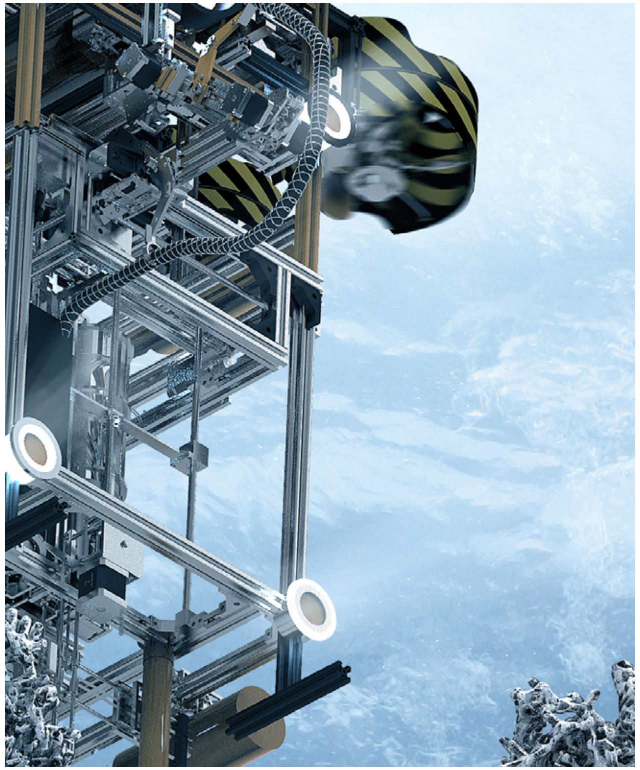
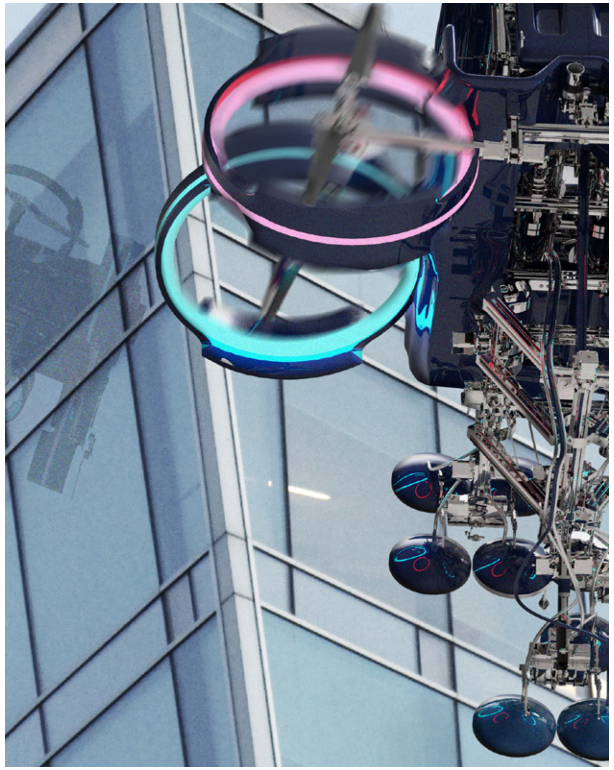
BREAK THE *grid*

SETTING 3D PRINTING FREE *to crawl, swim, fly*

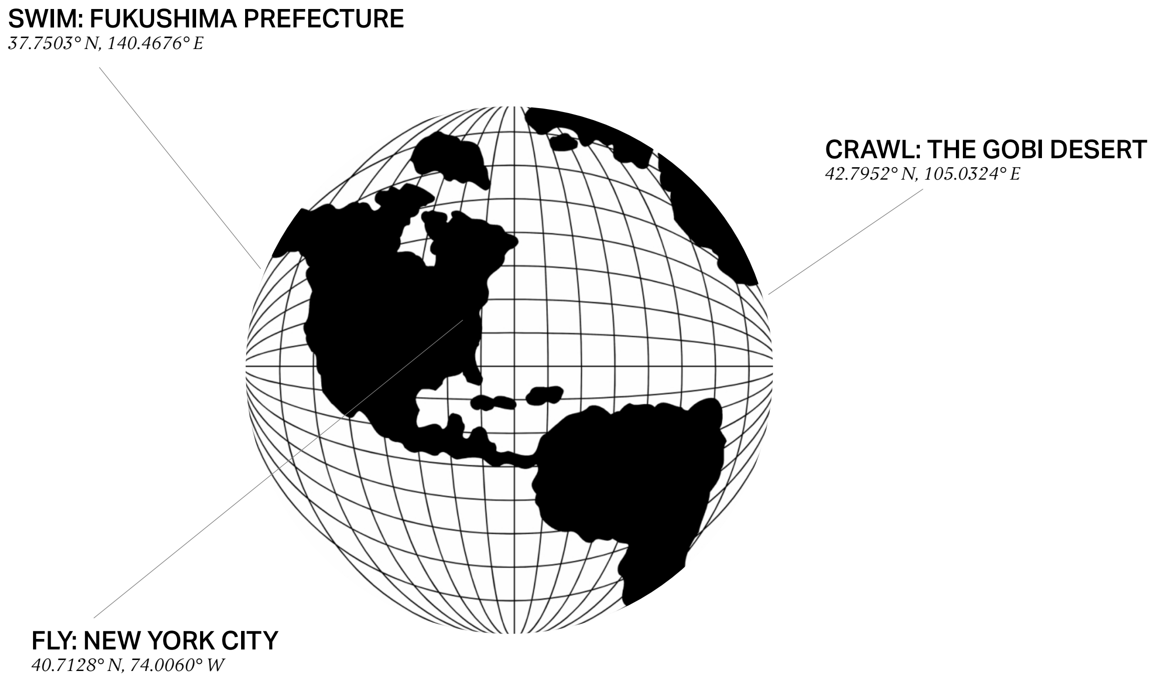
crawl



swim



fly

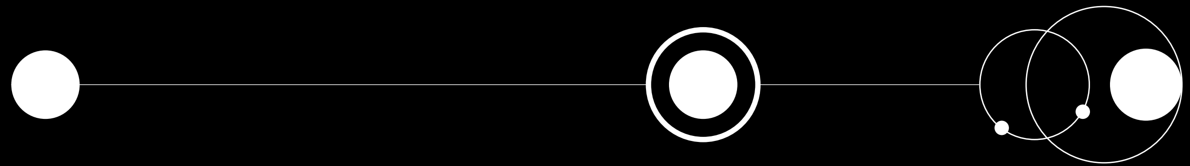


GLOBAL CHALLENGES CALLS FOR NEW *construction solutions*

Our buildings, infrastructure, and cities are straining under the combined pressures of explosive population growth and warming climate.

Freeing 3D printers to meet these challenges could be a revolution in the making – offering faster, cheaper, and better ways to respond to urban, social, and environmental change.
Combining mechanical and virtual prototypes we wish to expand the possibilities of architecture as an adaptive interface between ourselves and our environments.

BREAK THE *grid*



CRAWL
Infrastructure maintenance

SWIM
Coastal protection

FLY
Thermal insulation

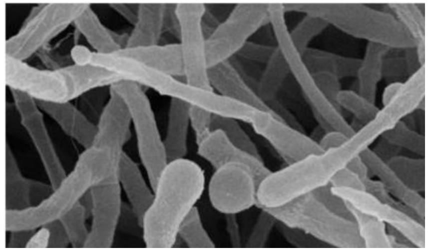
FIXING OUR DECAYING *infrastructure*

CRAWL: THE GOBI DESERT
42.7952° N, 105.0324° E

OUR GLOBAL INFRASTRUCTURE *is crumbling*

Asphalt degradation is one of the many challenges impacting transport infrastructure globally.

This is particularly a problem when dealing with isolated road networks. Small cracks and fissures in the asphalt, which could easily be patched, are often left unattended until erosion creates dangerously large openings in road pavements. At this point intervention becomes urgent and but costly. An autonomous system of crawling 3D printers could scan and patch small defects on isolated roads, solving the problem before it becomes unmanageable.



Micro-cracks

Tiny fissures make the concrete infrastructure that supports our global economy crumble fast.

Micro-cracks, tiny cracks no wider than the breadth of a hair, are the starting point for much worse damage to concrete infrastructure. The problem arises as micro-cracks allow water and oxygen into the structure, where it can corrode the reinforcement in its interior and lead to much larger damages if unaddressed. The deterioration resulting from micro-cracks requires expensive repairs, can causes long delays, and in worst cases lead to structural collapse.

Trichoderma Reesei

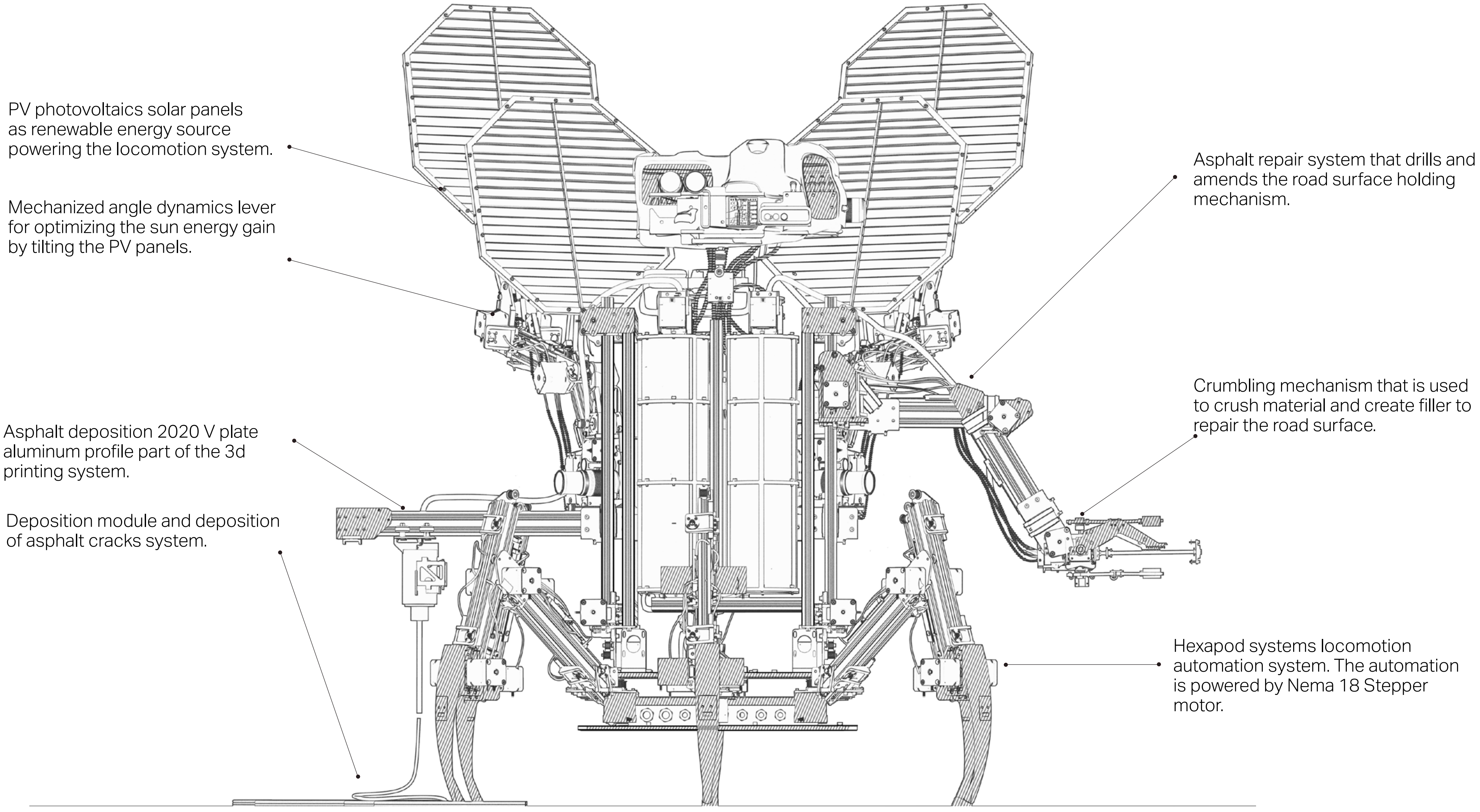
Fungi that promote formation of calcium carbonate can provide better, cheaper repair for concrete.

Researchers from Rutgers University and Bingham University have tipped the fungi Trichoderma Reesei as a potential ally in the fight against crumbling concrete infrastructure. It can germinate in highly alkaline conditions, forming a fibrous fungus that promotes formation of calcium carbonate. Calcium carbonate bonds well with concrete, has similar structural properties, and could act as a good filler for micro-cracks. Fungal spores can be injected into cracks mixed with a porous filler, once water flows into the cracks it will cause the spores to germinate and trigger the formation of calcium carbonate.

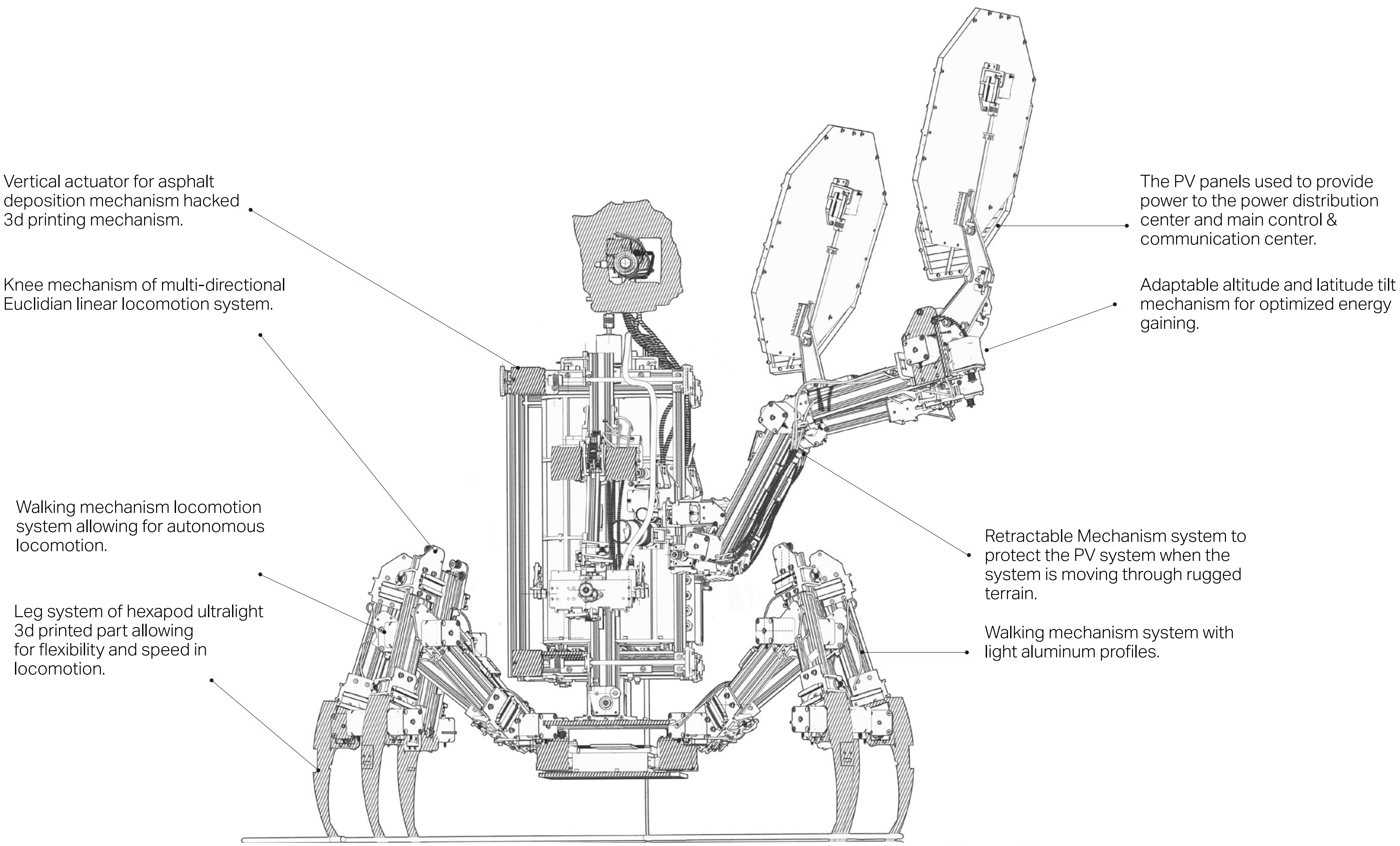
Value case

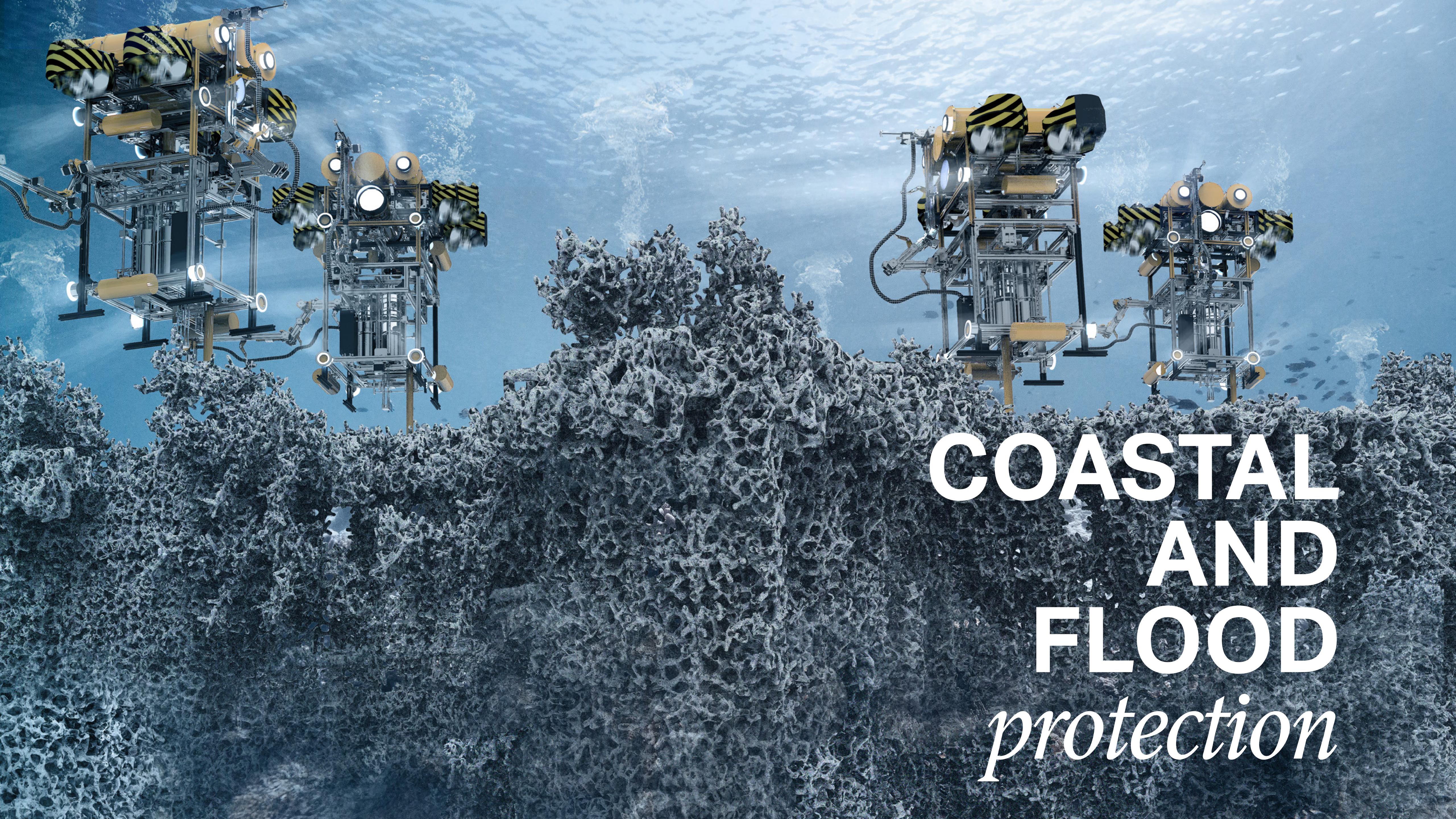
Crumbling infrastructure can cost the U.S. economy $4 trillion in lost business by 2025.

Microcracks left unrepaired develop into bigger ones that expose reinforcement structures in concrete. When these are damaged, repairs become costly and complex. According to the American Society of Civil Engineers, this problem will cost the U.S. economy almost $4 trillion in lost business by 2025 if it’s not addressed. To solve the problem of microcracks, autonomous hexapods can wander the lengths of our urban and remote concrete infrastructures, scanning for structural integrity and injecting cracks with filler containing the Trichoderma Reesei fungi for a cost-efficient bio-based solution to the problem.



PV photovoltaics solar panels
as renewable energy source
powering the locomotion system.
Mechanized angle dynamics lever
for optimizing the sun energy gain
by tilting the PV panels.
Asphalt deposition 2020 V plate
aluminum profile part of the 3d
printing system.
Deposition module and deposition
of asphalt cracks system.
Asphalt repair system that drills and
amends the road surface holding
mechanism.
Crumbling mechanism that is used
to crush material and create filler to
repair the road surface.
Hexapod systems locomotion
automation system. The automation
is powered by Nema 18 Stepper
motor.


Vertical actuator for asphalt deposition mechanism hacked 3d printing mechanism.
Knee mechanism of multi-directional Euclidian linear locomotion system.
Walking mechanism locomotion system allowing for autonomous locomotion.
Leg system of hexapod ultralight 3d printed part allowing for flexibility and speed in locomotion.
The PV panels used to provide power to the power distribution center and main control & communication center.
Adaptable altitude and latitude tilt mechanism for optimized energy gaining.
Retractable Mechanism system to protect the PV system when the system is moving through rugged terrain.
Walking mechanism system with light aluminum profiles.


COASTAL
AND
FLOOD
protection

SWIM: FUKUSHIMA PREFECTURE

37.7503° N, 140.4676° E

CLIMATE CHANGE IS DESTROYING OUR *coastal habitats*

Coastal conditions impact 600 million inhabitants globally, who are becoming more vulnerable as climate changes.

More than 10 % of the world coastal population live less than 10 meters above sea level. With climate change and more extreme weather, these people become vulnerable to both coastal storm surges and catastrophic tsunamis. New approaches to coastal protection can focus on the sea floor to set in where the problem forms before hitting our inhabited costs to cause large-scale social and economic damage.

Sea floor conditions

The coastal sea floor plays a decisive factor in the energy with which waves hit coastal regions.

Traditional solutions to coastal storms have included concrete tripods and walls for breaking the kinetic energy of waves and storm surges. However, these tend to be engineered to such sizes that they impact negatively on coastal access, industry and society. A tailor-made approach to altering sea floor dynamics and topography could mitigate wave impact and make coastal protection more affordable and effecient.

Bio-based cement

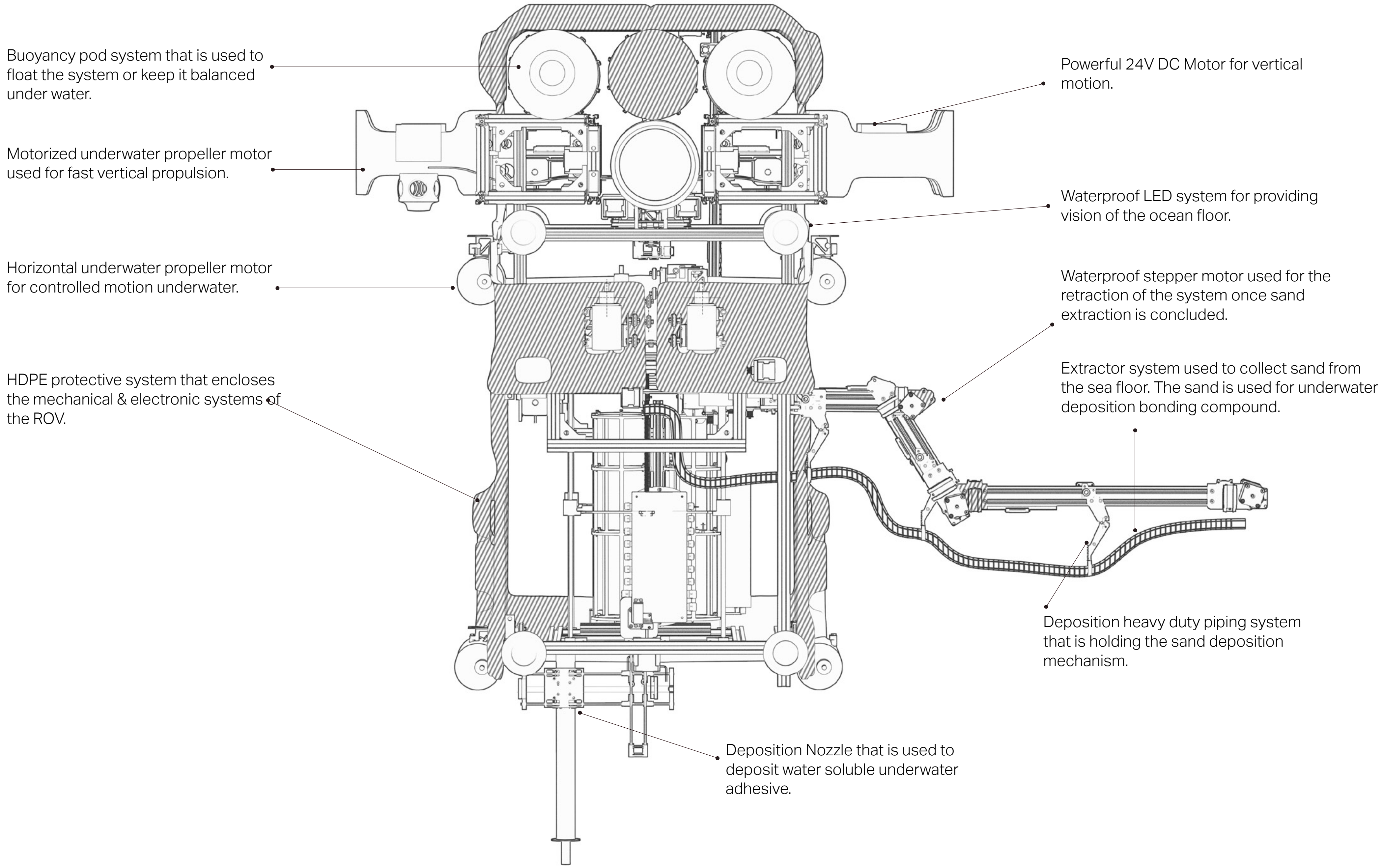
Wet-setting bio-based binders from oysters can be used to build artificial reefs.

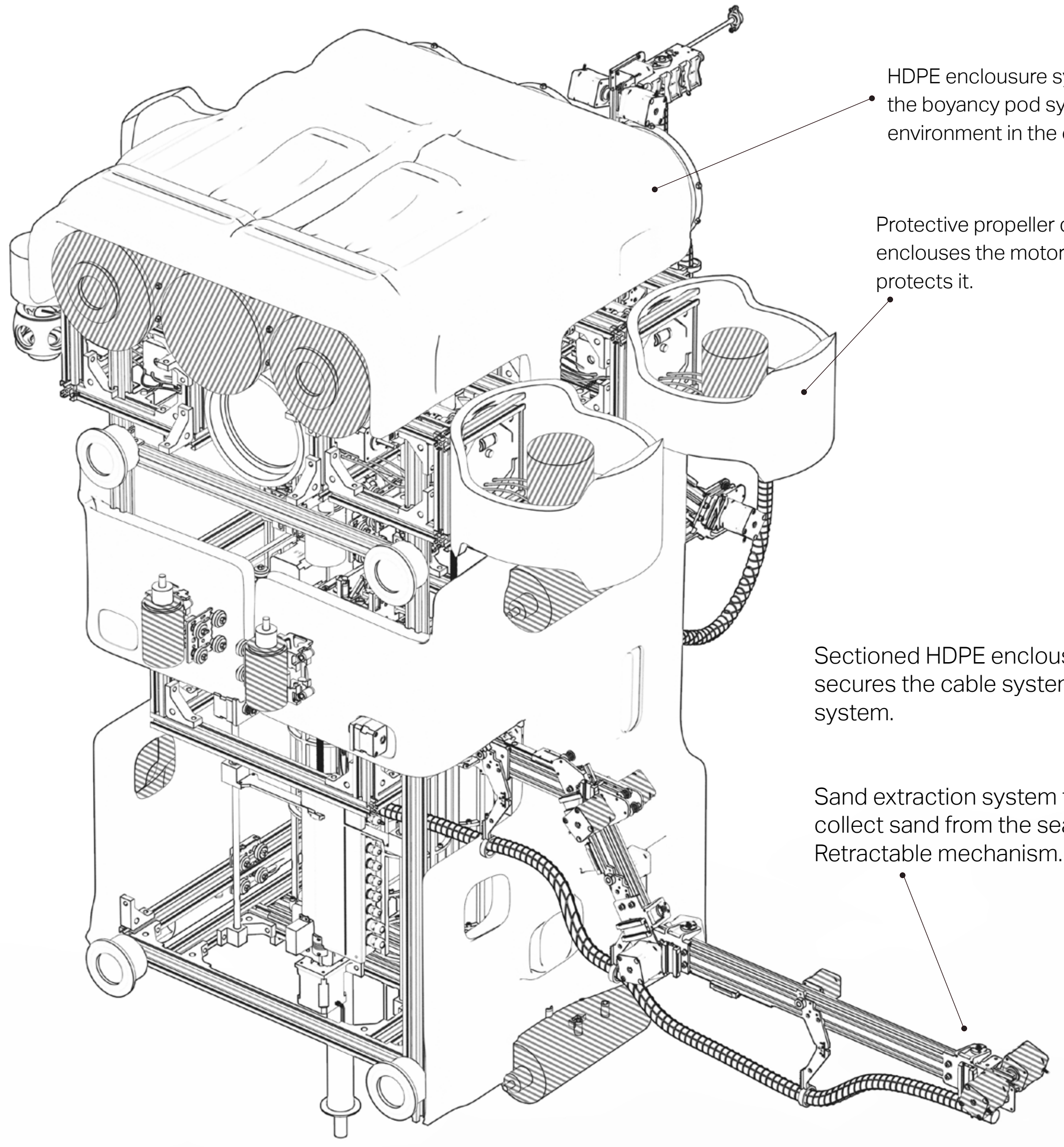
Oysters build their reefs using a specialized adhesive that differs in composition from their shells, as well as from other marine organism glues. Researchers from Purdue University have analyzed the chemical composition of oyster adhesive to develop synthetic glues with the same properties. Mixed with ocean floor sands, this type of glues could provide a wet-setting binder for creating artificial reef structures to protect our coasts while also creating vital habitats for marine life.

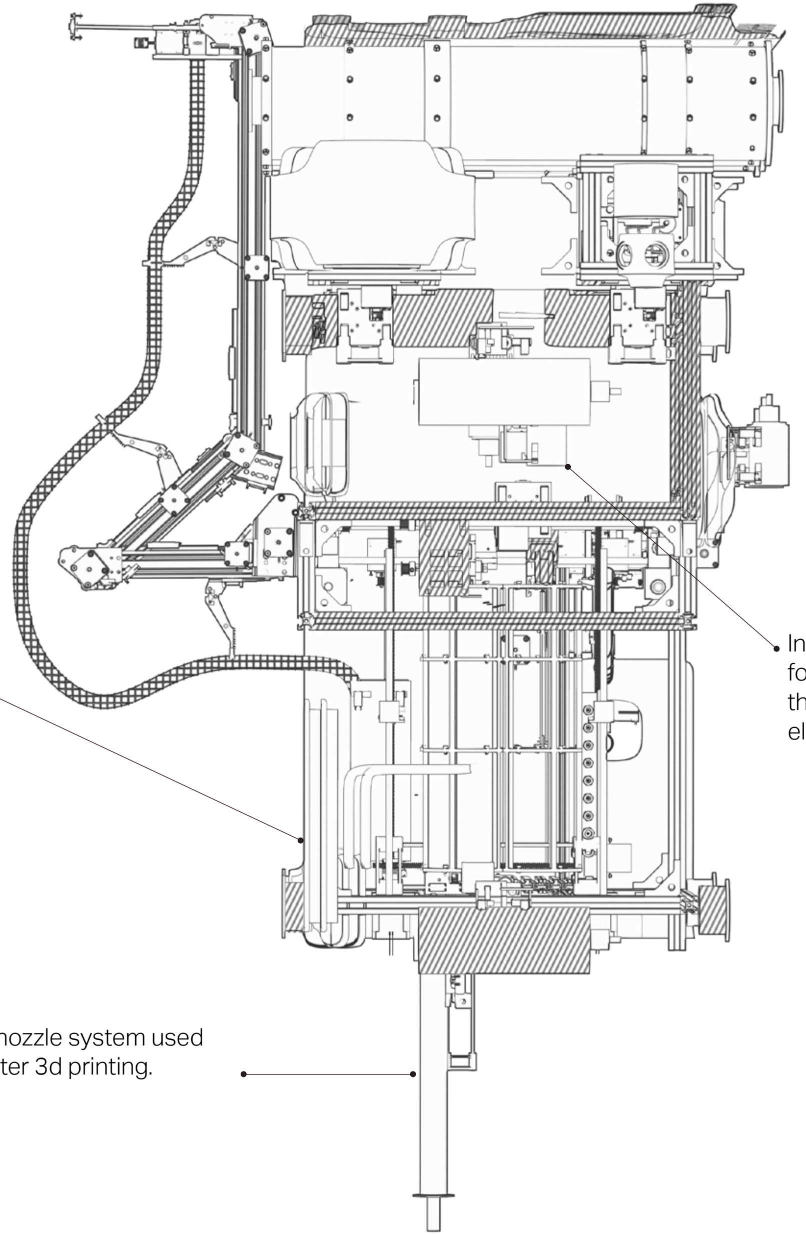
Value case

The year 2017 was the most expensive in recorded history for hurricane damage.

According to the National Oceanographic and Atmospheric Administration of the United States Major storms such as Harvey, Maria, and Irma caused unprecedented damage. Harvey alone caused an estimated $125bn in damage. In comparison, the 2011 earthquake and tsunami that hit Japan totalled 25 trillion yen or $309bn. Costs of repairing damage on the Pacific and Atlantic costs will only rise, as will costs of protecting cities from rising sea levels and storms. This provide a case for countries, cities and insurance agencies to invest in 3D printing ROVs which could use natural materials to protect coastal areas from the worst damage.


Buoyancy pod system that is used to float the system or keep it balanced under water.
Motorized underwater propeller motor used for fast vertical propulsion.
Horizontal underwater propeller motor for controlled motion underwater.
HDPE protective system that encloses the mechanical & electronic systems of the ROV.
Powerful 24V DC Motor for vertical motion.
Waterproof LED system for providing vision of the ocean floor.
Waterproof stepper motor used for the retraction of the system once sand extraction is concluded.
Extractor system used to collect sand from the sea floor. The sand is used for underwater deposition bonding compound.
Deposition heavy duty piping system that is holding the sand deposition mechanism.
Deposition Nozzle that is used to deposit water soluble underwater adhesive.


HDPE enclousure system that protect the boyancy pod system from the harsh environment in the ocean.
Protective propeller duct system that enclouses the motor system and protects it.
Sand extraction system that is used to collect sand from the sea floor. Retractable mechanism.


Sectioned HDPE enclousure that secures the cable system powering the system.
Interior space used for chambering the electrical and electronic systems.
Deposition nozzle system used for underwater 3d printing.

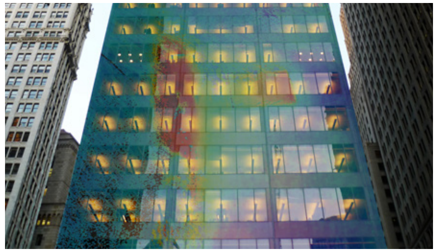
SEALING THERMAL BRIDGES *in high-rises*

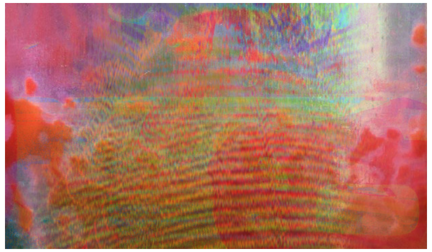
FLY: NEW YORK CITY
40.7128° N, 74.0060° W

AGEING STRUCTURES LEADS TO ENERGY *and economic loss*

The world's high-rises are not ageing well, leading to significant heat and energy waste in our cities.

Much of the high-rise built environment in major cities is of age to say the least. Low environmental requirements at different times in recent history have resulted in a large building mass with low energy efficiency. Many existing facades require repair or better insulation to combat degradation and energy loss. A better analysis of the energy performance of the facades on these high-rises would allow for efficient material solutions on a case by case basis, with much lower investment requirements and minimal human interaction.





Thermal bridges

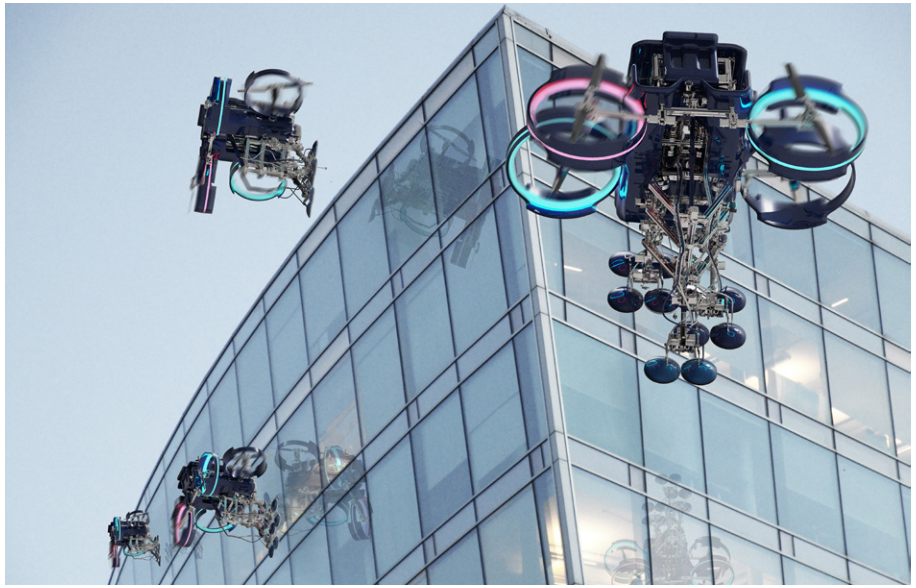
Ageing high-rises are leaking energy and money due to deficient and low performing facades.

Thermal bridges in facades stem from low or defective thermal insulation between external and internal walls which encourages formation of condensation. In older high-rises, these bridges multiply due to lower energy standards at the time of construction, or can emerge around windows and cladding, as insulation deteriorates. In either case the result is significant loss of heat, energy and money. The cost of assessing the state of high-rise facades and applying on site solutions, is often prohibitively expensive at present.

In-situ analysis and fixes

Functionally graded materials hold the promise to combine aesthetics and performance.

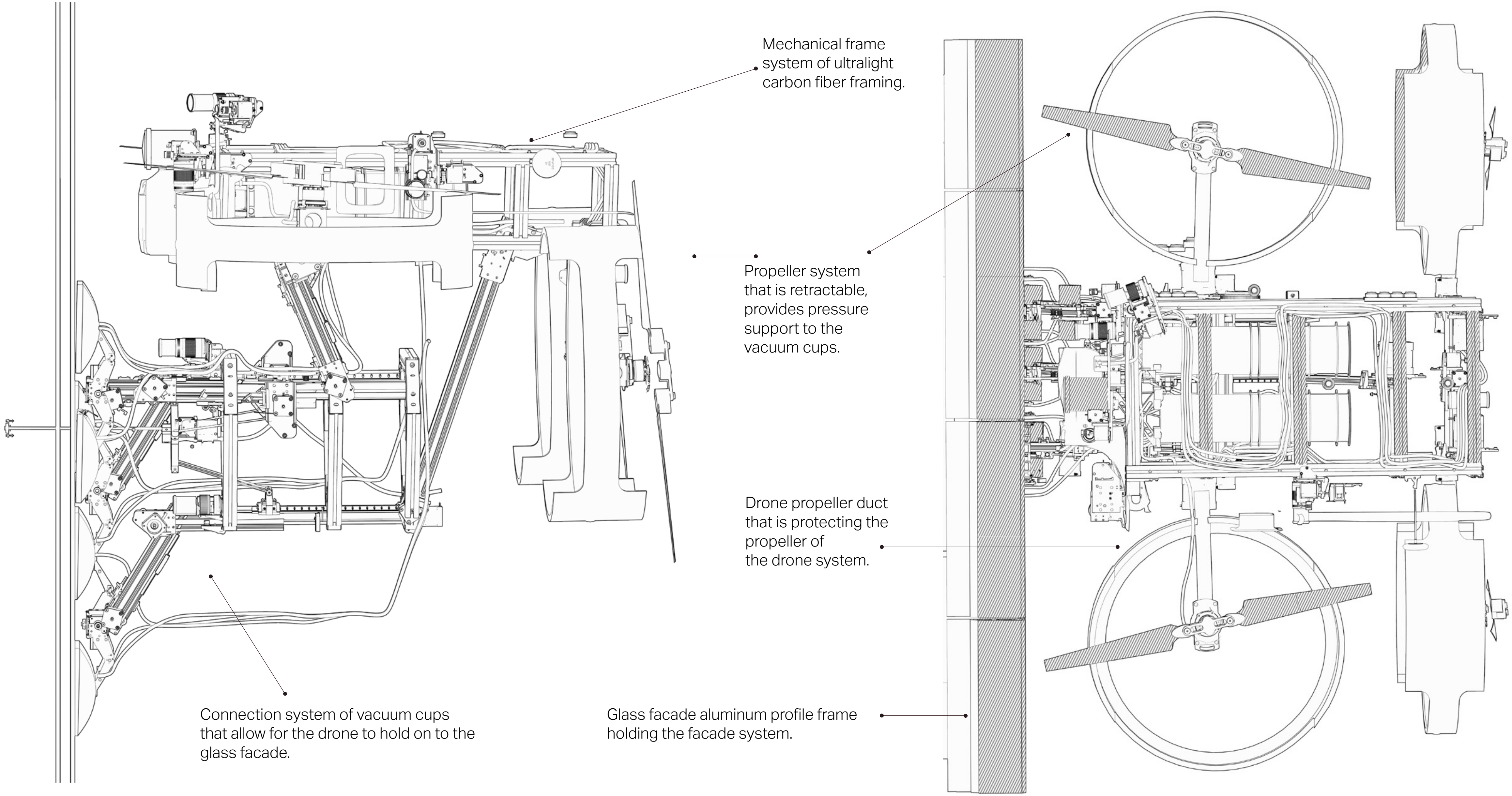
Researchers from both academia and practice are exploring how various materials can be combined in additive manufacturing to allow multi-material printing or functionally graded materials that fuse performance and aesthetics. Functionally graded materials could combine glass with high-performing polymers to provide new thermal insulation to old buildings. This would allow the application of project specific amalgamations based on in-situ analysis of façade composition and performance.

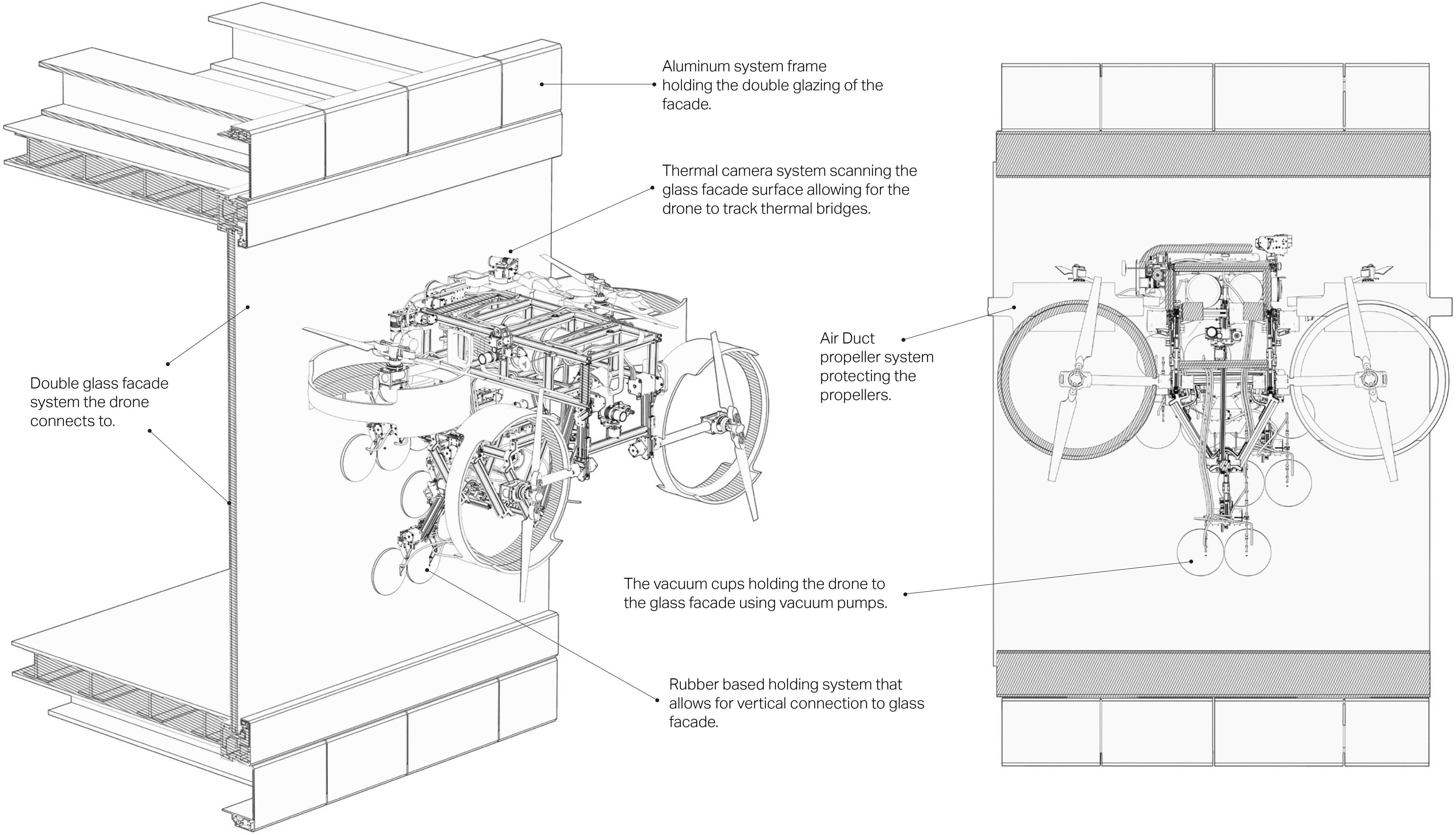


Value case

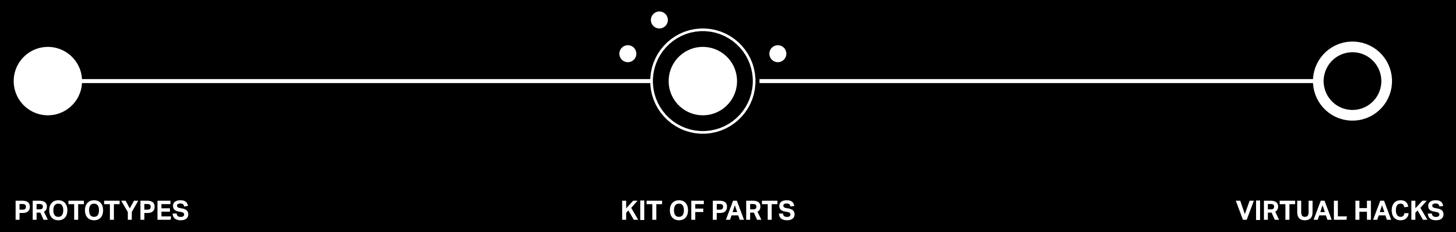
As building energy standards improve, the economic importance of thermal bridges has increased.

In otherwise well insulated buildings, thermal bridges can have significant effect on overall energy performance. In some cases, thermal bridges are responsible for up to 30% of heat loss of a building, driving an unmet need for new approaches to energy efficient maintenance. 80% of the buildings that will be with us in 20 years are already built today. As building regulations tighten, the market for cost-efficient in-situ alternatives to current costly retrofitting practice will grow further. With up to 30% savings on energy bills companies might pay for this via ESCO type models for achieving energy efficiency potentials.


Mechanical frame system of ultralight carbon fiber framing.
Propeller system that is retractable, provides pressure support to the vacuum cups.
Drone propeller duct that is protecting the propeller of the drone system.
Connection system of vacuum cups that allow for the drone to hold on to the glass facade.
Glass facade aluminum profile frame holding the facade system.


Aluminum system frame holding the double glazing of the facade.
Thermal camera system scanning the glass facade surface allowing for the drone to track thermal bridges.
Double glass facade system the drone connects to.
Air Duct propeller system protecting the propellers.
The vacuum cups holding the drone to the glass facade using vacuum pumps.
Rubber based holding system that allows for vertical connection to glass facade.

MECHANICAL AND VIRTUAL *prototyping*



PROTOTYPING THE FUTURE OF *additive manufacturing*

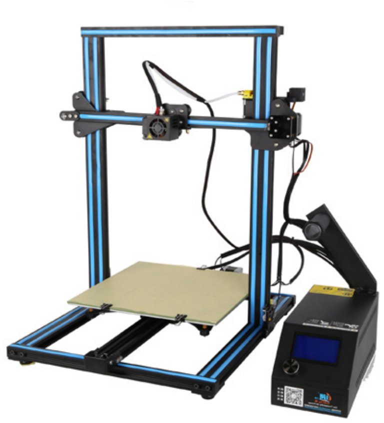
Sometimes, we need an abundance of creativity and ambition to push the limits of what 3D-printing can do.

This work is part of the Danish AM Hub Moonshots initiative. If additive manufacturing is genuinely to take us beyond current industrial practices, we must combine design and technology to shift our values and ways of thinking about additive manufacturing at present. Mechanical and virtual prototyping allows us to produce scenarios for how to respond to emerging ecological and cultural concerns while engaging current state-of-the-art.

HACKING EXISTING *technology*

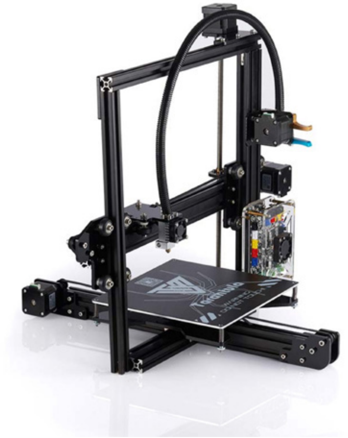
We used mechanical hacks to explore mobility and sensing capabilities of current low-cost technologies, and virtual hacks relying on proven printing mechanisms to extend functionality to new environments.

System design for both mechanical and virtual hacks were based on freely available parts used in popular 3D-printers. The hacking of commercially available systems allowed for implementation of existing 3D-printing mechanisms with other technologies such as robotics and sensors. Mechanical parts were kept to a minimum with low variation to enable hacked solutions that themselves were open for hacking.



Land

Creality3D CR - 10S 3D Printer

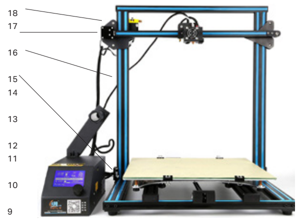


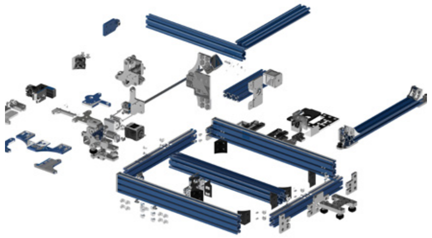
Sea

Tevo Tarantula 3D Printer Kit

Air

EZT Kossel Delta 3D Printer





Printing mechanism

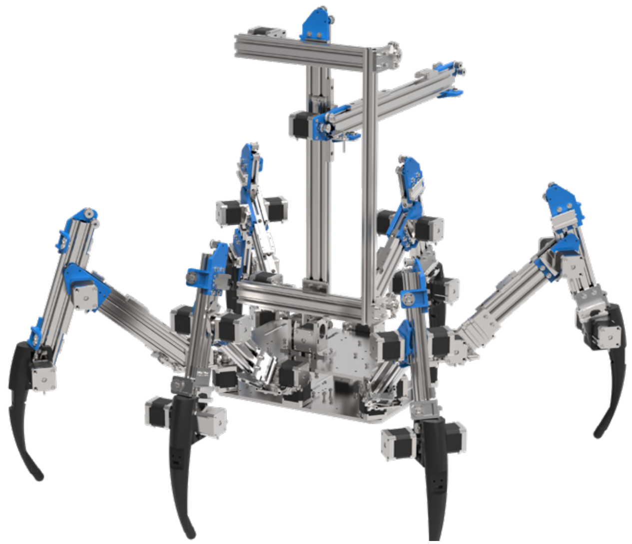
Hacking commercially available printers for a robust and simple kit of parts.

The Use of the Creality CR-10 3D-Printer, Tevo Tarantula 3D Printer Kit, and EZT Kossel Delta 3D Printer was based on their minimal parts and rigidity of the 3d printing mechanical arrangement.

Kit of parts

The kit of parts rely on widely available and standardized elements.

Mechanical prototypes and virtual hacks were based on mechanical parts from the printers rearranged to fit the use and properties of the mobile robotic systems. The capabilities of the mobility aspect of the machine also required electo-mechanical adaptations of the system to make it fit the new function.



Virtual hacks

Creating viable body plans from the kit of parts to explore functionalities and design.

The body plans for the three mobile 3D printing systems were based on experiments with the mechanical prototypes to explore mobility in challenging conditions.

Their 3D-printing mechanisms were based on proven technology from the Creality, Tevo, and EZT printers.

Protection of the mechanical body is imagined through the use of HDPE enclosures, blow-moulded and assembled to protect the electronic and mechanical systems.

Converging technologies

enable new approaches to construction

Additive manufacturing

The latest trends in additive manufacturing combine efficient and sustainable materials with machine learning and robots.

Additive manufacturing offers an unprecedented freedom of form and whole new opportunities for mass-customization, material efficiency, and product integration. Printing speeds in construction are increasing fast and AM systems can now do in hours what would normally take weeks. 3D printing is reducing material waste, uses less energy, fewer resources, and enables on-site production and variability for greater architectural freedom.

Advanced robotics

Robots and drones are developing fast while converging with new techniques in machine learning and automated fabrication.

Artificial intelligence unlocks entirely new possibilities for robots to become responsive to the world around them. This makes robots easier to train, reduces costs of installation and programming, and points to a future of autonomous crowd-based learning. Advances in sensing and 3D vision will provide robots with the nervous system required to navigate our cities and react to signs of material instability or environmental danger that cannot be seen by humans.

Machine learning

A second wave of artificial intelligence promise to vastly increase efficiency and quality in construction.

Data-driven design enables smart and cost-efficient architectural solutions. Project planners will be able to control networks of distributed machines while receiving real-time feedback to enhance efficiency in project delivery. Machine vision and new analytics platforms can collect and analyze data from networks of sensors to identify and improve unsafe conditions, while sensor-equipped drones can monitor our infrastructure and plan for maintenance on the fly.

Materials science

New bio-based and hybrid materials enable high performing 3D printing purposefully adapted to our environments.

3D printers in will soon be able to combine different materials to allow making new functional and high-performing components with properties to match each individual project. Whether applying highly efficient and sustainable materials or local products such as sand and construction waste with bio-based glues, this will allow additive manufacturing to create structures uniquely matched to their environments.

Business models

The construction industry is one of the few sectors left to reap the benefits of digitization and automation.

While other industries have seen more than doubling in productivity numbers, construction has flatlined. Increased knowledge of new technologies and business models is crucial for change. Reports indicate that additive manufacturing can cut construction costs by 50-70%, cutting labor costs by up to 80% and reduce waste produced in construction by up to 60%. This will increase economic returns in the sector while also contributing to sustainable development.

Project
partners

Danish AM Hub

GXN INNOVATION

MAP ARCHITECTS

DANISH AM HUB

Danish AM Hub is Denmark's platform for digital and additive manufacture.

The AM Hub wants to bring together the Danish ecosystem and to combine, change and advise on AM, with the aim of getting Danish industry to see the multifaceted potential of the AM technology. We work to build future-proof competencies and bring new knowledge into the development of new business models and innovative solutions.

GXN INNOVATION

GXN drives independent and applied design research into new technologies and materials.

GXN Innovation was established in 2007 as the independent research company of 3XN Architects. GXN's approach combine strategic consultancy and design with ongoing human-centered and technical research. The innovation unit has carried out more than 100 research projects aimed at advancing new approaches to ecological design in all its diversity and across its material, technical and social dimensions.

MAP ARCHITECTS

MAP Architects is active globally, engaged mostly with projects in challenging environments.

Design work spans various scales and spheres of action, often challenging the status quo through inventiveness and a cross-disciplinary approach. Collaborative work with engineers and the scientific community, like collaboration with UNESCO's water resilience department, or NASA, is part of every project undertaken.

COLLABORATE WITH US

Contact us to collaborate on AM Hub Moonshots and develop additive manufacture applications.

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