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MEMORANDUM FOR IN-HOUSE PUBLICATIONS

FROM: PROI (TI) (STINFO) 9 Jul 98

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-1998-150
Dave Perkins "Reusable Orbit Transfer Vehicle Propulsion Technology Considerations"
AIAA Slides **(Statement A)**

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Reusable Orbit Transfer Vehicle Propulsion Technology Considerations

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ROTV: The Interest

- Cost of Space Access is Prohibitive: ~$10B/Yr for World
  - Expendable Launch Hardware limits potential cost reduction
  - Upper Stages and Orbit Transfer Vehicles are Big Cost Element
    - ~25% of total launch service to destination orbits
- The key claim is 10X cost reductions thru Reusability
  - ROTVs amortize their cost over many missions
  - Benefit of large number of reuses at marginal cost
- ROTVs enable Space Salvage via Space Tug

ROTV Concept of Operations Ground Based

1. ROTV & PL are Integrated on the Ground
2. Propellant Loaded before Launch
3. RLV performs LEO Insertion
4. ROTV (with PL) Deployed from RLV
5. ROTV transfers to Destination Orbit
6. PL Deployment &/or Pickup
7. ROTV Return to LEO
8. Rendezvous w RLV: Safe and Vent
9. ROTV Capture and Storage
10. Reentry, Land, ROTV Removal
11. Process for Next Mission

ROTV Concept of Operations
Space Based

1. PL & Propellant (in flight Dewar) Loaded into RLV
2. RLV launch and rendezvous with ROTV
3. On-Orbit Propellant Transfer
4. PL transfer from RLV to ROTV
5. ROTV transfers to Destination Orbit
6. PL Deployment &/or Pickup
7. ROTV Return to LEO
8. Safe, Vent and Self-Maintain On-Orbit

   On-Orbit Maintenance must be separately planned & performed

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Space Based Vs. Ground Based

- Space Based has fewer operations, however
  - Requires dewars that are RLV flight hardware
  - On-orbit maintenance with very good health monitoring
    - 1 pound per sensor x many hundreds of sensors
  - On-Orbit propellant transfer
    - Low weight with High transfer efficiency
    - Must limit number of replenishable fluids in SB ROTV
  - PL transfer w autonomous operations will scare PLs
  - Orbital Inclination Limitations
    - Orbital plane changes are just too expensive
      - That's why LVs Launch to PL inclinations when possible
    - Limits number of missions that SB ROTV can capture
- Ground Based is better

ROTVs: Some Cautions

- SB or GB ROTVs require Reusable Launch Vehicles
  - RLV is a Giant Horse necessary for ROTV Cart
- Economic viability demands large # of ROTV reuses
  - High mission success reliability is essential
  - Large ROTV development scope (cost & sched) concern
- ROTV LEO return leg uses propellant that reduces PL
  - Demands high ISP propulsion
    - A pound of propellant in LEO is worth ~$5000 today
  - Limits chemical systems to lower energy missions
- ROTVs & Dewars are sized for largest mission
  - Limits RLV volume available for PL
- ROTV interfaces w PL will need to be very general OR ROTV limited to specific markets

ROTV Propulsion Technology
Chemical Propulsion

- Storable Propulsion
  - Flexibility for long term on-orbit ops; No boil-off
  - Use limited to LEO and low MEO constellations
  - Relatively dense propellants limit volume problems

- Cryogenic Propellants
  - Higher ISP allows full MEO access, better PL fractions
  - Lower propellant density coupled with insulation req'm't
    - Heavier tanks & dewars and Smaller payload volumes

- In either case, high ISP and low stage mass needed
  - Low thrust pump fed engines; closed engine cycles
  - Light weight integrated tank, structure, and insulation

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ROTV Propulsion Technology
Solar Thermal Propulsion

- ISP limited by working fluid, but very high
  - H2 to ~1000 sec; NH3 to 450 sec
  - Can achieve all important Earth Orbits!
- Thrust is power (reflector size) limited to 10-100 lbf
  - Trip times to GEO from days to a couple of months
  - Thermal storage concepts raise thrust but lower ISP
    - Lowers trip times by factors of 2 to 5
- LH2 creates many volume and handling issues
  - RLV payload bay volume constraint may be limiting
- Large integrated time in radiation belts
  - Heavier solar concentrators required
  - PLs will not be pleased ADVERSE IMPACT ON PAYLOAD
- Need deployable concentrators that are restowable

PL 3 ?

ROTV Propulsion Technology
Electric Propulsion

- ISP range of 1200 to 5000 sec and beyond
  - Tremendous PL capability
- Power limited thrust of under 1 lbf
  - Forces less efficient continuous thrust spiral transfer
  - Trip times of months to a year or more
  - Limited to circular destination orbits
- Propellants such as Xenon store well
  - No volume constraint issues
- Very long times in radiation belts
  - Radiation hardened solar arrays needed
  - Power processor units should be shielded
  - PLs generally won't like radiation design constraint
- Need light weight radiation resistant power arrays that are deployable and restowable

Conclusions

- ROTVs enable space tugs and space salvage
  - RLV required to implement ROTV not yet well defined
- ROTV for Space Trans has a lot to prove to PLs
  - Esp. if RLV recurring cost becomes higher than advertised
- Ground based better than space based ROTV
  - Ground based ROTV useful for more missions
  - Less challenging technology required: Less risk to PL
- ROTV propulsion technologies to consider
  - Chemical rockets have limited mission capture
  - Solar thermal rockets capture most missions but LH2 issues
  - Electric has highest PL without volume constraint
    - Longest trip time, large PL radiation dose
    - Elliptical destination orbits not available
- All technologies require more $ to enable ROTV!