

# Prop Transfer Module



# SM Partially Loaded Propellant

- Goal is to reduce weight of SM as much as possible for launch by only partially loading propellant tanks and filling on orbit
  - ◆ With Propellant fed directly from Transfer vehicle to SM Main Engine the CEV mass would be less than SBT-4 (ISS kit)
    - CBE: CEV mass would be ~1800 lbs less than SBT-4
    - SBT-4 prop design with one set of SM tanks and transfer lines
    - SBT-3 ECLSS mass is less than SBT-4 (due to 4 vs 6 crew's consumables)
    - SBT-4 sized for ISS payload(2 CMGs @ ~700 lbs each)
    - SBT-4 sized for 6 crew (205 lbs each)
- Can also off-load LSAM Descent stage by using PTM to allow CEV to perform LOI
  - ◆ Reduces LSAM descent stage by optimizing LSAM tanks solely for Lunar descent, not LOI and Lunar descent
    - Would not take empty tanks from LOI in LSAM to lunar surface, which could be big potential mass savings



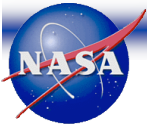
# Off-SM Propellant Vehicles

- System challenges
  - U.S. propellant feed systems mix pressurant and propellant (Russian systems keep propellant and pressurant separate via tank bellows)
    - Vent pressure from SM propellant tanks (and dump some propellant with it) to allow fluid transfer to tanks (contamination issues), or
    - Isolate and pressurize only one set of tanks for launch (increased system complexity and weight) or
    - Use propellant directly from prop vehicle (integration complexity, requires more mass to moon)
    - Ensure minimal helium ingestion (screens remain wet)
  - Transfer gauging will require complexity beyond a PVT system. Might need flow meters to monitor how much propellant has been transferred
  - How to track/purge trapped propellant in lines when systems disconnected
  - Is a leak check required prior to starting propellant transfer
  - Resupply propellant only or propellant and pressurant
    - Resupply the pressurant that is vented overboard for propellant transfer, or
    - Load SM with additional pressurant at launch
  - SM and Supply tank connection (increased interface complexity)
    - Plumb through CM docking port (extra weight)



# Propellant Transfer Module

- Launch a separate “propellant transfer tunnel” Module
  - Launch attached to LSAM on CaLV
  - Fully functional two fault tolerant stage
  - Can be used as propellant supply for CEV and return with it to Earth
  - Provides extra habitable volume and propellant storage
  - ~18,000 lb (~30,000 lbs if also performing LOI with CEV)
- Launch SM with  $\frac{1}{2}$  of propellant (or less) needed for lunar mission
  - Enough to safely launch and return from LEO
  - Verify good transfer prior to committing to TLI
  - Use propellant directly from Propellant transfer module
- Drawbacks
  - Requires development of another vehicle
  - Increased complexity of CEV due to routing propellant from PTM to CM to SM
  - Increased weight to CaLV for launch and EDS for circularization burns
  - Increased weight of stack going to moon requiring more EDS propellant (and increase to SM propulsion system if returning to Earth)
  - Increased weight to LSAM Descent for LOI due to PTM structural mass increase on stack mass
- Benefits
  - **Can save ~8,000+ lbs from launch weight of SM**
  - **Can save LSAM Descent Stage mass by removing propellant and tanks from LSAM for LOI and adding additional tanks to PTM for CEV to perform LOI.**

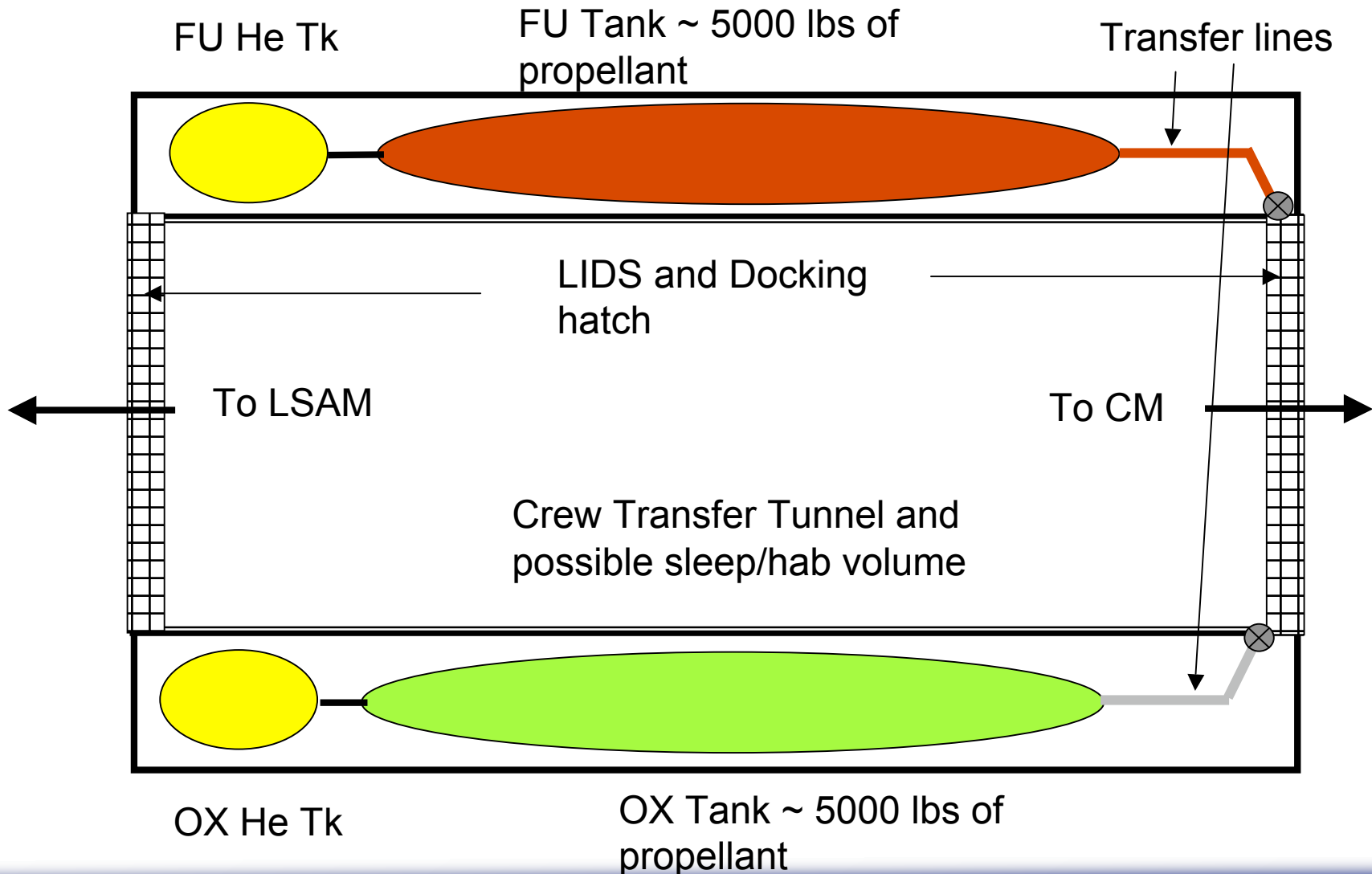


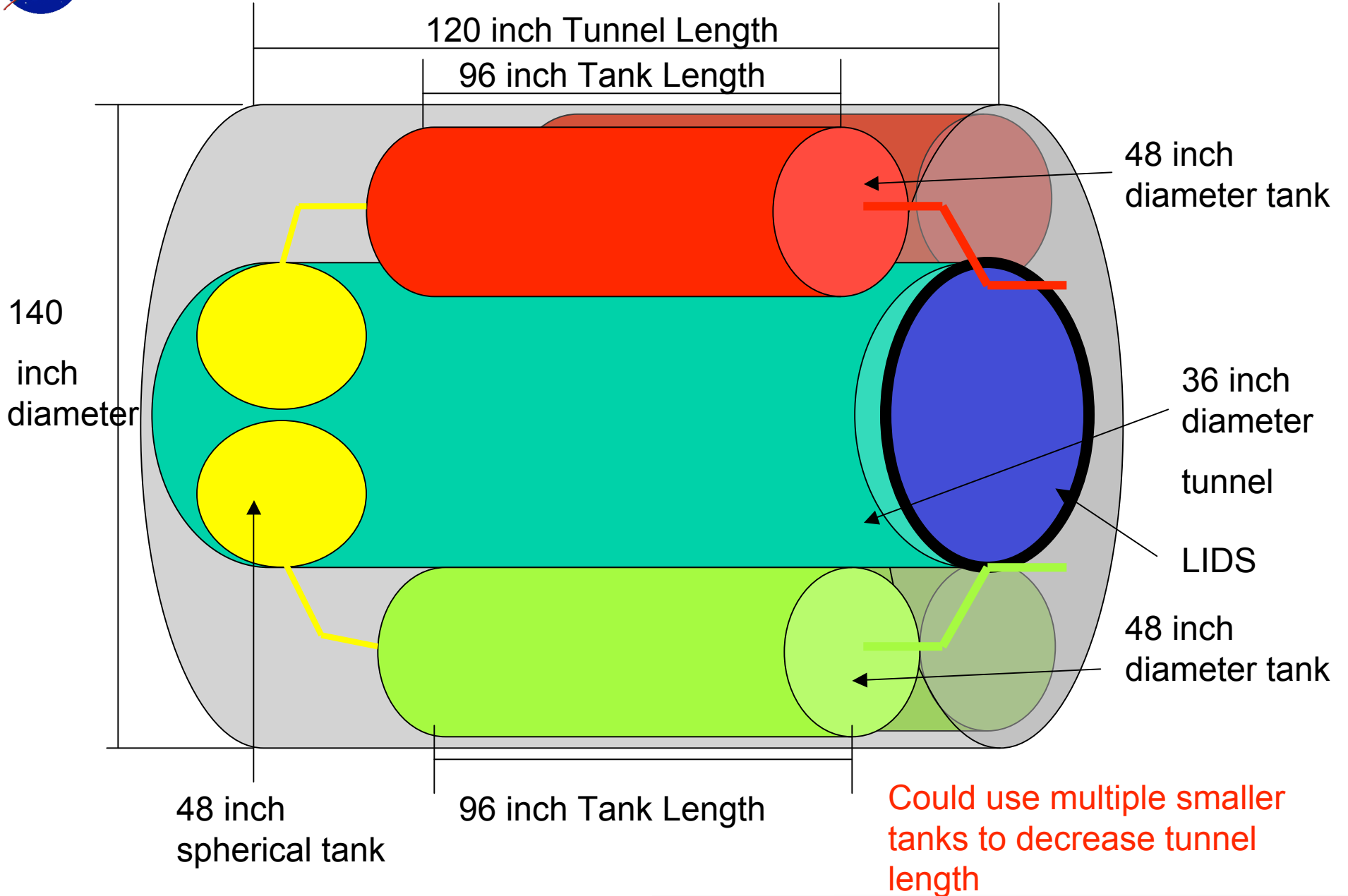
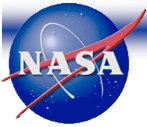
# Propellant Transfer Module Design

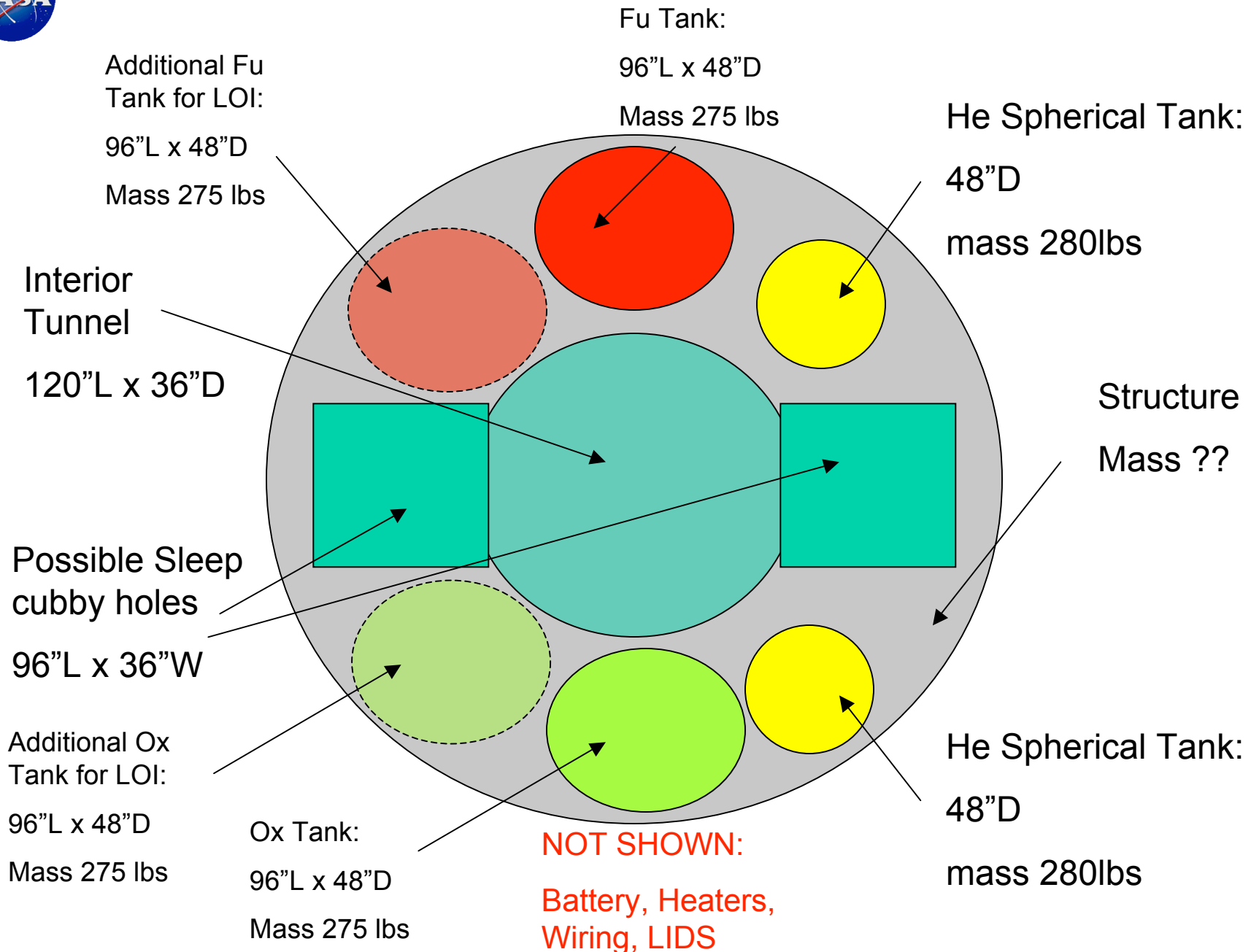
- PTM has Prop tanks to supplement delta V requirements for the SM
  - ~12000 lb wet mass (3000 fps delta V for CEV usage)
  - Transfer equipment (helium or pumps) for moving Propellant From Prop Transfer Module to Service Module ME
  - Could go with multiple smaller tanks to shorten the PTM length but removes tank commonality with SM
  - Could also use additional tanks to allow SM to perform LOI
    - Adding a second set of tanks would increase the Delta V capabilities of the CEV by ~3000 fps which would allow the CEV to perform LOI
      - Saves LSAM Descent Stage from carrying empty tanks to lunar surface
    - Should not be a big increase to CaLV or EDS since the LSAM was already supposed to have this wet mass for LOI (strictly structure/feed system mass hit)
- Has a LIDS docking system at each end of the module for mating with LSAM and CM
- Uses Passive thermal for LEO Loiter prior to CEV docking
- Can get power from LSAM, CEV or possibly skin mounted Solar cells and Batteries
- Provides transfer tunnel and increase to Habitable volume for LSAM/CEV stack.
- PTM stays docked to CM during Lunar Loiter and Trans Earth Coast
  - SM would have to have control authority for CEV with PTM attached
    - Increases Delta V required for TEI
  - Provides increased hab volume for Trans Earth Coast depending on when jettisoned



# Propellant Transfer Module









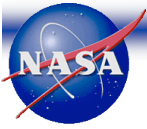
# Mass Rollup

- Tanks:
  - ◆ Propellant: 275 lbs x 2 (or x4 if CEV performs LOI)
    - Could use multiple smaller tanks or increase delta V available by using more tanks.
  - ◆ Helium: 280 lbs x2(or x4 if CEV performs LOI)
  - ◆ Wet propellant: ~11000 lbs (22000 lbs if CEV performs LOI)
  - ◆ Wet helium: 100 lbs
- Valves
  - ◆ Isolation: 3 lbs x10
  - ◆ Check Valves: 3 lbs x2
- Regulators: 4.5 lbs x4
- Lines: mass ??
- Structure: mass??
  - ◆ Could reduce structure by using multiple smaller prop tanks which would reduce tunnel length
- Wiring: mass ??
- Heaters: mass ??
- Power system (solar or battery or feed from LSAM and/or CEV: mass ??
- LIDS: 750 lbs x2
- Ground interface: mass ??



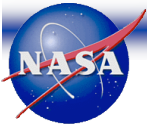
## Lunar Constellation Design using a PTM

- SM only has 1 set of Prop tanks (like LEO Mission Kit Configuration with out payload)
  - ◆ 3000 fps delta V and ~12000 lb wet mass removed from SM
  - ◆ PTM feeds directly to the ME Inlet Line before SM uses onboard prop for ME burns (constant prop transfer)
  - ◆ Most likely wont jettison PTM until during Trans Earth Coast when PTM tanks are depleted from TEI burn
- Assumes CaLV can lift extra ~20000 lb in addition to LSAM to orbit
  - ◆ CBE: 12000 lb for prop + 8000 lb for structure, two LIDS docking systems, passive thermal and any power system required
- Assumes can transfer Propellant From Prop Transfer Module to Service Module through CM LIDS docking interface

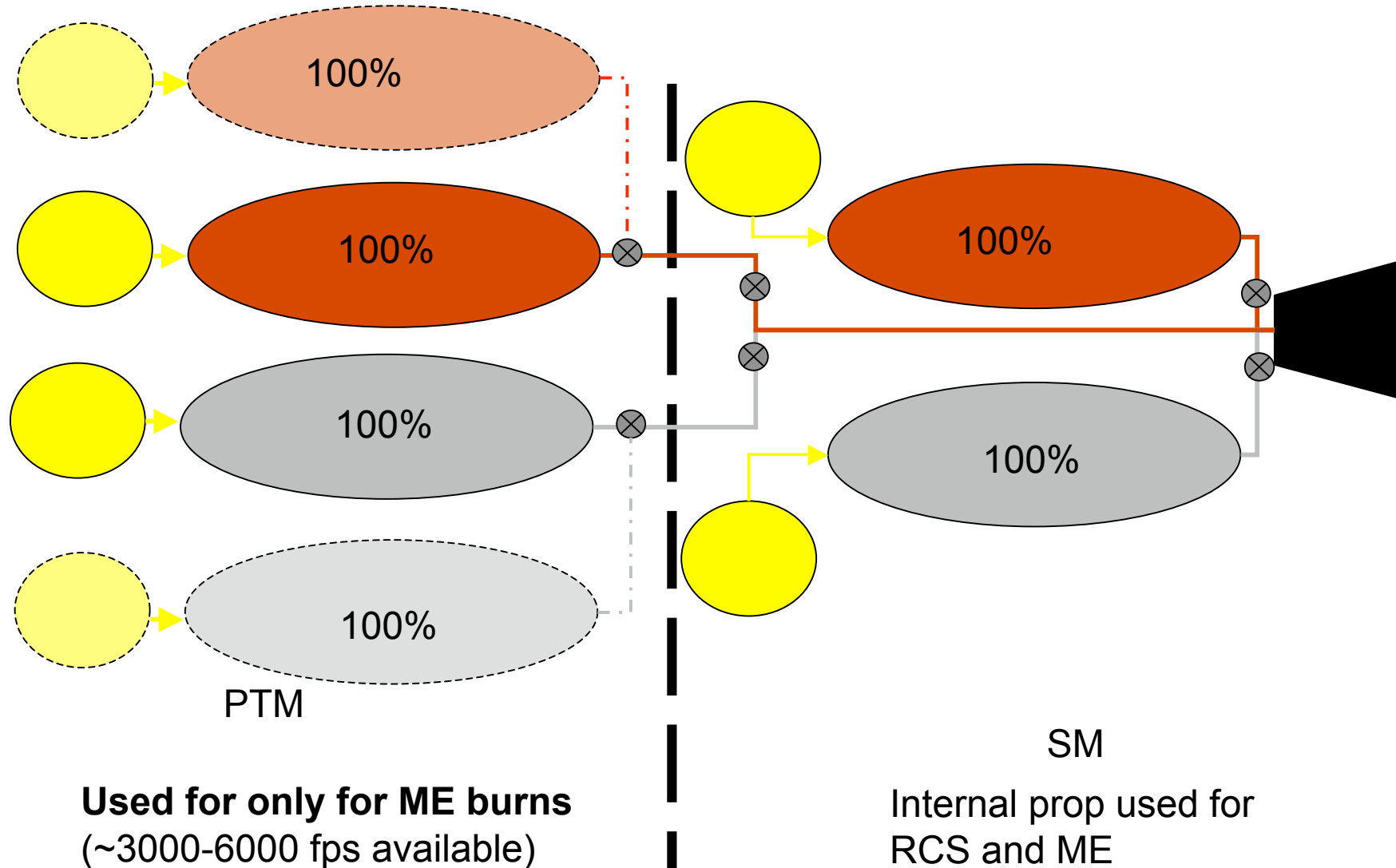


## Lunar Constellation Mass Design using a PTM

- SM Offloads ~13,000 lbs of wet mass
  - 3,000 fps transferred to PTM from SM
- LSAM Offloads ~13,000 lbs of wet mass for LOI
  - 3,000 fps transferred to PTM from LSAM
  - LSAM descent stage prop system optimized for lunar descent which could yield additional mass savings
- CLV decreased mass to orbit requirement
  - CEV mass will be less than current SBT-4(ISS)
- CaLV increased mass to orbit requirement
  - Only for the wet mass of the SM propellant and PTM structure
  - LSAM wet mass that was transferred to PTM is not a CaLV upmass hit
    - Since LSAM and PTM launch together what mass is transferred to PTM from LSAM is no impact



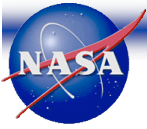
# PTM Propellant Flow



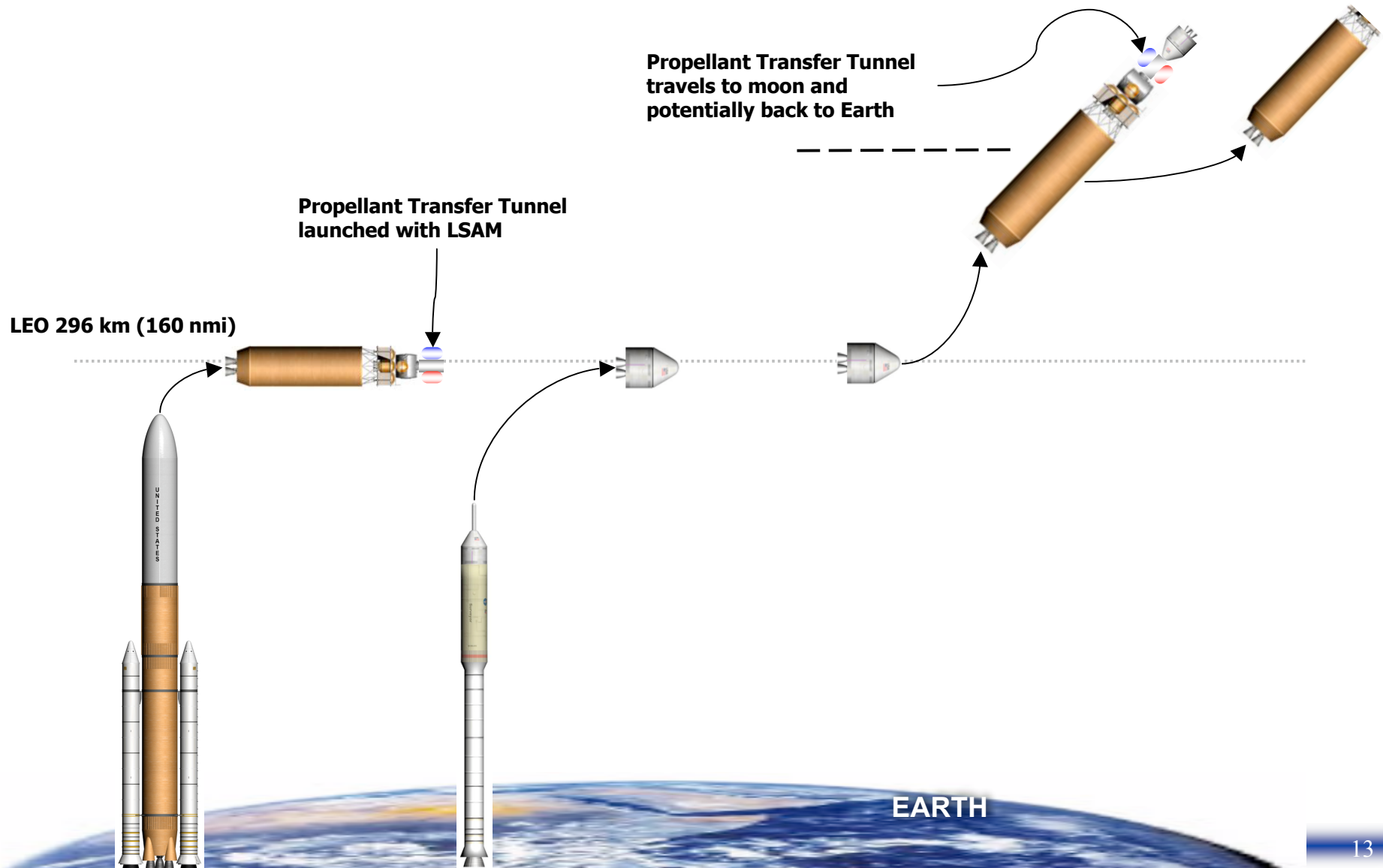
**Used for only for ME burns**  
(~3000-6000 fps available)

Second set of tanks is for LOI Burn

CM not shown

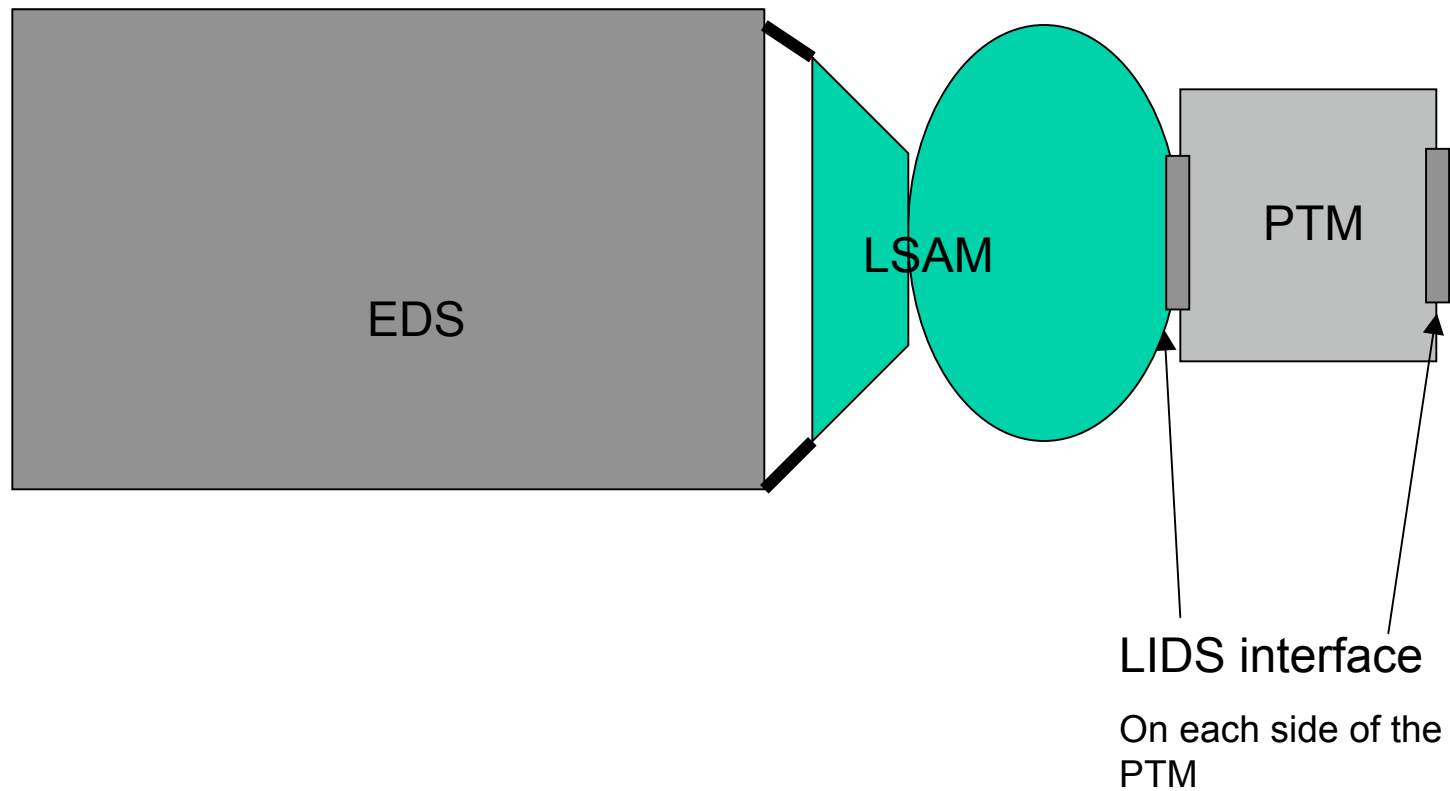


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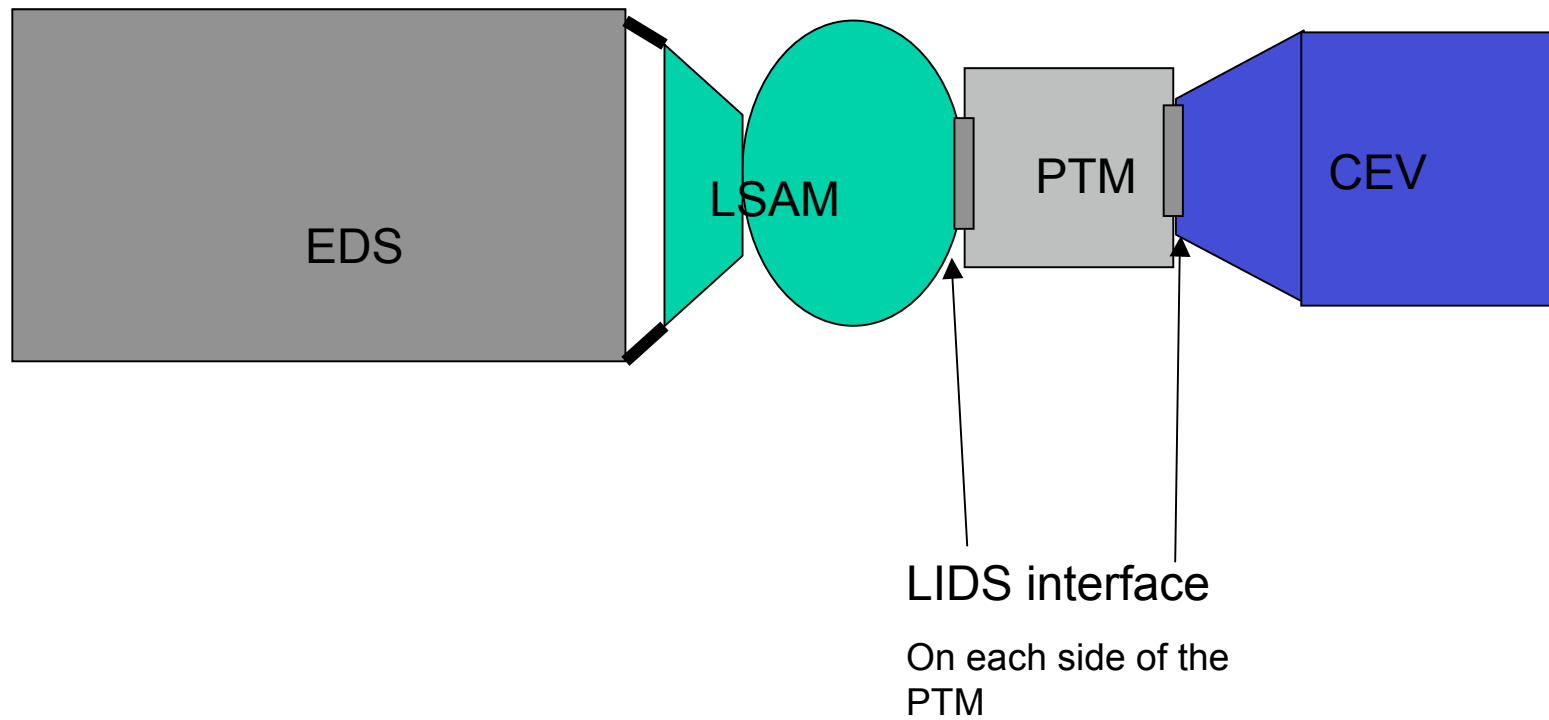


# LEO Orbit EDS Loiter





# LEO Orbit RNDZ





# Lunar Orbit

