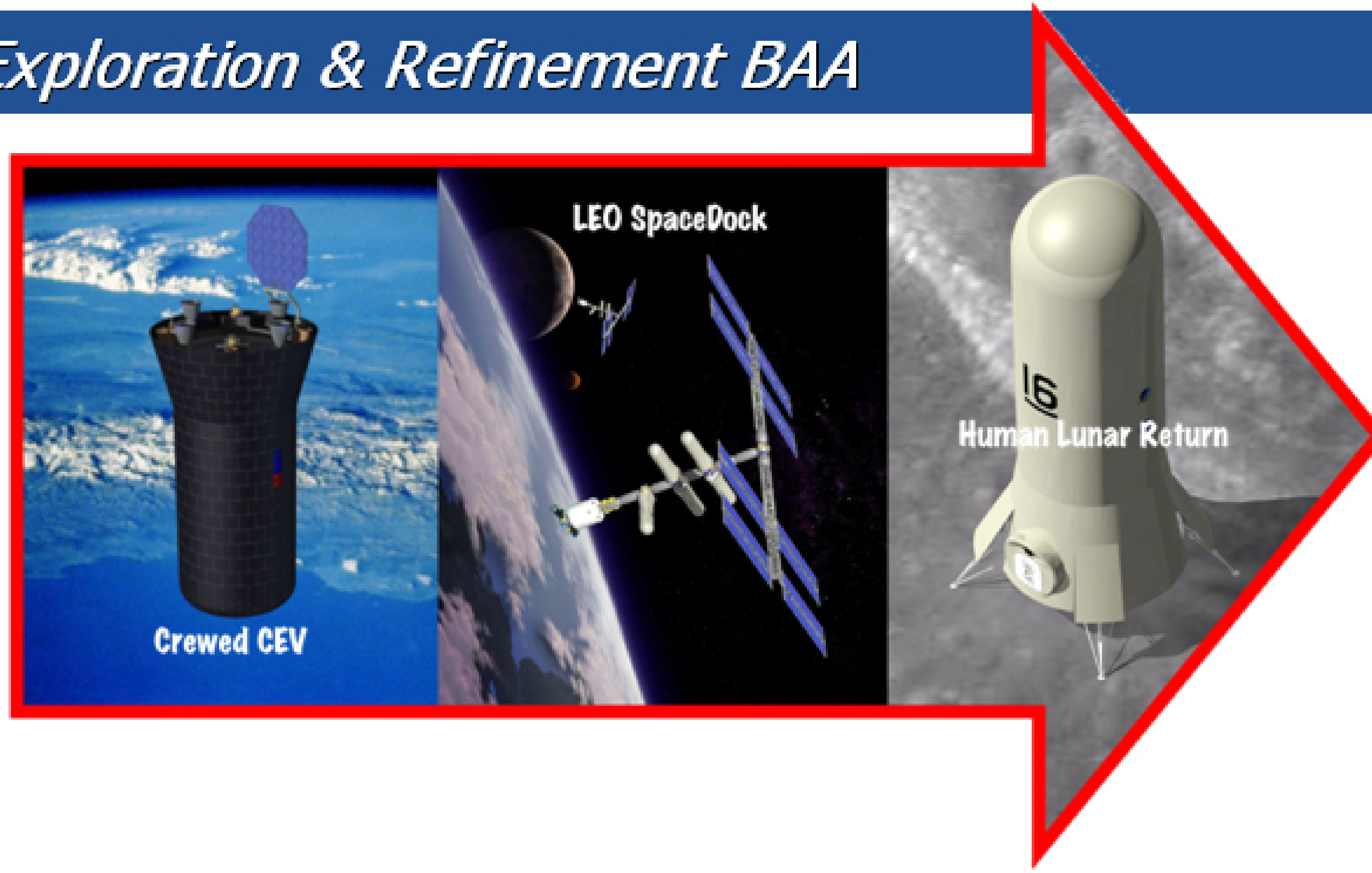
Concept Exploration & Refinement BAA



Sustainable Lunar Exploration Requires a Competition-Based Open Architecture

Sept. 13, 2004

Working Group:

Open architecture strategies

Earth to orbit activities are separated from in-space transit

In-Space vehicles and lunar habitats are small and modular

Open architecture strategies

Earth to orbit activities are separated from in-space transit

- The barrier to entry is lower if companies aren't required to develop complete Earth-surface-to-lunar-surface services; this enhances competition
- Existing cargo ELVs and new Earth-to-LEO passenger vehicles easily fit into the lunar initiative, enhancing competition and economies of scale

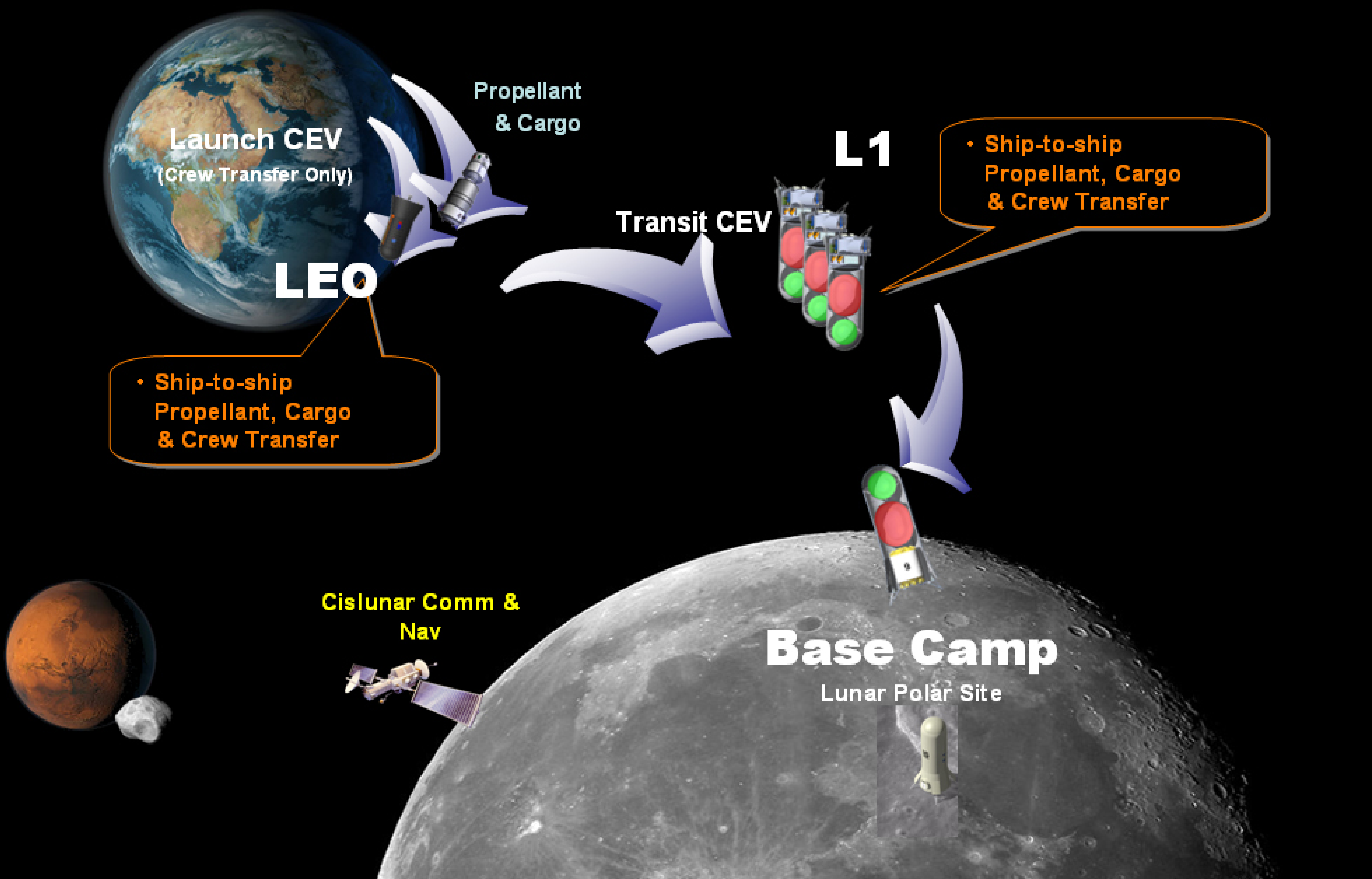
In-Space vehicles and lunar habitats are small and modular

- ***Battlestar Galactica*** model causes many constraints (available volume for installing new gear, limits on access the vehicle surface for antennas, etc.)
- Mix-and-match method allows new entrants to develop specialized add-on exterior modules, for faster technology uptake and enhanced competition
  - For example, a closed-loop life support module that could be added to an in-space vehicle that started off with expendable air/water systems

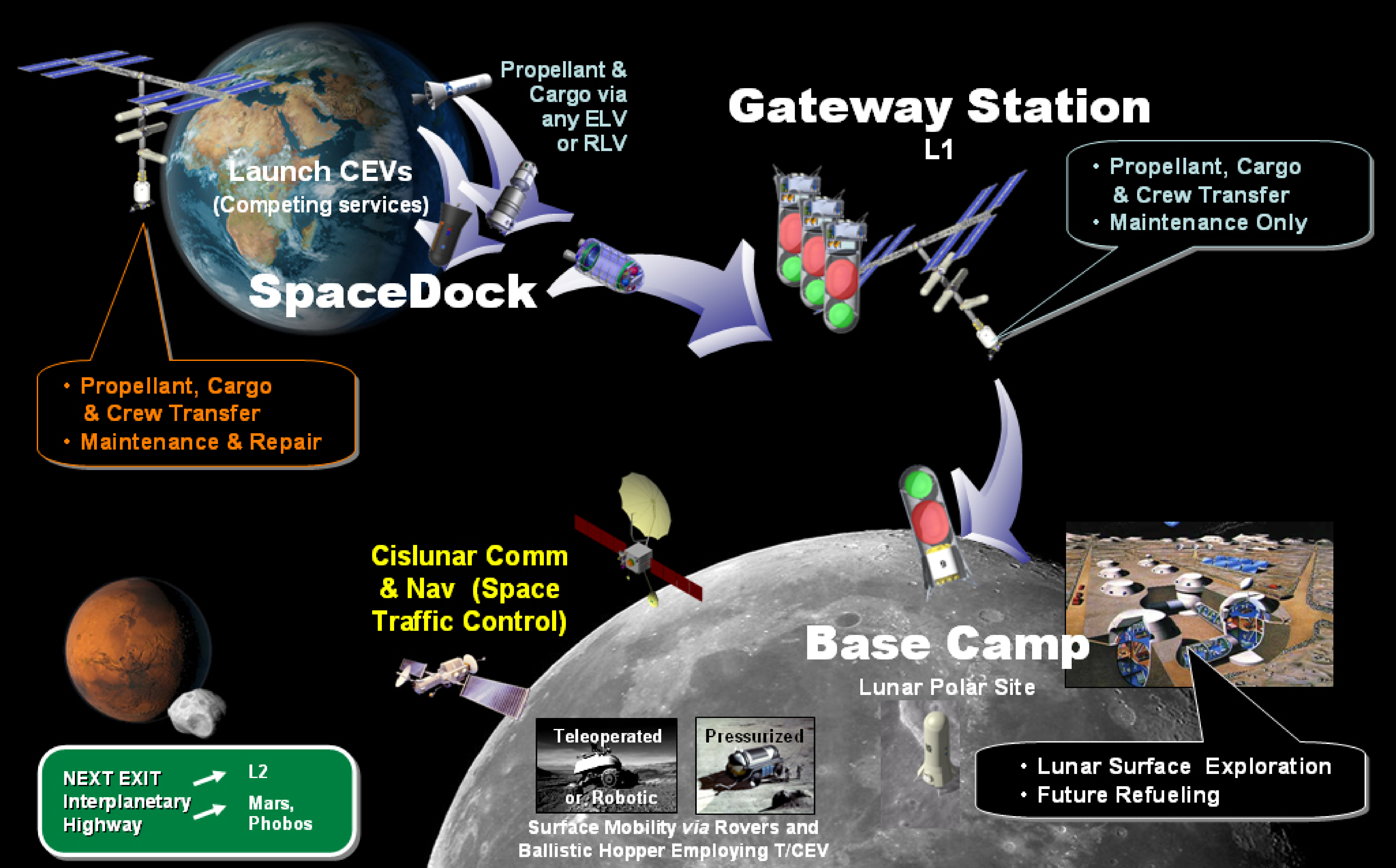
Achieving an open architecture

- **Open architecture implemented with three staging points**
  - Low Earth Orbit (SpaceDock™)
  - L1 (Gateway Station) or on-the-way refueling
  - Lunar South Pole
- **Additional staging areas may be developed by industrial participants to serve their business models**
  - Additional LEO stations or depots
    - At different inclinations or altitudes
    - Using alternate rendezvous methods: berthing instead of docking, or tethers
  - Non-polar lunar stations or depots
  - Cycling orbits or other Earth centric high orbits

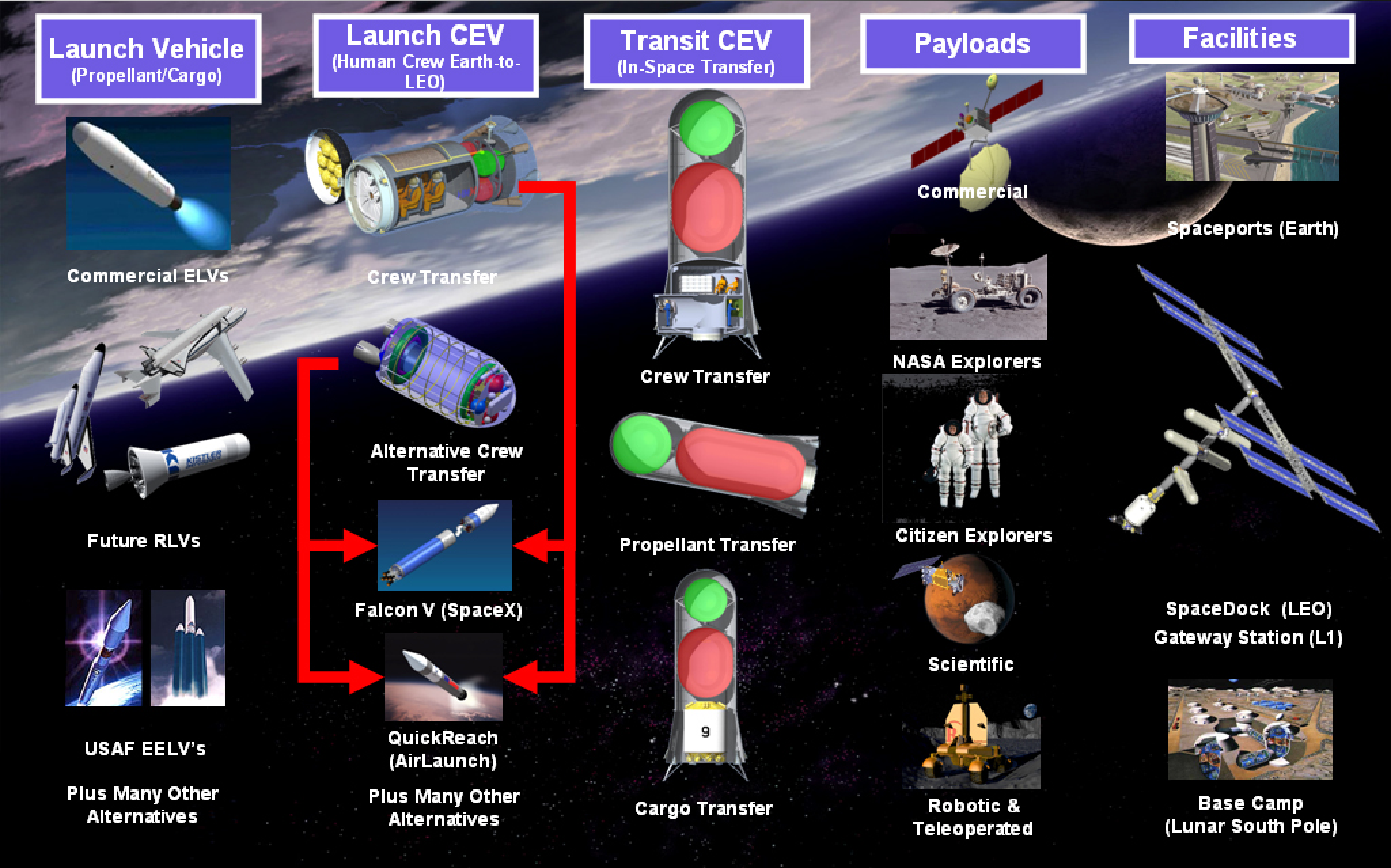
Minimal initial structure is put in place by t/Space



...And added to incrementally by competitors and partners

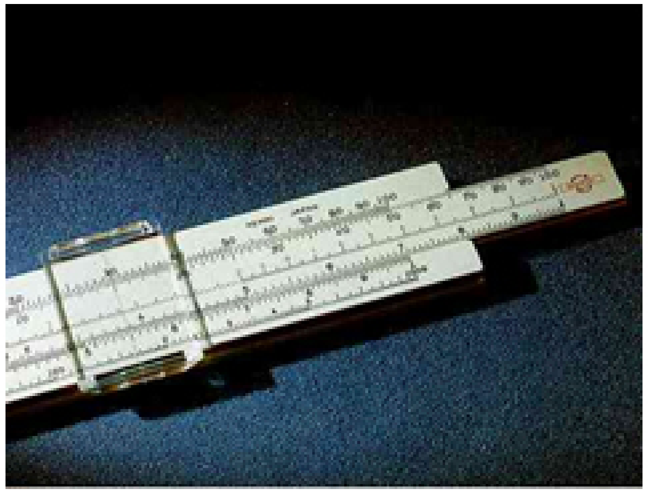


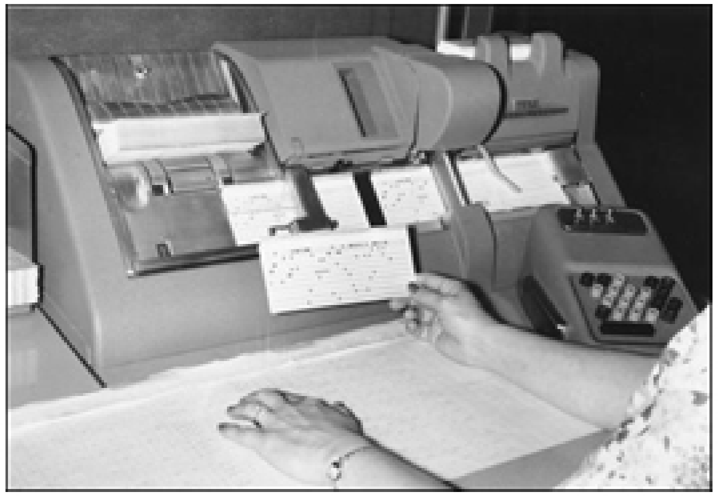
Many elements contribute to a vibrant cislunar economy



Technology must *not* be the goal

- **Sufficient technology for the Moon existed in 1969**





...tools that now resemble the stone ax

Value, not new technology, is the right metric

Three ingredients of lunar value

Reduced Development Cost

- NASA always will be in a mixed mode of development ***and*** operations; every development dollar cuts into what the initiative actually can ***<u>do</u>***

Reduced Operations Costs

- Labor drives the cost of operations. We cannot afford the past practice of shifting big development workforces into big operations workforces

<u>Valuable</u> outputs

- The results must impress the public
  - Visible economic paybacks
  - Opportunities for greater public participation, esp. telepresence
- Lunar science wasn't sufficiently interesting to save Apollo
- Program must seek benefits to Earth from lunar resources, and from how the NASA initiative can jump-start vastly greater LEO-GEO enterprises

How to reduce development costs

- **Use the rapid prototyping mode of Scaled Composites & AirLaunch LLC as the ultimate in "spiral development"**
  - Many specifications flow from discovering what current hardware can do, rather than inventing hardware to match specifications

- **NASA should not set minimum unit-size requirements**
  - Good: "six astronaut-explorers delivered to the Moon"
  - Bad: "six astronaut-explorers per flight delivered to the Moon"
  - Big vehicles are more expensive to develop, limiting the number of companies that could compete to offer such services

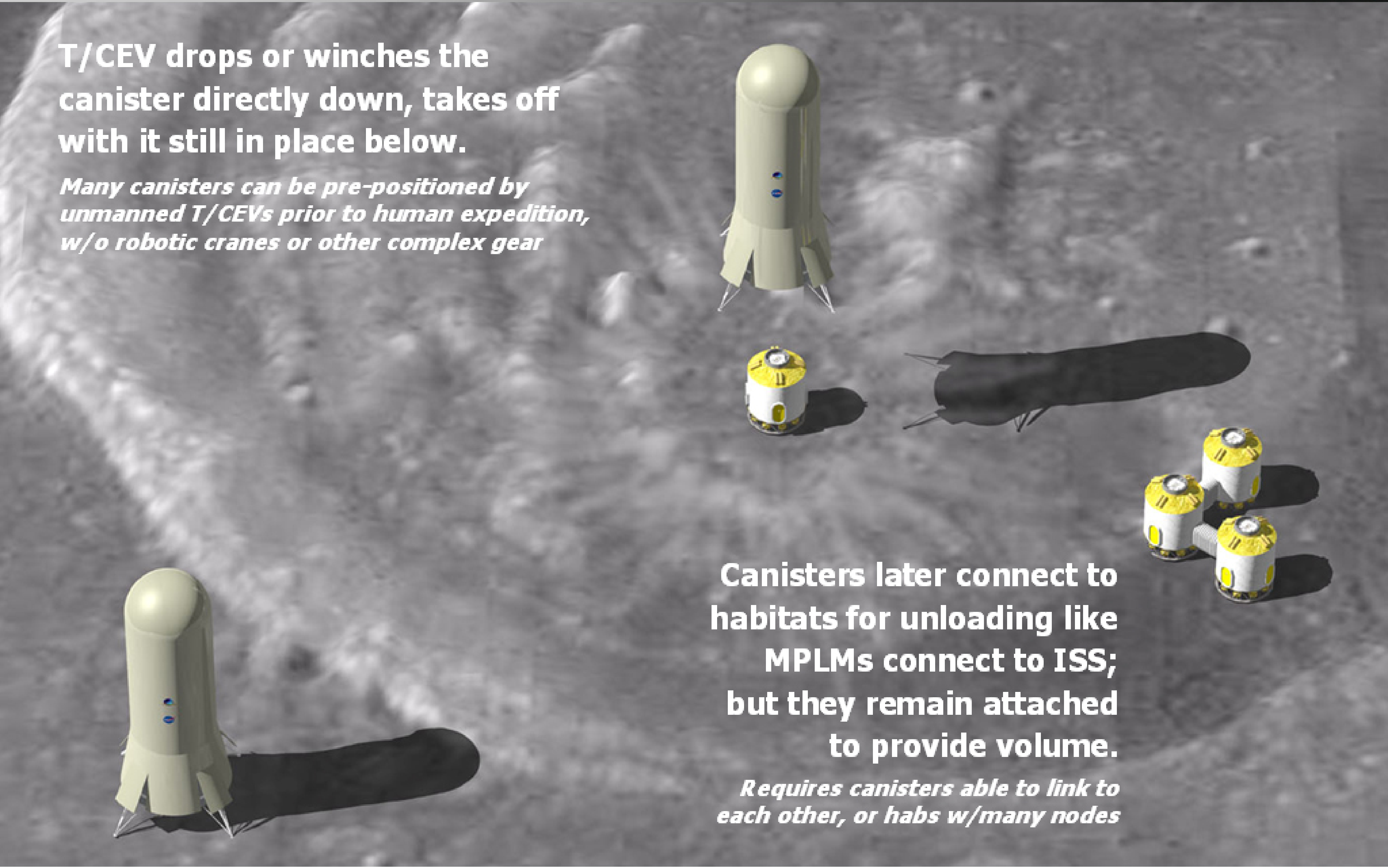
Additional development cost ideas

- **Use CEV program to spur passenger travel to LEO**
  - If NASA "invents" a competitive LEO passenger market through its contracting strategy, it will reap huge economies of scale
  - Economies make human-assisted in-orbit assembly cost effective
  - Commercial market will rapidly overtake dollar volume of NASA ETO spending, shifting development costs to the private sector
- **Use EELVs as long as possible for heavy lift**
  - Compensate for modest lift capability via assembly in space
    - With a robust passenger market, the cost of human labor will be much cheaper, avoiding expensive tech-dev for robotic assembly methods
  - Not spending $18 billion in 2010-20 on invisible-to-the-public heavy lift development means $18 billion more will be available for actual operations in space that the public can see and understand

Reduced ops costs + greater output

- **Most lunar facilities needed by NASA should be privately owned to facilitate add-on commercial uses**
  - For example, specialized surface gear (rovers of various types, hoppers, diggers, etc.) would be rentable by private users
- **Even "science labs" ought to be owned commercially so that essential services can be sold to non-NASA users**
  - A rock sample lab, for example, should be available after hours to prospectors needing analysis of their finds
- **This will bring economies of scale and provide NASA with diverse and competitive supply sources**
- **This approach also gives the public the maximum emotional return on their investment**
  - Private ventures will expand the range of "frontier" activities well beyond often-esoteric government science projects

Example penny-pinching technique: Cargo canisters as habitat add-ons



T/CEV drops or winches the canister directly down, takes off with it still in place below.

Many canisters can be pre-positioned by unmanned T/CEVs prior to human expedition, w/o robotic cranes or other complex gear

Canisters later connect to habitats for unloading like MPLMs connect to ISS; but they remain attached to provide volume.

Requires canisters able to link to each other, or habs w/many nodes

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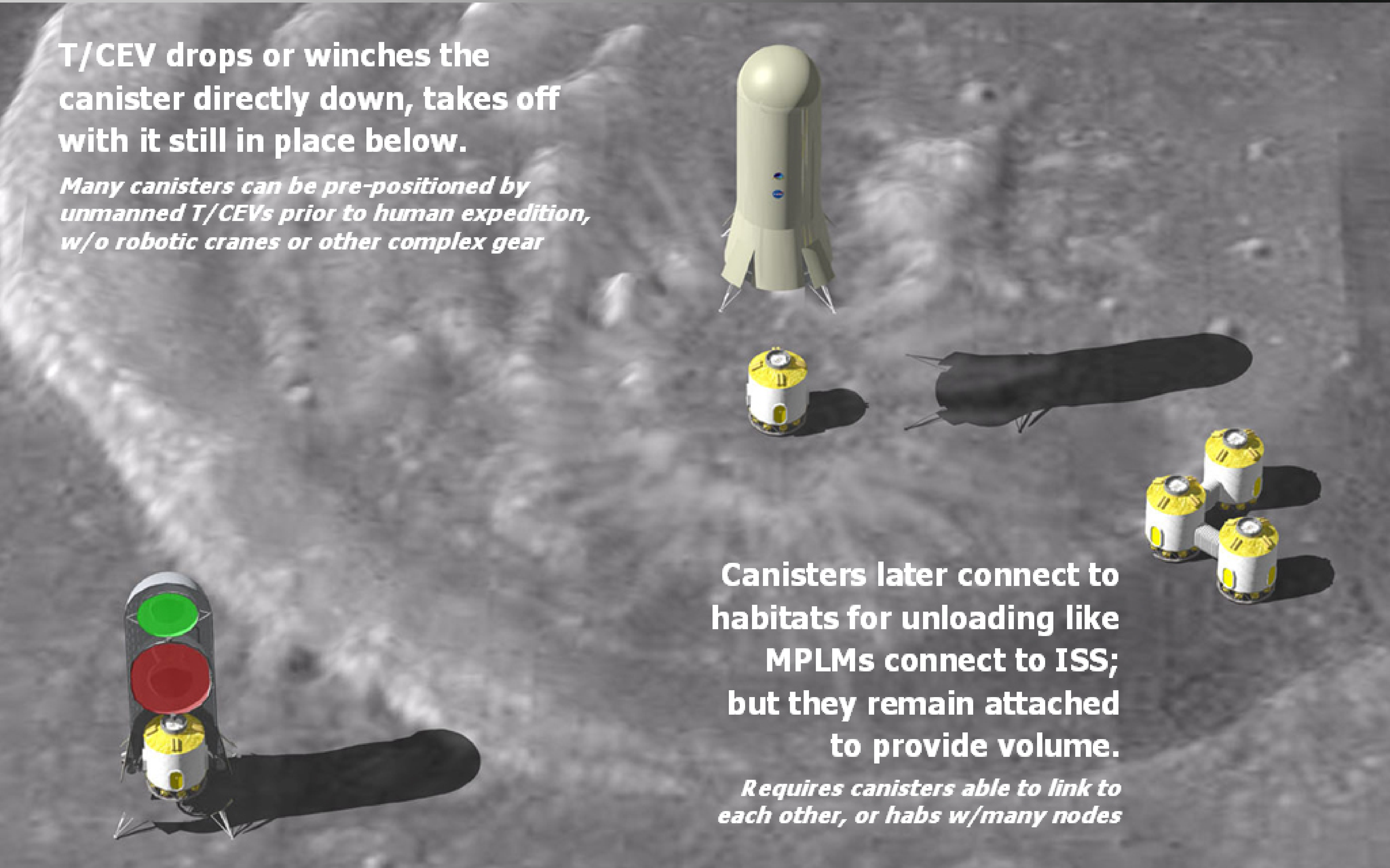

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Safety & "human rated vehicles"

Safety results from design choices, not oversight

- Attempting to produce safety by inspection, quality control, documentation, meetings etc., is ineffective and costly
- The right choices include a robust and resilient concept, vehicles with ample margins and reserves, and high flight rates using smaller vehicles

Flight history determines if a vehicle is "human rated"

- Requires hundreds of flights for statistical validity
- "Determination-by-analysis" is just an estimate

Cost *is* an object

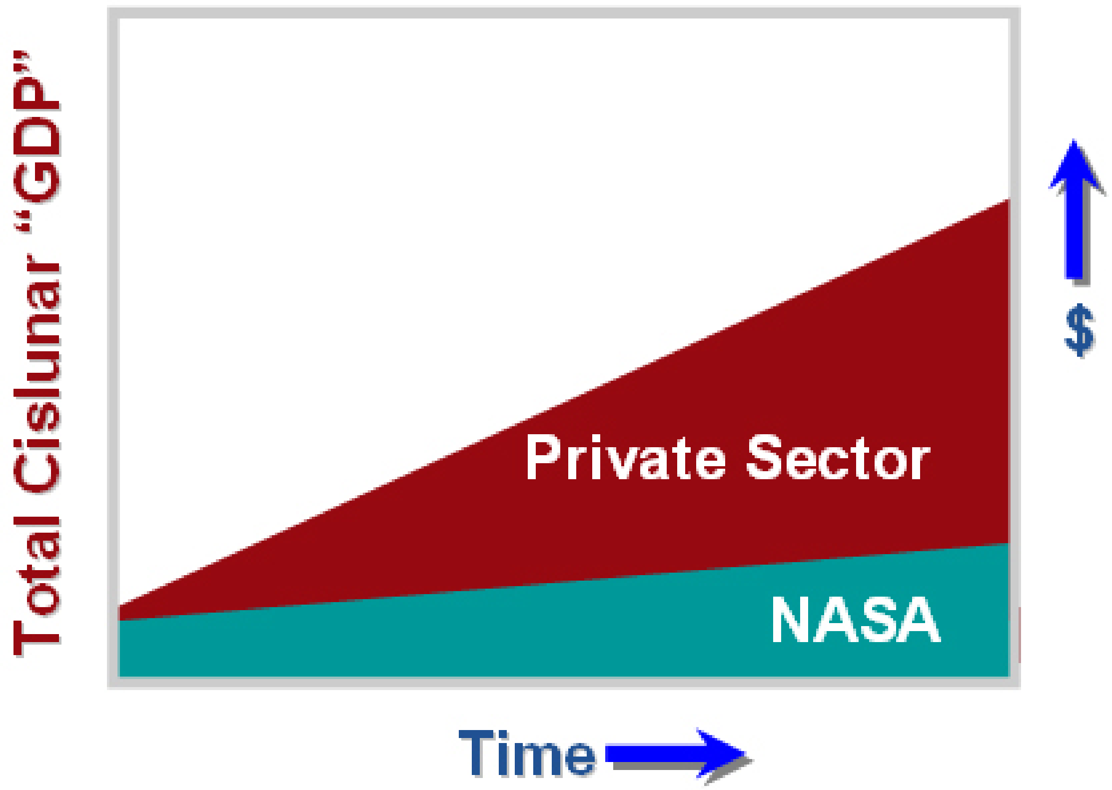
- Expensive systems have too few units built to give resiliency to the architecture, and/or high operating costs lead to unsafe low flight rates

Sustainability

- **Sustainability results from encouraging diversity of vehicles and systems, using our "Standard Gauge" view of interoperability of privately owned elements**
  - Sustainability will be produced when the NASA spending for exploration *is overtaken by* the total economy of Cislunar space.

- **Diversity of future suppliers will give NASA real control over its destiny:**

Poor performers can be fired, instead of being given bigger contracts to fix their failures



Summary

- NASA needs improved value-to-the-public via lower costs and more meaningful results
- An open, competitive architecture drives down costs and delivers a broader range of results
- t/Space will develop an architecture, and proposed NASA policies, that sharply reduce costs as they produce faster achievements