-IC from that which will exist with only the basic complement of five F-1 liquid propellant rockets. For example, interactions between the liquid propellant and/or solid propellant rocket exhaust plumes (a total of nine rocket exhausts are involved) may result in increased flow recirculation and attendant increases in base pressure and convective heating. Further, radiant heating to the base may also be significantly greater because of the presence of the aluminized solid propellant exhaust plumes.

In addition to these potential flight problems, consideration must also be directed toward the launch stand environment. Rocket exhaust recirculation from the flame deflector can produce a severe thermal environment in the booster base region during the ignition and lift-off sequence. Launch stand components must also be suitably protected to withstand the 5000°F exhaust gas impingement as the booster lifts off.

Discussion

An experimental program is being performed at the Cornell Aeronautical Laboratory (CAL) to 1) evaluate the S-IC booster base environment over a range of simulated flight conditions from lift-off up to Mach 2 and 2) obtain launch stand component heating and pressure data during the launch sequence. The test program employs short-duration combustion and testing techniques* previously developed at CAL. The test configuration is a 1/45-scale combustion model of the Saturn S-IC booster stage with four scaled 120-inch diameter solid rocket strap-ons as shown in Fig. 1.

The test program includes test firings with the model installed in a simulated Saturn launch stand complex composed of a scaled LUT (launch umbilical tower) and flame deflector (see Fig. 2). Data consist of heat transfer rates and pressures on both the vehicle base and launch stand complex for a number of booster locations which duplicate a lift-off trajectory.

In addition to the evaluation of launch stand effects, the model is also being tested in the CAL short-duration external flow system where base heating and pressure data are being obtained with and without strap-ons at simulated Mach 2 trajectory conditions.

The paper discusses the short-duration rocket testing techniques employed to simulate both the F-1 liquid and 120-inch solid strap-on rocket flows, describes the model configurations and specialized fast-response instrumentation employed, and reviews the experimental results obtained.

*This effort was sponsored by the Marshall Space Flight Center of NASA under Contract NAS 8-21097. Details and results of the program are presented in CAL report "A Scale Model Investigation of Rocket Exhaust Effects on an Improved Saturn V Booster Utilizing Solid Propellant Strap-Ons", Rept. No. AA-2406-Y-1, to be published during 1968.

*Rocket operating periods are typically less than 50 milliseconds.

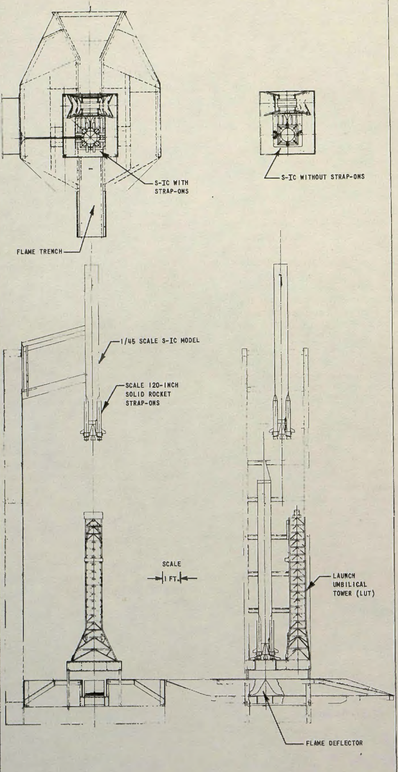

Figure 2 IMPROVED SATURN V/120 INCH STRAP-ON LAUNCH COMPLEX TEST CONFIGURATION

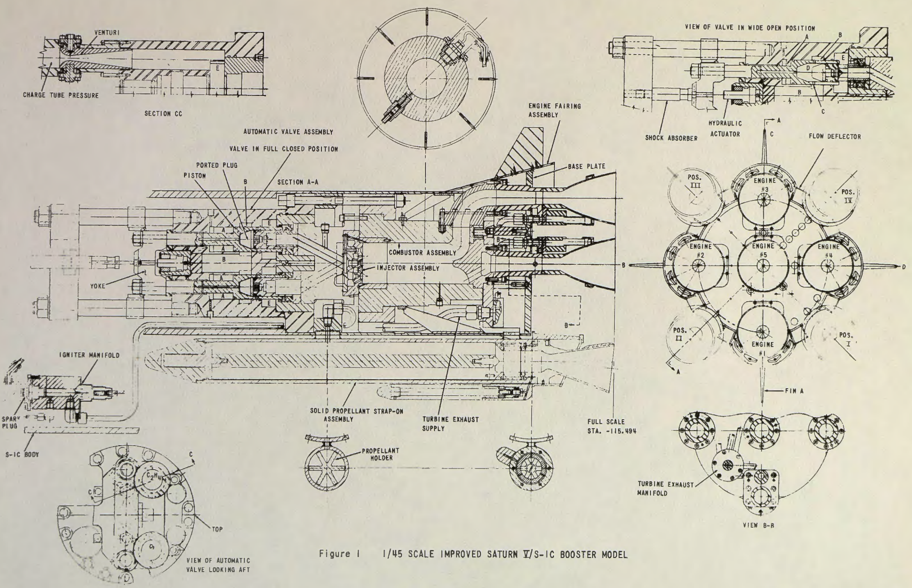

Figure 1 1/45 SCALE IMPROVED SATURN V/S-IC BOOSTER MODEL