

ADVANCED OTV ENGINES AND ISSUES

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Over the last decade Pratt & Whitney has studied the propulsion system requirements of Orbit Transfer Vehicles (OTV). Based on the current scenario for orbital operations in the late 1990's we have defined a baseline expander cycle engine which will meet those requirements.

The following presentation highlights the principal characteristics of our baseline engine and discusses some options which are available to accommodate OTV system optimization studies. A list of engine program issues are shown which are dependent on the mission scenario and the vehicle system configuration. Finally, a summary of the rationale for a new cryogenic OTV engine is given.

LATE 1990'S SCENARIO

- LEO space station with propellant depot
- Operational OMV
- Substantial LEO-GEO traffic
- Manned GEO sorties
- Reusable, cryogenic, aeroassisted OTV operational

Figure 1

REQUIREMENTS FOR OTV ENGINE

Must be compatible with:

- Space basing
- Aeroassist
- Man rating

Must have:

- High performance
- Long life
- High reliability
- Versatility
- Low operational cost

Figure 2

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OTV ENGINE OPERATING MODES

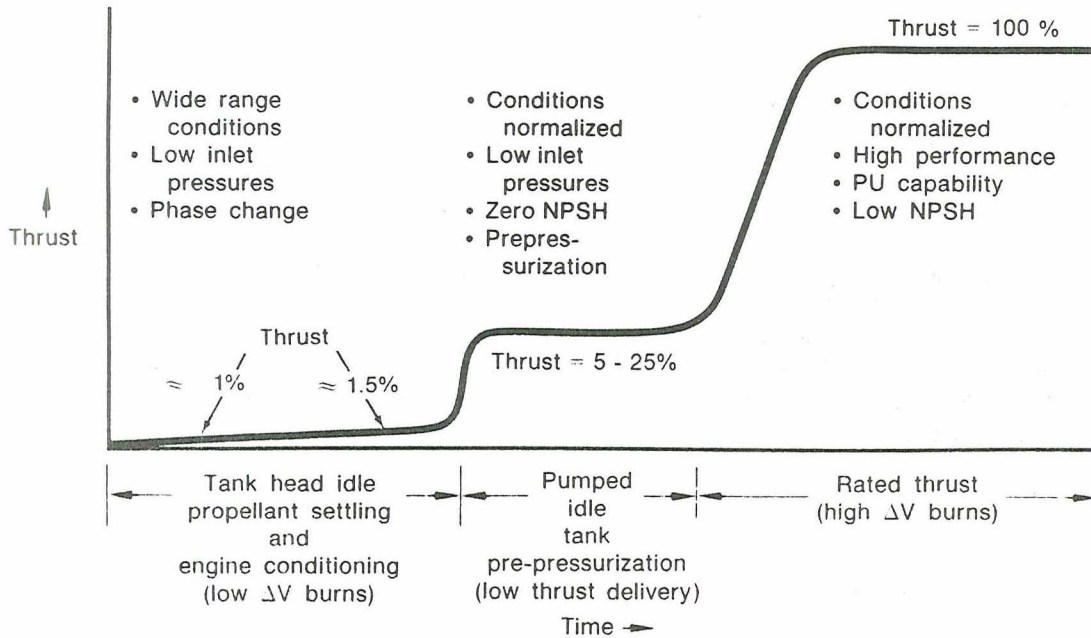
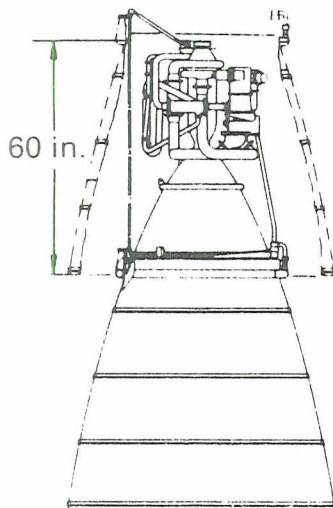


Figure 3

DESIGN CHARACTERISTICS

Advanced expander cycle engine



Thrust	: 15,000 lb
Mixture ratio	: 6.0:1 to 7.0:1
Chamber pressure	: 1500 psia
Area ratio	: 640
I_{sp}	: 482.0 sec at 6.0 MR
Operation	: Full thrust (low NPSH)
	: Pumped idle
	: (1500 lb thrust)
	: (saturated propellants)
Conditioning	: Tank head idle
Weight	: 427 lb
Life (design TBO)	: 300 firings/10 hr

Figure 4

INSTALLATION

Advanced expander cycle engine (1980)

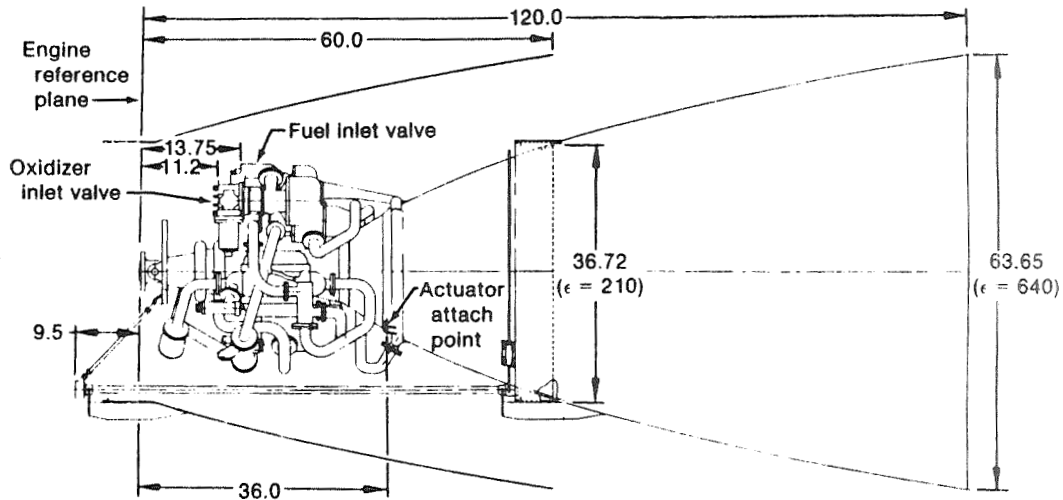


Figure 5

PROPELLANT FLOW SCHEMATIC

Advanced expander cycle engine at full thrust

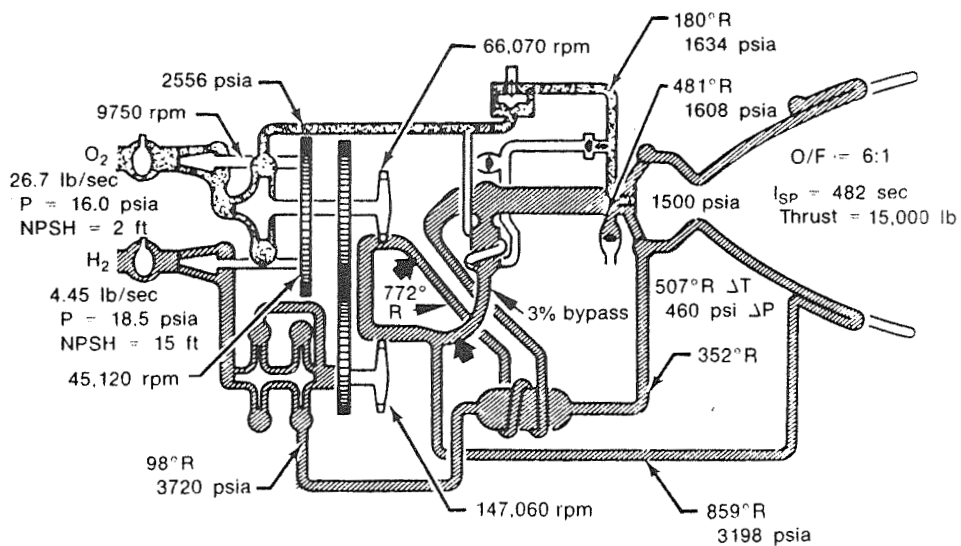


Figure 6

ADVANTAGES OF ADVANCED OTV ENGINE

- High reliability
 - Substantial design margins
 - Simple control system
- Adequate life
- Health monitoring relatively simple
- High performance
- Options available

Figure 7

ENGINE OPTIONS AVAILABLE

- Full thrust level
- Engine geometric size
- Throttling capability
- Mixture ratio range
- Special mission kits

Figure 8

FULL THRUST LEVEL AND SIZE

- Thrust levels evaluated: 500 to 30,000 lb
- Area ratios evaluated: 400 to 1,000
- I_{SP} (and size) proportional to thrust
- Optimum area ratio: 700 to 900
- DDT&E cost not significantly affected by thrust
- Limited applicability of technology for scaling

Figure 9

ADVANCED NOZZLE EXTENSION MECHANISM

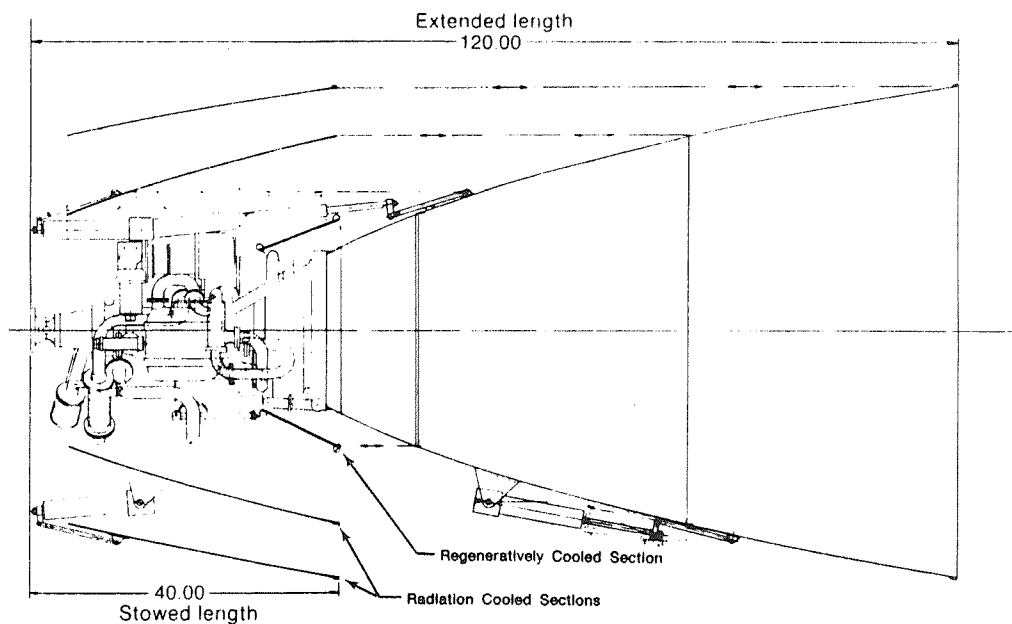


Figure 10

THROTTLING CAPABILITY

- Most missions
 - Full thrust for major burns
 - Very low thrust for trim burns (THI)
 - No requirement for intermediate levels
- Special G-level limited missions
 - “Continuous” throttling to hold max allowable T/W will yield higher average I_{SP}
 - Continuous throttling requires more complex engine system than a few discrete steps
- Potential throttled burn during aeroassist maneuver
 - Range and levels TBD

Figure 11

FULL THROTTLE RANGE CONCEPT

Continuous gaseous O_2 injection

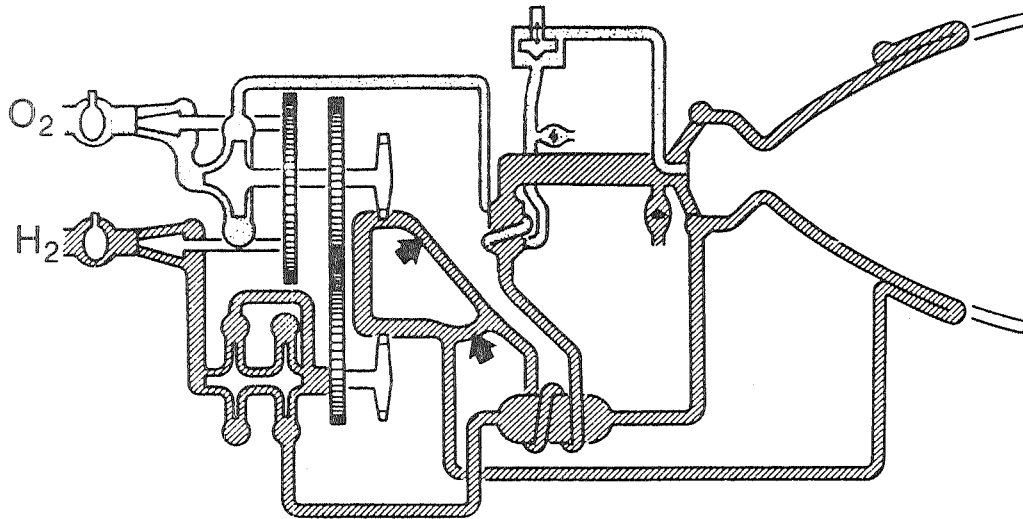


Figure 12

MIXTURE RATIO RANGE

- Optimum mixture range function of P_c (for $\epsilon \sim 750:1$)
 - 6:1 at $P_c \sim 1000$
 - 5:1 at $P_c \sim 500$
 - 4:1 at $P_c \sim 50$
- Off-nominal range required for vehicle considerations
 - Boiloff
 - Tanking uncertainty
 - Special mission requirements

Figure 13

SPECIAL MISSION KITS

Examples

High thrust expendable mission

- Low thrust components might be eliminated
- Nozzle area ratio might be increased w/o aero assist

Low thrust expendable mission

- Control system might be mission specific
- Nozzle area ratio might be increased w/o aero assist

Figure 14

ADVANCED OTV ENGINE ISSUES

- * • Engine thrust level(s)
 - Engine throttle requirements
- * • Engine geometry constraints (including number of engines)
 - Engine operational life/servicing requirements
 - Basing mode
 - Engine/aeroassist mode interaction
 - Is “low thrust deployment” a viable OTV mission?
 - Is manned GEO mission viable?

Figure 15

SUMMARY

- A new cryogenic OTV engine will significantly enhance the capability of the OTV system in the following areas:
 - Designed for space basing
 - Designed for aeroassist compatibility
 - Designed for man-rateability
 - Designed for versatility/very high performance
- Commitment to DDT&E should be based on sound design, low risk approach which for an advanced technology engine includes key component demonstrations
- 6-10 year leadtime needed for high technology engine (depending on preceding component technology demonstration programs)
- OTV open issues exist
- Continuing iterations with NASA/systems contractors required to resolve issues and focus technology program

Figure 16