DRAGONWORX BIOMIMETIC TECHNOLOGIES · R&D DIVISION

Animal Superpowers at Human Scale

A metamaterials research roadmap: 14 biological traits, the physics behind them, and the wearable technologies they unlock.

Every animal on earth is a materials science problem that evolution solved over millions of years. The electric eel doesn't "choose" to shock — it is built from a biological battery. The flea doesn't "try" to jump 200× its body length — its legs are pre-loaded catapults made from a protein that stores energy more efficiently than rubber. The water strider doesn't "balance" on water — its legs are superhydrophobic metamaterial structures that make sinking physically impossible.

This document applies engineering reverse-engineering to 14 of the most extreme biological capabilities, identifies the physical mechanisms responsible, and maps each to a specific metamaterial or fabrication pathway that DragonWorx can pursue as wearable suit technology, vehicle coatings, or embedded systems. Each entry includes a technology readiness level (TRL) estimate and a market opportunity signal.

14	9	4	$2.1T
Animal source traits analyzed	Distinct metamaterial tech paths	Wearable suit applications near-term	Addressable market across all verticals

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CONTENTS

What's Inside

SECTION I · AERIAL & HIGH-ALTITUDE

Aerial & High-Altitude

Flight is the most energy-intensive locomotion problem in nature. Every aerial animal has solved a unique subset of it — stall, drag, lift-to-weight, deployment speed. Three entries here, starting with one DragonWorx has already partially solved.

01 Humpback Whale (Megaptera novaeangliae)

Delays stall by 40% beyond any smooth leadi

BUILT · AERODYNAMIC · PASSIVE · WEARABLE

THE SUPERPOWER

Tubercle Leading Edges — Passive Stall Delay

Sinusoidal bumps along the pectoral fin leading edge allow the whale to execute tight turns at low speed without stalling. At human scale, equivalent to climbing at 28deg angle of attack where a normal airfoil fails at 22deg.

HOW IT WORKS — PHYSICS

Tubercles create spanwise vortex generators that energize the boundary layer. The sinusoidal geometry (wavelength ~30% chord, amplitude ~5% chord) breaks the stall front into discrete cells rather than a sudden global separation. The physics is: delayed boundary layer separation via controlled micro-turbulence injection, identical in principle to golf ball dimples but distributed along span.

METAMATERIAL / TECH PATH

TPU-molded sinusoidal strip bonded to leading edge of Carbon-Dyneema shell. Amplitude/wavelength tuned for 150-300mm chord at 30-60mph. Scout tier uses silk-screened surface print approximation. Full geometry requires precision thermoforming or multi-jet 3D print in Shore 60A elastomer.

DRAGONWORX APPLICATION

STATUS: Partially implemented in DragonSuit Apex tubercle leading edge strip. Next step: wind tunnel validation with a university a university aerodynamics research facility

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MARKET HINT

$340M extreme sports + $2.1B UAV aerodynamics

TRL: TRL 4 — lab validated, not yet flight-tested

02 Flying Squid (Todarodes pacificus)

Achieves 11.2m glide distance — 30x body l
combo.

CONCEPT | AQUATIC/AERIAL | DUAL-PHASE | MILITARY

THE SUPERPOWER

Jet-Assisted Glide Deployment

The flying squid fires a water jet to launch, then extends lateral fin membranes and tentacle webbing into a swept delta-wing configuration, achieving glide ratios near 4:1 at high speed before water-entry. At human scale: burst-assisted wingsuit deployment from near-zero altitude.

HOW IT WORKS — PHYSICS

Two-phase system. Phase 1: mantle cavity water jet — hydrostatic pressure converted to kinetic energy in ~80ms burst. Phase 2: passive membrane glide using the same geometry as flying fish. The key is the transition: the squid locks fin geometry via muscle tension the moment jet pressure drops, preventing chaotic flutter. The membrane is a fiber-reinforced viscoelastic skin with anisotropic stiffness — stiff spanwise, compliant in chord direction.

METAMATERIAL / TECH PATH

Phase 1 analog: CO_2 canister-triggered SMP panel deployment — panels stored flat (warm), lock into airfoil geometry on cool-down trigger (cold gas release). No mechanical actuators. Phase 2 analog: anisotropic Dyneema-Lycra weave identical to DragonSuit washout layer. The transition physics maps directly to SMP rib locking mechanism already in the Apex stack.

DRAGONWORX APPLICATION

Burst-assisted low-altitude DragonSuit deployment. Eliminates the minimum altitude problem entirely — the suit self-deploys on a 10m drop rather than requiring 27m+ free-fall for stable flight. Military HALO/HAHO applications.

MARKET HINT

$85M military HALO/HAHO gear + search & rescue

`TRL: TRL 2 — concept only, no prototype`

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03 Peregrine Falcon (Falco peregrinus)

389 km/h stoop dive. Slot feathers at wing tip

AERODYNAMIC | PASSIVE | AUXETIC | HIGH-VALUE

THE SUPERPOWER

Feather-Slot Wingtip Vortex Management

During a stoop the falcon spreads individual primary feathers like spread fingers. Each feather slot acts as a mini-wing that redirects tip vortex energy — reducing induced drag by ~30% vs. a smooth wingtip. At human scale: the equivalent of wingsuit tip slots that passively open under aerodynamic load.

HOW IT WORKS — PHYSICS

Each slotted primary feather operates as an independent small-AR lifting surface. Slots convert the rotating vortex core (pure drag) into small forward-directed thrust vectors. The feathers are passively compliant — they open under load and close at rest via rachis stiffness. The physics: tip vortex energy redistribution via serial Helmholtz vortex segmentation.

METAMATERIAL / TECH PATH

Spanwise tip slots in DragonSuit arm wing trailing/leading edge: perforated Carbon-Dyneema panels with auxetic geometry at the tip zone. Under aerodynamic load, auxetic expansion opens slot gaps (negative Poisson's ratio does this passively). At rest the panels return to closed. No actuators. This is a direct application of the auxetic panel already in the DragonSuit Apex stack — repurposed from camber control to vortex management.

DRAGONWORX APPLICATION

DragonSuit Apex tip zone redesign. Also: UAV wingtip retrofit coating. Potential licensing to commercial aviation for high-AR wing tips.

MARKET HINT

$400M UAV efficiency market + $12B commercial aviation

TRL: TRL 3 — component-level validated in literature

SECTION II · AQUATIC LOCOMOTION

Aquatic Locomotion

Water is 800x denser than air. Every aquatic adaptation is an extreme materials and geometry problem — the same physics principles apply at much higher forces and energy densities than aerial systems.

04 Boxfish (Ostracion cubicus)

A cube-shaped fish that is hydrodynamically hull.

AQUATIC | PASSIVE STABILITY | GEOMETRY-BASED | NEAR-TERM

THE SUPERPOWER

Paradoxical Turbulence-Stable Hull Geometry

The boxfish's boxy, ridged hull generates self-correcting vortices that stabilize it in crosscurrents. Counterintuitively, the keeled ridges create vortices that push the fish back toward center — passive yaw stability with no active fin control. At human scale: an AquaSuit hull that passively self-orients in ocean currents, dramatically reducing diver/swimmer exertion.

HOW IT WORKS — PHYSICS

Ridge geometry creates attached leading-edge vortices (LEVs) on the dorsal and ventral surfaces. These LEVs generate restoring moments in yaw and roll — the same physical mechanism as delta-wing aircraft at high AoA. The boxfish hull is a passive feedback control system built from geometry alone. No sensors, no muscles, no computation. Mercedes-Benz actually prototyped a car body based on this geometry (the Bionic Concept Car, 2005), achieving 0.19 Cd.

METAMATERIAL / TECH PATH

3D-printed or thermoformed hull panels with boxfish ridge geometry for underwater vehicles and diving suits. The ridge spacing and height are Reynolds-number-tuned to human swimming speeds (1-3 m/s). Material: flexible TPU over rigid carbon fiber skeleton — compliant ridges that maintain geometry under hydrostatic pressure. Surface coating: shark-denticle riblet film (already in DragonSuit stack) for additional friction drag reduction.

DRAGONWORX APPLICATION

AquaSuit v1 hull geometry. Underwater diver exosuit for SAR and military diving. DARPA and Navy SEAL community are active buyers of this class of tech.

MARKET HINT

$380M military diving + $1.2B commercial marine

TRL: TRL 3 — concept validated (Mercedes prototype 2005), not built wearable

05 Electric Eel (Electrophorus electricus)

Generates 860V, 1A bursts. Electrolocates pr
precision.

ENERGY HARVEST SENSING MILITARY ACCESSIBILITY

THE SUPERPOWER

Bioelectric Voltage Generation & Electrolocation

The electric eel contains ~6,000 electrocytes — living batteries stacked in series like Voltaic cells. Each electrocyte generates ~100mV; in series: 600V. Separately, the eel uses low-voltage pulses (10V) for electrolocation — sensing distortions in its self-generated electric field. At human scale: a suit that harvests ambient piezoelectric energy AND provides non-visual spatial awareness through electric field distortion sensing.

HOW IT WORKS — PHYSICS

Electrocytes are modified muscle cells (electrogenic ion channels). The stacking geometry is the critical insight — series electrical connection, parallel mechanical arrangement. The low-voltage electrolocation uses the body surface as an antenna array, detecting field perturbations at nanoamp sensitivity. The physics is pure electrochemistry + Maxwell's equations. The key metamaterial opportunity is the stacked dielectric architecture, not the biology itself.

METAMATERIAL / TECH PATH

Two distinct tech paths: (1) Piezoelectric metamaterial panels — stacked PVDF (polyvinylidene fluoride) films in series, harvesting body motion, breath, and impact into stored charge. Current PVDF stacks generate ~100mW from human walking motion — enough to power embedded sensors. (2) Flexible electrode array on suit surface (conductive graphene-nanoplatelet composite in silicone matrix) for near-field presence detection — detecting obstacles, people, and surfaces without vision at up to 2m range.

DRAGONWORX APPLICATION

ElectraSuit: energy-harvesting combat/SAR suit with passive power generation and non-visual obstacle detection. Enormous military value — night ops, underwater, smoke/dust environments. Also: electrosensory wheelchair suit for visually impaired users ($4.2B accessibility market).

MARKET HINT

$8.5B military wearable electronics + $4.2B accessibility

TRL: TRL 3 — PVDF harvesting validated, full suit integration not attempted

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06 Mantis Shrimp (Odontodactylus scyllarus)

Punches at 23 m/s. 160N force from a 5cm li

IMPACT BISTABLE SPRING-LOADED EXOSUIT

THE SUPERPOWER	HOW IT WORKS — PHYSICS	METAMATERIAL / TECH PATH
Spring-Loaded Saddle Mechanism + Cavitation Force The mantis shrimp's dactyl club stores energy in a saddle-shaped spring structure, releasing it in 3ms — faster than any muscle can contract. The strike hits hard enough to create cavitation bubbles whose collapse delivers a second impact. Total impulse: ~480g acceleration equivalent. At human scale: an exosuit joint pre-loader that amplifies punch/kick force 10-40x, or a rapid-deployment mechanism that fires in milliseconds.	The saddle spring is a curved beam under compression that buckles in a controlled snap-through event — same physics as a snap bracelet or bistable composite. The latch mechanism uses a mineralized 'periodic region' (herringbone fiber architecture) that resists fatigue across millions of cycles. The helicoidal fiber arrangement in the club itself distributes the impact stress across all fiber orientations simultaneously — no single crack propagation direction exists.	Bistable composite snap-through joints: unsymmetric composite panels (same bistable mechanism Dr. Dancila studies at UTA) embedded in suit elbow/knee joints. Stores mechanical energy in compressed state, releases in <5ms on trigger. Material: carbon fiber / shape memory alloy hybrid giving both the snap energy and fatigue resistance. Helicoidal fiber architecture (Bouligand structure) for impact panels — already validated in armor literature, not yet applied to wearable suits.

DRAGONWORX APPLICATION	MARKET HINT
JumpSuit / ImpactSuit joint actuators. Exosuit for construction, disaster response (moving rubble), and combat. Also: rapid-deployment mechanism for the squid-inspired suit deployment system (Entry 02).	$3.2B military exoskeleton + $1.8B construction exosuit **TRL: TRL 3-4 — bistable composites validated, suit integration is novel**

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07 Shark (Multiple species)

Drag reduced 8-13% by microscale denticles.

BUILT-ADJACENT PLATFORM MULTI-MARKET VALIDATED

THE SUPERPOWER

Dermal Denticle Riblet Skin

Already partially in DragonSuit. But the full application space is far broader than flight suits. Shark denticles reduce turbulent skin friction drag across any fluid — air OR water — at any scale from swimsuits to aircraft to submarine hulls to hospital surfaces (anti-biofilm).

HOW IT WORKS — PHYSICS

V-shaped riblets aligned with flow direction reduce turbulent boundary layer mixing by confining quasi-streamwise vortices to the valleys between riblets, preventing them from interacting with the wall. Optimal riblet spacing scales with flow velocity — faster flow = smaller optimal riblets. The geometry is universal: same physics in air at 200mph and water at 5mph, just different absolute dimensions. Speedo Fastskin and Lufthansa Technik riblet film both validated ~6-8% drag reduction in production applications.

METAMATERIAL / TECH PATH

Laser-etched riblet film (already in DragonSuit Apex). Extension to: (1) AquaSuit neoprene replacement — TPU sheet with laser-etched denticle pattern on outer surface, 8-10% drag reduction in swimming. (2) Vehicle wrap product: adhesive riblet film for boat hulls, aircraft fuselages, cycling helmets. (3) Anti-biofilm medical surface: denticle geometry physically prevents bacterial adhesion — no chemicals needed.

DRAGONWORX APPLICATION

Platform product with 5 distinct markets. Vehicle wrap is highest-volume, lowest-margin. Medical anti-biofilm is lowest-volume, highest-margin ($800/m2). AquaSuit is the wearable play.

MARKET HINT

$800M swimwear/cycling + $12B marine + $4.5B medical surfaces

TRL: TRL 6 — production-validated in aviation and swimwear, not DragonWorx-built yet

SECTION III · SURFACE INTERACTION

Surface Interaction

Grip, repulsion, and locomotion on extreme surfaces — wet, vertical, liquid. Three of the most investment-ready technologies in this document are here.

08 Gecko (Gekko gecko)

Holds 40x its body weight on glass. Dry adhe

NEAR-TERM | MILITARY | VALIDATED | PLATFORM

THE SUPERPOWER

Van der Waals Dry Adhesion — GripSuit

The gecko's toe pads contain ~6.5 million setae — hair-like structures that split into 100-1000 spatulae at their tips. The spatulae are so small (~200nm) that Van der Waals molecular attraction dominates gravity. The entire pad generates 10N/cm2 adhesive force with zero glue, zero suction. Releases by changing angle. At human scale: gloves and boots that allow vertical surface climbing on any hard surface, wet or dry, in vacuum.

HOW IT WORKS — PHYSICS

Van der Waals force is contact-area-maximization. Setae increase real contact area by ~1000x vs. a smooth surface on rough substrates. The hierarchical geometry (macrosetae → microsetae → spatulae) self-conforms at multiple scales. Release is purely geometric — angling the pad backward reduces real contact area to near zero. No chemical change, no suction, no energy input. Critical: the adhesion is STRONGER when wet (capillary + VdW combined).

METAMATERIAL / TECH PATH

Hierarchical micro/nano pillar arrays in polyurethane or PDMS, fabricated by nanoimprint lithography over laser-ablated master molds. Stanford, DARPA, and several startups (Setex Technologies) have demonstrated gecko-inspired climbing pads at up to 100kg load. The challenge is durability and contamination. DragonWorx approach: Carbon-fiber-backed PDMS microarray gloves and boot soles. Hierarchical pillar geometry (10um macro / 500nm micro). Self-cleaning via elastomer elastic recovery.

DRAGONWORX APPLICATION

GripSuit: Military building-scaling gloves and boots. Construction worker fall-prevention panels. Adaptive gripping exo-gauntlets for manufacturing. Secondary: medical surgical grip tools, robotic end-effectors.

MARKET HINT

$2.8B military special ops + $18B fall protection + $6B robotics

TRL: TRL 5 — demonstrated at human body weight by DARPA Z-Man program (2014)

09 Water Strider (Gerris remigis)

Walks on water. 15x body weight support. Se

AQUATIC | SURFACE TREATMENT | PASSIVE | NEAR-TERM

THE SUPERPOWER

Superhydrophobic Surface Locomotion

The water strider's legs have 10,000 microhairs per mm2, each coated with nanoscale grooves. The result is a superhydrophobic surface (contact angle >160deg) that traps air pockets — the Cassie-Baxter wetting state. Each leg dimples the water surface without piercing it, distributing body weight across a ~0.5cm2 contact area. Propulsion uses vortex pairs shed from leg stroke — no surface penetration. At human scale: AquaSuit boot soles that walk on water OR reduce drag by 40% in swimming via trapped-air plastron effect.

HOW IT WORKS — PHYSICS

Two distinct physics: (1) Static superhydrophobicity — re-entrant surface geometry with Cassie-Baxter air trapping. Contact angle >150deg achieved by surface roughness at two scales (micro + nano). Lotus leaf is the canonical example. (2) Dynamic plastron breathing — trapped air layer on submerged surfaces acts as an air-water interface, reducing friction drag by 30-40% (equivalent to drag-reducing polymer injection, but passive and permanent). Diving bell spider and some aquatic insects use this permanently.

METAMATERIAL / TECH PATH

Hierarchical surface texturing: laser ablation or chemical etching creates micro-pillar array, then nanoparticle coating (silica or fluorocarbon) provides the nano-scale roughness. Produces contact angle >155deg. AquaSuit application: neoprene replacement fabric with integrated superhydrophobic outer surface — passive drag reduction in swimming, water-repellency in surface ops. The trapped-air plastron effect could reduce competitive swimmer drag by 30% — an illegal performance enhancement for sport, but legal for military/SAR.

DRAGONWORX APPLICATION

AquaSuit v1 outer surface treatment. Military amphibious ops — surf zone, open-water swim. SAR diver efficiency. Competitive swimming (with regulatory carve-out). Boat hull anti-fouling coating.

MARKET HINT

$800M swimwear + $4.2B marine anti-fouling + $1.5B military aquatic

TRL: TRL 4-5 — superhydrophobic surfaces well-validated, plastron swim suit novel

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10 Flea (Siphonaptera)

Jumps 200x its body length. Accelerates at 10

EXOSUIT | NEAR-TERM | SPRING-LOADED JUMP

THE SUPERPOWER

Resilin Spring Pre-Loading — JumpSuit

The flea stores energy in resilin — a rubber-like protein with ~97% elastic efficiency (rubber is ~85%). The resilin pad in the flea's thorax is compressed by a muscle over ~0.1s, then released in 0.7ms by a latch mechanism. At human scale: if a 70kg human had flea-proportional jump capability, they could jump 120m high from standing. The math: 200x body length x human height 5'11' = 119m vertical jump. The limiting factor is not force — it's biology. A suit could deliver this via pre-loaded composite spring joints.

HOW IT WORKS — PHYSICS

Resilin achieves 97% elastic energy return because it has no crystalline structure — purely amorphous cross-linked network with near-zero hysteresis. The latch mechanism is a sclerotized cuticle click — bistable geometry that holds compression until a threshold is crossed, then snaps through. The physics: elastic pre-loading + bistable latch release. The energy density of resilin: ~2 MJ/m3. Carbon fiber composites: ~5 MJ/m3. So the material improvement is available — the challenge is the latch.

METAMATERIAL / TECH PATH

Carbon fiber leaf-spring joint inserts at ankle and knee: stores energy during gait flexion, releases on extension via bistable snap-through latch. Similar to Össur Flex-Run blade technology but with a snap-latch release. Full JumpSuit: series-elastic actuator (SEA) joints at ankle, knee, and hip with synchronized pre-load. 10x jump height enhancement is achievable with current carbon fiber spring technology — 3-4x even without bistable latch. Material: IM10 carbon fiber / epoxy leaf springs, 3D-printed TPU latch pawls.

DRAGONWORX APPLICATION

JumpSuit: military rapid assault, SAR cliff access, firefighter stair ascent. Paralympic sport (already proven by carbon blade runners). Industrial access (rooftop, tower work). Combine with GripSuit for complete vertical environment navigation system.

MARKET HINT

$6.5B military/SAR exosuit + $2.1B industrial access + $800M prosthetics

TRL: TRL 5 — spring-joint exosuits exist (MIT, Harvard), DragonWorx integration novel

Defense & Offense

The defense market is the highest-ASP, most forgiving-of-cost, and most accessible to novel materials technology of any vertical in this document. DARPA, SOCOM, and the Army Research Laboratory are all active funders of exactly this class of research.

11 Scorpion (Various species)

UV fluorescent exoskeleton. Venom delivered

MILITARY · MEDICAL · NOVEL · HIGH-MARGIN

THE SUPERPOWER

UV Fluorescence + Microfluidic Payload Delivery

Scorpions fluoresce intensely under UV light due to beta-carboline and related compounds in the hyaline layer of the cuticle. The biological purpose is debated — possibly UV detection, possibly predator confusion. The venom delivery is a masterpiece of microfluidic engineering: a hollow sting with two independent channels, each connected to a separate venom gland, delivering different toxin fractions with each pump cycle. At human scale: a suit surface that is passively detectable under UV (IFF — identification friend/foe) AND a microfluidic network that can deliver chemical payloads via surface contact.

HOW IT WORKS — PHYSICS

UV fluorescence: beta-carboline in the cuticle achieves quantum yield ~0.8 — extremely bright under 365nm UV. Microfluidic delivery: the sting is a hollow curved tube with two independent lumen channels, each 50-200um diameter, connected to paired venom glands. Compressor muscles drive sequential pulses. The physics is straightforward microfluidics — no novel mechanism, just extraordinary miniaturization achieved via chitin exoskeletal tube-drawing.

METAMATERIAL / TECH PATH

UV fluorescence: beta-carboline compounds (or synthetic analogs) embedded in polymer matrix coating outer suit panels. No power, no electronics — purely photoluminescent. Microfluidic network: PDMS channels (50-200um) laser-ablated or soft-lithography-patterned through suit outer shell layer, connected to a reservoir bladder. Delivers wound sealant, chemical marker, or deterrent agent on surface puncture or manual trigger.

DRAGONWORX APPLICATION

SentinelSuit applications: (1) Passive UV-IFF: suit panels fluoresce for friendly-force identification in UV-lit environments. No battery, no signal. (2) Microfluidic medical delivery: combat suit that delivers wound sealant or clotting agent automatically on surface laceration. (3) Anti-personnel chemical deterrent surface for police/corrections applications.

MARKET HINT

$1.2B military IFF + $3.8B combat medical + $800M law enforcement

TRL: TRL 2-3 — components exist, suit integration is novel

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12 Bombardier Beetle (Brachinus spp.)

Fires 100C steam jet at 500Hz, 360deg aim. C

PROPULSION | AQUATIC | SPACE | NOVEL

THE SUPERPOWER

Directed Chemical Pulse Micro-Propulsion

The bombardier beetle mixes hydroquinone and hydrogen peroxide in a reaction chamber, triggering an exothermic reaction that vaporizes water into 100C steam at ~500Hz pulse rate. The explosion chamber has a check-valve geometry that prevents blowback. The spray is directionally aimed by rotating the abdomen tip. At human scale: a suit or small vehicle with on-demand chemical thruster using non-toxic hypergolic propellant pairs — for maneuvering in zero-G, underwater propulsion, or emergency thrust.

HOW IT WORKS — PHYSICS

The beetle's reaction is a binary hypergolic pair — no ignition needed, reaction is spontaneous on mixing. The pulse valve is a passive check-valve that opens under pressure and closes between pulses — no electrical control. The 500Hz pulse rate creates a nearly continuous thrust with very fine impulse control. The key engineering insight: the explosion chamber geometry is a de Laval nozzle in miniature — pressure amplification built into organic tissue structure.

METAMATERIAL / TECH PATH

Microfluidic reaction chamber in polymer/ceramic composite: two reservoir channels converge at a reaction chamber with integrated check-valve geometry (3D-printed in ceramic resin). Non-toxic binary propellant: concentrated H_2O_2 + organic catalyst. Applications: (1) AquaSuit thruster — directional water jet propulsion, 5-15N thrust per unit. (2) Emergency DragonSuit altitude gain thruster. (3) Satellite attitude control (scalable to space). DARPA MENTOR program has funded microchemical thruster research.

DRAGONWORX APPLICATION

PropulsionSuit: AquaSuit underwater directional thruster array. Emergency DragonSuit climb-out thruster (fires once). Long-term: satellite micro-propulsion licensing.

MARKET HINT

$2.4B underwater propulsion + $1.1B space micro-propulsion

TRL: TRL 2 — beetle mechanism well-studied, suit application novel

13

Mantis Shrimp Club (Odontodactylus scyllarus)

Withstands 700N impacts at 50,000 rads/s. N

ARMOR HIGH-TRL MILITARY LICENSABLE

THE SUPERPOWER

Bouligand (Helicoidal) Fiber Architecture — ArmorSuit

The mantis shrimp's dactyl club is the most impact-resistant biological material known. It absorbs the same punch force it delivers — yet never fractures over millions of cycles. The secret is the Bouligand structure: fiber layers rotated by a small fixed angle (typically 20-30deg) between each ply. Any crack propagating through the material must rotate with the fiber direction, converting linear crack growth into a helical spiral — dramatically increasing the total fracture energy required.

HOW IT WORKS — PHYSICS

The Bouligand architecture prevents crack propagation via geometric toughening. A crack growing through conventional unidirectional fiber travels straight — following the fiber interface. In helicoidal layup the crack must continuously change direction, delaminating in a tight spiral and consuming far more energy per unit crack length. Additionally, the periodic region (herringbone fiber pattern) at the impact face redistributes stress laterally before it reaches the interior. Result: specific impact toughness 70% higher than equivalent carbon fiber unidirectional layup.

METAMATERIAL / TECH PATH

Helicoidal carbon fiber layup schedule: replace standard [0/45/90/-45] CFRP with [0/15/30/45/60/75/90...] continuous rotation schedule. No new materials needed — same carbon fiber, same epoxy, different ply stacking. Can be produced on standard automated fiber placement (AFP) machines. Weight-neutral with conventional CFRP. DragonWorx application: Apex-M and Apex-SAR outer shell panels in helicoidal CFRP for ballistic and impact resistance. Also: motorcycle helmets, body armor backing plates, vehicle panels.

DRAGONWORX APPLICATION

ArmorSuit: Apex-M combat suit outer shell in helicoidal CFRP. Vehicle armor panels. Helmet liner. Potential licensing to defense primes.

MARKET HINT

$28B body armor + $8B vehicle armor + $3B helmet market

TRL: TRL 5-6 — helicoidal CFRP validated in literature and prototype armor, production scale AFP implementation is TRL 4

Sensing & Biological Interface

14

Platypus (Ornithorhynchus anatinus)

40,000 electroreceptors in bill. Detects 50nV/

SENSING | MILITARY | ACCESSIBILITY | HIGH-VALUE

THE SUPERPOWER

Passive Electroreception Field Sensing

The platypus hunts entirely with eyes and ears closed, detecting micro-electric fields generated by the muscle contractions of prey buried in riverbed mud. Its bill contains 40,000 electroreceptors detecting fields as small as 50nV/cm at up to ~30cm range. At human scale: a suit or helmet with an array of flexible graphene electrodes that detects the presence of living organisms, hidden wires, electronic devices, or structural voids — through walls, in darkness, underwater, in smoke.

HOW IT WORKS — PHYSICS

Electroreception works because all living things and electrical devices generate oscillating electric fields — muscles at 10-100Hz, electronics at 50/60Hz harmonics, neurological activity at 0.1-100Hz. A high-sensitivity electrode array on the body surface can detect these fields by differential sensing between widely-spaced electrodes (the gradient, not the absolute voltage). The platypus bill processes the spatial gradient across 40,000 sensors to triangulate source position. Modern graphene electrodes achieve 1nV/sqrt(Hz) noise floor — theoretically better than the platypus.

METAMATERIAL / TECH PATH

Flexible graphene-nanoplatelet / PDMS composite electrode array embedded in suit helmet or collar: 64-256 electrodes over ~0.1m2 area, connected to low-noise differential amplifier array (commercial bio-signal chips, e.g., Texas Instruments ADS129x series). Signal processing: spatial gradient computation maps field sources in 3D space within ~2m. Outputs heads-up display spatial awareness overlay. Power: <50mW. No emitted signal — entirely passive, undetectable by opponent.

DRAGONWORX APPLICATION

SensorSuit helmet insert: combat soldier passive threat detection. SAR buried-victim detection. Firefighter through-wall life detection. Structural inspection (rebar location, hidden wiring). Eventually: consumer wearable for blind/visually impaired navigation.

MARKET HINT

$4.8B military ISR + $3.2B SAR + $4.2B accessibility

TRL: TRL 3 — graphene electrodes and bio-signal chips exist, spatial array integration in wearable form factor is novel

APPENDIX

Technology Summary & IP Landscape

TRL Matrix — All 14 Entries

Animal / Entry	Technology	TRL	Next Step	Est. Cost to TRL+1
01 Humpback Whale	Tubercle LE	4	Wind tunnel test @ UTA	$35K
02 Flying Squid	SMP burst deploy	2	Lab demo prototype	$80K
03 Peregrine Falcon	Auxetic tip slots	3	Component wind tunnel	$25K
04 Boxfish	Ridge hull geometry	3	3D-print + pool test	$15K
05 Shark	Riblet film	6	DragonWorx production run	$40K
06 Electric Eel	PVDF harvest + electrode	3	Bench prototype	$55K
07 Mantis Shrimp	Bistable joint	3-4	Joint prototype + test	$90K
08 Gecko	Micro-pillar adhesion	5	Glove + boot prototype	$120K
09 Water Strider	Superhydrophobic suit	4-5	Garment prototype	$65K
10 Flea / Resilin	Carbon spring joints	5	Jump bench test	$75K
11 Scorpion	UV IFF + microfluidic	2-3	Panel demo	$45K
12 Bombardier Beetle	Micro thruster	2	Reaction chamber fab	$110K
13 Mantis Club	Helicoidal CFRP	5-6	AFP panel production	$95K
14 Platypus	Electrode array	3	64-ch bench prototype	$85K

Metamaterial Platform Summary

Platform Tech	Entries Using It	Core Material	Fabrication Route
SMP Rib Skeleton	01, 02, 03	DiAPLEX / Veriflex SMP	Thermoform / injection mold
Auxetic Panel	01, 03, 09	Re-entrant PU foam / PDMS	Laser cut or 3D print lattice
Bistable CFRP	07, 10, 13	IM10 carbon / epoxy	Autoclave or AFP layup
Riblet Film	01, 04, 05, 09	PVDF or Kapton substrate	Laser ablation / nanoimprint
Micro-pillar Adhesion	08	PDMS / PU elastomer	Nanoimprint over laser master
PVDF Piezo Stack	06	PVDF film (Piezotech)	Multilayer lamination

Graphene Electrode	06, 14	GNP / silicone composite	Screen print or spray coat
Microfluidic Network	11, 12	PDMS or ceramic resin	Soft lithography / DLP print
Helicoidal CFRP	13	Standard UD carbon fiber	AFP with rotated ply schedule

Every trait in this document has been validated by millions of years of selection pressure operating on material science problems identical to ours. The animals didn't get it right by accident — they got it right because failure meant death. That is a more rigorous testing regime than any aerospace certification program. We are not copying nature. We are reading the engineering manual it left behind.

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