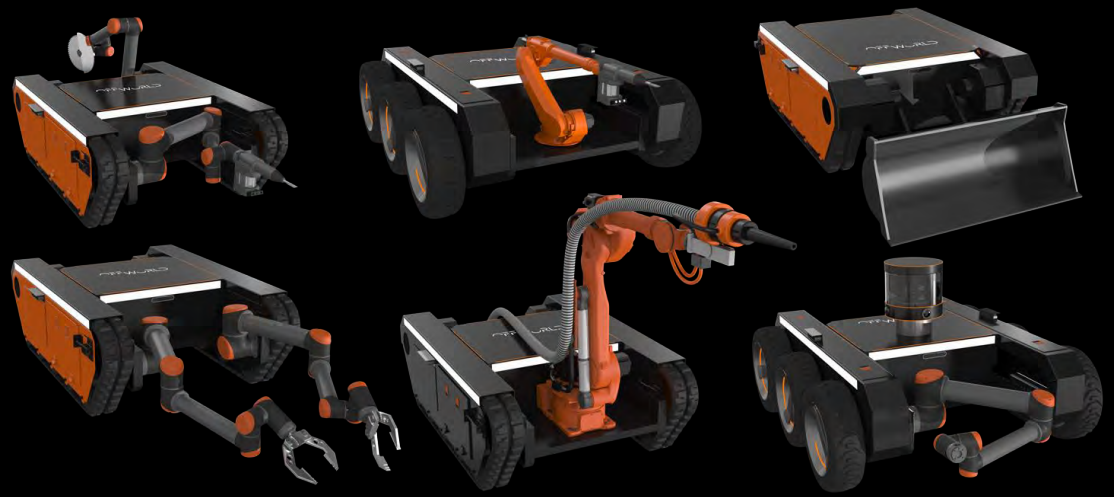
AI-POWERED INDUSTRIAL ROBOTIC WORKFORCE



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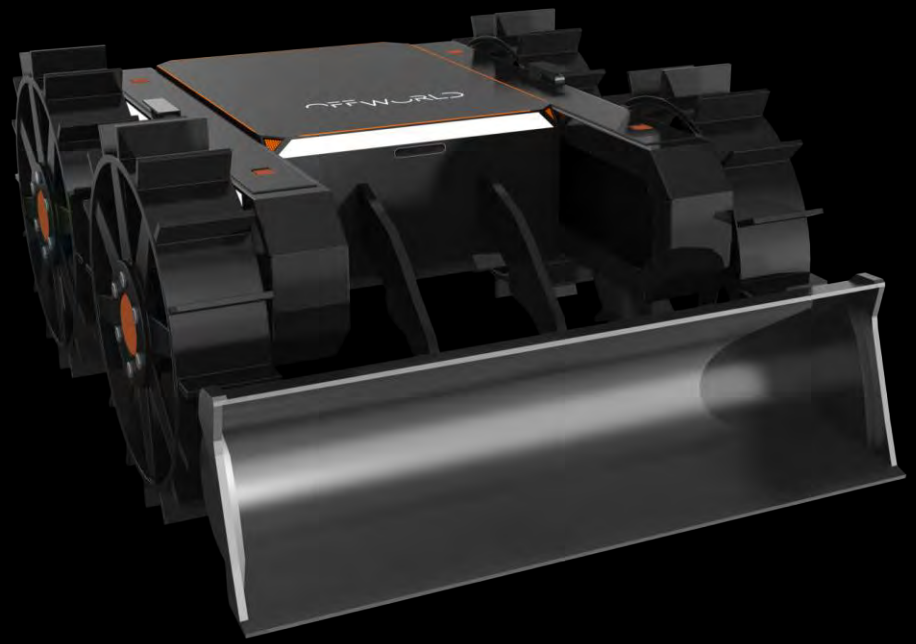

TOUGH JOBS ARE MADE FOR ROBOTS

We are developing a robotic workforce for heavy industrial jobs on Earth, Moon, asteroids & Mars.

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MILLIONS OF SMART ROBOTS

working under human supervision on- and offworld, turning the inner solar system into a better, gentler, greener place for life and civilization.

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AD ASTRA PER TERRAM
ENABLING HUMAN EXPANSION OFF OUR HOME PLANET

1. Life insurance policy
2. Sustainable development on Earth
3. The new frontier

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SETTLEMENT HAS ALWAYS BEEN DIFFICULT

- Limited supply chain
- Harsh environment
- Forced labor

SPACE SETTLEMENT IS EVEN HARDER

1. No usable atmosphere
2. Radiation environment
3. No supply chain
4. Variable gravities
5. Biological challenges
6. No indigenous foods
7. The most expensive labor

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SPACE NEEDS TAKERS FOR TOUGH JOBS

- build landing pads
- excavate underground habitats
- extract water ice and materials
- make drinkable water, breathable air and rocket propellant
- manufacture basic structures and solar cells
- produce electricity
- …and eventually replicate themselves

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CANNOT JUST EXPORT EARTH TECHNOLOGY...

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...MUST REINVENT HOW WE MINE, PROCESS, MANUFACTURE AND UNDERTAKE LOGISTICS ON EARTH

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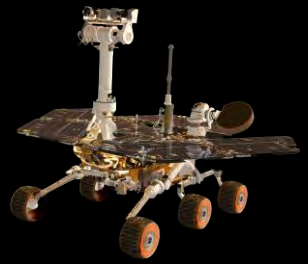
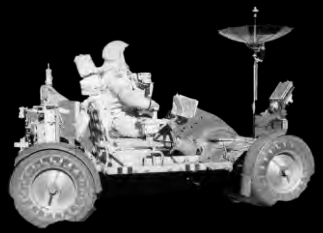
BUILDING ON LESSONS FROM DECADES OF REMOTE AUTOMATION





1. Expensive
2. One-offs
3. Long build times

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INTRODUCING A NEW GENERATION OF INDUSTRIAL ROBOTIC WORKFORCE

Core Platform

Operations

Welder

Digger

Bolter

Operations

Dozer

Sweeper

Lunar

Support

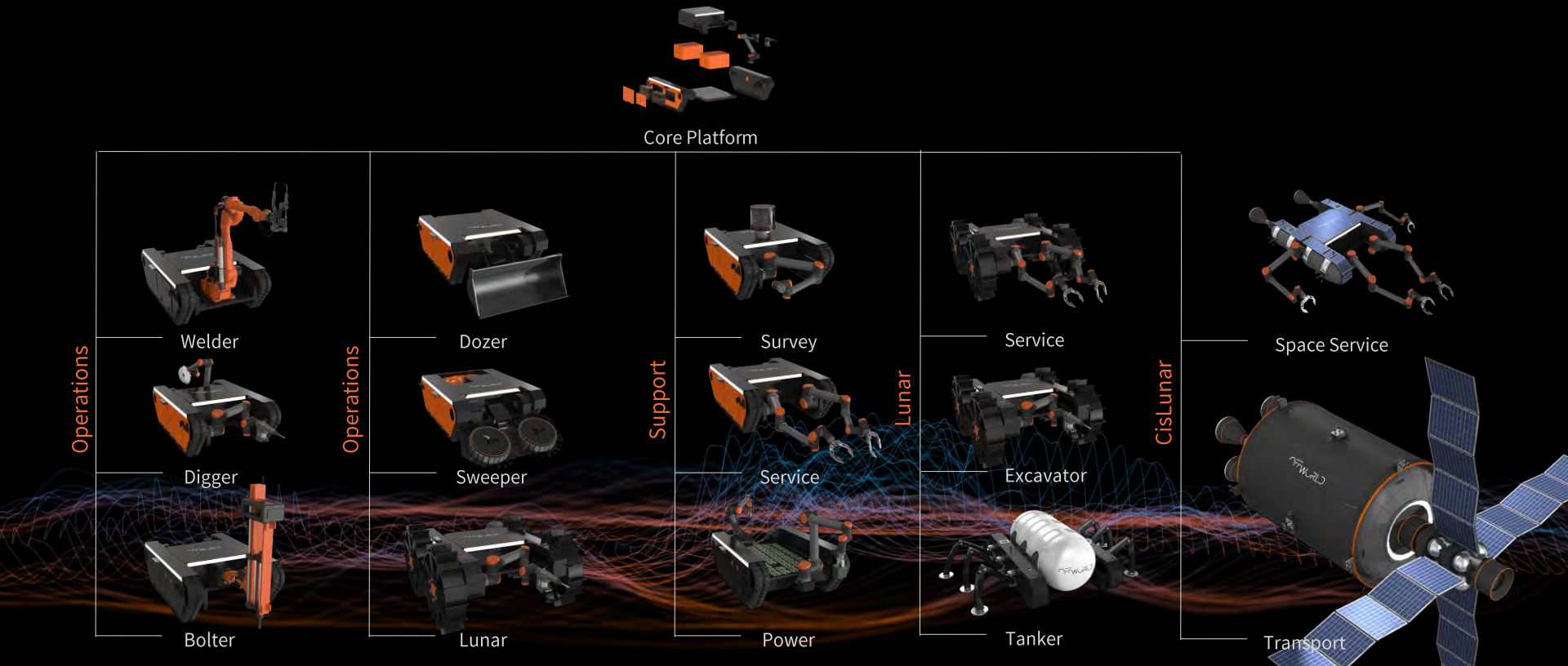
Survey

Service

Power

1. Ultra low cost
2. Thousands of robots
3. Solar system standard
4. Autonomous ops
5. Modular configuration
6. Humans remain safe

EXPANDING TO SPACE DEPLOYMENTS OF INDUSTRIAL ROBOTIC SPACEFORCE



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THREE AMBITIOUS GOALS

#1:

Reduce total cost of operations 10X

We are looking for at least an order of magnitude reduction in the total cost of operations within any industrial sector.

#2:

Create fully scalable solutions

We are after a solution where everything becomes an operational cost with no/little CAPEX. Our costs will be able to scale up and down in line with size of industrial operations.

#3:

Accelerate growth of industrial productivity

We aim to create a solution that does not just establish a new static level for industrial productivity. We aim to create a solution that has inbuilt levers for continued gains in productivity for decades to come.

FOUR DESIGN CONSTRAINTS

#1
No infrastructure
Assume we cannot build new facilities and other infrastructure, cannot access external power sources, etc.

IDEAL SOLUTION SPACE

#4
No consumables
Assume we cannot bring any consumables to the operations site or use locally sourced water in the process.

#2
No humans
Assume humans cannot be used to perform any of the industrial functions directly, only to oversee and enable the performance of robotic workforce.

#3
No footprint
Assume we cannot use fossil fuels to power robotic operations. Assume footprint at the site of operations must return to pre-existing format

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AMBITIOUS INTEGRATION REQUIREMENTS

A.I. & Computer Science

- Machine learning
- Virtual Assistants
- Structured analysis
- Knowledge representation
- Workflow automation
- Activity recognition
- Cyber & security
- Trusted systems
- Data analytics
- Automated reasoning
- Cyber-physical systems

Space and Planetary Surfaces

- Spacecraft propulsion
- Modular architectures
- In-space assembly
- Extraterrestrial mining
- In situ processing
- Volatile extraction
- Surface construction
- Remote operations
- Environmental systems
- Propellant transfer
- Radiation tolerant systems

Robotics & Automation

- Modular systems
- Manipulation
- Mobility
- Actuators
- Automation systems
- Machine learning
- Perception
- SLAM
- Electro-active materials
- Space operations
- Extreme environment robotics
- Teleoperations

Sensing & Interaction Devices

- Multi-spectral imagers
- Communication systems
- Radars
- Lasers
- RF
- Position
- Tactile & Force
- Physiological monitoring
- Speech recognition
- Perception
- Visual search
- Augmented reality
- Object recognition

Energy & Materials

- Custom polymers
- Solar power
- Gas separations
- Efficient energy transfer
- Sustainable materials
- Extreme deployment solar
- Resilient storage
- Supercapacitors

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NEW ROBOTIC GENERATION CHARACTERISTICS

1. SMALL AND ROBUST

To neatly pack into and survive launches on rockets

2. EXTREMELY ADAPTABLE

To function across a wide range of environments on Earth, Moon, asteroids and Mars without major redesign

3. SOLAR ELECTRIC POWER

To use the one sustainable power source we can count on in the inner solar system

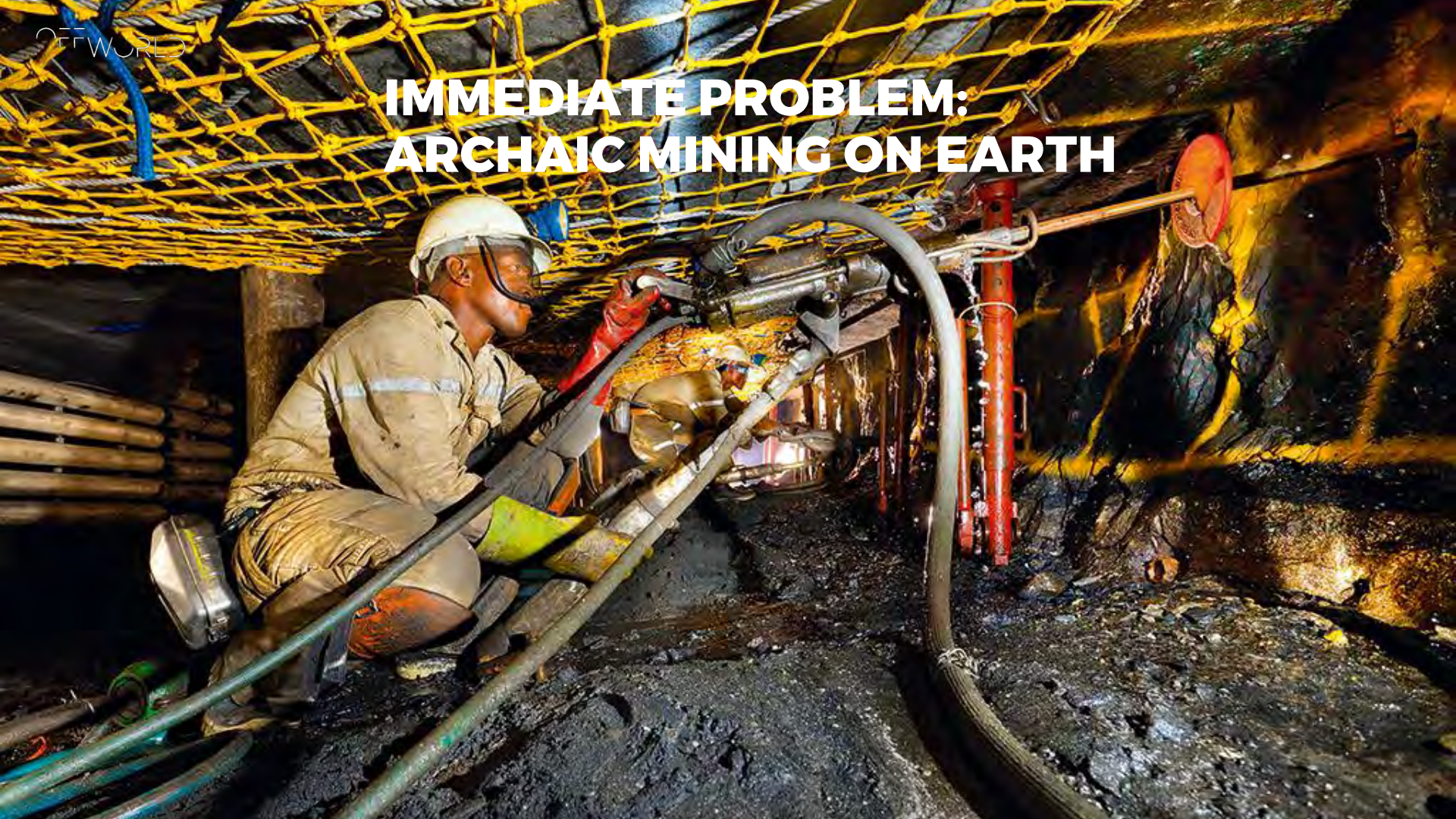
4. AUTONOMOUS AND FAST LEARNING

To get by with machine intelligence without onsite humans to bail them out

5. MODULAR AND RECONFIGURABLE

To maximize the re-use of launched hardware as there will be no local hardware shops or Amazon deliveries (for a while)

IMMEDIATE PROBLEM: ARCHAIC MINING ON EARTH



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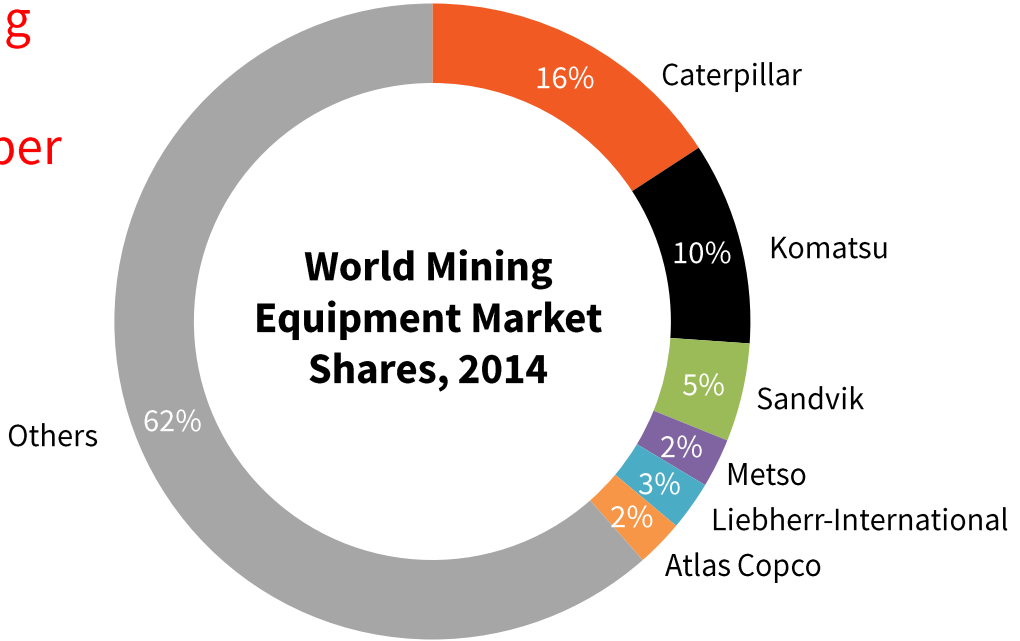
IMMEDIATE FOCUS: DISRUPT MINING ON EARTH

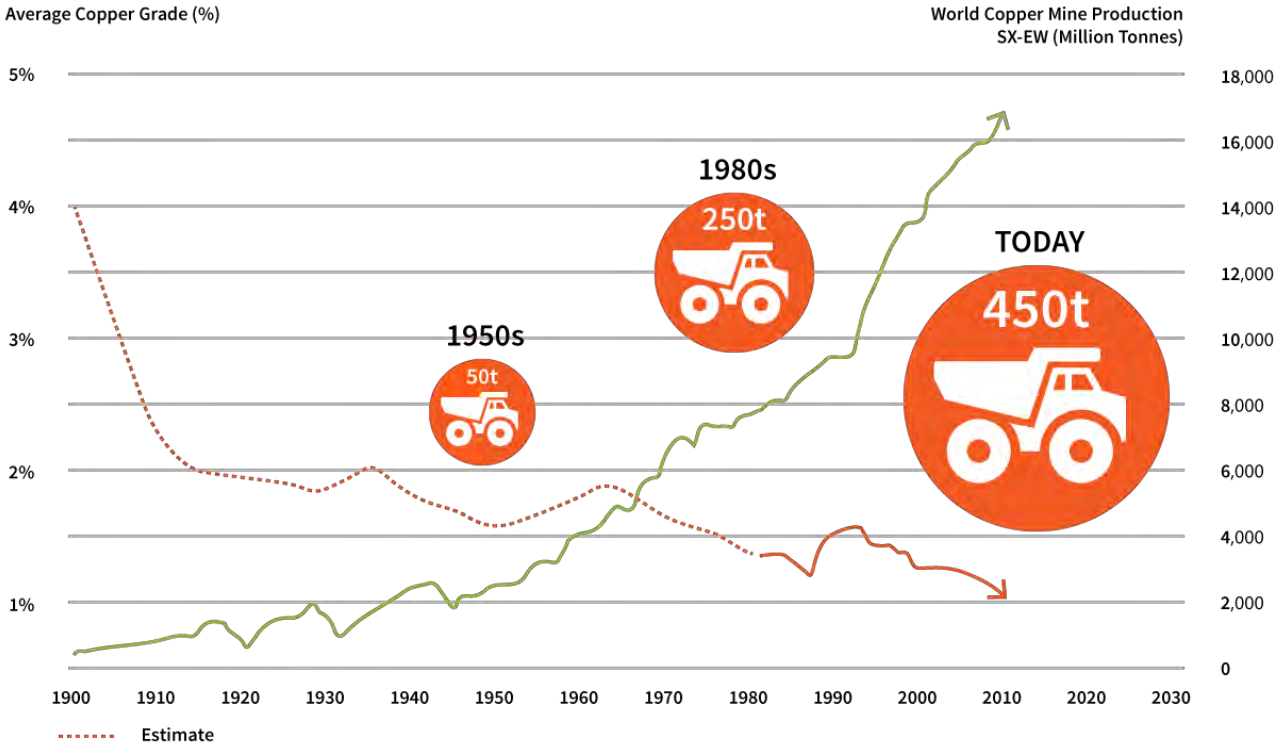
FIRST MARKET OPPORTUNITY: $100B+ MINING EQUIPMENT INDUSTRY

- Mining equipment manufacturing today is a ~$90 billion market
- demand forecast to grow at 7% per year



Source: Freedonia Group; team research.

MINING IS AT THE END OF CURRENT INNOVATION PARADIGM...



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TAKE HUMANS OUT OF HARM'S WAY

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BIG IDEA: REPLACE CONVENTIONAL BULK MINING WITH PRECISION SWARM ROBOTIC MINING (SRM)

	CONVENTIONAL MINING	SWARM ROBOTIC MINING
ORE BODY	Bulk mining	Precision mining
EQUIPMENT	Big & dumb	Small & autonomous
HUMANS	Miners at the rock face	Supervisors in C&C centers
DATA	Data is king in exploration	Data=productivity
ENVIRONMENT	Do what's required	Leave no trace

THE COST ADVANTAGE OF SRM

~3-15x total mining cost* reduction

CONVENTIONAL MINING

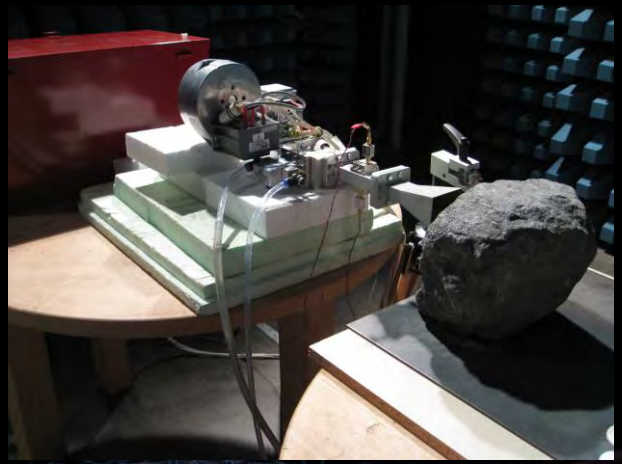
1. **Do much less work**
2. **Process *in situ***
3. **Mass-produced low cost bots**
4. **No human infrastructure underground**
5. **Lower environmental cleanup bill**

SWARM ROBOTIC MINING

DIGGER BOT IN THE FIELD

TECHNOLOGY DEVELOPMENT

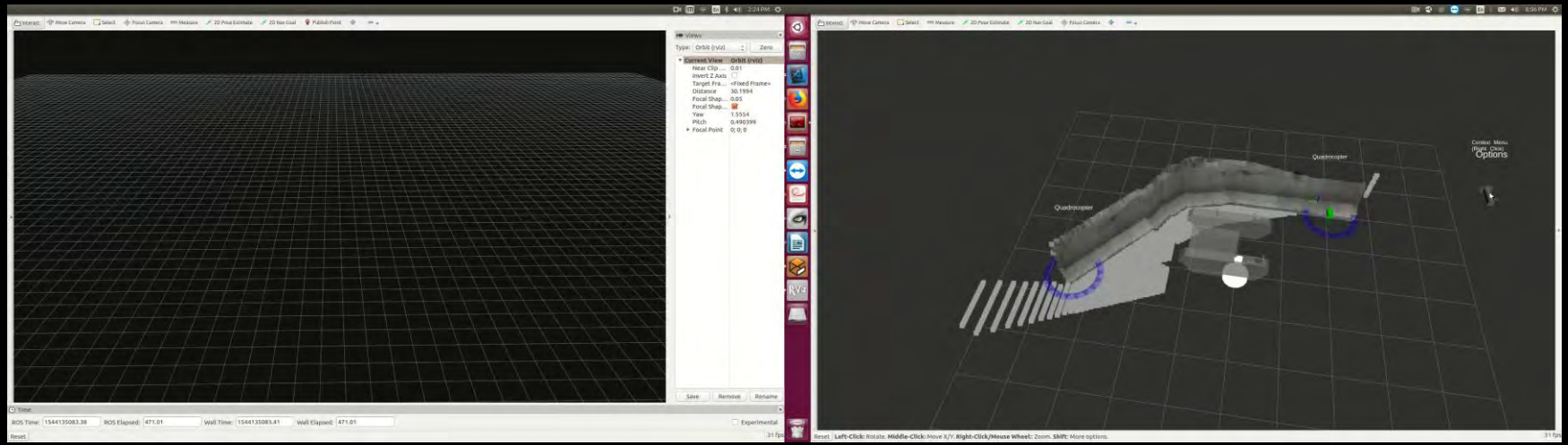
MICROWAVE



PLASMA

DRY ELECTROPULSE

OPERATION CONTROL SYSTEM



REAL

Technology:

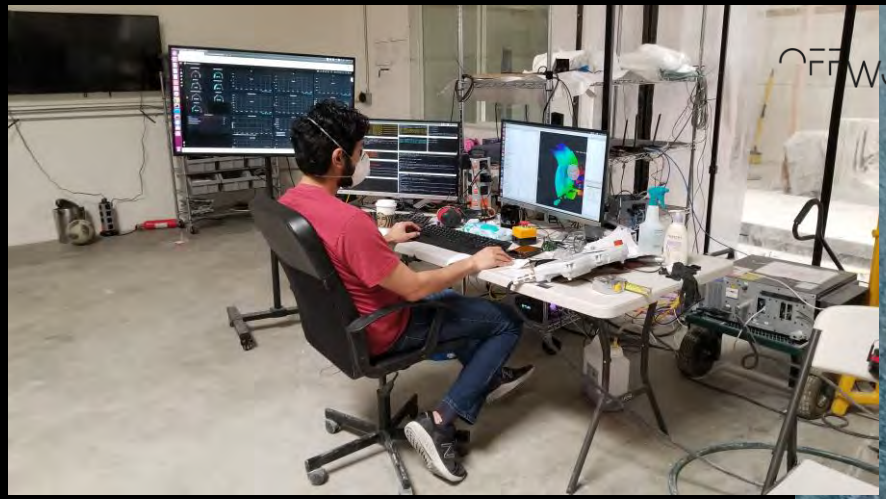
- Sensored Robotic platform
- Mine environment
- SLAM Packages
- Rviz visualization

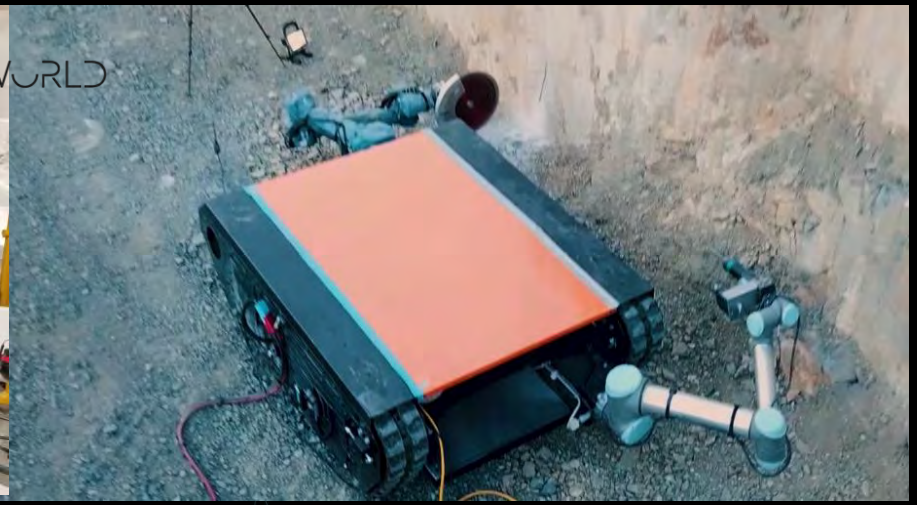
SIM

Technology:

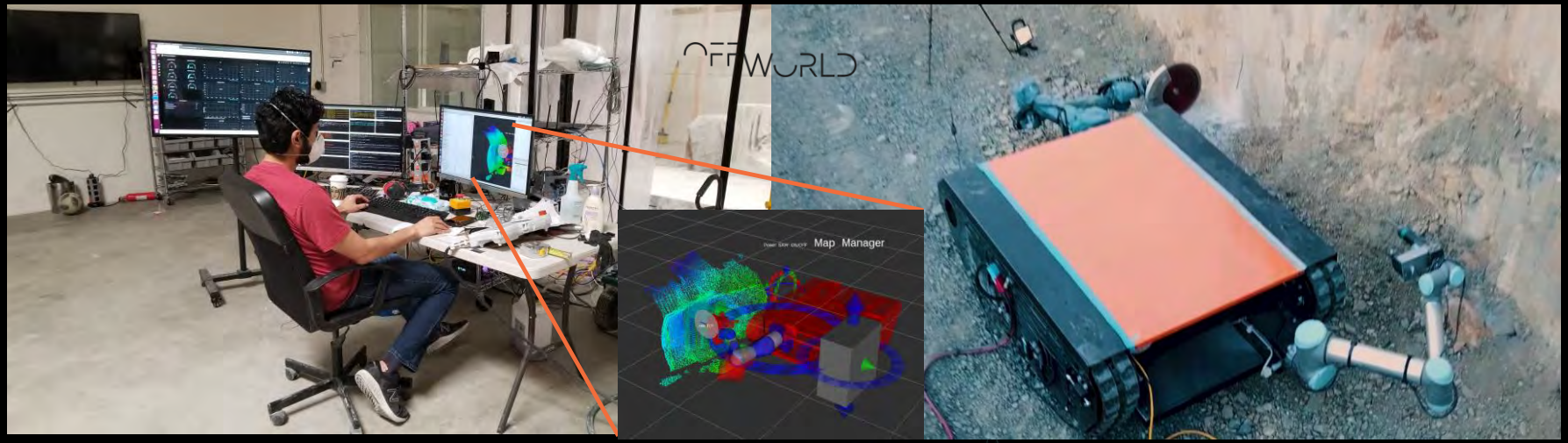
- Robotic platform URDF
- GAZEBO Mine environment
- SLAM Packages
- Rviz visualization

AVATAR TELEOPERATIONS CONTROL 1

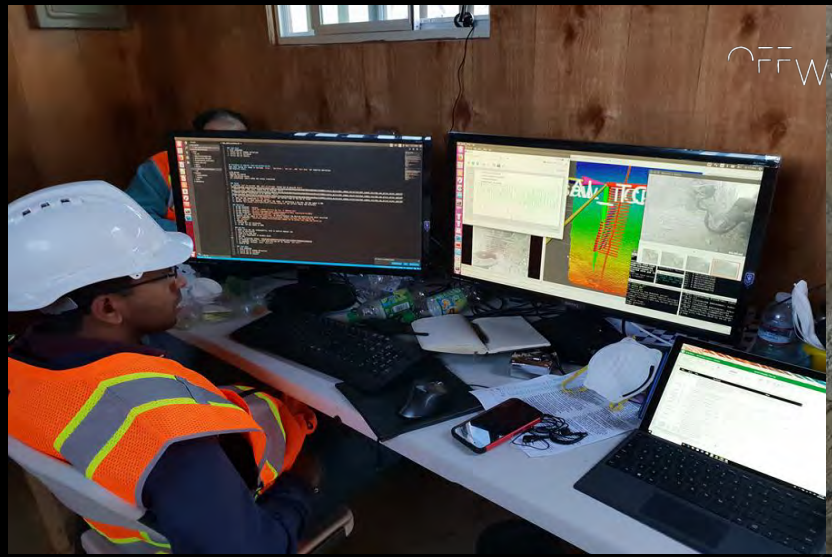




AVATAR TELEOPERATIONS CONTROL 1



AVATAR TELEOPERATIONS CONTROL 2



AVATAR TELEOPERATIONS CONTROL 3

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DEEP REINFORCEMENT MACHINE LEARNING

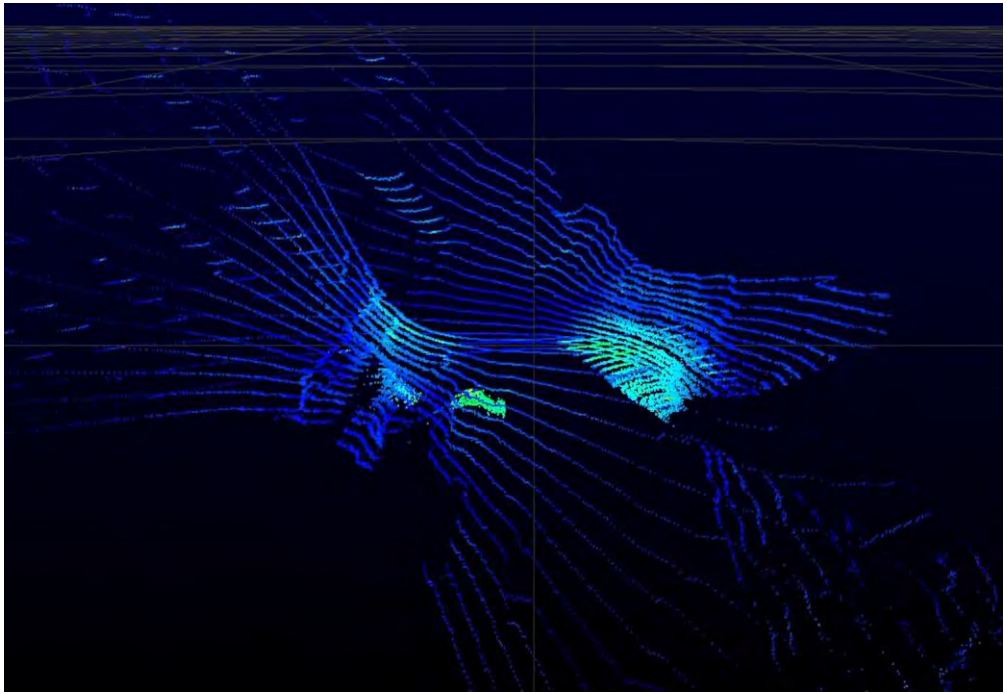
TARGETER NEURAL NETWORK

Goal:	Excavate rock
Setup:	Robotic chisel with RGBD camera excavating rock that falls and is weighed with USB scales
Reward:	Mass of excavated rock
Method:	Deep reinforcement learning agent developed and trained through IL followed by DRL on real world rock
Agent:	DQN with a CNN as q-value approximator in Python using Keras library with TensorFlow backend
Input:	Depth Image
Output:	Heat map of possible excavation target locations

DATA CAPTURE

Seamless, continuous data gathering from millions of robots:

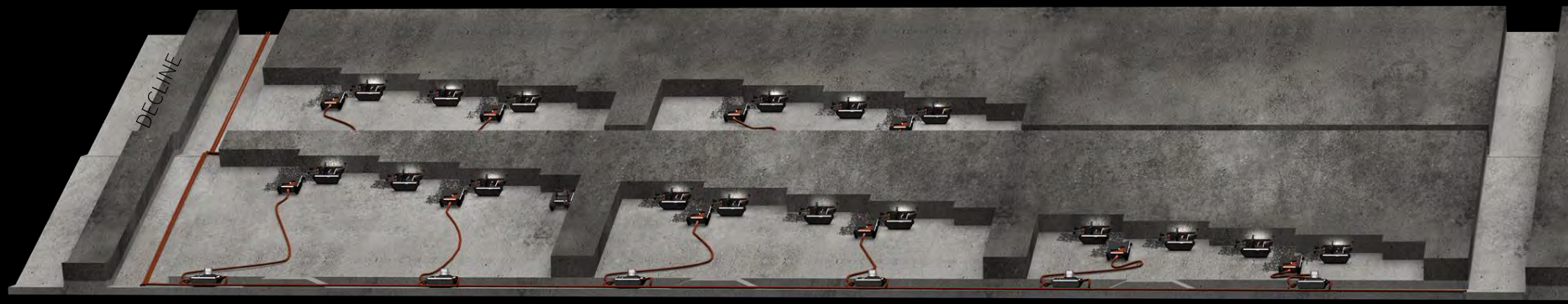
- High intrinsic asset value
- Soil & ore body chemistries
- mine air quality
- hardware vibration loading
- alloy corrosiveness levels
- etc…



2020 SYSTEM: TWO BOT SYSTEM

2021 DEPLOYMENT: THREE BOT SQUAD

FULL DEPLOYMENT: EMPOWERING HUMANS TO BACK OUT OF THE UNDERGROUND OPERATIONS



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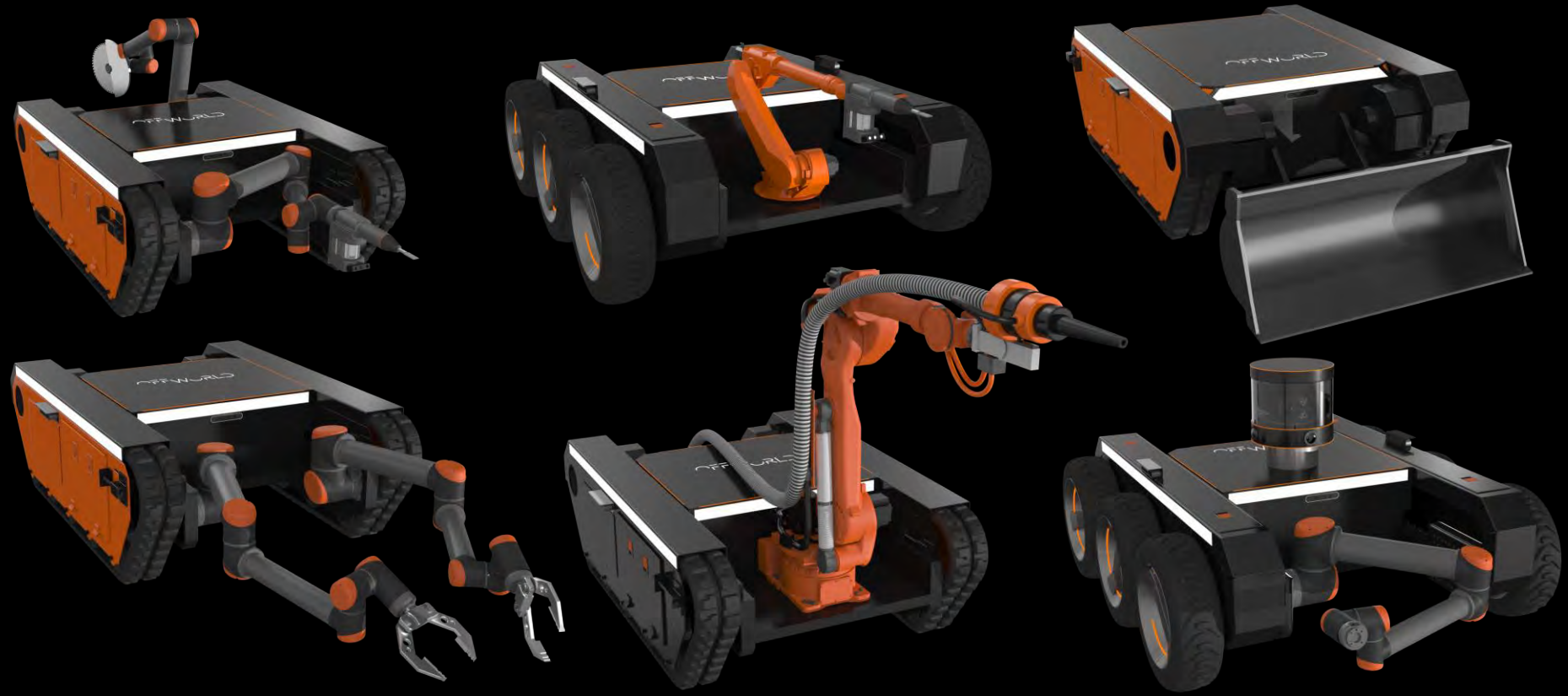
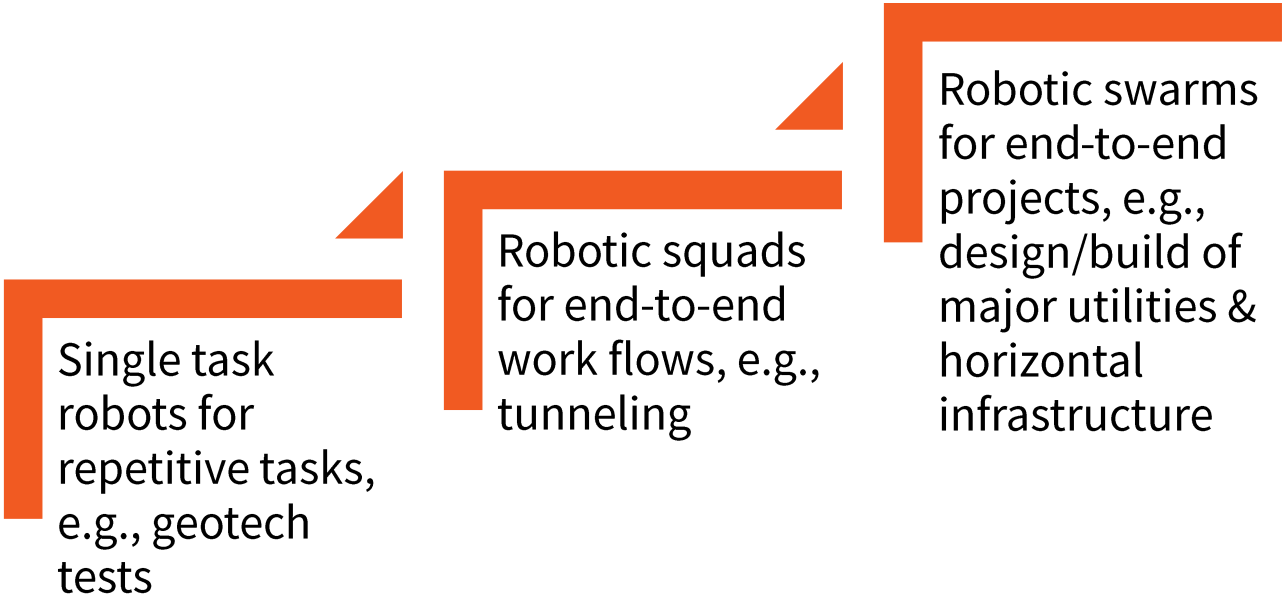
A NEW TYPE OF WORKFORCE



DEVELOPING ROBOTIC CONSTRUCTION SWARMS, STEP BY STEP

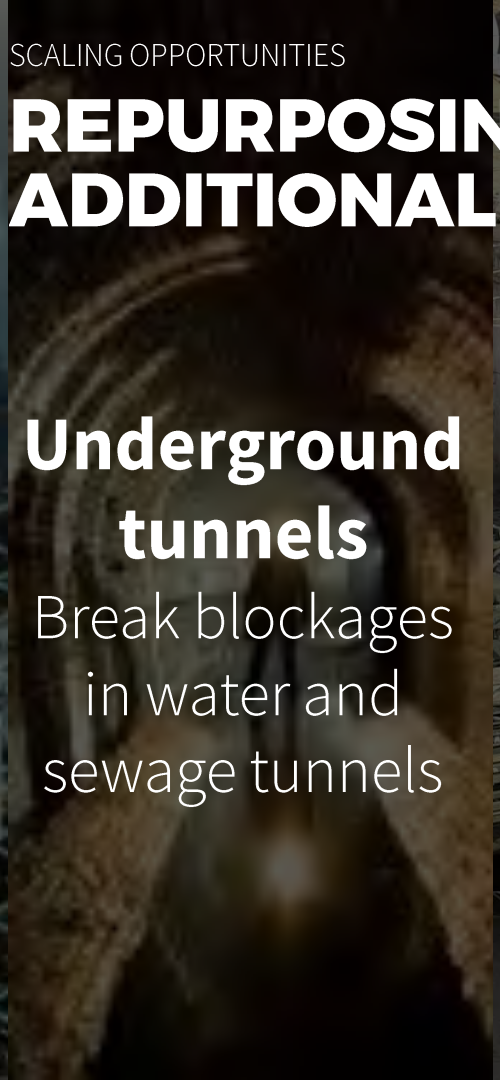


SCALING OPPORTUNITIES

REPURPOSING ROBOTS TO ADDITIONAL INDUSTRIES

Smart cities

Inspect, maintain and repair municipal infrastructure



Underground tunnels

Break blockages in water and sewage tunnels

Urban defense

Support and protect troops in logistics

Space

Surface resource exploration and construction

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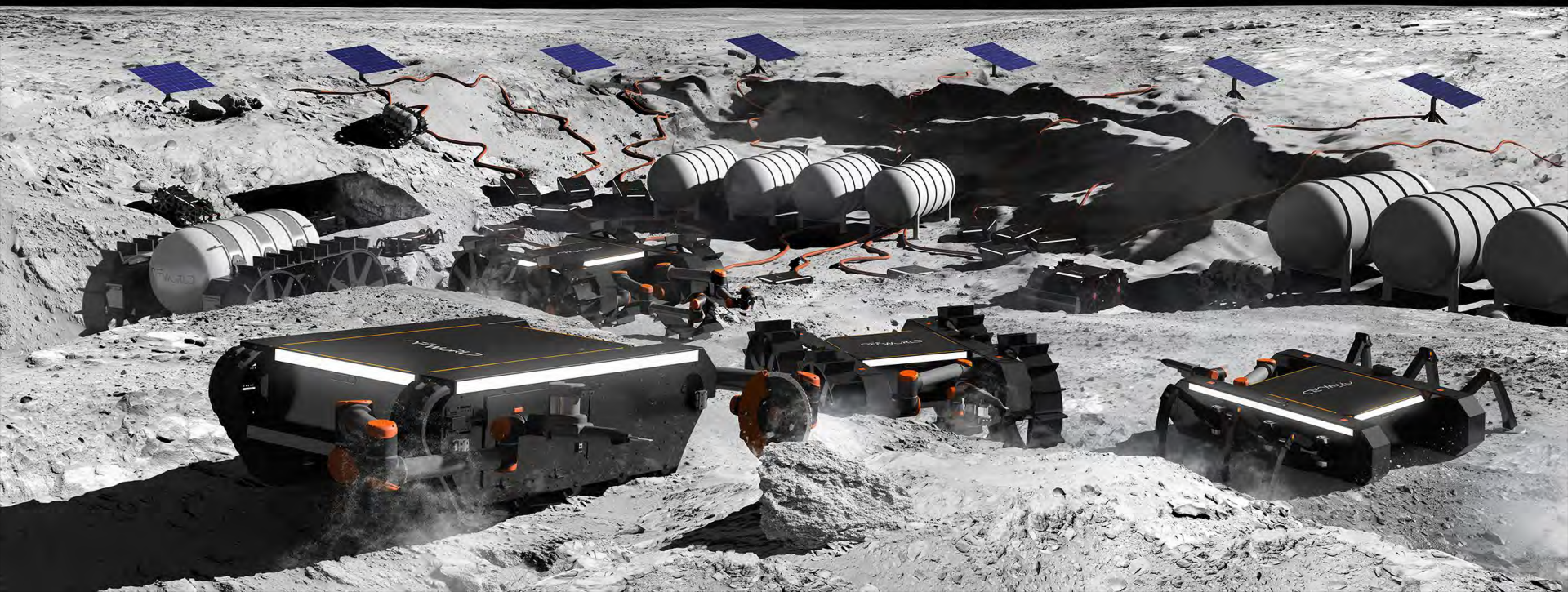
OFFWORLD SPACE MINING

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Azista BST
LEAFSPACE
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Oceanic and
spheric Administration