Learnings from the Australian Mining Industry applied to development of In-Situ Resource Utilisation systems for Mars.

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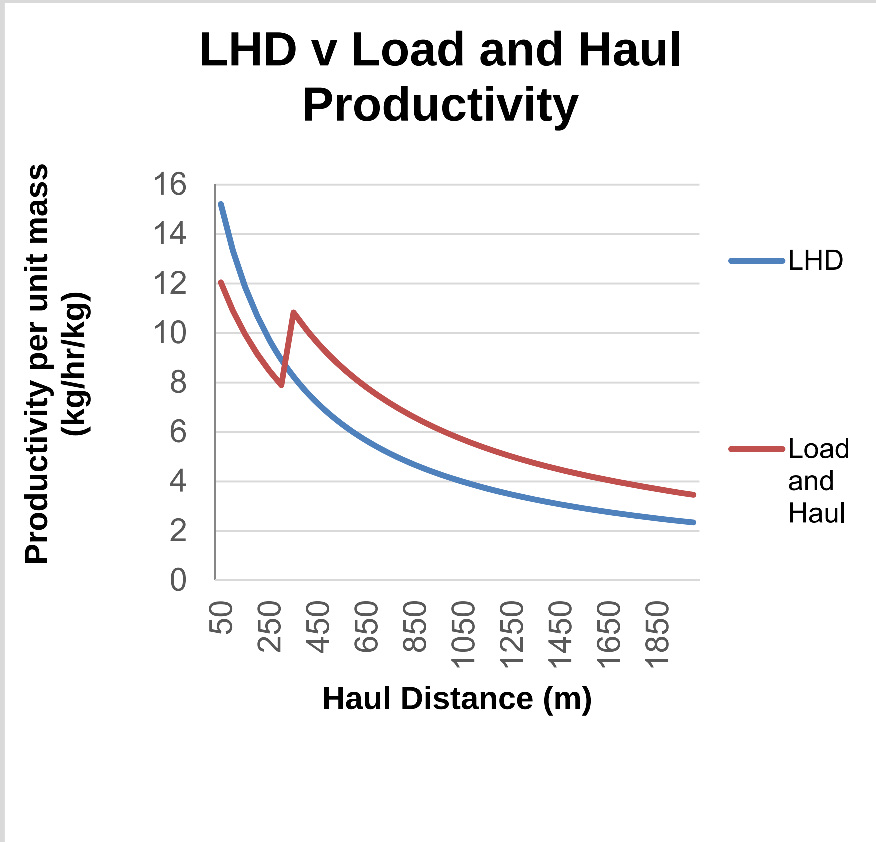
Photo: Century Mine, wikimedia commons

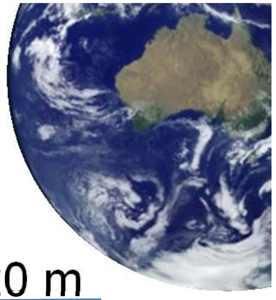
The Problem

Low confidence data, technology and models are used to support the hypothesis that ISRU on Mars will enable the first human mission.

<u>LHD v Load and Haul Operational Assumptions;</u>

Distance to ore body: [50:2000] m	
Distance to Waste dump: 100m average	
Haulage Speed: 0.8 m/s	(+/- 50%)
Excavation Speed Excavator: 0.25 m3/h	(+/- 30%)
Excavation Speed LHD: 0.27 m3/h	(+/- 20%)
Average Payload LHD: 60kg LHD, 100kg truck	(+/-20%)
Average Payload Hauler: 100kg truck	(+/-20%)
H2O Grade: 9%	(+/- 50%)
Recovery: 60%	(+/- 20%)
Hauler Mass: 8kg	(+50%)
LHD Mass: 8kg	(+50%)
Hauler Mass: 8kg	(+50%)
Daily Operating Hours: 6	(+/- 40%)

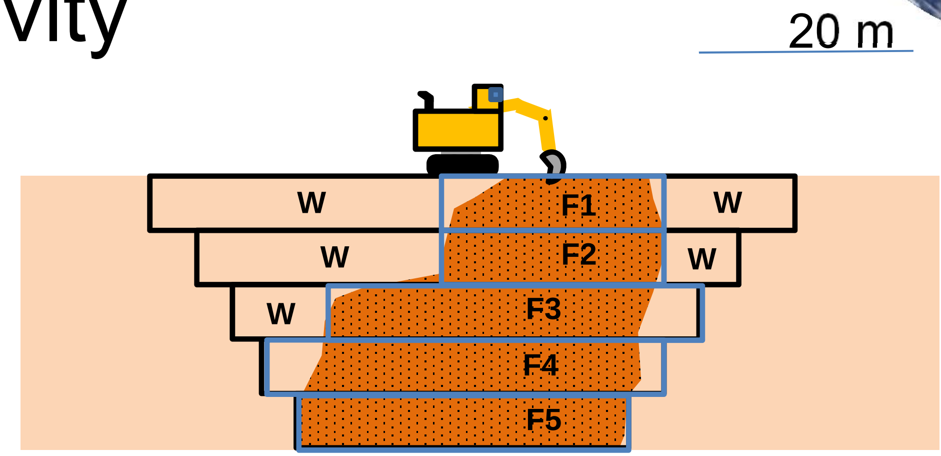




Terrestrial Industry Analogies - Grade Control and Selectivity

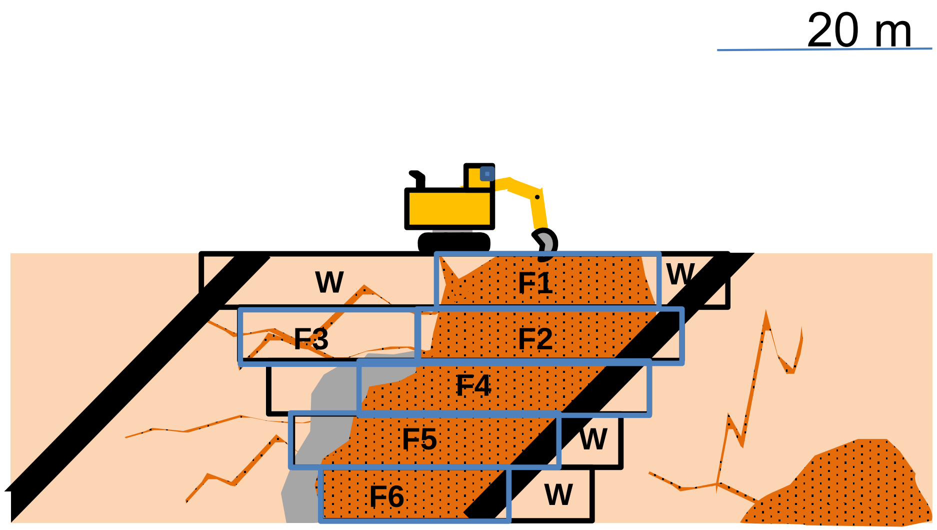
- **Expected geology (uncertain)**

F1 = 4000 t, 10%
F2 = 4000 t, 10%
F3 = 7000 t, 8%
F4 = 8000 t, 8%
F5 = 6000 t, 12%
Total ore = 29000 t, 9.3%
Waste = 15000 t

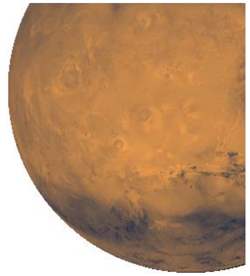


- **Actual geology**

F1 = 4000 t, 10%
F2 = 5000 t, 8%
F3 = 3000 t, 3%
F4 = 6000 t, 10%
F5 = 5000 t, 11%
F6 = 5000t, 12%
Total ore = 28000 t, 9.0%
Waste = 8000 t

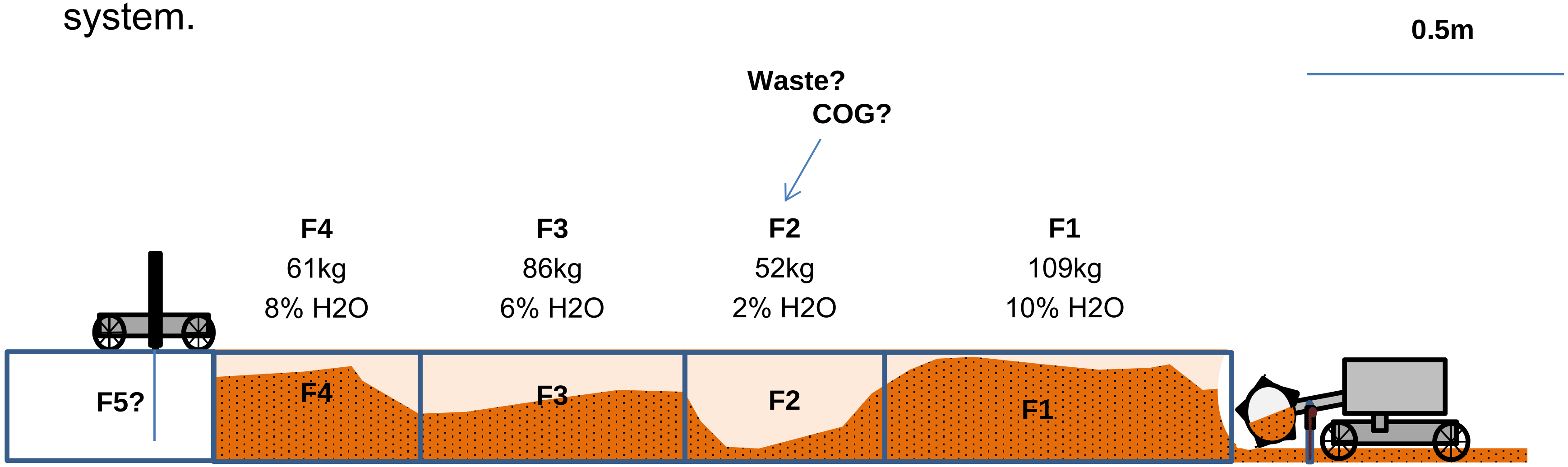


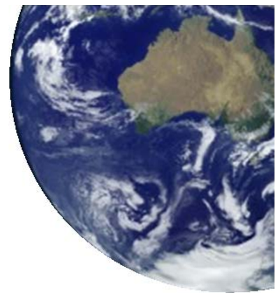
Mars Operational Hypothesis



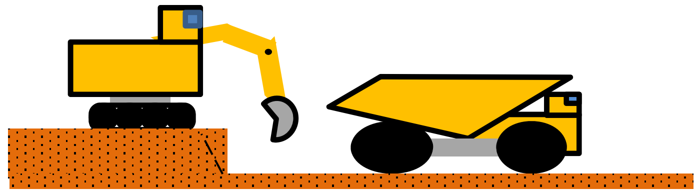
- Curiosity DAN data shows variability in location and depth. (Litvak et al, 2014)
- Risk of not achieving product targets (15 t H_2O for return mission) (Abbud-Madrid et al, 2016).

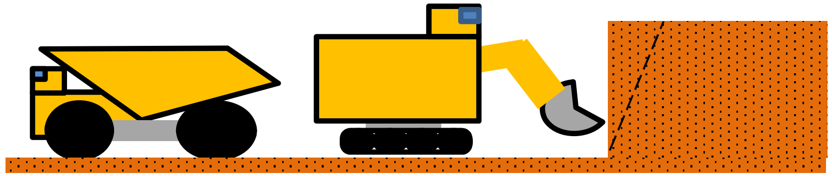
- Testing of areas for quality of ore before mining leads to improvements in the process.
  - High grade = Less material moved, for more product.
  - High grade = Less processing and mining equipment required for more product.
  - High grade = less thermal power required for processing.
- Selectivity in mining increases average grade and output in a mill constrained system.



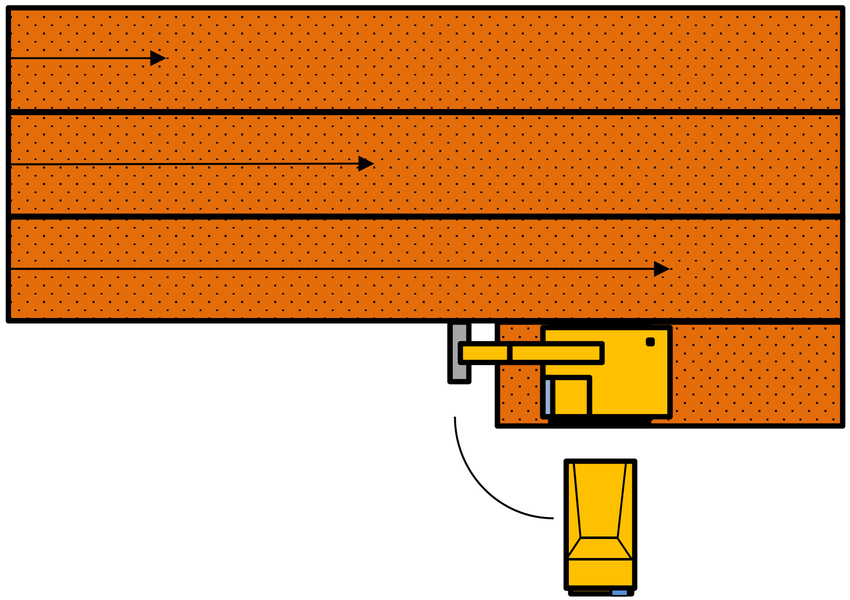


Terrestrial Industry Analogies – Efficient Excavation Setup

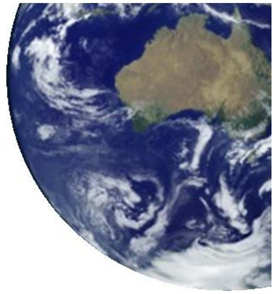


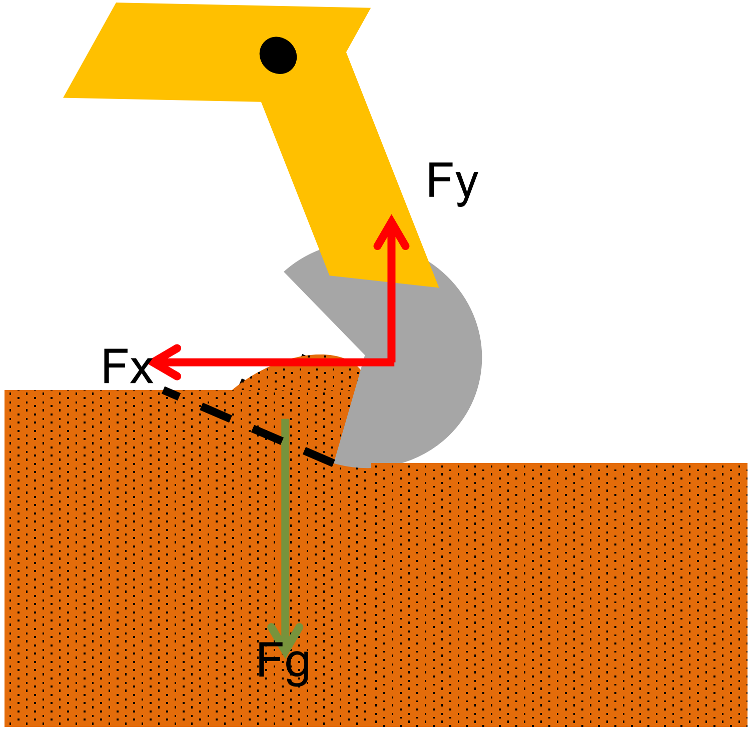


- Excavator productivity depends heavily on operator ability and setup.
- Setting up faces.
- Loading efficiency.
- Utilising gravity to propagate failure planes in rock.

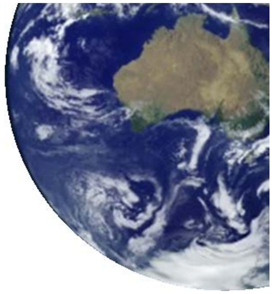


Horizontal excavation – necessary but inefficient

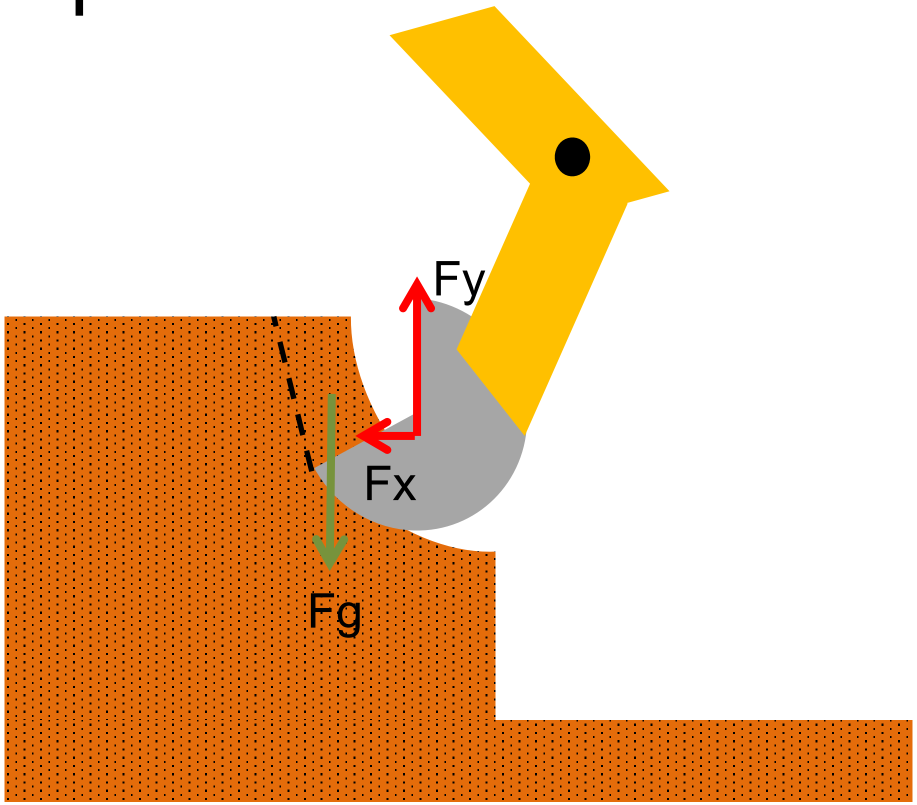




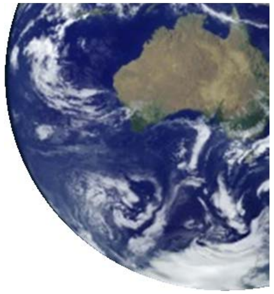
Pulling up – utilising gravity to propagate failure planes

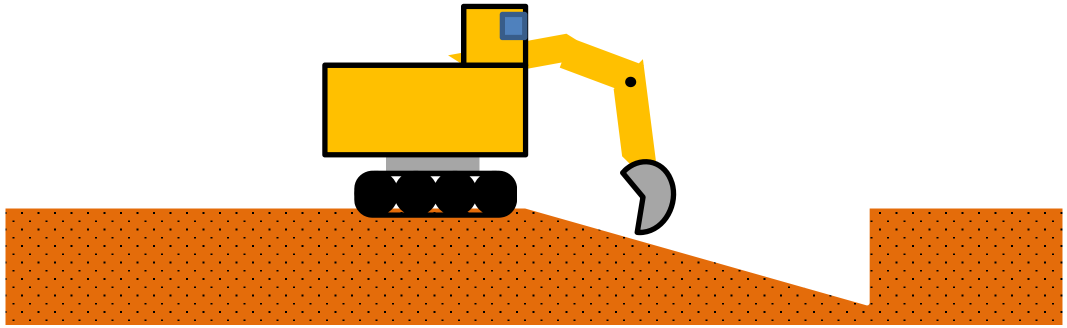


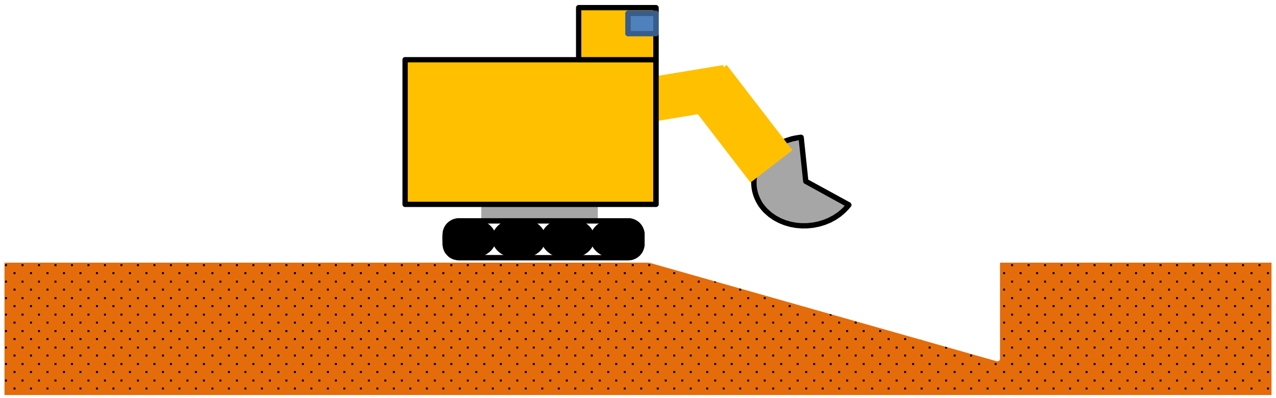
- **10-20% productivity gain compared to drop cut.**

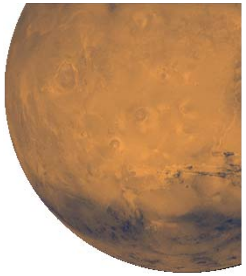


Horizontal “Drop Cut” to establish faces



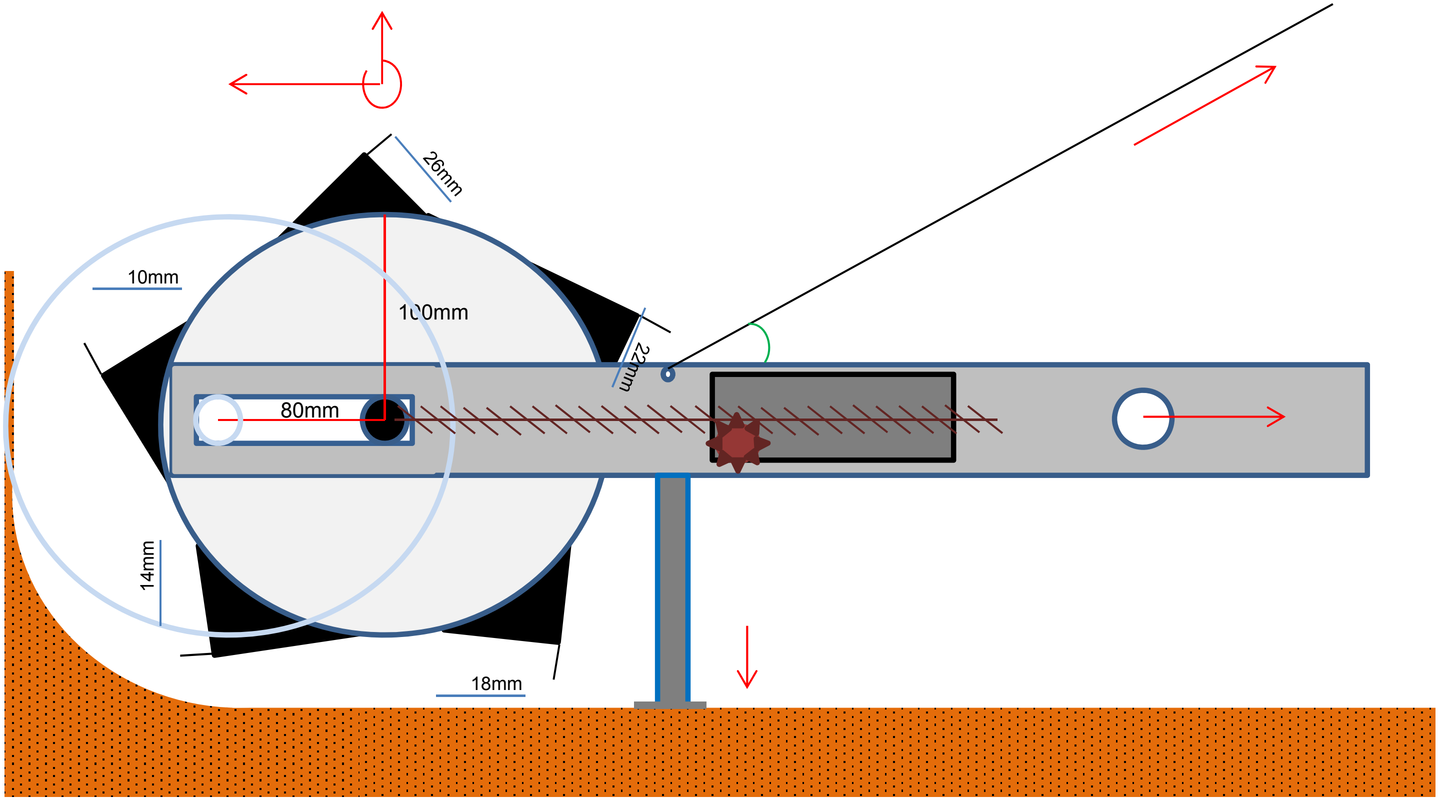


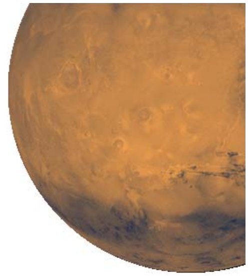




Mars Operational Hypothesis – Efficient Excavation

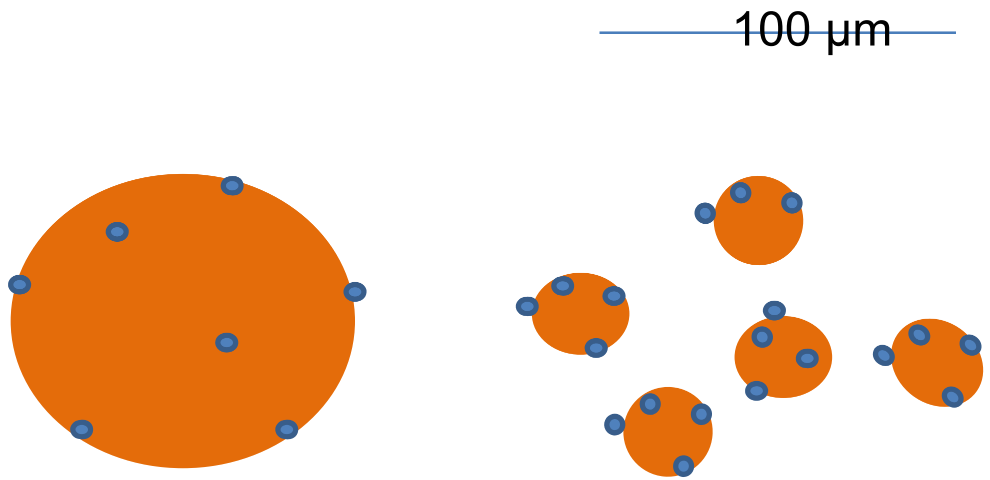
- Efficiency of excavation important in low gravity environments.
- Must consider the excavation setup to maximise productivity.
- Opens up opportunity to use leverage and anchoring.





Mars Operational Hypothesis – Particle Size and Recovery

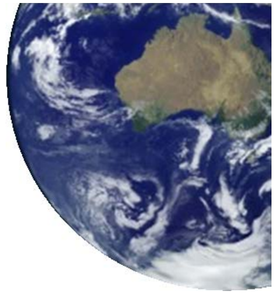
- Finer fragmented particles from excavation will lead to higher recovery from ore.
- From resource to product, the entire system must be considered as one to obtain maximum productivity. Not separate components.



$$Surface\ Area = 4\pi r^2$$

$$Exposed\ H2O\ molucules\ \propto Surface\ Area$$

$$\therefore Water\ Recovery \propto Surface\ Area$$

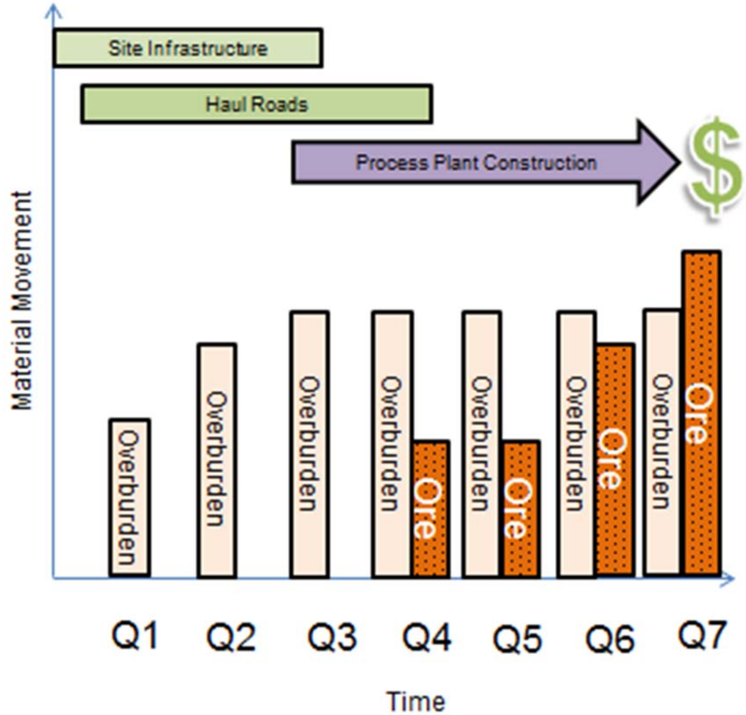


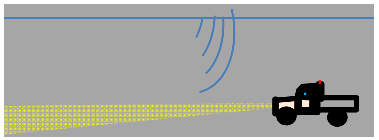
Terrestrial Industry Analogies – Infrastructure and Systems development

- Time and energy is required to properly establish a mine.

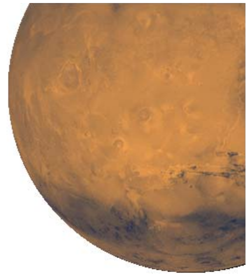
- Mine capital development.
- Processing plant
- Other

- Eg. Communications
  – UG communication and navigation
  – Significant effect on safety and productivity.



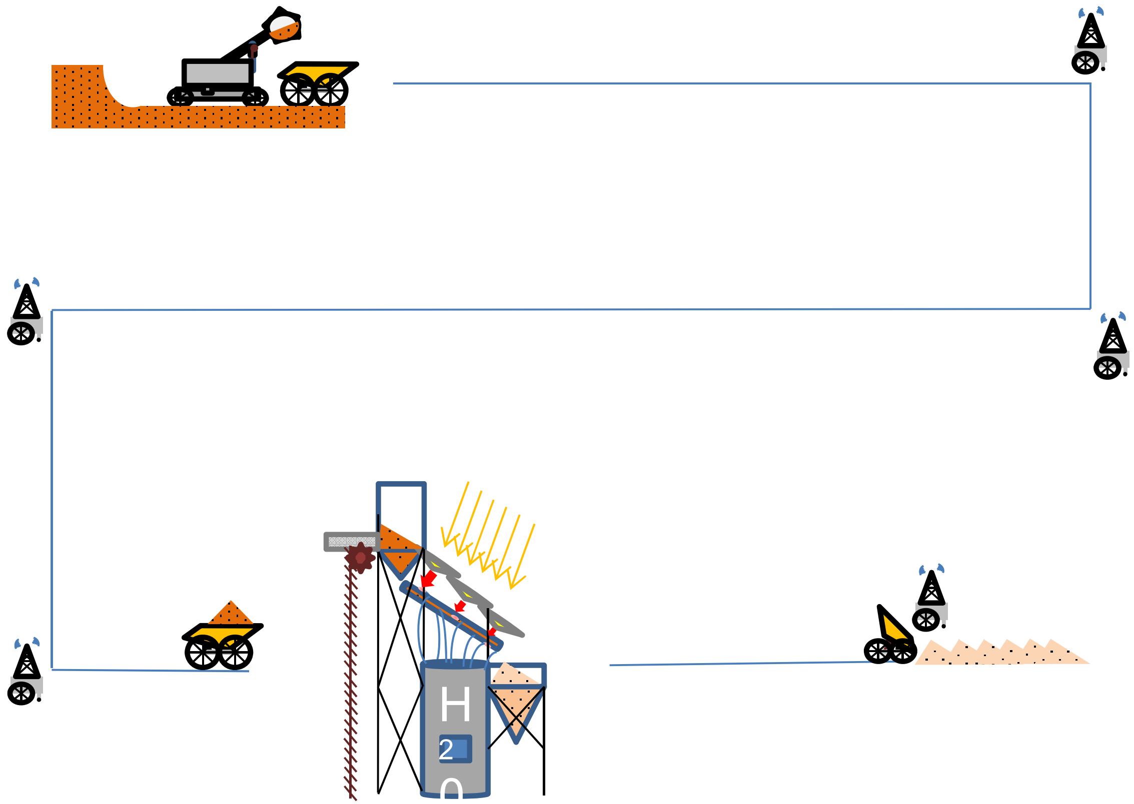


Mars Operational Hypothesis – Communications and Navigation

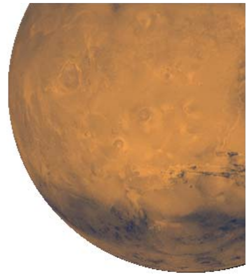


- Communications and navigation systems will need to be established in a similar fashion for robotic mining equipment on Mars.

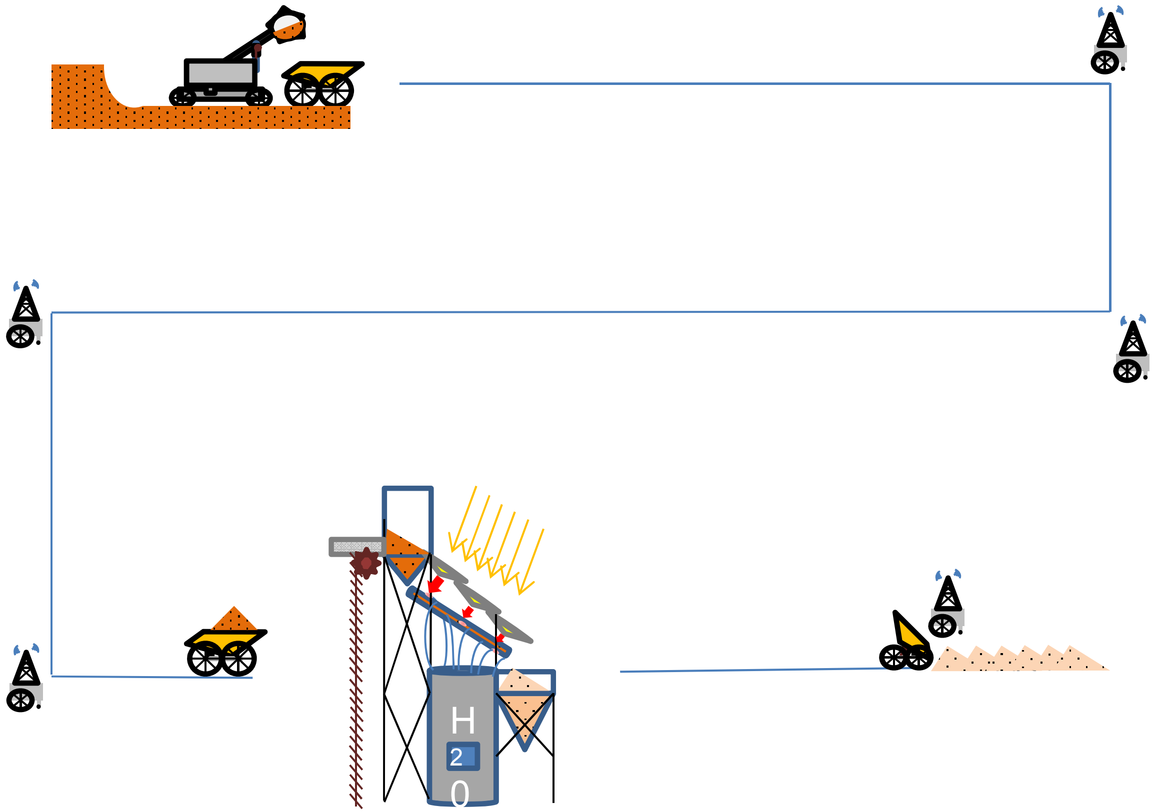
- This success of this system will have a significant impact on the productivity of the mine.

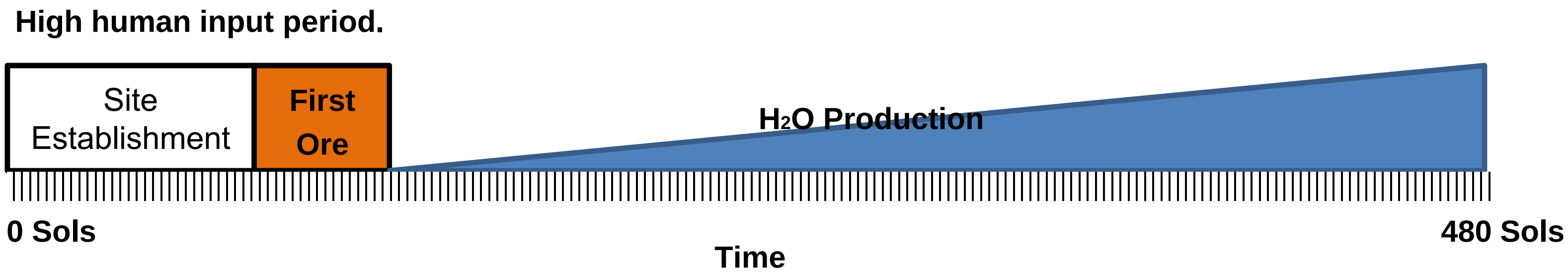


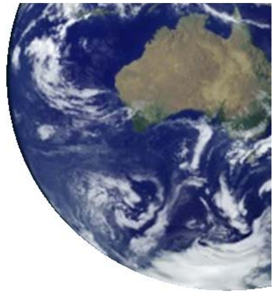
Mars Operational Hypothesis – Site Establishment



- Deployment of equipment
- Time Required to establish mining front.
- Establish haul route network.
- Time delay to first ore in process plant.

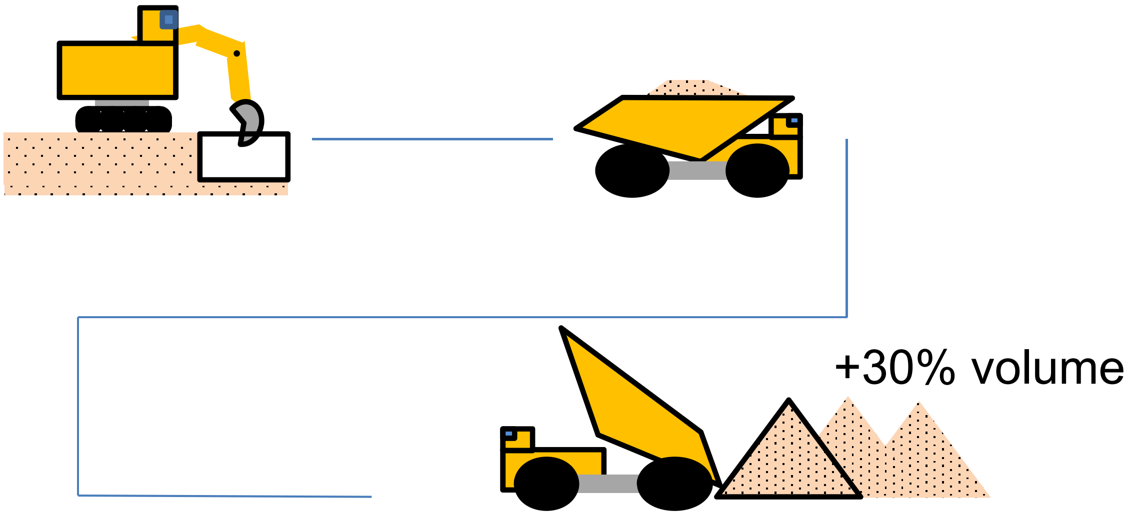


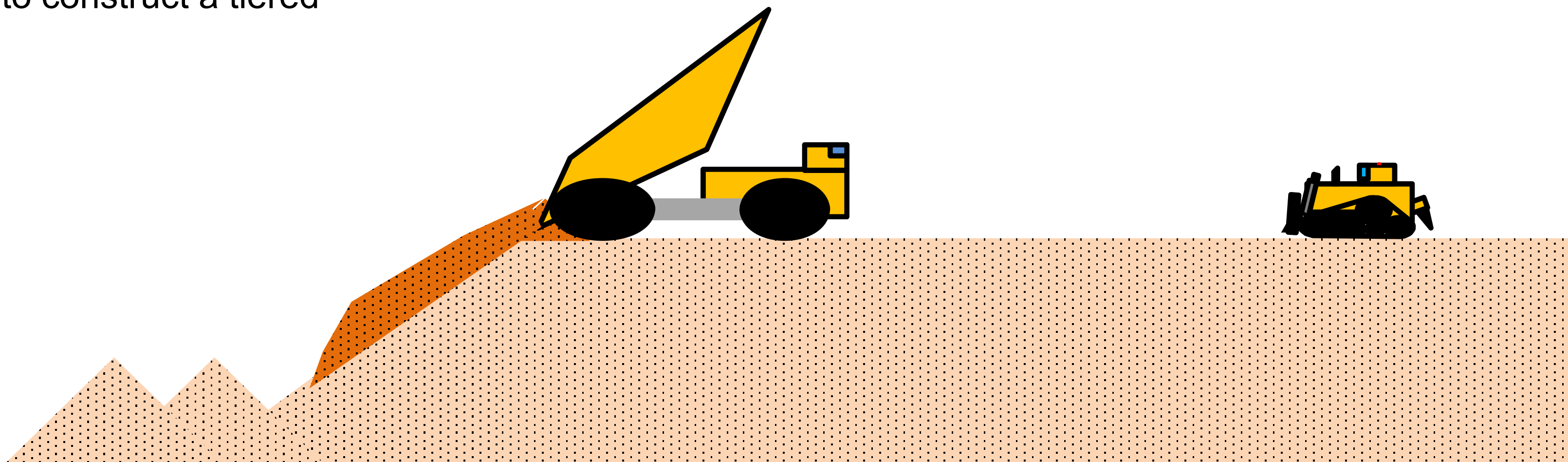




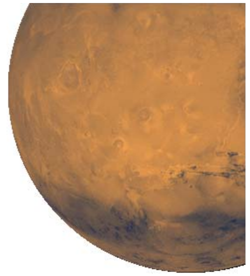
Terrestrial Industry Analogies – Waste Management

- Waste movement is the largest mining cost component for open pit operations.
- All material moved swells 30% volume after excavation.
- Open pit operations use paddock dumping initially to establish a tiered dump and tip-head. Ancillary equipment (dozer) is necessary to construct a tiered dump.

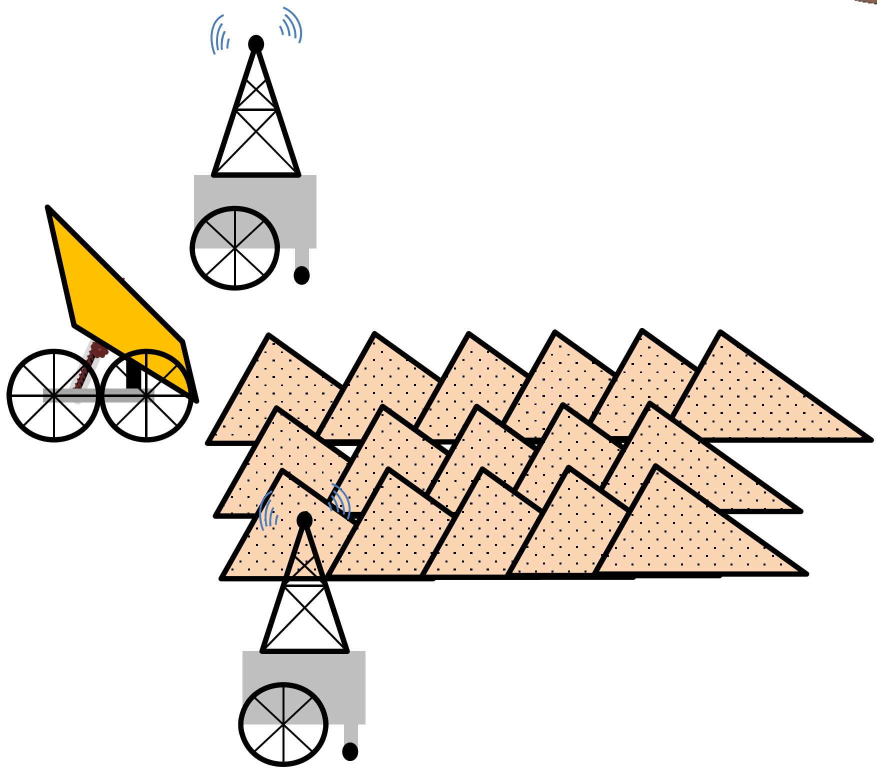




Mars Operational Hypothesis

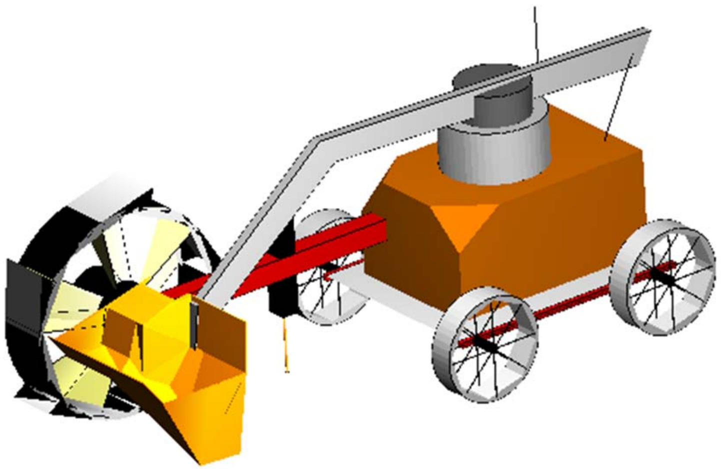


- More than 50% of all material volume moved will be tailings or waste.
- Footprint of waste dump depends on size of hauler tub.
- Dumping location to be controlled by navigation system.
- Efficient use of waste dumps is important.



Conclusion

Problem: *Low confidence data, technology and models are used to support the hypothesis that ISRU can be used on Mars for the first human mission.*



Solution:

1. Leverage terrestrial mine planning techniques and analysis as a tool.

2. Develop a Mars ISRU system using mining system for operational testing.

3. Demonstrate system in geological analogue environment to increase knowledge.

Questions?

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