ORBITAL TRANSFER VEHICLE STUDIES

PRESENTATION TO THE
CRYOGENIC FLUID MANAGEMENT TECHNOLOGY WORKSHOP

DON PERTKINSON
APRIL 28, 1987
NASA/MSFC

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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
**ORBITAL TRANSFER VEHICLE (OTV)**

|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|

**KEY MILESTONES**

- OTV Δ
- Ø B START
- OTV Δ
- Ø C/D START
- GBOTV Δ
- LAUNCH

**REUSABLE OTV**

- SYSTEM STUDIES
  - PHASE A
  - PHASE B
- AEROSAULT TECHNOLOGY
- VEHICLE TECHNOLOGY
- VEHICLE DESIGN & DEV.
- OTV ENGINE

**GBOTV** = GROUND-BASED OTV

**FFC** = FINAL FLIGHT CERTIFICATION
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REVISION NUMBER: 9 (STAS)
OTV SIZING MISSIONS

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

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<th>MISSION</th>
<th>SMALL STAGE</th>
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MASS (K-LB)  
14.6 (12/2)  21.8  12/10  33 (L.O.)  73 (L.O.)  32.3 (C3=49)

FIRST FLIGHT  

QUANTITY  
342  2  54  1  4  1
WEIGHTS

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**SPACE BASED OTV**

**PAYLOAD 12,000 up/10,000 DN**

- INFLATED TORUS
- TANK SURFACE 2090 ALUM ALY (TYP)
- METEOROID SHIELD (TYP)
- AVIONICS MODULE GRAPHITE EPOXY
- GRAPPLE
- 48 FT DIA AEROBRAKE
- RCS (2 PLCS)
- GRAPHITE POLYMIDE HONEYCOMB COVERED WITH CERAMIC FOAM TILES
- MULTI-Ply NICALON, Q FELT AND SEALED NEXTEL ON GRAPHITE POLYMIDE FRAME
- CRADLE INTERFACE
- GRAPHITE EPOXY STRUCTURE
BOEING SPACE BASED OTV

BALLUTE 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**

![Diagram of Modular Space-Based OTV](image)

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

36 ft-10 in. Growth

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<td>Vehicle ignition</td>
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<td>134,900</td>
<td>177,500</td>
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<td>Payload roundtrip</td>
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<td>31,450</td>
<td>42,840</td>
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OTV TECHNOLOGY REQUIREMENTS

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

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

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

PROPELLENT PUMP/PRESSURIZATION

- DEMONSTRATE PROPELLENT 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/AUTOGNOSIS 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
  - THICK ML1 WITH LONG LIFE IN VACUUM
  - INSULATE LH2 TANK FROM LOX TANK TO PROVIDE LONGER CAPABILITY AND TO MINIMIZE IMPACT OF SLOW FILL/DRAIN
  - MINIMIZE MICROMETEOROID/DEBRIS DAMAGE

- GROUND BASED OTV
  - ML1 ON LOX TANK
  - ML1 FOAM/INERT GAS ON LH2 TANK TO PREVENT CRYOPUMPING
  - INSULATE LH2 TANK FROM LOX TANK TO PROVIDE LONGER CAPABILITY

OTV SUPPORT TECHNOLOGY
(SPACE BASED)

- LONG TERM CRYOGENIC STORAGE
- VAPOR COOLED SHIELDS
- PARAVORTEX CONVERSION
- REFRIGERATION
- RELIQUEFACTION
- PROPELLANT DELIVERY