THE UNDERGROUND FAMILY

CS-425

THE TUNNEL CRAWLER FOR PASSAGES THAT ALREADY EXIST

A tracked crawler that enters tunnels and culverts on a fibre, maps them before anyone follows, and holds a passage on a person's confirmation.

CS-425 does not bore. It works passages that already exist: tunnels, culverts, storm sewers and service crawlspaces. It carries cameras, a lidar mapping unit and a gas sensor package on a fibre with a person at the far end, and on a confirmed cue it can interpose. It never strikes.

~25 kg	~450 mm	~0.8 m/s	~4 h	~500 m
CHASSIS MASS	PASSAGE DIAMETER AND ABOVE	CRAWL SPEED, ~2.9 KM/H	CONTINUOUS RECON ON THE BATTERY	FIBRE PER SPOOL, THE WAY BACK OUT

AT A GLANCE

A CRAWLER FOR PASSAGES THAT EXIST. A MAP BEFORE ANYONE WALKS IN.

Five figures size the machine. Four reasons explain why a buyer sends it in first.

NOBODY GOES IN FIRST

THE PASSAGE IS MAPPED BEFORE A PERSON ENTERS IT

CS-425 goes into a confined dark space instead of a person doing close-quarters clearance. The map, the camera feed and the gas readings come back up the fibre, so the first report on a passage never depends on someone having walked it.

NOTHING IN THE AIR

ONE FIBRE CARRIES THE WHOLE MISSION

Video, lidar, telemetry and command share one fibre with a person on the far end. There is no radio and no satellite receiver aboard in any tier: rock and soil stop both, and the design never leans on either.

ONE BAY

EVERY VARIANT IS A MODULE CHANGE

A single payload-bay interface carries the mechanical envelope, the power budget, the data interface and the mass cap. Mapping, atmosphere sensing, node emplacement and relay work become modules on one vehicle rather than new vehicles.

INTERPOSE, NEVER STRIKE

ITS ONLY EFFECT IS ITS OWN MASS

On a confirmed Trembler Line CS-435 cue, and only on a person's confirmation, it moves to a block position and holds the passage. Nothing detonates, fires or is thrown, and there is no warhead, fuze or energetic material in any variant.

IN THIS SHEET

01 · SPECIFICATION

THE CRAWLER, GROUP BY GROUP. EACH FIGURE BESIDE ITS BASIS.

The product specification and the systems engineering behind it, grouped the way an integration lead reads a tracked crawler: envelope, structure, drive, power, tether, locating, payload, response.

01 ENVELOPE AND MASS

PARAMETER	VALUE	BASIS
Chassis footprint	~300 mm W × 260 mm H × 520 mm L	design value, the product specification table
Chassis mass	~25 kg	design value, the product specification table
Passage clearance	Tunnels and culverts, ≥ ~450 mm diameter	design value, the product specification table
Configuration	Tracked crawler, sized for tunnel and culvert clearance	the product specification table
Stance	Low and wide inside a circular envelope; track base as wide as the invert allows	geometry rule: a curved floor is a tipping problem
Running-gear symmetry	Top-bottom symmetric; runs inverted after a rollover	geometry rule: a crawler that cannot run inverted in a pipe nobody can reach is a lost unit
Rear profile	No rearward-facing shoulder to catch a joint lip	geometry rule: reverse-out along the laid fibre is the primary recovery mode

02 STRUCTURE AND MATERIALS

PARAMETER	VALUE	BASIS
Chassis, track frames, load-bearing shell	Moulded glass-filled nylon	the fleet materials boundary: structural resin wherever a part carries load
Covers, spool flanges, handling fixtures	Recycled PET	the fleet materials boundary: parts that carry no drive loads
Axles, gears and fasteners	Metallic	where polymer cannot go
Governing load cases	Rollover · snag during reverse-out · a season of abrasive silt in the seals	the structural reading: an ingress and geometry problem rather than a stress case

03 DRIVE AND MOBILITY

PARAMETER	VALUE	BASIS
Drive	Tracked, dual electric drive	the product specification table
Running gear	Twin tracks, skid-steered, each track independently driven	the configuration the sewer and pipe-inspection trade settled on for wet, silted, stepped floors

PARAMETER	VALUE	BASIS
Crawl speed	~0.8 m/s · ~2.9 km/h	design value, the product specification table
Locomotion power while halted	Zero; brakes passive	a crawler pays nothing to stop
Working pattern	Creep, stop, look	speed costs traction, payout tension and map quality, and buys almost nothing

04 POWER AND ENDURANCE

PARAMETER	VALUE	BASIS
Energy aboard	Battery; the fibre carries comms and guidance, not power	the crawler's power architecture
Battery endurance	~4 h continuous recon	design value, the product specification table
Egress reserve	30 % of the pack, held for the way out	design rule of the recovery doctrine
Endurance lever	Duty-cycling the lidar and the lights	the power budget: on a small crawler the sensors and the computer out-consume the tracks

05 TETHER AND LINK

PARAMETER	VALUE	BASIS
Fibre per spool	~500 m, breadcrumb return	design value, the product specification table
Spool architecture	Robot-spooled: the spool rides the vehicle and pays the fibre out stationary onto the floor	the tether architecture
Tether drag	≈ zero at any range and any corner count	paid-out fibre lies where it falls; a dragged tether compounds friction at every corner
What the fibre carries	Teleoperation video · lidar stream · telemetry · commands	one fibre, both directions
Emissions, any tier	None: no radio, no GNSS	the product specification table
Loss of link	Stop, hold, wait, silent; never pushes forward blind through unmapped passage	the loss-of-link rule for confined space
Fibre break	Egress on the machine's own map	the minimum onboard autonomy the robot-spooled tether sets

06 GUIDANCE AND LOCATING

PARAMETER	VALUE	BASIS
Guidance tiers	Fibre-tethered teleoperation, the default · autonomous mapping (SLAM)	the product specification table
Autonomy ceiling	Mapping autonomy only; engagement autonomy does not exist	the product specification table

PARAMETER	VALUE	BASIS
Dead reckoning	Inertial unit · track odometry · paid-out fibre length	fused: the fibre-length odometer does not slip
Map matching	Lidar SLAM; junctions, joints and defects are the landmarks	the mapping sensor doubles as the locating sensor

07 SENSING AND PAYLOAD

PARAMETER	VALUE	BASIS
Sensor suite	Forward and aft cameras · lidar and mapping (SLAM) · gas sensor (O_2, CH_4, CO, H_2S)	the product specification table
Core set, always fitted	Visible camera with active illumination · thermal imager · small lidar	the core sensor set of the payload bay
Payload-bay interface	Mechanical envelope · power budget · data interface · mass cap	one interface for every module, so a variant is a module change
Bay modules	Mapper · atmosphere · node dropper · interpose fit · relay	the variant set
Payload	Sensor suite only; no warhead, fuze or energetic material	the product specification table

08 RESPONSE AND SAFETY

PARAMETER	VALUE	BASIS
Interpose response	Moves to a block position on a confirmed Trembler Line CS-435 cue	the product specification table
Engagement authority	A person confirms before any physical engagement, always	the product specification table
Interpose fit	Obstruction with high-intensity light and sound, switched on by a human command over the fibre	the interpose module, non-injurious by design
Stops	Hardwired e-stop · wired stop over the fibre	the fleet safety chain
Recovery	Reverse-out along the fibre on redundant drive channels; one failed motor still brings it home	the recovery doctrine
Last resort	Abandonment rule: a unit that has streamed its map up the fibre is a loss of hardware, not of the mission	the recovery doctrine

09 COMPLIANCE

PARAMETER	VALUE	BASIS
Munitions classification	Carrier, not a munition: no warhead, fuze or energetic material in any variant; no autonomous strike capability of any kind	the product specification table
Patent status	Patent pending	the product specification table
Export control	Export-controlled; international transfer subject to Canadian government permits; counsel first	the product specification table

02 · THE ENVELOPE

SIZED TO THE WORST PASSAGE. SHAPED TO BACK OUT OF IT.

A tunnel robot's useful cross-section is set by the worst passage on the mission, not the average one: partial blockages, offset joints, root intrusion and standing water.

CS-425 is sized to clear tunnels and culverts of about 450 mm in diameter and above, on a chassis of about 300 mm wide, 260 mm high and 520 mm long at about 25 kg. The class it works is the culvert, utility-tunnel and sewer class, the network that actually runs under a facility, a road or a perimeter.

Three geometry rules follow from the worst-passage premise, and each is a requirement rather than a feature.

STANCE

LOW AND WIDE IN A ROUND ENVELOPE

The track base is as wide as the invert allows, because a curved floor is a tipping problem before it is a traction problem.

SYMMETRY

IT RUNS UPSIDE DOWN

The running gear is top-bottom symmetric. A crawler that cannot run inverted after a rollover, in a pipe nobody can reach, is a lost unit.

PROFILE

NOTHING TO CATCH ON THE WAY BACK

No surface presents a rearward-facing shoulder that can anchor on a joint lip, because reversing out along the laid fibre is the primary recovery mode.

03 · THE BODY

NO LAUNCH SHOCK, NO AIR LOAD. THE SEAL IS THE STRUCTURAL SPEC.

The body lives continuously in ground that is wet, abrasive, corrosive and dark, and that keeps trying to jam the mechanism with silt.

The governing load cases are a rollover, a snag during reverse-out and a season of abrasive silt in the seals. None of them is a stress case: the body is a sealing and geometry problem rather than a strength problem.

Glass-filled nylon where it carries load. The chassis, the track frames and any load-bearing shell are moulded in the fleet's structural resin on moulds the group cuts in its own shop. In sewer atmospheres carrying hydrogen sulphide and chlorides the polymer does not rust, and it is light.

Recycled PET where it does not. Covers, spool flanges and handling fixtures carry no drive loads and are moulded in recycled PET. Metallics stay where polymer cannot go: axles, gears and fasteners.

A sealed body in still tunnel air has no forced convection. Every watt of the electronics load leaves through the shell by natural convection, by conduction through the tracks and by radiation, and a mud-coated shell insulates. The design answers are the chassis as the heatsink and duty-cycling the lidar, which is also what the energy budget asks for.

04 · RUNNING GEAR

TORQUE IS EASY AT THIS SCALE. TRACTION IS THE WHOLE PROBLEM.

Twin tracks, skid-steered, each independently driven: the configuration the sewer and pipe-inspection trade settled on for floors that are wet, silted and stepped.

The drive is tracked, with dual electric drive and a crawl speed of about 0.8 m/s. Obstacle capability scales with sprocket and track height: the climbable step is of the same order as the front sprocket radius, which is a statement about the machine's geometry. The ground is the harder half. A tunnel invert is the worst traction surface the fleet meets, with wet biofilm on concrete, loose silt over hardpan and sloped culvert walls.

- ✓ Slip on biofilm is large and asymmetric, so track odometry never carries the locating budget alone.
- ✓ Silt packing in the track run is the classic failure of inspection crawlers, so open, self-clearing track geometry is preferred over guards sealed for neatness.

05 · THE ENERGY BUDGET

STOPPING COSTS NOTHING. SEEING COSTS ALMOST EVERYTHING.

On a small crawler the sensors and the computer out-consume the tracks, and that one finding sets the way the machine is worked.

Unlike anything airborne, a crawler pays nothing to stop: locomotion power on station is zero and the brakes are passive. The electronics load runs whether the machine moves or not, and lighting is a first-class consumer of it, because a tunnel is absolutely dark and nothing is seen that is not lit. Endurance is therefore bought by duty-cycling the lidar and the lights rather than by drivetrain efficiency.

The working pattern that falls out is creep, stop, look: move slowly, halt often and sense hard while halted. Speed costs almost nothing in energy and a great deal in traction risk, fibre payout tension and map quality. The battery runs about four hours of continuous recon, and 30 % of the pack is held for the way out, which makes the reserve a range rule before it is a battery rule.

~4 h	30 %	~0.8 m/s
CONTINUOUS RECON	OF THE PACK HELD FOR EGRESS	CRAWL SPEED

06 · THE TETHER

THE ROBOT CARRIES THE SPOOL. THE FIBRE STAYS WHERE IT FALLS.

A tethered crawler has two possible architectures, and the choice between them decides how far one can go.

Surface-spooled. The console pays out and the robot drags the whole laid length behind it. A dragged tether's friction grows with that length and every corner multiplies it, which is what range-limits a dragged-tether robot.

Robot-spooled, the architecture here. The spool rides the vehicle and pays the fibre out stationary onto the floor behind it. The fibre lies where it fell, so tether drag stays near zero at any range and any number of corners.

Each spool carries about 500 m of fibre, and what it lays is the breadcrumb back out. The architecture has a cost: the spool rides the vehicle, the fibre is committed as it goes, and a snapped fibre ends communications. Egress then runs on the machine homing on its own map, which is what sets the minimum onboard autonomy on a platform whose working mode is a person driving.

One fibre carries the teleoperation video, the lidar stream, the telemetry and the commands together. Against this sensor suite its bandwidth is effectively unlimited, and latency is nil at these lengths.

07 · LOCATING

NO SATELLITE REACHES IT. THE FIBRE COUNTS THE DISTANCE.

Underground, the hard problem is knowing where the machine is, with no external reference of any kind to lean on.

DEAD RECKONING

THREE INPUTS, ONE THAT NEVER SLIPS

An inertial unit, track odometry and the paid-out fibre length. The tracks slip and a small inertial unit drifts, but paid-out fibre length is a path-length odometer that does not slip. Fused, the three bound along-path error better than any one alone.

MAP MATCHING

THE MAPPING SENSOR ALSO LOCATES

Lidar SLAM matches what the machine sees to the map it has built. Long uniform pipe is the hard case for scan-matching, and it is exactly where the fibre-length odometer carries the solution. Junctions, joints and defects are the landmarks.

A long run of identical pipe can fool a scan-matcher, and a slipping track can fool odometry. Neither can fool a count of fibre that has left the spool, and that makes the one input worth more than it looks. The locating record fused with the lidar map is also the product the mapper variant delivers.

08 · THE BAY

ONE PAYLOAD BAY. EVERY VARIANT A MODULE CHANGE.

The core sensor set is fitted on every build. Everything else rides one bay interface, so a new variant is a packaging change rather than a new vehicle.

The product specification carries forward and aft cameras, a lidar mapping unit and a gas sensor package reading oxygen, methane, carbon monoxide and hydrogen sulphide. The core set behind them is a visible camera with active illumination, a thermal imager and a small lidar for geometry capture. The thermal channel earns its place underground: a warm target or a recent heat trace stands out against cold tunnel walls.

The bay is one interface carrying four things, so every module in the variant set is a swap:

- ✓ A mechanical envelope
- ✓ A power budget
- ✓ A data interface
- ✓ A mass cap

Every module is a sensor, an annunciator, an emplaced node or an inspection package, and none carries a warhead, a fuze or energetic material, for any customer.

09 · THE ONE PHYSICAL RESPONSE

A PERSON CONFIRMS THE MOVE. AND AGAIN BEFORE ANY ENGAGEMENT.

CS-425 is the one platform in the family designed to confront a threat at all, and it does that by parking its own mass in a passage too narrow to go around.

Autonomy stops at the map. The machine builds its own passage map and creeps a known run on SLAM, and it cannot decide on its own to move into a block position. When a Trembler Line cue arrives over the fibre it presents the block position as an option. A person confirms before it moves in and holds, and a person confirms again before any physical engagement follows. There is no autonomous engagement tier in the design to enable, gate or unlock.

The interpose fit adds high-intensity light and sound to the obstruction: presence, warning and denial by being unmistakably there. It is non-injurious by design and switched on by a human command over the fibre. Nothing detonates, nothing fires and nothing is thrown.

> DOCTRINE
>
> **MAPPING AUTONOMY IS THE CEILING. A PERSON CONFIRMS, EVERY TIME.**
>
> No radio and no GNSS in any tier. No warhead, no fuze and no energetic material in any variant. The one physical response the family owns is a machine standing in the way, on a person's word, in a passage nobody had to walk.

10 · THE CUE

EARLY DETECTION BUYS THE TIME. THE STANDBY POSITION SPENDS IT.

The interpose role depends on the Trembler Line CS-435, the buried picket of CS-430 nodes that detects, localizes and cues.

1. **Detect** The buried nodes of the Trembler Line hear digging, tunnelling, footsteps or a vehicle.
2. **Localize** The head-end places the source from the pattern of arrival times along the chain.
3. **Cue** The cue reaches a person at the console, never an actuator. A person stands between the cue and any movement.
4. **Interpose** On that person's confirmation, a crawler already standing by on the network moves to a block position ahead of the intrusion's path and holds it.

CS-425 does not sprint to intercept. The picket's detection range and the standby position buy the interpose timeline; vehicle speed does not. A mission is loaded as either a recon route or a standby on a Trembler Line cue, so the sensing line and the response element are specified together. The node is CS-430 and the line it makes is Trembler Line CS-435.

11 · RECOVERY

NOTHING GOES IN AFTER IT. IT COMES BACK DOWN ITS OWN FIBRE.

A dead crawler deep in a small pipe cannot be fetched, so the recovery system is the machine itself, run backwards along the fibre it laid on the way in.

- ✓ Reverse-out along the fibre path on redundant drive channels: each track is independently driven, so one failed motor still brings the machine home.
- ✓ The body rules that make reversing possible: no rearward-facing shoulder to catch a joint lip, and running gear that works inverted.
- ✓ A battery reserve of 30 % of the pack, held for egress and never spent on the way in.
- ✓ An abandonment rule as the last resort. The map already sent up the fibre is the mission product, so a stuck unit that has streamed it is a loss of hardware and not of the mission.

The safety chain matches the rest of the fleet: a hardwired e-stop, a wired stop over the fibre, and a loss-of-link rule written for confined space that ends in stop, hold, wait, silent. The machine never pushes forward blind through unmapped passage. If a leg ends early it holds exactly where it stopped, silent and waiting for a person, and recovery is a walk down the fibre rather than a search.

12 · PAYLOAD MODULES

ONE VEHICLE, FIVE MODULES. THE MISSION PICKS THE FIT.

The core sensor set rides every build. The bay takes one module at a time through the same interface.

MAPPER

SURVEY AND CIVIL INSPECTION

The lidar record fused with the locating stack is the product: tunnel-network geometry and condition assessment. The civil inspection build is this module with reporting software, so the defence build and the civil one are the same build.

ATMOSPHERE

CONFINED-SPACE GAS SENSING

Oxygen, carbon monoxide, hydrogen sulphide and methane at the lower explosive limit. It answers whether a passage is survivable and whether there has been recent combustion or equipment activity, and it is the civil confined-space-entry survey.

NODE DROPPER

EMPLACING LISTENING NODES

Carries and releases CS-430-class listening nodes at chosen points, extending a Trembler Line CS-435 into passages no surface emplacement reaches.

INTERPOSE FIT

OBSTRUCTION, LIGHT AND SOUND

The response fit for a Trembler Line cue: the vehicle as a physical obstruction ahead of the threat's path, with high-intensity light and sound, switched on by a human command over the fibre. Non-injurious by design.

RELAY

A FIBRE JUNCTION NODE

A parked unit whose spool end becomes a network drop, so later units and emplaced nodes tap the laid fibre as backhaul.

13 · DOCTRINE AND SAFETY

IT CAN STAND IN THE WAY. IT CAN NEVER STRIKE.

The lines that hold in every variant, in every passage and for every customer.

- ✓ Carriers, not munitions: no warhead, no fuze and no energetic material in any variant of CS-425. Its only physical effect is its own mass, parked in a passage.
- ✓ Nothing aboard transmits by radio and nothing navigates on a satellite signal. The fibre is the only link, and a lost link ends in stop, hold, wait, silent.
- ✓ Human safety comes first, on every line. The machine goes into the passage so a person does not, and a person confirms before it moves to a block position and again before any physical engagement.
- ✓ Mapping autonomy is the ceiling. There is no autonomous engagement tier in the design to enable, gate or unlock.

THE CONVERSATION

BRING THE PASSAGES AND THE ACCESS POINTS. THE STANDBY POSITIONS FOLLOW FROM THEM.

A first conversation needs the passage classes, the access points and the distances between them, and what should happen when the picket cues.

Start a screened enquiry at cdnshield.ca/enquiries.

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