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AIR AUGMENTED CONVENTIONAL ROCKET ENGINES

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SYNOPSIS

An analytical study was conducted to assess and estimate the level of effectiveness of an ejector/rocket, or rocket engine nozzle after-burning concept for enhancement of a conventional rocket engine. Performance enhancement and thrust augmentation of an ejector/rocket system were evaluated for a National (or Advanced) Launch System (NLS or ALS) type engine, namely the Space Transportation Main Engine (STME), and its effects on the overall vehicle/propulsion system such as payload weight, gross lift-off weight, and propellant weight. The focus was on using a fixed geometry ejector and utilizing the otherwise wasted exhaust excess fuel of rocket engines and burning it with ingested atmospheric air to produce additional thrust. Limited analyses were also performed to determine effect of burning additional injected fuel with the secondary air on thrust augmentation.

Ideal flow analyses based on inviscid flow calculations with complete mixing and combustion of primary and secondary flow within the ejector length, estimated between L/D of 1 to 5, were conducted. The secondary flow was assumed to be choked (M = 0.9) at subsonic flight speeds and decelerated to subsonic flow through a normal shock at supersonic flight speeds (M = 2). A simple fixed geometry shroud configuration was optimized to operate as an ejector system in the flight speed range of Mach 0 to 2 to augment NLS rocket engine thrust. Parametric studies that were performed resulted in an ejector geometry with secondary inlet area of 80 sq ft. with area ratio of 1.63. This ejector produced substantial ideal thrust augmentation at all flight Mach numbers in the range of 0 to 2 with and without injection of additional fuel. The increased thrust was traded against increased ejector weight and external drag. This resulted in maximum payload increase in excess of 27% with NLS fixed vehicle size, or Gross Lift-Off Weight (GLOW) and propellant weight reduction in excess of 19 & 23% respectively with a constant NLS baseline payload of 120 Klbs. The gain is based on a closely matched flight trajectory for the ejector/rocket system determined for operation without any additional injected fuel. Based on calculated sensitivities to engine parameters, an increase of about 40 sec in I_{sp} would be required for an engine without after-burning to obtain the same (27%) payload increase for NLS.

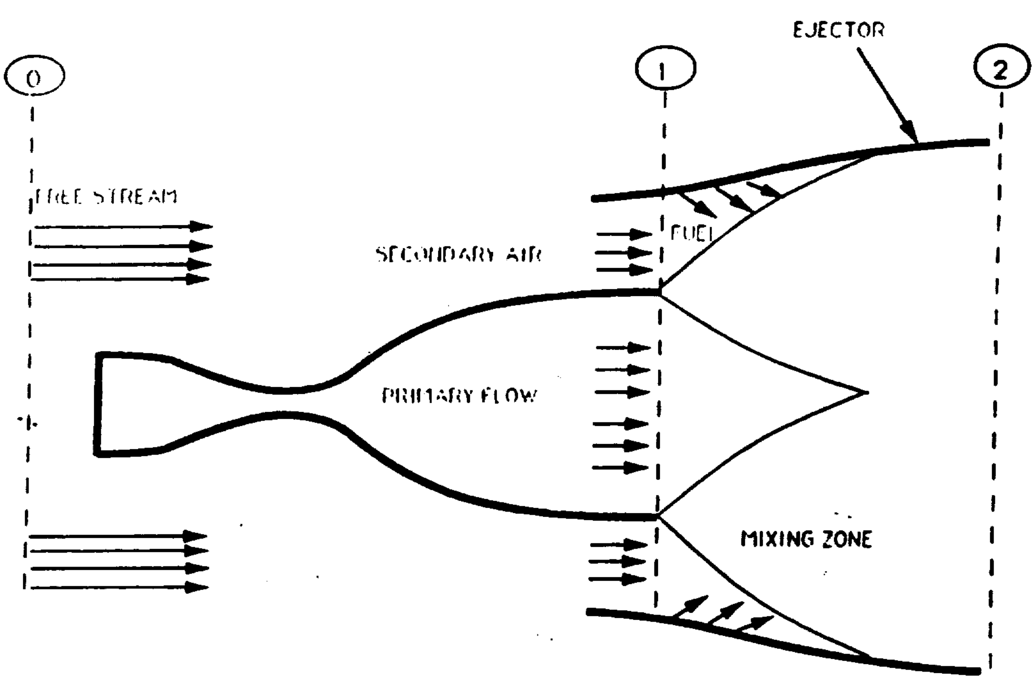
The performance benefits and increase in payload were estimated assuming that the ejector shroud was jettisoned at flight Mach number of 2. A brief study that was conduced, indicated that the payload increase in excess of 50% would be realized if the ejector was to be used as an extension of the rocket engine nozzle beyond Mach 2.

This substantial improvement in performance (thrust and Isp) indicates that an ejector/rocket propulsion system should be considered as candidate propulsion system for Single-Stage-to-Orbit application. The SSTO configuration greatly improves the launch operability of the boosters by reducing the number of systems and interfaces.

ASSESS EFFECTIVENESS OF ROCKET ENGINE NOZZLE AFTERBURNING CONCEPT

- EJECTOR/ROCKET COMBINED CYCLE ... SUPERSONIC COMBUSTION
- DEFINE FIXED EJECTOR GEOMETRY FOR MACH 0 TO 2
- DETERMINE EJECTOR THRUST & ALS ENGINE THRUST AUGMENTATION
- ESTIMATE SIZE AND WEIGHT
- IMPACT OF EJECTOR DESIGN ON OVERALL MISSION PERFORMANCE .. ALS TYPE VEHICLE & TRAJECTORY

ROCKET ENGINE NOZZLE AFTER-BURNING CONCEPT



AUGMENTATION DETERMINED BY 1-D INTEGRAL METHOD

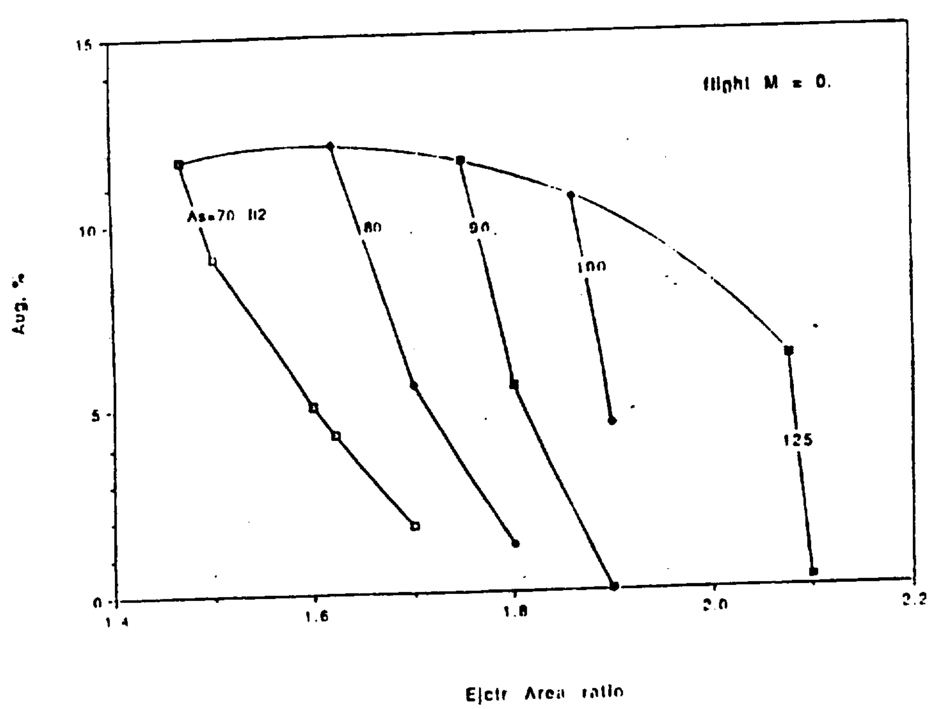
- COMPLETE MIXING WITH EQUILIBRIUM CHEMISTRY USED FOR THRUST CALCULATIONS

- AUGMENTATION IS BASED ON ASSUMED UNIFORM FLOW WITH NO HEAT, DRAG & VISCOUS, SHOCK(S), DIVERGENCE, AND KINETICS LOSSES

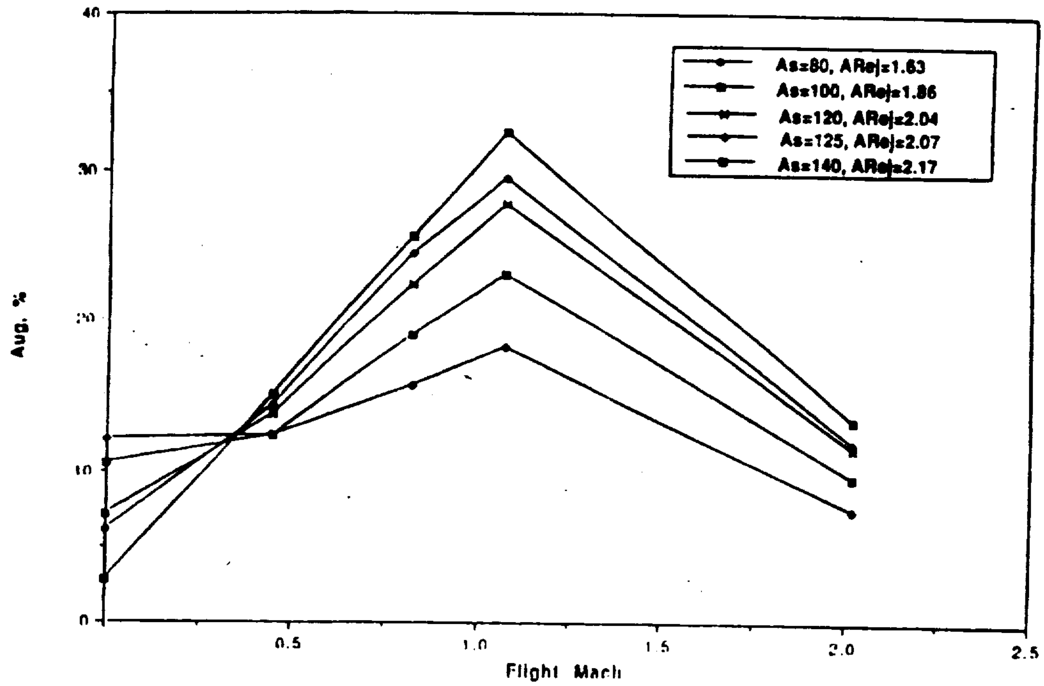
- INLET KINETIC ENERGY LOSSES INCLUDED

- CHOKED SECONDARY FLOW (M=0.9) AT SUBSONIC FLIGHT REGIME, AND RAM COMPRESSION TO SUBSONIC INLET FLOW AT FLIGHT M=2

Augmentation VS Ejector Area Ratio

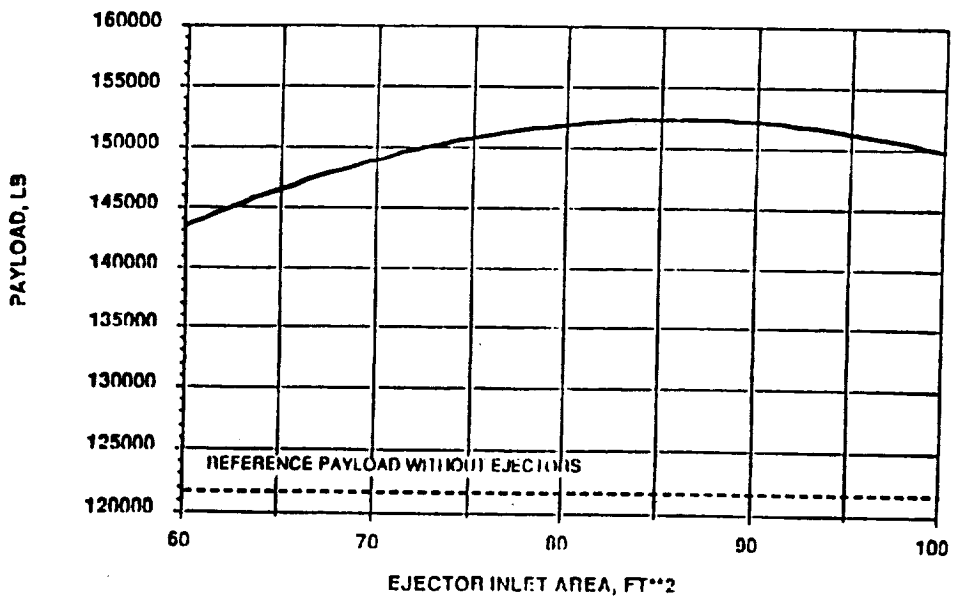


Thrust Augmentation VS Flight Mach

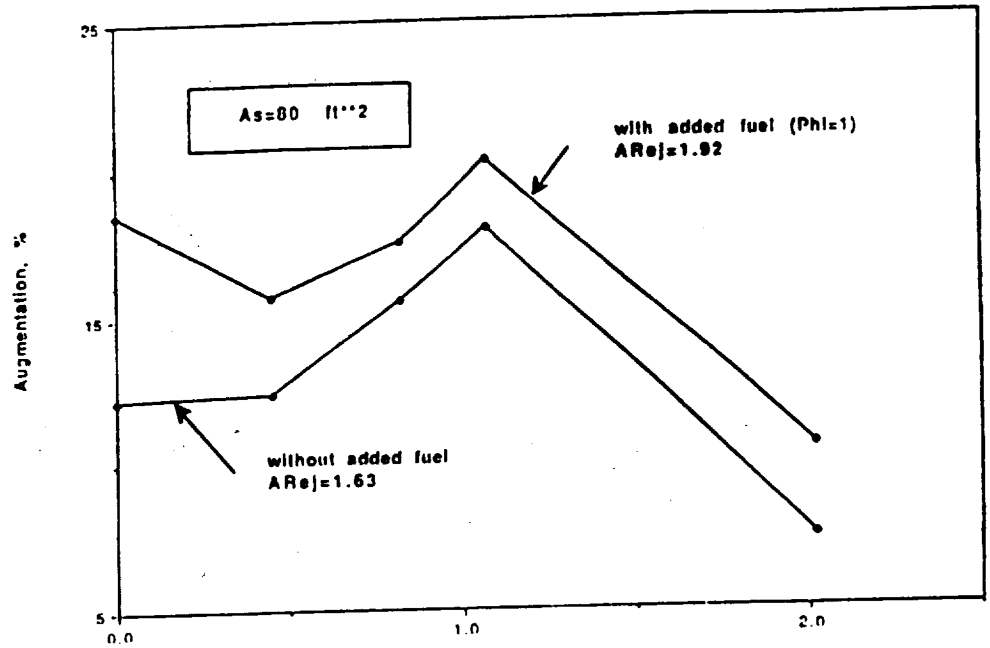


ALS PAYLOAD WITH EJECTORS ON STMEs

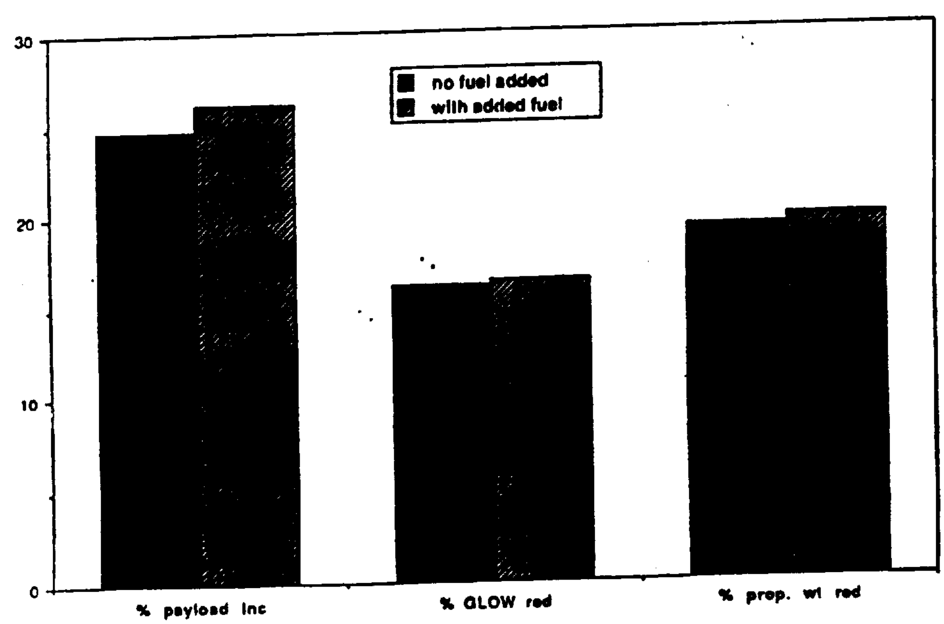
7/3 STMEs IN BOOSTER/CORE
ONE CORE ENGINE OUT



Thrust Aug. Comparison W & W/O Added Fuel

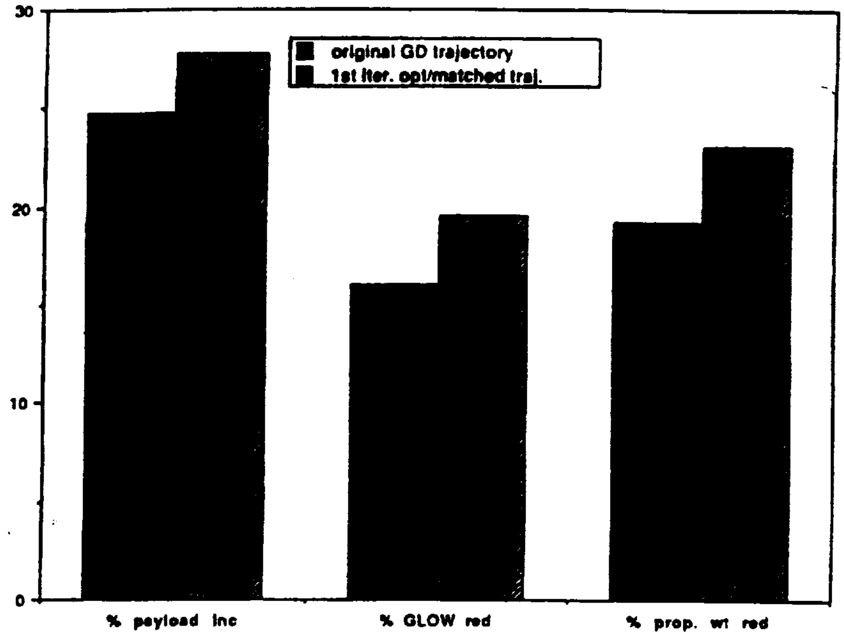


Latest GD Vehicle With & W/O Fuel Addition



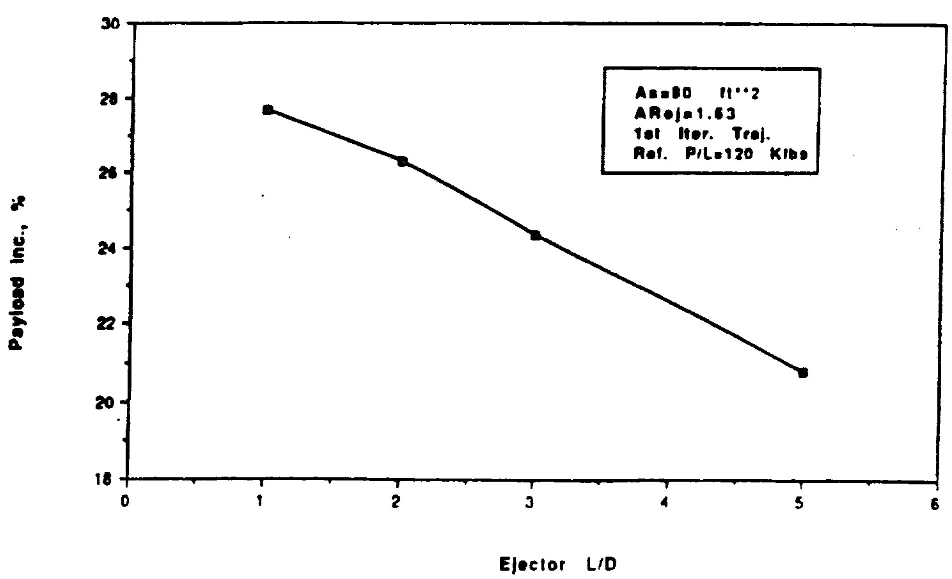
Note: As=80 ft**2, Arej=1.63, Ref p/L=120klb

First Trajectory Iteration, Increased Gain



Note: As=80 ft**2, ARej=1.63, w/o added fuel, ref. P/L=120klbs

Payload Increase vs Ejector Length



SIGNIFICANT IDEAL THRUST GAIN WITH EJECTOR/ROCKET

- SIGNIFICANT POTENTIAL Isp INCREASE POSSIBLE WITH AIR AUGMENTATION OF CONVENTIONAL ROCKET ENGINES
- FOR BASELINE VEHICLE AND TRAJECTORY
  - In excess of 27% payload increase w/o added fuel
  - 30% payload increase with injection of additional fuel ... higher with optimum geometry/trajectory
- UTILIZATION OF EJECTOR AS NOZZLE EXTENSION COULD INCREASE PAYLOAD IN EXCESS OF 50%
- POSSIBILITY OF ELIMINATING A STAGE OR NUMBER OF ENGINES

EFFORTS REQUIRED TO ADDRESS MAJOR ISSUES

- EFFECT OF MIXING ON AUGMENTATION, USE OF MIXING AIDS ... EJECTOR LENGTH
- INLET FLOW / PUMPING CAPABILITY
- ENGINE/VEHICLE INTEGRATION
- VARIABLE GEOMETRY EJECTOR

BRIEF INTRODUCTION

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(Paper Not Received in Time for Printing)