LUNAR CRUISER

TOYOTA

Ken Yamashita
Project Head
Advanced R&D and Engineering Company
Lunar Exploration Mobility Works Project
Toyota Motor Corporation

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Lunar Cruiser Project Significance and Value

Contribution to the society and to the overall good

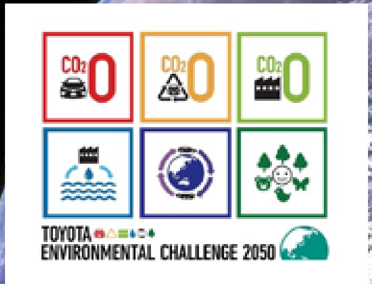
Contribute to international cooperation and the Artemis Program

Technology development

Feedback

Earth to Moon, Moon to Earth

Apply technologies fine-tuned through lunar rover development on the Moon back on Earth



Technology improvement

Take up the challenge of entirely unrelated technology

Human resources development

Help people grow in the toughest conditions they have ever experienced

Truly **circular technology**: Powering **lifestyles and vehicles** with only **sunlight and water**

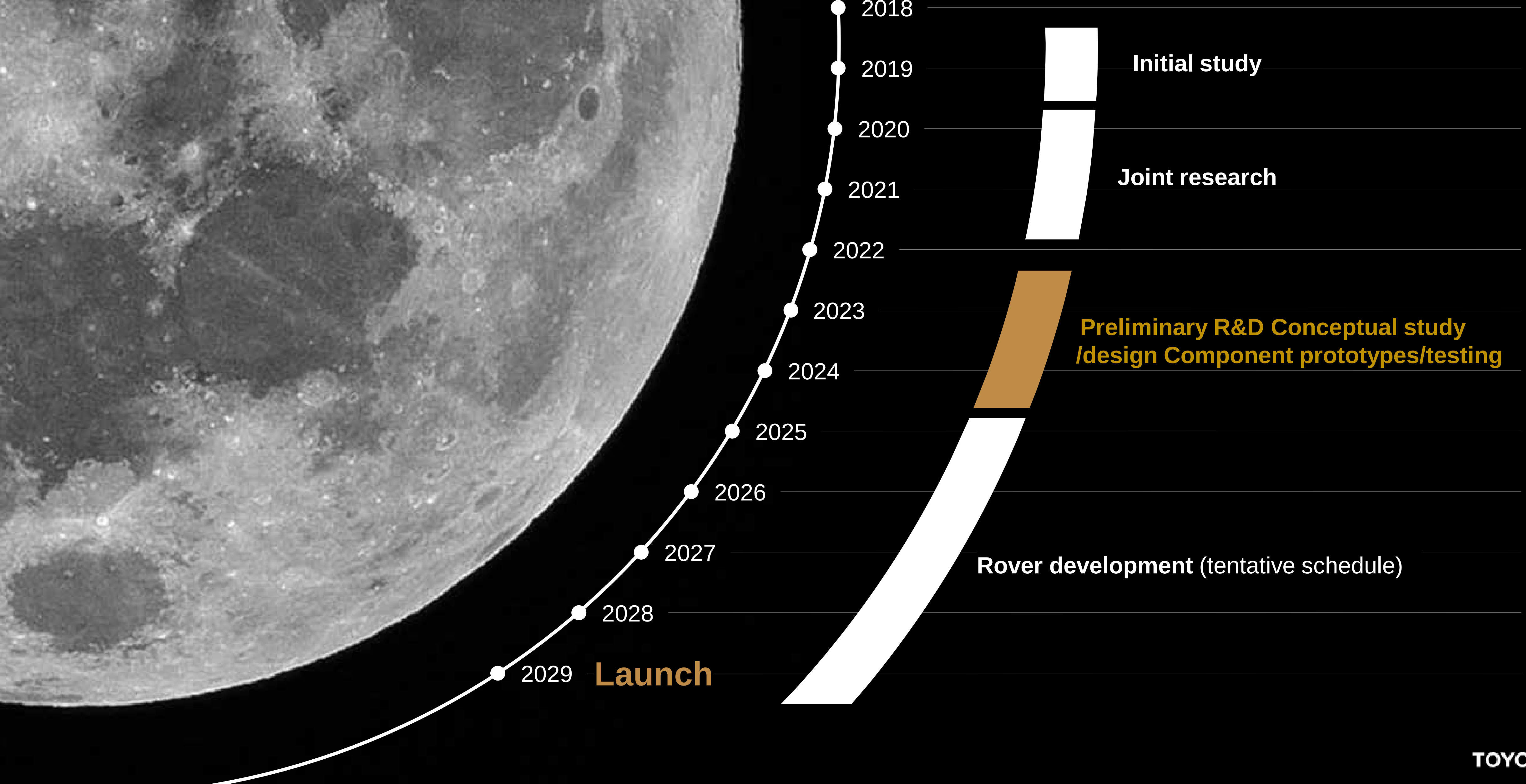
Realization of a circular economy

<Moon> Develop circular systems using sunlight, water and hydrogen
→ <Earth> Contribute to a carbon-neutral circular economy

People-centric town and mobility development

<Moon> Augment the value of mobility: Lunar vehicle and lunar community challenges
→ <Earth> Develop towns where people live happily; make mobility safe for everyone

Overall Development Roadmap



Core Technology

01

Regenerative fuel cells (RFC)

02

Off-road driving performance

03

Automated off-road driving

04

User experience (UX)

Habitability, visibility, operability, etc.

Regenerative Fuel Cells (RFC)

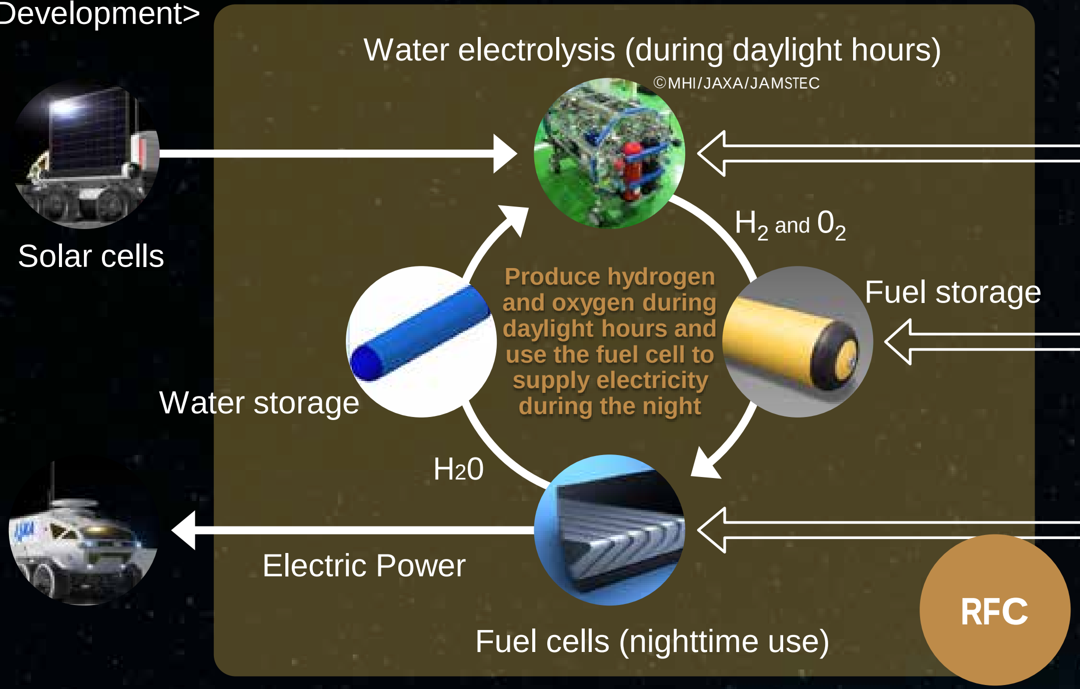
Requirements for the Mission/for the Lunar Environment

Getting through lunar night (14 days) without sunlight

Issues/Challenges

Compact, lightweight, sustainable energy system to repeatedly regenerate large amounts of energy during lunar daytime

<Technology Development>



Apply marine technology (Partnership with MHI)

Further reduce tank weight

Improve efficiency/structure through specialized development

Harness Earth-built fuel cell technology/reliability on the Moon

※1 ※2 Source : TOYOTA INDUSTRIES CORPORATION website

Next step: **Confirm functionality and performance through demonstration tests simulating lunar operations.**

Regenerative Fuel Cells (RFC)

Benefits for Earth: Sustainable Hydrogen Society —Towns that Can Be Lived in Forever—

Fuel cell technology

Water electrolysis technology

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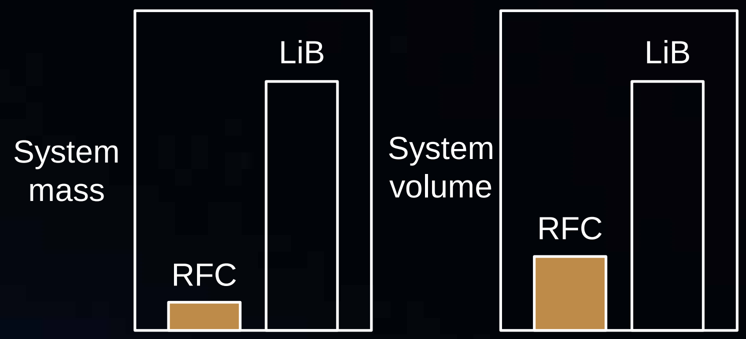
RFC system

Enables high-efficiency hydrogen production using sunlight, **making it compact and lightweight** enough to be mounted in vehicles

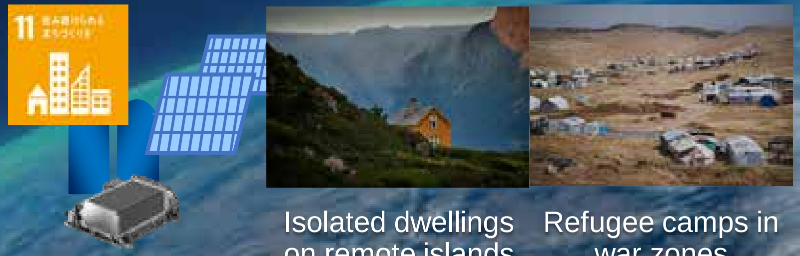


Estimation based on assumed conditions for a lunar vehicle

RFCs are effective as a compact, lightweight energy source

Earth

Contribute to circular living and carbon neutrality worldwide—anywhere, anytime



Isolated dwellings on remote islands or in remote villages

Refugee camps in war zones

Use only water and sunlight

Semi-permanently sustainable

Zero running costs

Marine vessels

Disaster evacuation centers

02

Off-road Driving Performance

Requirements for the Mission/for the Lunar Environment

Safe driving in varied environments with regolith, craters, rocks and slopes

Issues/Challenges

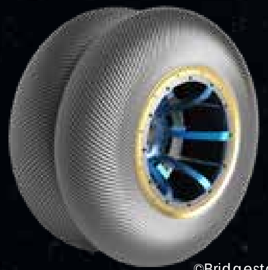
Development of regolith-compatible tires and driving force control, achieving balance between driving performance and power consumption

<Technology Development>

Off-road driving test vehicle #1

- Two-tonne vehicle capable of off-road driving
- Motion control optimized using four-wheel independent in-wheel motors and steering mechanisms

Component development examples



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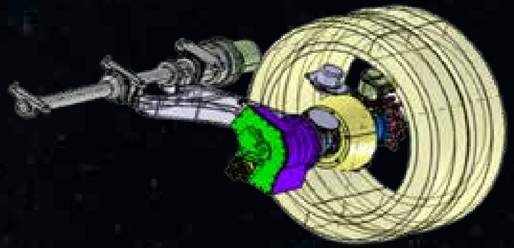
Metal tires (Bridgestone)



Suspension combining the robust structure cultivated with the Land Cruiser and electrification technology

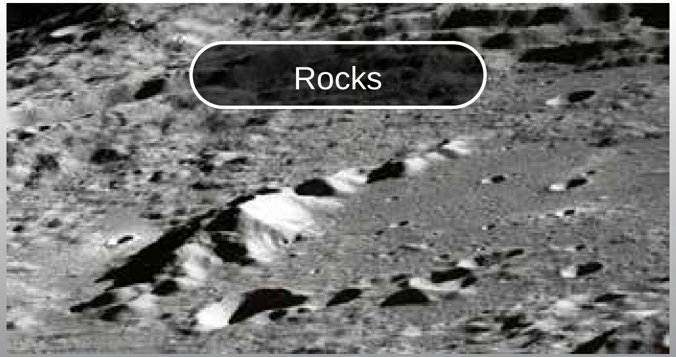
High-efficiency driving performance/rollover risk prediction in varied environments

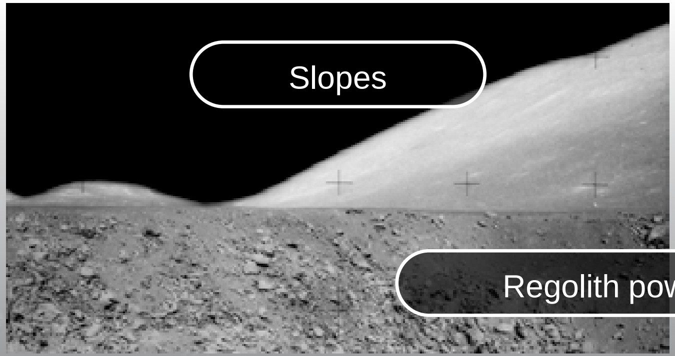
Next step: **Off-road driving performance development with full-scale off-road driving test vehicle #2**

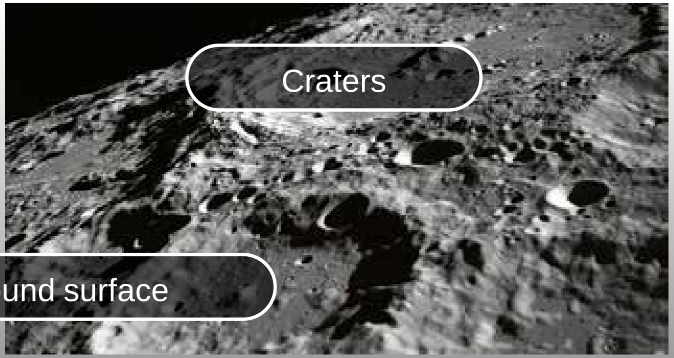
02

Off-road Driving Performance

Benefits for Earth: Driving Technology—Driving/Automated Driving Over Unfamiliar Terrain







Rock traversing

→ Crawl control

Avoid large boulders

Control speed depending on risk

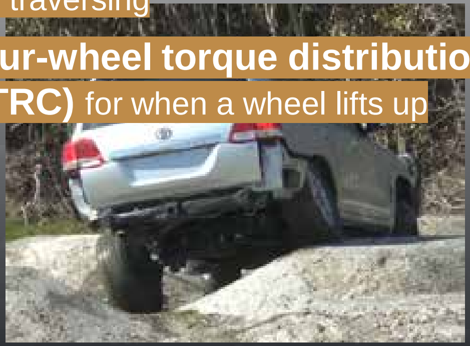
→ Automated off-road driving

Slip ascent/descent

→ eTRC/eABS incorporating terramechanics

Slope camber driving

→ Rollover prevention control with left-right torque distribution/independent steering



Crater traversing

→ Four-wheel torque distribution (eTRC) for when a wheel lifts up

Technology from the Moon

Technology developed for uncharted, roadless Moon terrain, supporting safe driving on all kinds of terrain on Earth

03

Automated Off-road Driving

Requirements for the Mission/for the Lunar Environment

Automated driving on untraveled off-road routes

Issues/Challenges

Lunar surface self-localization, obstacle detection, avoidance route creation

<Technology Development>

Unvisited place

Estimate current position

Navigation technology (self-localization)

Radio navigation

Estimate current position using radio signals

Star tracker

Estimate attitude angle from star positions

Inertial navigation

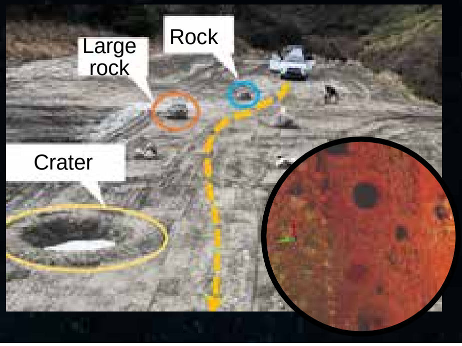
Estimate speed, distance traveled from acceleration on three axes

Ascertain surrounding environment

Obstacle detection using LiDAR point clouds

Determine traversable surfaces

Identify obstacles and surface gradients

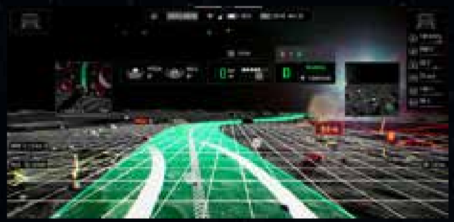


Generate route to the goal

Avoidance route generation

Optimal route search

Generate routes for safe driving
→ Automated driving along a route
→ Guide for manual driving



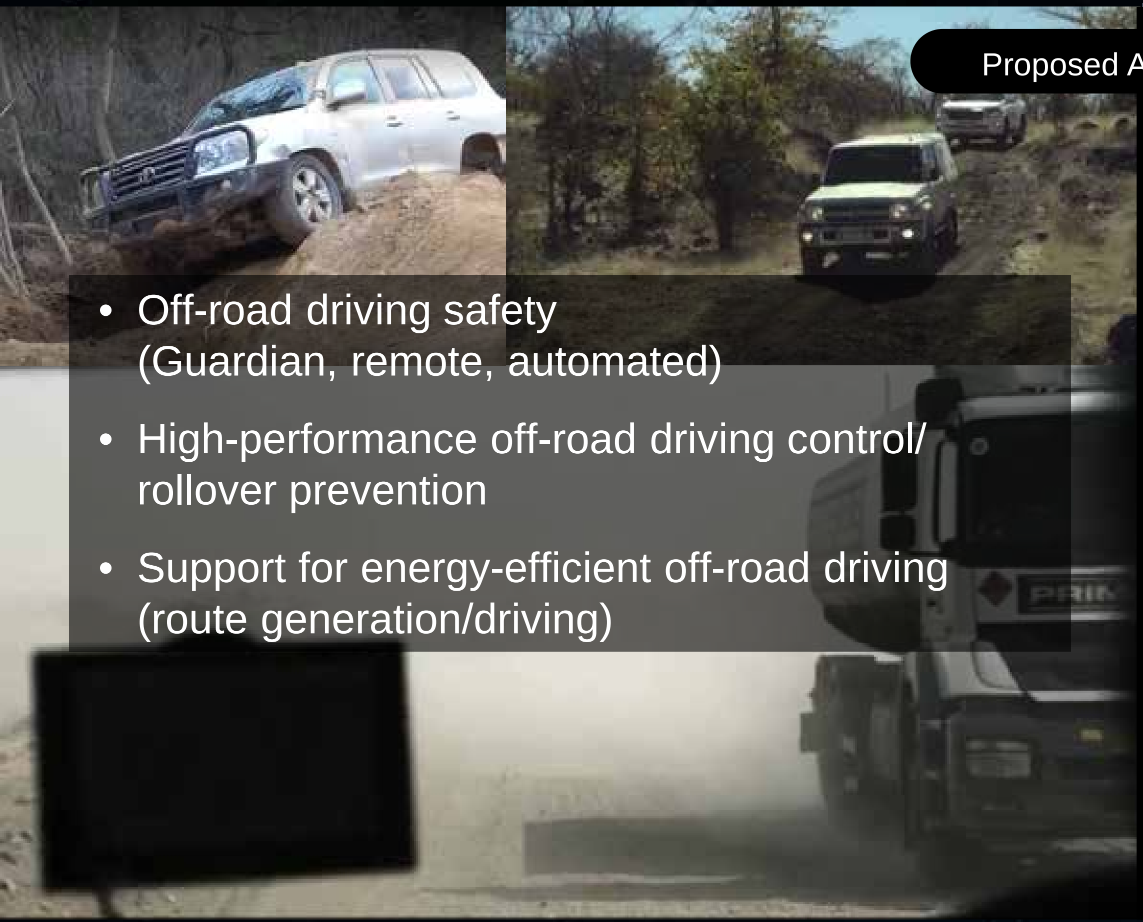
Next step: **Develop and evaluate automated driving functions with full-scale off-road driving test vehicle #2 on lunar mockup test course**

03

Automated Off-road Driving

Benefits for Earth: Driving Technology—Driving/Automated Driving Over Unfamiliar Terrain

Proposed Applications



- Off-road driving safety (Guardian, remote, automated)
- High-performance off-road driving control/ rollover prevention
- Support for energy-efficient off-road driving (route generation/driving)

- Checking of disaster circumstances (remote, automated)
- Goods transportation in dangerous areas (remote, automated)

04

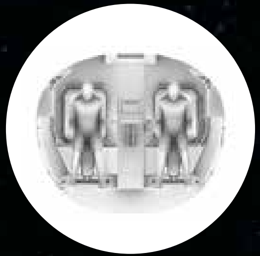
User Experience (UX)

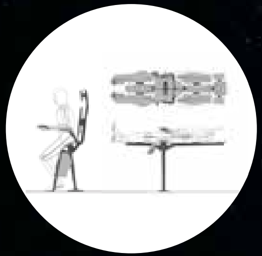
Requirements for the Mission/for the Lunar Environment ››› **Issues/Challenges**

Requirements for the Mission/for the Lunar Environment	Issues/Challenges
(1) Living on-board (confined space) for one month	**(1) Large mental strain, affecting crew work efficiency/motivation**
(2) 100% off-road driving on monochromatic lunar surface (up to 8 hrs/day, 6 days in a row)	**(2) Unsafe activity as it is hard to make out travel path with eyes only, resulting in operating/judgment errors**

<Technology Development>

Comfortable living space | **Safe, dependable control features**



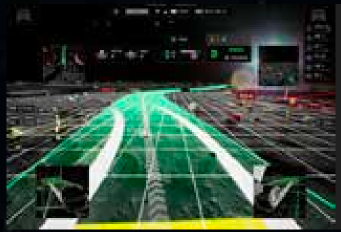


Body posture support in multiple scenarios (e.g. driving, living, sleeping)

Design of spacious-feeling spaces
- No wall-ceiling boundary
- Expand areas around lines of vision

Habitability verification using full-scale mockup

Intuitive driving control with a compact, lightweight device



Driving assistance on a superimposed display

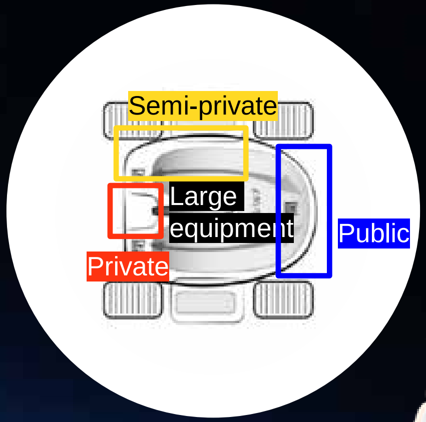
Operability verification with a driving simulator

Next step: **Improve rover safety and comfort through verification using mockups and a driving simulator**

User Experience (UX)

Benefits for Earth: People-Centric Mobility Design

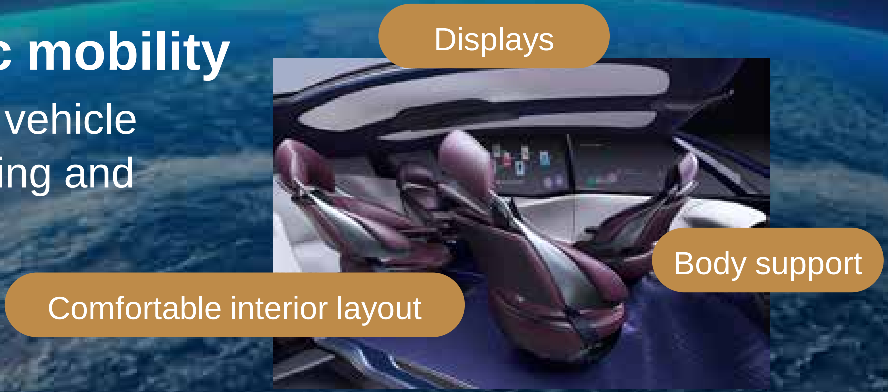
Provide freedom to people in extreme conditions in a confined space far from Earth, and achieve comfortable, dependable mobility, healthy living with public-private balance, and a moving experience.

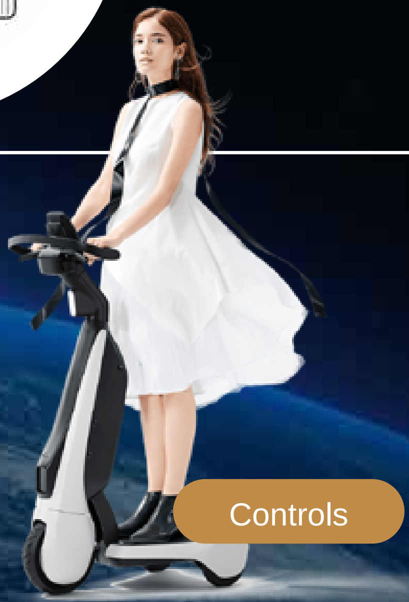


Space design with public/private zoning to optimize the feelings and relationships of multiple occupants

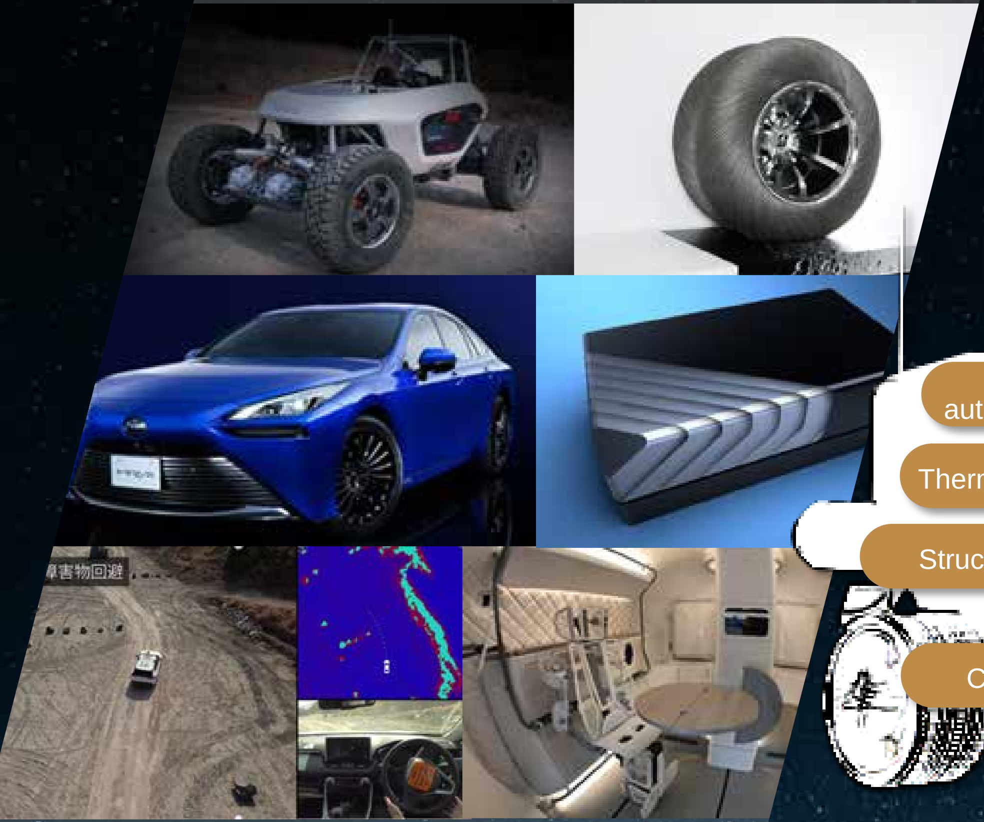
Earth

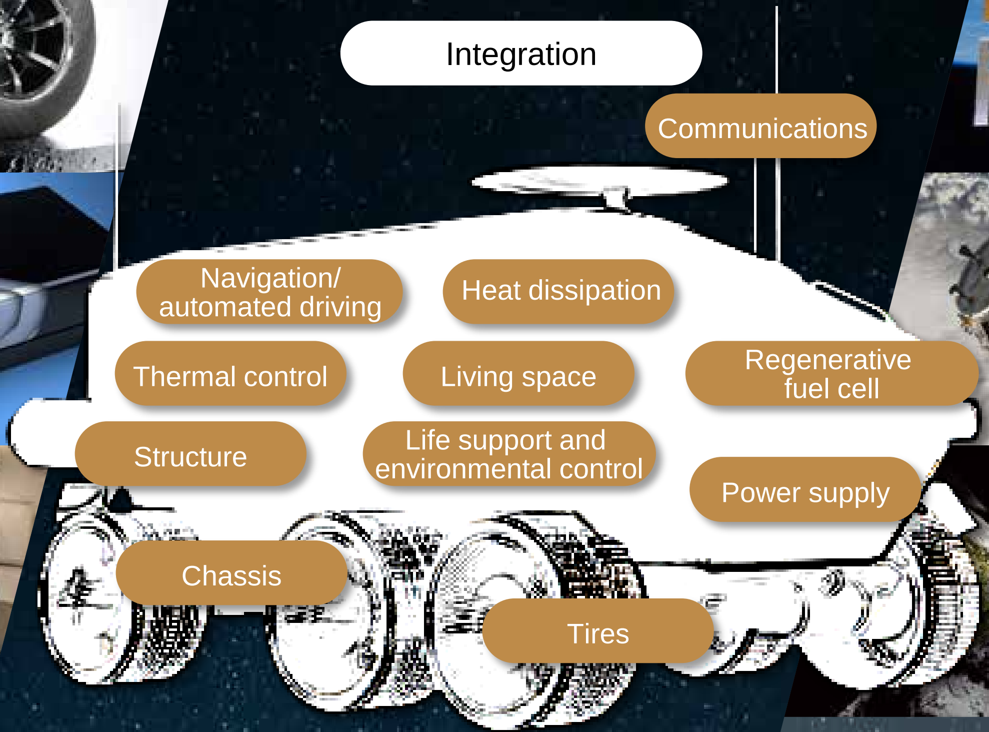
Contribute to **people-centric mobility design** to support diversifying vehicle trends, including automated driving and personal mobility





Integration of Space and Automotive Technologies





Automotive technology

Space technology

Partnership Between Toyota and Mitsubishi Heavy Industries

Mid-2020s — 2029

Support exploration with human spaceflight technology


©JAXA/NASA
International Space Station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H-II Transfer Vehicle(HTV)


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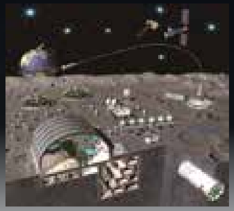
Gateway I-Hab

- Human space stay technology (Pressurized spaces, Environmental Control and Life Support System)


Lunar base construction

Support exploration with mobility technology

- Driving demonstration expertise
- Lunar surface data

- Living space + mobility function
- Driving for more than 10 years/10,000 km

MITSUBISHI HEAVY INDUSTRIES

- Spacecraft integration technology
- Space environment resistance technology
- Human space stay technology

TOYOTA

- Quality, durability, reliability (QDR)
- Driving performance, fuel cells, automated driving
- People-centric mobility development


END