IN SITU RESOURCE UTILIZATION PLANNING THE MINE AND MINING THE PLAN

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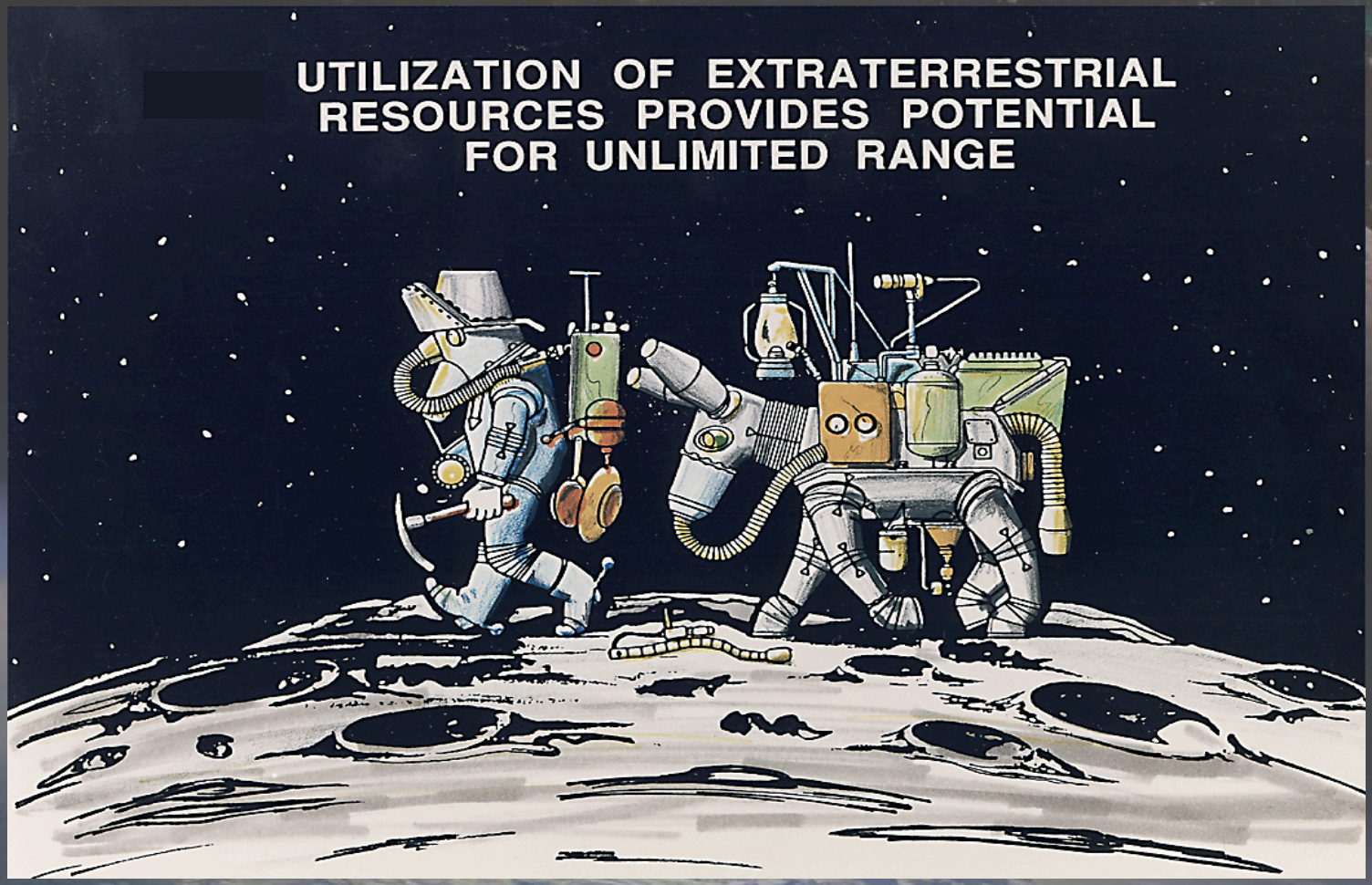
Space Mining is one form of In Situ Resource Utilization (ISRU)



The Mining Cycle

REHABILITATION

PRODUCT

REFINING

MINING

EXPLORATION

Photos Courtesy Falconbridge Nickel

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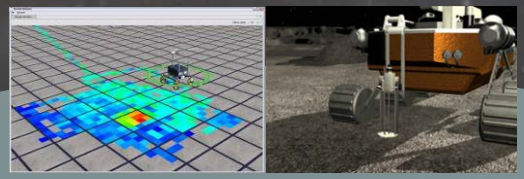
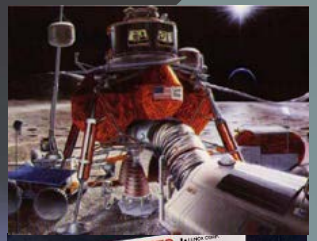
Lunar ISRU Operations Cycle

Global Resource Identification



Local Resource Exploration/Planning

Mining

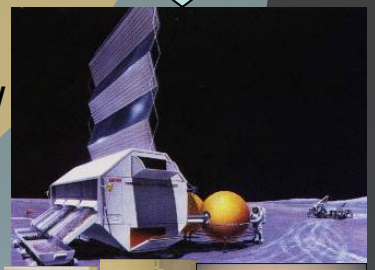


Product & Utilization

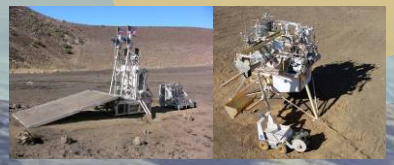
Communication & Autonomy

Site Preparation

Maintenance & Repair



Crushing/Sizing/ Beneficiation



Processing

Waste

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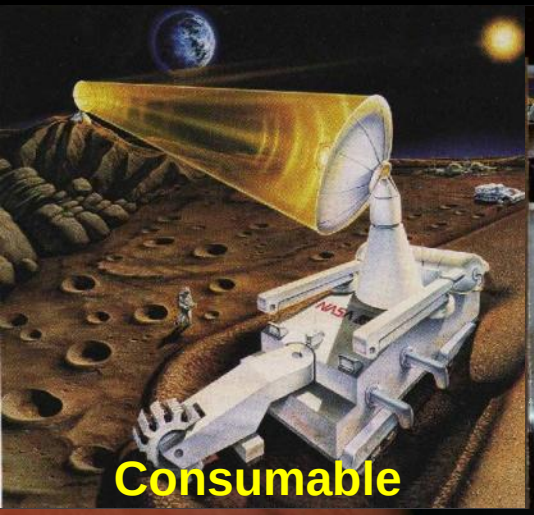
What Do You Mean “We got it wrong?”

- Mining Cycle is only a portion of the overall Mine Planning Activity
- Lunar Operations BEGIN after the Mine Plan is executed (Stage 4)
- Failure to plan appropriately yields … unexpected results

To find an new gold mine …
start with an old gold mine

Using Space Resources Constellation Program



Consumable Production

- Propellants
- Life Support
- Fuel Cell Reactants
- Metal Feedstock
- Plastic Feedstock

Resource Prospecting

- Lunar Ice/Volatiles
- Mars Water
- Near Earth Objects

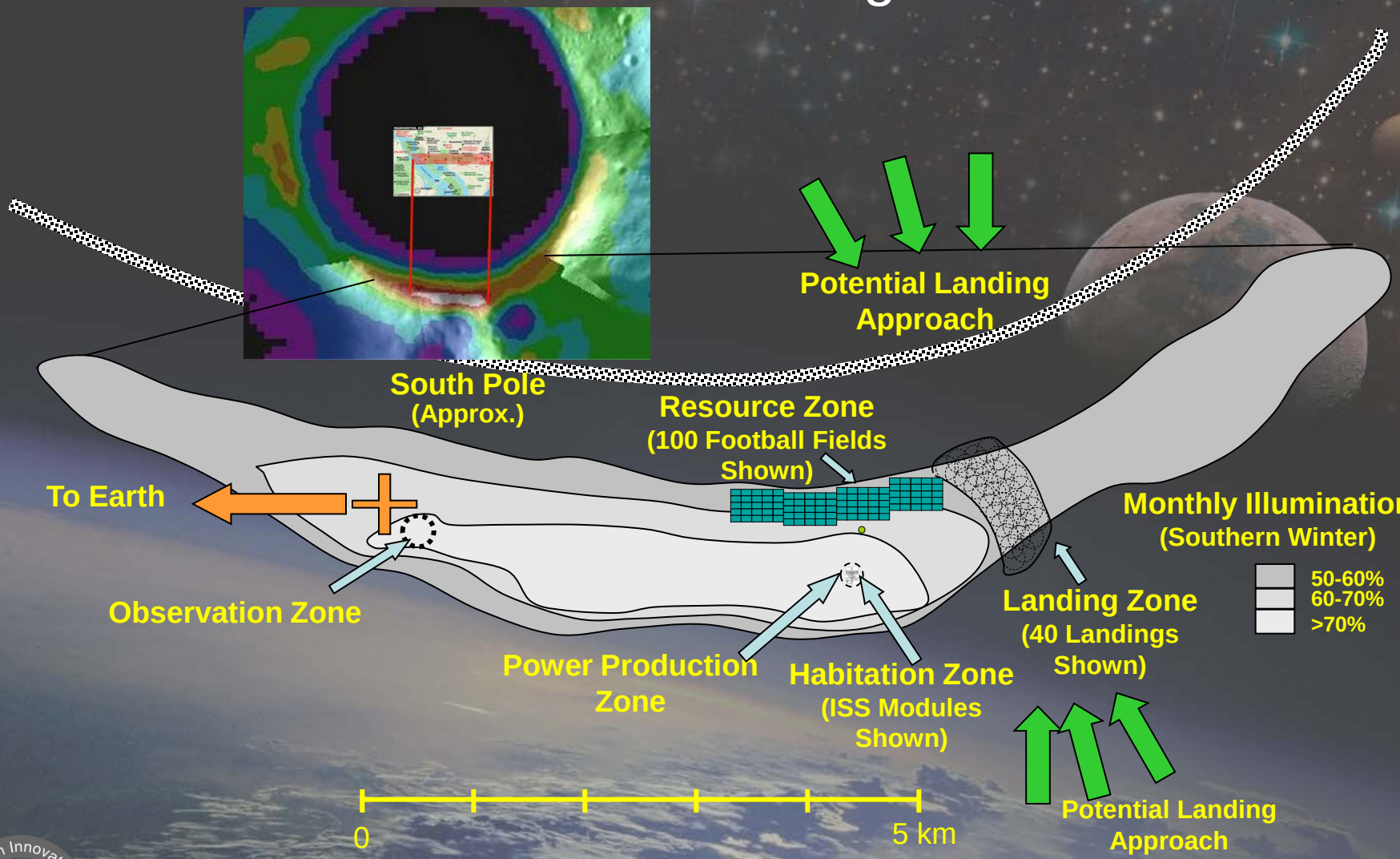
Civil Engineering & Construction

- Civil Engineering:
- Landing Pads, Roads, Berms
- Habitats

Energy

- Thermal Storage
- Solar Array Production
- Space-based Solar power Beaming
- Helium-3 Mining

Notional Shackleton Crater Rim Outpost Constellation Program



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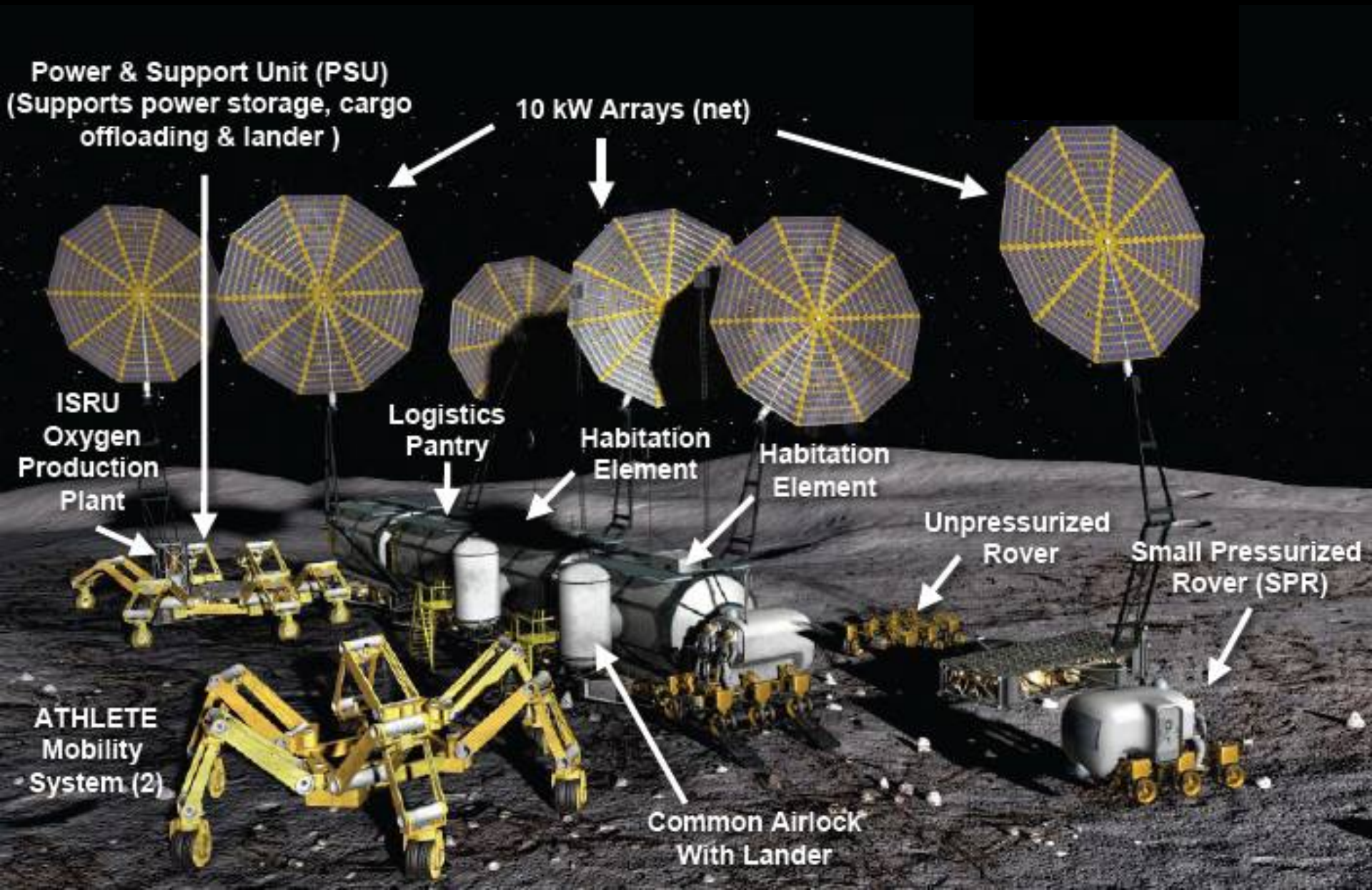
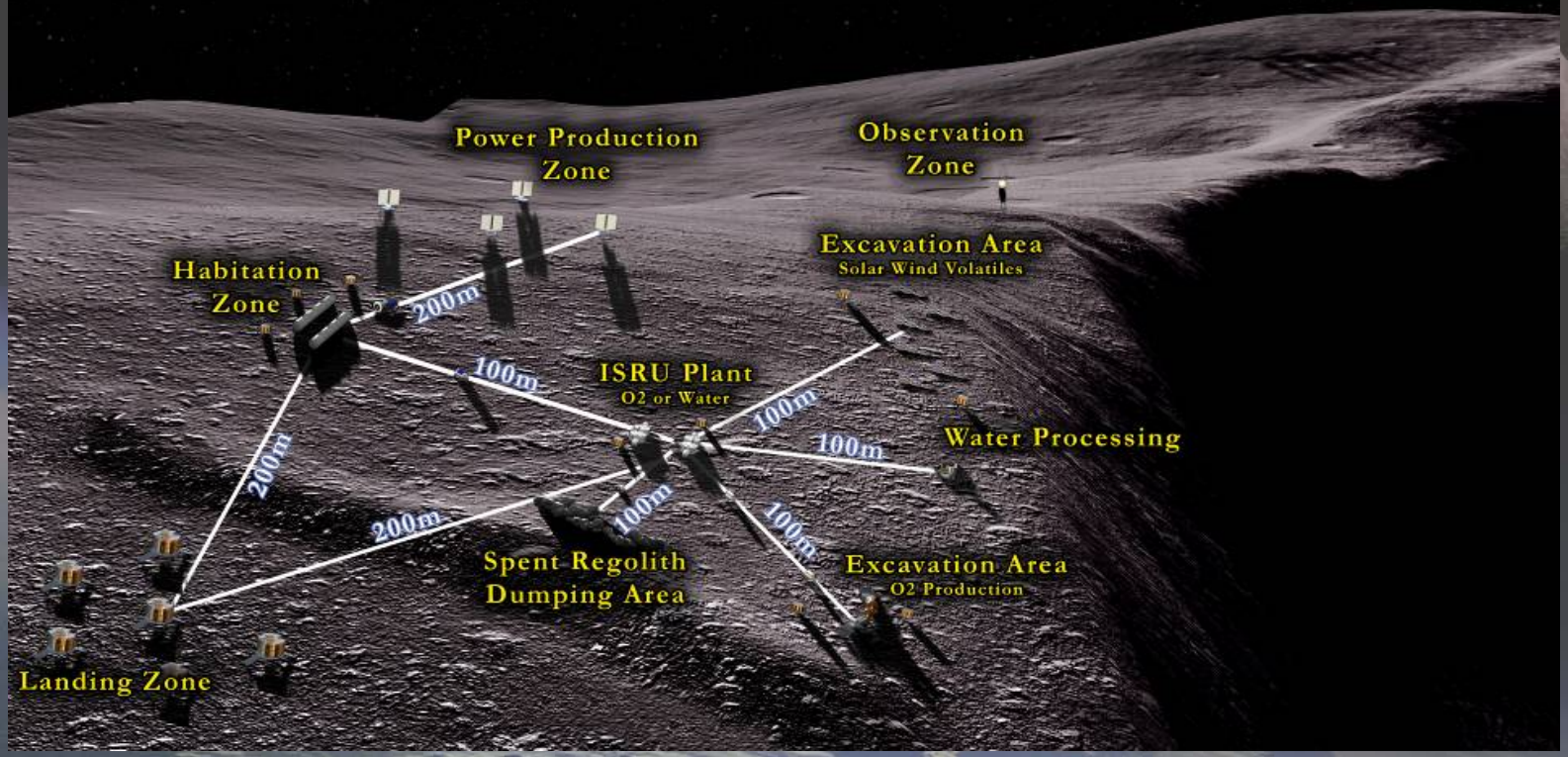
Conceptual NASA Lunar Surface Architecture



Notional Shackleton Crater Rim Outpost Constellation Program



Establish Basic Assumptions

Client	Mine Site	Production	Life Cycle	Delivery Point	Projected price point
• Lunar Lager Brewing Company Ltd.	• Cabeaus Crater	• 1000 tonnes purified water per year	• 10 year Production	• Lunar Outpost • Shackleton Rim • Clive's Bar and Grill – hamburger stand and refueling depot	• $500 per kg

Phases of Project

Stage 1
- Concept Development

Stage 2
- Technology Selection and Development

Stage 3
- Feasibility Study

Stage 4
- Execution

Handover
- Working water facility on the Moon

Stage 1 Concept Development

1

- Cost cap budget for project set at $1600 million

2

- Early results indicate
  - 7% water ice by weight average over mining site of 100 hectares.
  - Average depth is 2 m;
  - overburden is 40 cm desiccated material.
  - Rubble field geology requiring handling of large (1 m) rubble as overburden and embedded waste.
  - Estimates show that 40% of the available area is accessible; remainder is under excessive rubble or trapped by rock outcroppings.

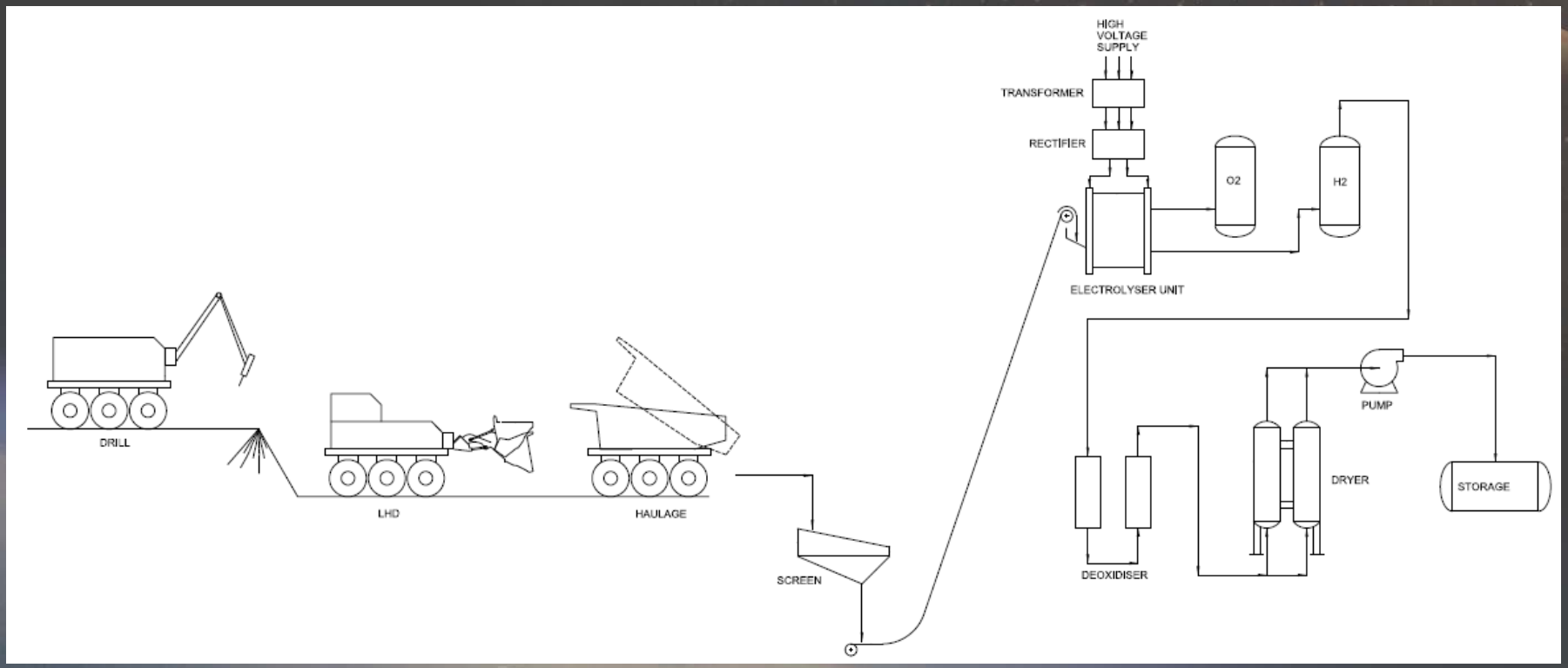
3

- Technology Development State of Art
  - Small ISRU-specific mobile platforms (500 kg) are reasonably mature and can be used to provide most mobile services.
  - Sampling technologies well developed for detailed ore body definition.
  - Refining systems are at early TRL stages.
  - Storage of product can be evolved from known technologies.

4

- Technology development plans
  - excavation systems,
  - command and control with Direct To Earth (DTE) link or via specialized orbiter or crater rim emplaced links.
  - Power systems to be RTG stacks and/or crater rim mounted solar voltaic cells.

Stage 1 Concept Development



Stage 2 Technology Selection

1
- CRS revised to include Level 2 requirements.

2
- Mining process selected.
  - Open bench mining
  - Overburden dump site selected for ease of access at later date in support of habitat requirements.

3
- Plan revised to incorporate new fusion power system development.

4
- Technology development roadmap completed.
  - Contact made with OEM's
  - Develop target technologies in joint venture/ speculation style sub-projects.

5
- Execution Stage (Stage 4) concept will rely upon robotic pre-cursors to develop infrastructure, roadways, maintenance sites.

6
- Overburden from mine site will be used as required for fill.

Stage 3 Feasibility Study

1
- CRS revised to include Level 3 Requirements.

2
- Time-based technology deployment completed.

3
- Fleet make up of
  - 2 roadway maintenance rovers,
  - 2 construction robots,
  - 1 mobile exploration drill,
  - 2 Load Haul Dump machines,
  - 4 haulage trucks
  - Deployed in order indicated over 3 years.

4
- Refining process to be in situ thermal release of water ice from regolith with water filtration plant for 98% purity.

5
- Bulk storage tank farm with auto loaders for pure water storage.

6
- Technical risks 80% retired: remaining risks are in the area of long term machine availability

7
- Management risks remain with long term financing and market volatility for end product.

Stage 4 Execution

1. • Establish project execution team.
2. • Secure launch, cruise and lander contracts
3. • Secure OEM equipment procurement contracts and schedule.
4. • Establish ground based command and control center.
5. • Deploy road building systems to establish landing pads, basic infrastructure, mine pit roads.
6. • Deploy construction robot team.
7. • Deploy LHD robots.
8. • Deploy long-haul trucks.
9. • Commissioning of systems and ramp up to full production.
10. • Hand-over to Client (Operations).