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USING NVIDIA OMNIVERSE™ TO SUPPORT SPACE MISSION DESIGN: SIMULATION-FIRST

softserve

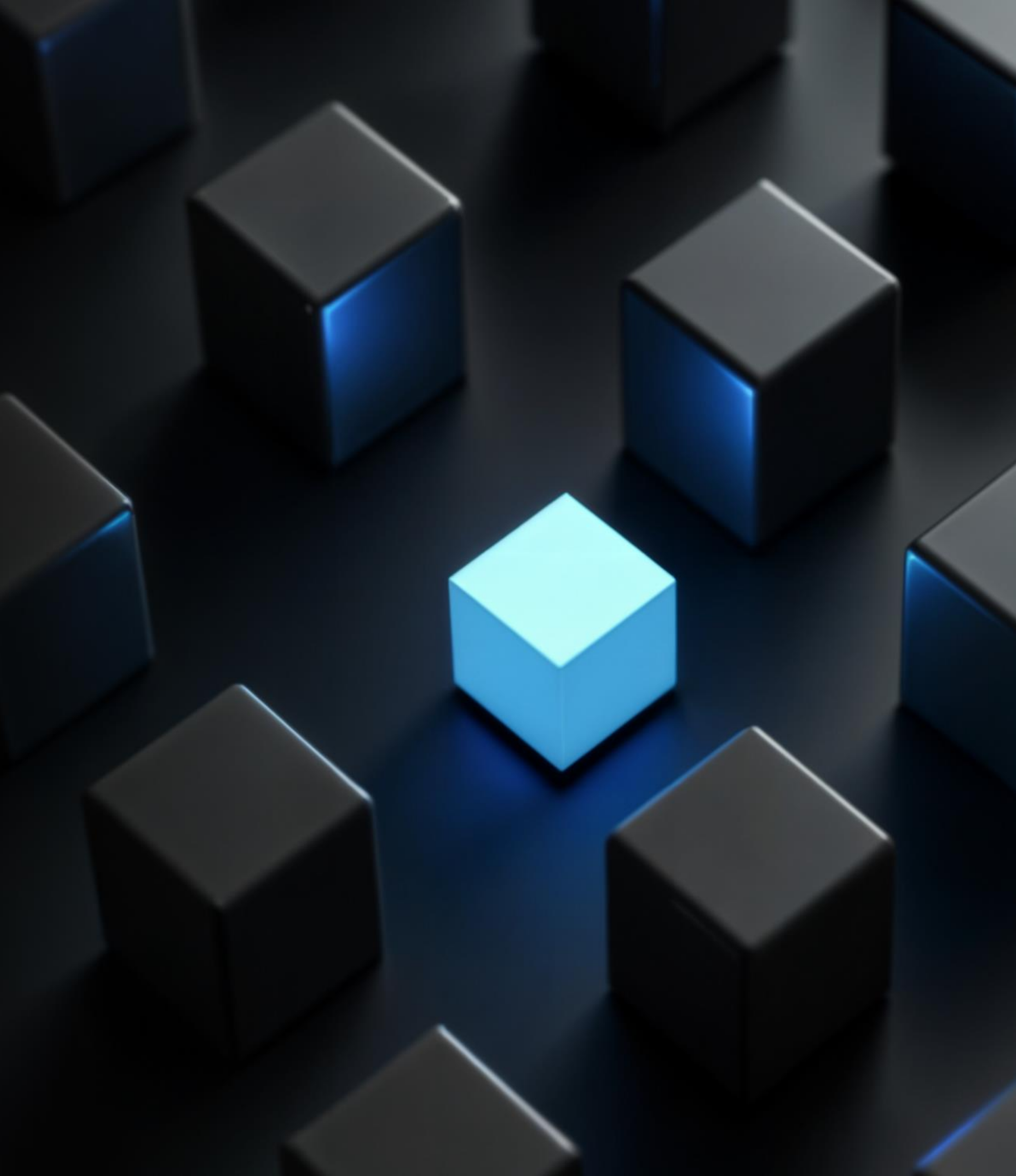
SPEAKER

LUTZ RICHTER

SoftServe Space Projects Consultant

AGENDA

01	NVIDIA Omniverse 101
02	The Space Domain: Some Trends and Pains
03	SoftServe space use cases with the Omniverse
04	On-going novel directions: SDG and GenAI
05	Takeaways



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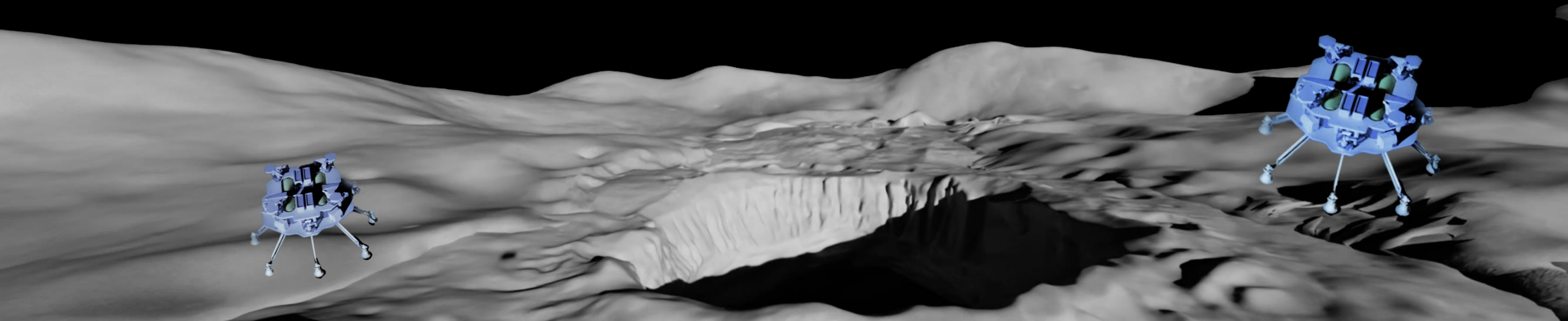
NVIDIA OMNIVERSE 101



OMNIVERSE KEY PARTS

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NVIDIA Omniverse™

NVIDIA

CONNECT

- Connecting CAD & 3D tools
- Bi-directional
- Uni-directional
- Export/import
- Custom extensions

NVIDIA:

- Connectors
- Extensions

NUCLEUS

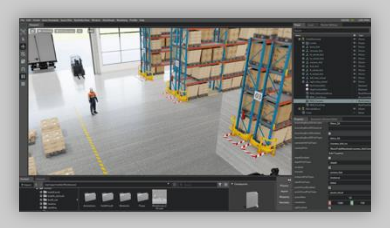
- Deployment
- Scalability
- Security
- Integration active directory, SSO, etc.

NVIDIA:

- Workstation
- On-premises
- Cloud

KIT

- Create
- Audio2Face

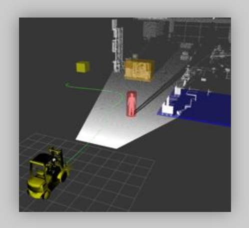


NVIDIA:

- Core tools
- Materials
- Streaming
- Animation

SIMULATION

- Physical simulation
- Isaac Sim
- Robotics enablement
- Synthetic data generation



NVIDIA:

- Physics
- Vehicle dynamics
- Blast destruction
- Fluid dynamics

RTX RENDERER

- 3D content creation
- Ray-tracing
- AR/VR

NVIDIA:

- Real time
- Accurate
- Multi-GPU scalable

DIGITAL TWIN & ROBOTICS

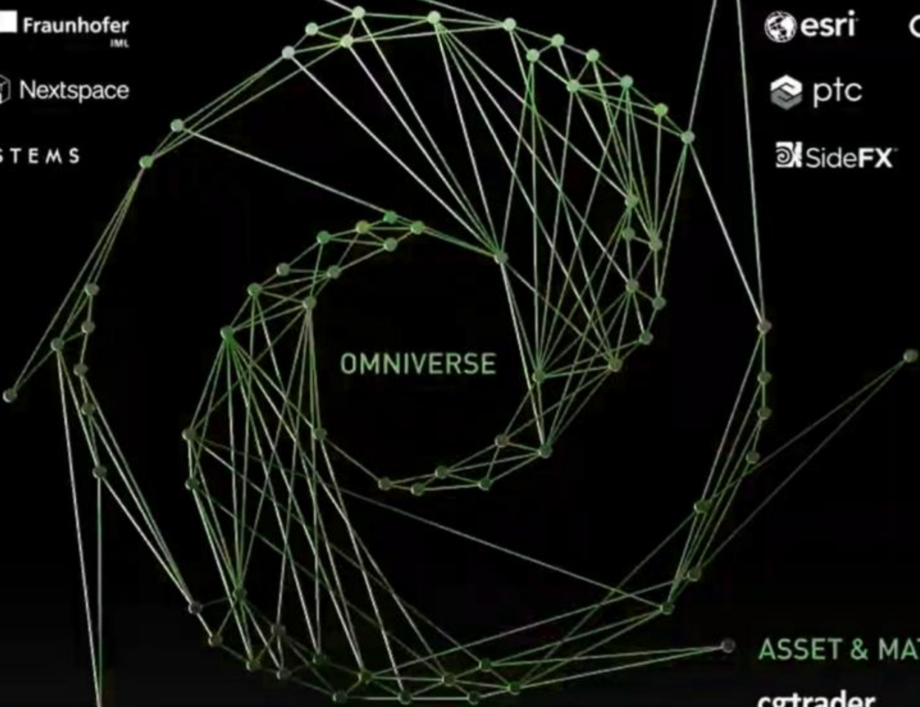
amazon robotics, aspentech, AUTODESK, Bentley, DELTA, esri, FESTO, FUJISOFT, FLEXIV, Fraunhofer IML, HALODI robotics, idealworks, ipolog, ptc, Nextspace, RIOS, READY ROBOTICS, SIEMENS energy, 6 RIVER SYSTEMS, Trimble, VISUAL COMPONENTS

SYSTEMS INTEGRATORS

kineticvision, Deloitte., NETALLIED SYSTEMS, quantiphi, softserve

SENSOR MODELS

Ansys, Continental, HELLA, LUMINAR, SONY, Valeo



DESIGN & CONTENT CREATION

Adobe, AUTODESK, blender, CLO Virtual Fashion, esri, GRAPHISOFT, kitware, MAXON, ptc, PLANTFACTORY, Rhinoceros, REALLUSION, SideFX, Trimble

RENDERING

AUTODESK, blender, chaos, MAXON, otoy, RENDERMAN

ASSET & MATERIAL LIBRARIES

cgtrader, REALLUSION, Sketchfab, TURBOSQUID by shutterstock, twinbru

82 Connections

150k Downloads

106k Unique Users

NVIDIA

SOFTSERVE AND NVIDIA

ELITE SERVICE DELIVERY PARTNER STATUS

150+

People experienced in NVIDIA stack and Professional Services as an Elite SDP

750+

Experts in BigData, AI/ML, Robotics, IoT, AR/VR and R&D

NVIDIA Elite Partner

GLOBAL LAUNCH PARTNER FOR OMNIVERSE

Dedicated Omniverse Competency Team being deployed, capable of developing connectors, extensions, IsaacSim robotic simulation, CloudXR, and heavy focus around Digital Twins industrial solutions.

NVIDIA Omniverse™

EXPERTISE IN USING GPUS IN THE CLOUD

1,200+

Cloud Experts

We have the highest level of partnerships with AWS, GCP, Azure and OCI.

Google Cloud GLOBAL Partner of the Year Machine Learning 2020

aws PARTNER Premier Tier Services

Microsoft Solutions Partner Data & AI Azure Specialist Analytics

ORACLE CLOUD

NVIDIA OMNIVERSE EXPLORER GLOBAL LAUNCH PARTNER

NVIDIA AI ENTERPRISE SERVICE DELIVERY PARTNER

EMBEDDED EDGE COMPETENCY PARTNER

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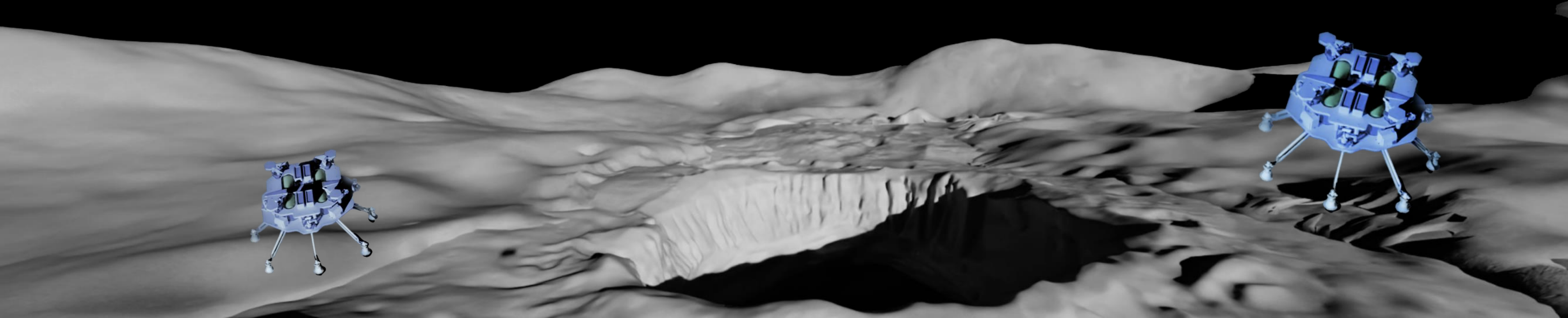
SPACE DOMAIN: SOME TRENDS AND PAINS



CURRENT GLOBAL THEMES FOR IN-SPACE TECHNOLOGIES

SATELLITE-BASED OBSERVATION OF EARTH & OTHER BODIES

- Systemic imaging of Earth's surface in various wavelengths & atmospheric sounding: environmental monitoring, change detection / security -> private and public actors
- Orbiters around the Moon and other solar system objects
- Ever more sophisticated instruments lead to unprecedented amounts of data

CONNECTIVITY & COMMUNICATIONS

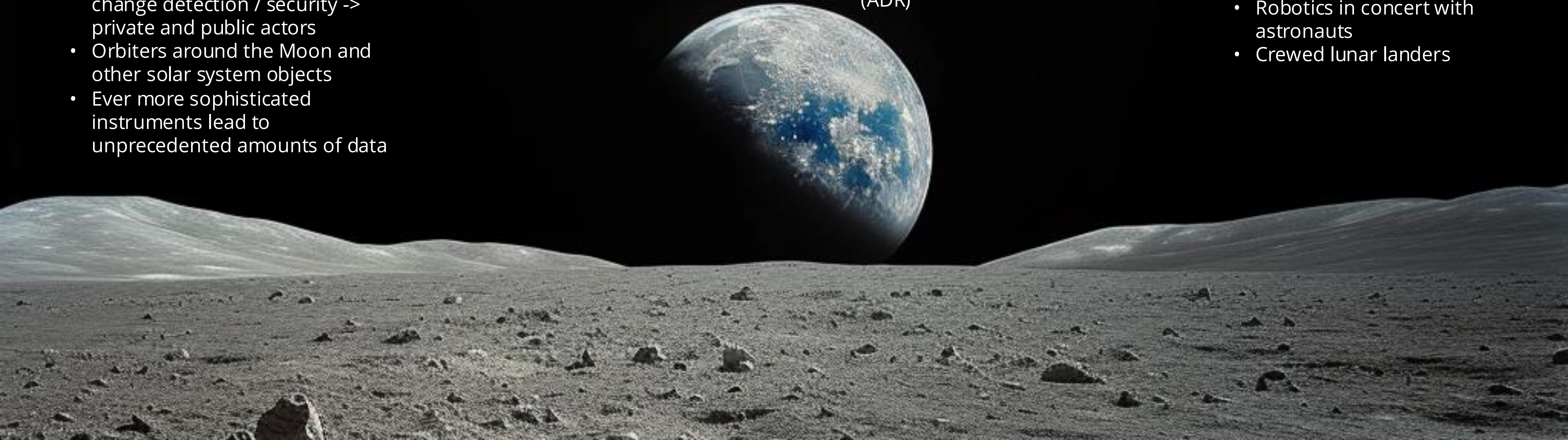
- Large constellations ("mega constellations") for data services
- Operations of multi-robot architectures

SPACE ROBOTICS IN EARTH ORBIT *("SUSTAINABLE SPACE")*

- On-orbit servicing / satellite life extension (OOS)
- Active removal of defunct satellites and upper stages (ADR)

LUNAR & PLANETARY ROBOTICS

- Enabling sustainable lunar missions by astronauts: scouting for reserves & their exploitation (ISRU)
- Robotics in concert with astronauts
- Crewed lunar landers



LUNAR EXPLORATION: RECENT HIGHLIGHTS

01

NEW ORBITERS (1994-NOW)

Filling knowledge gaps from Apollo: mapping of minerals, chemistry, terrain

02

NEW UNCREWED LANDERS

Chinese Chang'e program: landers, rovers, sample return
ISRO & JAXA landers & rovers
NASA CLPS commercial landers

03

NEW CREWED SYSTEMS IN DEVELOPMENT

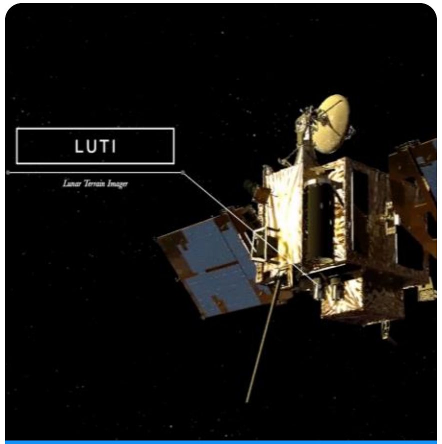
US-led Artemis program, China-led ILRS

04

PLANS FOR SUSTAINABLE CREWED EXPLORATION & COMMERCIAL INTERESTS

ISRU


LRO (2009-today)



KPLO / Danuri (2022)


Chang'e 3 (2013)

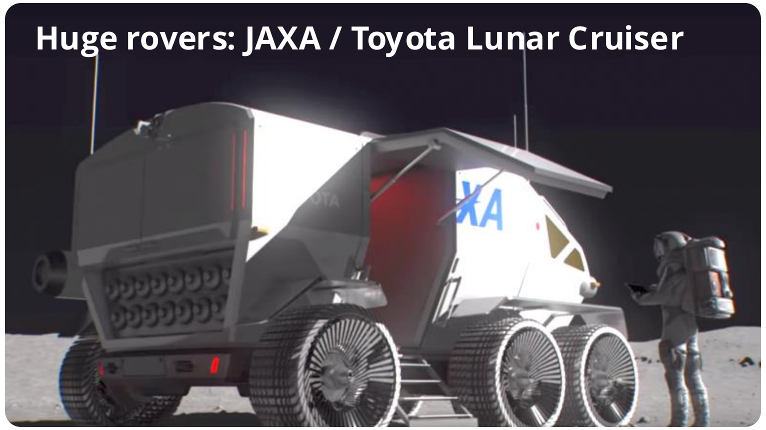

Chang'e 6 lander & ascender (lunar farside)


US return to the lunar surface

THE NEW LUNAR ERA

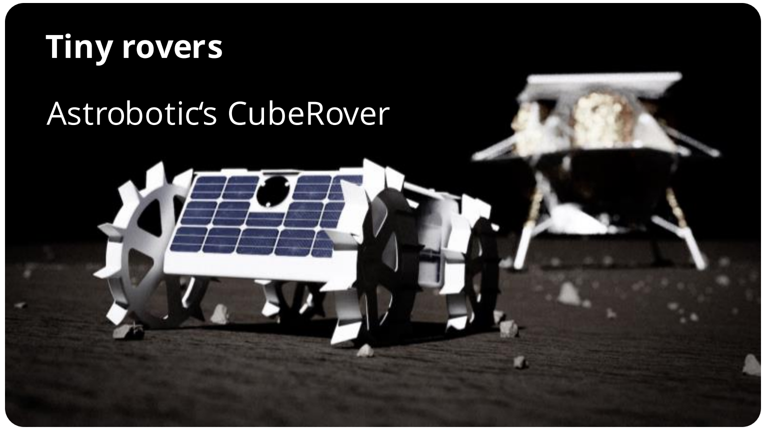
Vision of mining on the Moon

Huge rovers: JAXA / Toyota Lunar Cruiser



Tiny rovers

Astrobotic's CubeRover



There will be more lunar rovers

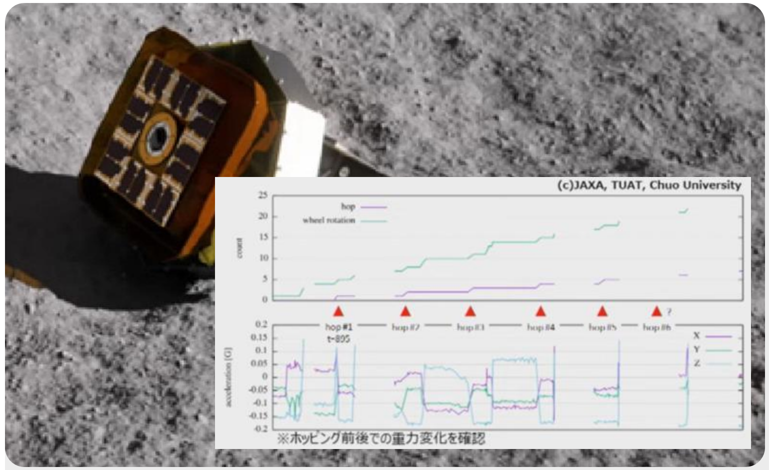
…a lot of actors (commercial and institutional) already doing it; **both short-range vehicles and long-range vehicles, uncrewed and crewed**

Excavation and handling equipment for lunar soil and ice: ISRU

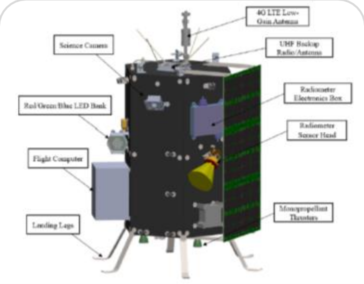
Very interesting (and demanding) mechatronics applications

Advanced ways sought for identifying reserves that can be mined

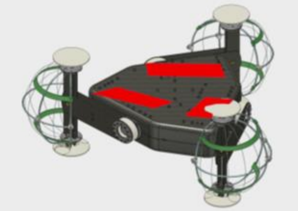
Hopping and flying mobile systems deployed from landers



LEV-1 hopping robot of Japanese (JAXA) SLIM lunar lander (January 2024)



Intuitive machines "Micro Nova" thruster-driven hopper



GALAGO (Astronika) for hopping mobility at lunar and Mars gravity (need to release ~50…100 J of energy per jump for a 10 kg robot)

SPACE PROJECTS PAINS AND POSSIBLE SOLUTIONS

HOW DEPLOYMENT OF NVIDIA OMNIVERSE CAN HELP

PAIN		APPROACH WITH HELP OF OMNIVERSE
Verification & Validation (V&V): often curtailed by budget limitations and schedule pressure -> can lead to mission loss	→	Adopt comprehensive system simulation including interaction with environment (**digital twinning**), perform virtual commissioning (VC), software-in-the-loop (SIL) testing
(Series) production: acceptance test & quality issues	→	Production site rendering and digital twinning -> adopt approaches from industrial metaverse
(Space) robotics: challenges with materials, sensors, cabling, and other components; robust prediction of system behavior in the relevant environment	→	Simulation-first: high fidelity (co-)simulation of the robotic system and interaction with its environment: **sensors simulation**, control system, advanced control with AI (ML, PINNs, training using synthetic data), teleoperations I/F, operators training (XR & AR)
Satellite constellations & formations, orbital debris, space situational awareness	→	Orbit control (active S/C), user-friendly tools for prediction of encounters
Lunar and other extraterrestrial resources: comprehensive mapping and estimation of reserves (deposits whose exploitation is economically viable)	→	Digital twinning of geologic settings and deposits (descriptive models), AI-assisted mineral association analysis

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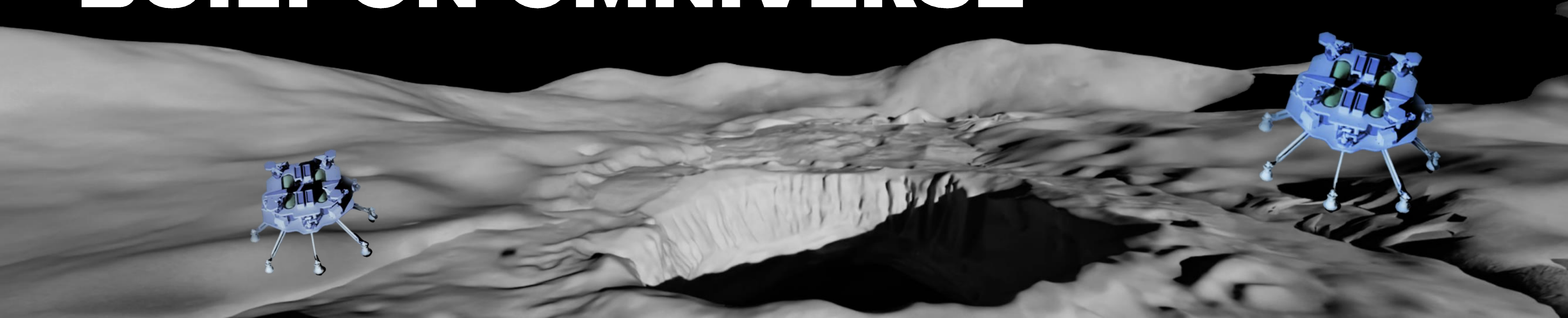
NVIDIA OMNIVERSE™ SOFTSERVE USE CASES FOR SPACE: OUR SPACE ROBOTICS PRACTICE IS BUILT ON OMNIVERSE

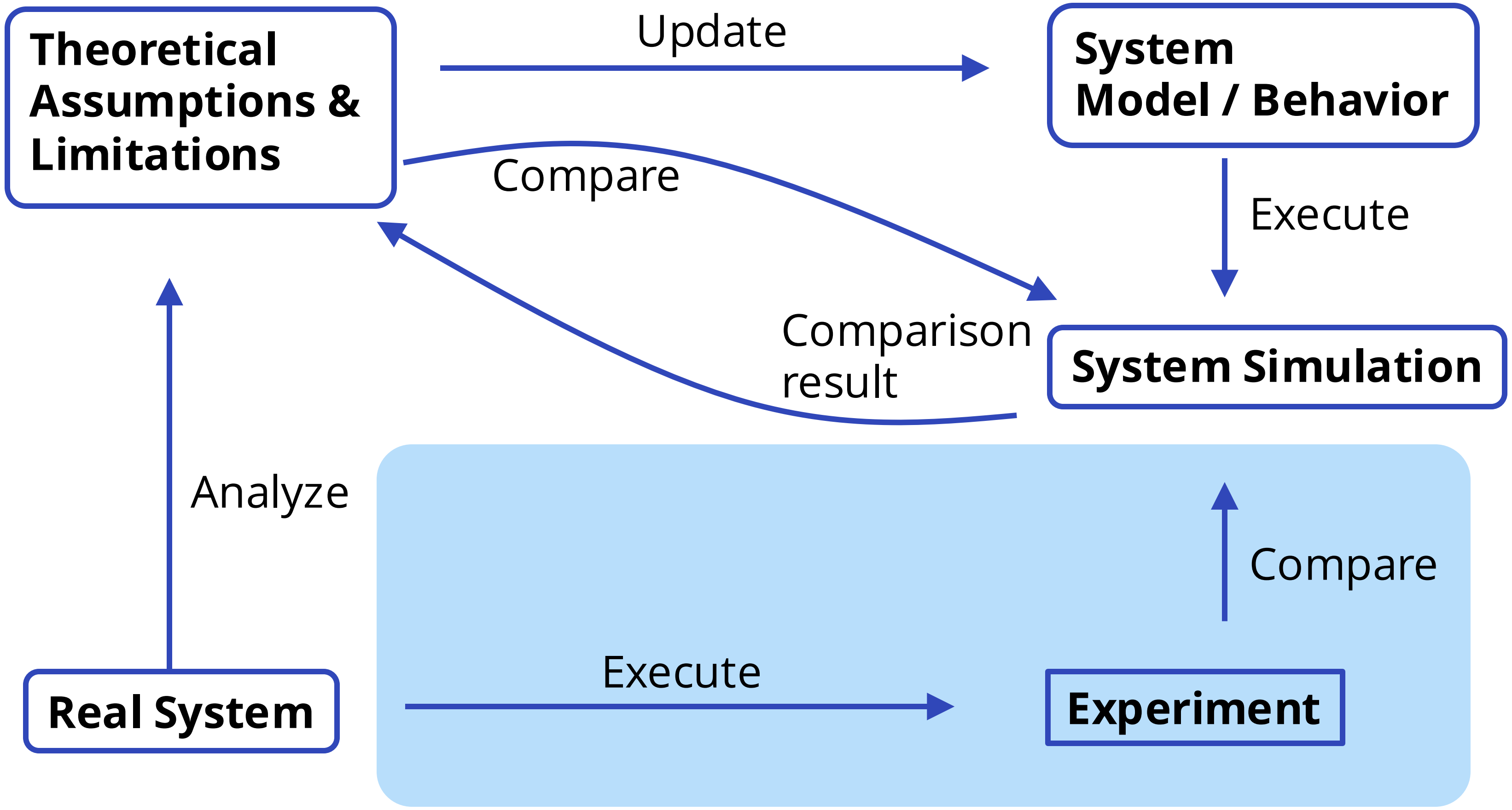


SPACE IS DIFFICULT, DANGEROUS, AND EXPENSIVE

SIMULATING IS NOT

It is easy, safe, and cost-effective

SIMULATION-FIRST IS MORE AGILE AND CHEAPER

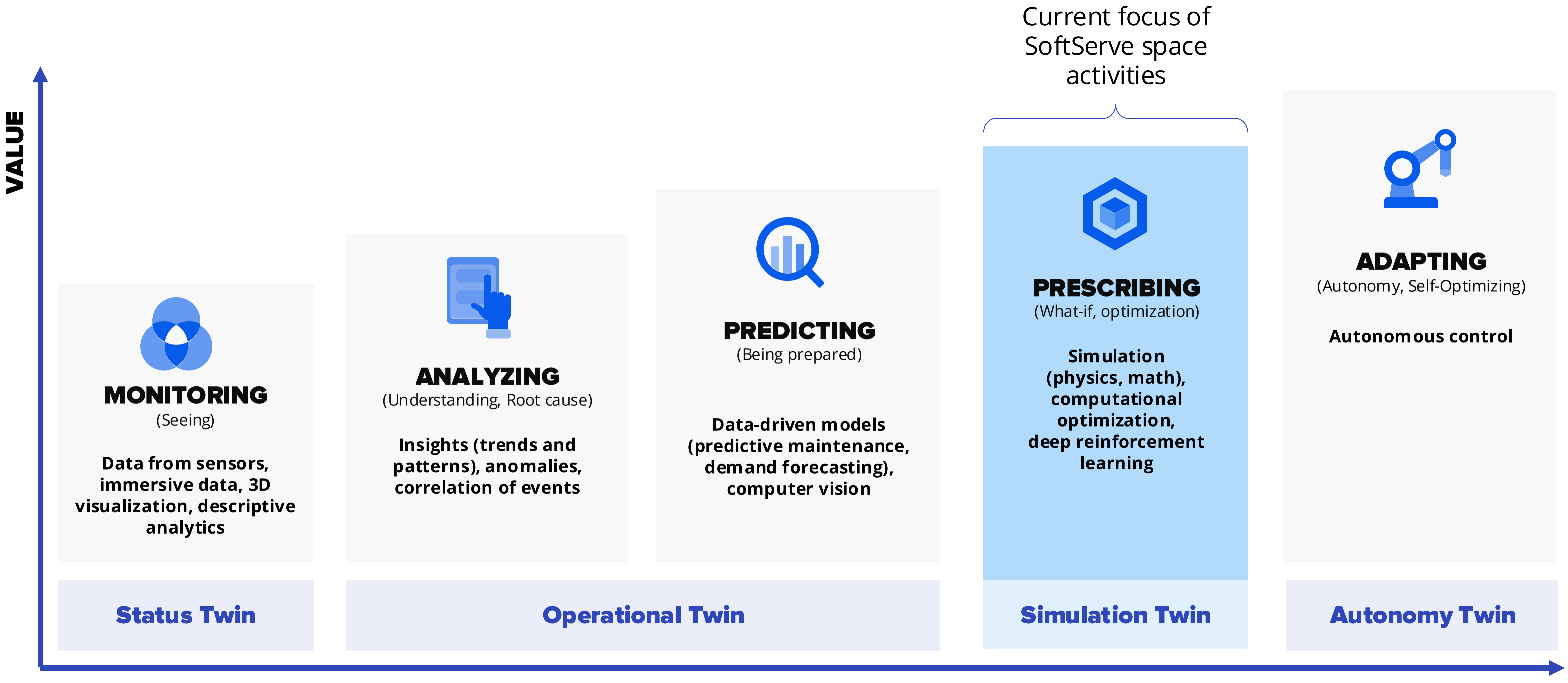


Robot simulation enables developers to train, simulate, and validate advanced robotic systems through virtual robot learning and testing. It all happens in physics-based digital representations of environments, prior to deployment

30%
Duration saving

27%
Cost saving

DIGITAL TWINS SPECTRUM



* Simulation can be a first step in the journey for greenfield initiatives

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WHY SIMULATE?

- Component selection
- General functionality ideation
- Marketing needs
- Rapid idea validation
- Compatibility assurance
- Distributed team
- Costly hardware
- Math models usage
- Difficult or dangerous prototyping
- Business logic integration
- Human-robot interaction
- Swarm dynamics
- Physical interaction, collision
- Use in various environments
- Synthetic data usage

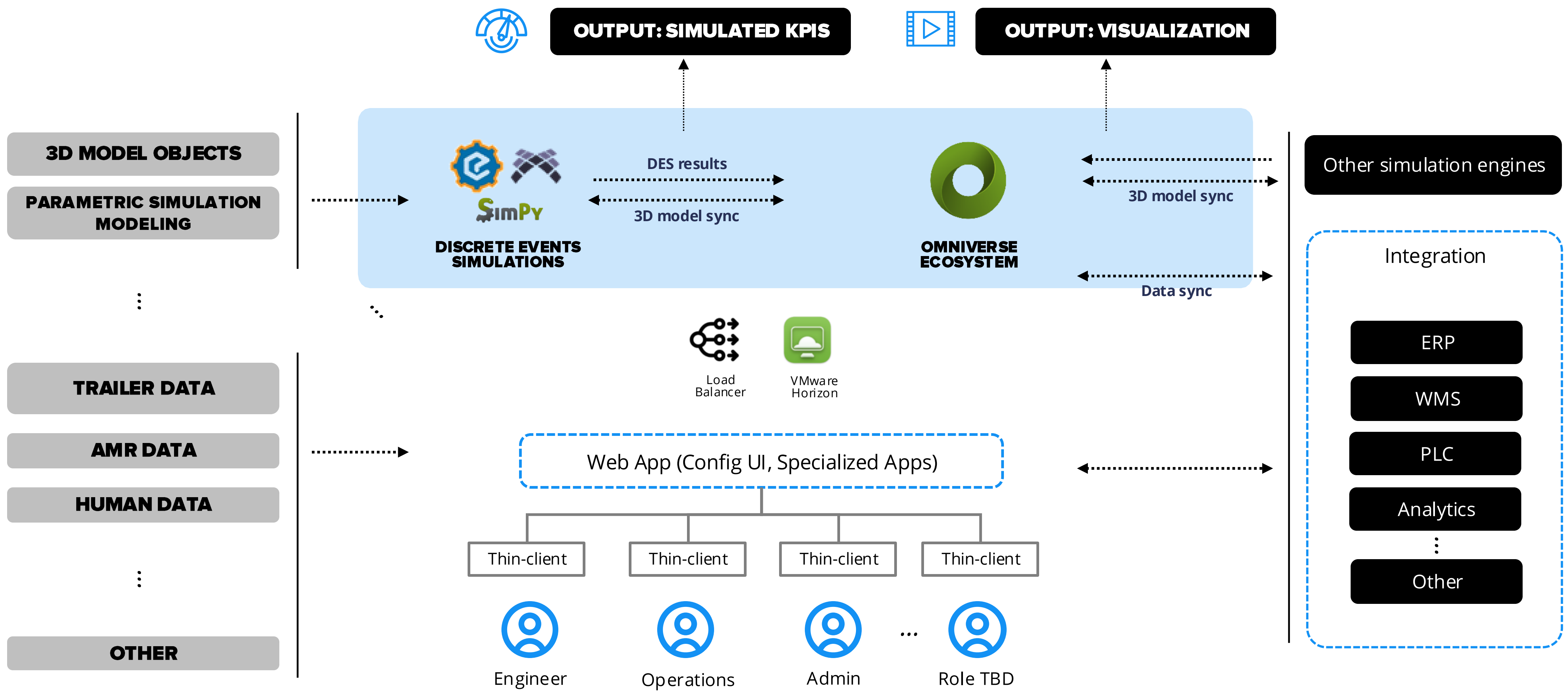
3D Visualisation
Promo picture,
Exploded-view diagram

Prototype
Design hardware before
physics simulation

High-Fidelity simulation
Physical phenomena

Robotics simulation
Physics, Environment,
Collision

OMNIVERSE BRINGS IT TOGETHER



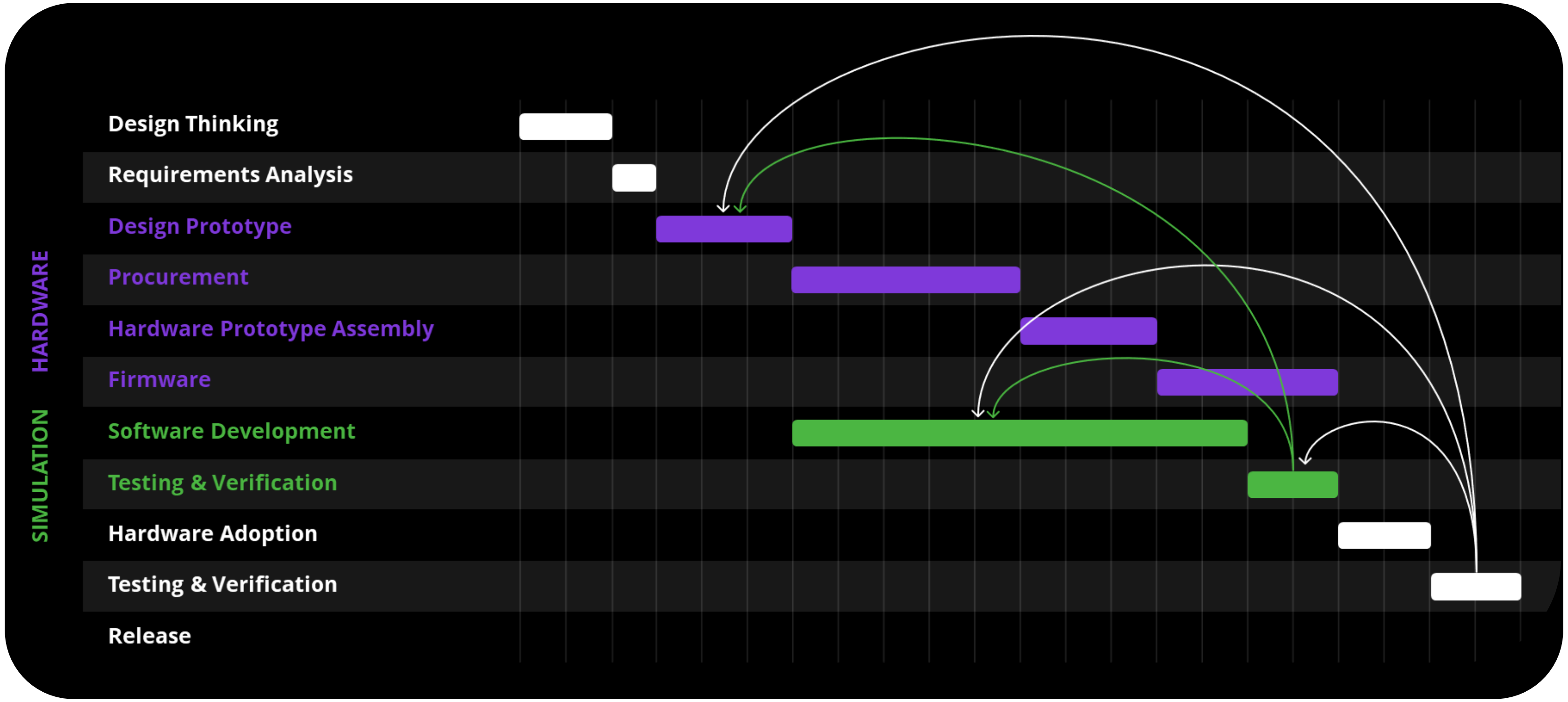
COLLABORATIVE DESIGN AS A KEY MEASURE TO ACCELERATE SPACE PROJECT DEVELOPMENT CYCLES

SoftServe promoting the following approach to space system developers:

Apply **collaborative engineering** using NVIDIA Omniverse™, allowing to:

- Apply "simulation-first" approach
- Stream 3D models and simulations to stakeholders
- **Convert traditional design reviews and project checkpoints into a continuous process with much shorter iteration cycles**

Deploy Gen AI to support generation of project documents and manuals



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SOFTSERVE REGOLITH CONVEYING SOLUTION

BUSINESS CHALLENGE

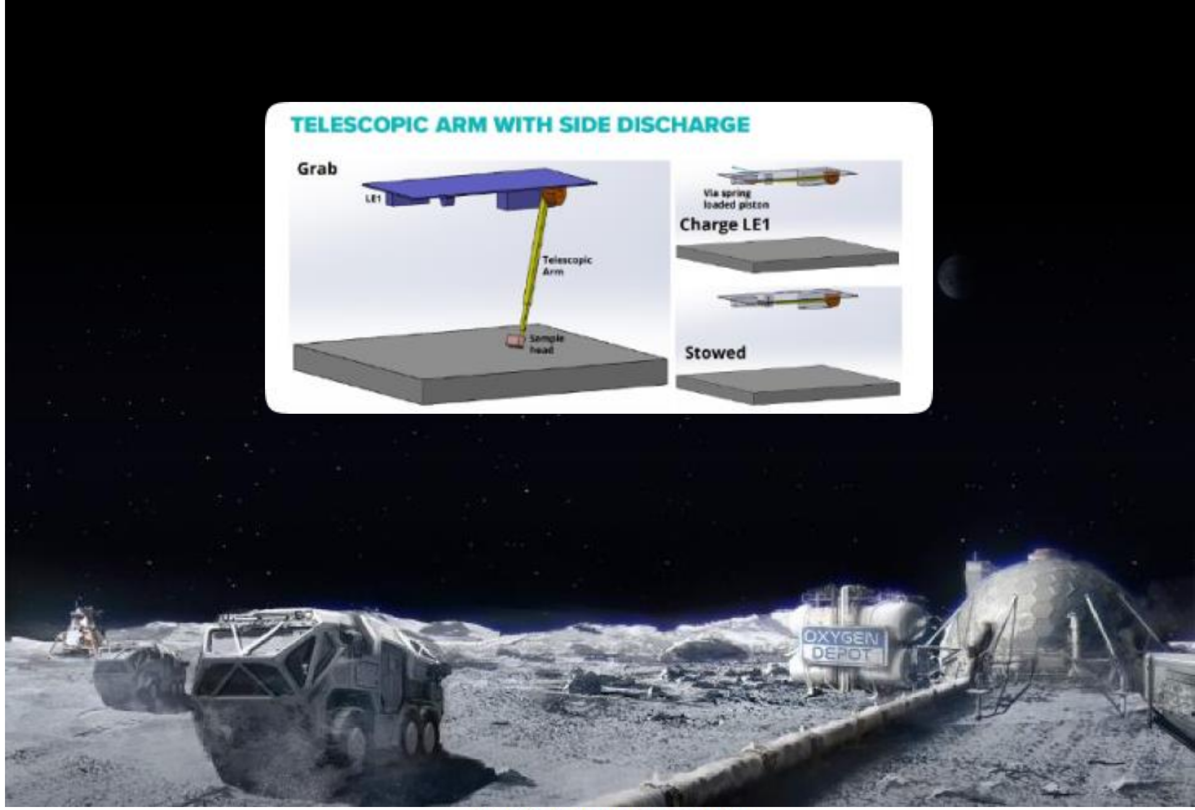
A space exploration startup was looking for an electromechanical system to feed lunar regolith into a chemical processor that would demonstrate extraction of mineralogically-bound oxygen from the lunar soil as part of local resource utilization concepts for the Moon.

SOLUTION

SoftServe conceived a low mass design with minimized degrees of freedom in just a week's time.

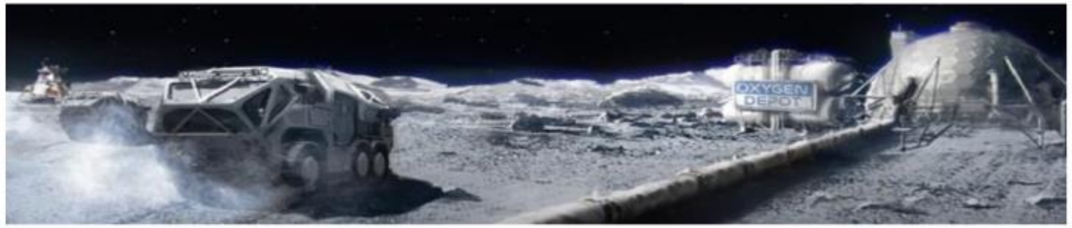
VALUE DELIVERED

- Design of the electromechanical system produced in record time.
- **Framework of simulation set up using NVIDIA Omniverse™.**



Part B: technical description

OXYMOON: A COMPREHENSIVE OXYGEN PRODUCTION SYSTEM FOR SUSTAINABLE HUMAN PRESENCE ON THE MOON AND BEYOND



#@APP-FORM-HERIAIA@#

Participant No *	Participant organization name	Short name	Country
1 (Coordinator)	Helios Project Ltd	HP	Israel
2	Absolut System	AS	France
3	SoftServe	SS	Poland
4	Ispace	IE	Luxembourg

S/C THERMAL ANALYSIS

PROBLEM

Our customer is one of the lunar landing probes service providers to NASA. They already had a thermal simulation model for the spacecraft and its interaction with the environment. But they found that its fidelity and computational efficiency needed improvement, soliciting development of a new tool solution that was also going to be used in the mission ground control segment for real-time predictions.

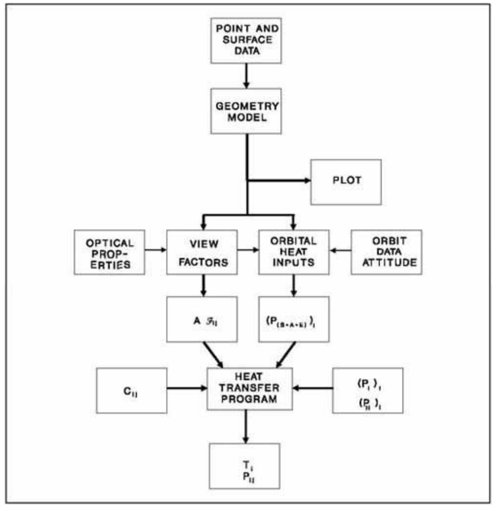
SOLUTION

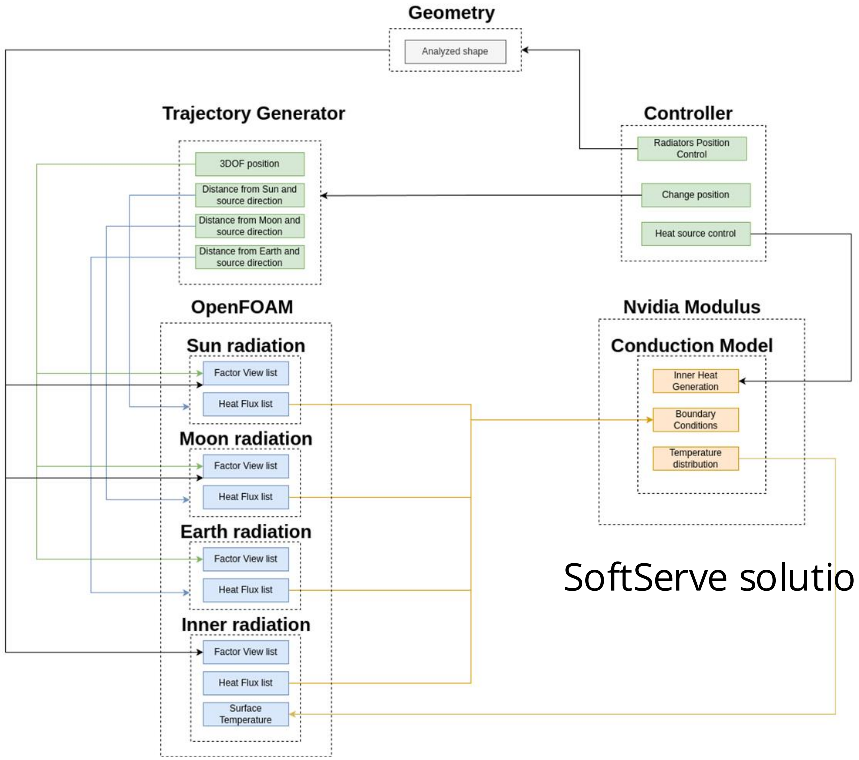
- Toolchain devised by SoftServe
- Trajectory Generator: gives the information about the position and transfer of directional radiation sources
- **OpenFOAM**: generating database of view factors depends on the position -> generates the heat fluxes for each surface -> sent to **NVIDIA Modulus**
- **NVIDIA Modulus** sends the surface temperature to generate output heat fluxes for each S/C surface (inner radiation nodes) -> inner radiation nodes send back heat fluxes to **NVIDIA modulus** -> generate the new temperature distribution
- Controller: responsible for changing the position of the element, the inner source control and shape of the radiator's elements
- **NVIDIA Modulus**: solver

IMPACT

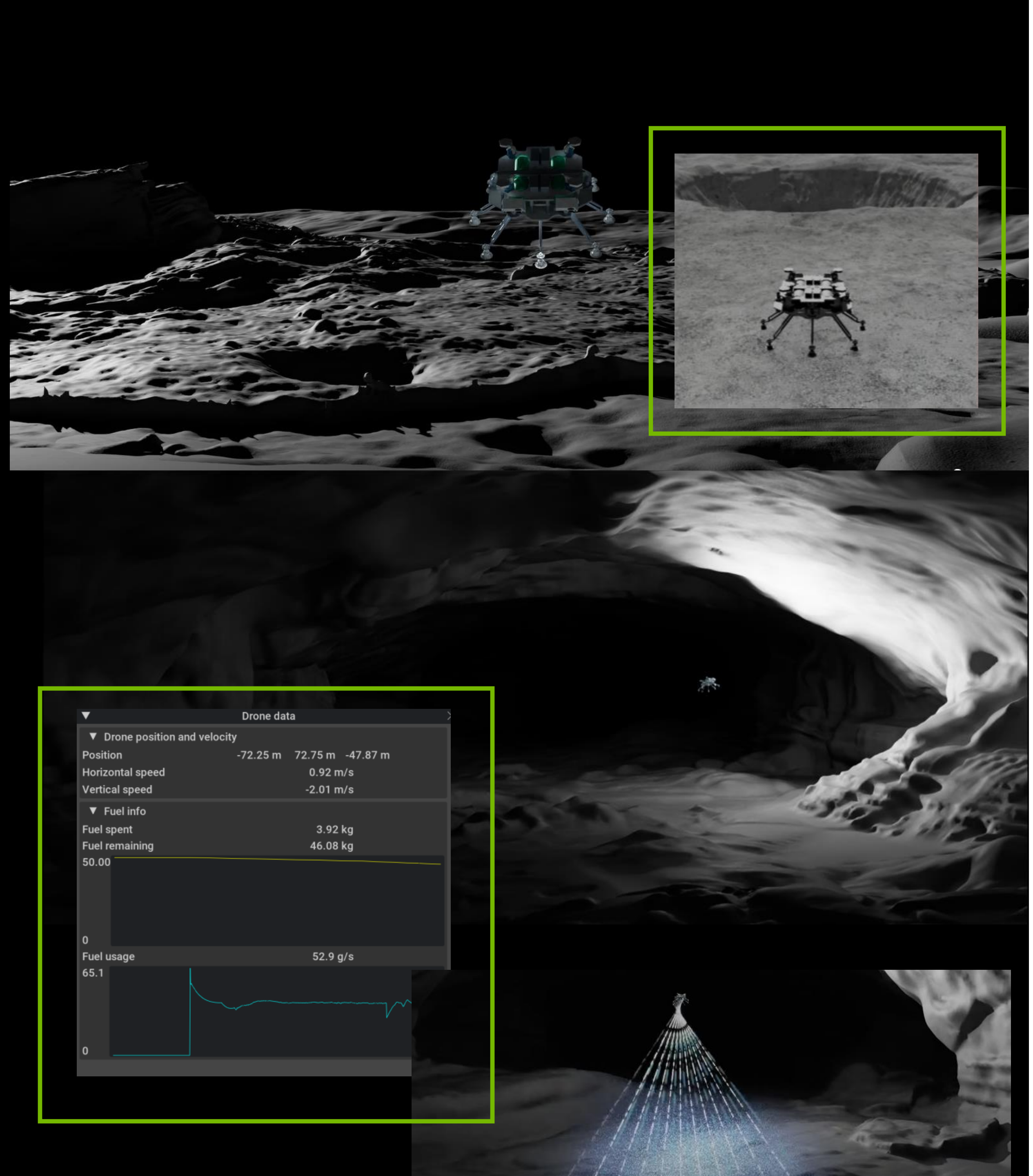
- Efficient solution implementation **drawing heavily on already measured thermal behavior of the S/C**
- **Modular solution** allowing description of changes in S/C features such as heaters
- **Rapid implementation** within three months (**schedule driven by mission launch**)

General approach for S/C thermal modeling





SoftServe solution



SOFTSERVE LUNAR DRONE SIMULATION

BUSINESS CHALLENGE

- **LUNAR ISRU:** A space exploration startup was studying a thruster-driven vehicle for controlled powered flight over the lunar surface for resource prospecting (e.g., searching for ice deposits on the Moon). They approached SoftServe to assess the GNC system.
- **LUNAR SCIENCE:** A Texas-based R&D institution approached SoftServe to consider the thruster-driven drone for carrying a mass spectrometer to analyze ices within lunar caves and lava tubes.

SOLUTION

SoftServe conceived a notional vehicle concept along with its guidance system. Using ROS2 and **NVIDIA Isaac Sim**, the vehicle with its sensors and control system was modeled, and simulations performed of flights over a synthetic lunar landscape created in Blender.

VALUE DELIVERED

- Conceptual design of a guidance and flight control system for a thruster-driven lunar “drone”
- Implementation of a system model **in NVIDIA Isaac Sim** and running complete flight simulations for the design reference mission of **flying into, through, and out of a lunar lave tube (using a “skylight” as entry and exit points)**

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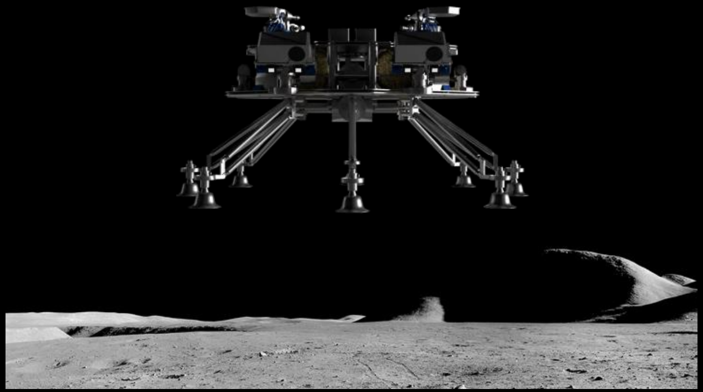
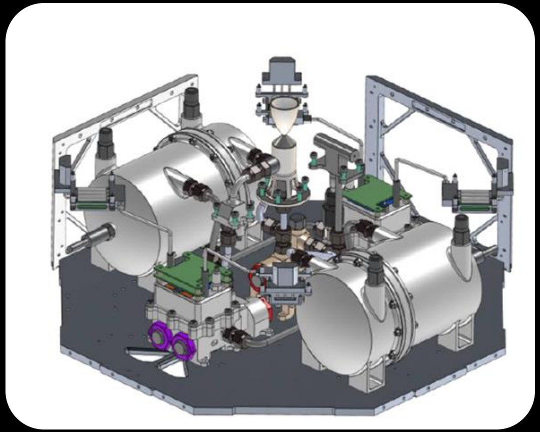


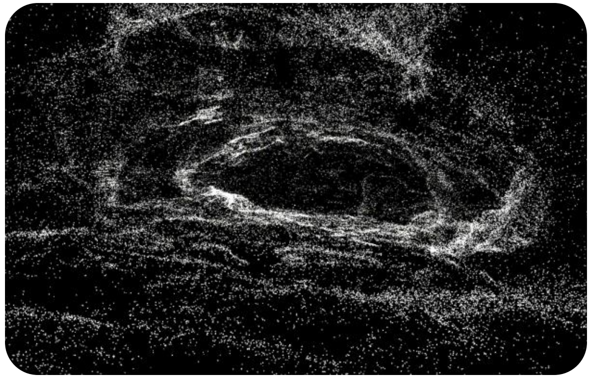
Vehicle with two camera heads



Propulsion system

SOFTSERVE LUNAR DRONE SIMULATION

- Thruster driven vehicle for controlled flights with option for refueling
- Flight control sensors: two monocular cameras and an IMU
- Linear Kalman filter for sensor fusion and state prediction
- Sensors feeding a visual SLAM algorithm (simultaneous localization and mapping), performing autonomous navigation to reach pre-assigned targets while generating a map via point clouds



Point cloud example from simulated flight through lava tube

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MODELING OF THE LUNAR TERRAIN

ASSET GENERATION

Asset Library

Batch Processing
Data Conversion
Clean Up

Manual Modelling

Model Missing Assets
Manual Optimizations

SCENE ASSEMBLING

Data Driven Modelling

CAD/BIM Data Extraction
Assets Assembly

USER INTERFACE

Omniverse Platform

Assets Review
Scene Customizations

MODELING OF LUNAR LAVA TUBES

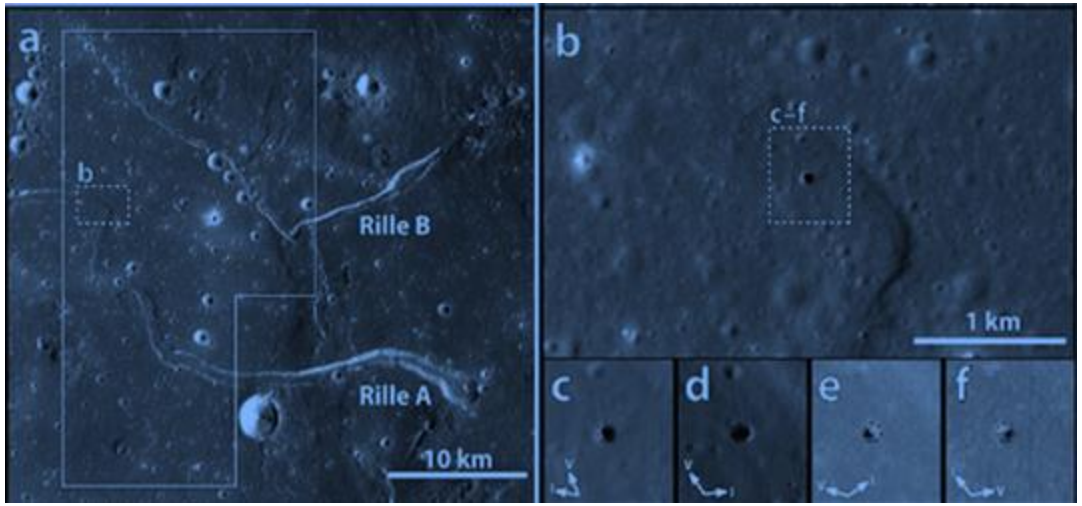
Recreated an example terrain and lava tube model using lunar satellite data and published models on lunar skylights and pits

- Skylights imaged from lunar orbit; presence of lava tubes inferred from orbiting ground penetrating radar measurements (e.g., from KAGUYA lunar orbiter)

Lava tubes: exciting features on the Moon because could be a "safe haven" (protected from thermal extremes and radiation) for future crewed outposts

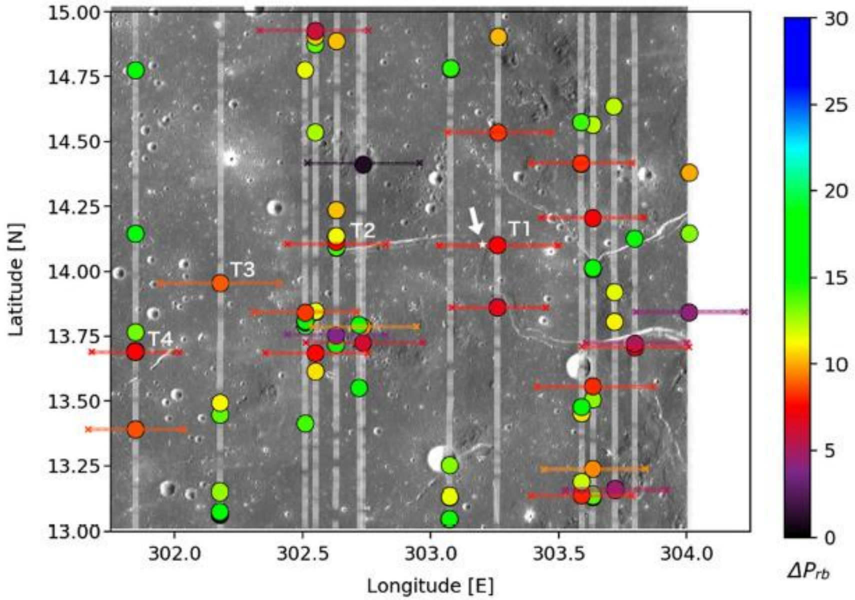
- Moreover, some could be harboring ice (easier to access than in polar shaded regions)

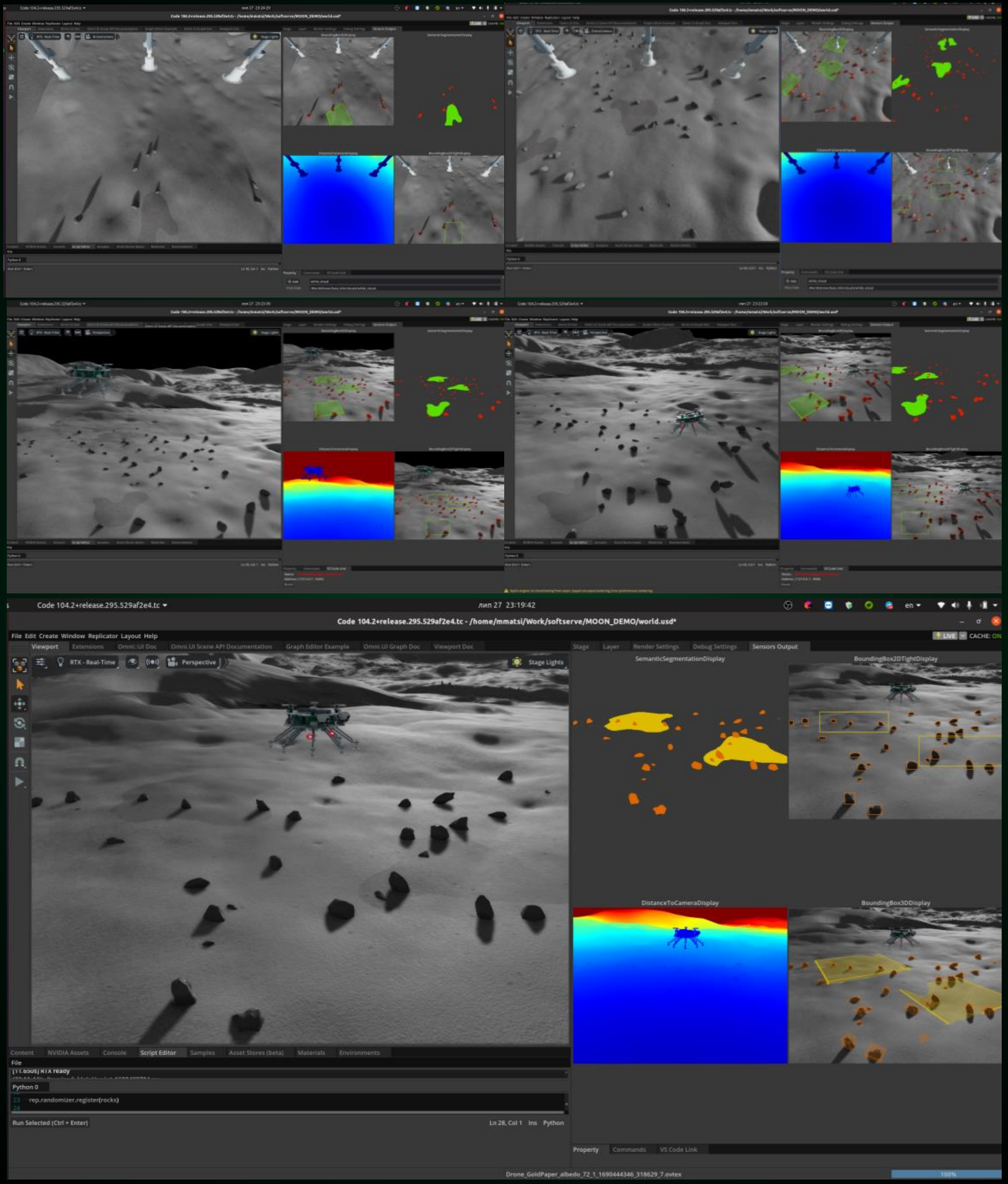
Potential image of a lunar lava tube skylight with a diameter of 65 m in the Marius Hills area. (**a**) Panoramic view of the region, showing the designated area for crater counting marked by a solid white polygon. (**b**) Marius Hills Hole (MHH). (**c**–**f**) Magnified images of the MHH, with arrows indicating the direction of sunlight illumination (I) and camera perspective (V).



(Qiu et al., 2023)

Candidate sites of potential underground caverns in the Marius Hills region. The color of the circles represents the power difference between the first and second echo peaks (DPrb). The lower the DPrb value, the greater the possibility of the existence of underground lava tubes.





MODELING OF SYNTHETIC LUNAR TERRAIN: USING NVIDIA REPLICATOR

BUSINESS OVERVIEW

As part of the lunar drone simulation work by SoftServe:

- Reduce implementation time through automatic world modification

SOLUTION

- Utilize **NVIDIA Replicator** and **Isaac Sim** for environment randomization
    - Drone position
    - Stone quantity, shape, and size
- Test the algorithm in various environments
- Fine-tune the algorithm based on test results
- Enable obstacles recognition for safe landing

IMPACT

- Increased the quality of the designed drone mapping algorithm
- Enabled synthetic dataset generation for obstacle recognition
- Decreased the time needed for environment randomization

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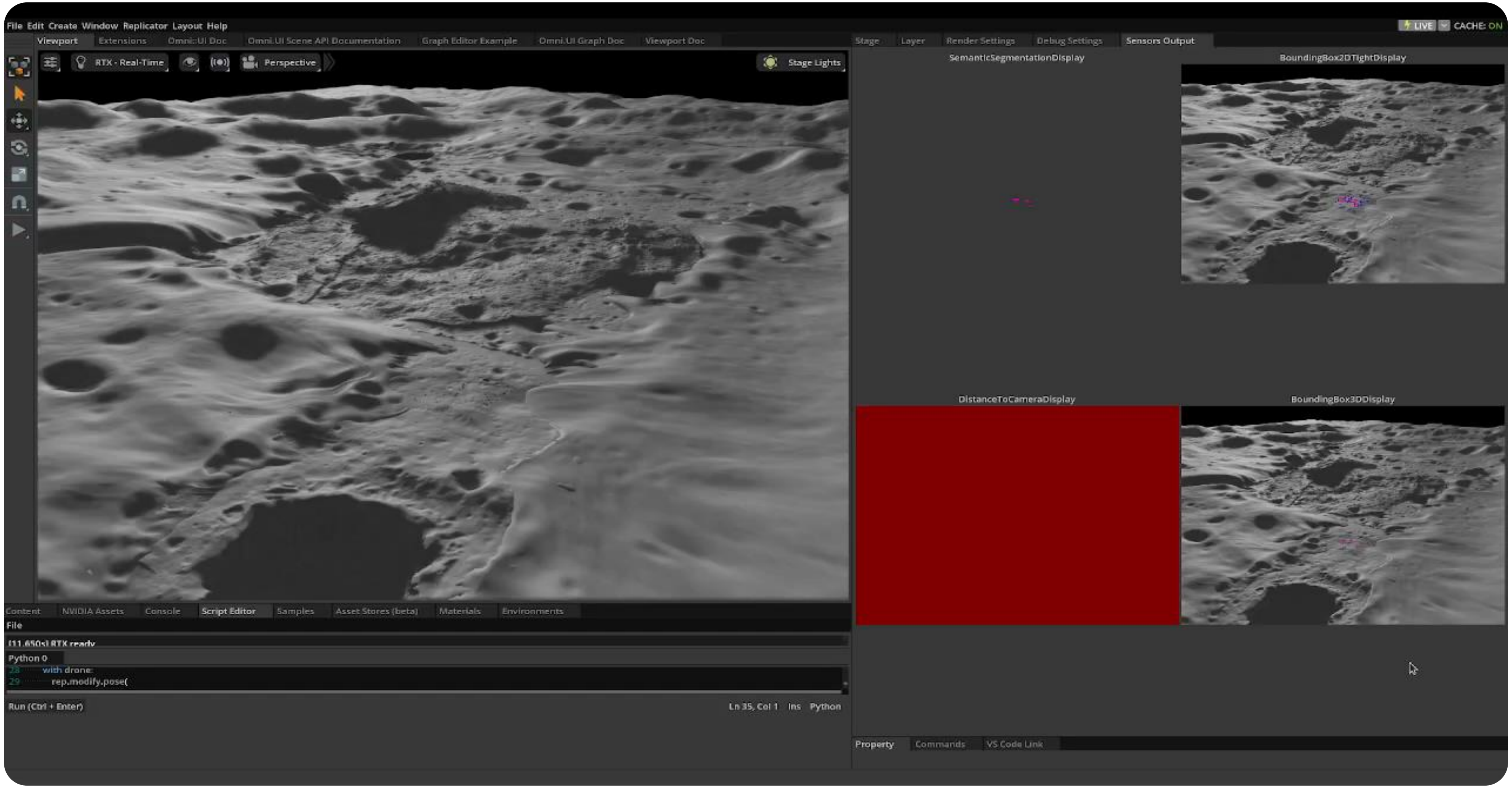
MODELING OF THE LUNAR TERRAIN: USING NVIDIA REPLICATOR



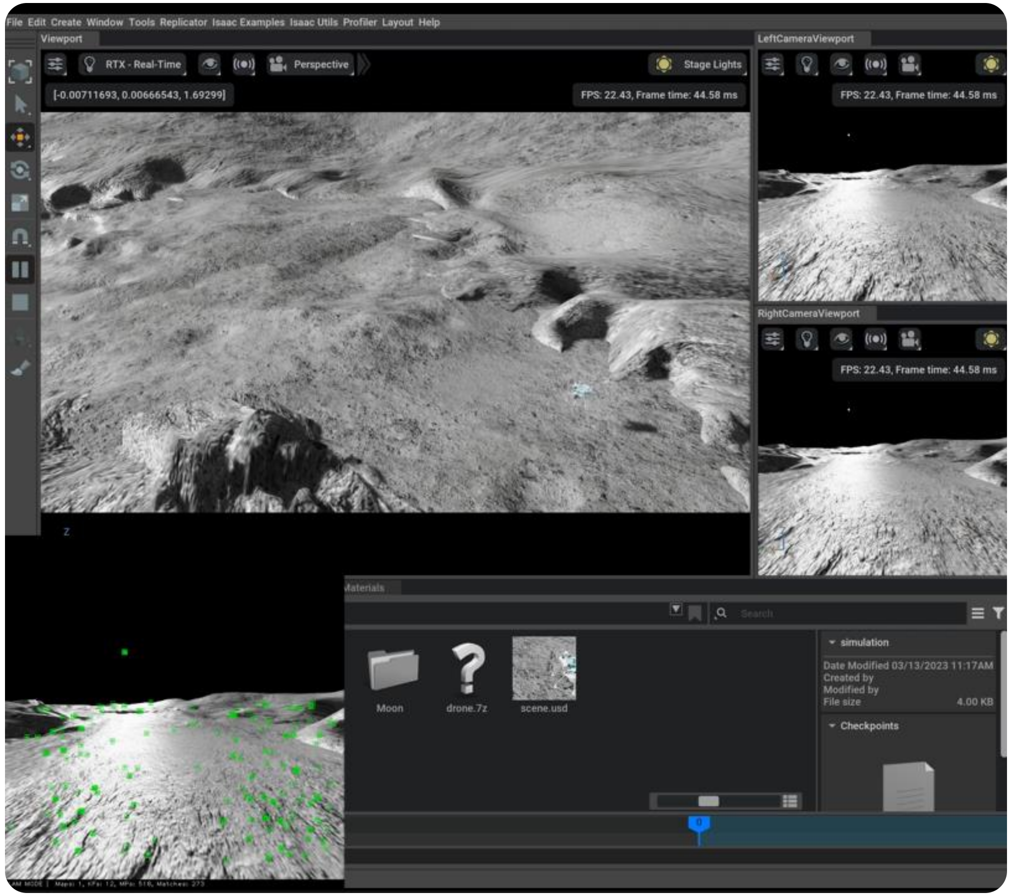
MAPPING APPROACH

- **vSLAM**: visual simultaneous localization and mapping
- Providing absolute position and attitude (in world frame) for sensor fusion
- Solution used in this software is a modified version of ORB_SLAM3
- ORB SLAM3 provides tracking of keypoints (KP)
- Each keyframe (KF) consist of a set of keypoints. Each map consists of a set of keyframes. The vSLAM package publishes all trackable KFs along with the camera position that was used to capture a given KF

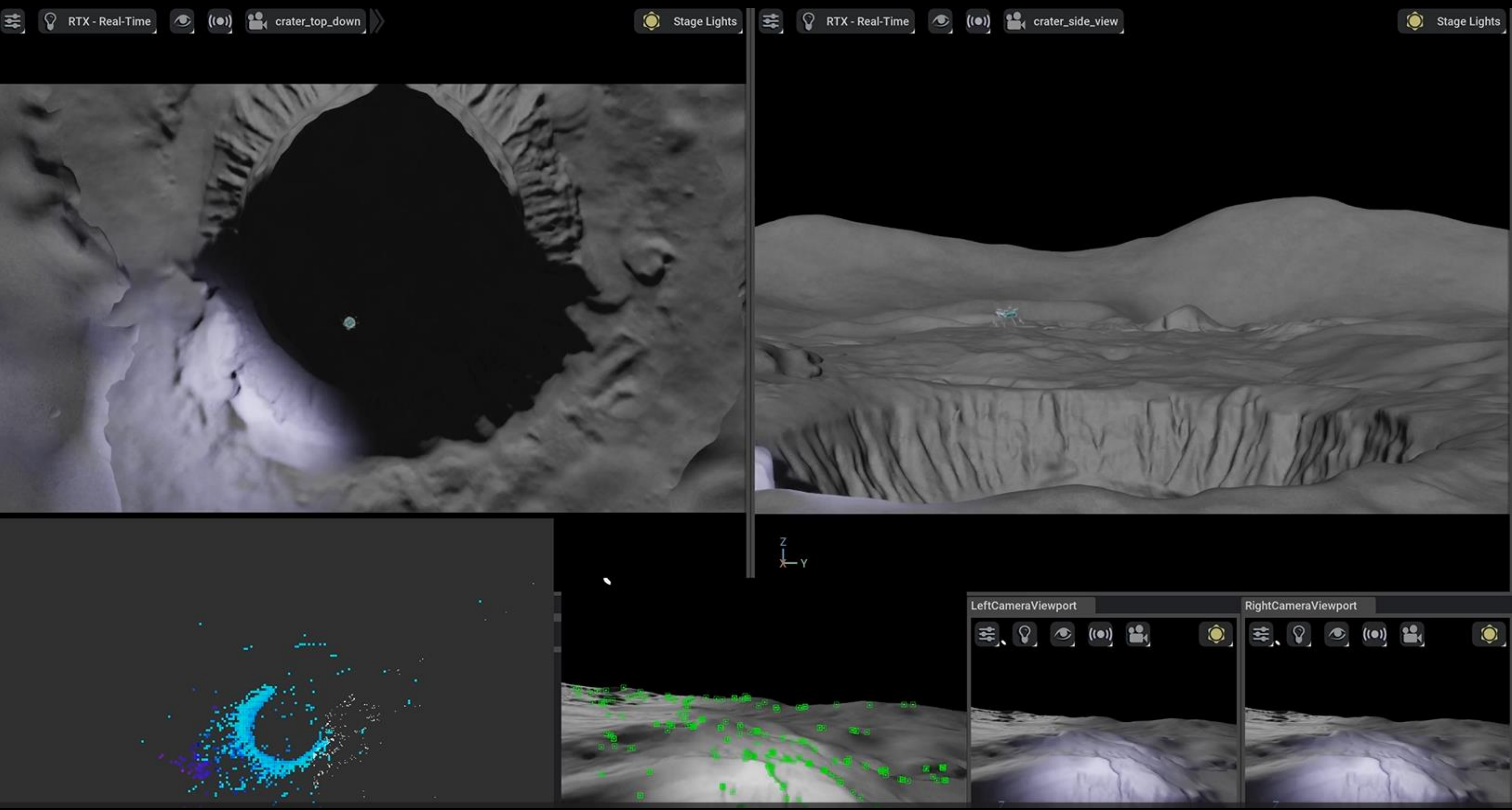
Occupancy map: the drone uses an occupancy map to safely navigate and explore the environment: based on an OctoMap library. OctoMap works by casting rays from the camera to the KPs and marking visited volume (voxels) as:

- Free - volume is known to contain nothing
- Occupied - volume is known to contain an obstacle
- Unknown - volume has not been seen

Behavior tree including a graph-based exploration algorithm1



The basic idea behind a graph-based exploration algorithm is to represent the environment as a three dimensions occupancy map with nodes representing locations in the environment and edges representing the paths between them. The algorithm then explores the graph by moving from node to node, with the goal of maximizing the *exploration gain*. This gain is given as a function of the distance, path straightness and *volumetric gain*.


RTX - Real-Time
crater_top_down
Stage Lights
RTX - Real-Time
crater_side_view
Stage Lights
Z
Y
LeftCameraViewport
RightCameraViewport

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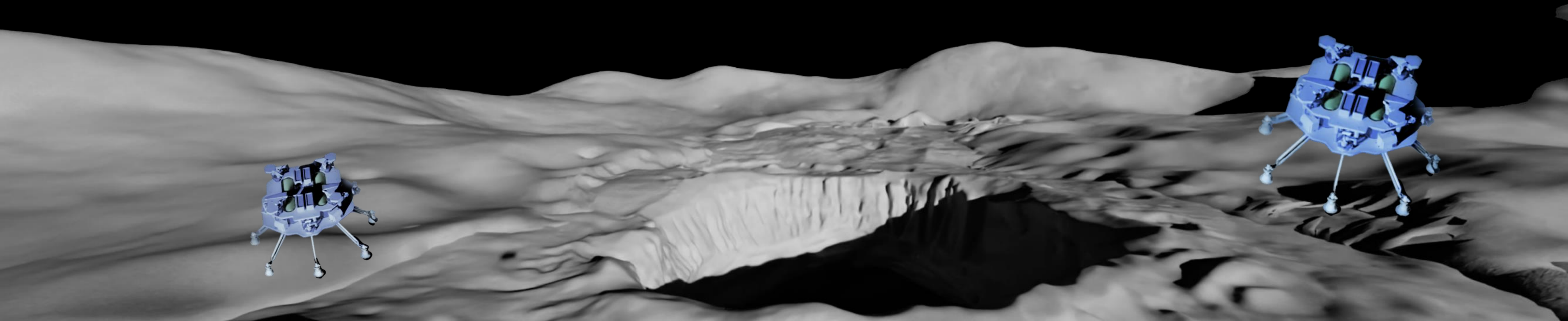
SIMULATION MOVIE SNIPPET



SIMULATION MOVIE SNIPPET

Simulation of flight through a lunar lava tube

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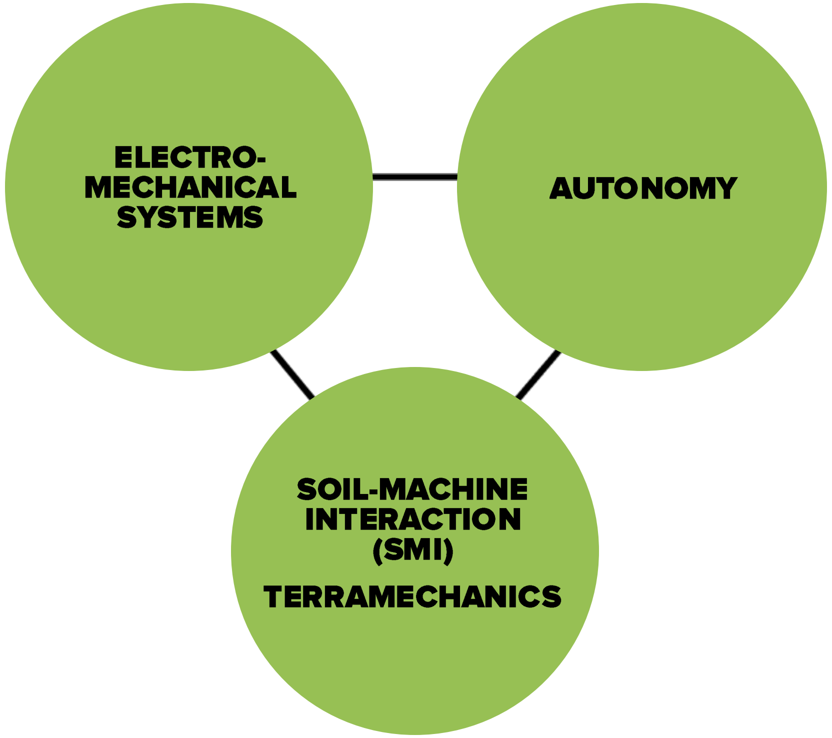
CO-SIMULATION FOR LUNAR ROBOTICS

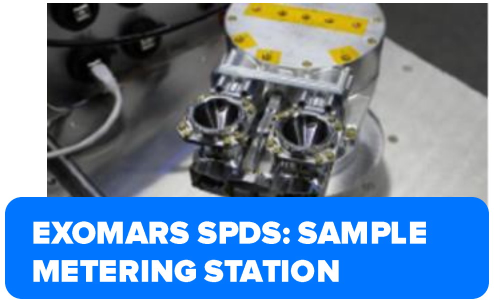
Proper energy consumption on the Moon is an important factor for successful mission accomplishment.

SoftServe’s simulation approach utilizes **co-simulation to enable combination of high-fidelity model for tool-regolith (terramechanical) interaction modeling with robotics simulation**.

Mechatronics systems interacting with surface materials include:

- Landing gear
- Rover mobility systems
- Excavation, sampling, and sample handling





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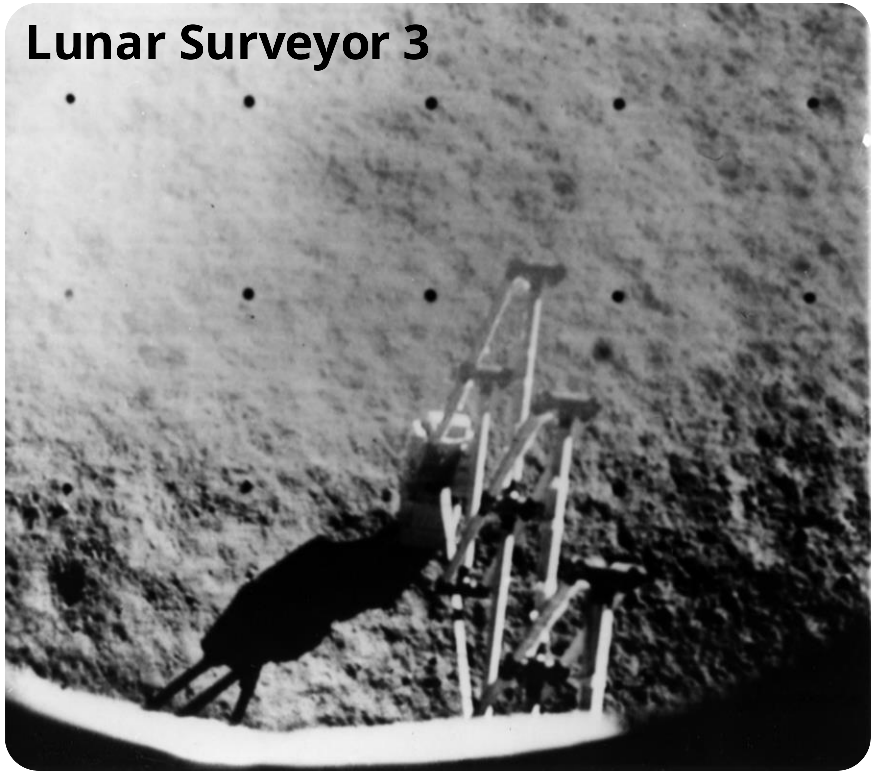
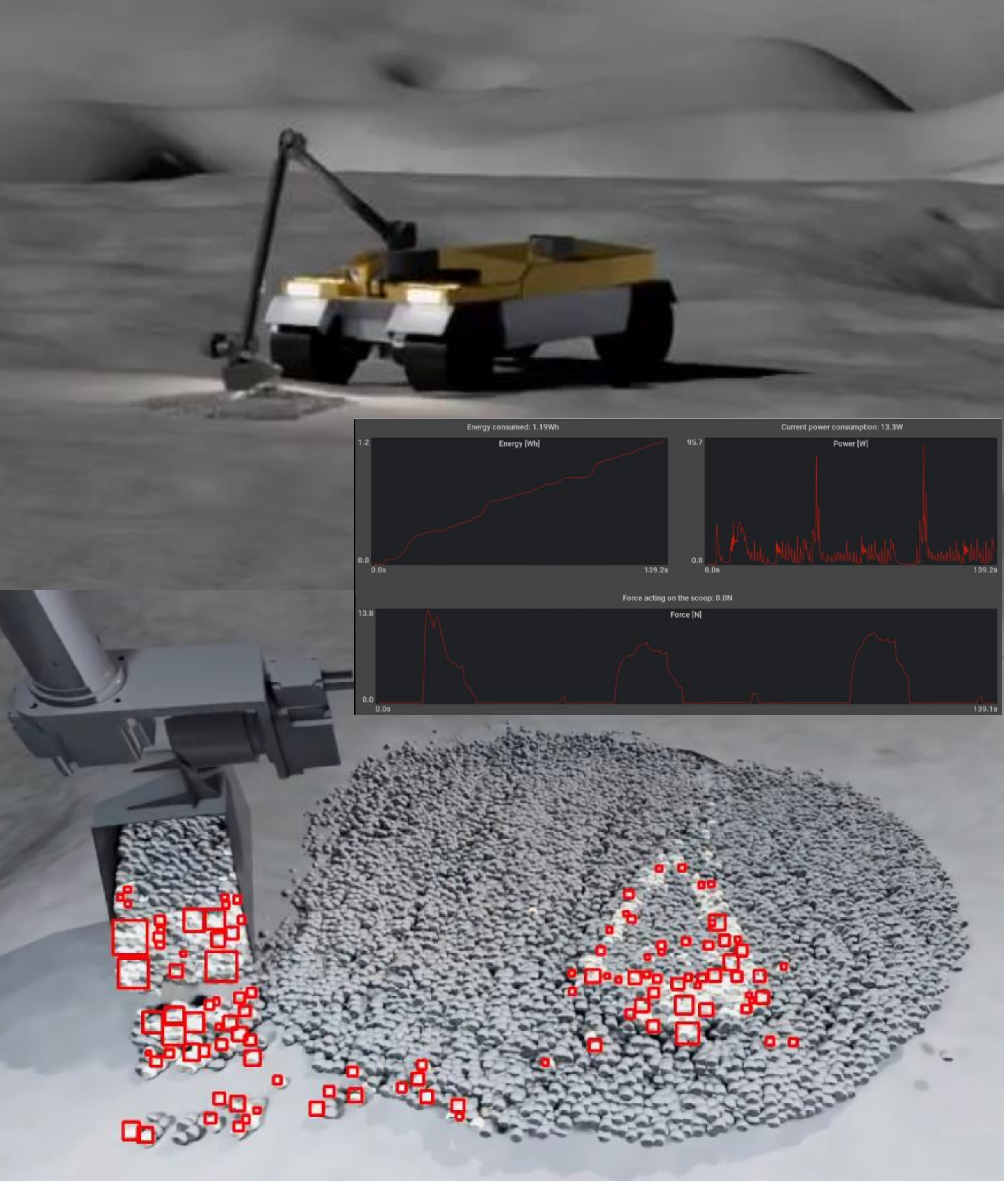
USE CASE: EXCAVATION ON THE MOON

Soil excavation essential for future mining to extract resources (concept of ISRU)

So far: only done at small scales for scientific purposes -> larger scale solutions needed in the future as part of ISRU -> **simulations required to support concept finding and design**

Proper design solution needs to consider lower gravity on the Moon





SOFTSERVE L-REX

NVIDIA Omniverse™

BUSINESS OVERVIEW

The SoftServe robotics team developed a solution to a mobile platform equipped with a robotics arm with a scoop and a vibratory mechanism to scoop the regolith searching for ice deposits on the Moon. The solution had to include the following features:

- Scoop the Moon regolith for exploration or construction
- **Detect ice deposits while scooping**
- **Enable energy efficient operations**

SOLUTION

- **NVIDIA Omniverse** capabilities of high-fidelity simulation with use of FMI/FMU co-simulation standard and **PhysX engine**
- Provide a conceptual design of hardware components of the robot able to perform scooping on the Moon
- Design a **vibratory mechanism to ensure energy-effective scooping**
- Apply simulation-first approach for efficient scooping
- Utilize robotics perception for ice deposit detection
- Implement high-fidelity terramechanics approach to calculate the forces acting between the scoop and regolith (**NVIDIA WARP**)
- Enable **real-time energy consumption tracking** to enable energy-efficient mission accomplishment

IMPACT

- Increase mission duration with energy efficient scooping
- **Enable real-time ice deposit detection**
- Validate complex robotics solution in simulation **using NVIDIA Omniverse**

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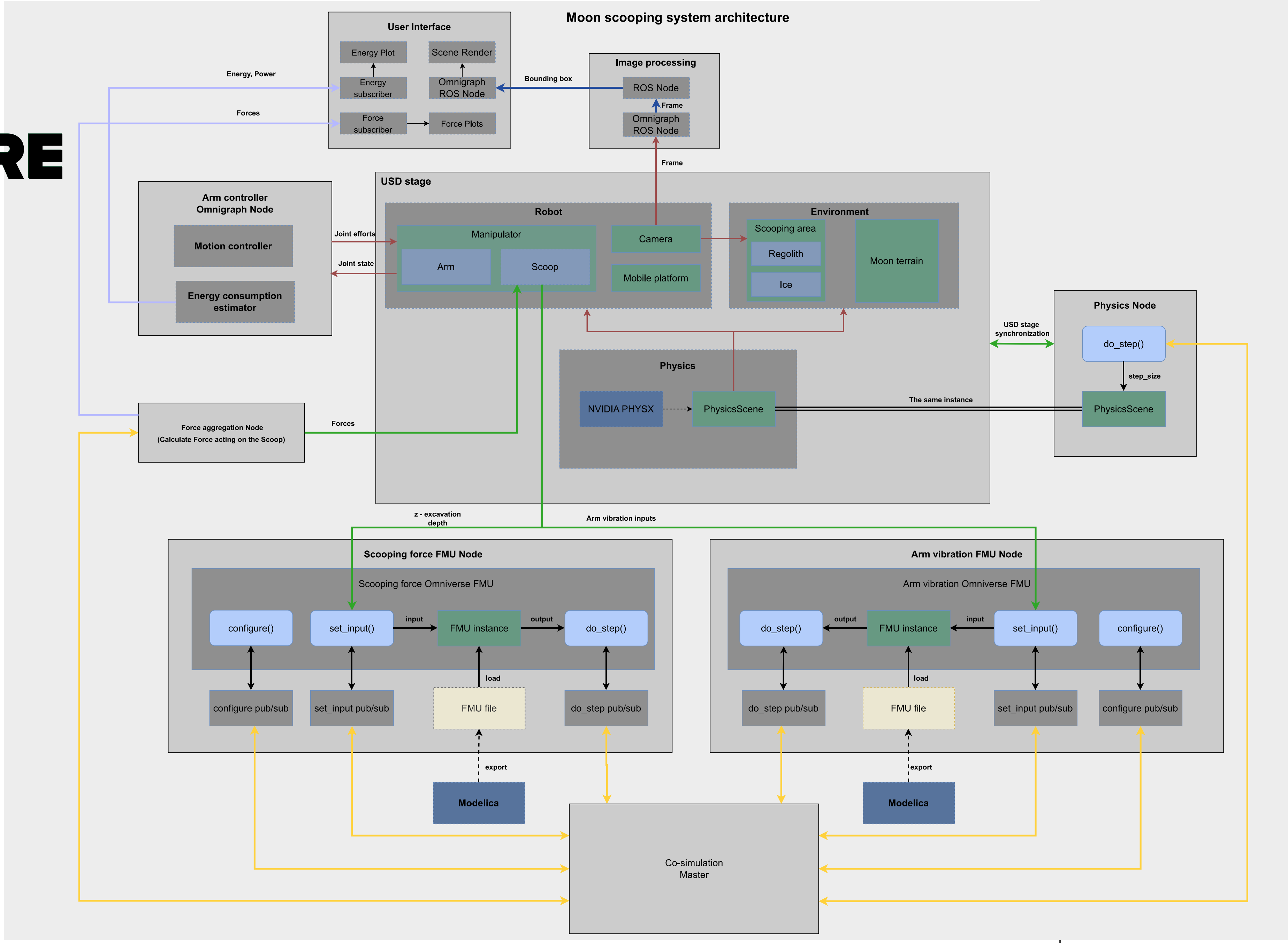
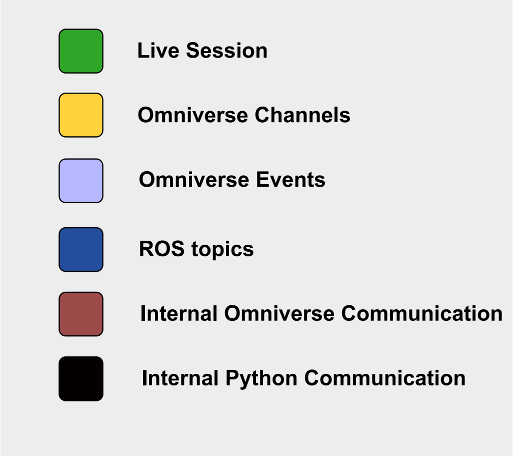
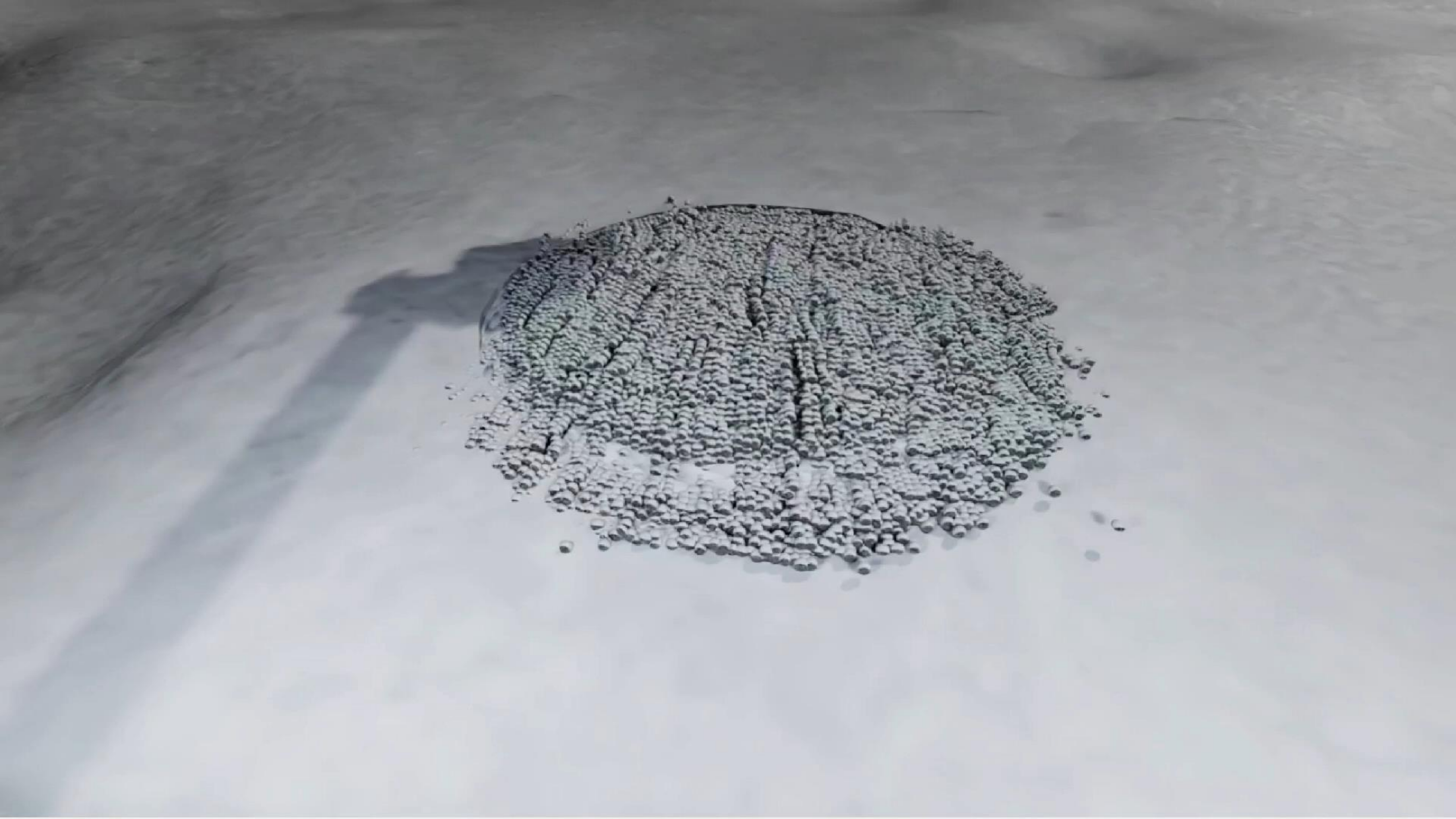
L-REX CO-SIMULATION ARCHITECTURE







FEED FORWARD TO PROJECT FOR NASA

DEC 22, 2023

EN

SOFTSERVE JOINS INTERNATIONAL TEAM TO DEVELOP NASA-FUNDED LUNAR LANDING AND LAUNCH PAD TECHNOLOGIES

Companies team up to develop Moon landing and launch pad technology with funding from NASA's STTR 2023 Program

AUSTIN, Texas (Dec. 22, 2023) – SoftServe, a premier IT consulting and digital services provider, today announced plans of joining an international coalition on a NASA-funded project to develop lunar technologies. The project comes after San Antonio-based Astroport Space Technologies won a NASA STTR 2023 Phase II

READ MORE

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CO-SIMULATION WITH NVIDIA ISAAC SIM FOR GROUND VEHICLES MOBILITY SIMULATION

Terramechanics Simulation

Progress Update

CO-SIMULATION WITH NVIDIA ISAAC SIM FOR GROUND VEHICLES MOBILITY SIMULATION

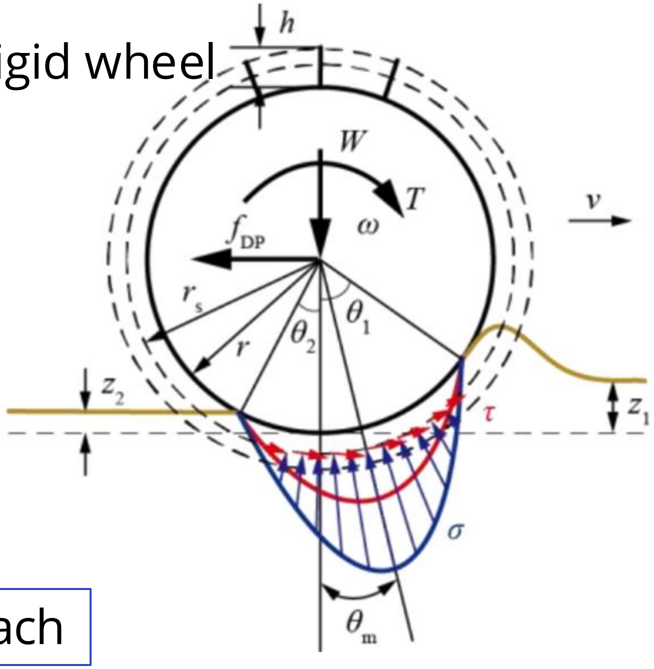
Semi-empirical modeling as pioneered by M. G. Bekker

Extensive heritage and validation base for terrestrial vehicles since 1950’s

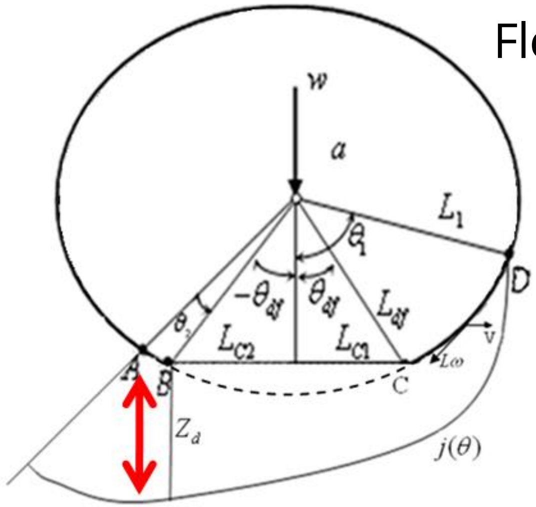
Successfully used to design mobility systems for lunar rovers (Apollo LRV, Yutu), Mars rovers (JPL Mars rovers, ExoMars, Zhurong)

Terramechanics approach

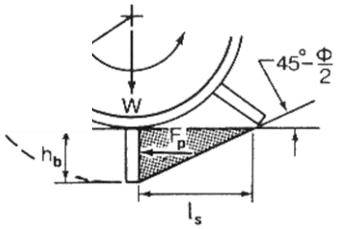
Rigid wheel

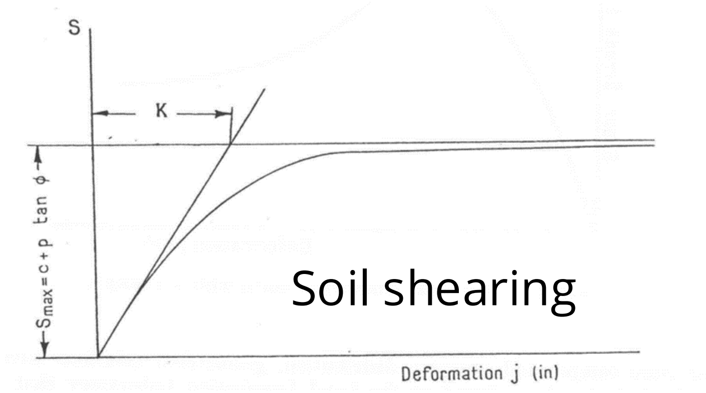


Flexible wheel

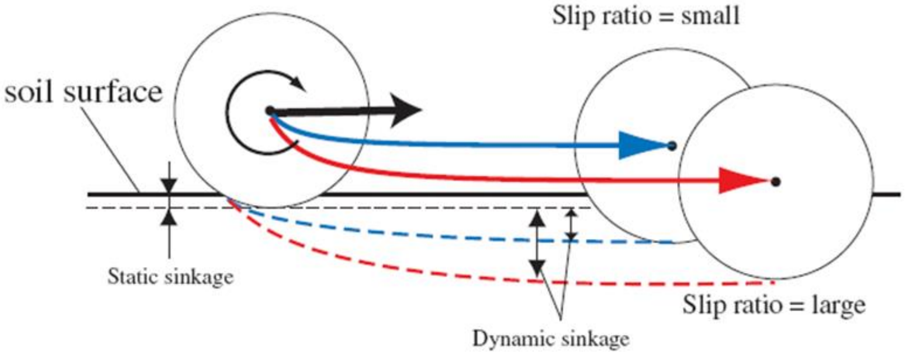


grouser





Soil shearing



Slip-sinkage

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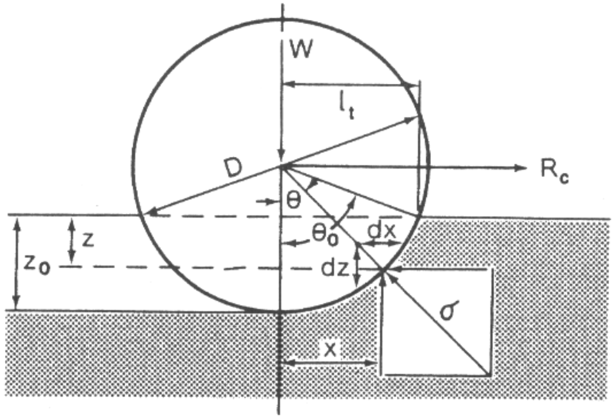
CO-SIMULATION WITH NVIDIA ISAAC SIM FOR GROUND VEHICLES MOBILITY SIMULATION



sinkage, resistance terms, torque

slip-sinkage model

$$z_s = 2h\left(i - \tfrac{1}{2} i^2\right)$$

$$R_c = b \cdot u \cdot k * \int_0^{z_t} z^n \mathrm{d}z = b \cdot u \cdot k * \frac{z_t^{n+1}}{n+1}$$

$$R_b = \frac{b\sin(\alpha+\phi)}{2\sin\alpha\cos\phi}\left(2zC_0k_c + \gamma z^2 k_\gamma\right) + \left(\frac{\pi\gamma l^2(90-\phi)}{540} + \frac{\pi C_0 l^2}{180} + C_o l^2 \tan\left(45 + \phi/2\right)\right)_w$$

$$\tau(\theta) = \left[c + p(\theta)\tan\phi\right]\left[1 - e^{-\left(r/K\right)\left[\theta_0 - \theta - (1-i)(\sin\theta_0 - \sin\theta)\right]}\right]$$

$$F = b\left(\frac{1}{2}\gamma_s h_b^2 N_\phi + q h_b N_\phi + 2c h_b \sqrt{N_\phi}\right)$$

$$M_{\omega,total} = r^2 b \int_0^{\theta_0} \tau(\theta)\mathrm{d}\theta + F\left(r + \frac{2}{3}h_b\right)$$

Terramechanics approach

Single wheel:

$$W = -b \cdot u \cdot k * \int_0^{z_0} z^n \frac{2(z_0 - z) - D}{2\sqrt{D(z_0 - z) - (z_0 - z)^2}} \mathrm{d}z$$

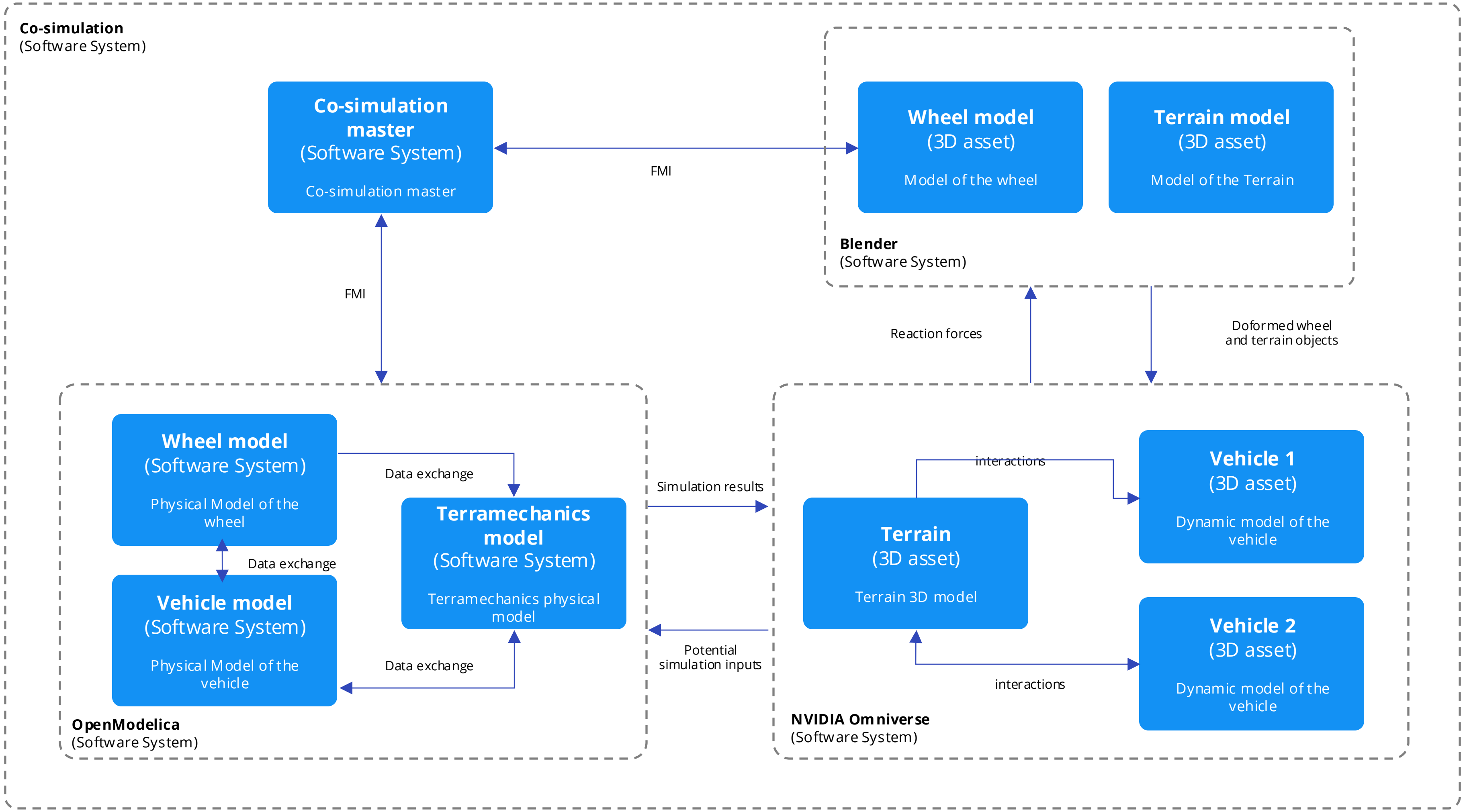
Tandem:

$$W = b \cdot u \cdot k * \sqrt{Dz_2}\left[(z_0 + z_2)^n - \frac{n}{3}(z_0 + z_2)^{n-1} z_2\right]$$

Triplet:

$$W = b \cdot u \cdot k * \sqrt{Dz_3}\left[(z_0 + z_2 + z_3)^n - \frac{n}{3}(z_0 + z_2 + z_3)^{n-1} z_3\right]$$

CO-SIMULATION WITH NVIDIA ISAAC SIM FOR GROUND VEHICLES MOBILITY SIMULATION



MULTI-ROBOT ON THE “MOON”

SoftServe internal accelerator to build a framework for **orchestration of fleets of autonomous robots**

Without limiting generality, reference use case: multi-robot team on the Moon for resource prospecting, exploratory sampling, mining, and hauling near a crewed lunar outpost

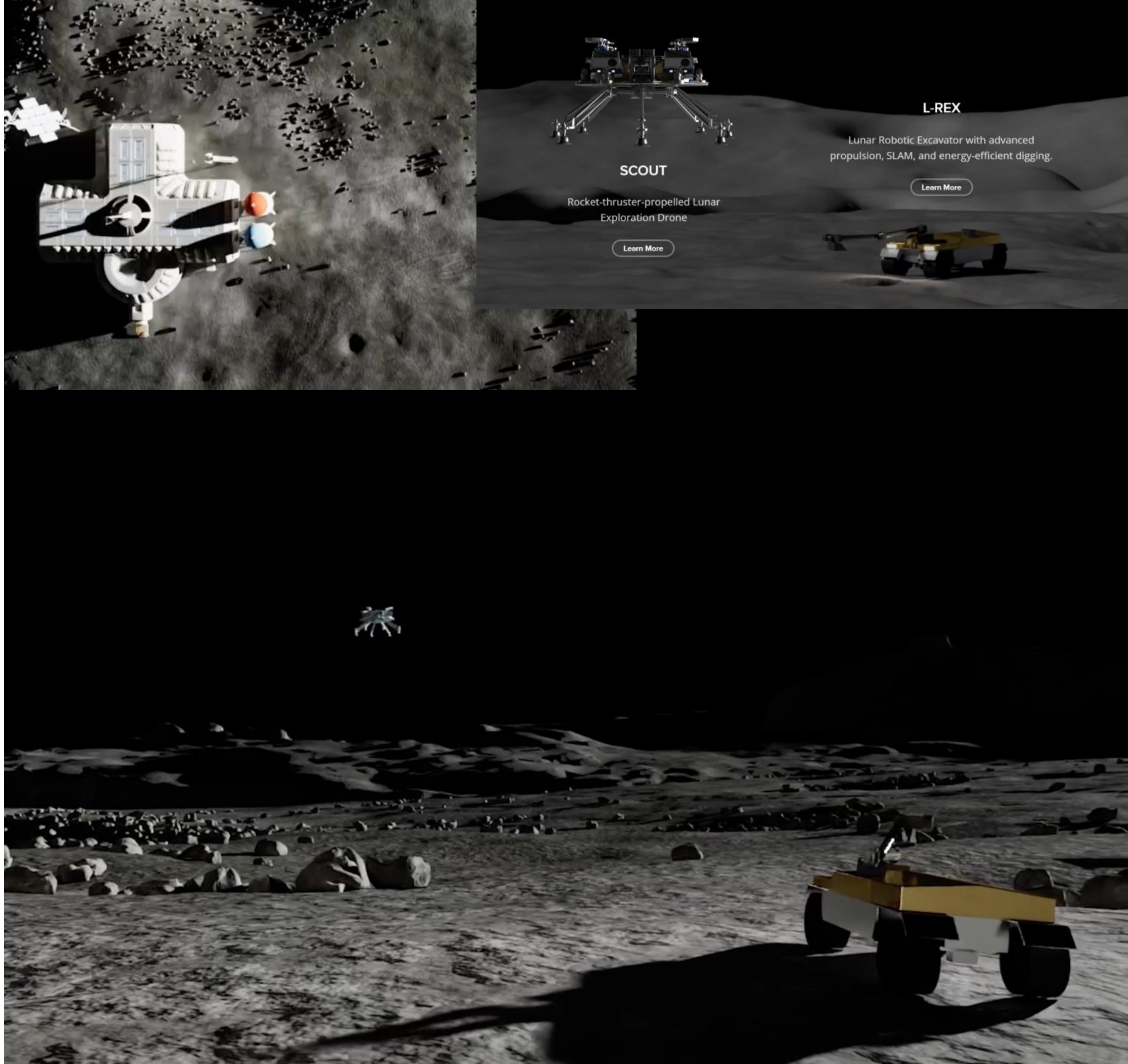
The SoftServe thruster-driven drone flying overhead, several L-REX excavators and haulers

-> combining it all together

NVIDIA Omniverse and **Isaac Sim** to model a notional lunar terrain and the robots, along with their perception and overall control

Central, autonomous orchestration of the robots’ activities

Simulation-first approach: **powered by physical AI** and the SLAM algorithm, our approach tests multi-robot orchestration algorithms in simulated environments



MULTI-ROBOT ON THE "MOON"

TECH STACK:

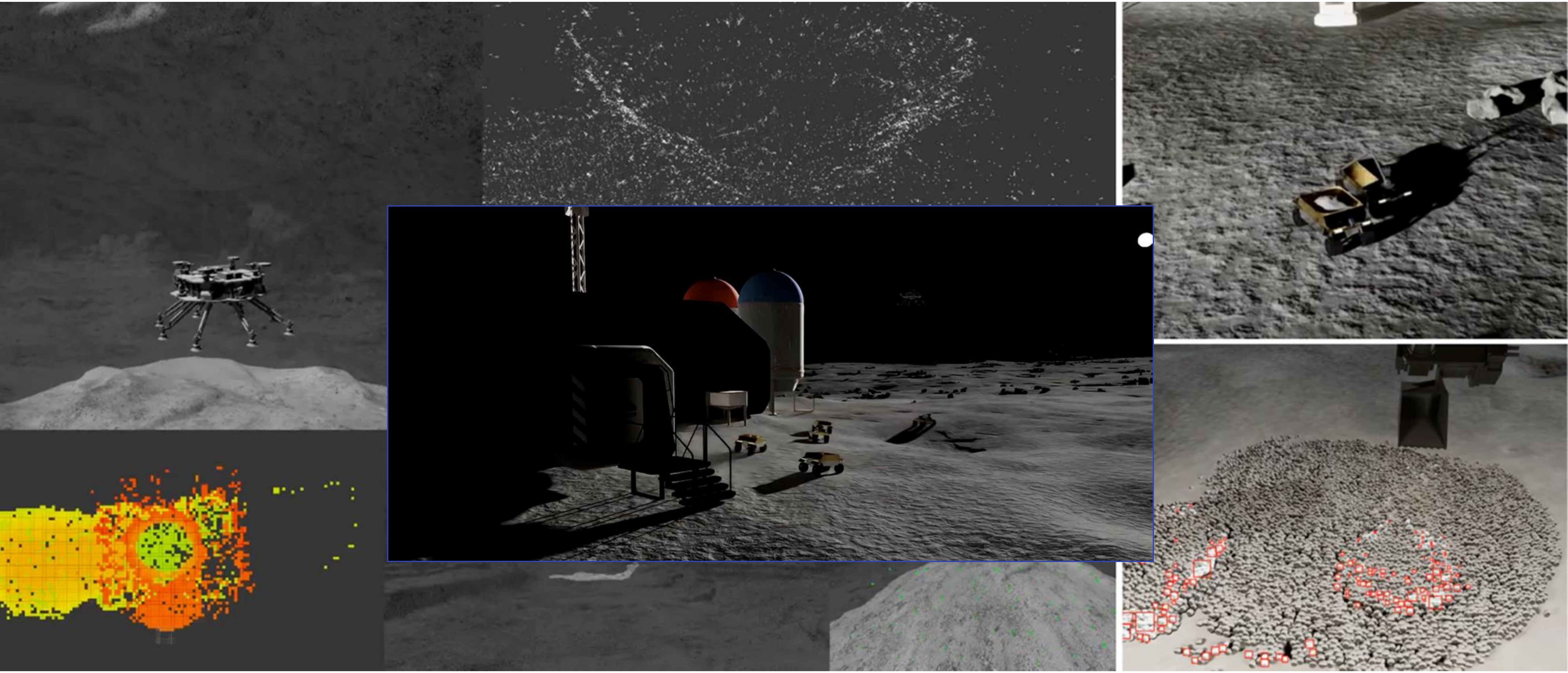
- **Physical AI**: AI-driven physics modeling and optimization for precise simulation, control, and decision-making in challenging environments like space and robotics
- **Multi-Robot SLAM**: Real-time mapping and navigation for autonomous robots
- **Vibration System**: Optimizes digging techniques and energy efficiency for L-REX excavators
- **Co-Simulation with Modelica**: High-fidelity simulations integrating multiple physical interaction environments
- **NVIDIA Isaac Sim™ and Omniverse**: Realistic simulations with advanced visualization and physics-based capabilities
- **ROS 2 Middleware**: Enhances communication and coordination between multiple heterogeneous autonomous robots

COMPONENTS:

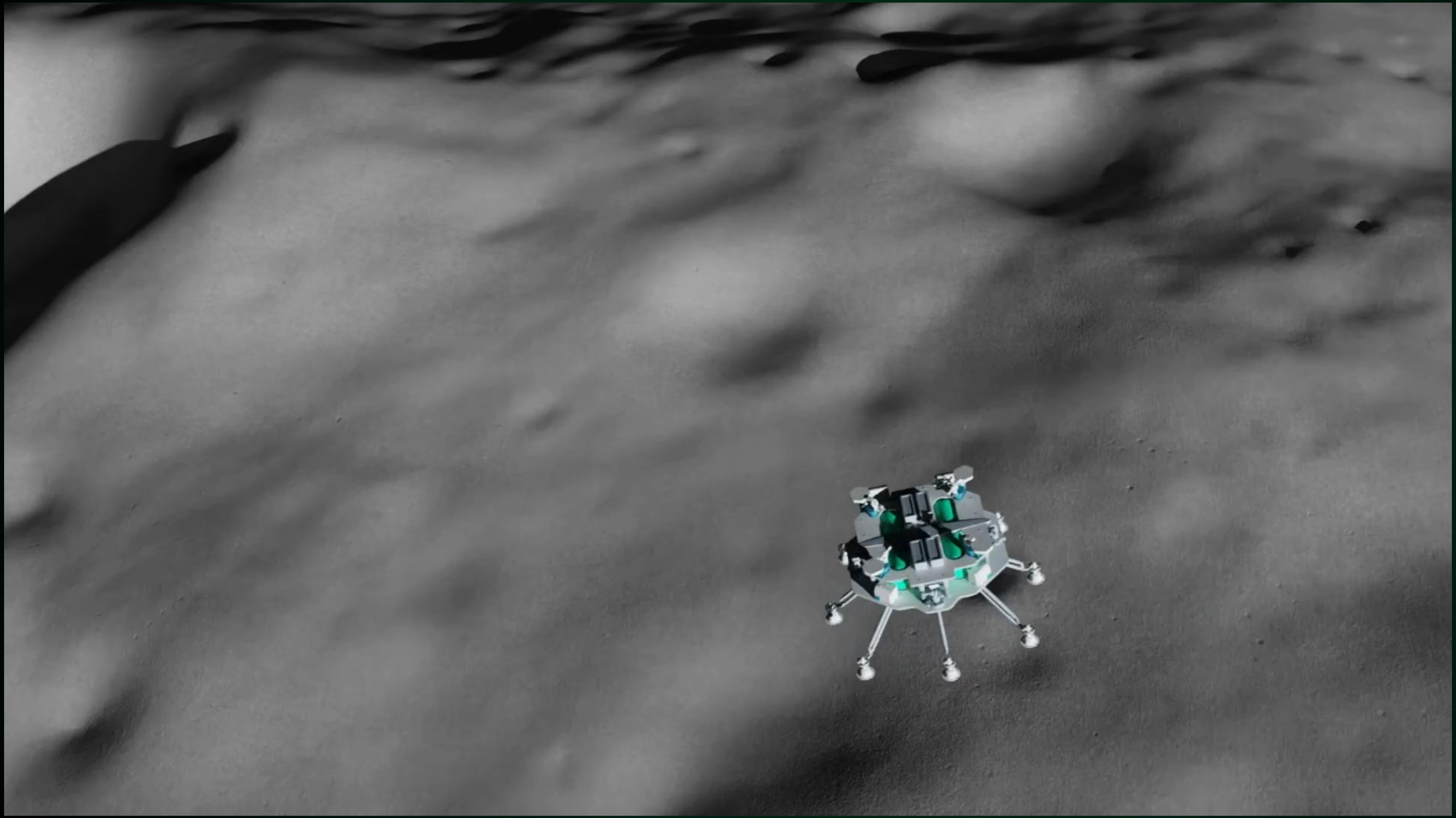
- **SoftServe-Owned Lunar Surface Simulation**: Enables testing of various and complex edge cases in a realistic lunar environment
- **Navigation System**: Capable of maneuvering through deep craters and complex cave systems, accessing previously unreachable resources
- **Terramechanics Modeling**: Provides pre-configured models for simulating soil interactions and optimizing excavation techniques for L-REX excavators
- **Multi-Spectral Vision System**: Pre-built simulation modules for visualizing and identifying icy particles within the soil mass, enhancing autonomous resource mapping and extraction accuracy
- **Multi-Robot Fleet Orchestration**: Scalable system for managing and coordinating diverse robotic fleets, ensuring seamless collaboration

TERRESTRIAL INDUSTRY APPLICATIONS: Adapt the space solution, such as simulation and software development, to Earth industries, including mining, construction, and more

MULTI-ROBOT ON THE “MOON”



MULTI-ROBOT ON THE “MOON” VIDEO



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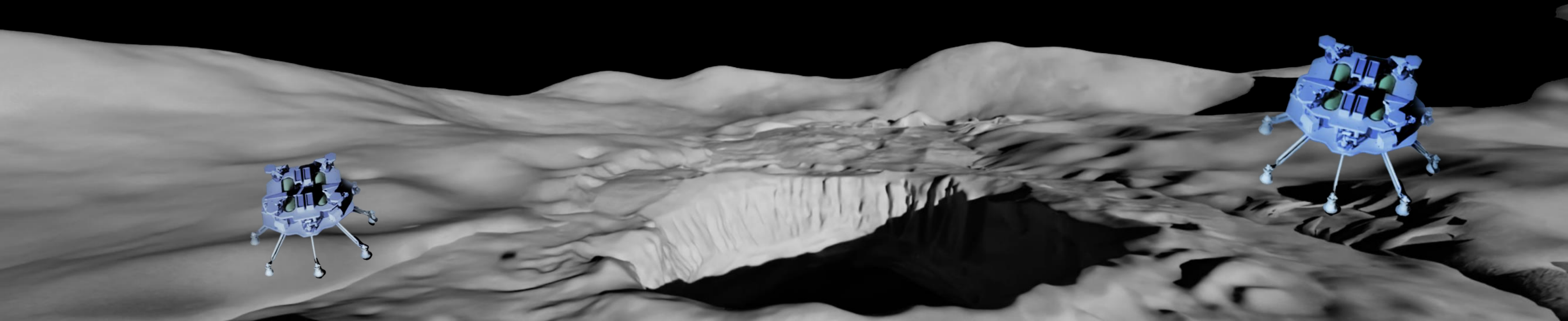
ONGOING NOVEL DIRECTIONS AT SOFTSERVE

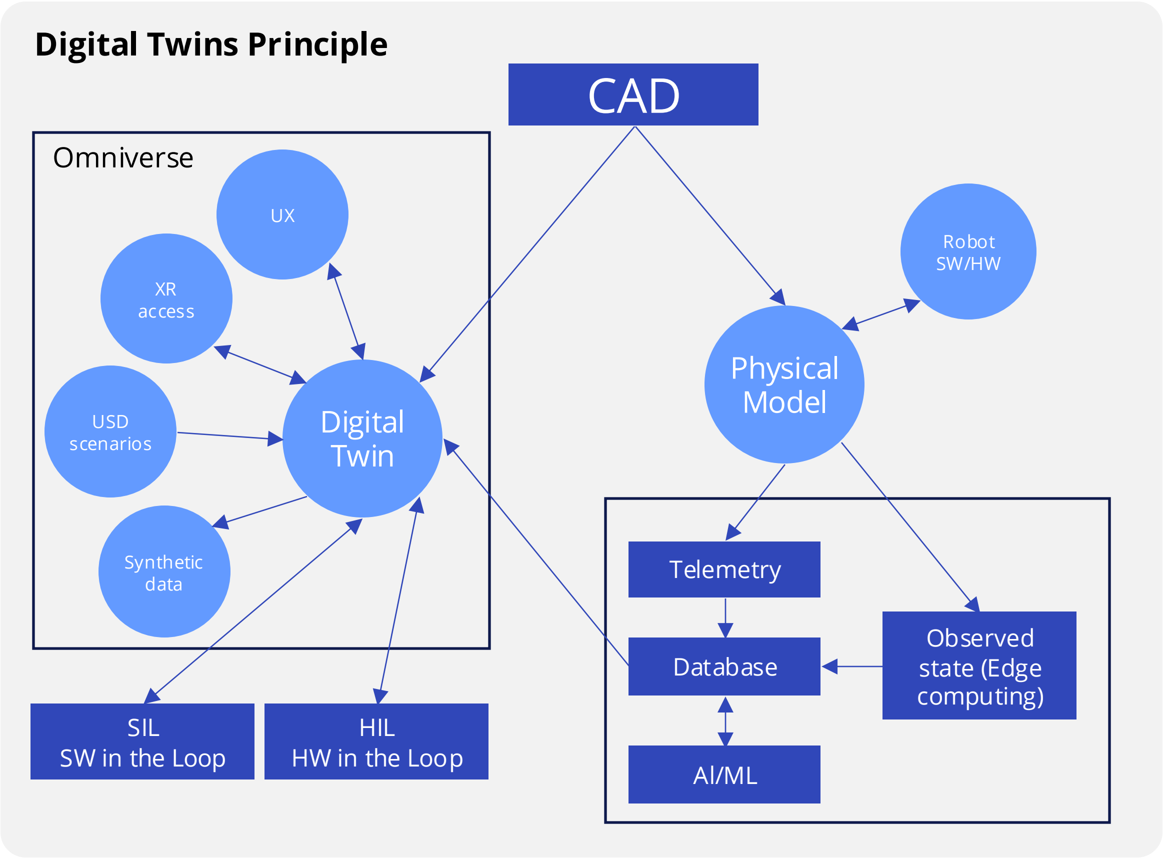


DIGITAL TWINNING OF SATELLITES, SPACE ROBOTIC SYSTEMS, AND OF MISSION SCENARIOS

Adopt comprehensive system behavior simulation including interaction with environment (digital twinning)

Simulation of end-to-end space system behavior: dynamics of satellite formations / clusters / constellations, along with behavior of communications links (digital twin satellite networks (DTSNs)), GNSS interactions (pointing & position knowledge), and other aspects

Perform virtual commissioning (VC), software-in-the-loop (SIL) testing



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OPTIMAL CONTROL OF DYNAMICAL SYSTEMS

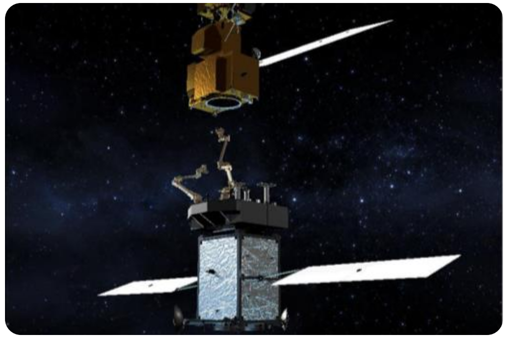
AI-enabled approach to adapt goal function to changing system states, changing environments, and in the face of system uncertainties

Many space use cases, including:

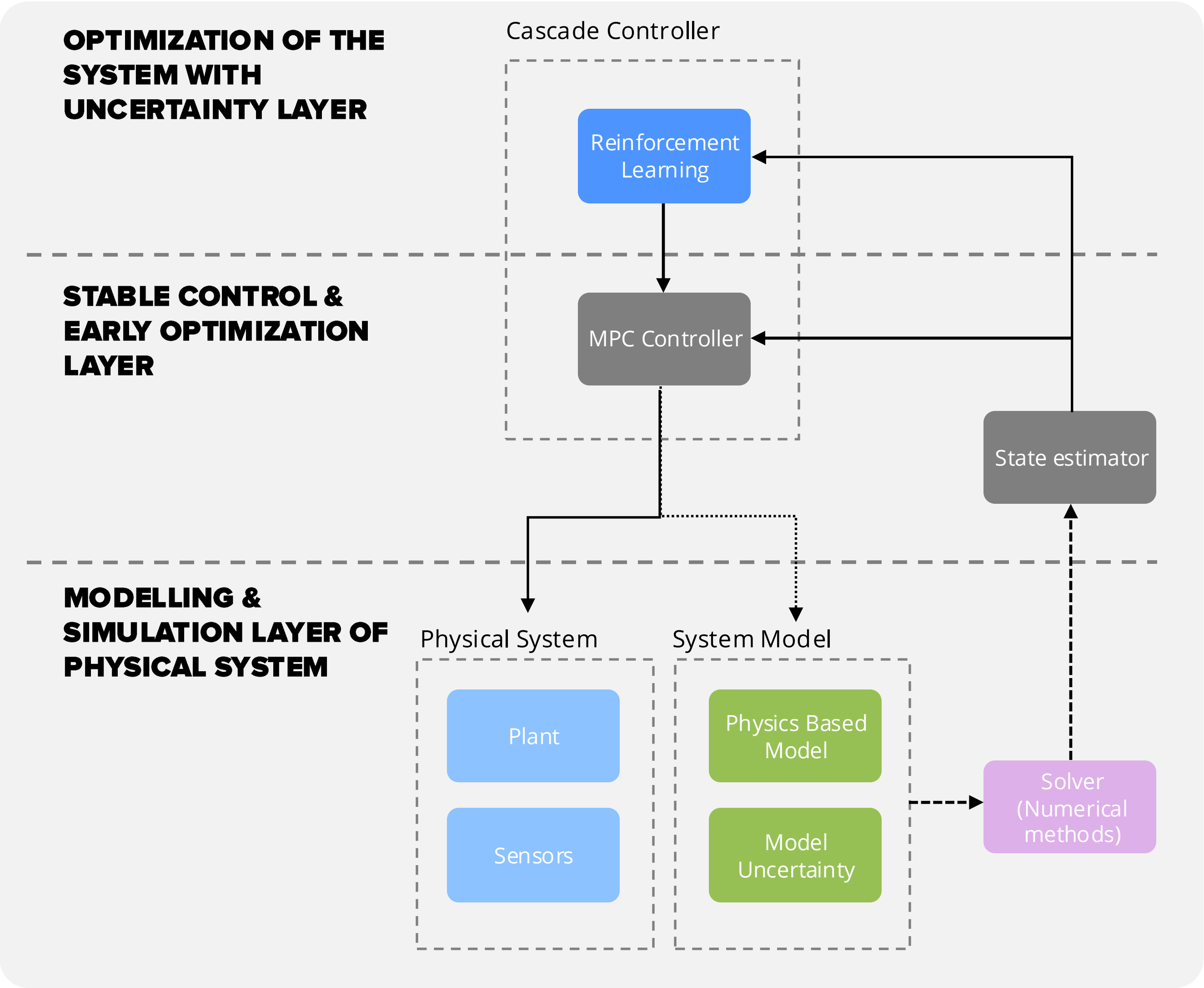
- Proximity operations for rendezvous and capture in orbit (on-orbit servicing / refueling, active debris removal)
- Orbit and position control for satellite formations or constellations

Proper design of such control approach relies on digital twinning and physics-based simulations

CloudCT Nanosat formation of S4 GmbH (Germany)



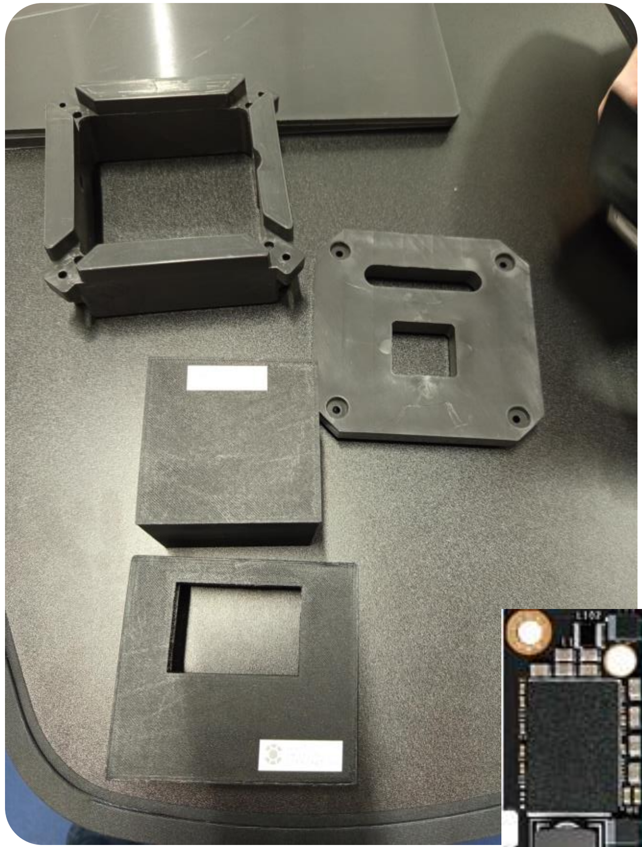
Satellite servicing concept (NASA)



ONBOARD COMPUTE FOR ADVANCED CONTROL

SoftServe running several collaborations:

- E.g. NVIDIA Jetson™ with custom composite radiation shielding



NVIDIA Jetson with dedicated radiation shielding

	PROTOTYPE OF STUDY PROJECT	FLIGHT-READY SOFTWARE		
		Unit test & integration stage	*Validation stage*	*Qualification & Acceptance stage*
LEVEL OF COTS SW UTILIZATION (flight software, simulators, etc)	Very high	High	High	High-medium
EXECUTION ENVIRONMENT	representative HW Dev workstation	representative HW Dev workstation	representative HW Dev workstation	flight-intended HW

Substantial code rewrite may be needed in the next stage

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THE PREMISE OF GEN AI FOR ROBOTICS

Gen AI is transforming SDG, enabling highly automated, scalable, and diverse data pipelines tailored to the needs of physical AI.

Gen AI creates comprehensive datasets essential for training AI models in robotics, autonomous systems, and manufacturing.

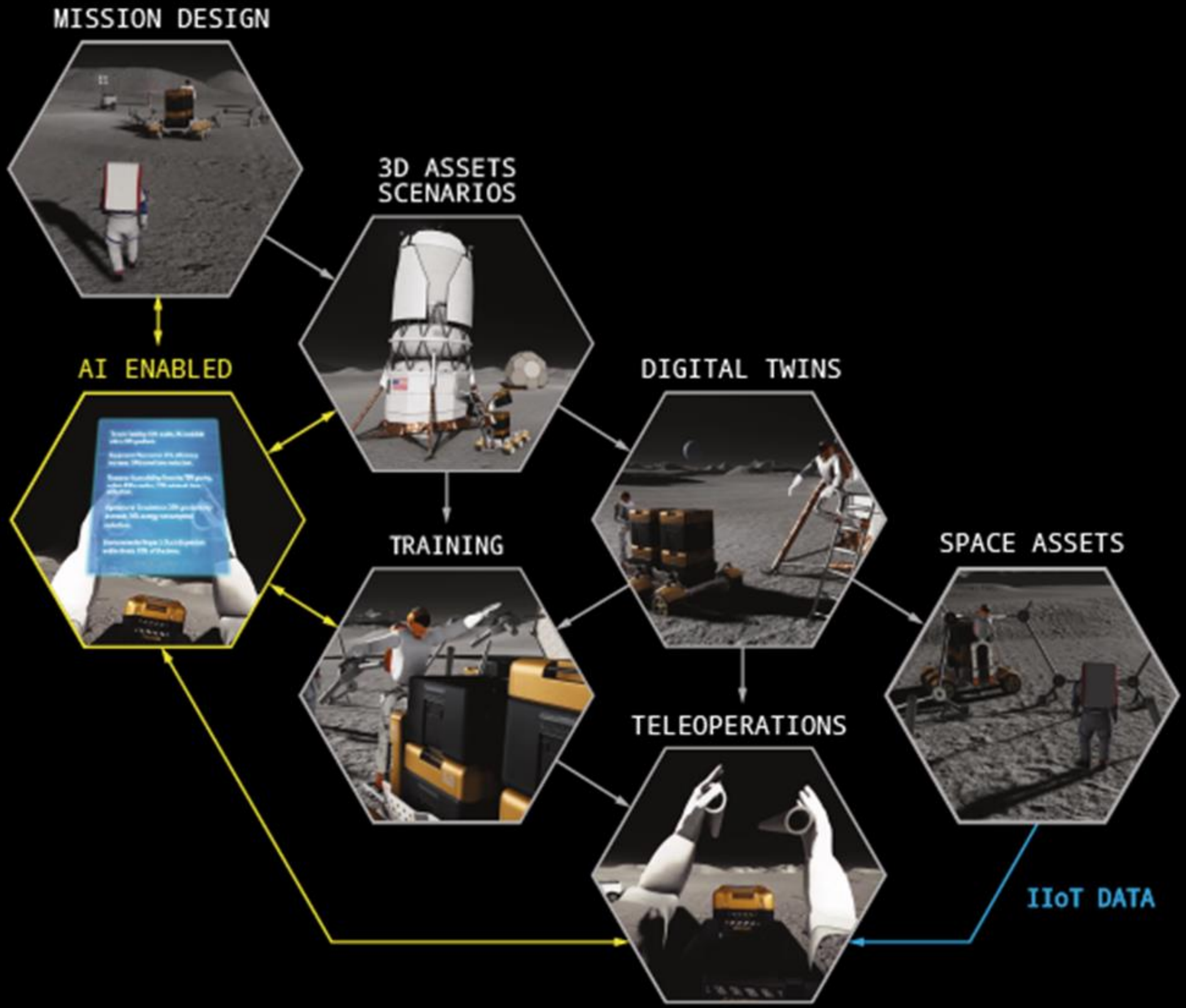
Building scalable pipelines that generate highly diverse synthetic datasets, accelerating the development of robust physical AI solutions across industries.

Leads to smarter, safer, and more effective robots capable of navigating unpredictable environments

→ **ESSENTIAL FOR SPACE ROBOTICS OF THE FUTURE.**

SPACE ROBOTICS AND GEN AI – USE CASE #1

Use case: astronaut & robot interaction via voice control: domain-based vocabulary extension



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SPACE ROBOTICS AND Gen AI – USE CASE #2

Use case: manipulation of unknown objects

SPACE ROBOTICS AND Gen AI – USE CASE #3

- **Use case:** real-time and autonomous adaption to changing environments
- Gen AI allows adding the next level of complexity to reinforcement learning, enabling planning of longer and more complex actions
- **L-REX lunar excavator use case**: excavator is scooping icy regolith, starting with some predefined policy. But as it works, it collects more data and tries to apply better strategy (identifying interaction with rocks, engaging vibratory actuator)
- **NVIDIA Cosmos™** can initialize world state from image -> ***physical AI***. It requires post-training on scooping data, to better incorporate ground physics, but after collecting such data, it can be utilized as "robot's imagination"
- The feedback loop is much shorter than what a teleoperation from the Earth can achieve

Generated via **NVIDIA Cosmos™**:

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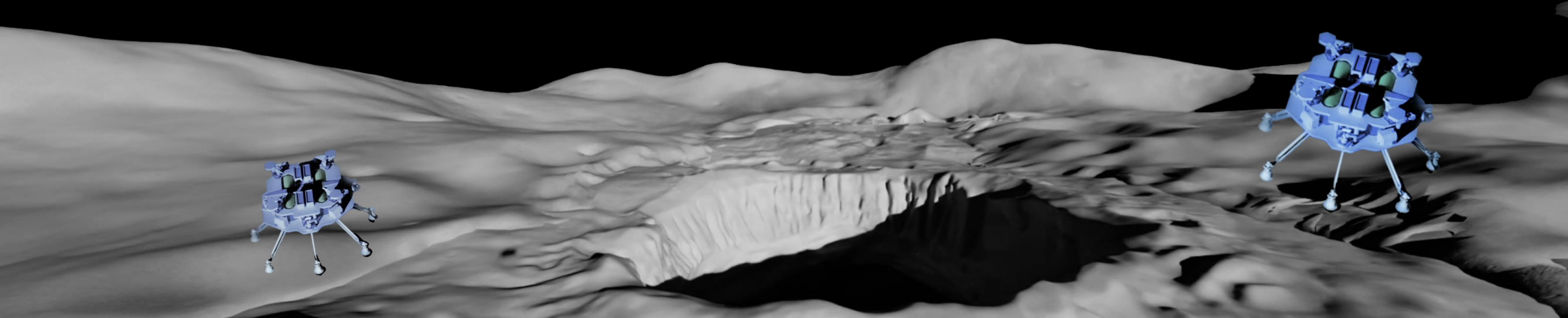
TAKEAWAYS



SOFTSERVE IN SPACE & IN THE LUNAR ECONOMY

There is a lot going on in space and lunar exploration

There is money to be made: using in-situ resources to make and sell consumables (rocket propellants, breathing air, water, …)

SoftServe is part of this effort: for now, with "simulation-first", alongside system design & testing

SoftServe's space robotics practice is built on NVIDIA Omniverse-> physics engine, various extensions, visualization

NVIDIA Omniverse™

NVIDIA Isaac Sim enables space-related simulations, digital twinning, and physics-based modeling

High-fidelity modeling and simulation of complete spacecraft (digital twinning) including sensors and complex instruments, controllers, data models, agents, robotics systems, interaction with the free space and surface environment

…and we have a lot more on our space agenda!

LET'S TALK!

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THANK YOU!

LUTZ RICHTER

Space Projects Consultant, SoftServe
lrich@softserveinc.com

ANY QUESTIONS?
LET'S TALK

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FOR THE FUTURE