DRIVES AND BENEFITS OVERVIEW

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The presentation covers the major technology issues for an advanced OTV engine to be used in conjunction with a space based, reusable orbit transfer vehicle. A brief summary of the results of the space station studies conducted in 1983 as they relate to the OTV is given as well as a brief review of ground rules and guidelines for a reusable OTV vehicle study which is currently being initiated at MSFC. The technology drives are presented and related to benefit categories i.e., mission versatility, increased reliability or reduced cost. The technology drivers and the associated benefits are then covered in detail with regard to relative significance and impact on the on-going OTV engine technology program. The concluding summary recommends that based on the maintenance opportunity afforded by the Space Station, the broad range of mission requirements and the long term potential cost benefits a new engine is needed for the space based reusable OTV.

OTV PROPULSION ISSUES
DRIVERS & BENEFITS

- IN THE MID 1990'S THE U. S. WILL NEED A NEW SPACE BASED OTV WHICH WILL BE PART OF AN INTEGRATED SPACE TRANSPORTATION SYSTEM CONSISTING OF:
  - SHUTTLE ORBITER (STS) (EXISTING)
  - SPACE STATION (SS) (1990)
  - SPACE BASED ORBIT TRANSFER VEHICLE (OTV) (1995)
  - ORBITAL MANEUVERING VEHICLE (OMV) (1990)
- OTV VEHICLE STUDIES ARE BEING INITIATED NOW AT MSFC TO DEFINE REQUIREMENTS AND CONCEPTS. A SUMMARY OF GROUND RULES AND GUIDELINES FOR THESE STUDIES ARE AS FOLLOWS:
  - INVESTIGATE USE OF SYSTEMS/SUBSYSTEMS FROM EXISTING AND PLANNED VEHICLES
  - ALL CONFIGURATIONS SHALL <u>EVOLVE</u> TO BECOME: (OR BE THAT WAY FROM OUTSET)
    - REUSABLE
    - SPACE–BASED
    - INCORPORATE AERO ASSIST (OR ALTERNATE APPROACHES)
    - MAN RATABLE
    - CRYOGENIC (OR ALTERNATE APPROACHES)
  - SUFFICIENT DETAIL TO DETERMINE COST AND VIABILITY OF EVOLUTIONARY APPROACH
  - GROUND BASED CONCEPTS SHALL INCLUDE OPERATION IN CONJUNCTION WITH THE SPACE STATION

Figure 1

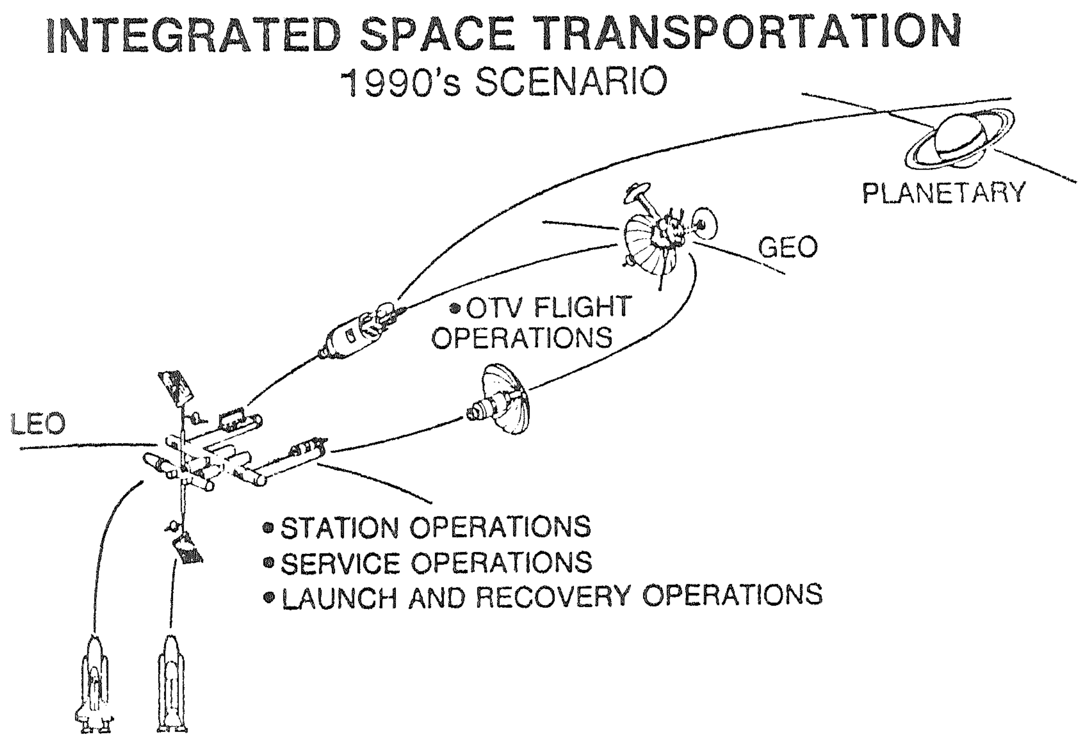
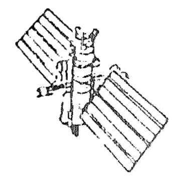


Figure 2

Mature Configuration (ACC)



Modular ACC Option

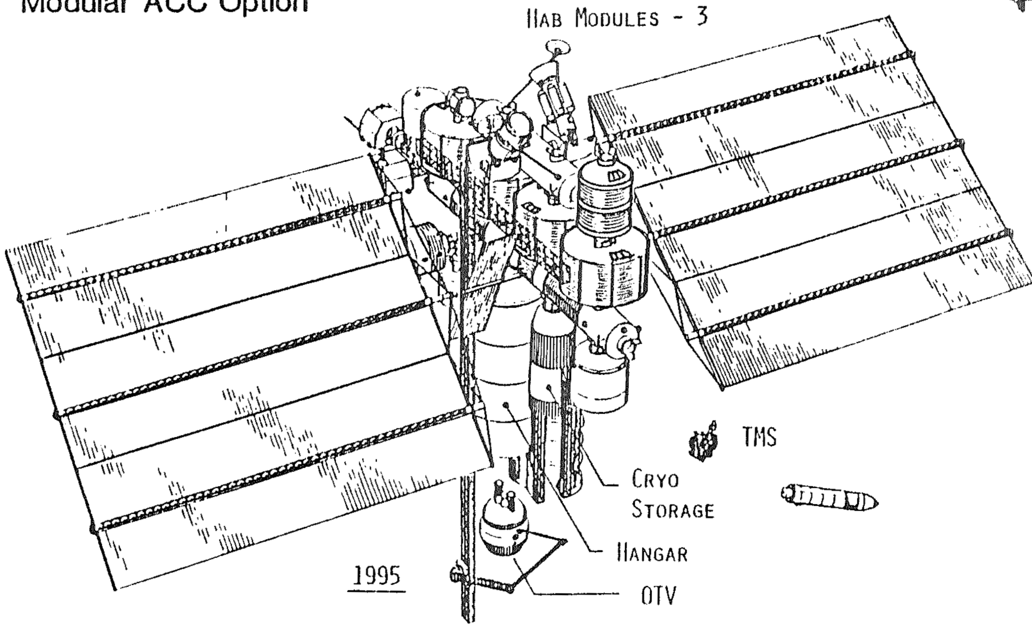
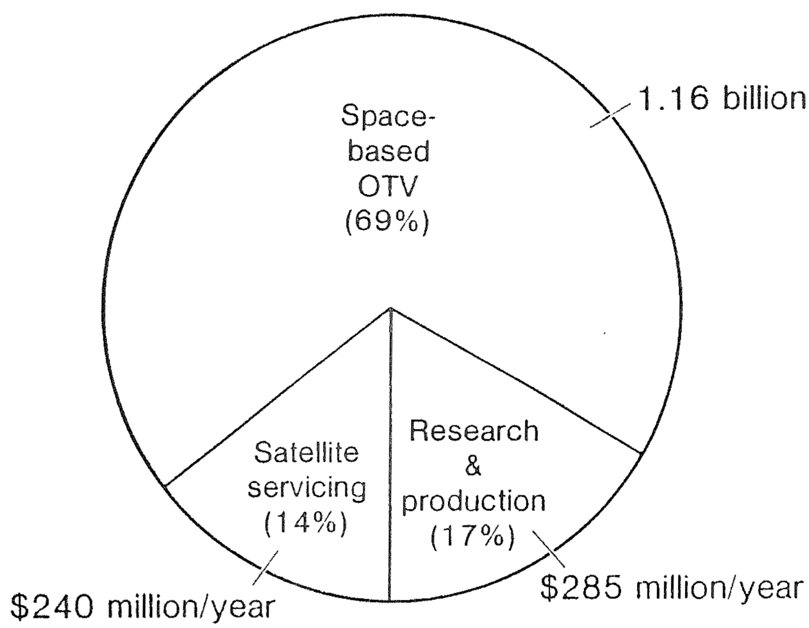


Figure 3

SPACE STATION ECONOMIC BENEFITS
(1984 $)



Total economic benefit: $1.685 billion

Figure 4

OTV PROPULSION ISSUES
DRIVERS & BENEFITS

TECHNOLOGY DRIVERS AND BENEFITS

TECHNOLOGY DRIVER	BENEFITS MISSION VERSATILITY	INCREASED RELIABILITY	REDUCED COST
SPACE BASED	√	√	√
MAN RATED	√	√	
THRUST LEVEL	√		
AERO ASSIST COMPATIBLE	√		√
PERFORMANCE	√		√
REUSABILITY/LIFE		√	√

Figure 5

OTV PROPULSION ISSUES
DRIVERS & BENEFITS

SPACE BASING BENEFITS FOR OTV MISSIONS

- SPACE STATION SERVES AS A HOLDING AREA FOR:
  - PROPELLANTS
  - OTV SYSTEMS
  - PAYLOADS

  THESE ITEMS CAN BE LAUNCHED, STORED AND ASSEMBLED IN MOST COST EFFECTIVE WAY
- POTENTIAL ECONOMIC BENEFIT FOR OTV MISSIONS IS ESTIMATED TO BE $5B THRU CY2000
- SPACE STATION CREATES OR ENHANCES OPPORTUNITY FOR:
  - LOW COST DELIVERY OF OTV PROPELLANT TO SS
  - MULTIPLE PAYLOADS ON OTV
  - MISSION VERSATILITY WITH MODULAR OTV SYSTEMS

IMPACT OF SPACE BASING ON EXISTING OTV PROPULSION TECHNOLOGY DRIVERS

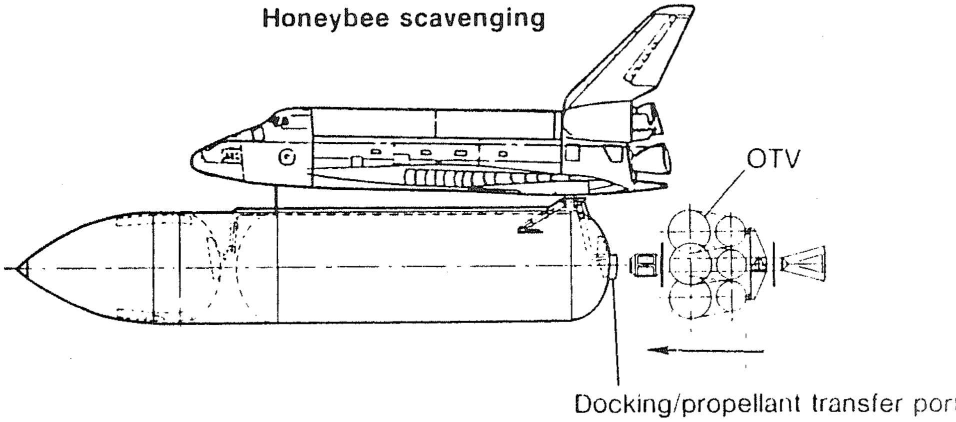
- PERFORMANCE – REDUCED PROPELLANT DELIVERY COST
- LIFE – SERVICE AND MAINTENANCE OPTIONS CREATED
- SIZE – FINAL ASSEMBLY AT SPACE STATION

NEW TECHNOLOGY DRIVERS INTRODUCED

- MODULAR DESIGN – ON-ORBIT ASSEMBLY
- HEALTH MONITORING, DIAGNOSTICS AND IN-FLIGHT CHECKOUT

Figure 6

PROPELLANT DELIVERY SYSTEM CONCEPTS



Performance

- Propellant delivered to station per mission — 11,300 pounds
- Propellant delivered to station per year — 230,000 to 270,000 pounds
- Propellant delivery cost — $250/pound

Figure 7

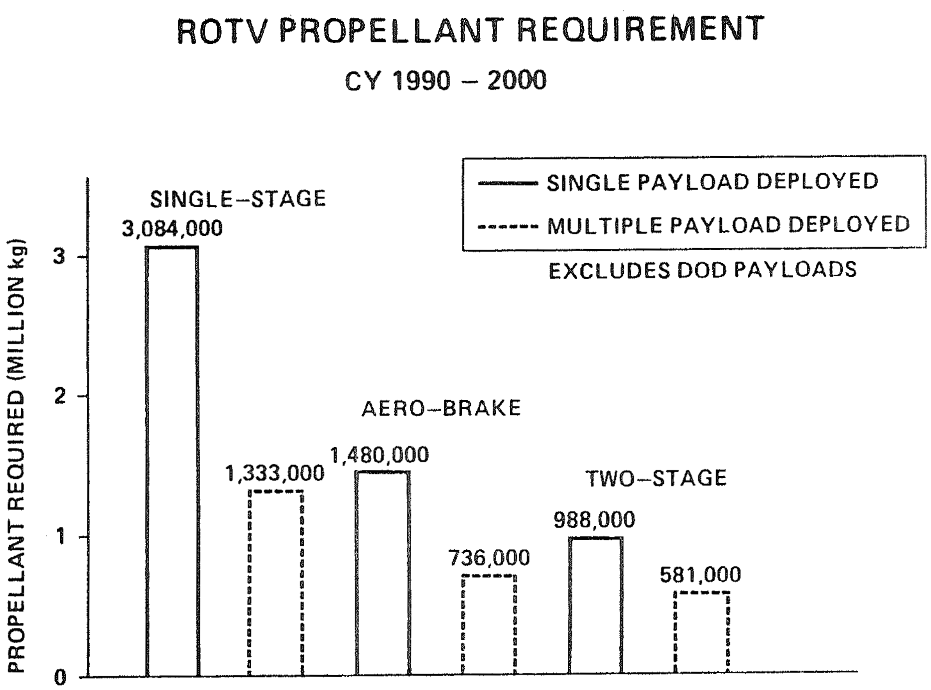


Figure 8

STS/SPACE BASEABLE PACKAGING CONCEPTS

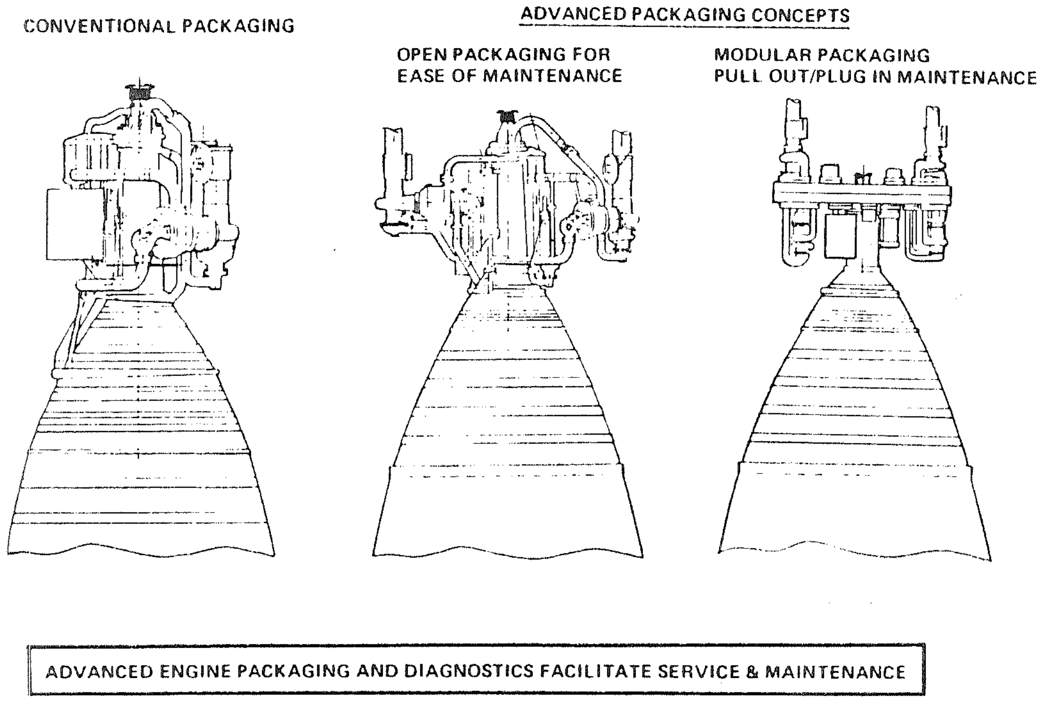


Figure 9

DIAGNOSTICS FOR MAINTAINABILITY APPROACH

ACHIEVED BY USING A BETWEEN-FLIGHT AND/OR IN-FLIGHT CONDITION MONITORING SYSTEM CONSISTING OF STATE OF THE-ART AND/OR NOVEL AUTOMATED DETECTION TECHNOLOGIES AND TAILORED DATA PROCESSING AND COMPUTERS

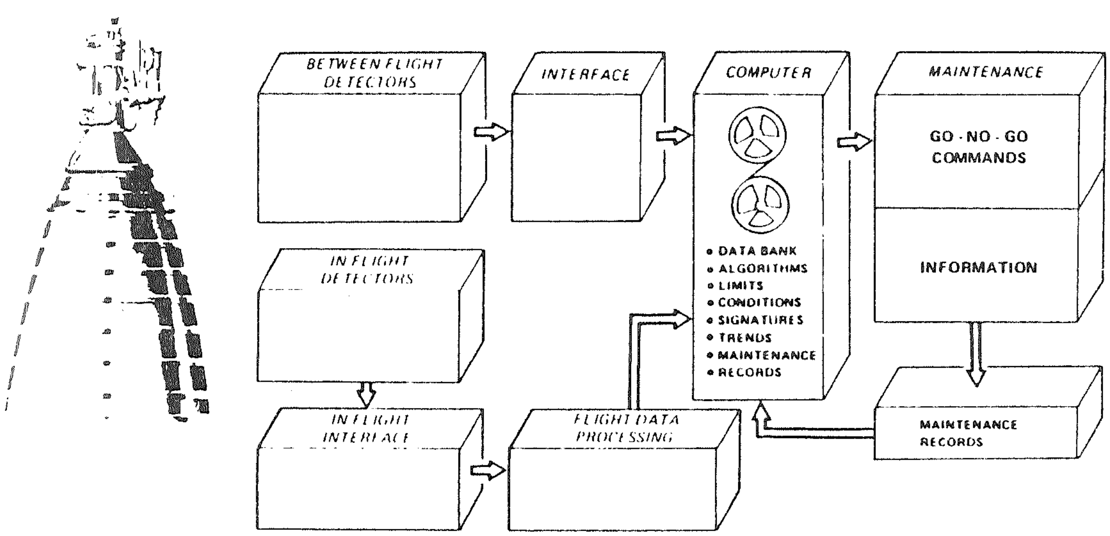


Figure 10

OTV PROPULSION ISSUES
DRIVERS & BENEFITS

MAN RATABLE OTV BENEFITS

- ENABLES COMPLEX SATELLITE SERVICING TASKS
- ENHANCES MISSION VERSATILITY AND RELIABILITY
- COULD SAVE REPLACEMENT OF A COMPLEX PAYLOAD

MAN RATABLE OTV PROPULSION TECHNOLOGY DRIVERS

- MAN RATING MEANS REDUNDANCY OR THE ELIMINATION OF ALL SINGLE POINT FAILURES
- LARGER MARGINS OF SAFETY ON STRUCTURAL COMPONENTS
- CONCENSUS IS MAN RATED OTV WOULD HAVE 2 ENGINES
  - MAN RATING THEN LEADS TO ENGINE THRUST LEVEL ISSUE
  - TOTAL THRUST FOR OTV ESTIMATED TO 10 – 20 K LB.
  - SINGLE ENGINE THRUST ON 2 ENGINE VEHICLE IS THEN 5 – 10 K LB.

Figure 11

OTV PROPULSION ISSUES
DRIVERS & BENEFITS

THRUST LEVEL BENEFITS

- MISSION VERSATILITY WHICH INCLUDES LOW g AND MANNED MISSIONS
- CONTINUOUS LOW THRUST THROTTLING TO MAINTAIN CONSTANT T/W RATIO ON LARGE DEPLOYED STRUCTURE PAYLOADS
- SELECTION OF A PROPULSION/ENGINE SYSTEM WHICH BEST ACCOMMODATES THE RANGE OF KNOWN OR ANTICIPATED MISSION REQUIREMENTS

THRUST LEVEL RELATED OTV PROPULSION TECHNOLOGY DRIVERS

- THE SMALL LH_2/LO_2 PUMP FED ENGINE (5 – 10K) IS ITSELF APPROACHING A NEW TECHNOLOGY AREA
  - DESIGN AND MANUFACTURING TECHNIQUES FOR SMALL DIAMETER HIGH SPEED PUMP COMPONENTS IS A NEW TECHNOLOGY AREA
  - BOUNDARY LAYER EFFECTS ON HEAT TRANSFER AND PERFORMANCE BECOME MORE SIGNIFICANT AS THE SIZE OF ENGINE IS REDUCED
- SPACE BASING AND MODULAR ENGINE DESIGN ENHANCES OPPORTUNITY TO USE "KITS" TO ACHIEVE A LOW THRUST ENGINE CONFIGURATION, i.e., PUMPS, INJECTORS, THRUST CHAMBER OR NOZZLES DESIGNED FOR LOW THRUST OPERATION AND MAXIMUM PERFORMANCE.

Figure 12

TECHNOLOGY SCALING

GOAL	EASE OF ACHIEVEMENT	IMPACTS
PERFORMANCE	MORE DIFFICULT AT LOWER THRUST	• LOW PUMP AND TURBINE EFF. • HIGH COOLANT JACKET ΔP • LOWER TURBINE ADMISSION
SYSTEM CONTROL	MORE DIFFICULT AT LOWER THRUST	• LOWER FLOWRATES • GREATER INSTRUMENT PRECISION REQ.
ENGINE CONDITIONING	MORE DIFFICULT AT LOWER THRUST	• HIGHER MASS PER UNIT FLOWRATE • LARGER SURFACE AREA PER UNIT FLOW
MANUFACTURABILITY	MORE DIFFICULT AT LOWER THRUST	• LESS METAL TO CUT • TIGHTER TOLERANCES • TURBINE, PUMP, AND T/C FAB LIMITS
MAINTAINABILITY	MORE DIFFICULT AT LOWER THRUST	• SMALLER PASSAGES • MORE DIFFICULT INSPECTION • DIAGNOSTIC SENSORS NOT SCALEABLE • SMALLER TOOLING
SYSTEM DESIGN	MORE DIFFICULT AT LOWER THRUST	• BETTER MATERIALS REQUIRED
LIFE	MORE DIFFICULT AT LOWER THRUST	• HIGHER ΔP FOR EQUAL LIFE • HIGHER SURFACE TEMPERATURES

Figure 13

OTV PROPULSION ISSUES
DRIVERS & BENEFITS

AERO ASSIST BENEFITS

- REDUCED PROPELLANT REQUIREMENT BY USING ATMOSPHERE AS BRAKE
- TWO STAGE OTV IS EQUALLY EFFECTIVE FOR DELIVERY ONLY MISSIONS
- AERO ASSIST MOST EFFECTIVE FOR DELIVERY AND RETURN MISSIONS, i.e., MANNED MISSIONS OR PAYLOAD SERVICING AT SPACE STATION

AERO ASSIST RELATED OTV PROPULSION TECHNOLOGY DRIVERS

- MEDIUM TO HIGH L/D CONCEPTS HAVE STRONG PREFERENCE FOR SMALL ENGINES WHICH CAN BE CONTAINED WITHIN THE VEHICLE PROFILE.
- LOW L/D BALLUTE CONCEPT REQUIRES THE ENGINE TO PROVIDE A GAS LAYER THERMAL BARRIER OVER THE INFLATED BALLUTE MATERIAL.
- LOW L/D RIGID SHIELD CONCEPT IS SENSITIVE TO ENGINE LENGTH SINCE DEPLOYMENT OVER THE ENGINE IS REQUIRED FOR THERMAL PROTECTION.

Figure 14

OTV PROPULSION ISSUES
DRIVERS & BENEFITS

PERFORMANCE BENEFITS

- REDUCED PROPELLANT REQUIREMENT AND PAYLOAD DELIVERY COST
- ADVANCED CONCEPTS ARE PREDICTED TO DELIVER ~ 480 SEC ISP OR A 40 SEC. INCREASE OVER RL–10–3A REF. ENGINE (440 SEC)
- INCREASED PERFORMANCE (440 – 480 SEC) REPRESENTS 20% REDUCTION IN PROPELLANT REQUIRED OR 20% INCREASE IN PAYLOAD
- THE OVERALL SIGNIFICANCE OF THIS IMPROVED PERFORMANCE IS A FUNCTION OF:
    - PROPELLANT DELIVERY AND STORAGE COST AT LEO OR SS
    - USE OF AERO ASSIST OR STAGING CONCEPTS

PERFORMANCE RELATED OTV PROPULSION TECHNOLOGY DRIVERS

- HIGHER CHAMBER PRESSURE AND PUMP SPEEDS
- ENHANCED HEAT TRANSFER TO PROVIDE MORE POWER TO PUMPS
- HIGH AREA RATIO NOZZLES WHICH, DEPENDING ON ENGINE SIZE, MUST BE SEGMENTED IF ENGINE LENGTH IS CONSTRAINED.

Figure 15

EFFECT ON SPECIFIC IMPULSE ON OTV PROPELLANT REQUIREMENTS

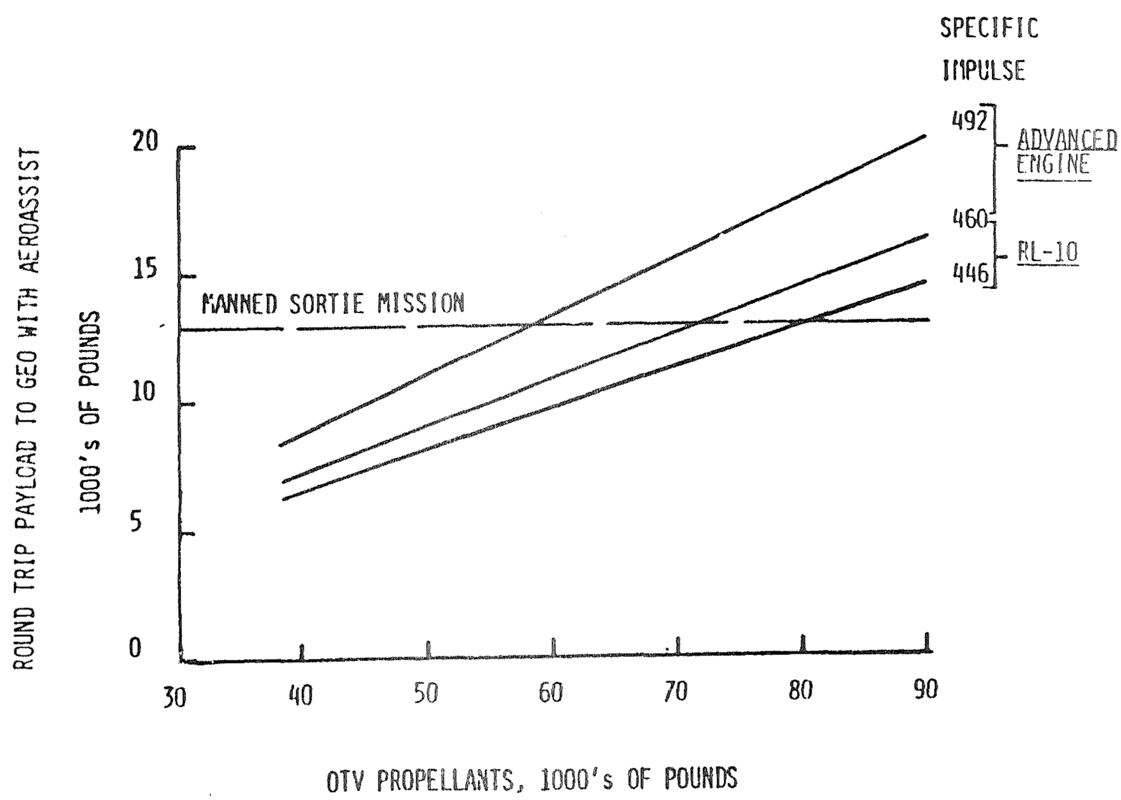


Figure 16

ADVANCED ENGINE PROVIDES PERFORMANCE FLEXIBILITY

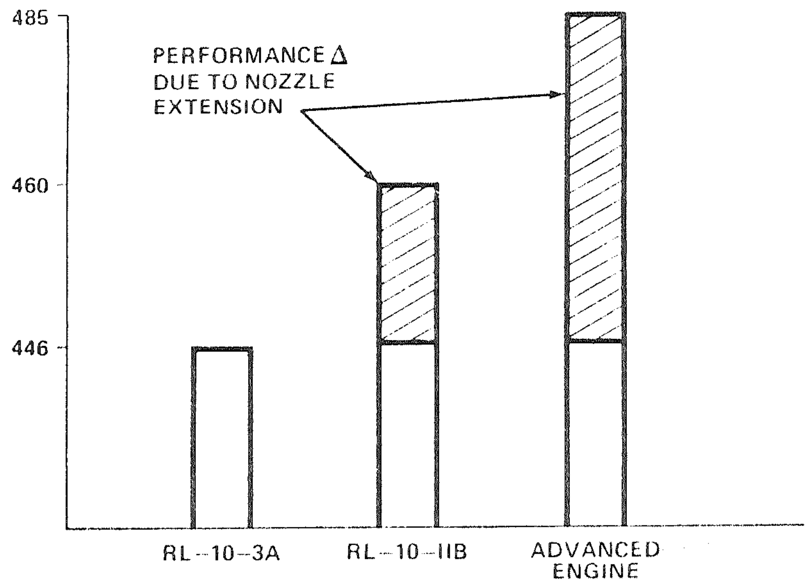


Figure 17

OTV PROPULSION ISSUES
DRIVERS & BENEFITS

<u>REUSABILITY AND EXTENDED LIFE BENEFITS</u>

- REDUCED OPERATING COST

<u>LIFE RELATED OTV PROPULSION TECHNOLOGY DRIVERS</u>

- IMPROVED BEARING, SEAL AND GEAR MATERIALS AND DESIGNS
- IMPROVED THRUST CHAMBER MATERIALS AND DESIGNS
- IMPROVED NOZZLE MATERIALS AND DESIGNS
- NEW CONTROL SYSTEMS, HEALTH MONITORING AND DIAGNOSTIC SYSTEMS TO CONTINUOUSLY MONITOR ENGINE STATUS OVER THE LIFE OF ENGINE

<u>OTV PROPULSION TECHNOLOGY PROGRAM PERSPECTIVE</u>

- THE 1995 SPACE BASED OTV WILL NEED A NEW HYDROGEN/OXYGEN FUELED ENGINE
  - PROVIDES FOR BROAD RANGE OF MISSIONS FROM LOW g TO MANNED FOR NEXT 20 – 40 YEARS
  - WILL TAKE FULL ADVANTAGE OF SERVICING OPTIONS AFFORDED BY THE SPACE STATION
  - PROVIDES IMPROVED RELIABILITY WITH INTEGRATED CONTROL AND HEALTH MONITORING SYSTEMS
  - EXTENDED LIFE AND INCREASED PERFORMANCE WILL PROVIDE A LONG TERM COST BENEFIT

Figure 18