ORBITAL TRANSFER VEHICLE STUDIES
OVERVIEW

PRESENTATION TO THE
CRYOGENIC FLUID MANAGEMENT TECHNOLOGY WORKSHOP

DON PERKINSION
APRIL 28, 1987
NASA/MSFC
ORBITAL TRANSFER VEHICLE CONCEPT DEFINITION AND SYSTEM ANALYSIS STUDIES

OBJECTIVES:

- Investigate alternative OTV concepts and conduct program level studies and assessments which will allow focusing the OTV program toward future development.

- Define potential space station accommodations hardware elements, resources, and interfaces necessary to support a space-based OTV fleet.

CONTRACTOR DATA:

- Two parallel studies under competitively awarded contracts
  - Boeing Aerospace Company (Seattle, WA)
  - Martin Marietta Aerospace (Denver, CO)

- One parallel study conducted under company funds during phases I & II
  - General Dynamics Space Systems Division (San Diego, CA)

- $1.6 M each contracted study

DURATION: 43 months, initiated July 1984 (contracts), phase III extends to February 1988

MSFC TECHNICAL MANAGER: Donald R. Saxton, PF20

HEADQUARTERS MANAGERS: Ted Simpson, MD
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OTV SIZING MISSIONS

- SPACE BASED, FULLY REUSABLE OTV
- LOX/LH, 483 SEC, BALLUTE AEROASSIST

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<th>PROPELLANT REQUIRED (K-LB)</th>
<th>SMALL STAGE</th>
<th>LARGE STAGE</th>
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<td>MISSION</td>
<td>CIVIL &amp; DOD S/C (MULTIPLE P/L)</td>
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SPACE BASED OTV
MARTIN MARIETTA
PAYLOAD 12,000 UP/10,000 DN

WEIGHTS

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<th>Component</th>
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<td>LOADED WEIGHT</td>
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GRAFITE POLYIMIDE
HONEYCOMB COVERED
WITH CERAMIC FOAM TILES

MULTI-PLY NICALON,
Q FEAT AND SEALED
NEXTEL ON GRAPHITE
POLYIMIDE FRAME

INFLATED TORUS

48 FT DIA AEROBRAKE

GRAPPLE

AVIONICS MODULE
GRAPHITE EPOXY

TANK SURFACE
2090 ALUM ALEY
(TYP)

METEOROID SHIELD
(TYP)

CRADLE INTERFACE
BOEING SPACE BASED OTV
BALLUTEC BRAKED

UNIQUE FEATURES

- BALLUTE
  - NEXTEL/CS 105
  - 1500°F BACKWALL
  - TURNDOWN RATIO = 1.5
  - 1 USE
- HEAT SHIELD—RSI
  - 20 USES
- NO INITIAL ON-ORBIT ASSEMBLY

STAGE WEIGHT SUMMARY (LBS)

- DRY 9189
- MAIN PROP. 63,890
- OTHER FLUIDS 1,061
- STARTBURN 74,140

FOR MANNED GEO SORTIE (7.5K R.T.) OR 20K GEO DELIV
GENERAL DYNAMICS

MODULAR SPACE-BASED OTV

Avionics
Oxygen tank
Hydrogen tank
Geotruss aerobrake

Growth
36 ft-10 in.

Twin engines (5,000 lb, 485 sec lsp)

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<td>Vehicle ignition</td>
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<td>134,900</td>
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<td>Usable propellant</td>
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<td>122,500</td>
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OTV TECHNOLOGY REQUIREMENTS

- ZERO G PROPELLANT TRANSFER
  - PROPELLANT PUMP/PRESSURIZATION
  - CHILL DOWN & VENT SYSTEM
  - PROPELLANT ACQUISITION (TANKER/STORAGE)
  - ABORT DUMP/TRANSFER (OTV)
  - QUICK CONNECT/DISCONNECTS

- PROPELLANT MASS GAUGING
  - ZERO G MEASUREMENT
  - PROPELLANT MASS TRANSFERRED
  - PROPELLANT REMAINING DURING BURN

- INSULATION
  - MLU ONLY FOR SPACE BASED OTV
  - MLU/FOAM/INERT GAS FOR GROUND BASED OTV

PROPELLANT PUMP/PRESSURIZATION

- DEMONSTRATE PROPELLANT TRANSFER BETWEEN TANKS BY CRYOGENIC COMPATIBLE PUMPS AND/OR TANK PRESSURIZATION

- MEASURE HEAT ADDED TO CRYOGEN BY PUMP

- DETERMINE EFFECTS OF ZERO G ON PUMP OPERATION, BUBBLE FORMATION, SUCTION LINE FLUID FLOW, ETC

- DETERMINE EFFECTS OF ZERO G ON PRESSURANT GAS/FLUID SEPARATION

- MEASURE G NECESSARY TO SETTLE FLUID, FLUID SLOSH IN LOW G, ETC

- BUBBLE UP/AUTOGENOUS PRESSURIZATION
CHILL DOWN & VENT SYSTEM

- CHILL DOWN OF A WARM TANK
- ULLAGE VENTING AND FILL OF A PARTIALLY FILLED TANK
- A THERMODYNAMIC VENT SYSTEM HAS BEEN DESIGNED FOR THE CENTAUR AND DEMONSTRATED ON THE GROUND
- DEMONSTRATE THERMODYNAMIC VENT SYSTEM IN ZERO G
- DEVELOP AND DEMONSTRATE A ZERO G HELIUM VENT SYSTEM (?)

PROPELLANT ACQUISITION/MANAGEMENT (TANKER/STORAGE FACILITY)

- DEMONSTRATE LIQUID ACQUISITION AND VAPOR FREE OUTFLOW
- DETERMINE SPACECRAFT DYNAMICS DURING PROPELLANT TRANSFER
- COMPARE STORAGE TANK/TANKER REQUIREMENTS TO OTV DETANK REQUIREMENTS
- CONTROL FLUID DYNAMICS (SLOSH, SETTLING)

ABORT DUMP/TRANSFER (OTV)

- PROPELLANT RECOVERY AFTER MISSION ABORT NEAR THE SPACE STATION
- PROPELLANT DUMP
- RETURN OF RESIDUAL PROPELLANT TO STORAGE FACILITY
QUICK CONNECT/DISCONNECT FLUID INTERFACES

- "ZERO LEAKAGE" CONNECTIONS
- MINIMIZE ALIGNMENT REQUIREMENTS
- PROVIDE SEAL VENTING FOR PRESSURIZED SYSTEMS
- CONSIDER LEAK DETECTION, SEAL REPLACEMENT, INSPECTION, ETC
- MINIMIZE PRESSURE DROP ACROSS INTERFACE

ZERO G MASS GAUGING

- NO PROVEN METHOD FOR LARGE TANKS IN ZERO G
- NEED METHOD PROVIDING 1% OR BETTER ACCURACY
- ADDRESS SENSITIVITY TO PRESSURE OR TEMPERATURE

PROPELLANT MASS TRANSFERRED

- MEASURE PROPELLANT TRANSFER RATE AND TOTAL TRANSFERRED
- CORRECT FOR TEMPERATURE EFFECTS
- DETERMINE AND CORRECT FOR PRESENCE OF BUBBLES IN FLUID
- PROPELLANT UTILIZATION/MANAGEMENT IN MULTI-TANK OTV CONFIGURATIONS
PROPELLANT REMAINING DURING BURN

- Measure propellant during 0.01 to 1.0 g acceleration
- Provide rapid measurement update

INSULATION

- Space based OTV
  - Insulate MLI with long lift in vacuum
  - Insulate LH2 tank from LOX tank to provide shorter capability and to minimize impact of slow fill/drain
  - Minimize micrometeoroid/debris damage

- Ground based OTV
  - MLI on LOX tank
  - MLI foam/inert gas on LH2 tank to prevent cryopumping
  - Insulate LH2 tank from LOX tank to provide shorter capability

OTV SUPPORT TECHNOLOGY
(SPACE BASED)

- Long term cryogenic storage
- Vapor cooled shields
- Paraorthogonal conversion
- Refrigeration
- Reliquefaction
- Propellant delivery