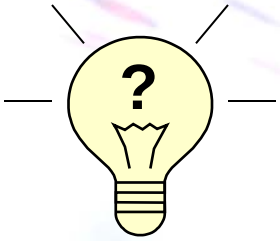
Energy Systems Division

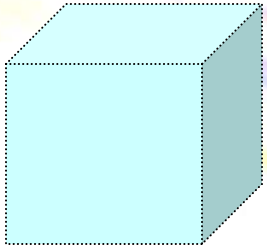
# CHEERS poster board

## Capsule Heating Enhanced Entry Reaction System

Sept 30, 2010

JSC: Joseph Cook, Rich Schoenberg
JPL: Rebekah Tanimoto, Dan Turner

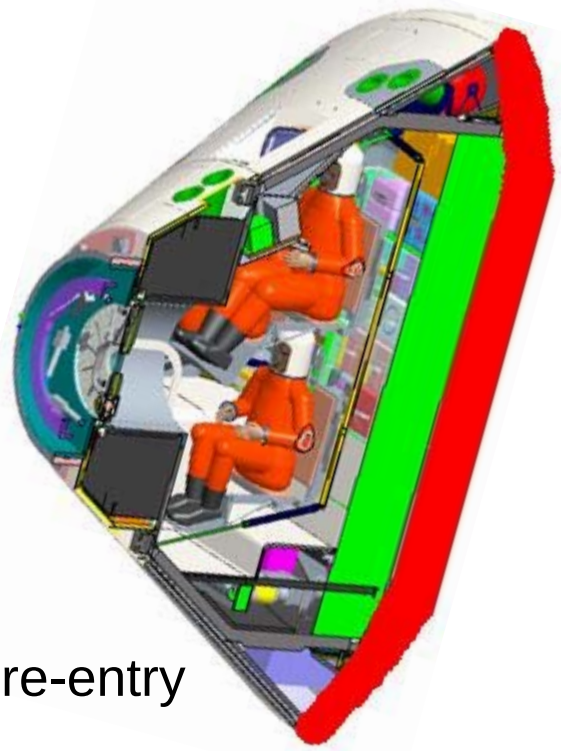


*Think Outside the Box*

# *Concept*

- Idea
  - **C**apsule
  - **H**eating
  - **E**nhanced
  - **E**ntry
  - **R**eaction
  - **S**ystem



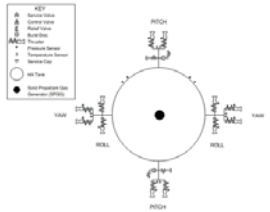
- Leverage **beneficial heating** available from re-entry
  - **Superheat** inert propellant
  - **Improve** thruster performance
  - **Enable** mass competitive option
  - **Avoid hazards** of reactive, toxic propellants

**CHEERS**

# Tank Approach Concept for Leveraging HX

Energy Systems Division

## Where we started….

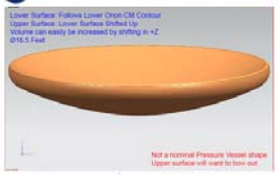


| Dry Mass Item | Quantity | Mass / Unit | Mass | Basis |
|---|---|---|---|---|
| HX Tank | 1 | 466 | 466 | 16"OD-0.025"WT, 0.5"L, C-103 density 0.32 lbm/ci |
| Thruster | 12 | 10 | 120 | 2lb/valve, 1lb/p-dcr, 5-lb ch/mod |
| SPGG | 1 | 25 | 25 | 25lbm equiv N2H4 initial pressurization |
| Distribution Manifold | 4 | 7 | 26 | 1"OD-.1"WT, 72"L, C-103 density 0.32 lbm/ci |
| BD/RV | 2 | 5 | 10 | 2lb/BD, 3lb/RV |
| Service Valve/Cap | 2 | 1 | 2 | 0.75lb/sv, 0.25lb/cap |
| Pres Transducer | 2 | 1 | 2 | 1lb/p-ducer |
| Temp Sensor | 10 | 0.25 | 2.5 | 0.25/lb/temp sencor |
| | | | 0 | |
| | | | 653 | |

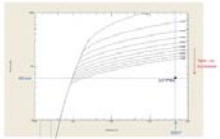
| Consumable Item | Quantity | Mass / Unit | Mass | Basis |
|---|---|---|---|---|
| Water | 1 | 322 | 322 | |
| | | | 322 | |

## HX Tank Design Layout, Materials & Sizing

Tank Concept #1 JPL

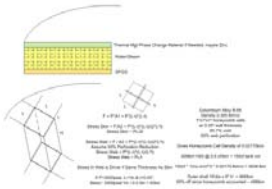



P vs T plot w/ const sp. vol. JPL



Materials Trade JPL

- Want: Material with low density, yet high melting point
- Titanium looks like a front runner
  - Non-exotic material
  - Experience working with Ti
  - Weldable
  - Used in today's propellant tanks
- Few materials have a high melting point, by greater density



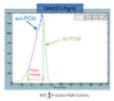
## HX Tank Performance Analysis

Simplified Model Description JPL

- Delays heating of steam by heating phase change material layer
- Does not account for walls and assumes both PCM and steam as lumped thermal masses
- Initial Conditions
  - Steam
    - Temperature: 60F
    - Pressure: 0.167 psi (Psat at 60F)
    - Mass: 200 lbm
  - Phase Change Material
    - Temperature: 888F
- Assumes
  - Perfect heat transfer from one CV to the next
  - Tank sp. vol. = 0.5 ft3/lbm
  - Heating begins at t=0 s; profiles based on stagnation point heating applied to entire surface
  - Heating area doesn't account for curvature & honeycomb
  - Engine start at t=120s
    - Assumed SPGG produces thrust prior to this
    - Mass flow begins here based on Isp/regulator performance
  - 4F(lbf) 2psi/ft, 1x10ft target PSSM
  - Thank Pulse

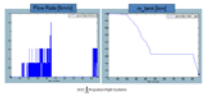
Heating Input JPL

- Q_dot that steam sees
- Can adjust initial T_PCM to take away desired portion of heating



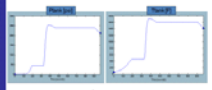
Mass Flow Inputs JPL

- No mass flow for first 120 seconds
- Mass flow according to trajectory analysis



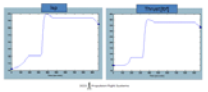
Simple Model Results JPL

- Tank pressures and temperatures



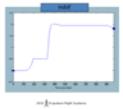
Simple Model Results JPL

- Isp and Thrust calculated from interpolated Thrust Performance data
- Isp is function of Thank
- Thrust is function of Pcank



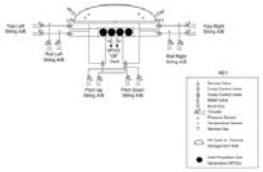
Simple Model Results JPL

- Mass flow rate determined from Isp and Thrust



*Q1: Initial latency > 2 minutes – when phase change material warmed up there is ample energy to finish profile*

## Where we ended up…



| SYSTEM | MASS |
|---|---|
| CHEERS | 9108 |
| Reference | 3489 |
| Propulsion Dry Mass | 604 |
| Propulsion Consumable Mass | 322 |
| Heat Shield | 2563 |
| % Difference | 163% |

| Dry Mass Item | Quantity | Mass / Unit | Mass | Basis |
|---|---|---|---|---|
| HX Tank | 1 | 6121 | 6121 | 16"OD-9"ID-0.05"WT w/ 1" Honeycomb for 0.5ct/ltem sp.vol, B-4M density 0.305 lbm/cc |
| Tank Thermal Management | 1 | 3091 | 3091 | 16"OD - 1/4" thic B.0.05" Tungsten |
| Thruster | 12 | 8 | 96 | 2lb/valve, 1lb/p-dcr, 5-lb ch/mod |
| SPGG | 4 | 100 | 400 | equiv. 250lbm hydrazine over 2 min w/ 1400lbf thrust, 220sec Isp |
| 3-way Manifold Isolation Valves | 8 | 8 | 64 | 8lb/valve |
| Distribution Manifold | 4 | 29 | 116 | 1.5"OD-.1"WT, 144"L, Inconel 625 density 0.305 lbm/ci |
| BD/RV | 2 | 5 | 10 | 2lb/BD, 3lb/RV |
| Service Valve/Cap | 2 | 1 | 2 | 0.75lb/sv, 0.25lb/cap |
| Pres Transducer | 2 | 1 | 2 | 1lb/p-ducer |
| Temp Sensor | 8 | 0.25 | 2 | 0.25lb/temp pesdoe |
| | | | 0 | |
| | | | 6888 | |

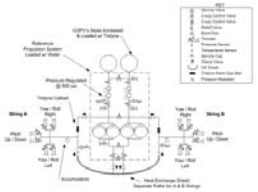
| Consumable Item | Quantity | Mass / Unit | Mass | Basis |
|---|---|---|---|---|
| Water | 1 | 300 | 300 | |
| | | | 300 | |

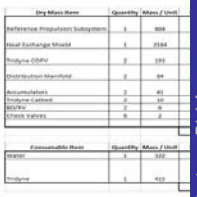
*Mass of HX tank approach estimated to be on the order of ~3x reference system (propulsion plus TPS heat shield)*

# Shield Approach Concept for Leveraging HX

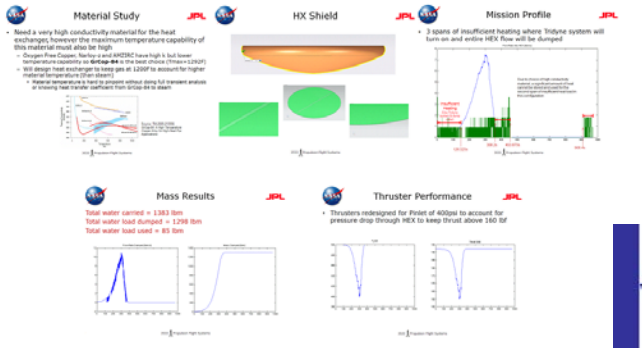
Energy Systems Division

### Where we started…



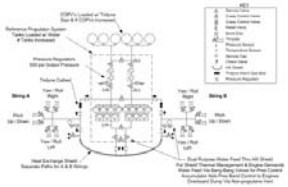


### HX Shield Design & Performance Analysis

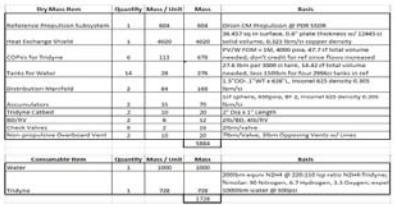



*Q1: Shield transfers heat while energy is available – Tridyne provides initial and final propulsive motive*

### Where we ended up…



| SYSTEM | MASS |
|---|---|
| CHEERS | 7612 |
| Reference | 3489 |
| Propulsion Dry Mass | 604 |
| Propulsion Consumable Mass | 322 |
| Heat Shield | 2563 |
| % Difference | 118% |



*HX shield approach reduces mass, but is still on the order of ~2x reference system (propulsion plus heat shield)*