



# **Strategic Reusability for Human Space Exploration – A Comparison of Two Architectures**

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# Introduction

- Purpose
- ROM Cost Modeling
- Analysis Results - 2 Architecture Comparison
- Apollo-Like Baseline is Compared:
  - Architecture A: With no reusability
  - Architecture B: With Selected Reusability of “High-Value” Assets
  - 4 Missions only examined for trend



# ROM Cost Estimation

- **Inputs:**
  - **Hardware Mass (“High Value”)**
  - **Launch Vehicle Related mass (“Medium Value”)**
  - **Consumables Mass (“Low Value”)**
  - **Specific Cost Assumptions (\$/kg)**
    - **Hardware, LV, Consumables, Launch-to-Surface Delivery**
- **Outputs**
  - **Hardware Cost by Element**
  - **Delivery Cost**
  - **Consumables Cost**



# Acquisition Cost Key Metrics

- **Specific Cost Assumptions:**
- **Propellants: \$100/kg (Thus, “Low Value”)**
- **LV – type Hardware: \$2,600/kg (Thus, “Medium Value”)**
- **Space Vehicle Hardware (non-propulsive) \$100,000/kg (Thus, “High Value”)**
- **Notes:**
  - Propellants are order of magnitude estimate
  - LV estimate based on Delta LV program
  - Space vehicle hardware is a rough industry average
  - This form of cost estimation is best used for relative comparisons



# Delivery Cost Key Metrics – Test on Apollo Architecture

- **Specific Delivery Cost:**
- **Launch (Earth surface to LEO): \$22K/kg**
- **LEO to Lunar Orbit: \$2.42K/kg**
- **Lunar Orbit to Surface \$1.24K/kg**
  
- **These are baseline architecture metrics that need to be “beaten” to be more cost effective**
  
- **Note that the initial specific cost is the most significant – LESS total mass in LEO will result in the least amount of delivery cost**
  
- **Acquisition Costs of the Delivery Systems are embedded in these specific cost numbers**



# Architecture Elements:

- Base
  - Crew Hab (CH), Mission Module (MM), Resource Module (RM)
- Delivery Related
  - TLI Stage (TS), Command Module (CM), Service Module (SM), Lunar Module Descent Stage (LM DS), Decent Stage (DS) for Base Modules
- Return Related
  - LM Ascent Stage (AS), SM, CM
  - Earth Orbital Insertion (EOI) Stage, Crew Return Vehicle



# Key Reusable Elements

- CEV Has Commonality Variants:
  - **CRV**
  - **In Space Transport**
  - **Lunar Ascent/Descent**
- Single CRV for Crew Return from Space
- Single CEV Space Transport to go between LEO and LLO
- Single Lunar CEV to provide Crew Ascent/Descent
- Single Cargo Ascent/Descent Vehicle
- Base: Crew Hab & Mission Module



# Expendable Elements

- Earth to Orbit Rocket Stages
- Stages for: TLI, LOI, TEI, EOI (for Transport CEV to remain in LEO – perhaps dock with ISS)
- Base: Resource Modules



# Base Elements

Element	Arch. A	Arch B.
Crew Hab	4	1
Mission Module	4	1
Resource Module	4	4
Total	12	6

– Reuse of Crew Hab & Mission Module



# Delivery Elements

Element	Arch. A	Arch B.
TLI Stage	16	7
SM LOI Stage	16	7
Command Module	4	1
Base Module DS	6	1
LM DS	4	1
Total	46	17

– Reuse of CM, LM DS, Base Module DS



# Return Elements

Element	Arch. A	Arch B.
LM AS	4	1
SM TEI Stage	4	4
Command Module	Double Cnt	Double Cnt
EOI Stage	0	4
CRV	0	1
Total	8	10

– Reuse of LM AS, CRV



# All Elements

Element	Arch. A	Arch B.
Base	12	6
Delivery	46	17
Return	8	10
High Value	16	6
Med-Low Value	50	27
Total	66	33

- Arch A Has Significantly More Total Elements and High Value Elements



# Conclusions

- **Reusability of High Value Elements may significantly reduce the number of Total Elements required (~50%)**
- **Compounded Result is Much Less Hardware required for Acquisition and Delivery to LEO (largest delivery cost hit)**