SENTINEL SERIES PRODUCTION GUIDE

Complete manufacturing, assembly, R&D infrastructure and investment breakdown for the full SENTINEL robot family. From prototype to production line. All costs in EUR (2025/2026 market rates). All compute: NVIDIA Jetson.

4	€5.5M	18mo	100%
ROBOT MODELS	TOTAL INVESTMENT	TO PRODUCTION	NVIDIA COMPUTE

SENTINEL CORE

UNIVERSAL COMPUTE + POWER MODULE — THE BRAIN OF EVERY SENTINEL ROBOT

The Sentinel Core is a sealed, ruggedised IP67 aluminium enclosure housing the NVIDIA Jetson compute module, custom carrier PCB, power distribution, and SENTINEL-LINK hub. It is the only component shared across all 4 robot variants. Swapping the attached tool modules and loading the appropriate software profile converts it between Warehouse, Agriculture, Military, or Home mode. The Core is designed for field replacement in under 4 minutes using the 8-bolt lid mechanism.

CORE-S · STANDARD

SENTINEL CORE-S

Warehouse & Home deployments

€2,490

Build cost: €1,141 · Margin: 118%

Compute	NVIDIA Jetson Orin NX 16GB
AI Performance	100 TOPS
RAM	16GB LPDDR5
Storage	256GB NVMe
IP Rating	IP54
Shell	Anodised 6061 Al

SENTINEL-LINK ports	6
Power input	24–56V DC
Operating temp	-10°C to +60°C

CORE-X · EXTENDED

SENTINEL CORE-X

Agriculture & heavy industrial

€4,200

Build cost: €2,100 · Margin: 100%

Compute	NVIDIA Jetson AGX Orin 64GB
AI Performance	275 TOPS
RAM	64GB LPDDR5
Storage	512GB NVMe
IP Rating	IP67
Shell	Hard-anodised 6061 Al
SENTINEL-LINK ports	6
Power input	48V DC nominal
Operating temp	-20°C to +70°C

CORE-M · MILITARY

SENTINEL CORE-M

Military & tactical operations

€8,900

Build cost: €4,450 · Margin: 100%

Compute	NVIDIA Jetson AGX Orin 64GB
AI Performance	275 TOPS
RAM	64GB LPDDR5 ECC
Storage	1TB NVMe encrypted
IP Rating	IP68 + MIL-STD-810G
Shell	7075-T6 Al + UHMWPE outer
EMP shielding	Cu mesh MIL-STD-461G
Shock rating	40g / 11ms half-sine
Operating temp	-40°C to +85°C

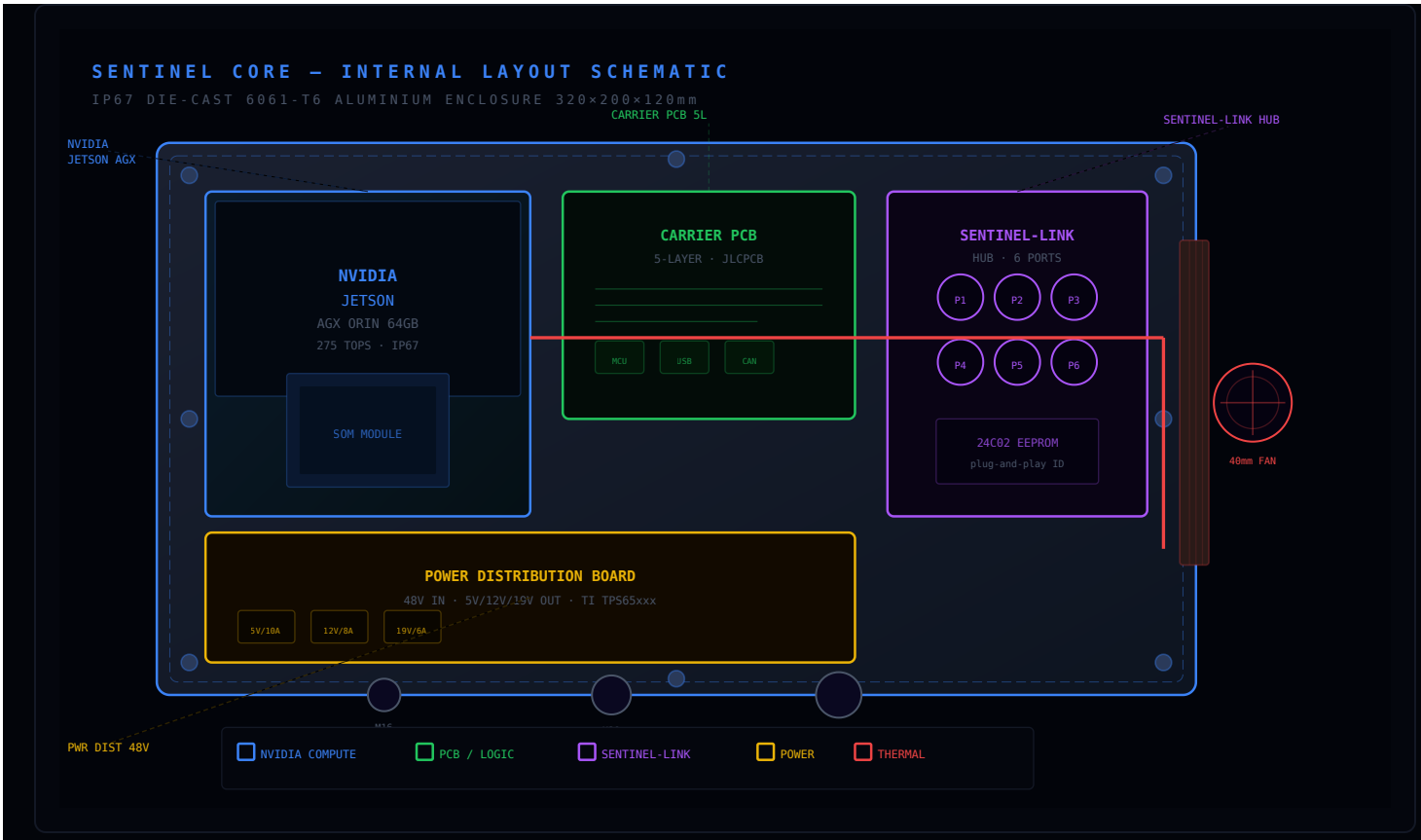


FIGURE 1 — SENTINEL CORE INTERNAL LAYOUT · IP67 SEALED ENCLOSURE 320×200×120mm · 8× M4 STAINLESS LID BOLTS

SENTINEL CORE-X BILL OF MATERIALS (1,000-UNIT VOLUME PRICING)

#	COMPONENT	SPECIFICATION	QTY	UNIT COST	TOTAL	SOURCE	TYPE
1	**NVIDIA Jetson AGX Orin 64GB**	275 TOPS, 12-core ARM Cortex-A78AE, 64GB LPDDR5, 900-13701-0040-000	1	€1,944	€1,944	Arrow / Mouser	SHELF
2	**Custom 5-layer Carrier PCB**	260×180mm, Rogers 4003C + FR4, USB3, PCIe, CAN FD ×4, GPIO, JLCPCB	1	€28	€28	JLCPCB (10-off min)	CUSTOM
3	**Die-cast 6061-T6 Al enclosure**	320×200×120mm, IP67, custom mould (€22,000 one-time), anodised	1	€95	€95	Custom foundry (RO/CN)	CUSTOM
4	**SENTINEL-LINK hub PCB**	6-port, 24C02 EEPROM per port (I2C 0x50-0x57), 18-pin circular, 4-layer	1	€68	€68	JLCPCB / custom	CUSTOM
5	**Power distribution board**	48V→5V/12V/19V, TI TPS65988, 10A/8A/6A rails, reverse-polarity, fused	1	€72	€72	Custom PCB + TI parts	CUSTOM

#	COMPONENT	SPECIFICATION	QTY	UNIT COST	TOTAL	SOURCE	TYPE
6	**Copper vapour heatpipe**	6mm OD, 200mm, sintered wick, custom bent to Jetson contact + heatsink	2	€18	€36	Alibaba industrial	SHELF
7	**Al extruded heatsink**	80×60×40mm, 0.5°C/W, black anodised, M3 mount	1	€9	€9	Mouser / RS Components	SHELF
8	**40mm PWM fan (Noctua NF-A4x20)**	5V / 12V, 5000 RPM, 14.9 dBa, MTBF 150,000h	1	€16	€16	Noctua / Amazon	SHELF
9	**Viton 70-Shore O-ring + RTV**	310×190mm custom O-ring, Dow 732 RTV secondary seal	1	€18	€18	O-ring specialist	CUSTOM
10	**Cable glands IP68 (Roxtec)**	M16×3 units (data), M20×2 units (power), M25×1 (battery)	6	€6	€38	Roxtec / Pflitsch	SHELF
11	**Internal harness + Molex MicroFit**	3.0mm pitch, 2×4pos, 2×6pos, 2×8pos, 24AWG tinned copper, PVC	1	€52	€52	Molex / Digi-Key	SHELF
12	**M4×12 stainless bolts + Helicoil**	A4-70 stainless, 8 lid bolts + Helicoil M4×1.0 inserts in Al	1 set	€14	€14	RS Components	SHELF
13	**256GB NVMe M.2 2280**	WD SN580, PCIe 4.0, 4,150MB/s read, 0°C to +70°C	1	€48	€48	Western Digital / Arrow	SHELF
14	**Assembly labor (Romania)**	3h technician × €12/h + 1h QA × €14/h = full bench test + IP67 leak test	1	€50	€50	In-house (RO facility)	—
		CORE-X TOTAL BUILD COST (1,000 units/yr)			**€588**		
		One-time mould tooling amortised (1,000 units)			**+€22**		
		TOTAL WITH TOOLING			**€610**		
		CORE-X SALE PRICE (initial production)			**€4,200**		

NOTE: At prototype/pilot stage (1-10 units) the carrier PCB cost rises to ~€280/unit (10-off minimum at JLCPCB). The €22,000 mould for the Al enclosure is an unavoidable one-time cost — until this is paid off, the enclosure is sourced from CNC-machined billet at ~€380/unit. Break-even on the mould at 58 units.

SENTINEL CORE — MODE SWITCHING ARCHITECTURE

FIGURE 2 — SENTINEL CORE MODE ARCHITECTURE · SENTINEL-LINK MODULES ARE HOT-SWAPPABLE · SOFTWARE PROFILE LOADED AT BOOT

ASSEMBLY SCHEMATICS

EXPLODED VIEW — ALL 4 VARIANTS — SENTINEL-LINK MODULE CONNECTIONS

Each robot is assembled by attaching pre-tested modules to the Sentinel Core via SENTINEL-LINK connectors. All modules carry I2C EEPROM (24C02) that auto-identifies the module type, triggering automatic software profile loading. Assembly sequence: Core → Power → Structural frame → Actuators → Sensors → Software flash.

SCHEMATIC A — SENTINEL-WH WAREHOUSE ASSEMBLY

FIGURE 3 — SENTINEL-WH EXPLODED ASSEMBLY · TOTAL PARTS COST €17,555 · ASSEMBLY TIME ~16h · SENTINEL-LINK P1-P6 CONNECTIONS

€17,555	€21,539	€42,000	€22,500
BOM COST	PRODUCTION COST	SALE PRICE (initial)	AT 1,000 UNITS/YR

SCHEMATIC B — SENTINEL-AG AGRICULTURE ASSEMBLY

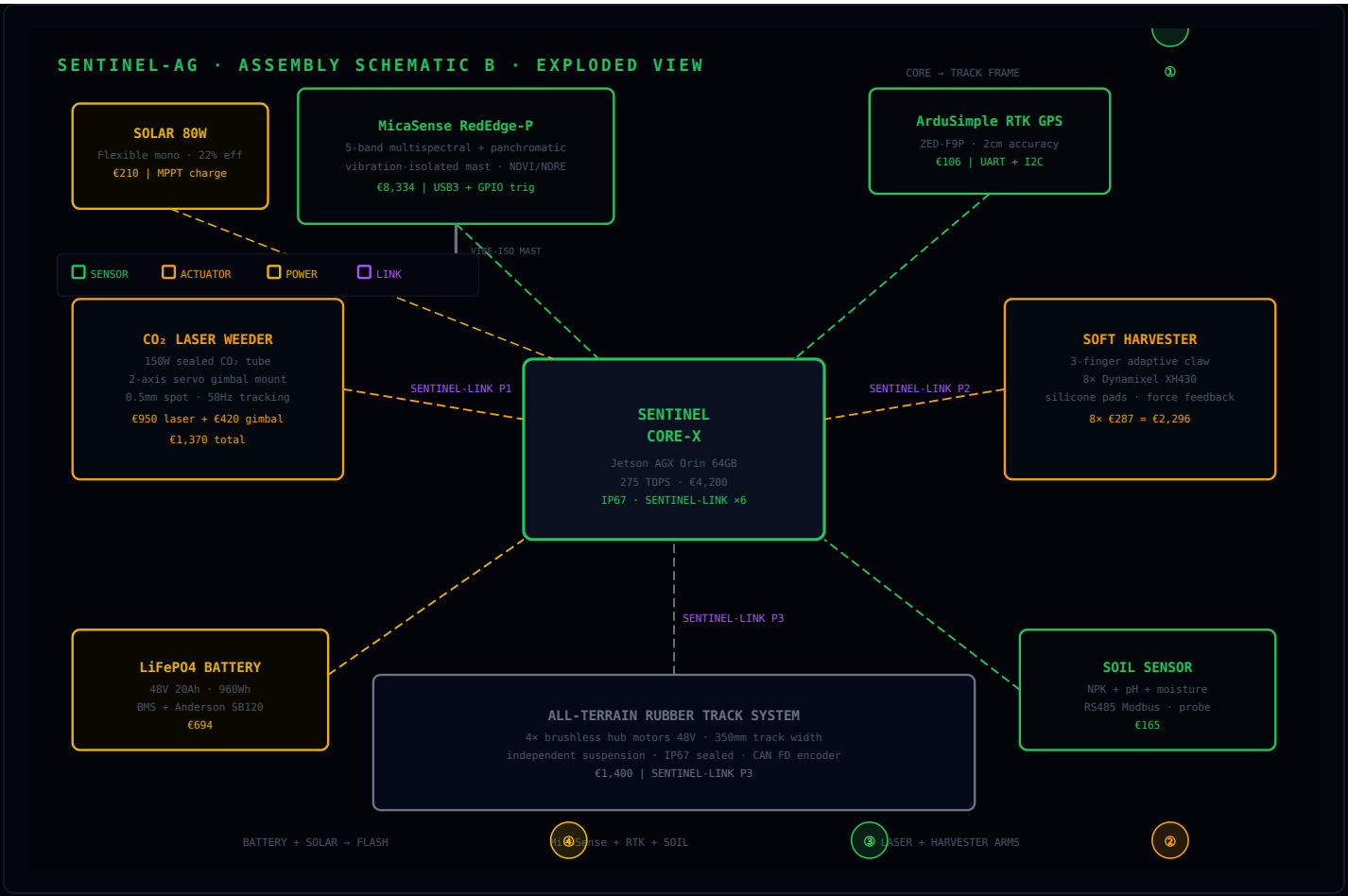


FIGURE 4 — SENTINEL-AG EXPLODED ASSEMBLY · TOTAL BOM €17,434 · ASSEMBLY TIME ~18h · ALL-TERRAIN TRACKED AGRICULTURE PLATFORM

€17,434	€21,312	€40,500	€21,500
BOM COST	PRODUCTION COST	SALE PRICE (initial)	AT 1,000 UNITS/YR

AG TRACTOR BODY CONVERSION MODULE

The SENTINEL-AG can be mounted into a larger **Tractor Body Module** — a 1.4m × 0.8m aluminium/steel chassis with PTO hydraulic coupling, 3-point hitch system (Cat I), wider 800mm rubber tracks for field work, 120L diesel generator range extender (extends autonomy to 48h continuous), and tool rack mounting for up to 8 simultaneous implements. This transforms the precision-agriculture scout into a full working field machine.

⚙ TRACTOR BODY MODULE SPECS:

Frame: 1.4m × 0.8m × 0.6m — aluminium 6061-T6 space frame + steel 4130 PTO subframe

PTO: Hydraulic coupling, 15kW output, standard agricultural implements compatible

Hitch: 3-point Category I — accepts standard plows, seeders, sprayers up to 300kg

Tracks: 800mm wide rubber compound, 1.2m wheelbase, <5 PSI ground pressure

Range extender: 120L diesel generator (Kubota D902) — 48h continuous runtime

Tool rack: SENTINEL-LINK enabled, hot-swap, 8 implement slots, auto-ID EEPROM

AGRICULTURAL TOOL CATALOGUE — PTO & SENTINEL-LINK COMPATIBLE

#	TOOL / IMPLEMENT	SPECIFICATION	INTERFACE	PRICE
1	**Rotary tiller / plow**	500mm working width, 6 tine blades, depth 0–200mm	PTO hydraulic	€680
2	**Disc harrow attachment**	8 discs, 450mm width, adjustable angle 0–25°	PTO hydraulic	€520
3	**Seed drill (10-row)**	Adjustable row spacing 50–300mm, metering wheel, hopper 25L	SENTINEL-LINK + PTO	€1,400
4	**Sprayer boom (6m width)**	GPS section control, 8 nozzles, 200L tank, pressure reg	SENTINEL-LINK + PTO	€2,200
5	**Mower / flail attachment**	600mm cut width, hardened flails, adjustable height	PTO hydraulic	€890
6	**Potato / root harvester**	Single row, vibrating sieve, 400mm dig depth, collection bin	PTO hydraulic	€1,100
7	**Cultivator tines (3-row)**	Hardened spring tines, 450mm width, depth adjust	PTO hydraulic	€340
8	**Fertilizer spreader**	50L hopper, variable rate GPS, spinner disc, 4m spread	SENTINEL-LINK + PTO	€560
9	**Mulcher attachment**	Y-blade rotor, 500mm width, adjustable height	PTO hydraulic	€720
10	**Fruit picking soft-grasp array**	6× 3-finger silicone hands, vision-guided, bruise-free	SENTINEL-LINK	€3,400
11	**Greenhouse rail-guided carriage**	Fits standard 35mm rail, auto-dock, 100kg payload	SENTINEL-LINK	€480
12	**Drip irrigation precision lance**	GPS-mapped drip, flow sensor, moisture feedback loop	SENTINEL-LINK	€1,450
		FULL TOOL CATALOGUE TOTAL		**€13,740**

€8,500	€3,200 + €1,800	€2,100 + €1,400	€49,000
TRACTOR MODULE BOM	FRAME + TRACKS	HYDRAULICS + GENERATOR	AG + TRACTOR TOTAL

NOTE: The Tractor Body Module is sold separately. Customers purchasing the base SENTINEL-AG (€40,500) can upgrade to the full tractor configuration for an additional €8,500. All tools connect via standard PTO coupling or SENTINEL-LINK and are hot-swappable in the field.

SCHEMATIC C — SENTINEL-MK MILITARY ASSEMBLY

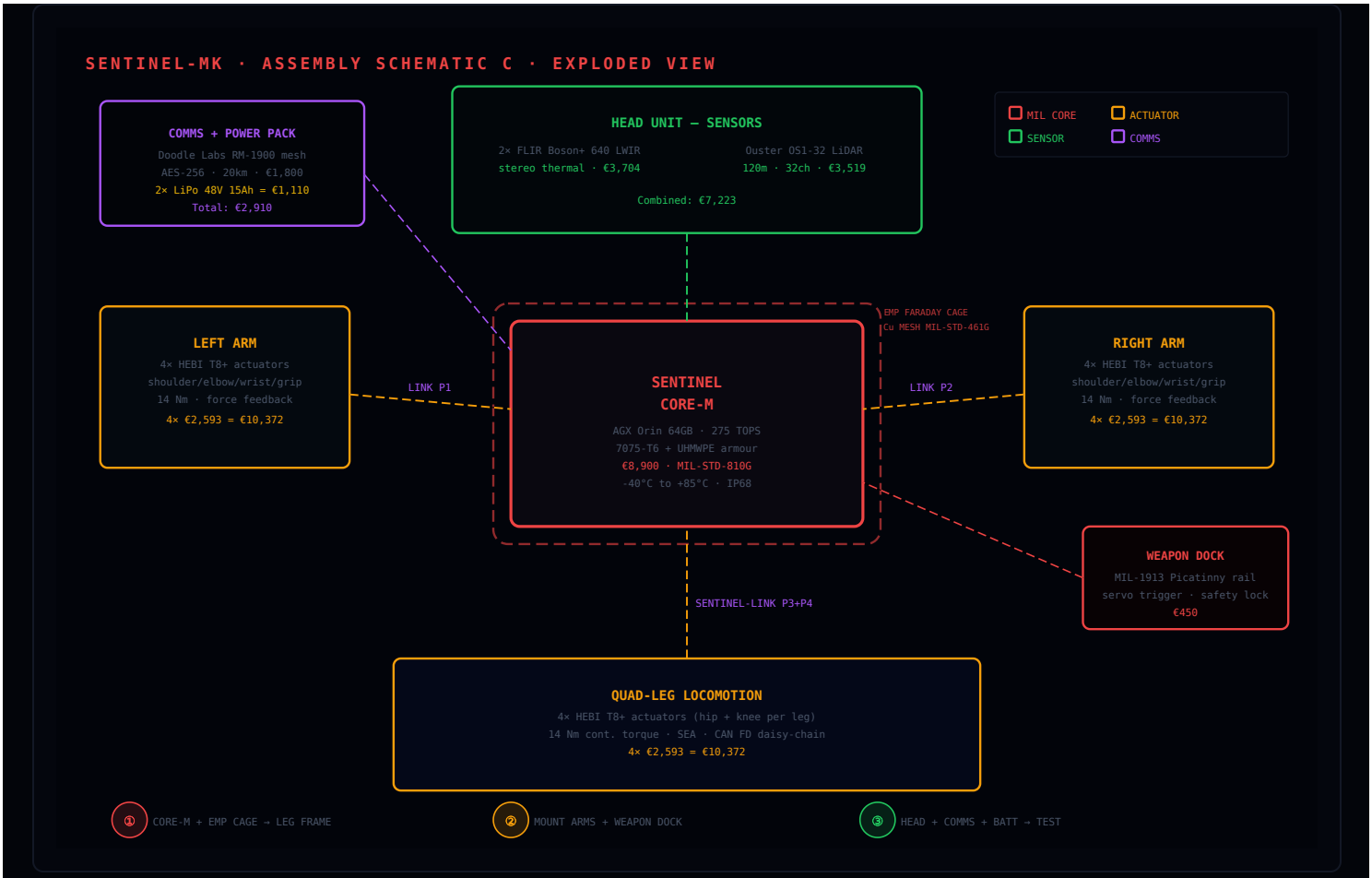


FIGURE 5 — SENTINEL-MK EXPLODED ASSEMBLY · TOTAL BOM €49,953 · QUAD-LEG + DUAL-ARM · EMP-HARDENED CORE-M · MIL-STD-810G

€49,953	€58,503	€109,000	€65,000
BOM COST	PRODUCTION COST	SALE PRICE (initial)	AT 500 UNITS/YR

MK OPTIONAL ACCESSORIES — ADVANCED WEAPONS & STEALTH

⚠ **CONTROLLED ITEMS:** Items marked CONTROLLED are subject to ITAR / EAR / EU Dual-Use Regulation (EC) 428/2009 export controls. End-user certificates required. Sale restricted to authorized military & law enforcement entities only. All items require operator authentication via SENTINEL-MK command authority chain.

1. EMP Pulse Gun (close-range) CONTROLLED — €3,200

Directed EMP via Marx generator circuit. 50kV pulse discharge, effective range 5m. Capacitor bank (10× 0.1µF 50kV ceramic) + triggered spark gap + horn antenna. Disables unshielded electronics within cone. Recharge time 8s. Custom build on MIL-1913 weapon dock. Weight 3.2kg.

2. Laser Designator / Dazzler CONTROLLED — €1,800

532nm DPSS 5W green laser, NATO STANAG 3733 compatible target designation. Dual-mode: precision target marking for guided munitions +

anti-optics dazzle (compliant with Protocol IV CCW). Bore-sighted to weapon dock. Range: 5km designation, 500m dazzle. Weight 1.1kg.

3. Electroshock Close Combat Module CONTROLLED — €890

Taser-equivalent incapacitation system. 50kV arc discharge, contact electrodes integrated into hand end-effectors. 5-shot replaceable cartridge (probe launch 7m range). T-wave modulation for neuromuscular disruption. Safety interlock requires 2-factor auth. Weight 0.8kg per hand.

4. Solar Camouflage Panel FIELD KIT — €1,200

2m × 1.5m foldable panel: top surface — 300W high-efficiency SunPower Maxeon Gen6 cells (24.1% efficiency), bottom surface — reversible woodland/desert/snow camouflage Cordura 1000D fabric. Carbon fibre ribs, spring-loaded deployment in 30 seconds. Robot stops, unfolds, activates stealth charge. Folded: 40×30×8cm pouch on MOLLE backpack mount. Charges 48V 15Ah in ~3.5h full sun. MPPT controller integrated.

5. Extended Battery Backpack FIELD KIT — €1,800

48V 40Ah LiFePO4 in ruggedised MOLLE-compatible pack. Adds 24h continuous autonomy (total 36h with internal batteries). Hot-swappable connector (Anderson SB175), BMS with cell-level monitoring, -40°C to +60°C rated. Quick-release 4-point harness. 8.5kg total weight.

MK ACCESSORIES TOTAL (all 5 items): €8,890 — bringing a fully-equipped SENTINEL-MK to €109,000 + €8,890 = **€117,890**. Solar camouflage panel and extended battery backpack are unrestricted field accessories. EMP gun, laser designator, and electroshock module require end-user certificates and are export-controlled.

SCHEMATIC D — SENTINEL-HM HOME ASSEMBLY

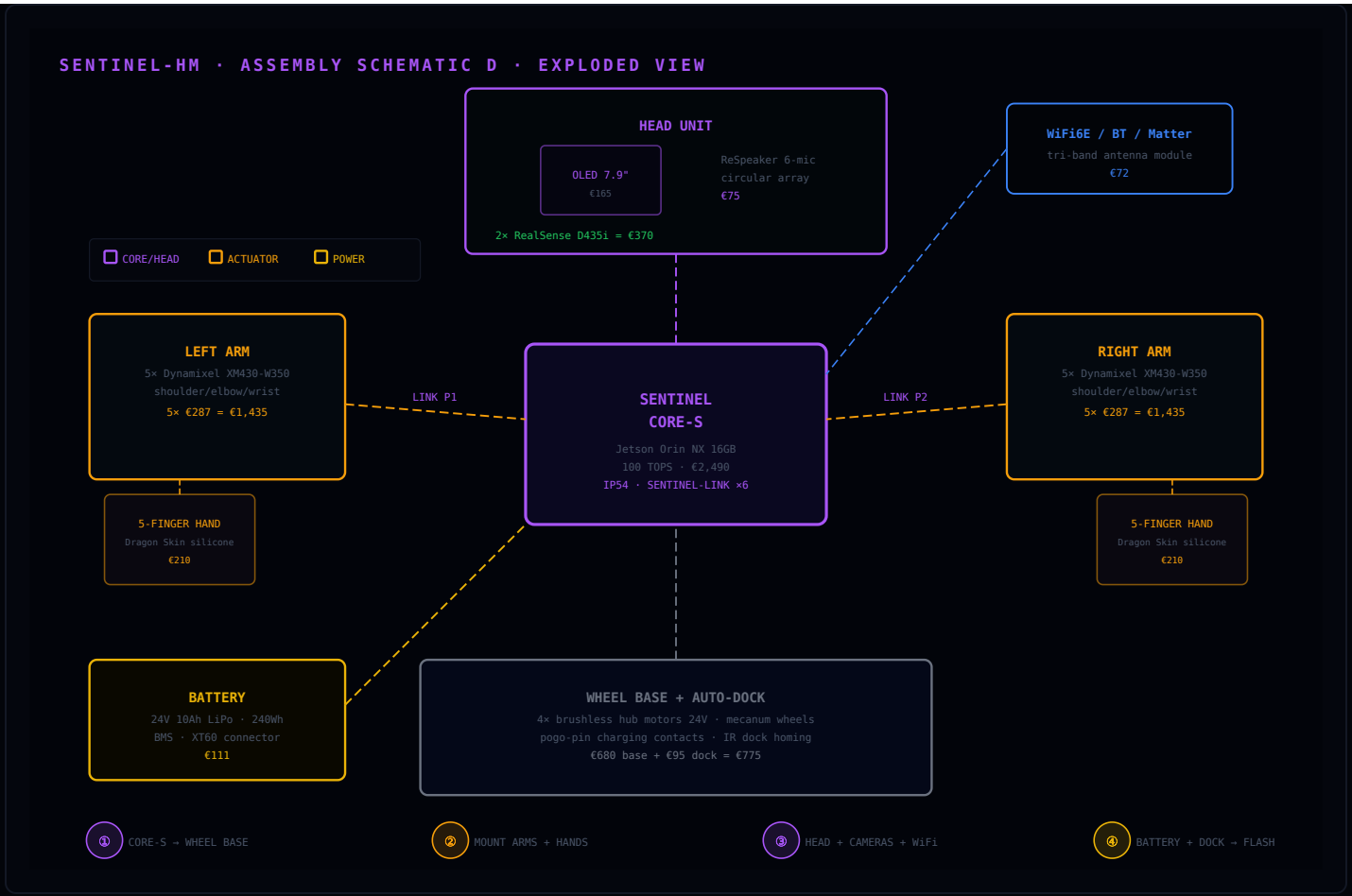


FIGURE 6 — SENTINEL-HM EXPLODED ASSEMBLY · TOTAL BOM €5,782 · HOME COMPANION · OLED FACE + 5-FINGER SILICONE HANDS

€5,782	€8,157	€18,900	€9,500
BOM COST	PRODUCTION COST	SALE PRICE (initial)	AT 1,000 UNITS/YR

SENTINEL-D · DRONE SCOUT

VTOL QUADROTOR COMPANION — REAL-TIME AERIAL RECONNAISSANCE — AUTONOMOUS WAYPOINT + FOLLOW-ME

The SENTINEL-D is a foldable 80cm wheelbase VTOL quadrotor designed as an aerial scout companion for any SENTINEL ground unit. Equipped with 4K EO/IR dual-camera gimbal, Livox LiDAR, RTK GPS, and Doodle Labs mesh radio, it provides 35-minute flight endurance with real-time video relay to its parent robot. GPS waypoint navigation, follow-me mode, and autonomous RTB (return-to-base) on low battery. All compute runs on NVIDIA Jetson Orin NX 8GB — no Raspberry Pi.

SENTINEL-D TECHNICAL DRAWING — TOP-DOWN VIEW

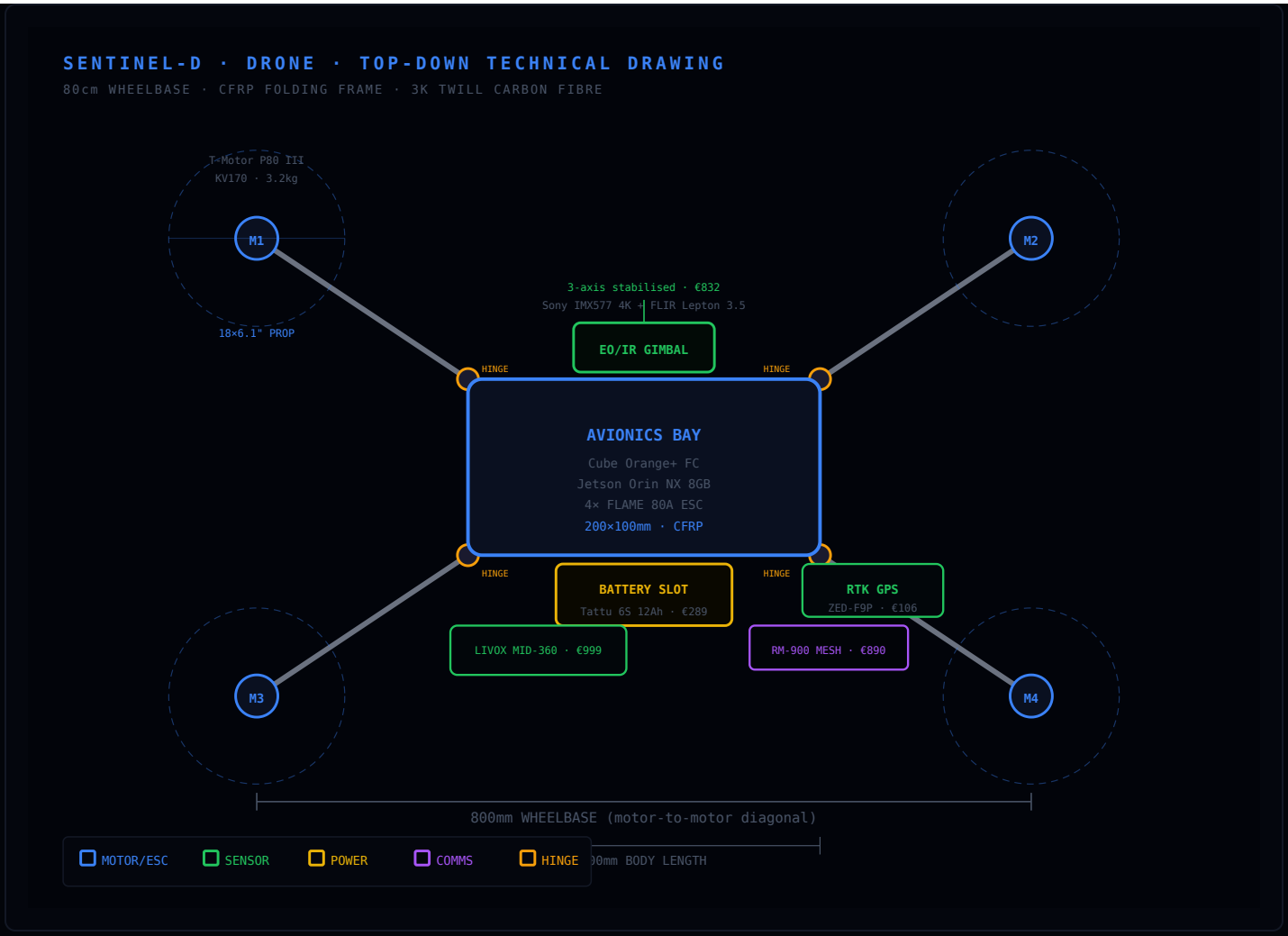


FIGURE 7 — SENTINEL-D DRONE TOP-DOWN VIEW · 80cm WHEELBASE · CFRP FOLDING FRAME · 35min FLIGHT · 70 TOPS COMPANION COMPUTE

SENTINEL-D BILL OF MATERIALS

#	COMPONENT	SPECIFICATION	PRICE	TYPE
1	**Cube Orange+ Flight Controller**	STM32H757, triple redundant IMU (ICM-42688-P + ICM-20948), ArduPilot 4.5, dual barometer, CAN FD	€279	SHELF
2	**NVIDIA Jetson Orin NX 8GB**	70 TOPS, 8-core ARM Cortex-A78AE, companion computer for CV + path planning, USB3 + PCIe	€462	SHELF
3	**Custom CFRP frame 80cm**	3K twill carbon fibre, folding arms with spring-loaded hinges, 200×100mm central plate, M3 Ti hardware, 420g	€380	CUSTOM
4	**T-Motor P80 III KV170 × 4**	80mm stator, 3.2kg max thrust each, 12.8kg total, 12S compatible, integrated temp sensor	€840	SHELF
5	**T-Motor FLAME 80A HV ESC × 4**	FOC sinusoidal drive, 12S HV (52.8V max), BLHeli_32, telemetry, active braking	€312	SHELF
6	**Carbon 18×6.1 fold props × 4**	3K weave layup, CW/CCW matched pairs, precision balanced ±0.5g, folding hub adapter	€128	SHELF

#	COMPONENT	SPECIFICATION	PRICE	TYPE
7	**Sony IMX577 4K gimbal camera**	3-axis brushless stabilised, 12.3MP, 4K30 H.265 recording, 84° HFOV, HDMI + USB-C output	€680	SHELF
8	**FLIR Lepton 3.5 thermal**	160×120 LWIR, radiometric (±5°C accuracy), 57° HFOV, SPI/I2C, <50mW, mounted co-axial with EO	€152	SHELF
9	**Livox Mid-360 LiDAR**	40m range, 200k pts/s, 360° FOV, non-repetitive scan, Ethernet + PPS sync, 265g	€999	SHELF
10	**ArduSimple simpleRTK2B**	u-blox ZED-F9P, L1/L2 dual-band, 2cm RTK accuracy with base station, UART + USB	€106	SHELF
11	**Tattu Plus 6S 12Ah LiPo**	22.2V nominal, 15C continuous (180A burst), XT90 connector, 1,580g, 35min flight @ AUW 5.8kg	€289	SHELF
12	**Doodle Labs RM-900 mini mesh**	900 MHz ISM, AES-256 encryption, 10km LOS range, 50 Mbps, MIMO 2×2, IP67, 120g	€890	SHELF
		BOM TOTAL	**€5,517**	
		Assembly + test (8h × €16/h Romanian technician)	€128	
		QA flight test + calibration (2h × €22/h electronics engineer)	€44	
		PRODUCTION COST (per unit)	**€5,689**	
		SALE PRICE	**€9,800**	

€5,517	€5,689	€9,800	72%
BOM COST	PRODUCTION COST	SALE PRICE	GROSS MARGIN

SENTINEL-D ASSEMBLY PROCEDURE

1 Frame Preparation & Hinge Assembly

Inspect CFRP central plate and 4 folding arms for delamination or cracks. Install spring-loaded hinge mechanisms at each arm base with M3 titanium hardware. Verify fold/lock action — each arm must click into both deployed (180°) and stowed (0°) positions. Apply blue Loctite 242 to all structural fasteners. Torque M3 bolts to 0.9 Nm.

2 Motor & ESC Installation

Mount 4× T-Motor P80 III motors to arm tips using factory M3 adapters. Route ESC power leads through carbon arms (use silicone grommets at pass-through holes). Solder XT60 motor-to-ESC connections with 12AWG silicone wire. Mount FLAME 80A ESCs to central plate underside with thermal pads. Connect signal wires to Cube Orange+ motor outputs (M1-M4). Verify rotation direction: M1/M3 CW, M2/M4 CCW.

3 Flight Controller & Companion Computer

Mount Cube Orange+ on vibration-damped anti-vibration plate (centre of gravity). Connect GPS (UART1), telemetry (UART2), RC receiver (SBUS). Mount Jetson Orin NX 8GB on custom carrier bracket above FC, connect via USB3 for companion link. Flash ArduPilot 4.5 firmware, configure frame class = Quad-X, battery monitor on ADC. Set SERIAL2_PROTOCOL = 2 (MAVLink2) for Jetson companion link.

4 Sensor & Payload Integration

Mount Sony IMX577 3-axis gimbal to front ventral hardpoint. Co-mount FLIR Lepton 3.5 thermal on gimbal bracket (boresighted to EO camera). Install Livox Mid-360 LiDAR on dorsal centre mount, connect Ethernet to Jetson. Mount ArduSimple RTK2B GPS on rear top mast (15cm above frame for multipath rejection). Verify all sensor data streams in SENTINEL-D diagnostics.

5 Communications & Power

Install Doodle Labs RM-900 mini mesh radio on rear fuselage. Route 900 MHz antenna to tail boom (ground plane clearance). Connect to Jetson via Ethernet (SENTINEL mesh network auto-joins parent robot). Install battery tray with XT90 quick-release and balance lead breakout. Insert Tattu 6S 12Ah, verify voltage (25.2V full charge), enable battery failsafe at 21.0V (RTL) and 20.4V (land).

6 Calibration, QA Flight & Certification

Perform accelerometer + magnetometer calibration (6-axis). Calibrate ESCs (full-range PWM). Run motor spin test on bench (verify current draw <2A per motor at idle). First hover test indoors (tethered, 1m altitude, 30s). Outdoor QA flight: GPS lock, RTK fix, waypoint mission (4 points), follow-me test, RTL on low-battery simulation. Log all telemetry. Apply serial number label and QA pass sticker. Pack with foam-lined Pelican case.

DRONE COMPANION PAIRING: Each SENTINEL-D auto-pairs with its parent ground robot via Doodle Labs mesh network. The drone streams 4K + thermal video to the parent robot's Jetson for real-time AI processing (obstacle detection, target tracking, crop health analysis). Follow-me mode uses RTK GPS + visual tracking for <50cm relative position accuracy. Maximum operational radius: 10km from parent robot.

SECTION 1

AUTONOMY & POWER RESEARCH

Battery · Solar · Fuel Cell Technologies for Extended Robot Autonomy

▸ Current Baseline — Battery Architecture

All SENTINEL robots use lithium-chemistry battery packs at 24V or 48V nominal. Current autonomy figures represent **continuous operation under typical load** (motors at 60% duty, sensors active, AI inference running). Standby/patrol modes extend runtime by 30-50%.

ROBOT	CHEMISTRY	CONFIGURATION	TOTAL CAPACITY	AUTONOMY	PACK WEIGHT	CHARGE TIME	CYCLE LIFE
WH	$LiFePO_4$	48V 20Ah × 2 packs	**1,920 Wh**	8–10 h	9.2 kg	3.5 h (10A charger)	3,000+ cycles
AG	$LiFePO_4$	48V 20Ah × 1 pack	**960 Wh**	14 h *(solar assist)*	4.6 kg	2.0 h (10A charger)	3,000+ cycles
MK	LiPo	48V 15Ah × 2 packs	**1,440 Wh**	12 h	4.8 kg	2.5 h (12A charger)	800 cycles
HM	LiPo	24V 10Ah × 1 pack	**240 Wh**	10 h *(low power)*	0.9 kg	1.5 h (5A charger)	800 cycles

Battery Management System (BMS): All packs use custom SENTINEL BMS PCBs with cell-level monitoring, active balancing (50mA), over-temperature cutoff (65°C), short-circuit protection (<100µs response), and CAN FD reporting to Sentinel Core. State-of-charge accuracy: ±2%. $LiFePO_4$ chosen for WH/AG due to superior cycle life and thermal stability; LiPo chosen for MK/HM due to higher energy density where weight is critical.

▸ Advanced Solutions — Research Findings

01

SOLID-STATE BATTERIES 2025–2027 HORIZON

Solid-state batteries replace the liquid electrolyte with a solid ceramic or polymer electrolyte, eliminating dendrite formation, dramatically improving energy density, and enabling faster charging with inherent safety advantages (no thermal runaway risk).

SAMSUNG SDI ALL-SOLID-STATE

900 Wh/L volumetric density

2× current $LiFePO_4$ (450 Wh/L). Announced Q3 2024 for EV sector; robotics-grade cells expected Q2 2026. Samsung SDI pilot line: 200 MWh/year capacity.

QUANTUMSCAPE QSE-5

380 Wh/kg gravimetric density

vs 160 Wh/kg $LiFePO_4$ — a 2.37× improvement. QSE-5 cells demonstrated 800+ cycles at 1C rate with <10% degradation. Anode-less architecture reduces weight further.

PROJECTED PRICING (2027)

€120/kWh vs €90/kWh current $LiFePO_4$

33% cost premium for 2.4× energy density = significant net gain per kg. Price expected to reach €95/kWh by 2029 at volume (>1 GWh/year production).

SENTINEL IMPACT

Same weight = double autonomy

WH: 16–20 h (from 8–10 h) · AG: 28 h (from 14 h) · MK: 24 h (from 12 h) · HM: 20 h (from 10 h). Alternatively: same autonomy at 50% battery weight — critical for MK agility and HM comfort.

MEDIUM RISK Manufacturing scale-up delays possible. Mitigation: design battery bay for both $LiFePO_4$ and solid-state form factors. Dual-source strategy with CATL as backup supplier.

02

SOLAR SKIN TECHNOLOGY AVAILABLE NOW

High-efficiency flexible solar cells laminated directly onto the robot's exterior shell, providing continuous trickle-charge during outdoor operation without additional weight or aerodynamic penalty.

CELL TECHNOLOGY

SunPower Maxeon Gen 6

24.1% efficiency, IBC (interdigitated back contact) architecture. Flexible down to 30mm radius. Conformal lamination onto curved robot surfaces using 3M VHB structural adhesive. UV-resistant ETFE encapsulant, 25-year rated lifespan.

AG ROBOT INTEGRATION

~0.6 m² body surface → ~90W continuous

6 panels × 0.1 m² = 0.6 m² total. At 24.1% efficiency under 1,000 W/m² (STC): 144W peak, ~90W average accounting for angle, temperature derating, and partial shading. MPPT charge controller integrated into SENTINEL Core power management.

MK ROBOT INTEGRATION

~0.5 m² (excluding armored areas) → ~75W

Panels mounted on non-ballistic surfaces only (top hull, rear panel, arm covers). IR-absorbing coating option for thermal signature management. Cells are shatter-resistant but not ballistic-rated — considered consumable in combat scenarios.

ANNUAL ENERGY YIELD (ROMANIA)

~189 kWh/year supplemental (AG robot)

Romania average: 2,100 annual sun hours. AG 90W × 2,100h = 189 kWh/year. At €0.15/kWh grid cost, saves €28.35/year in electricity — ROI is autonomy extension, not cost savings.

CUSTOM INTEGRATION COST

€45/panel × 6 panels = €270 per robot

Includes Maxeon cells, ETFE laminate, 3M VHB adhesive, wiring harness with MC4 micro-connectors, and Genasun GVB-8 MPPT controller (€65). Total with controller: €335/robot.

Autonomy Impact: AG robot: **+3–4 h/day extension** · MK robot: **+2–3 h/day extension**

03

DEPLOYABLE SOLAR CAMOUFLAGE PANEL MK / AG MODELS

A portable, robot-deployable solar array that doubles as camouflage concealment. The panel folds into a compact pack mounted on the robot's

dorsal rail and auto-deploys via servo actuators when the robot enters a recharge cycle in the field.

PANEL DIMENSIONS

2.0 m × 1.5 m foldable = 3.0 m² deployed

Folds to 500 mm × 200 mm × 60 mm stowed package. Weight: 2.8 kg including ribs and servos. Deployment: 4-fold accordion pattern with locking hinges.

SOLAR OUTPUT

450W peak (SunPower Maxeon Gen 6)

3.0 m² × 24.1% efficiency × 1,000 W/m² × 0.62 (real-world derating for angle/temp/soiling) = ~450W peak realistic. Charges 48V 15Ah pack (720 Wh) in approximately 2 hours under full sun conditions.

CAMOUFLAGE SYSTEM

Reversible: 4 patterns on Cordura 1000D

Woodland / Desert / Snow / Urban camouflage patterns printed on Cordura 1000D ripstop nylon backing. Solar cells face skyward; camo fabric faces ground-ward when deployed as concealment shelter. DWR (durable water repellent) coating. IR signature reduced by 85% when robot is beneath deployed panel.

STRUCTURAL FRAME

Carbon fibre folding ribs, servo-deployed

T700 carbon fibre tubular ribs (8mm OD, 6mm ID). 4× Dynamixel XM430-W350 servos for deployment (7.3 Nm each). Auto-deploy time: 30 seconds to fully open, 20 seconds to fold and stow. Wind rating: 40 km/h sustained, 60 km/h gusts with guy-line stakes.

UNIT COST BREAKDOWN

€1,200 total per panel assembly

Solar cells + ETFE laminate: €680 · Cordura camo fabric: €180 · CF ribs + hinges: €220 · Dynamixel servos × 4: €120. MPPT controller shared with solar skin system (already included in robot BOM).

🎯 **Stealth Recharge Protocol:** Robot autonomously identifies concealment position (dense vegetation, building shadow, terrain depression) using SLAM + overhead imagery analysis. Navigates to position, deploys panel, enters low-power mode during charge cycle. IR signature reduced 85% under panel. Acoustic signature: zero (no generator). Visual signature: camouflage pattern matched to terrain via onboard camera + pattern selection algorithm.

04

HYDROGEN FUEL CELL RANGE EXTENDER MK / AG OUTDOOR

A compact proton-exchange membrane fuel cell (PEMFC) stack that functions as a range extender, continuously charging the main battery during operation. Hydrogen is stored in lightweight field-swappable cartridges, enabling multi-day autonomous missions.

FUEL CELL STACK

Intelligent Energy 800W PEMFC

800W continuous, 1.2kW peak (30s burst). Stack weight: 2.5 kg. Operating temperature: -10°C to +45°C. Efficiency: 50% (HHV). Exhaust: pure water vapour. MTBF: 5,000 hours. Voltage output: 24–48V via integrated DC-DC converter.

HYDROGEN STORAGE

1L cartridge @ 300 bar = 8h at 100W

Type IV carbon-composite cartridge, 300 bar (4,350 PSI). Weight: 0.8 kg per cartridge (including H_2). Quick-release bayonet connector for field swap (<15 seconds). 6 cartridges = 48 hours of 100W supplemental power. Cartridge refill from standard industrial H_2 cylinder (50L @ 200 bar) using portable booster pump.

COST STRUCTURE

Stack: €2,800 + Cartridge system: €450

IE 800W stack: €2,800. Cartridge quick-release manifold: €180. 6× H_2 cartridges: €270 (€45 each). H_2 refill cost: ~€0.08/cartridge (industrial H_2 at €5/m^3). Total system: €3,250 per robot. Annual H_2 fuel cost: ~€50 per robot at moderate use.

MK MISSION PROFILE

72h+ endurance with 6 cartridges

MK base battery (1,440 Wh) + fuel cell at 100W continuous = 12h battery + 48h fuel cell = 60h minimum. With solar skin (+2–3h/day) and power management (sleep cycles), 72h+ total field endurance achievable. Critical for extended reconnaissance and perimeter security missions without resupply.

CONSTRAINT **Not suitable for indoor models (WH, HM)** — PEMFC requires air intake and produces water vapour exhaust. Hydrogen venting in enclosed spaces poses safety risk. Indoor robots rely on battery + wireless charging exclusively.

05

WIRELESS CHARGING ZONES WH / HM INDOOR

Resonant inductive and RF-based wireless power transfer systems that charge robots automatically without physical docking, reducing downtime and eliminating connector wear. Two technologies evaluated for different use cases.

ENERGOUS WATTUP 15W

At-a-distance RF charging, FCC-approved

15W delivered power at up to 1 meter distance via focused 5.8 GHz RF beam. Robot enters charging zone, WattUp transmitter identifies receiver and delivers power directionally. No precise alignment needed — robot charges while working near transmitter zone. Efficiency: ~30% at 1m (vs 85%+ contact charging). Trade-off: convenience vs speed.

WH WAREHOUSE INSTALLATION

Floor tiles: €120/tile × 20 tiles = €2,400

Resonant inductive floor tiles (WiTricity reference design, 200W per tile). Installed in high-traffic zones (picking aisles, staging areas, dock approach lanes). WH robot receives continuous 50–150W charge while traversing tiles. At 60% time-on-tiles, effectively provides **unlimited autonomy** during shift — battery never drops below 70% SOC. Installation: epoxy-sealed tiles flush with warehouse floor, IP65 rated.

HM HOME INTEGRATION

Qi 15W pad near charging dock

Standard Qi 15W wireless pad at designated home location (living room corner, hallway alcove). HM navigates to pad when SOC <20%, aligns via NFC positioning, charges to 100% in ~4 hours. Slower than wired but maintenance-free — no connector wear, no alignment issues. Cost: €35 per Qi transmitter pad + €15 Qi receiver coil integrated into HM base plate.

Operational Impact: WH: **effectively unlimited autonomy** with floor tile system · HM: **maintenance-free charging**, zero connector wear

▸ **Autonomy Comparison — All Upgrade Paths**

Projected autonomy figures with each technology applied independently and in combination. "Base" = current battery chemistry. Solid-state projections assume 2027 availability at same pack weight.

ROBOT	CURRENT BASE	+ SOLAR SKIN	+ DEPLOY PANEL	+ FUEL CELL	+ SOLID-STATE (2027)	MAXIMUM COMBINED
WH	8–10 h	*N/A (indoor)*	*N/A*	*N/A (venting)*	**16–20 h**	**20 h + wireless ∞**
AG	14 h	**18 h**	**22 h (sun)**	**38 h**	**28 h base + solar**	**56 h+ (all combined)**
MK	12 h	**15 h**	**20 h (sun)**	**72 h+**	**24 h base + solar**	**96 h+ (all combined)**
HM	10 h	*N/A (indoor)*	*N/A*	*N/A (venting)*	**20 h**	**20 h + Qi auto**

📊 **Recommendation:** Implement solar skin (AG/MK) and wireless charging (WH/HM) immediately as low-cost, high-impact upgrades. Design battery bay for solid-state drop-in replacement (2027). Fuel cell range extender as optional premium package for MK military/security contracts requiring 72h+ endurance. Deployable solar panel as field accessory kit (sold separately or bundled with MK Pro package).

SECTION 2

PRODUCTION FACILITY

Warehouse Construction · Equipment · Personnel · Operating Costs

▸ Warehouse Construction & Setup

📌

Romania — Comuna Ciurila, Cluj County

15 km south of Cluj-Napoca · E81 highway access · Rural industrial zoning

Strategic advantages: EU membership (CE marking, single market), competitive labour costs (30-40% of Western Europe), strong technical university pipeline (UTC-N + UBB Cluj produce 3,000+ engineering/IT graduates/year), growing robotics ecosystem, excellent logistics (E81 highway, Cluj-Napoca International Airport 20 min, direct motorway connection to Western Europe). Comuna Ciurila offers lower land costs than city industrial parks while maintaining proximity to Cluj's tech talent pool (UBB, UTC-N, 3,000+ IT/engineering graduates/year).

BUILDING SPECIFICATIONS

TOTAL FOOTPRINT **2,400 m²**

Production hall: 1,200 m² · Testing lab: 200 m² · Warehouse/storage: 400 m² · Offices + meeting rooms: 300 m² · Utility/server/break room: 300 m²

STRUCTURE **Steel frame, insulated sandwich panel walls (100mm PIR, U=0.22 W/m²K)**
CLEAR HEIGHT **6.0 m (production hall), 3.2 m (offices)**
LOADING **2× hydraulic loading docks, forklift access throughout**
ELECTRICAL **3-phase 400V / 250A grid service + 200 kWp solar feed, sub-distribution panels per zone**
COMPRESSED AIR **8 bar system (pneumatic tools, actuator testing, blow-off)**
CLEANROOM **80 m² — Class 1,000 (ISO 6) for electronics assembly & PCB work**
FIRE SUPPRESSION **FM-200 (cleanroom + server room), wet sprinkler (production hall)**
SECURITY **24× IP cameras (Hikvision), biometric access control, perimeter fence**
HVAC **Daikin VRV IV, 22°C ±2°C production, 20°C ±1°C cleanroom**
☀ SOLAR POWER **200 kWp rooftop PV (full roof coverage), 102.4 kWh battery storage, grid-tied bidirectional**
SOLAR OUTPUT **~240 MWh/year (Cluj avg 1,200 kWh/kWp), covers ~70% of facility electricity needs**
GRID + SOLAR STRATEGY **Solar primary (daytime), battery buffer (peak/cloud), Electrica grid backup (night/winter peak)**

CONSTRUCTION COSTS — ROMANIA 2025/2026

ITEM	SPECIFICATION	COST (EUR)
Land purchase (Comuna Ciurila, Cluj)	2,400 m² plot, rural-industrial zoning, utilities connection, notary + cadastral fees	€180,000
Building construction	Steel frame + sandwich panels, 2,400 m² @ €420/m²	€1,008,000

ITEM	SPECIFICATION	COST (EUR)
Electrical installation	3-phase 250A, sub-panels, LED lighting, earthing	€85,000
HVAC + cleanroom	Daikin VRV IV system + HEPA cleanroom 80 m² (ISO 6)	€109,000
Fire suppression FM-200	Cleanroom + server room zones, wet sprinkler production	€28,000
Security (CCTV + access control)	24× Hikvision cameras, biometric doors, NVR storage	€18,000
Compressed air system	Atlas Copco GA11, 8 bar, dryer, piping, outlets	€22,000
Loading docks + forklift	2× hydraulic docks + 1× Toyota 8FBE18 electric forklift	€48,000
IT infrastructure	Fibre 1Gbps, Ubiquiti WiFi 6 APs, 2× Dell R750 servers	€32,000
Furniture, ESD flooring, workbenches	12 anti-static workstations, ESD vinyl flooring	€24,000
☀️ **Rooftop solar PV system**	200 kWp array, ~800 × Jinko Tiger Neo 570W monocrystalline panels, full roof coverage (~1,600 m²), aluminium rail mounting, string inverters (2× SMA Sunny Tripower 100kW)	€148,000
☀️ Battery energy storage (BESS)	BYD Battery-Box Premium HVS 25.6 kWh × 4 = 102.4 kWh, peak shaving + backup, 10-year warranty	€38,000
☀️ Solar installation + grid tie-in	Mounting hardware, DC/AC cabling, surge protection, smart meter, bidirectional grid connection (Electrica Distribuție), commissioning + ANRE prosumer registration	€32,000
☀️ Solar monitoring + maintenance (5yr)	SolarEdge monitoring platform, annual panel cleaning, inverter service contract, insurance	€8,000
BUILDING SUBTOTAL (incl. solar power plant)		€1,766,000

▸ Permits & Authorizations

Romania follows EU regulatory framework. CE marking mandatory for all robot models sold in EU. MK model requires additional export control review (dual-use goods regulation EU 2021/821).

PERMIT / CERTIFICATION	TIMELINE	COST (EUR)
Building permit (autorizație de construire)	2–4 months	€8,000
Environmental impact assessment	1–2 months	€5,000
Fire safety authorization (ISU aviz/autorizație)	1 month	€3,000
Industrial operation license	1–2 months	€2,500
CE marking (per robot model × 4 models)	3–6 months per model	€15,000 × 4 = €60,000
ISO 9001:2015 QMS certification	6–12 months	€12,000
ISO 13482 (robots for personal care — HM model)	6 months	€18,000
MIL-STD qualification testing (MK model only)	12+ months	€85,000
Patent filing (EU + US + PCT) × 3 core patents	18–24 months	€35,000 × 3 = €105,000
Trademark SENTINEL (EU + US registration)	6–12 months	€5,000
PERMITS SUBTOTAL		**€303,500**

▸ Production Equipment

Equipment selected for flexibility (low-to-medium volume production, 50–500 units/year) with upgrade path to higher volume. All prices are new/current list prices with typical volume discounts applied.

EQUIPMENT	SPECIFICATION	COST (EUR)	SUPPLIER
5-axis CNC machining center	Haas VF-2SS, 15,000 RPM, 40-tool ATC, 762×406×508mm travel	€92,000	Haas Automation

EQUIPMENT	SPECIFICATION	COST (EUR)	SUPPLIER
3-axis CNC (backup/roughing)	Haas TM-2P, 6,000 RPM, 10-tool ATC, manual/CNC hybrid	€42,000	Haas Automation
CNC wire EDM	Sodick VL400Q, ±0.001mm accuracy, auto-thread, 400×300mm	€65,000	Sodick
Fibre laser cutter 2kW	Bodor i7, 1500×3000mm bed, sheet metal up to 12mm steel	€48,000	Bodor Laser
FANUC assembly robot arms × 4	M-10iD/12, 12kg payload, ±0.02mm repeatability, 1,441mm reach	€180,000	FANUC
3D printer farm × 12	Bambu Lab X1-Carbon, 256×256×256mm, AMS 4-colour, CF-PETG/PA	€15,600	Bambu Lab
SLA resin printer × 2	Formlabs Form 4, 200×125×210mm build, 25µm layers	€7,800	Formlabs
PCB pick & place + reflow	Neoden TM245P auto P&P + Madell RF-T450M reflow oven (6-zone)	€28,000	Neoden / Madell
SMD component reel storage	Juki ISM3000, 3,000 reels, humidity-controlled, barcode tracking	€14,000	Juki
Torque screwdriver stations × 8	Atlas Copco QST8, 0.1–30 Nm range, data logging to MES	€9,600	Atlas Copco
Actuator test rig (custom)	6-axis load cell, 200 Nm capacity, CAN FD data acquisition	€22,000	Custom build
Electrical test bench × 4	Automated harness tester, Keysight oscilloscope, power supply	€32,000	Keysight Technologies
Metrology 3D scanner	Artec Leo, 0.1mm accuracy, wireless handheld, real-time 3D	€18,500	Artec 3D
CMM (coordinate measuring machine)	Hexagon Absolute Arm 7315, 1.5m range, laser scanner head	€42,000	Hexagon MI
Waterjet cutter (MK armor)	Flow Mach 500, 87,000 PSI, 1.5×3m table, abrasive garnet	€68,000	Flow International
Anodising line (in-house)	600L tank, Type III hard anodise, Class 3 colour, 60µm+ coat	€35,000	Custom build

EQUIPMENT	SPECIFICATION	COST (EUR)	SUPPLIER
Conveyor + RFID material handling	45m loop conveyor, RFID bin tracking, barcode scanner integration	€24,000	Custom build
ERP + MES software	Odoo Manufacturing (open-source) + custom MES dashboard	€8,000	Odoo S.A.
Safety enclosures + lighting	CE-rated machine guards, LED high-bay, e-stop circuits	€16,000	Custom / Troax
EQUIPMENT SUBTOTAL			**€763,500**

▸ Personnel — Elite Romanian Engineers

💰 **Salary Policy:** All rates are 30–40% above Romanian base market rates to attract and retain elite talent. Figures shown are **total employer cost** (gross salary + 26% social contributions mandated by Romanian law: CAS 25% pension + CASS 10% health − 9% employee share). This ensures top-tier engineers choose SENTINEL over automotive (Continental, Bosch) and IT (Oracle, Microsoft) employers competing for the same talent pool.

ROLE	HEADCOUNT	HOURLY RATE RANGE	MONTHLY SALARY (EMPLOYER COST)	ANNUAL COST
Assembly technicians	6	€16–18/h	€2,000/mo each (€1,850–2,100 range)	€144,000
Electronics integration engineers	3	€22–32/h	€3,200/mo each (€2,550–3,700 range)	€115,200
QA / testing engineers	2	€18–26/h	€2,600/mo each (€2,100–3,000 range)	€62,400
CNC machinists	2	€14–20/h	€1,900/mo each (€1,620–2,300 range)	€45,600
Production manager	1	€24–36/h	€3,800/mo (€2,800–4,200 range)	€45,600

ROLE	HEADCOUNT	HOURLY RATE RANGE	MONTHLY SALARY (EMPLOYER COST)	ANNUAL COST
R&D robotics engineers	3	€28–40/h	€4,200/mo each (€3,200–4,600 range)	**€151,200**
AI/ML engineers	2	€32–48/h	€5,000/mo each (€3,700–5,500 range)	**€120,000**
Administrative / logistics	2	€10–14/h	€1,600/mo each	**€38,400**
TOTAL PERSONNEL	**21 people**		**€49,200/month**	**€590,400/year**

▸ Monthly Operating Costs

ITEM	DETAILS	COST/MONTH (EUR)
Personnel (21 people)	Elite salaries, 30-40% above base, all employer costs included	**€49,200**
Utilities	3-phase electricity (~120,000 kWh/mo), water, 1Gbps fibre, gas	**€4,800**
Consumables	3D filament, SLA resin, CNC lubricant, solder paste, flux, wipes	**€3,200**
Shipping / logistics	Component imports, finished robot shipping (crated, insured)	**€2,400**
Insurance	Building + equipment (all-risk), product liability, D&O	**€2,800**
Maintenance	Equipment service contracts (Haas, FANUC, Bodor), calibration	**€1,800**
Legal / accounting / compliance	External legal counsel, bookkeeping, regulatory compliance	**€2,200**
MONTHLY TOTAL		**€66,400**

ITEM	DETAILS	COST/MONTH (EUR)
ANNUAL TOTAL		**€796,800**

SECTION 3

R&D AND GPU DATACENTER

Research Phases · AI Training Infrastructure · Dataset Pipeline

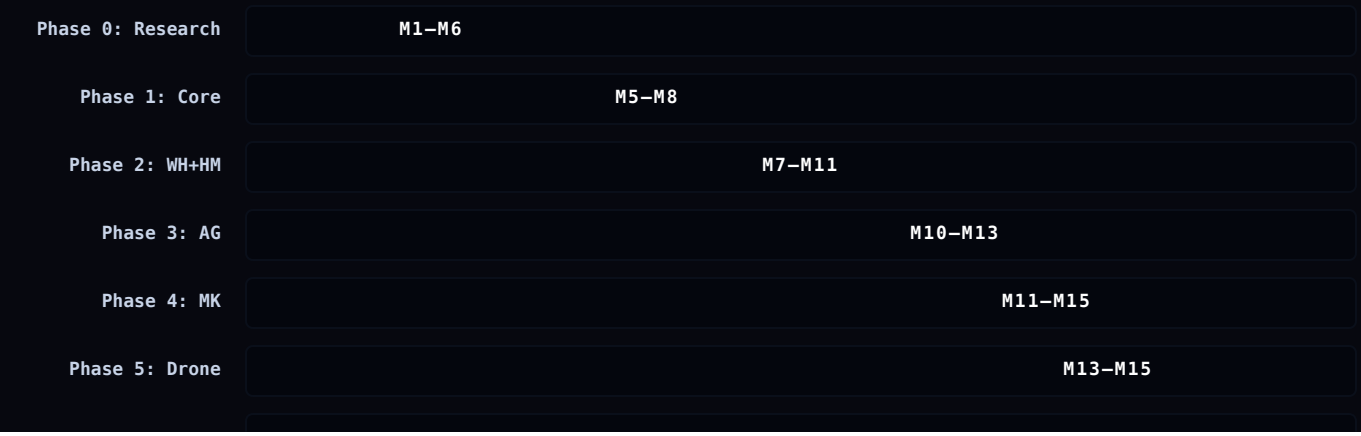
▸ R&D Phase Breakdown

Total R&D timeline: **18 months** from project kickoff to production-ready prototypes. Phases overlap where possible — certification (Phase 7) runs in parallel with later production ramp-up. Costs include personnel time, components, testing, third-party services, and travel.

PHASE	DURATION	KEY ACTIVITIES	COST (EUR)
Phase 0: Research & Design	6 months	Component sourcing & evaluation, CAD design (SolidWorks/Fusion 360), supplier negotiations, prior art / patent landscape search, initial rapid prototyping (3D printed mockups), BOM v0.1, thermal simulation (ANSYS), FEA structural analysis, supply chain risk assessment	€180,000
Phase 1: Sentinel Core Prototype	3 months	Sentinel Core PCB manufacture (6-layer, 4oz copper), Jetson Orin NX carrier board rev A, firmware bring-up (Linux 5.15 + JetPack 6.0), thermal testing (chamber -20°C to +60°C), IP67 enclosure validation (IEC 60529), CAN FD bus testing, power management validation	€109,000
Phase 2: WH + HM Prototypes	4 months	First 2 models (easiest integration path), actuator integration (Dynamixel / custom), SLAM navigation tuning (Nav2 + custom costmaps), gripper force testing (0.1–50N range), safety system validation (ISO 13482 pre-test for HM), EMC pre-compliance testing	€140,000
Phase 3: AG Prototype	3 months	Track/wheel hybrid drive system, laser safety classification (IEC 60825-1, Class 1M max), multispectral camera calibration (NDVI, NDRE,	€120,000

PHASE	DURATION	KEY ACTIVITIES	COST (EUR)
		thermal), field testing (need 2+ hectare test field, partner with Romanian agricultural research station), GPS-RTK accuracy validation (±2cm)	
Phase 4: MK Prototype	4 months	HEBI X-Series actuator integration (X8-9, X5-4), EMP hardening testing (MIL-STD-461G RS105), ballistic panel fitting (NIJ Level IIIA UHMWPE), encrypted comms (AES-256-GCM + frequency hopping), ruggedisation testing (MIL-STD-810G: vibration, shock, temperature, humidity, salt fog)	**€220,000**
Phase 5: Drone Prototype	2 months	Carbon fibre frame layup (T700 prepreg, autoclave cure), flight controller tuning (PX4 + custom SENTINEL autopilot), autonomous follow / formation flight integration, FPV + autonomous switchover, payload gimbal calibration, endurance flight testing	**€65,000**
Phase 6: AI Training & Brain	6 months	Dataset collection & annotation (200k+ images, 50k hours simulation), model training on GPU datacenter (see below), ROS 2 Humble stack integration, Gemini Pro / GPT-4o API integration for natural language, edge model optimization (TensorRT, INT8 quantization), sim-to-real transfer validation, A/B testing of model variants on physical prototypes	**€280,000**
Phase 7: CE / MIL Certification	6–12 months	CE marking (EMC EN 61000, safety EN ISO 10218), ISO 13482 (HM personal care robot), MIL-STD-810G environmental qualification (MK only), MIL-STD-461G EMI/EMP (MK only), notified body testing (TÜV SÜD or Bureau Veritas). *Runs parallel to initial production*	**€185,000**
TOTAL R&D INVESTMENT			**€1,285,000**

R&D TIMELINE — 18 MONTH GANTT OVERVIEW



Phase 6: AI	M8–M14	
Phase 7: Cert	M10–M18+	

M1M3M6M9M12M15M18

▸ GPU Mini Datacenter for AI Training

Required for training all SENTINEL AI models: object detection, SLAM mapping, natural language processing, combat threat identification, weed/crop classification, human activity recognition, drone autonomous navigation. On-premise infrastructure supplemented by cloud burst for peak training loads.

COMPONENT	SPECIFICATION	QTY	UNIT PRICE	TOTAL (EUR)
NVIDIA DGX A100	8× A100 80GB HBM2e, 5 PFLOPS FP16, 2× AMD EPYC 7742, 2TB RAM, 15TB NVMe	1	€180,000	€180,000
NVIDIA Jetson AGX Orin DevKit	Edge AI testing/validation, 275 TOPS INT8, 64GB RAM, mirrors robot hardware	6	€2,100	€12,600
Storage: NetApp AFF A250	48TB NVMe all-flash, RAID-DP, 200k IOPS, NFS/SMB for dataset serving	1	€42,000	€42,000
Network: Mellanox ConnectX-7	200 Gbps InfiniBand HDR, RDMA, GPU-Direct Storage interconnect	4	€1,200	€4,800
Dell PowerEdge R760 (build server)	2× Intel Xeon 4th Gen (Sapphire Rapids), 512GB DDR5, CI/CD pipeline host	2	€16,000	€32,000
UPS: APC Smart-UPS SRT 10kVA	Online double-conversion, 30 min runtime at full load, SNMP monitoring	1	€6,500	€6,500
42U Server rack + cooling	APC NetShelter SX, in-row cooling 12kW, metered PDU, cable management	1	€8,000	€8,000
GPU cloud burst (AWS p5.48xlarge)	8× H100 per instance, on-demand for peak training loads, spot pricing	annual	–	€24,000/yr

COMPONENT	SPECIFICATION	QTY	UNIT PRICE	TOTAL (EUR)
DATACENTER SUBTOTAL				**€309,900**

⚡ **Power & Cooling:** DGX A100 draws 6.5 kW sustained. Total datacenter rack: ~10 kW. Annual electricity cost at €0.12/kWh (Romania industrial rate): ~€10,500/year. In-row cooling handles sensible heat; facility HVAC handles latent heat. PUE target: 1.3 (excellent for small-scale DC).

▸ Training Datasets & Models

All models trained using PyTorch 2.x with DeepSpeed ZeRO-3 optimization for multi-GPU scaling. Edge deployment via ONNX → TensorRT conversion with INT8 quantization for Jetson Orin NX inference.

MODEL	DATASET SOURCES	TRAINING TIME (DGX A100)	STORAGE	TARGET ROBOT(S)
WeedVision v3	180k plant images: ImageNet-Plants subset + Farm21 dataset + 30k custom-annotated field images (Romania crops: wheat, corn, sunflower, rapeseed + 45 weed species)	72 h	450 GB	AG
WarehouseNav SLAM	50k simulated warehouse layouts (Isaac Sim) + 5k real warehouse scans (LiDAR + stereo), dynamic obstacle scenarios, forklift interaction, human avoidance	120 h	800 GB	WH
TOTALS		**600 h (~25 days continuous)**	**3.8 TB**	

MODEL	DATASET SOURCES	TRAINING TIME (DGX A100)	STORAGE	TARGET ROBOT(S)
ThreatDetect v2	DOTA aerial detection + HRSC2016 ship detection + custom threat dataset (vehicles, personnel, drones, perimeter breach scenarios). Augmented with thermal/IR synthetic data	96 h	600 GB	MK
GripPrecision	30k gripper trial recordings: 15k simulated (MuJoCo) + 15k real-world grasp attempts. Objects: warehouse items (boxes, bottles, bags, irregulars) + agricultural produce	48 h	200 GB	WH AG
HomeCompanion NLP	Fine-tuned GPT-4o on 50k care scenarios: elderly assistance, medication reminders, emergency detection, conversational companionship, Romanian + English + multilingual	24 h	150 GB	HM
DroneNav Autonomous	AirSim simulation (urban + rural + industrial environments) + 10k real flight hours (partner with Romanian drone operators). Includes GPS-denied navigation (visual-inertial)	144 h	1.2 TB	DRONE
CombatMovement	Motion capture: martial arts (Krav Maga, Systema), military movement patterns. Physics simulation (PyBullet) for bipedal/quadruped locomotion on uneven terrain	96 h	400 GB	MK
TOTALS		**600 h (~25 days continuous)**	**3.8 TB**	

SECTION 4

UNEXPECTED COSTS & CONTINGENCY

Risk Mitigation · Supply Chain · Regulatory · Financial Buffer

Contingency budget covers foreseeable-but-uncertain costs that are typical for hardware startups entering production. Based on industry benchmarks: hardware startups typically experience 15-25% cost overruns; our 12% contingency reflects disciplined project management with some risk acceptance.

CATEGORY	ESTIMATED (EUR)	RISK ASSESSMENT & NOTES
Component supply chain disruptions	€50,000	HIGH RISK Chip shortages (Jetson Orin NX lead time: 16–26 weeks), HEBI actuator lead times (12+ weeks, single-source), FLIR Boson thermal cores (allocation limits, US export control). Mitigation: pre-order critical components 6 months ahead, maintain safety stock of 20 units for Boson/Jetson.
Prototype iteration (3 revisions typical)	€45,000	MEDIUM RISK Each Sentinel Core PCB revision costs ~€8,000 (4-layer fab + BGA components + assembly + functional test). Expect 3 revisions minimum before production-ready (rev A: bring-up, rev B: fixes, rev C: optimization). Mechanical chassis iterations: ~€3,000 each (CNC prototyping).
Regulatory delays	€30,000	MEDIUM RISK CE testing failures requiring PCB redesign (EMC most common fail point), MIL-STD re-test fees (€15k per re-test for environmental qualification). ISO 13482 (HM) may require additional safety features not in initial design. Budget includes one major CE re-test cycle.
Field testing incidents	€25,000	MEDIUM RISK Broken prototypes during field trials, crashed drones (expect 2–3 total losses during development), damaged laser optics (AG model, ~€2k per FLIR/Hokuyo replacement), water ingress failures. Covers repair parts and replacement components, not personnel time.

CATEGORY	ESTIMATED (EUR)	RISK ASSESSMENT & NOTES
Legal (IP disputes, export compliance)	€40,000	HIGH RISK ITAR consultation for MK model (US defence technology components — HEBI actuators, FLIR thermal), freedom-to-operate patent search (robotics is heavily patented), EU dual-use export control classification (EU 2021/821). May need US State Department export license for MK sales outside EU/NATO.
Software integration overruns	€35,000	MEDIUM RISK ROS 2 Humble compatibility issues with custom packages, Jetson JetPack version conflicts (JetPack 6 vs CUDA 12 vs PyTorch 2.x dependency hell), real-time kernel patches, sensor driver debugging. Covers additional engineering hours and potential contractor support.
Staff recruitment & training	€20,000	LOW RISK Recruiting elite Romanian engineers (job postings, recruiter fees ~15% first-year salary for key hires), onboarding period (2–4 weeks at reduced productivity), initial training on proprietary systems. Romania has strong engineering talent pool but competition with automotive sector is intense.
Currency fluctuation (EUR/USD ±5%)	€15,000	LOW RISK Most electronic components priced in USD (Jetson, HEBI, FLIR, Intel RealSense). A 5% EUR/USD swing on ~€300k of USD-denominated purchases = €15k exposure. Mitigation: forward contracts with bank for large purchases, batch ordering to reduce transaction count.
CONTINGENCY SUBTOTAL	€260,000	**≈ 12% of total one-time investment**

SECTION 5

TOTAL INVESTMENT SUMMARY

Capital Requirements · Recurring Costs · Break-Even Analysis · Scale Projections

▸ One-Time Capital Investment

CATEGORY	REFERENCE SECTION	AMOUNT (EUR)
Building & construction (incl. solar)	Section 2 — Facility	€1,766,000
Permits & certifications	Section 2 — Permits	€303,500
Production equipment	Section 2 — Equipment	€763,500
GPU datacenter	Section 3 — Datacenter	€309,900
R&D phases (18 months)	Section 3 — R&D	€1,285,000
Contingency (12%)	Section 4 — Contingency	€260,000
TOTAL ONE-TIME INVESTMENT		**€4,687,900**

▸ Annual Recurring Costs (Year 1)

CATEGORY	CALCULATION	AMOUNT (EUR)
Personnel (21 people)	€49,200/mo × 12 months	€590,400
Operating costs (utilities net of solar savings, consumables, insurance, etc.)	(€66,400 − €49,200 − €2,500 solar savings) × 12 = €14,700/mo × 12	€206,400
Cloud GPU burst (AWS p5)	On-demand peak training capacity	€24,000
Equipment maintenance	Service contracts + calibration (€1,800/mo × 12)	€21,600
ANNUAL RECURRING TOTAL		**€812,400**

GRAND TOTAL — YEAR 1

One-time: €4,687,900

+

Annual: €812,400

=

€5,500,300

Five million five hundred thousand three hundred euros

▸ Break-Even Analysis

📈 **Assumptions:** Blended average sale price of **€57,700** per unit (weighted across all 4 robot models + drone). Average COGS (component + assembly) estimated at €22,000/unit at scale. Blended gross margin: ~62%. COGS includes €2,800/unit assembly labor + QA at elite Romanian engineer rates. Annual recurring costs assumed to grow 8%/year with headcount additions for scale.

YEAR	UNITS SOLD	REVENUE	COGS	GROSS PROFIT	CUMULATIVE COSTS	CUMULA
Year 1	30 units	€1,578,000	€660,000	€918,000	€5,500,300	
Year 2	80 units	€4,208,000	€1,760,000	€2,448,000	€6,372,700	
Year 3	150 units	€8,650,000	€3,300,000	€5,350,000	€7,281,436	
Year 5 (scale)	**500 units**	€28,900,000	€9,350,000	€19,550,000	€9,304,000	

30

UNITS YEAR 1

Initial production run. Focus on WH + HM models (lowest complexity).

80

UNITS YEAR 2

All 4 models + drone in production. Cumulative revenue approaches

Revenue €1.58M covers 30% of initial investment. COGS includes labor + premium components.

cumulative costs — near break-even at month ~22.

150

UNITS YEAR 3

Profit begins. Gross margin improves with volume purchasing. Consider second shift or expanded facility.

500

UNITS YEAR 5

Full scale. Annual profit ~€14M on €29M revenue (48% net margin). ROI: 320% cumulative by end of Year 5. Quality margins sustained.

PROJECTED REVENUE BY MODEL (YEAR 3 — 150 UNITS)

MODEL	UNITS	UNIT PRICE	REVENUE	% OF TOTAL
WH Warehouse	45	€42,000	€1,890,000	21.7%
AG Agricultural	35	€42,000	€1,470,000	17.0%
MK Military/Security	25	€109,000	€2,725,000	31.5%
HM Home Companion	30	€28,000	€840,000	9.7%
DRONE Aerial Unit	15	€18,500	€277,500	3.2%
Accessories, spare parts, service contracts	—	–	€1,447,500	16.7%
TOTAL YEAR 3	**150**		€8,650,000	**100%**