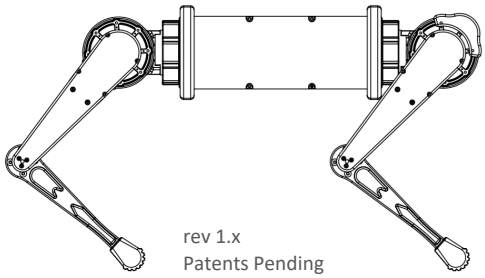
Ghost Spirit™ 40 | Q-UGV™

GHOSTROBOTICS
Robots That Feel the World®

Ghost Spirit™ 40 small-sized all-terrain unmanned ground drone, with platform-wide SDK for university and enterprise R&D, and commercial and military application development

Tele-op or autonomous. Inspection, swarming, comms meshing, and general experimentation



Benefits of Legs vs. Wheels & Tracks

Simply put, legs outperform wheeled and tracked unmanned ground vehicles (UGVs) at smaller scale on unstructured terrain: uneven surfaces, debris fields, the great outdoors, stairs and even verticals.

Legs are not only good at traversing complex terrains, but they have greater agility, and substantially improve user acceptance if designed well.

But the complexity to build a low-cost, durable and agile legged robots has been insurmountable to-date.

Ghost Robotics is Changing That

Ghost is developing the next-generation of legged robots with a low-cost R&D models, as well as modular field-repairable, agile, high-endurance and customizable industrial and military platforms.

Users and partners can leverage Ghost's robust SDK to enhance and build new behaviors, integrate any sensor, radio or electronics, and create a host of solutions and apply lab experiments.

Spirit Series

A fast, lightweight and back-packable research and application development Q-UGV perfect for university and enterprise robotics R&D, as well as inspection, military and swarming experiments. And eventually a framework for a future range of smaller Vision ™ and Wraith ™ series ruggedized field-use robots.

Model	Size	Primary Uses
Spirit 40	**Small**	**R&D, Confined Inspection**

Key Features & Benefits v1.x

The Ultimate Research Robot. Built on same software, SDK and electronics as the Vision and Wraith series Q-UGVs for enterprise and military.

Fast & Agile. Up to 1 m/s fast-walk; 2 m/s run *

Long Endurance. 6km (3.7 miles) in 2 hours on a single charge. 3 - 5 hrs. mixed use & 12 hrs. standby.

Any Terrain. Traverse a range of unstructured terrains and substrates, and even stairs *

Unstoppable. Designed to self-right from any immobilization, and even operate when inverted

Very Robust. Blind Locomotion" over unstructured terrain, sensing forces through the motors even with reduced or complete loss of vision sensing

Tele-Op. Any controller or Ghost Mobile™ Android w/ dual joystick. Support for DoD IOP/JAUS & ATAK

Object Avoidance. Ghost safeguard avoidance AI under tele-op and autonomy modes

Autonomous. Ad-hoc or persistent autonomy ^

GPS-Denied Use. Odometry and sensor fusion for accurate GPS-denied positioning ^

Communications. 2.4, 5.8 GHz Wi-Fi; any IP/Ethernet or USB radio including SAT & SDR

Task Sensors. Any IP/Ethernet or USB camera, gas or specialty with a range of mounting points

Patents Pending. Pilot Models, specs subject to change. (** partial release or currently in early use or beta stage. ^ future release)*

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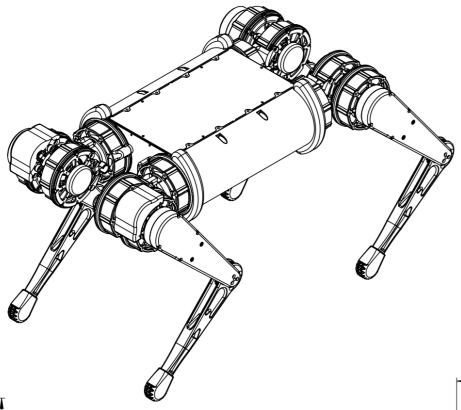
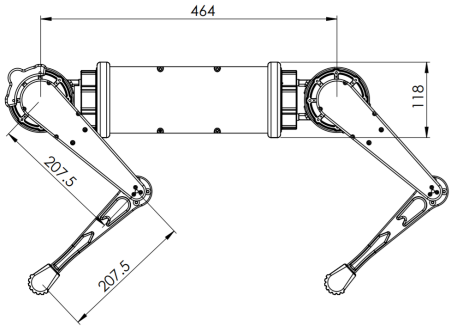
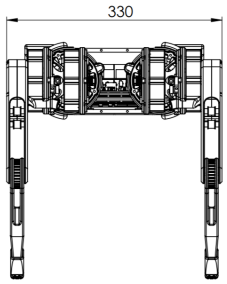
General Specifications (rev 1.x)





rev 1.0
Patents Pending



Summary Specs: rev 1.0

Robot Design	All-electric Q-UGV w/ software-based compliance. Constructed from ALU and composites with mounting points for 3rd party electronics
Actuation, Legs & Toes	3-DOF 12-Motor w/ 90º abduction, 300º hip and 320º continuous rotation knee articulation; removeable slide-on toes
Key Dimensions cm (in.)	L: 75cm (29.5) | W leg-2-leg: 33cm (13) | H at stand: 30cm (12)
Core Electronics | Compute | Sensors & Comms	Ghost proprietary | NVIDIA TX2 | Various 3rd party (see page 4)
Sensor & Comms I/O | Power	IP/Ethernet, USB 3.0 | 24V power; 5V, 12V regulated
Battery	275 WH Lithium-Ion Battery
Mass kg (lbs.)	Tare: 11.2kg (24.7) | w/ Base Battery: 12.5kg (27.6)
Available Payload@ kg (lbs.)	w/ Base Battery: 3kg (6.6)
Endurance w/ Base Battery base config. hrs.	Standby: 12 | Mixed Use: 3 -5 | Continuous Walk: 2
General MTBF	N/A

Available Configurations

Perception Package	• Spirit 40, Pelican case, with battery & direct charge system • Software: Ghost OS, SDK, Ghost Mobile, safeguard avoidance * • Comms: 2.4 and 5.8 GHz Wi-Fi • Tele-Op Controller: Wi-Fi dual joystick Android tablet remote • Computing: (1) NVIDIA TX2 computer • Sensors: fore (1) TOF and (1) RealSense Stereo

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Ghost OS™, SDK & Software Specs (rev 1.x)

Ghost OS & Platform

Comprehensive, from low-level firmware with 1kHz (2kHz *) closed-loop robot control, to higher-level sensing, autonomy, comms and admin, and SDK.

Ghost SDK

Leverage the Ghost SDK to create your own Q-UGV behaviors and autonomy applications. Build integrated solutions with fixed sensor, UAS, enterprise and DoD ecosystem platforms and task applications.

Low-Level API

- Direct access to motor torques & toe forces
- Libraries available for higher-level leg impedance control and force estimates; proprioception & IMU sensor fusion and state estimation; logging, power control, OCU interaction, messaging …
- Implement feedback-stabilized behaviors
- Low-latency sensor data availability

High-Level API

- High-level access with set modes: body & limb/arm velocity; direction & heading; waypoint & geo-fence; (de)activate obstacle avoidance…
- Messaging-based, no recompilation of core code
- Flexible: new sensors added with minimal changes; Interact with OCU for telemetry transmission, signals, mode selection, velocity commands
- Single operator to multi-operator/multi-robot

Behaviors

General. Walk 0.8m/s and fast-walk up to 1.0m/s (3.9 ft./s) and ; Run at 2m/s (6.6 ft./s) *; Crouch, crawl and crab *; Leap gaps up to 0.3m (1.1 ft) ^; Ground clearance 0-30cm (0-12 in.)

Blind-Mode. Traverse unstructured terrain by feeling the environment without visual sensors

Self-Right & Inverted Operation. Self-right from any immobilization; operate in inverted position

Stairs. Ascend and descend stairways ^

Sloped Surface. Varies by surface friction and toe

Manipulate. Programmable appendages

Ghost Autonomy™

Safeguard Avoidance. Minimizes collision risk with environmental objects under autonomous or tele-operation; with tunable parameters

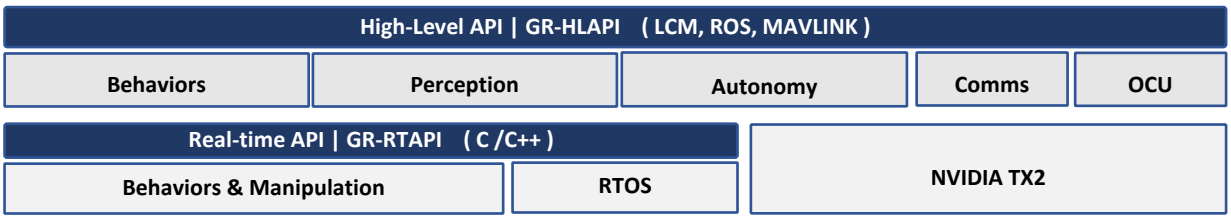
Object Detection. API accessible deep learning platform for creating use-specific applications

Autonomous Operation. Pre-defined mission routes or ad-hoc area exploration and mapping ^

Ghost Mobile™

- Mobile: Android mobile controller, admin, telemetry and video streaming application

Ghost SDK accessible components *



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Actuator, Electronics & Energy Specs (rev 1.x)

Actuators and electronics also sold Individually for R&D; building agile arms, bipeds & multi-leg robots; exo-limbs & other back-drivable motor applications

GR-UGV™ Actuators & Electronics

S40 Individual Actuator Modules & Leg

- 3-piece 3DOF leg with individual actuator motor-pods located proximally to minimize inertia, and removable multi-surface generic toes
- Unsealed actuators and belt-driven lower-link for indoor use, or outdoor environments with little to no moisture or particulates. *Sealed Actuators and belt-drive for possible future release ^*
- Maximum output torque: hip and abduction motors at 21Nm, and knee motor at 32Nm
- Maximum speed: hip and abduction motors at 360 rpm, and knee motor at 245 rpm

Motor Controllers

- In-body mounted; EtherCAT w/ current control; position, velocity, current, voltage, speed & impedance sensing
- Input 8-43V; current >80A peak, 15A RMS

Mainboard

- Dual-core processor RTOS; 1kHz (2kHz^) control loop
- EtherCAT comms with calibrated high-grade IMU
- Onboard multi-band RTK GNSS ^

Power Output

- 5V or 12V regulated, 24V unregulated, not to exceed 150W

Communication, Control & Telemetry

- Radios: 2.4 & 5.8 GHz Wi-Fi
- Any IP/Ethernet compatible radio (SAT, SDR)

Tele-Op Controllers

- WiFi Android controller w/ dual joysticks
- Most 3rd party joystick or touchpad controllers; Ghost Mobile using any Android phone/phablet
- DoD ATAK compatible & IOP /JAUS compliant

Computing

- NVIDIA® TX2 GPU with I/O 1x Ethernet, 2x USB

Sensors

Integrated Nav & Perception (fore)

- (1) TOF 3D image, 45fps, 224 x 171 and 62 -45°FOV
- (1) RealSense stereo @ 60 FPS, 640x480

External Sensors

- Any IP/Ethernet or USB 3.1 compatible sensor

GNSS ^

- Mainboard integrated multi-band RTK GNSS

Energy

- Swappable Li-Ion 275 WH w/ integrated BMS

Pilot Model Ambient Operating ℃	
Spirit 40 Robot	0 – 50 (122 °F)
GR-UGV Electronics & Actuators	0 – 50 (122 °F)
3rd party Electronics	varies

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