

Kestrel R1 — Cost & BOM-Thinking Pass

Two-Body Wearable Warehouse Scanner

Program-kickoff cost estimate · Kestrel program · Hardware & manufacturing engineering Revision A · September 28, 2026 · Currency: USD · All figures are program-kickoff estimates, not quotes

How to read these numbers

Every figure in this document is a program-kickoff estimate, not a quote. No supplier has been RFQ'd; no tooling has been quoted; no unit has been built. These are the honest planning numbers a hardware team uses to decide whether a program pencils out and where the cost fight will be. When a real number gets pinned in later (a Bosch/TI actuator quote, a Zebra OEM engine price), it moves — and the ranges below are wide on purpose because that is the truth at kickoff.

Two numbers you cannot skip, because they change everything:

- 1. Volume assumption.** Cost per unit is almost entirely a function of volume, because tooling and NRE amortize over the units built. **The base assumption for this pass is 25,000 units/year, a ~3-year program (≈ 75,000 units lifetime).** Where a line item swings hard with volume, the pass shows it at **1k / 10k / 50k** so the sensitivity is visible.
 - 2. What "cost" means.** This pass reasons in three layers, and keeps them separate:
 - **BOM cost** — the landed cost of the parts.
 - **Manufacturing cost (COGS / factory-gate)** — BOM + assembly labor + test + yield loss + tooling amortization + a factory margin.
 - **Sell price** — what the kit lists for. In this category, an RS5100 *kit* streets around **\$1,200–\$1,500**. The gap between COGS and that price is the margin story in §6.
-

1. BOM by subsystem — at 25,000 units/year

Component costs below are **per-unit, at ~25k/yr volume**, as rough estimates. The dominant line, by a wide margin, is the scan engine.

Scan module (finger)

Line item	Est. unit cost (US D)	Notes
Imaging engine (SE4770-class, standard range)	\$28 – \$45	The dominant cost line. OEM enterprise area-imaging engines are the single most expensive component in any scanner by a wide margin — they bundle the sensor, optics, aimer laser, illumination, and the decode capability. Sourcing an SE-class engine as an OEM module (from Zebra or an equivalent-class supplier) lands in this range at program volume. A long-range SE55-class engine is materially more (~\$55–\$90) — priced only into the long-range SKU.
Hardened optical PC window + molded hood	\$0.40 – \$0.80	Small optical part
Primary trigger (mechanical paddle + dome/switch)	\$0.60 – \$1.20	Rated for millions of actuations
Status LED (RGB) + light pipe	\$0.20 – \$0.40	
Tap haptic motor (small ERM/LRA in saddle)	\$0.60 – \$1.50	Local aim/confirm cue
Flex/interconnect within module	\$0.50 – \$1.00	

Line item	Est. unit cost (USD)	Notes
Scan module subtotal	~\$31 – \$50	Imager is ~90% of it

Wrist pack

Line item	Est. unit cost (USD)	Notes
Main board (PCB, assembly, passives)	\$4 – \$8	4–6 layer rigid-flex, moderate density
SoC / MCU (nRF52840-class BLE SoC)	\$4 – \$7	Real: nRF52840 streets ~\$6.78/1 → ~\$4.07 at 3k reel; program volume lands in this band. Integrates the BLE 5.2 radio + NFC tag, so no separate radio part on the base SKU.
BLE radio	(included in SoC)	The nRF52840 is the radio — this is why the SoC choice matters to the BOM
External flash (QSPI, 4–16 Mbit)	\$0.30 – \$0.60	Logs / connection-loss staging
Battery cell (standard, ~1,300 mAh prismatic Li-ion)	\$3 – \$6	Custom prismatic pack; extended/freezer cell adds ~\$3–5
Battery pack: BMS/protection, contacts, housing	\$2 – \$4	Per swappable pack; the <i>device</i> carries the receiver + contacts + latch
Hot-swap latch mechanism (slide-and-latch, contacts, retention)	\$1.50 – \$3.50	Mechanical + gold-plated contacts; must survive thousands of swap cycles
Buffer supercap / coin cell (holds pairing across swap)	\$0.50 – \$1.20	Keeps BLE alive during the 10 s swap
Piezo beeper (≥ 90 dB target) + resonant cavity	\$0.40 – \$1.00	Louder-than-category piezo

Line item	Est. unit cost (USD)	Notes
Strong LRA haptic	\$1.50 – \$3.50	Quality LRA (not a cheap ERM) — the primary confirm channel through a glove
Second trigger (paddle + switch)	\$0.60 – \$1.20	
Charge-state LEDs + directional LED bar	\$0.60 – \$1.20	Pick-path guidance
NFC antenna (pairing/config)	\$0.20 – \$0.50	Driven by the SoC's NFC tag
Wrist pack subtotal	~\$19 – \$34	

Flex bridge

Line item	Est. unit cost (USD)	Notes
Over-molded flex circuit (4-conductor, power + data)	\$2.50 – \$5.00	FPC + elastomer over-mold; the sealed, foldable interconnect over the knuckle. Custom part, moderate NRE.
Two board-to-board / bridge connectors (sealed)	\$1.00 – \$2.50	Must hold the IP boundary and separate tool-free
Flex bridge subtotal	~\$3.50 – \$7.50	

Housings & mount

Line item	Est. unit cost (USD)	Notes
PA66-GF30 shell parts (saddle roof + hood, pack housing, trigger cores)	\$2.00 – \$4.00	Molded resin cost, at volume; tooling is amortized separately (\$3)
TPE/TPU over-mold (grip, bumpers, trigger caps, gaskets)	\$1.50 – \$3.00	Co-molding is a two-shot / insert-mold operation — cheaper per-part than assembly but pushes tooling cost up (\$3)

Line item	Est. unit cost (USD)	Notes
Strap / mount soft goods (S/M/L, nylon webbing, hook-and-loop, metal cam buckle)	\$2.50 – \$5.00	Soft goods; launderable; the replaceable/consumable part
Housings & mount subtotal	~\$6.00 – \$12.00	

BOM roll-up (base SKU, standard range, BLE-only, ~25k/yr)

Subsystem	Est. BOM (USD)
Scan module (imager-dominated)	\$31 – \$50
Wrist pack	\$19 – \$34
Flex bridge	\$3.50 – \$7.50
Housings & mount	\$6 – \$12
Fasteners, adhesives, gaskets, misc.	\$2 – \$4
Total BOM, base SKU, ~25k/yr	≈ \$61 – \$107
BOM planning midpoint	≈ \$85

The imager alone is 35–55% of the BOM. Every cost conversation in this program starts there. The second-tier drivers are the battery/hot-swap system and the quality LRA haptic. The SoC, at ~\$4–7, is not a cost problem — choosing an integrated BLE+NFC SoC is what keeps it that way.

SKU deltas (added to base BOM)

SKU option	BOM delta	Why
Long-range engine (SE55-class)	+\$25 – \$50	Bigger, pricier multi-focus engine
Wi-Fi 6 (802.11ax) direct-to-network	+\$8 – \$18	Wi-Fi SoC/module + antenna + higher power design; also cuts battery runtime (bigger cell or shorter shift)
Extended / freezer battery	+\$3 – \$5 per pack	Cold-optimized cell; sold as spare packs too
IP67 sealing	+\$2 – \$5 unit + sealing NRE	Extra gasketing, sealed connectors, validation

2. How BOM cost moves with volume

The imager and the electronics are volume-sensitive; the soft goods less so. Directional estimate for the **base-SKU BOM midpoint**:

Annual volume	Est. base BOM/unit	Driver
1,000/yr	~\$115 – \$135	No volume pricing on the engine or SoC; small-lot resin; low-cavity tools
10,000/yr	~\$95 – \$105	Engine and SoC pricing start to move
25,000/yr (base)	~\$85	The plan's assumption
50,000/yr	~\$72 – \$80	Best engine pricing; multi-cavity tools fully earning out

Below ~10k/yr this product is hard to build economically — the enterprise imager does not discount at hobby volume, and the tooling has too few units to amortize against (\$3). This is a program that wants scale to work; the reference-set vendors all run at high volume.

3. Tooling & NRE — the hard-tooling story

The injection-molded housings need **hard steel tooling**, and this is where a two-body, two-material, three-size product gets expensive.

What has to be tooled

Tool	Type	Est. NRE (USD)	Notes
Wrist-pack housing (multi-part)	Multi-cavity, hardened steel; two-shot for the co-molded TPE	\$60k – \$120k	The most complex tool — wedge geometry, sealed seams, battery bay, latch features, over-mold
Scan-module saddle + hood	Multi-cavity, two-shot (PA66-GF + TPE floor)	\$45k – \$90k	Optical hood tolerances matter

Tool	Type	Est. NRE (USD)	Notes
Trigger paddles (×2), caps, small parts	Family/multi-cavity tools	\$25k – \$50k	Several small parts grouped into family tools
Flex-bridge over-mold tool	Insert-mold tool	\$20k – \$40k	Over-molds the FPC
Mount / strap tooling (buckles, clips; ×3 sizes)	Multiple small tools	\$25k – \$50k	Three shell sizes multiply the tool count
Total hard-tooling NRE (est.)		≈ \$175k – \$350k	

Why multi-cavity, and what it costs

- **Multi-cavity tools** (2, 4, or 8 identical cavities in one mold) are how you hit 25k+/yr without a wall of machines. A multi-cavity tool costs more up front but drops the per-part molding cost — it is a volume bet. At 25k/yr, 2–4 cavity tools are the right call; at 50k/yr, higher cavitation earns out.
- **Two-shot / co-molding tooling is more expensive** than single-material tooling because the tool has to do two operations in registration. The soft-touch grip and the sealing gaskets are worth it, but they push the housing tool NRE up.
- **Three mount sizes (S/M/L)** multiply the soft-goods and mount tooling. This is a real cost of the ambidextrous, size-adjustable ergonomics — named here so it is not a surprise.

Tooling amortized into unit cost

Spread the ~**\$175k–\$350k tooling NRE** over the program:

Lifetime volume	Tooling \$/unit
3k (1k/yr × 3)	\$58 – \$117/unit — punishing
30k (10k/yr × 3)	\$6 – \$12/unit
75k (25k/yr × 3, base)	\$2.30 – \$4.70/unit
150k (50k/yr × 3)	\$1.20 – \$2.30/unit

This table is the volume argument in one number. At the base 75k lifetime, tooling adds only ~\$2–5/unit — negligible against an \$85 BOM. At 3k lifetime it adds \$58–117/unit and the program does not pencil. **Tooling is not the cost problem at scale; it is the reason the program needs scale.**

Full program NRE (beyond hard tooling)

The hard tooling above is one slice. The whole front-end NRE to a shippable product also carries:

NRE bucket	Est. (USD)	Notes
Hard tooling	\$175k – \$350k	Above
Electrical design (schematic, PCB layout, firmware)	\$150k – \$400k	Board bring-up, BLE stack, decode integration, power management, OTA
Mechanical / ID engineering (DFM, CAD, tolerance)	\$100k – \$250k	Two bodies, sealing, hot-swap mechanism design
Certification (FCC, CE/RED, BT SIG, IEC 60825 laser, UN 38.3, IEC 62133, IP + MIL-STD-810H testing)	\$100k – \$250k	\$9 of the spec names each; environmental + radio labs are the big line
Prototyping (EVT/DVT/PVT builds, iterations)	\$150k – \$400k	Below
Total front-end NRE (rough, ex-tooling already counted)	≈ \$500k – \$1.3M on top of tooling → ~ \$675k – \$1.65M all-in to production readiness	Program-kickoff order of magnitude

4. Assembly & test

Where the labor is

- **Assembly is hand + semi-automated, in a contract-manufacturing (CM) line** in a low-cost-labor region (the Foxconn / Flex / Jabil / mid-tier-CM tier). This is a small, high-mix, multi-part product with soft goods and over-molds — it does **not** fully automate at this volume; it is **operator cells with fixtures**, not a lights-out line.
- **The labor-heavy steps:** mating the flex bridge to two bodies, seating and sealing the imager, closing the sealed housings with gaskets, attaching soft goods, and the final IP-seal verification. Estimate ~**\$4–\$9/unit assembly labor** at 25k/yr in a mid-cost CM region — it comes down with fixtures and volume, up with the sealing complexity.

Test & calibration — a real, non-trivial cost

- **Every imager must be tested and calibrated.** An area-imaging engine needs a decode/focus/aim verification against a test-target board on the line — this is a real station, real cycle time, and real yield loss. Budget ~\$2–\$5/unit for imager test + device functional test (BLE link, feedback channels, trigger, battery/charge).
- **Sealing verification** (IP) adds a leak/pressure check on a sample or 100% basis depending on the IP target — heavier for the IP67 SKU.
- **Yield loss:** at a new-program EVT/DVT stage expect meaningful fallout on the sealed, over-molded, optical assembly; budget a yield reserve in COGS (a few percent of BOM+labor) until the line matures.

Manufacturing cost (COGS) roll-up, base SKU, ~25k/yr

Layer	Est. (USD/unit)
BOM (midpoint)	~\$85
Assembly labor	~\$4 – \$9
Test + calibration	~\$2 – \$5
Tooling amortization (75k lifetime)	~\$2 – \$5
Yield reserve + scrap	~\$3 – \$6
CM margin / overhead	~\$8 – \$15
Est. factory-gate COGS, base SKU	≈ \$105 – \$125/unit

5. Prototype path — what it takes to a buildable prototype

The program does not go straight to tooling. The standard hardware gate sequence, and roughly what each costs:

Phase	What it is	Rough cost
Proof-of-concept / breadboard	Off-the-shelf imager eval kit + nRF52840 dev board + a 3D-printed body, wired, to prove the two-body split, the flex bridge, and the runtime budget on the bench	\$25k – \$75k
EVT (Engineering Validation)	First real PCBs, soft (3D-printed / urethane-cast / soft-tool) housings, hand-built units to validate function and fit	\$100k – \$250k

Phase	What it is	Rough cost
DVT (Design Validation)	Near-production units on soft or bridge tooling; run the real environmental gauntlet (drop, IP, temp, vibration, ESD); begin certification	\$150k – \$400k
PVT (Production Validation)	Hard-tooled parts, the real CM line, a pilot lot; finish certification	\$150k – \$400k (overlaps tooling NRE)

To a "buildable prototype" the client can hold and demo — a working EVT unit that scans, pairs, gives three-channel feedback, and holds its shape — the honest number is **~\$150k–\$350k and 4–7 months**, dominated by the electrical + mechanical engineering and the first real boards. Full production readiness (all of §3's NRE, certified, tooled) is the **~\$675k–\$1.65M** program figure.

6. Target unit cost & the margin story

The reference: an RS5100 kit streets at roughly \$1,200–\$1,500. That is a *kit* price (scanner + mount + often a charger and support), through a channel, with enterprise margin, brand, software ecosystem, and support behind it — it is **not** the factory cost of the device. A ring scanner's COGS is a fraction of its sell price; the enterprise value is in the ecosystem (management software, battery consoles, WMS integration, support, brand trust), not the bare hardware.

Putting the layers together, base SKU, ~25k/yr:

Layer	Est. (USD)
BOM	~\$85
Factory-gate COGS	~\$105 – \$125
Landed cost (COGS + freight, duty, inbound logistics to US warehouse)	~\$120 – \$150
Warranty + support reserve	+ a few \$/unit
Fully-burdened cost basis	~\$130 – \$165

Against a **\$1,200–\$1,500 kit sell price**, that is a healthy gross-margin structure *on the hardware* — but the honest read is:

- **The hardware margin is real but it is not where the enterprise money is.** The incumbents make their return on multi-year fleet deals, software, batteries-as-consumables, and support contracts. A new entrant competing on hardware alone, without that ecosystem, cannot assume the full \$1,200+ price — it competes closer to hardware cost + a defensible margin until it earns ecosystem trust.

- **The differentiator (two-body, fingertip aim + off-finger mass) is a real product story that supports a premium** if the ergonomic claim (≤ 22 g finger, 12-hr comfort) is validated and the human-factors case holds. That is what justifies a price near the incumbents rather than a discount-challenger price.
 - **Realistic entry pricing:** a device with this COGS can be sold profitably in the **\$500–\$1,000/unit** band as a hardware-led challenger and still carry good margin, or positioned at the incumbent **\$1,200+** kit tier *once* the software/support ecosystem and the validated ergonomic claim are in place. The pricing decision is a go-to-market call, not a cost call — but the cost basis ($\sim \$130$ – $\$165$ fully burdened) supports either.
-

7. The cost picture in three sentences

1. **The imager is the program.** It is 35–55% of the BOM; every dollar of cost discipline starts and largely ends there, and the standard-range-vs-long-range engine choice is the biggest single BOM lever.
 2. **The program needs volume to work.** At 25k+/yr the $\sim \$175$ k– $\$350$ k tooling amortizes to $\$2$ – $\$5$ /unit and the BOM lands near $\$85$; below ~ 10 k/yr the enterprise imager and the tooling both refuse to discount and the unit cost balloons.
 3. **The margin exists but the money is in the ecosystem.** A $\sim \$130$ – $\$165$ fully-burdened unit against a $\$1,200$ – $\$1,500$ incumbent kit price is a comfortable hardware margin — but the incumbents' real return is software, consumable batteries, and support, and a new entrant should price as a hardware-led challenger first and earn the premium tier as the ecosystem and the validated ergonomic claim mature.
-

Every number in this document is a program-kickoff estimate stated with its volume assumption (base: 25,000 units/year, $\sim 75,000$ lifetime). Component-cost anchors reference real parts (nRF52840 SoC street pricing, enterprise OEM imaging-engine class, standard prismatic Li-ion cell). The $\$1,200$ – $\$1,500$ kit reference is the street price of the Zebra RS5100 kit, the category incumbent. Nothing here is a quote; every figure moves when a supplier is RFQ'd and tooling is quoted, and the ranges are wide because that is the honest state of the numbers at kickoff.