LUNAR CRUISER



TOYOTA

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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 improvement

Take up the challenge of entirely unrelated technology

Human resources development

Help people grow in the toughest conditions they have ever experienced

Technology development

Feedback

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

Earth to Moon, Moon to Earth

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





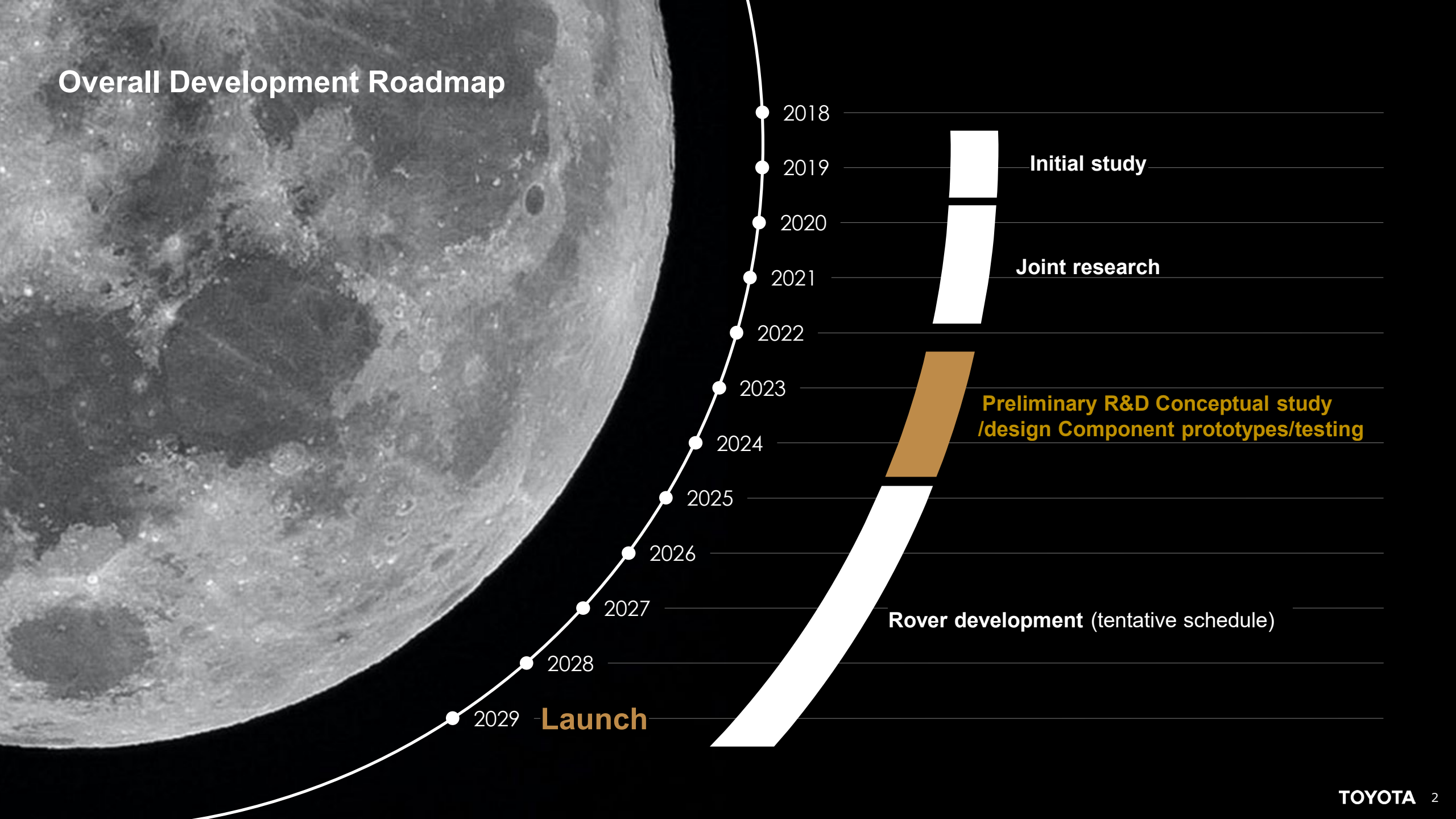
Realization of a circular economy

<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



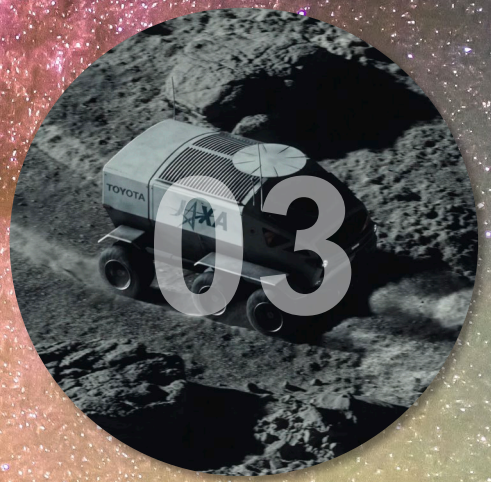
Core Technology



Regenerative fuel cells (RFC)



Off-road driving performance



Automated off-road driving



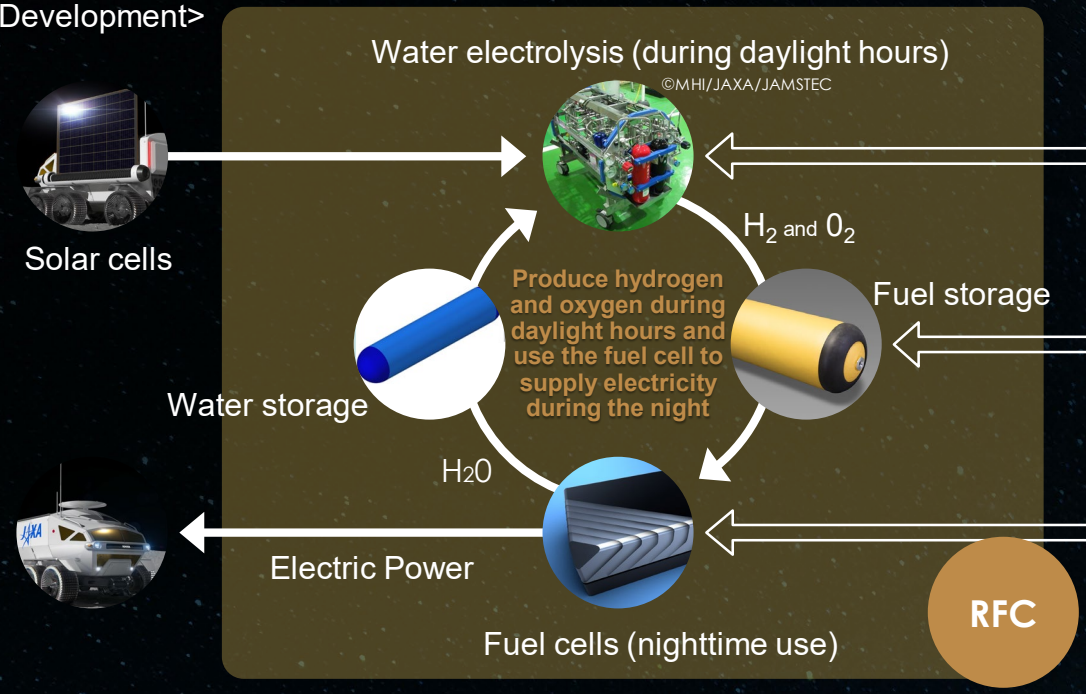
User experience (UX)

Habitability, visibility, operability, etc.

01 Regenerative Fuel Cells (RFC)

Requirements for the Mission/for the Lunar Environment	Issues/Challenges
Getting through lunar night (14 days) without sunlight	**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

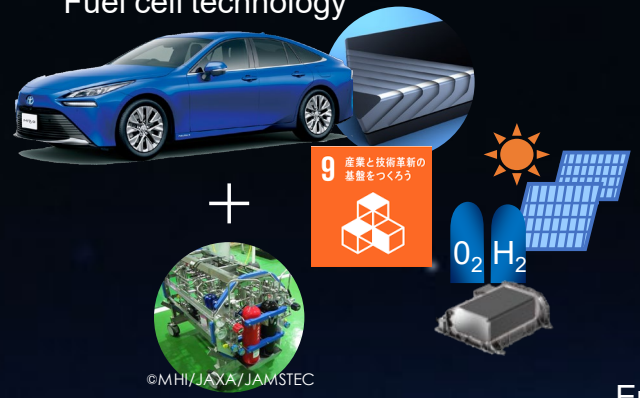
※1 ※2 Source : TOYOTA INDUSTRIES CORPORATION website

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

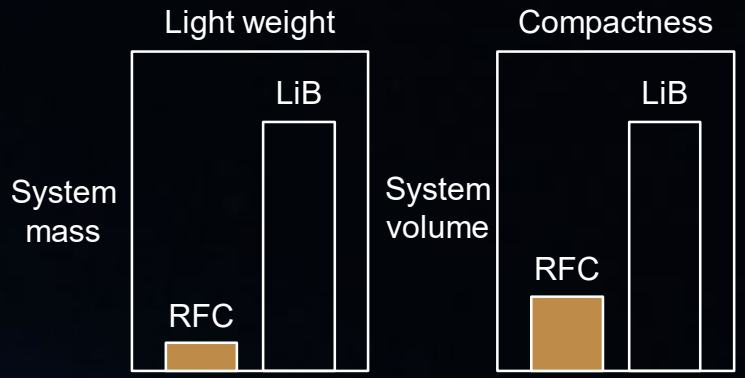


Water electrolysis technology

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

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Issues/Challenges

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

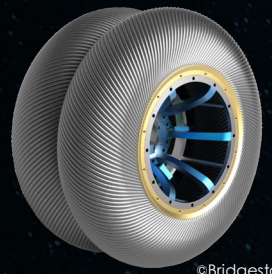
<Technology Development>

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



Metal tires (Bridgestone)



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



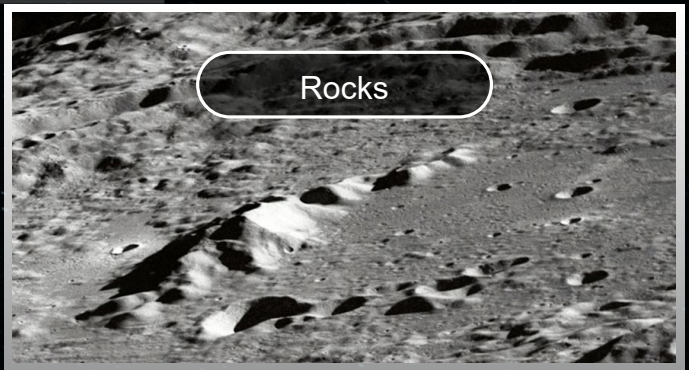
High-efficiency driving performance/rollover risk prediction in varied environments

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

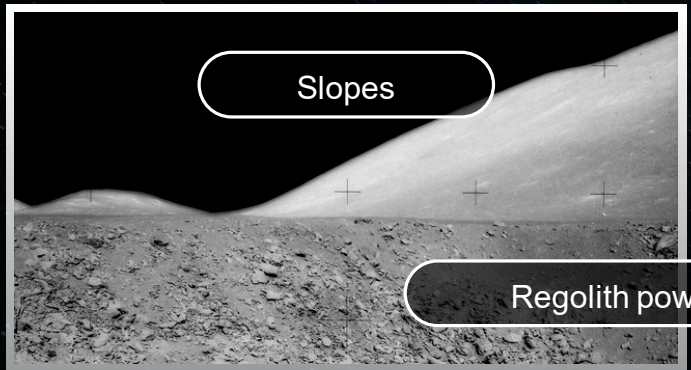
02

Off-road Driving Performance

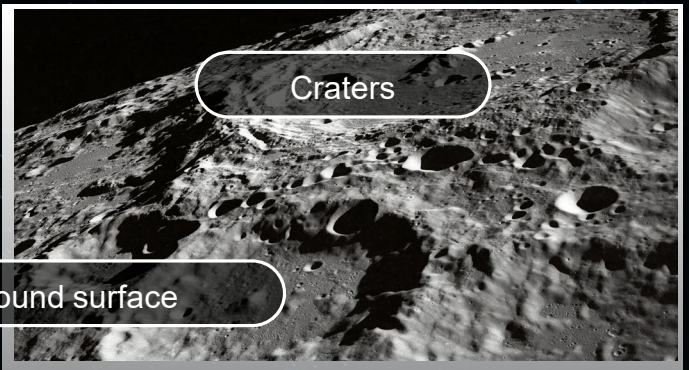
Benefits for Earth: Driving Technology—Driving/Automated Driving Over Unfamiliar Terrain



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Rock traversing
→ Crawl control

Avoid large boulders

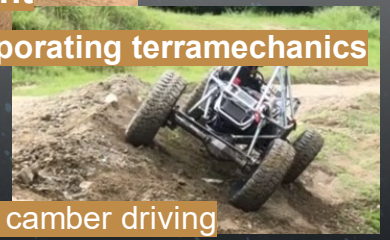
Control speed depending on risk

→ Automated off-road driving



Slip ascent/descent

→ eTRC/eABS incorporating terramechanics

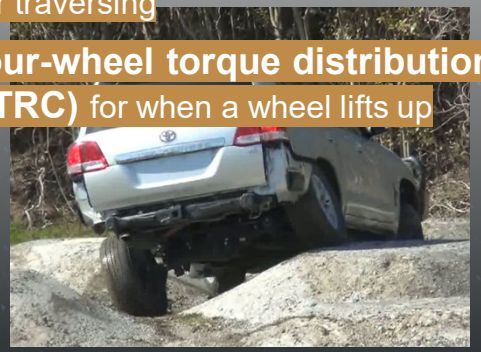


Slope camber driving

→ 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

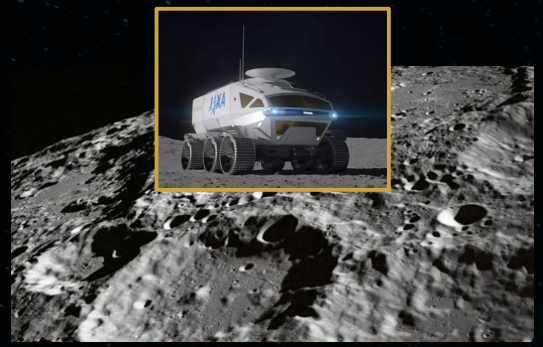
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Issues/Challenges

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

<Technology Development>

Unvisited place	Estimate current position	Ascertain surrounding environment	Generate route to the goal



Navigation technology (self-localization)

Radio navigation

Estimate current position using radio signals

Star tracker

Estimate attitude angle from star positions

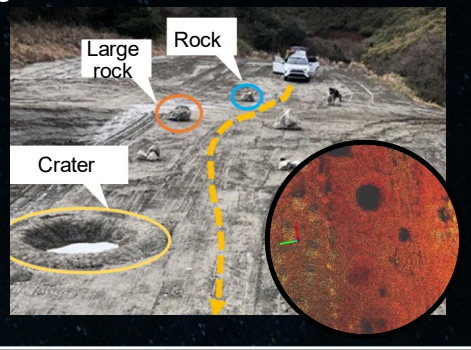
Inertial navigation

Estimate speed, distance traveled from acceleration on three axes

Obstacle detection using LiDAR point clouds

Determine traversable surfaces

Identify obstacles and surface gradients



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**

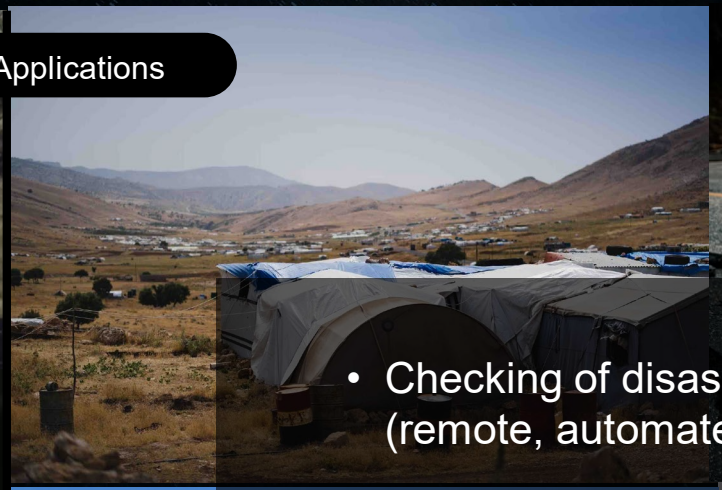
03 Automated Off-road Driving

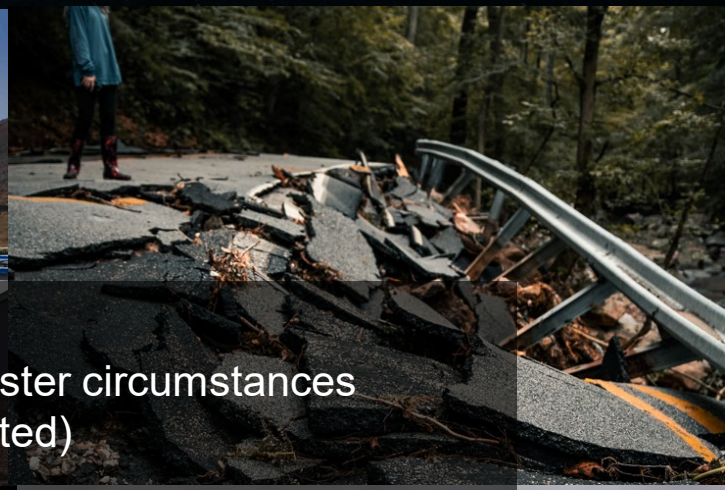
Benefits for Earth: Driving Technology—Driving/Automated Driving Over Unfamiliar Terrain



- 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)

Proposed Applications





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





04 User Experience (UX)

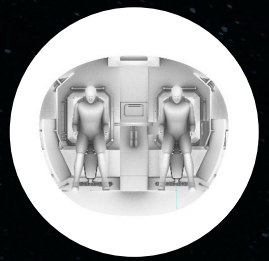
Requirements for the Mission/for the Lunar Environment ››› **Issues/Challenges**

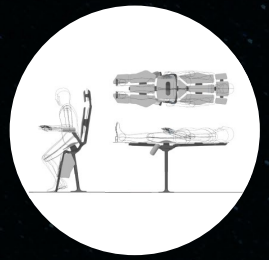
(1) Living on-board (confined space) for one month
(2) 100% off-road driving on monochromatic lunar surface (up to 8 hrs/day, 6 days in a row)

(1) Large mental strain, affecting crew work efficiency/motivation
(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

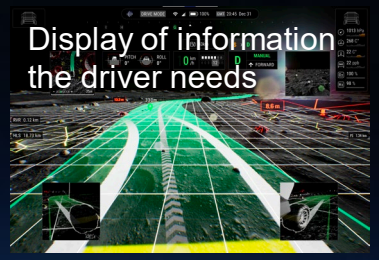
Next step: **Improve rover safety and comfort through verification using mockups and a driving simulator**

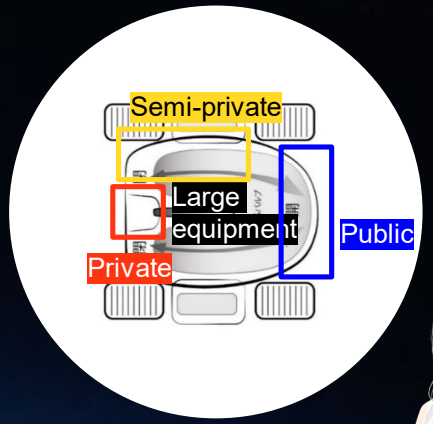
User Experience (UX)

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.



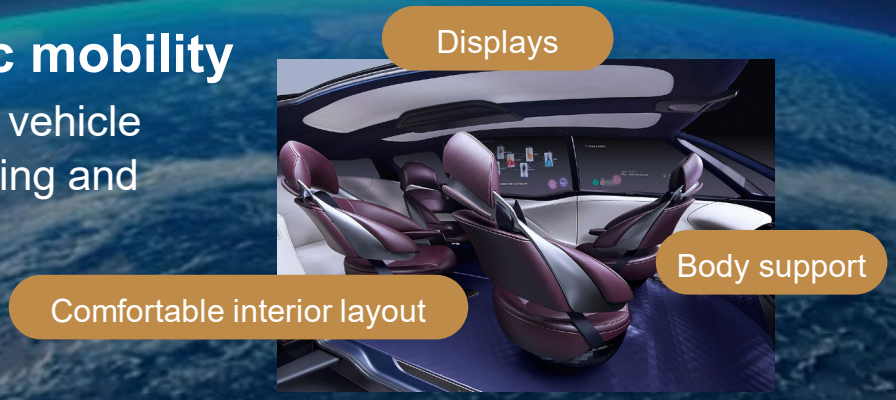


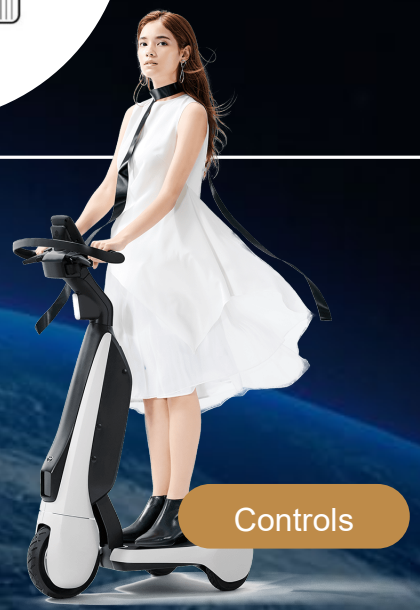


Space design with public/private zoning to optimize the feelings and relationships of multiple occupants

Earth

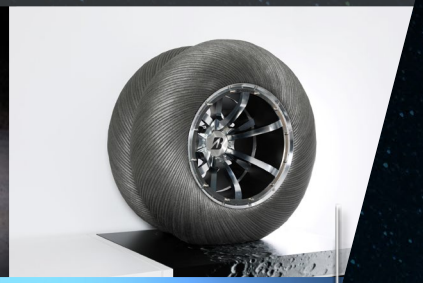
Contribute to **people-centric mobility design** to support diversifying vehicle trends, including automated driving and personal mobility



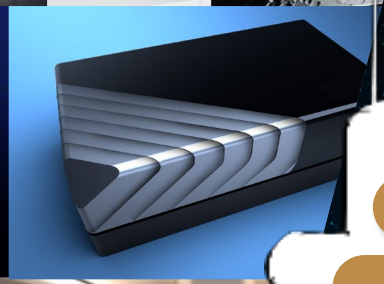


Integration of Space and Automotive Technologies















Integration

Communications

Navigation/ automated driving

Heat dissipation

Thermal control

Living space

Regenerative fuel cell

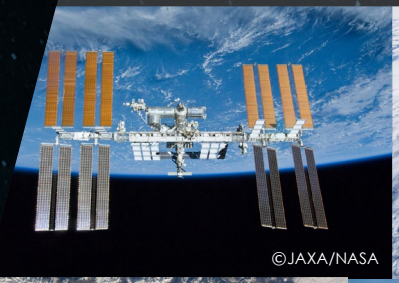
Structure

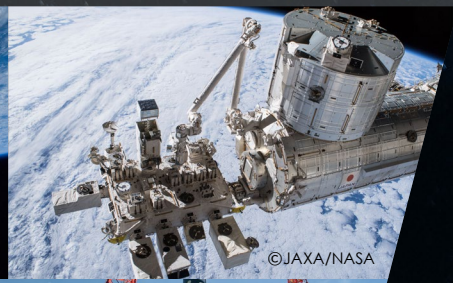
Life support and environmental control

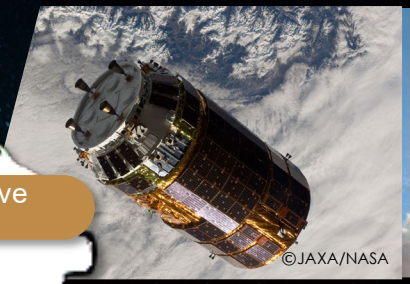
Power supply

Chassis

Tires

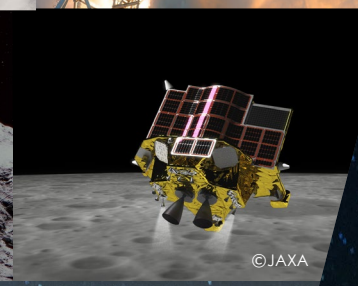












Automotive technology

Space technology

Partnership Between Toyota and Mitsubishi Heavy Industries

Mid-2020s

Support exploration with human spaceflight technology



International Space Station



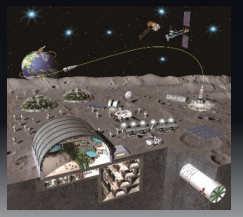
H-II Transfer Vehicle(HTV)



Gateway I-Hab

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

2029


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