

# RLV-Compatible Orbital Propellant Depots

Space Access 2010  
Phoenix, AZ

Jonathan Goff, Lead Propulsion Engineer

Masten Space Systems, Inc.

*1570 Sabovich St, Bldg 25*

*Mojave, CA 93501*

*(801) 362-2310*

[jongoff@masten-space.com](mailto:jongoff@masten-space.com)

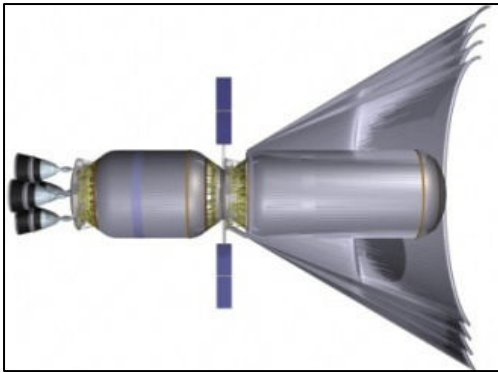


# Depots as an Important Early RLV Market

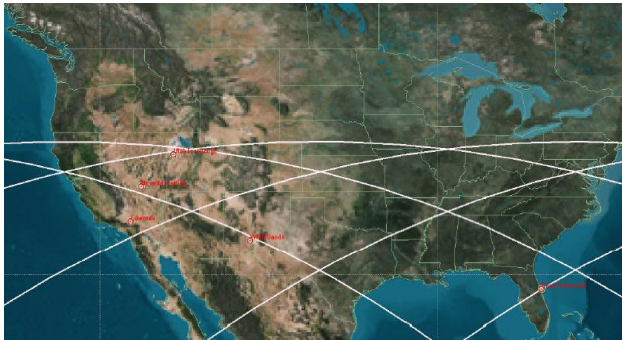
- RLVs are critical for low-cost LEO access.
- Business/Financing obstacles can be just as daunting as technical ones
  - So far, only Kistler raised enough money to have a chance to fail technically
  - No market has *demonstrated* adequate demand yet
  - RLVs need >25-50 flights/year
- Prediction: Realistic near-term RLVs will be <1 ton to LEO
- Ideal RLV payloads:
  - Finely divisible
  - Good demand elasticity
  - Easily produced w/ short lead times
  - Demonstrate sufficient demand before RLV available
- Propellants look interesting:
  - Just 1-2 GEO satellites per year would provide enough demand
  - Or one “Around the Moon” tourism flight per year



# Location, Location, Location

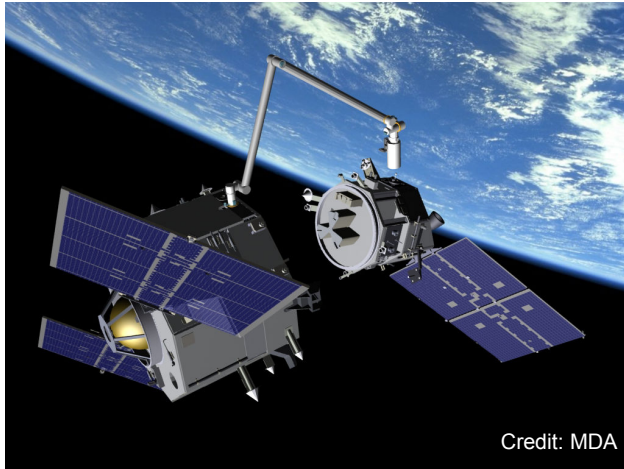


Dual Fluid Depot (Credit: ULA)

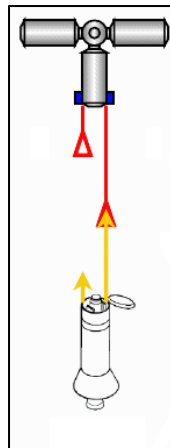
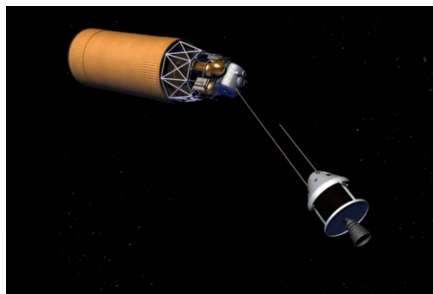


- Small Depots in LEO as well as BEO locations
  - RLVs most likely only able to reach LEO
  - Depots at both ends allows for smaller, single-launch depots to be used
  - More small LEO depots better than one big LEO depot
    - More frequent delivery opportunities
    - More frequent BEO launch windows
  - Use reusable tankers to transfer prop between LEO and BEO depots
- Resonant (Repeating Groundtrack) Orbits
  - At right combination of inclination and altitude, passes over same point at same time every day
  - Enables routine flight operations, simplifies single-orbit (or few orbit) rendezvous
  - Enables many launch sites to participate, not just one.
  - For many launch sites you get two daily launch and landing opportunities per depot
  - Multiple depots in the same inclination and altitude, but with different RAAN allows even more frequent flight opportunities

# Reaching Out in New Ways



- Space Tugs
  - Early RLVs likely to be small (< 1 tonne to LEO)
  - Offload AR&D hardware to a reusable tug to improve payload fraction
  - Apogee tugs can enable RLV delivery to low altitudes, with tug providing boost to depot altitudes at lower cost
  - Common “dumb” interfaces make it easier for multiple players to compete for deliveries



- Boom Rendezvous with Depot
  - Initial connection point on an extendable boom, far from depot or tug
    - Like mid-air refueling
  - Greatly reduces odds of damaging depot accidentally by failed rendezvous
  - Potential large increase in AR&D reliability
  - Possibly simplifying some of the AR&D hardware and processes