ORBITAL TRANSFER VEHICLE STUDIES

PRESENTATION TO THE
CRYOGENIC FLUID MANAGEMENT TECHNOLOGY WORKSHOP

DON PERKINSON
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

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#### Reusable OTV

- **System Studies**
  - Phase A
  - Phase B

- **Aeroassist Technology**

- **Vehicle Technology**

- **Vehicle Design & Dev.**

- **OTV Engine**
  - Definition
  - Engine Design & Dev.

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**GBOTV** = GROUND-BASED OTV

**FFC** = FINAL FLIGHT CERTIFICATION
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OTV SIZING MISSIONS

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

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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) |
QUANTITY | 342         | 2   | 54   | 1         | 4         | 1           |
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 MANAGED GEO SORIE (7.5K R.T.) OR 20K GEO DELIV
GENERAL DYNAMICS

MODULAR SPACE-BASED OTV

Avionics
Oxygen tank
Hydrogen tank
Geotruss aerobrake

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

Growth

36 ft-10 in.

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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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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
  - MIL ONLY FOR SPACE BASED OTV
  - MIL/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 RE 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 MLI WITH LONG LIFTS IN VACUUM
  - INSULATE LH2 TANK FROM LOX TANK TO PROVIDE LOXER 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 LOXER CAPABILITY

OTV SUPPORT TECHNOLOGY
(SPACE BASED)

- LONG TERM CRYOGENIC STORAGE
- VAPOR COOLED SHIELDS
- PARAVORTHO CONVERSION
- REFRIGERATION
- RELIQUEFICATION
- PROPELLANT DELIVERY