

Robot Locomotion

Programme Thesis

v1.0

Jenny Read, Programme Director

CONTEXT

This document presents the core thesis underpinning a programme that is currently in development at ARIA. We share an early formulation and invite you to provide feedback to help us refine our thinking.

This is not a funding opportunity, but in most cases will lead to one – sign up [here](#) to learn about any funding opportunities derived or adapted from this programme formulation.

An ARIA programme seeks to unlock a scientific or technical capability that

- + changes the perception of what's possible or valuable
- + has the potential to catalyse massive social and economic returns
- + is unlikely to be achieved without ARIA's intervention.

PROGRAMME THESIS, SIMPLY STATED

An overview of the programme thesis, accessible & simply stated

This programme aims to produce one or more new types of robot that can move through the world in ways today's robots cannot: not just in demos, labs, warehouses or carefully prepared spaces, but in the messy physical environments where useful work actually happens.

It might not seem like robots have a problem moving around. Autonomous mobile robots already trundle around warehouses. Quadcopters fly. Robot dogs run up steps. Humanoids can dance and do backflips better than all but the most athletic humans. But this apparent capability hides serious limitations. Wheels are hard to beat on the smooth, level floors of factories and warehouses, but become much less useful on stairs, rubble, mud, vegetation

or rough terrain. Quadcopters need no road, runway or landing strip, but carrying meaningful payloads over useful distances quickly creates short range, noise, downwash and safety risks. Legged robots can perform astonishing athletic feats, but a body that can briefly coordinate huge forces for a backflip is not necessarily one that can spend a shift carrying loads over uneven terrain without overheating, falling or breaking.

We want to build robots that transcend these limitations. At this stage, we are open to any form of locomotion: walking, running, jumping, crawling, burrowing, flying, swimming, climbing, rolling, or combinations. Each team should be building towards a specific use case, a target robot profile, and a credible route to adoption. We are not aiming to create impressive demos for their own sake - we are interested in locomotion that unlocks economically valuable tasks. That might mean inspecting infrastructure, carrying loads across construction sites or farms, maintaining offshore assets, or delivering goods where roads are slow or absent.

Our central insight is that the limitations of current robots cannot be overcome by AI and control alone. In many real-world settings, the body is the constraint that better software cannot simply route around. We are inspired by evolved animal bodies: they store and release energy elastically, exploit resonance, use compliant structures, distribute intelligence between the body and the nervous system, and use the environment rather than treating every disturbance as an error.

We are seeking to activate a community of builders ready to work with physics rather than against it: roboticists, biomechanists, materials scientists, actuator and transmission engineers, controls researchers, energy and thermal specialists, manufacturers, startups, and customers who are prepared to turn strange-looking but high-performing bodies into useful products.

This programme thesis is derived from the ARIA opportunity space: [Smarter Robot Bodies](#).

PROGRAMME THESIS, EXPLAINED

A detailed description of the programme thesis, presented for constructive feedback

Why this programme

What we hope to accomplish

The programme aims to create and demonstrate a new class of robot locomotion platforms that can move through real-world environments in ways that exceed the capabilities of today's robots. The programme will culminate in a series of challenges in which each team pits its robot against the most plausible competitor(s).

The nature of the challenge will be determined by each team, subject to ARIA's acceptance, based on the target robot profile (TRP) and associated metrics.

For example, for an agribot, the challenge might involve carrying a 20kg feed sack across a wet farm while traversing gates and avoiding livestock. For a subsea robot, it might involve swimming for six hours with a sensor payload while producing virtually no acoustic and hydrodynamic disturbance. For a sewer robot, it might mean entering through a standard manhole, travelling kilometres through a live sewer network and returning without becoming a blockage. In each case, the demo will be designed to showcase how a new platform outperforms the best available alternative on the metrics that matter for adoption.

The programme will also fund the enabling components that make such platforms possible. These might include elastic or variable-stiffness actuation; high-efficiency transmissions; compliant and damage-tolerant structures; legs, wings, fins, feet, skins and grippers; onboard energy storage and thermal management; robust sensing and proprioception; docking and recharging; and control architectures that exploit the body's mechanical intelligence.

Why it's worth shooting for

Much valuable work happens in places that are not designed for machines: unpaved ground, stairs, ramps, rails, cables, wet decks, cages, ship hulls, turbine towers, bridges, tunnels, plant rooms, construction sites, farms, coasts, and disaster zones. When machines cannot operate in these environments, humans must travel, climb, dive, lift, inspect, and repair instead.

Autonomous robots that can safely carry useful payloads in challenging environments would unlock or expand several markets:

- + Quiet aerial logistics and maintenance, including higher-payload, longer-range, lower-noise drones that can operate in wind and land with less downwash.
- + Ground delivery and service logistics, where robots must handle kerbs, gates, steps, gravel, mixed indoor-outdoor routes, and meaningful payloads.
- + Climbing inspection and repair, where robots could reduce rope access, shutdowns, risk, and cost for bridges, rails, ship hulls, offshore structures, and wind turbines.
- + Aquaculture and offshore robotics, where long-endurance machines must work around nets, cages, moorings, currents, waves, and docking constraints without constant retrieval.
- + Future combined locomotion and dexterity, where machines can not only reach awkward places but also manipulate, repair, clean, maintain, or assemble once there.

Demand for physical work in difficult places is rising just as the workforce available to do it is shrinking. The energy transition means more distributed assets — wind turbines, solar

panels, batteries, cables and substations — often remote, exposed or hard to access, all needing inspection, cleaning, vegetation management and repair. At the same time, demographic change means fewer working-age people supporting each older person. To sustain complex societies and high standards of living, robots will need to be far more capable of a variety of physical labour than they are today.

Why it's differentiated

The last few years have seen huge investment in humanoids and other robots. Much of this progress has come from making familiar body plans work better: more torque-dense electric actuation, better batteries, cheaper sensors, faster compute, improved simulation, and more capable control. Quasi-direct-drive and related actuator architectures have been especially important for dynamic legged robots. But the underlying forms have remained strikingly conservative.

This programme will take a higher-risk route. We will fund teams that are willing to rethink the robot body itself: actuation, transmission, compliance, energy storage, morphology, sensing, thermal management and control, all designed together around a specific target robot profile. Conventional electric actuators will not be the default assumption. We are interested in artificial muscle technology, variable-stiffness mechanisms, compliant and resonant structures, soft-hard hybrids, and other approaches that could let robots move in ways today's wheels, propellers, and legs cannot. ARIA's Robot Dexterity programme is already exploring a number of new actuation technologies which could be useful here.

Much robotics work implicitly assumes the body is a platform on which better software runs. For ARIA's Smarter Robot Bodies, the body is part of the computation. The body should store and return energy, absorb shocks, sense contact, exploit resonance, adapt to terrain, and simplify control.

What we expect to fund

At this stage, we are deliberately keeping the aperture wide. The examples in this thesis are not intended to define priority sectors or preferred locomotion modes. They are simply illustrations of the kinds of physical-world bottlenecks we think may be unlocked by radically better robot bodies. Through the discovery workshop, feedback process and any subsequent concept-paper stage, we expect to learn which use cases are genuinely blocked by locomotion hardware, which are commercially compelling, and where ARIA intervention could make the greatest difference.

Programme timeline

We propose funding in three phases, as shown in Table 1 and Figure 1 below.

For this programme, we want new platform teams to form, develop a sound go-to-market strategy for a novel robot locomotion platform, and define a Target Robot Profile and associated metrics that demonstrate a credible path to market. We recognise that forming new teams and developing these plans rigorously may require more time than is available before the solicitation deadline. Accordingly, we propose to select around 10-15 promising teams and fund them initially for a one-year Phase 1. We will then select a subset to proceed to a second year for Phase 2. Finally, we will select a handful to proceed to Phase 3. This timeline is sketched out in Figure 1.

Phase	Duration (years)	What happens	Rough number of teams	Total budget ballpark
1	1	All teams de-risk technology. Platform teams refine commercialisation strategy, TRP and target metrics. Component teams demonstrate utility to platform teams.	10-15	£8M
Gate 1		<i>Phase 2 platform teams selected. All component teams either linked up with platforms or terminated.</i>		
2	1	Platform teams build integrated prototypes, incorporate components and continue to plan GTM strategy.	4-7	£10M
Gate 2		<i>Teams demo their capabilities. Phase 3 platform teams are selected.</i>		
3	2	More advanced prototypes. Paid pilots and field trials. TRPs and target metrics updated as necessary. Teams agree TRP and end-of programme challenges with ARIA.	1-4	£30M
Final demo		<i>ARIA commissions third-parties to run a series of challenges pitting each team's platform against the best available competition.</i>	-	£2M

Table 1. Proposed programme timeline.

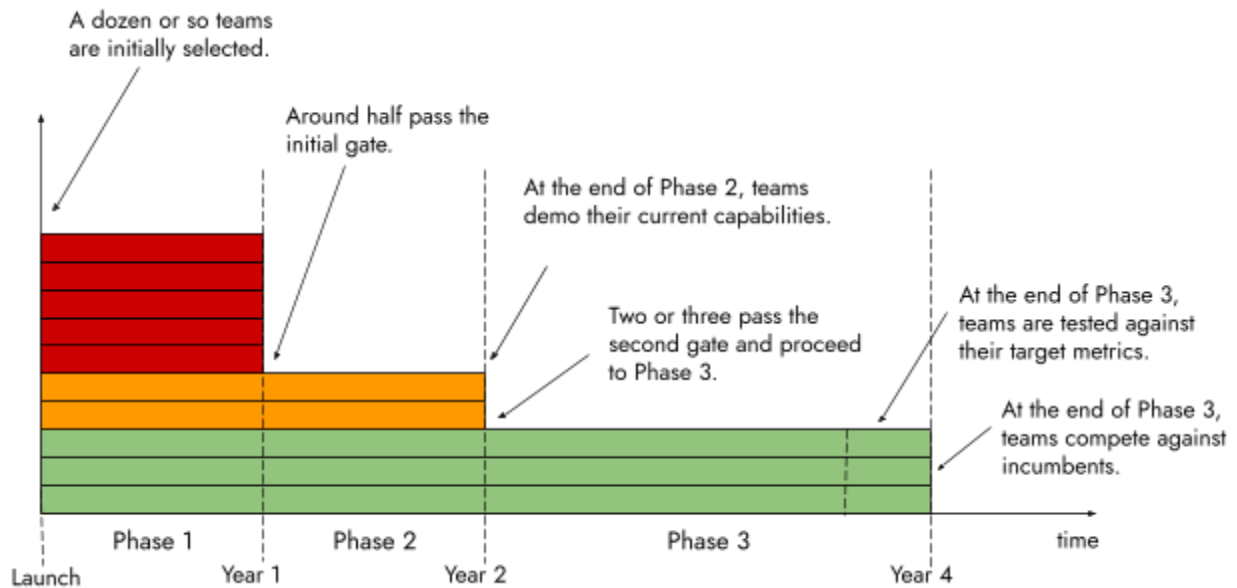


Figure 1. Proposed programme timeline (number of teams only indicative). The programme has formal selection gates at the end of Year 1 and Year 2. The bar colours show which gates the teams survive. In accordance with ARIA's usual funding terms, projects may also be terminated with three months' notice if ARIA believes they are no longer serving the programme goals.

Who (types of people/orgs) we expect to fund and what we expect them to do

The programme will fund two types of team: platform teams and component teams.

Platform teams

Platform teams will be responsible for building complete robot locomotion platforms around a specific Target Robot Profile: a use case, customer, operating environment, performance envelope and route to adoption. They will own the end-to-end challenge: integrating hardware, control, sensing, energy, safety and manufacturing into a robot that can outperform the most plausible incumbent in a real-world task.

Platform teams can be a single entity or a consortium of a lead applicant plus subcontractors or unfunded collaborators. Subcontractors can be any type of entity. The lead applicant for platform teams should be a company or startup that is either based in the UK or willing to relocate or open an office here before a contract is signed.

Component teams

Component teams will develop the enabling technologies that make those new platforms possible: novel actuators, transmissions, compliant structures, energy-storage mechanisms,

feet, skins, sensors, thermal systems, control methods, simulation tools, and manufacturing processes. They will not be judged by lab performance alone, but by whether their technology improves a platform team's target metrics in the field.

Component teams may be any type of entity - whether based in the UK or overseas- including startups, academic groups, research institutes, individuals or industrial labs. They will work on enabling technologies such as:

- + Elastic, resonant, variable-stiffness, high-power-density, or high-efficiency actuators.
- + Transmissions, tendons, springs, dampers, clutches, brakes, linkages, feet, claws, adhesion mechanisms, fins, wings, and compliant structures.
- + Skins and multimodal sensors for contact-rich locomotion.
- + Lightweight structures that tolerate impacts, abrasion, water, dust, extreme temperatures, and partial failure.
- + Energy systems, thermal management, regenerative mechanisms, and harvesting from wind, thermals, waves, or flow.
- + Simulation, digital design, and rapid manufacturing methods that can cope with noisy, flexible, high-degree-of-freedom bodies.
- + Test rigs, benchmark methods, and field instrumentation for measuring performance outside the lab.

Component teams will not be funded beyond Phase 1 unless it is clear that one or more platform teams depend on their technology. Component teams are encouraged to find platform "customer(s)" as early as possible, for example using our [online teaming tool](#).

Where a component team is tightly linked to one platform team at the point of application, it will usually make more sense to participate as a subcontractor of the platform team rather than apply directly to ARIA. Figure 2 sketches what the programme structure might look like by Phase 3.

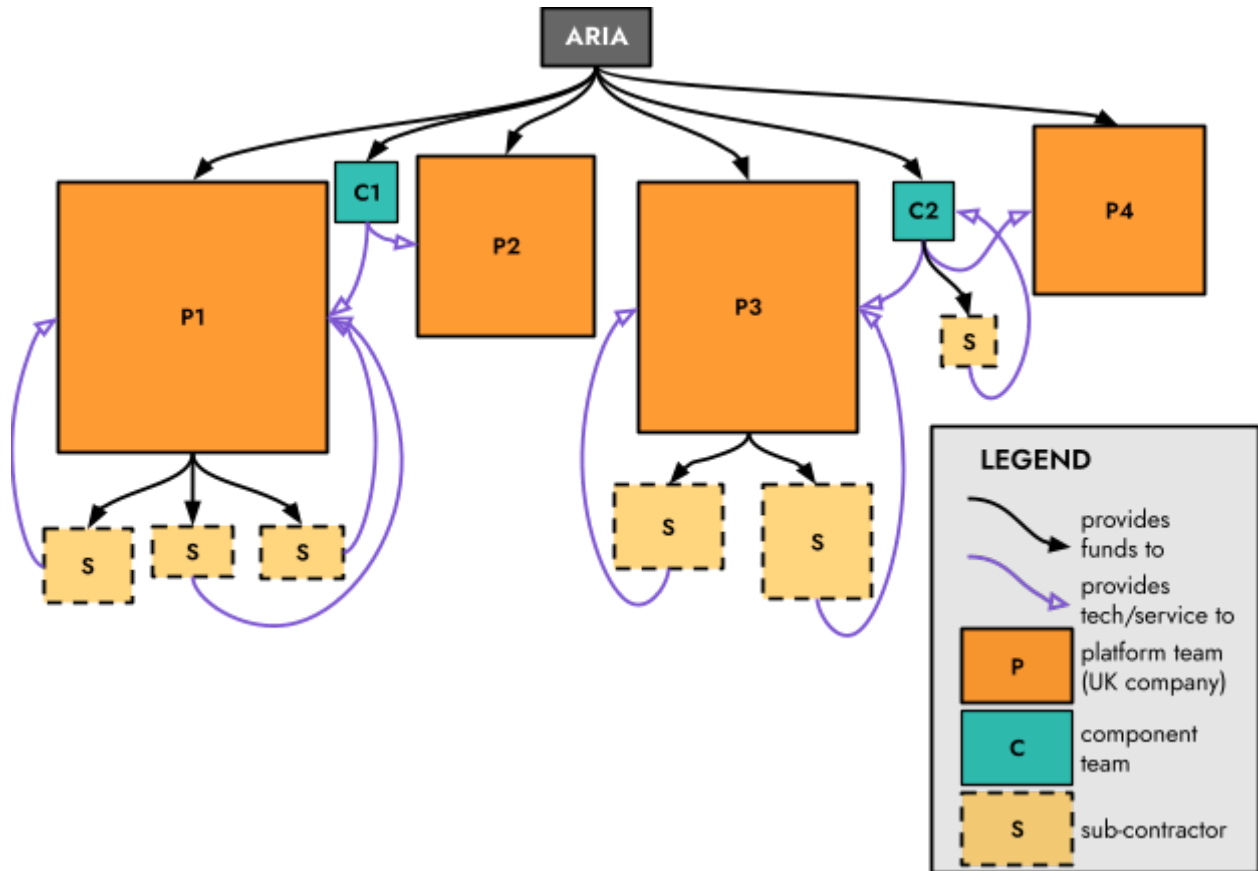


Figure 2. Possible Phase 3 programme structure. In this example, ARIA funds 4 platform teams, two of whom then fund subcontractors to provide services or components they need. ARIA also funds two component teams who each provide components to two platform teams. One of the component teams also funds a subcontractor. Bigger boxes indicate higher budgets.

How we plan to coordinate their efforts

We are envisaging that platform teams will work independently in parallel. Platform teams should coordinate their own work internally and with subcontractors, collaborators, and component teams. We are not expecting platform teams to be in direct competition with each other, as each will likely be targeting a distinct challenge.

ARIA will help broker partnerships between platform and component teams, make field testing unavoidable from early in the programme, and use independent assessors to compare performance against incumbents. Through our Activation Partners and other means, we will aim to provide translation support to help teams convert successful prototypes into pilot deployments, customer agreements, manufacturable designs, and investable companies.

How we plan to measure success

Platform teams will apply with a proposed use case and go-to-market strategy, which will guide a target robot profile and target metrics. This will be iteratively refined over the course of the programme. By Year 4 of the programme, successful teams (Figure 1) will have a well-defined target robot profile, targeted metrics, potential customers and ideally planned or completed targets. They will also have agreed to an end-of-programme challenge designed to showcase their prototype's abilities compared to a plausible incumbent. These will have been reviewed by ARIA and external stakeholders, including likely competitors. See Appendix for one possible example.

What we are still trying to figure out

Where are robot bodies limiting?

Which applications are genuinely blocked by locomotion hardware rather than by perception, planning, regulation, business model, or customer adoption? The strongest applications will choose markets where better robot bodies clearly unlock value and where customers can define success in measurable terms.

Disconfirming evidence

Cases where smarter robot bodies would not produce meaningful progress, e.g. the bottleneck is regulation, safety, perception, procurement, insurance or operations.

What do we need?

Some required components may not yet exist at the needed scale, lifetime, power density, efficiency, manufacturability, or cost. We need to know which missing pieces are most likely to create platform-level gains within programme timescales.

Who will use this?

We are seeking potential customers, commercial partners and field sites to ensure that research is closely focused on the barriers to adoption. Specific input that would strengthen the thesis includes:

- + Customer evidence on tasks currently impossible or uneconomic because robots cannot move well enough.
- + Baseline data for current robots and incumbent non-robotic methods.
- + Credible target metrics for payload, energy, endurance, noise, robustness, and terrain capability.
- + Examples of UK teams that could lead platform companies or supply critical components.
- + Field sites willing to host staged trials.
- + Component data for actuators, transmissions, compliant structures, skins, sensors, batteries, docking, and energy harvesting.

- + Safety, regulatory, insurance, and certification constraints for drones, outdoor ground robots, climbing systems, and marine robots.
- + Views on whether programme resources should favour platform teams, component teams, benchmark infrastructure, or translational support.

ENGAGE

The next step is to refine this thesis into a fundable programme design and, if warranted, a solicitation. To this end, we are requesting feedback through an [online form](#) and through an [in-person workshop](#) on 30 June and 1 July 2026.

We particularly welcome feedback on which applications are commercially blocked by locomotion hardware, which metrics matter, which missing components or body architectures could create a step-change, and which UK teams could credibly build and commercialise such systems.

Interested parties are encouraged to form partnerships early, especially where strong proposals require component and platform teams to work together. We are especially interested in hearing from teams building components or systems that point in this direction; customers with blocked use cases; field-site owners; investors; and researchers from robotics, biomechanics, materials, manufacturing, energy systems, controls, sensing, and commercial translation. We have created a form [here](#) for interested parties to register interest in teaming up.

APPENDIX

Here is an example of a hypothetical target robot profile, associated targeted metrics, and an end-of-programme challenge for a sewer robot. This example is included purely for illustrative purposes and does not imply that such areas are our priority.

Target robot profile

1. **Use case:** Autonomous inspection of sewers, culverts, storm drains and buried water infrastructure without requiring confined-space human entry or above-ground disruption.
2. **Primary customers:** Water utilities, local authorities, infrastructure inspection firms, civil engineering contractors, flood-resilience teams. Autonomous inspection of sewers, culverts, storm drains, and buried water infrastructure without requiring confined-space human entry or above-ground disruption.
3. **Problem addressed:** Existing sewer inspection often relies on tethered CCTV crawlers, human entry, or the flushing and isolation of pipe sections. These approaches struggle with long distances, partial blockages, bends, branches,

variable pipe diameters, flowing water, sediment, grease, debris, and poor communications. A robot designed for this environment could make inspection more frequent, cheaper and safer.

4. **Target environment:** Live sewer and drainage networks with pipe diameters from roughly 225 mm to 1,500 mm, including flowing water, sediment, grease and debris; bends, branches, drops, junctions and partial obstructions; intermittent GPS, radio and visual signal loss; biofouling, corrosive fluids, and decontamination requirements.
5. **Robot concept:** A semi-soft, eel-like robot with a washable sealed compliant body, distributed tactile sensing, variable-stiffness segments and hybrid crawling / swimming / bracing locomotion. It should be able to move with the flow where beneficial, brace against pipe walls when needed, squeeze past partial obstructions, survive tumbling or inversion, and avoid becoming a blockage itself.
6. **Incumbents to beat:** tethered CCTV crawlers; human confined-space inspection teams; flush-and-camera inspections; small tracked pipe robots; and opportunistic inspection during maintenance shutdowns.
7. **Commercial adoption claim:** “Inspect more metres of live sewer per shift, with fewer road closures, fewer confined-space entries, fewer failed inspections and better defect maps than current CCTV crawler workflows.”

Metric category	Threshold target	Stretch target
Access	Deployable through a standard manhole by two operators without lifting equipment.	Deployable by one operator from a van, with less than 15 minutes setup.
Pipe compatibility	Operates in 300–1,200 mm pipes.	Operates in 225–1,500 mm pipes, including irregular culverts.
Mission distance	Inspect 1 km of live sewer per mission.	Inspect 5 km per mission.
Mission duration	2 hours continuous operation.	6 hours continuous operation.
Autonomy	Complete 80% of route distance without teleoperation.	Complete 95% of route distance without teleoperation.
Human intervention	Fewer than 1 physical intervention per kilometre.	Fewer than 1 physical intervention per 10 km.

Recovery	Self-recover from inversion, low-speed tumbling and shallow sediment entrapment.	Self-recover from inversion, moderate flow tumbling, minor snagging and partial burial.
Obstruction tolerance	Pass through or around partial obstructions occupying 25% of pipe cross-section.	Pass through or around obstructions occupying 50% of pipe cross-section where a safe gap exists.
Flow tolerance	Operate in shallow flow up to 0.5 m/s.	Operate in turbulent or variable flow up to 1.5 m/s.
Navigation	Localise defects to within 2 m along the pipe.	Localise defects to within 0.5 m and identify the connected branch/junction.
Inspection quality	Capture usable visual or geometric data for 90% of inspected length.	Capture usable multi-modal data for 98% of inspected length.
Defect detection	Detect cracks, deformation, root ingress, deposits and blockages above agreed severity threshold.	Classify defect type and severity to utility-grade reporting standard.
Non-blockage safety	Robot must not become a persistent blockage; must be retrievable.	Robot includes certified fail-safe collapse / flotation / beacon / retrieval mode.
Decontamination	Cleanable and redeployable within 60 minutes.	Cleanable and redeployable within 20 minutes.
Cost proxy	Lower cost per inspected metre than human-entry inspection.	Lower cost per inspected metre than tethered CCTV for complex routes.
Environmental robustness	Survive immersion, abrasion, biofouling and mild chemical exposure for 50 missions.	Survive 500 missions with replaceable outer skin or modules.

Table 2. Targeted metrics.

End-of-programme challenge

The robot must enter through a standard manhole, navigate a live-equivalent sewer course with a variety of pipe diameters, inspect a multi-branch route, identify defects, pass partial obstructions, survive flowing water and sediment, and return to a recoverable point without becoming a blockage. The course includes shallow and deeper flowing-water sections; sediment, grease-like material and loose debris; and a partial blockage. The ARIA prototype will compete directly against incumbents such as tethered CCTV crawlers. We will also assess its performance against human entry, using historic data.

KEY SOURCES

1. Seok S, Wang A, Chuah MY, Hyun DJ, Lee J, Otten DM, et al. Design principles for energy-efficient legged locomotion and implementation on the MIT Cheetah robot. *IEEE/ASME Trans Mechatron.* 2015;20(3):1117-1129. Available from: <http://doi.org/10.1109/TMECH.2014.2339013>
2. Araz M, Siebert T, Badri-Spröwitz A, Schmitt S, Haeufle DFB. Muscle–tendon mechanics resolve the trade-off between energy-efficient and robust locomotion. *Biol Lett.* 2025;21(11):20250200. Available from: <http://doi.org/10.1098/rsbl.2025.0200>
3. Pfeifer R, Bongard J. *How the body shapes the way we think: a new view of intelligence.* Cambridge (MA): MIT Press; 2006. Available from: <http://doi.org/10.7551/mitpress/3585.001.0001>
4. Buchner TJK, Fukushima T, Kazemipour A, Gravert SD, Prairie M, Romanescu P, et al. Electrohydraulic musculoskeletal robotic leg for agile, adaptive, yet energy-efficient locomotion. *Nat Commun.* 2024;15(1):7634. Available from: <https://doi.org/10.1038/s41467-024-51568-3>
5. Burden SA, Libby T, Jayaram K, Sponberg S, Donelan JM. Why animals can outrun robots. *Sci Robot.* 2024;9(89):eadi9754. Available from: <https://doi.org/10.1126/scirobotics.adi9754>
6. Wang T, Pierce C, Kojouharov V, Chong B, Diaz K, Lu H, et al. Mechanical intelligence simplifies control in terrestrial limbless locomotion. *Sci Robot.* 2023;8(85):eadi2243. Available from: <https://doi.org/10.1126/scirobotics.adi2243>
7. Chong B, He J, Soto D, Wang T, Irvine D, Blekherman G, et al. Multilegged matter transport: a framework for locomotion on noisy landscapes. *Science.* 2023;380(6644):509-515. Available from: <https://doi.org/10.1126/science.ade4985>