N91-28236

PRESENTATION 4.1.3

HEAVY-LIFT LAUNCH VEHICLE PROPULSION CONSIDERATIONS

SPACE TRANSPORTATION PROPULSION TECHNOLOGY SYMPOSIUM
PENNSYLVANIA STATE UNIVERSITY

NASA / JOHNSON SPACE CENTER
SYSTEMS ENGINEERING DIVISION

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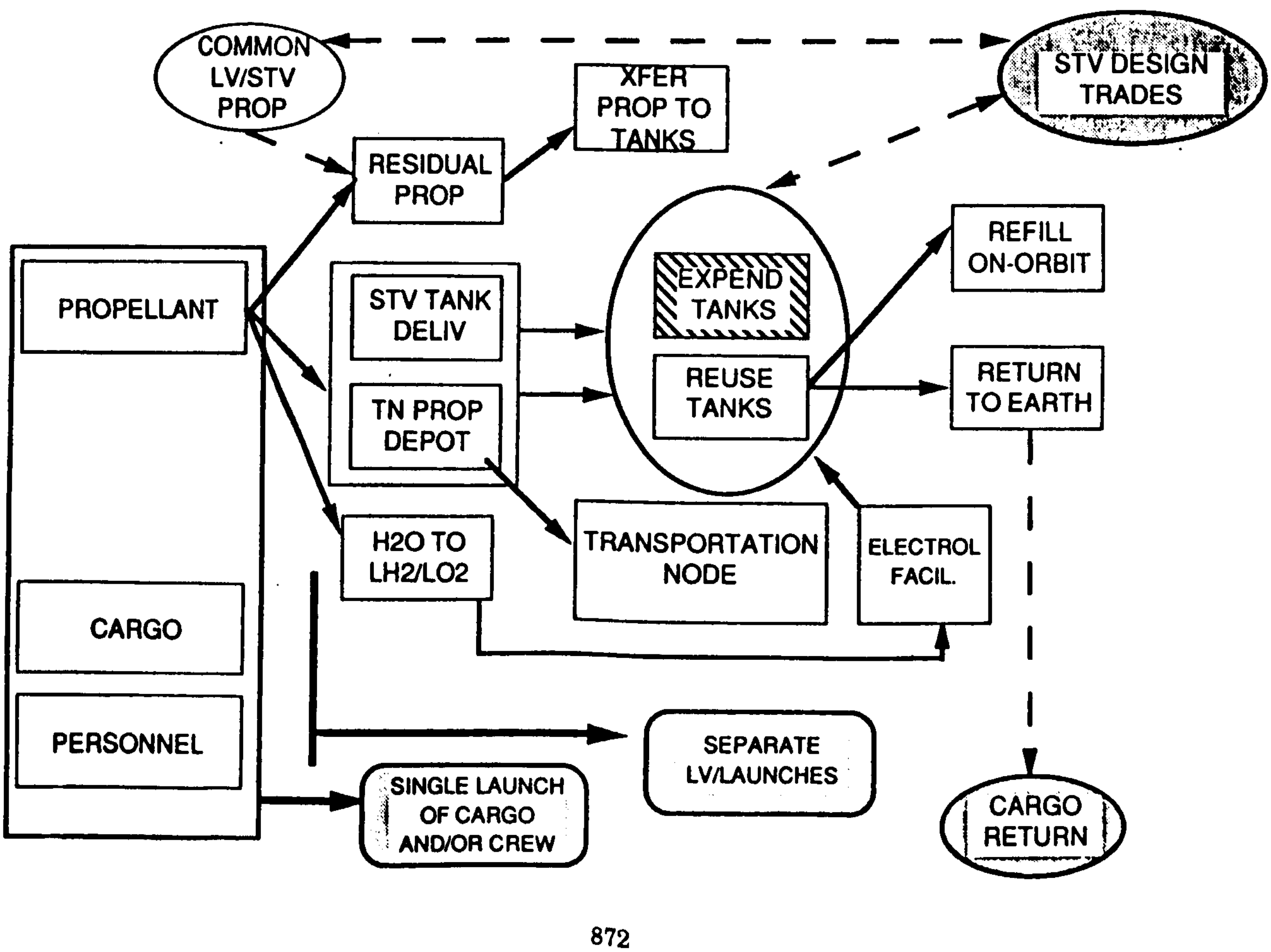
JUNE 1990

PRESENTATION OVERVIEW

- TRANSPORTATION SYSTEM ISSUES
- STUDY OBJECTIVES
- ETO SYSTEM REQUIREMENTS
- LAUNCH VEHICLE SIZING RESULTS
- HLLV THRUST REQUIREMENTS
- PROPULSION SYSTEM RELIABILITY
- PROPULSION ISSUES

TRANSPORTATION SYSTEMS FOR LUNAR / MARS OUTPOST MUST BE TREATED AS AN INTEGRATED SYSTEM



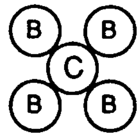
STUDY OBJECTIVES

- INVESTIGATE ETO OPTIONS WHICH
  - MIMIMIZE ON-ORBIT OPERATIONS AND IMPACTS TO SSF
    - DIRECT LAUNCH
    - AUTOMATED RENDEZVOUS/DOCKING OF ASSEMBLED ELEMENTS
  - HAVE REASONABLE CAPABILITY TO SUPPORT MARS MISSIONS
  - MINIMIZE MASS IN LEO
- CONSIDER POTENTIAL SYNERGISM WITH STS

TRANSPORTATION SYSTEM REQUIREMENTS

- MODULAR, TO BE OPERATED ROUTINELY IN ITS MINIMAL CONFIGURATION
- SIZED TO ENABLE A LUNAR MISSION IN A SINGLE LAUNCH, AND ALLOW A REASONABLE MARS CAPABILITY
- LEO MASS BREAKPOINTS
  - TOTAL LUNAR MISSION MASS 450K
  - PROPELLANT MASS 300K
  - INERT MASS 150K
- TYPICAL MARS MISSION TOTAL MASS > 2.0 M lbs
- AEROBRAKED SYSTEMS RESULT IN LARGE VEHICLES (LUNAR-62 X 50 ft; MARS 170 X 115 ft)
  - ASSEMBLED IN LEO
  - DEPLOYED

SINGLE CORE / 4 BOOSTER HLLV SIZING



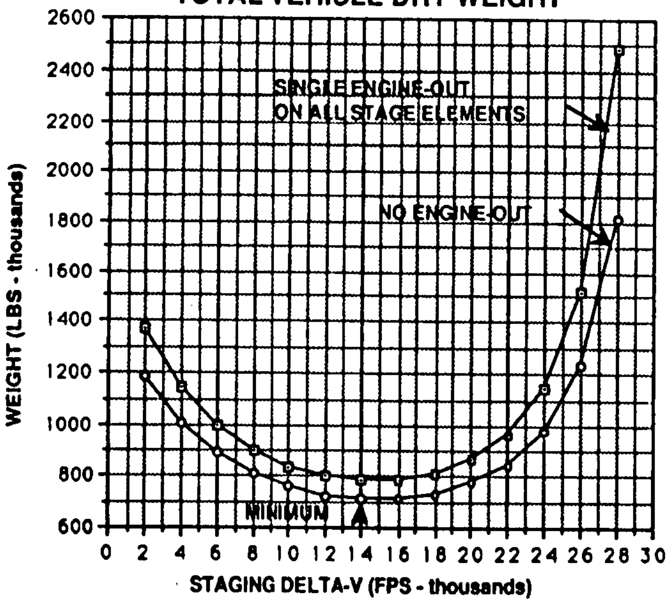
SIZING CRITERIA

- 450,000 LB LIFT CAPABILITY
- TOTAL DELTA-V + 2% RESERVE = 29,000 fps
- T / W lift-off = 1.4

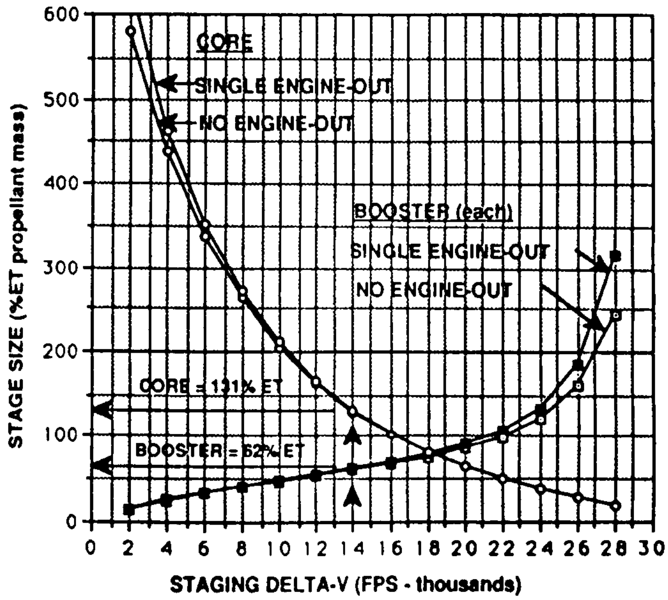
ASSUMPTIONS

- STME TECHNOLOGY
- ENGINE T / W = CONSTANT
- ENGINE-OUT THROTTLE-UP = 33%

TOTAL VEHICLE DRY WEIGHT

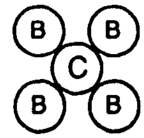


RELATIVE CORE AND BOOSTER SIZES



WITH A VEHICLE SIZED FOR MINIMUM DRY WEIGHT, THE PENALTY FOR SINGLE ENGINE-OUT CAPABILITY IS A 10% INCREASE IN DRY WEIGHT AND A 3% INCREASE IN TOTAL REQUIRED PROPELLANT (ADDITIONAL12% OF ET).

SINGLE CORE / 4 BOOSTER HLLV SIZING



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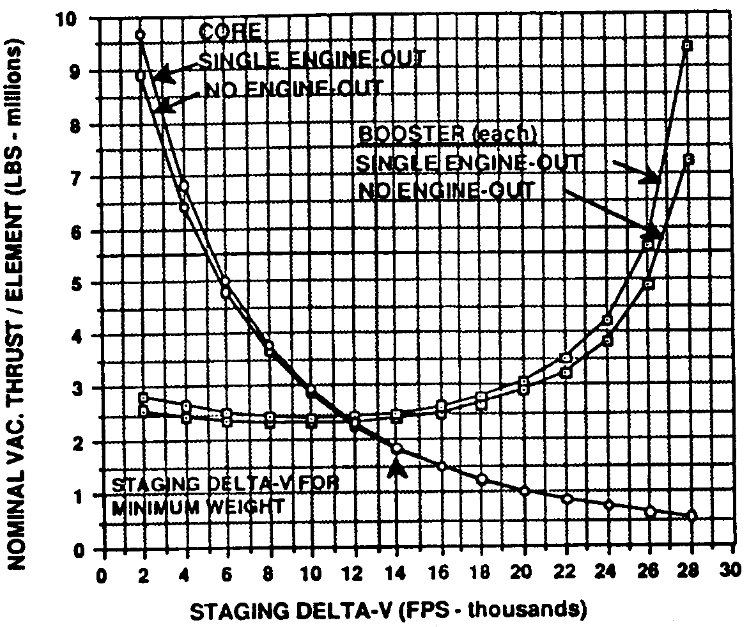
NOMINAL VACUUM THRUST REQUIREMENTS



FOR THE MINIMUM DRY WEIGHT DESIGN, NOMINAL OPERATION THRUST (VAC) REQUIREMENTS ARE INCREASED BY 31K LBS ON THE CORE AND BY 100K LBS ON EACH BOOSTER WITH SINGLE ENGINE-OUT CAPABILITY.

SINGLE CORE / 4-BOOSTER HLLV SUMMARY

RESULTS SUMMARY	CORE	BOOSTER	STS LRB
SIZE (%ET Prop. Mass)	131	62	45
NOMINAL THRUST (MLbs-Vac.)	1.851	2.499	2.320
DRY WEIGHT (Lbs-thousands)	188.1	134.9	122.8

#	HLLV MODULAR BOOSTER (SINGLE ENGINE-OUT)				PROPOSED STS LRB (NO ENGINE-OUT)			
BSTRs	L.O.* T / W	STAGING DV (Fps)	GLOW (MLbs)	LIFT (KLbs)	L.O.* T / W	STAGING DV (Fps)	GLOW (MLbs)	LIFT (KLbs)
1	1.05	8,890	3.59	153.1	1.10	6,760	3.28	131.4
2	1.22	11,215	4.83	262.8	1.34	8,775	4.21	225.4
3	1.33	12,810	6.07	369.8	1.49	10,250	5.14	312.3
4	1.40	14,000	7.30	450.0	1.60	11,430	6.05	378.4

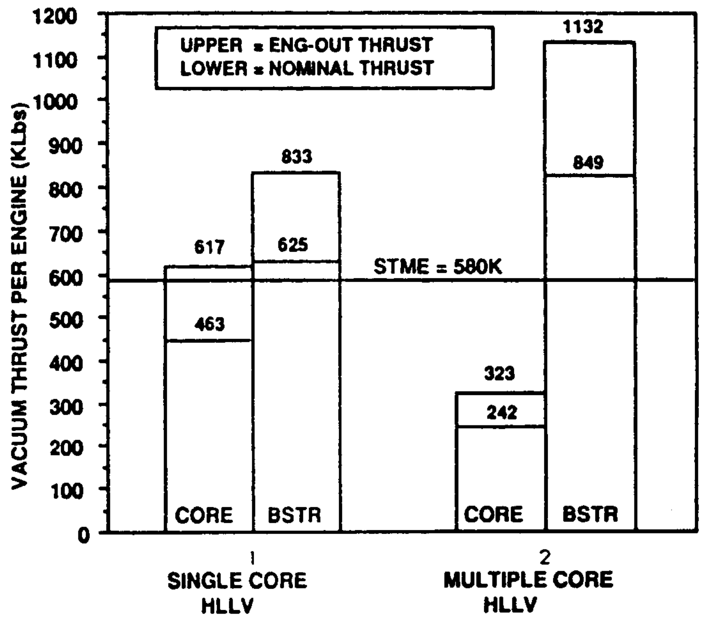
* FOR T / Ws < 1.4, MARGINS ADDED TO TOTAL DELTA-V FOR INCREASED LOSSES

A MODULAR HLLV OPTIMIZED FOR 450K LBS LIFT CAPABILITY CAN ENABLE A SINGLE LAUNCH LUNAR MISSION WHILE PROVIDING VERSATILE LIFT PERFORMANCE. USE OF THE PROPOSED STS LRB AS AN INTERIM BOOSTER OFFERS SYNERGISM WITH THE SPACE SHUTTLE.

THRUST REQUIREMENTS FOR 450KLB LIFT HLLVs

HLLV CONCEPT	TOTAL CORE VAC. THRUST (KLbs)	TOTAL BOOSTER VAC. THRUST (KLbs)
SINGLE CORE	1,851	2,499
MULTIPLE CORE	969	3,395

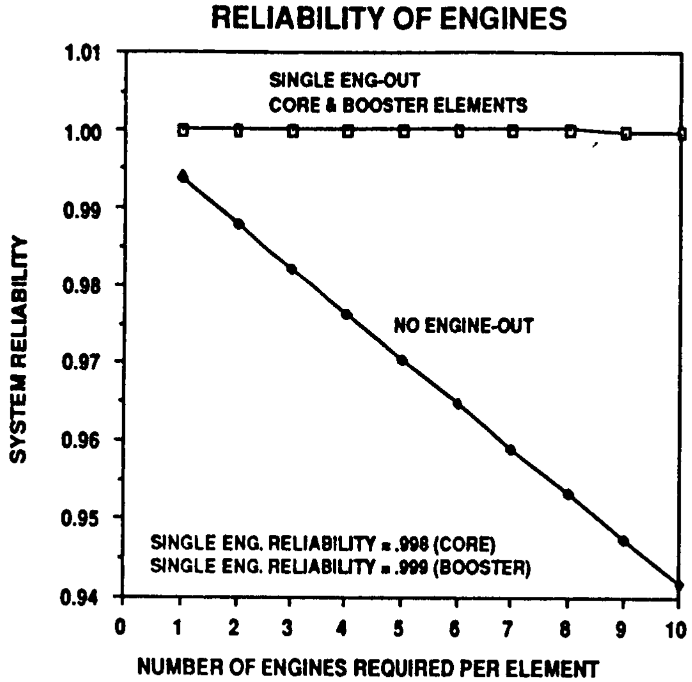
ENGINE THRUST REQUIREMENTS *

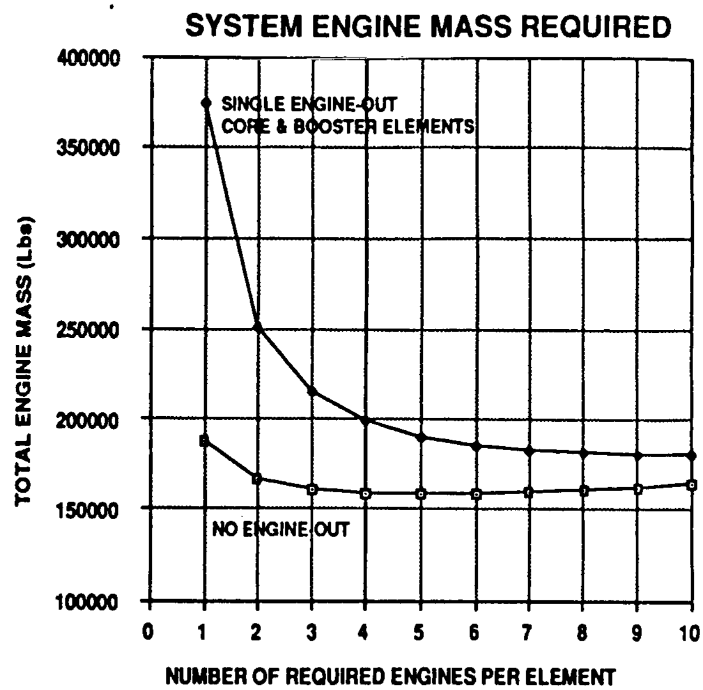


* 4 ENGINES PER STAGE
SINGLE ENG-OUT THROTTLE-UP = 33%

HLLVs REQUIRE ENGINE THRUST LEVELS GREATER THAN THE REFERENCE SPACE TRANSPORTATION ENGINE FOR REASONABLE NUMBERS OF ENGINES PER STAGE.

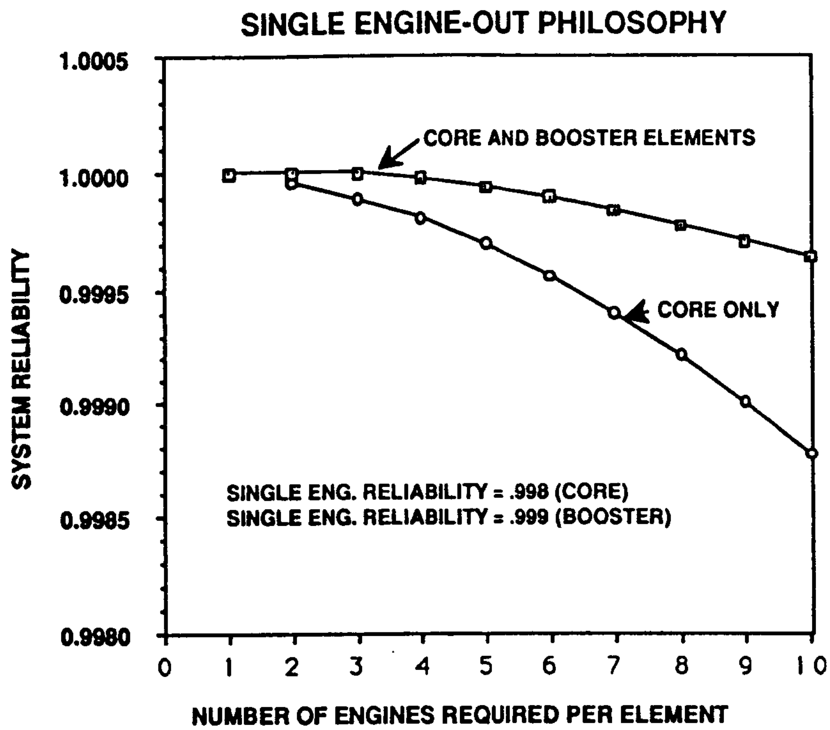
SINGLE CORE / 4-BOOSTER HLLV





THE SYSTEM RELIABILITY CAN BE SUBSTANTIALLY INCREASED WITH SINGLE ENGINE-OUT CAPABILITY ON THE CORE AND BOOSTER ELEMENTS. WITH FEWER ENGINES, RELIABILITY INCREASES BUT WITH THE PENALTY OF INCREASED SYSTEM MASS.

SINGLE CORE / 4-BOOSTER HLLV



THE APPROACH TO ENGINE-OUT CAPABILITY REMAINS AN ISSUE AND NEEDS TO BE ASSESSED. HIGH RELIABILITY IS OBTAINABLE WITH CORE ENGINE-OUT CAPABILITY ONLY BUT REQUIRES SUBSTANTIAL CORE FUEL MARGINS TO COVER BOOSTER ENGINE-OUT.

HLLV PROPULSION ISSUES

- o HLLV SYSTEMS NEED HIGH RELIABILITY
  - FAULT TOLERANT SYSTEMS / ENGINE-OUT CAPABILITY
  - RELIABLE THROTTLING CAPABILITY
  - ONBOARD CHECK-OUT / HEALTH MONITORING AND CONTROL
- o APPROACH TO ENGINE-OUT PROTECTION
- o REFERENCE STME THRUST LEVEL APPEARS TOO LOW
- o DESIGN TRADES TO FACILITATE SYSTEMS ANALYSIS
  - ENGINE RECOVERY VS. EXPENDABILITY
  - DESIGN REQUIREMENTS FOR REUSABILITY
  - ENGINE SCALING RELATIONS WITH THRUST LEVEL (Weight, Isp, Pc, Mixture Ratio, Throttling Capability)
  - THROTTLING
    - System Capability vs. Complexity
    - Step Throttle vs. Continuous (g-limiting)
  - ENGINE GIMBALLING VS. DIFFERENTIAL THRUST FOR CONTROL
  - ENGINE UPRATE CAPABILITY VS PROPULSION DESIGN (GROWTH)
    - o
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