# Issues Relating to Large Scale Material Handling with Mobile Systems

**Edward D. McCullough**

**Former Start-UP Manager at Bechtel**

# Topics to be Covered

*Application for Mobile System*

*Vehicles*

*Vehicle Specs*

*Vehicle systems and Issues*

*Lunar Environmental Issues*

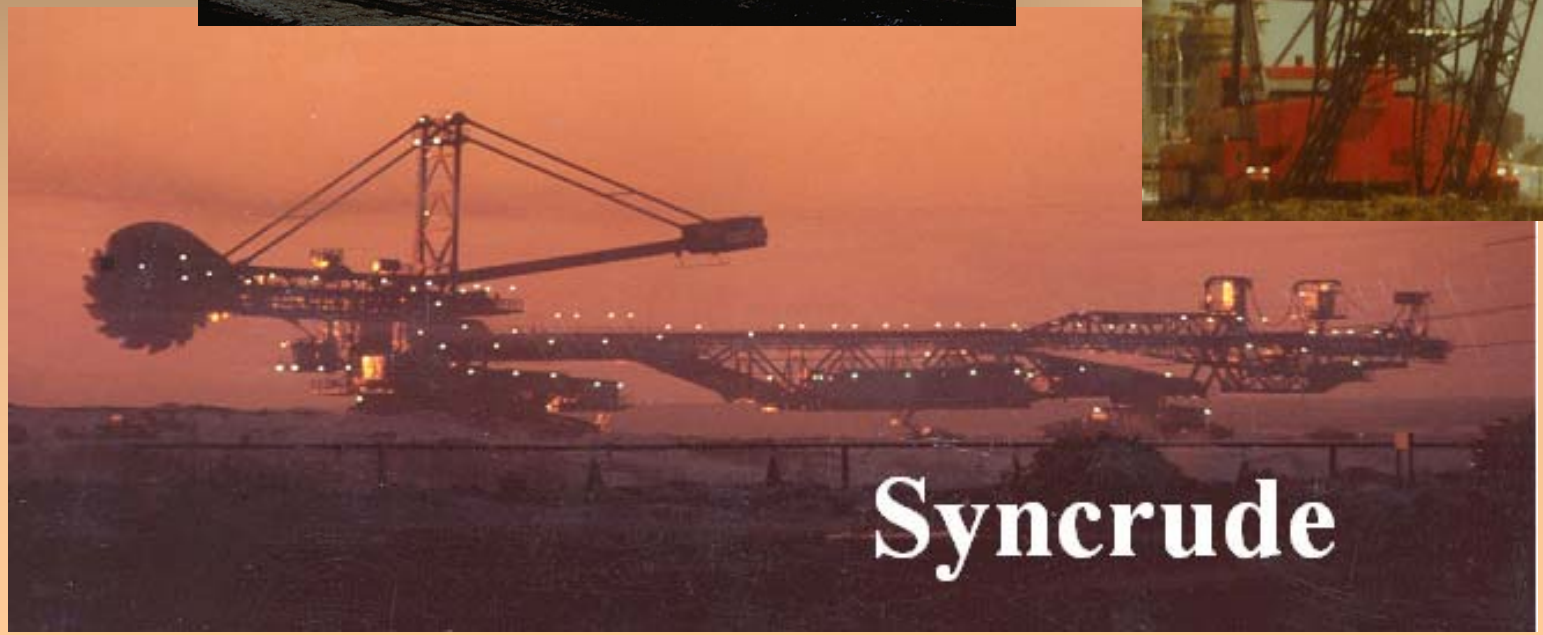
*Transportation options*

*Conclusions*

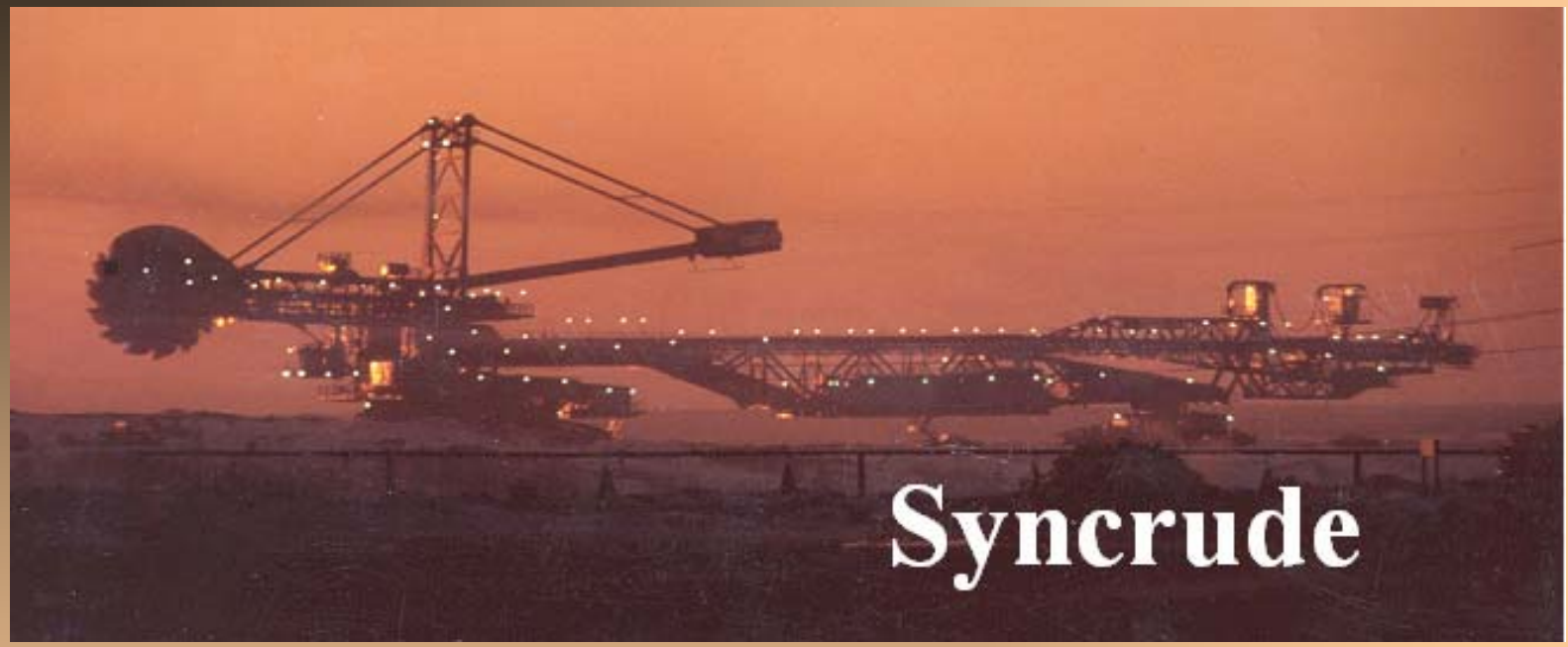
# Material Handling Requirements for the Recovery of He3

| | |
|---|---|
| *Production Rate* | *- 1 tonne/year* |
| *Concentration* | *- 30 ppb* |
| *Recovery Efficiency* | *- ~ 33%* |
| *Mining requirement* | *- ~ 100 M tonnes/year* |
| *Utilization* | *- 50%* |
| *Excavation Rate* | *- 10,000 per hr* |
| *Time required* | *- 590 days* |
| *At 50% utilization* | *- ~ 1180 days* |
| *With 4 production units* | *- ~ 300 days* |
| *Mass of production unit* | *- > 100 tonnes* |
| *Fabrication and construction* | *- In place, 95 % lunar mat.* |

# Mobile Systems for Mining Tar Sand



# 7,000 TPH Bucket Wheel Reclaimer




| | |
|---|---|
| *Power* | *- 25,000 Volt AC extension cord* |
| *Capacity* | *- 7,000 tons per hour* |
| *Mobility* | *- Crawling* |
| *Height* | *- ~ 180 ft* |
| *Motors* | *- Delta Delta resistor start AC induction motors* |
| *Slew* | *- Rotating bridge and counter weight on thrust bearings* |
| *Tracks* | *- O&K Crawlers with AC induction motors* |
| *Conveyors* | *- Wheel, Bridge and offload with AC motors* |
| *Wheel* | *- ~ 21 ft in diameter with AC motors* |

# Bucyrus Erie 80 yard Dragline

| | |
|---|---|
| *Power* | *- 20,000 HP* |
| *Power Supply* | *- 25,000 Volt AC cord* |
| *Capacity* | *- 80 cubic yards* |
| *Mobility* | *- Walking* |
| *Height* | *- 200 ft* |
| *Controls* | *- Ward Leonard* |
| *Motors* | *- 28 7 ton series wound DC* |
| *Generators* | *- 28 series wound DC generators connected directly to motors* |
| *MG Sets* | *- 4 5,000 HP motor generators with 7 generators each* |
| *Slew* | *- Revolving frame on roll path with 8 DC motors* |
| *Shoes* | *- Powered by 4 DC motors through an eccentric* |
| *Lift drum* | *- 8 DC motors* |
| *Drag Drum* | *- 8 DC motors* |

# The Moon is Different

- **Automotive suspension engineers will enjoy designing for this environment. It doesn’t take much to get the vehicle vacuum borne.**

# The Moon is Different

- Traction is 6 times lower (like driving on ice?)
- Heat rejection is radiative only
- Surface temperature at noon is 395 deg. K (251 deg. F)
- Dust is ultra fine and sharp down to nanometer scales
- Dynamic stability of volatile laden dust being investigated
- Charged dust levitates off the surface
- The environment is anaerobic and vacuum welding is a constant threat
- Volatiles
  - Concentrations at low latitudes is reasonable well known
  - General concentrations of H2 in higher latitudes is known
  - Concentration ratios of known lunar volatiles in polar regions is not known
- The terrain is cratered on all scales (micro to mega meters)

# Material Handling Systems for the Recovery of He3

- ***Vehicle Systems***
  - ***Energy systems***
  - ***Traction system***
  - ***Suspension system***
  - ***Drive train***
  - ***Lubrication systems***
  - ***Payload systems***
  - ***Maintenance***
- ***All systems are subject to extreme temperature gradients***
- ***All mechanical sliding, rotating joints and bearings are subject to an invasive, abrasive dust environment***
- ***All electrical, communication and instrumentation systems are subject to invasive dust and lunar volatiles in concentrations high enough to present contamination control issues and materials problems***

# Bucket Wheel System Issues

| Item | System | Elements | Issues |
|---|---|---|---|
| 1. | **Energy** | Transformers<br>Circuit breakers<br>Conductors / Insulation<br>Slip rings<br>Controllers<br>Load Centers<br>Heaters / Coolers | Cooling, contamination (dust and volatiles,) alteration of material properties, vacuum welding, thermal management, circuit interruption capability deterioration, heat rejection to the lunar surface ( 251 deg. F at lunar noon) or to space. |
| 2. | **Traction** | O&K Crawlers<br>Hydraulic steering system | Brittle fracture, vacuum welding, wear due to dust contamination, thermal management, lube system failure, contamination of other systems via off gassing lubricants, mismatch between traction system design and environmental reality |
| 3. | **Suspension** | Damped spring system on yoke | Brittle fracture, thermal management |
| 4. | **Lubrication** | Central point lubrication system<br>Lubricants shed to the environment<br>Gear box oil must be maintained<br>Lubricated every few shifts<br>Hydraulics systems serviced | Loss of lubricants to environment, failure of improperly specified and certified lubricant system, central point lube system simplifies servicing but complicates assembly and is subject to damage, lubrication scheme must take a totally new approach, lubrication paradigm must be re-evaluated with new approaches to refurbishment of worn parts instead of lubrication, function requiring lubrication should be eliminated if possible. |
| 5. | **Vehicle Geometry** | Mast, bridge, crawler slew system<br>Mast elevation systems<br>Off load bridge elevation | Failure of boots and bellows on hydraulic systems, maintenance of the hydraulic system, contamination of bearings, sliders and slip rings with dust or volatiles, vacuum welding of bearings, sliders and slip rings, dynamic instability during motion. |

# Bucket Wheel System Issues

| Item | System | Elements | Issues |
|---|---|---|---|
| **6.** | **Drive Train** | Delta / delta resistor start induction motors and controller<br>Direct drive through lubricated reduction gear system | Induction motors require AC distribution system and resistor interruption system to start. DC systems require commutators, slip rings etc. Entire prime mover system approach needs to be re-evaluated. Issues associated with lubrication efficiency in 1/6 th G and in the thermal environment |
| **7.** | **Maintenance** | Repair<br>Refurbishment of worn or spent parts and materials<br>Preventative maintenance | Almost all repairs will be dangerous for the astronauts so autonomous repair vill be required (no touch labor,) refurbishment will require disassembly or advanced in place manufacturing techniques and the number of preventative maintenance tasks (replacement of worn parts prior to failure etc.) will be high. |
| **8.** | **Conveyance systems** | Bucket wheel, conveyors | Fall rates on the moon are lower due to the 1/6 g conditions while inertia is the same, tractional acceleration on conveyor belts will be lower by a factor of 6, material falling off of conveyors or wheel buckets will follow shallower trajectories making transfer more difficult, charged material will lift off of belts and adhere to structures. |