Propellant from Lunar Water: Cislunar Competitive Landscape / Tradespace

Use in High Orbits. Use Waste Oxygen as/in Products, & with High-Oxygen Engines. There is a Competitive Slippery Slope from the Lunar Surface to LEOs

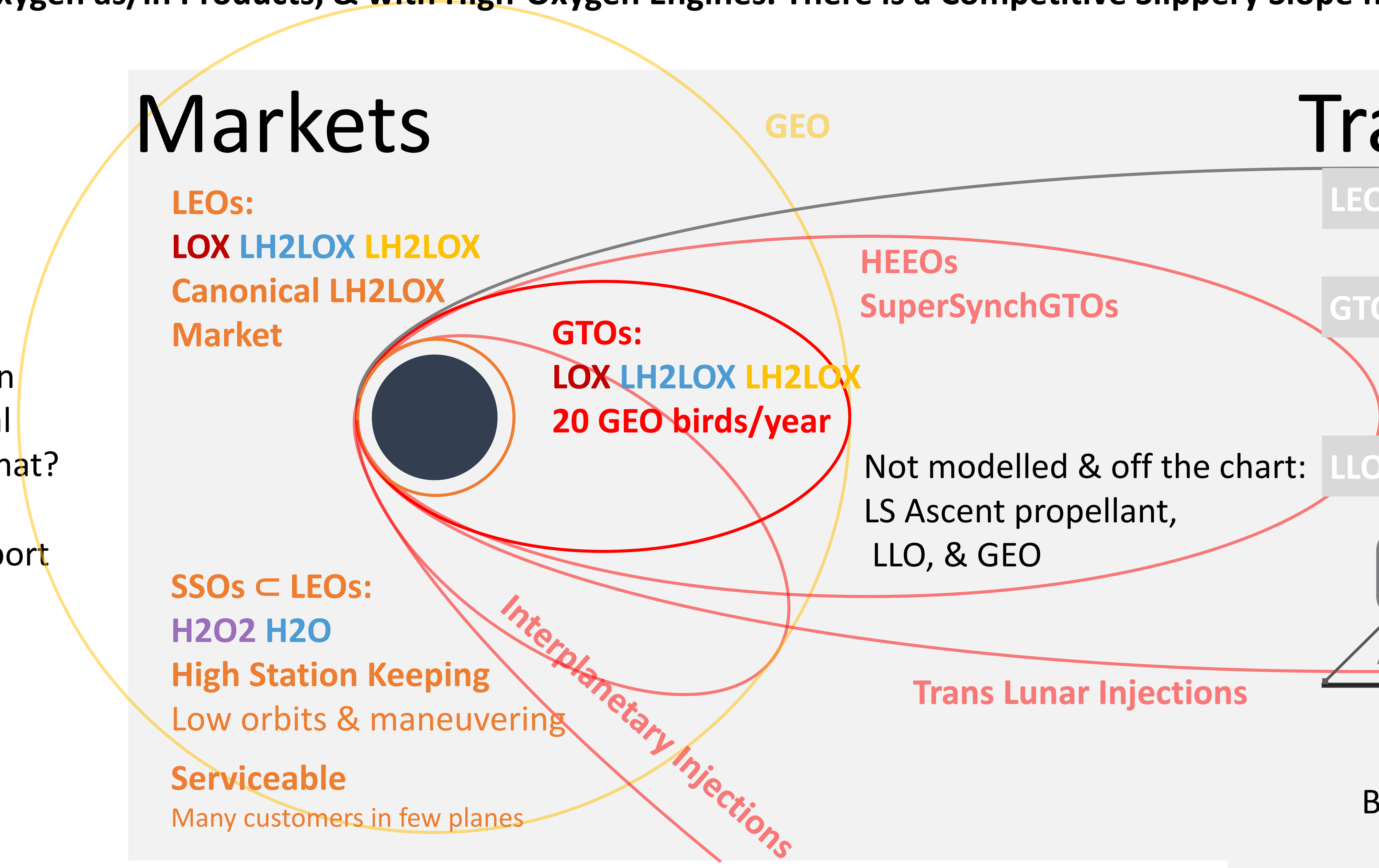
Introduction

- ACSER: Australian Centre for Space Engineering Research
- Space Resources Group; extraction, economics, & policy
- Engage Australia's resource industry with space resources

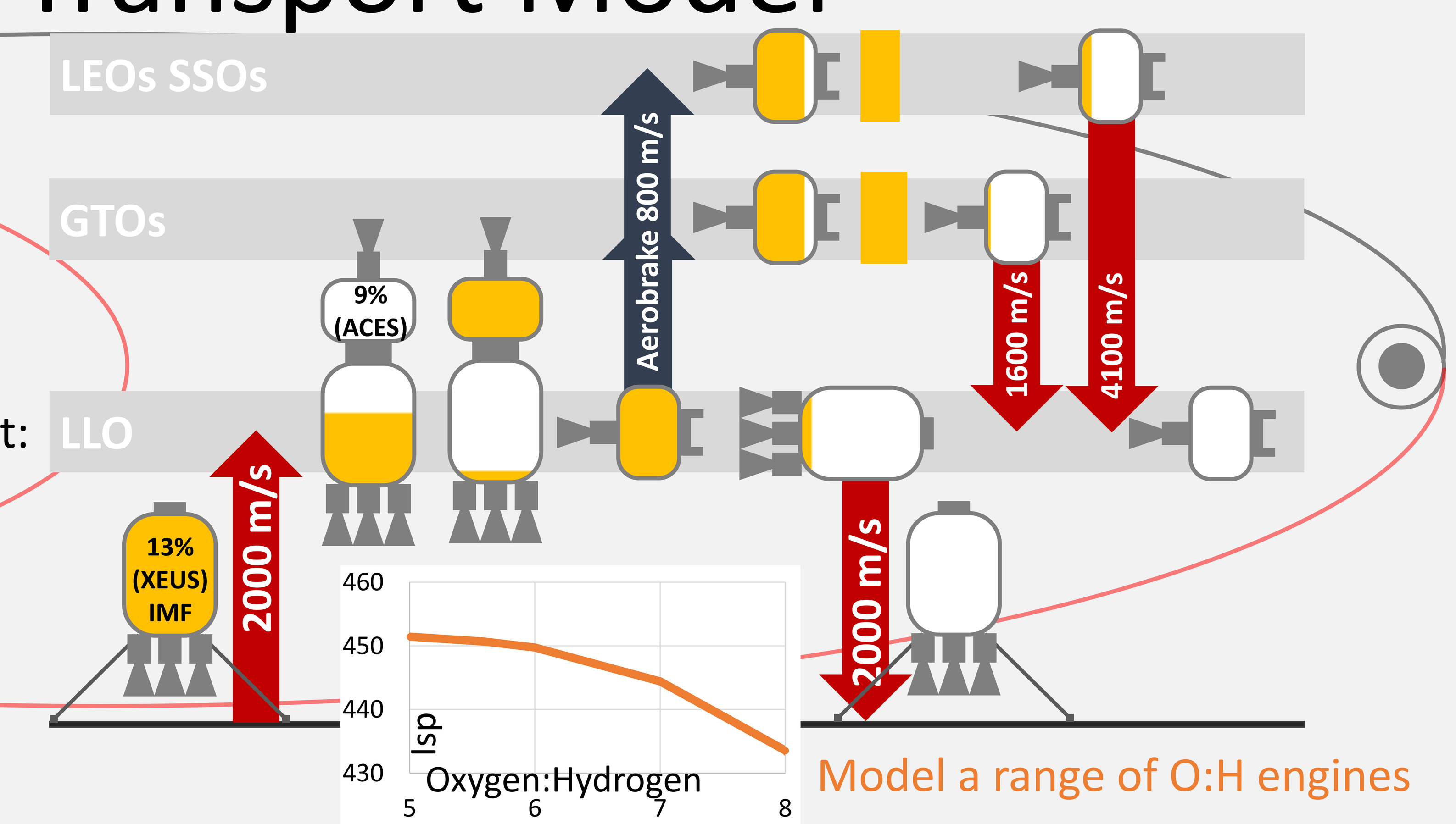
- Take the perspective of a propellant from lunar water operation
- Same arguments hold for usefulness/efficiency and commercial
- Downstream: I spent $ to extract and electrolyse water now what?

- Recoverable value as a function of Markets, Products, & Transport
  - Strategies for maximizing recoverable value
  - Useful technology developments
  - Desirable customers

Markets



Transport Model

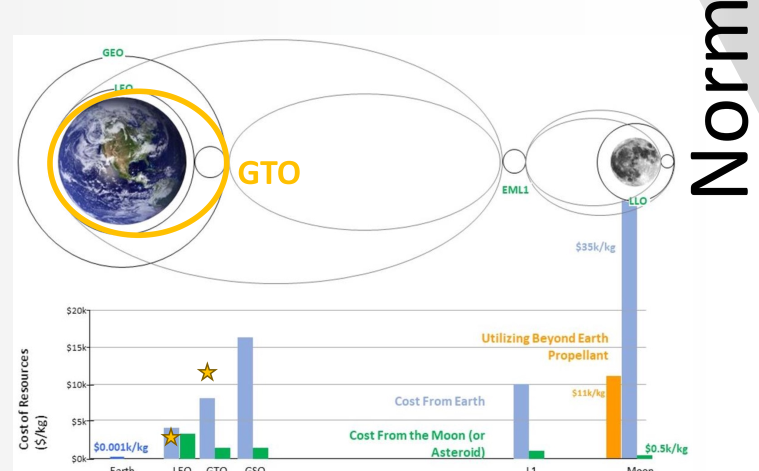


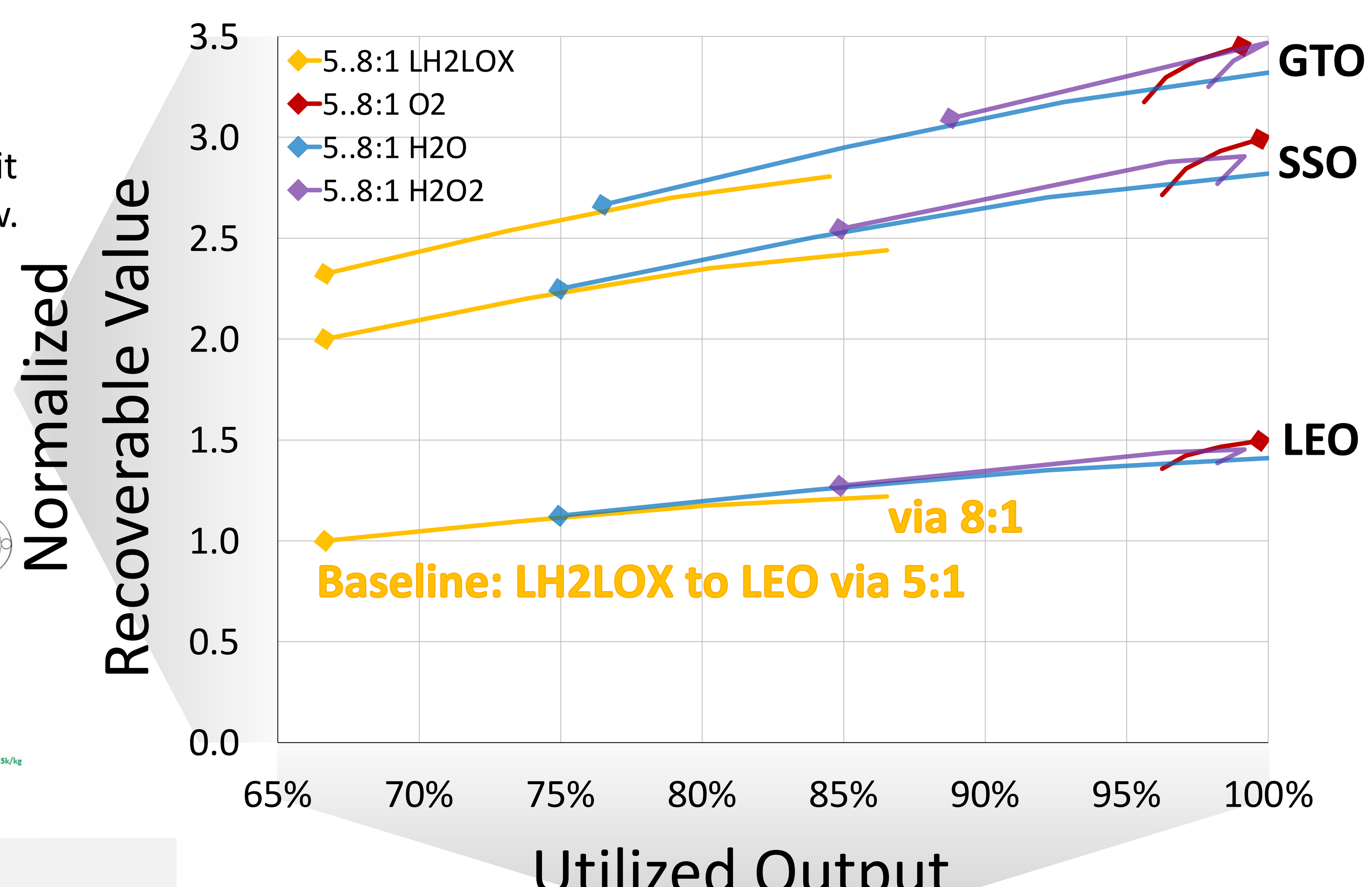
Better Mass Estimating Relationships will shift things a bit

- Higher is better
- Normalize value to "deliver lunar LH2LOX to LEO"

- Earth launch cost determines recoverable value/kg in an orbit
- Transport parity / gear ratio argument. Good enough for now.
- Qualitatively realistic, conservative: GTO | SSO = 2 * LEO
  - SSOs = LEO + >90 degrees inclination
  - GTOs = LEO +2400 m/s

- For higher resolution:
  - Better MERs
  - Per product tankage
  - Volume aero interactions?
  - CONOPs?



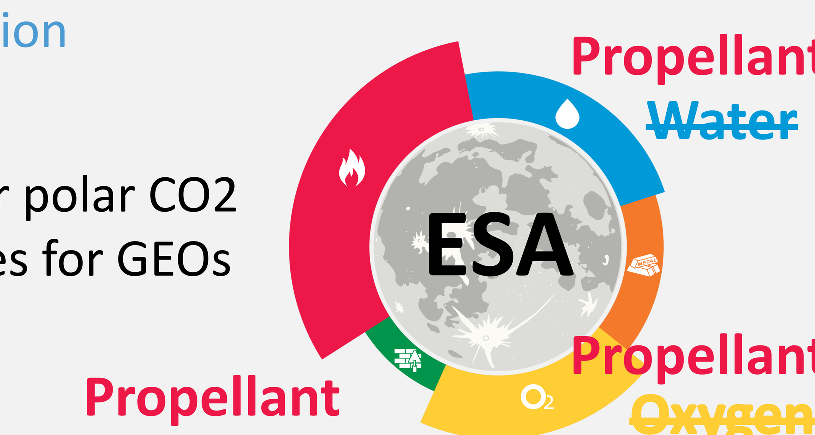


Products

- O:H Only water products were modelled

- **LOX** 80% CH4LOX & LH2LOX, 10 t = 30 person years ECLSS
- 5.5:1 **LH2LOX**
- 16.0:1 **H2O2** Hydrogen Peroxide, station keeping & tugs in SSO, ?
- 8.0:1 **H2O** station keeping & tugs
- 8.0:1 **Stoichiometric LH2LOX** (≡ water series)
  - higher deliverable mass from same cost base
  - scope for price competition

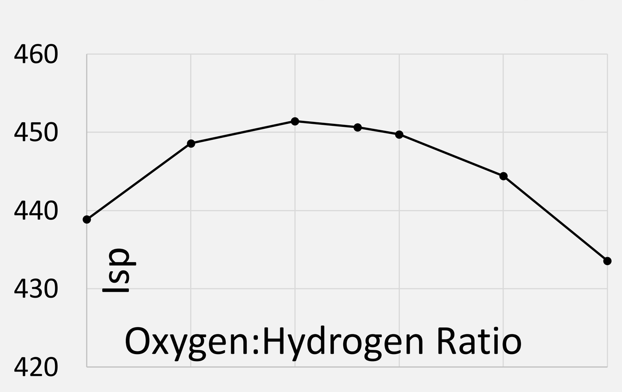
- Others are looking at:
  - hydrocarbons from lunar polar CO2
  - lunar hypergolic storables for GEOs
  - regolith oxygen

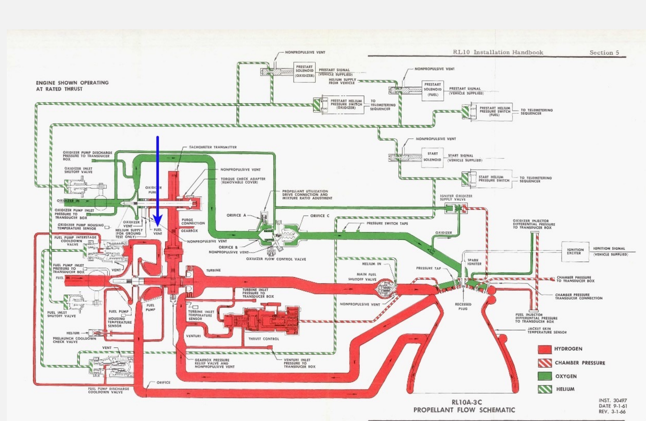


Stoichiometry & Hydrolox

- Regular hydrolox from water creates an opportunity loss
- 28% of $ spent obtaining lunar hydrolox are "in" the waste oxygen

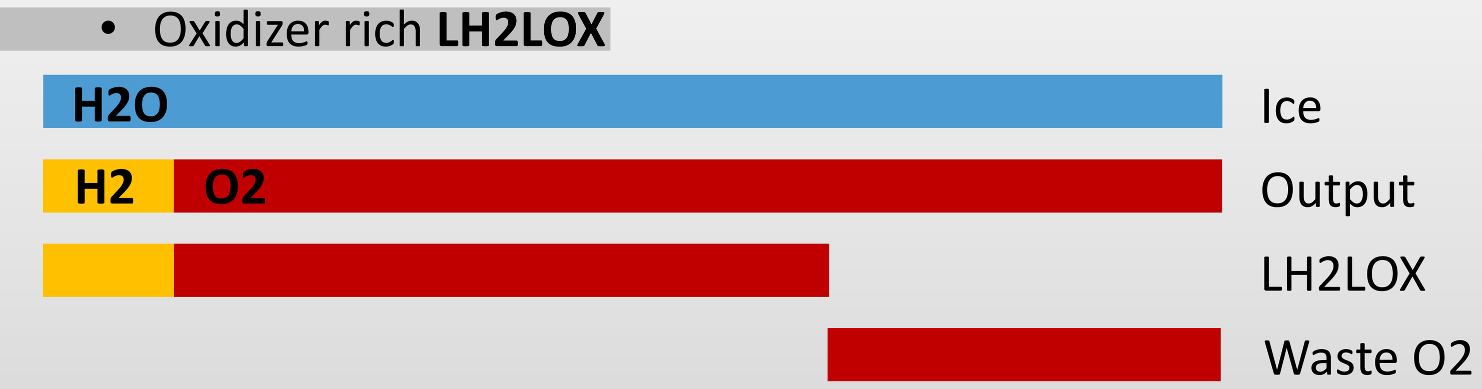
- High LOX hydrolox? more propellant, but lower Isp
- Engineering challenges including high combustion heat, but
- Expander cycle engine like RL-10 uses heat to drive turbopumps
  - surface area vs volume/mass flow, square-cube law
  - engine size is limited by heat exchange area (& heat)
- It's a challenge with a payoff, see Conclusions.





- Higher is better
- Regular hydrolox from water creates an opportunity loss
- Lunar LH2LOX production needs huge investments
- 28% of $ spent to obtain lunar hydrolox are in waste oxygen

- **H2O** 8.0:1 oxygen to hydrogen by mass
- **LH2LOX** 5.5:1
- Use the waste oxygen / by-product
  - Life support? 10 t = 30 person/years breathing
  - As Product: it's 80% of CH4LOX & LH2LOX
  - In Products: **H2O** & **H2O2** are useful propellants
  - Oxidizer rich **LH2LOX**



Conclusions

- Profit is at the margin: +revenue => +++internal rate of return
- Higher recoverable value gives more headroom to compete

- Acronyms: Recoverable Value (RV), baseline cost base (BCB)
- Sell High: 2.3x RV @ BCB
- Sell LOX: +40% RV @ BCB
- Sell H2O2 & H2O +20% RV @ BCB

- Stoichiometric/High LOX engines: BCB + ?development $
  - +10% RV if operation only uses them to deliver regular hydrolox
  - +40% RV if customers also use them and take high LOX hydrolox
  - Protectable intellectual property
  - Defensible competitive advantage
  - Smoothes the competitive landscape

- There is a competitive slippery slope from LS to LEOs mix and match markets, products, and transport

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