ARTEMIS PROGRAM IN-SITU RESOURCE UTILIZATION REALITIES AND A CRITICAL NEW ROLE FOR COMMERCIAL SURFACE CREW

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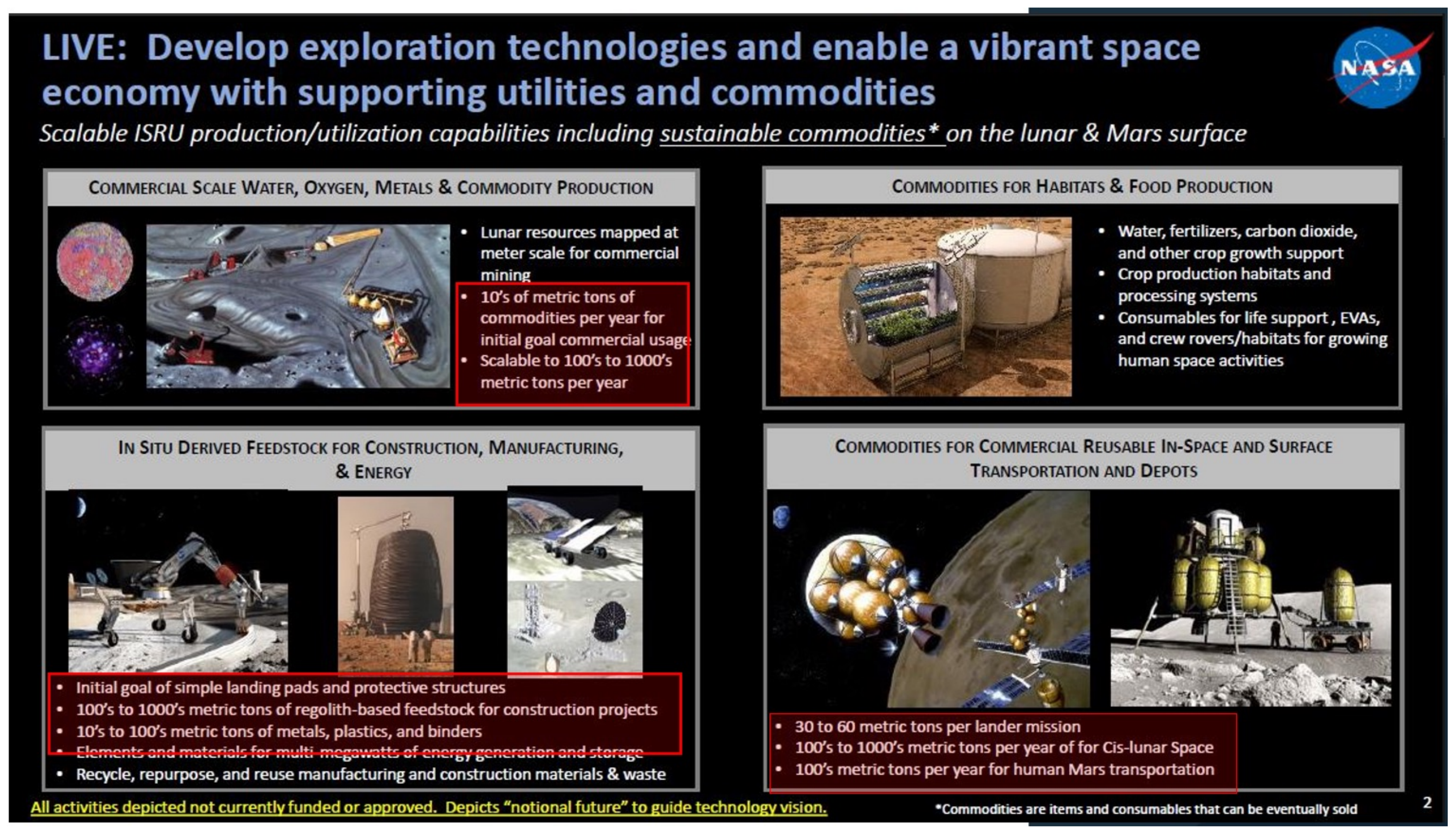
1: The lunar environment is at least an order of magnitude more challenging for industrial equipment than the harshest terrestrial coal mines.

2: Lunar industrial equipment, especially those types that interact most heavily with the lunar regolith, will suffer breakdown rates in excess of terrestrial counterparts.

3: Lunar resource providers must anticipate an indispensable need for human maintenance technicians to rescue and repair lunar industrial robotics.

1 If robotics are going to produce this:

"100's to 1000's of tons" of lunar-sourced products…



NASA 2023. Space Technology Mission Directorate Strategic Framework. "Excavation, Construction, and Outfitting (ECO) Envisioned Future Priorities", viewed 19 July 2023, <https://techport.nasa.gov/framework/>.

2 In an environment…..

At least 1 OOM harsher than the most challenging terrestrial coal mines…..

Table 2: Mohs versus Absolute Hardness Scales: Coal Compared to Typical Lunar Minerals Present in Regolith. (Mukherjee 2011)

Mineral	Mohs Mineral Hardness Scale	Absolute Hardness
Talc	1	1
Anthracite (hardest terrestrial coal)	2.88	12
Enstatite / Ilmenite (lunar regolith components)	5.5	60
Anorthite (lunar regolith component)	6.0	72
Labradorite / Olivine (lunar regolith components)	7.0	100
Spinel / Hercynite (lunar regolith components)	8.0	200
Diamond	10	1500

← Harshest terrestrial coal mine (Anthracite)

} Lunar regolith (Enstatite / Ilmenite through Spinel / Hercynite)

Chief mechanical breakdown vector in a mine:

Hardness / Abrasivity of Dust[1]

Resultant lunar context:

Dust: harder / more abrasive

Quantity: vastly more

Adapted from: Mukherjee, S. 2011. "Applied mineralogy : applications in industry and environment." Springer Science and Business Media. Dordrecht: Springer.

[1]Ho, M., and M. Hodkiewicz. 2013. "Factors That Influence Failure Behaviour and Remaining Useful Life of Mining Equipment Components." Advances in Mechanical Engineering, 5, p.913048..

3 Terrestrial mining breakdown state-of-the-art:

Despite Billions of $ spent on

Preventative maintenance…

82% of maintenance is unscheduled[2]

Coal mine breakdown rates[3]:

Excavator: 24.9%

Loader: 22.5%

Transporter: 10%

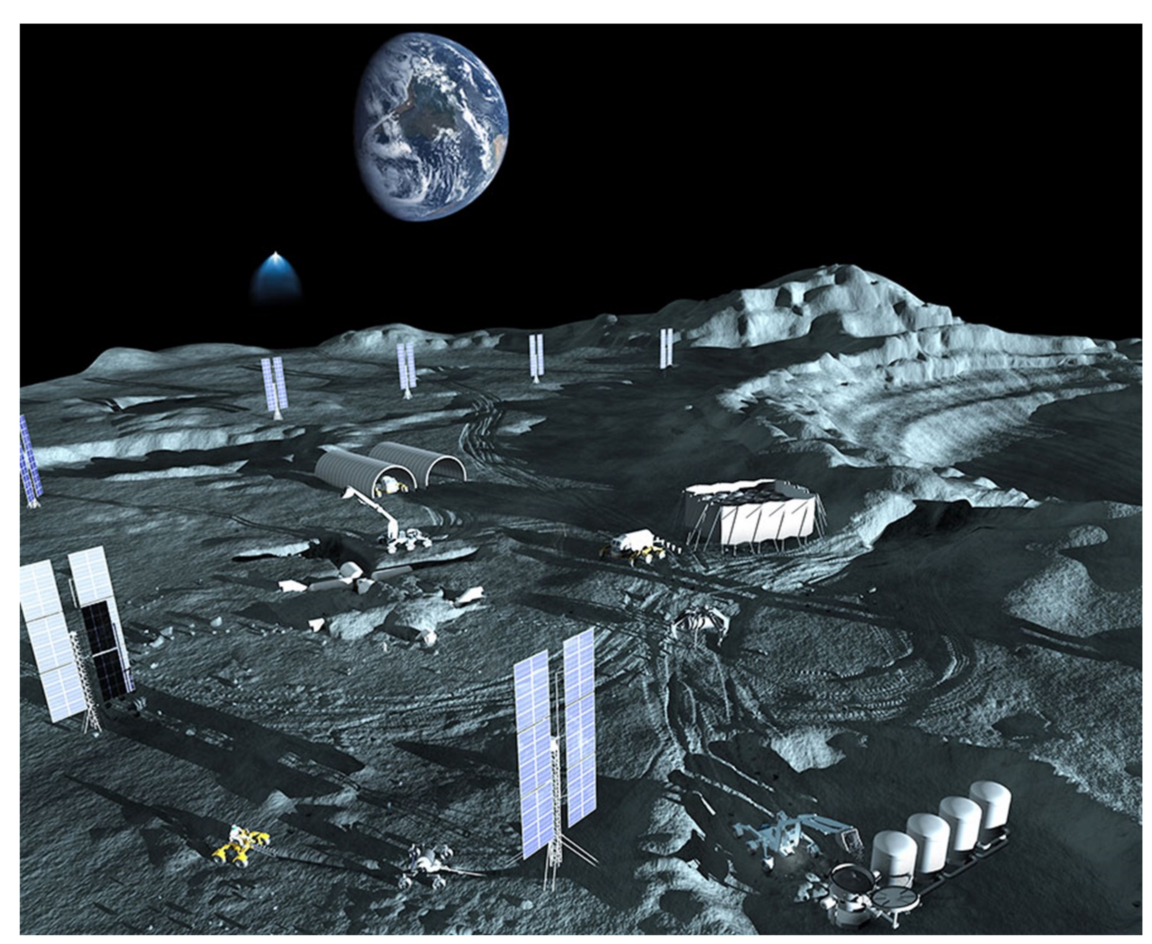
60% of onsite MX personnel perform their work: "In the field"[4]

[2]Stummer, R. 2018. "How new technology and AI can control rising maintenance costs." Australasian Mine Safety Journal, 16 November 2018, viewed 12 Dec 2021, <https://www.amsj.com.au/mining-maintenance-costs-technology/>.

[3]Samanta, B., Sarkar, B. and Mukherjee, S.K. 2001. "Reliability centred maintenance (RCM) for heavy earth-moving machinery in an open cast coal mine." The CIM Bulletin. 94. 104-108.

[4]Mining Global 2020. "Implementing Effective Maintenance Strategies for Long Term Production Goals." Mining Global, viewed 3 Jan. 2022, <https://miningglobal.com/supply-chain-and-operations/implementing-effective-maintenance-strategies-long-term-production-goals>.

4 Thus, a commercial lunar industrial-scale resource provider should expect….



Lunar polar mining base with buried crew habitats, widely spaced solar power panels, propellant production plant and depot tank farm. Image: anna.j.nesterova@gmail.com.

Significant maintenance will be required

Especially for industrial robotics

Lunar industrial robotics will breakdown/embed at rates greater than their terrestrial counterparts

Just like on Earth, humans will be required to keep the machinery operating.

Without persistent on-site human maintenance support, it is likely not possible to produce industrial quantities of lunar-derived products.