Project Plan Summary

IDEA, INNOVATION, BUSINESS: A SCIENCE CHALLENGE | Phase 1 | November 6, 2026

Field	Submission
Your name	David Allen Blubaugh
Project title (as posted)	E6B-AI NAV: AI-Assisted, Physics-Constrained GPS-Denied Navigation Co-Processor
Project link	https://www.teraopenscience.com/project/11765-e6b-ai-nav-ai-assisted-physics-constrained-gps-denied-navigation-co-processor/
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Jury-oriented equivalent of the supplied BIRE summary template. All budgets, hours, hardware selections and performance thresholds below are proposals requiring confirmation, not completed results. The source project is public and categorized under Aerospace / Space Technology.

How the plan is scored

Section	Weight	Jury focus
Innovation	25%	What is new and different
Technical plan	25%	How it will be built and tested
Execution plan	25%	Milestones, resources, supply chain, business
Capacity to deliver	15%	Skills, support and time
Real-world impact	10%	Who benefits and why

0 Project summary

E6B-AI NAV is a proposed laboratory navigation-integrity co-processor for small unmanned aircraft using a TI MSPM0G5187 Cortex-M0+ and TinyEngine NPU. It combines deterministic E6B wind-triangle consistency checks, MEMS inertial measurements, lightweight estimation, TinyML anomaly recognition and validity-aware telemetry. By April 23, 2027, the intended deliverable is a bench-tested demonstrator with recorded/synthetic sensor inputs, fault injection, repeatable comparisons against baseline methods, and a documented hardware/software bill of materials. It will not be represented as an operational GPS replacement or flight-certified avionics.

1 Innovation | 25%

What is new about your idea?

The proposed research contribution is a constrained, auditable division of labor: a deterministic physics monitor checks wind/airspeed consistency, a tiny NPU classifies sensor behavior, and a bounded estimator incorporates the evidence without granting AI actuator authority. Individual E6B calculations, Kalman filters and anomaly classifiers are established; the testable novelty is their low-resource integration and measured benefit under controlled faults.

How is it different from existing tools, methods or products?

Compare four configurations on identical datasets: (A) INS propagation only; (B) INS plus deterministic E6B plausibility checks; (C) conventional gated fusion; (D) gated fusion plus TinyML-informed sensor-quality weighting. Commercial autopilot EKFs and existing fault monitors are reference approaches, not presumed inferior. An E6B wind relationship is not an independent absolute position fix.

What does it improve, and by roughly how much?

Proposed research thresholds: detect at least 90% of pre-defined injected anomaly events on held-out scenarios while reporting false-positive rate; show at least 15% lower median navigation error than the matched conventional-fusion baseline in at least one specified degraded-sensor scenario without worse uncertainty calibration; meet 100% invalid-input rejection for enumerated tests; and record CPU, SRAM, flash, inference time and energy. These are stretch targets, not promises or results.

What part is your own original thinking?

The proposed E6B-AI NAV architecture, explicit separation of learned confidence from deterministic acceptance, resource-aware integration plan, comparative experiments and test evidence are the applicant’s proposed work. TI silicon/software, third-party sensors, MAVLink and established estimation methods are attributed to their respective owners.

2 Technical plan | 25%

How will you build it?

Stage 1: host-reference E6B solver and unit tests, using true-course/wind-from conventions and corrected crosswind geometry. Stage 2: MSPM0G5187 LaunchPad firmware with timer, UART/I2C/SPI, watchdog, fixed-point or carefully benchmarked numerical routines. Stage 3: IMU and environmental sensors plus calibrated timestamps; run a compact complementary/error-state estimator appropriate to measured memory limits. Stage 4: label sensor windows and deploy a small TinyEngine classifier using supported TI tooling. Stage 5: integrate deterministic innovation gating and bounded covariance adjustment, then emit explicit validity, fault and covariance fields to a ground-station receiver. Optional mmWave radar, DTED matching, factor-graph smoothing and full autopilot integration belong on a companion processor and are conditional, not required for the first demonstrator.

Equipment, hardware and tools required

Item / example	Purpose and interface	Planning cost (USD)
TI MSPM0G5187 LaunchPad (verify orderable SKU)	Target MCU + NPU, debugger, GPIO/serial; confirm board pinout and TI support	$25–$60
6-axis IMU breakout (e.g., BMI270/ICM-42688-P class)	3-axis gyro and accelerometer, SPI/I2C, 3.3 V compatible	$15–$45
Barometric sensor (BMP390-class)	Pressure/altitude reference; I2C/SPI	$10–$25
3-axis magnetometer (LIS2MDL-class)	Heading-aid experiments, calibration needed	$10–$25
Differential-pressure sensor + pitot/static tubing	Air-data bench stimulus; sensor full scale and 3.3 V interface must match	$60–$180
USB-UART, level shifting, breadboard, wiring, connectors	Safe serial interface, test harness and prototyping	$40–$100
Regulated bench supply and current measurement	3.3 V supply verification and power profiling	$80–$250
Logic analyzer + multimeter	Bus, timing and electrical debugging	$60–$180
Oscilloscope (owned/borrowed/shared preferred)	Signal integrity, supply ripple and timing; buy only if unavailable	$0–$400
Host PC and storage (existing assumed)	Code Composer Studio, Python, Git, data capture, reports	$0–$150

Item / example	Purpose and interface	Planning cost (USD)
Optional PX4/ArduPilot flight controller	Later MAVLink/HIL validation; not needed for first bench gate	$100–$250
Optional TI mmWave evaluation board	Radar feasibility only; radar processing stays on radar device	$150–$450
Optional companion SBC / terrain data	DTED/factor graph processing; deferred	$80–$200

Prices are illustrative 2026 planning allowances, not vendor quotations; tax, shipping, stock and exact compatible SKUs must be checked before purchase. Avoid connecting 5 V signals directly to 3.3 V-only pins. Pitot sensing requires pressure calibration and air-density correction. Radar must demonstrate true ground-relative velocity observability; a radar SoC does not automatically provide a usable velocity vector.

Software and facilities

TI Code Composer Studio, TI SDK/DriverLib, supported TI Edge AI Studio/TinyEngine workflow (availability and licensing to verify), Python 3 with NumPy/SciPy/pandas/pytest, C/C++ compiler, Git, Jupyter, KiCad for optional PCB, MAVLink tooling, PX4/ArduPilot SITL and a simulation data generator. A PC, safe bench workspace, USB access, pressure-test fixture and repeatable motion/vibration test setup are needed. SysML v2 tooling is optional for requirements traceability; no institutional laboratory allocation is assumed.

What are the biggest unknowns, and how will you resolve them?

(1) TinyEngine availability/model compatibility: run a vendor example on the exact board before committing to a model. (2) RAM/CPU feasibility: measure stack, heap, worst-case scheduling and inference on target. (3) Observability: simulate constant wind, turns, outages and bias to identify states not constrained without absolute fixes. (4) Confidence calibration and correlated evidence: reserve disjoint test scenarios and prevent AI scores from bypassing innovation gates. (5) Pressure/heading sensor quality: calibrate and inject known errors. (6) Radar/terrain viability: defer until core bench evidence passes.

How will you test, prototype or iterate?

Freeze a versioned dataset with ground truth and event labels. Use numerical unit tests (zero wind, headwind, tailwind, crosswind, infeasible crosswind, invalid TAS, overflow), then hardware sensor logging and fault injection. Compare all four estimator configurations on the same time-aligned sequences. Report detection precision/recall, false alarms, RMS/95th-percentile position and velocity error, uncertainty coverage, processor load, missed deadlines, power and restart behavior. Never claim a GPS-denied position fix when no absolute reference is observable.

How will you know it works?

Acceptance gate: host reference and target wind calculations agree within stated quantization tolerances; all enumerated invalid cases fail closed; classifier reaches the pre-registered detection goal on held-out scenarios; a deterministic monitor can veto an AI-favored measurement; no watchdog deadline violations in 60-minute bench replay; output contains timestamps, units, validity and fault flags; clean build and three repeatable runs are archived. Navigation error improvements are reported as observed, not assumed.

3 Execution plan | 25%

The following periods parallel the organizer’s supplied BIRE template. Proposed effort totals 250 planned hours plus 26 contingency hours = 276 hours, approximately 12 hours per week across 23 weeks. Two- and four-month reporting dates and final-defense window should be confirmed with the organizer.

Period	Milestone and effort	Done when
Nov 16–Dec 15, 2026	Requirements, procurement, reference E6B (50 h)	Exact TI SKU and NPU example verified; BOM quoted; host math tests pass; data contract and hazards frozen.

Period	Milestone and effort	Done when
Dec 16–Jan 15, 2027	Board bring-up, IMU, data logging (50 h)	Repeatable timestamped IMU stream; power and timing measurements; fixed-point E6B runs on MCU; 2-month report.
Jan 16–Feb 15, 2027	Estimator and TinyML model (55 h)	Baseline estimator and NPU inference execute on hardware; training/test split and resource report archived.
Feb 16–Mar 15, 2027	Fault injection and comparative evaluation (50 h)	Four configurations replay identical cases; calibration and false alarms reported; 4-month report.
Mar 16–Apr 23, 2027	Freeze, replication, final defense (45 h)	By Mar 19 freeze evaluation; by Apr 9 draft report; by Apr 16 clean build/replay; defend Apr 19–23.
Contingency, distributed	Unexpected supply/firmware issues (26 h)	Use only against documented risks; disclose reduced scope if critical gates fail.

3.2 Business outline

Target customer: who pays?

Initial customer hypothesis: university avionics labs, embedded-AI educators, small UAS R&D; teams and robotics integrators needing an inspectable sensor-integrity demonstration. Conduct at least three discovery interviews and one supervised bench evaluation; no customers are presently committed.

Value: why choose it?

A low-cost, reproducible testbed combining E6B physical checks, sensor anomaly inference and explicit confidence reporting may reduce experimentation effort and improve fault transparency. The value proposition is conditional on measured performance against conventional approaches.

Rough economics: price, cost and business model

Core bench cash budget: target $1,500 including equipment and modest contingency, assuming a suitable PC and shared oscilloscope; optional radar/flight-controller/companion expansion adds approximately $330–$900. Proposed full research cash ceiling $2,500, including shipping/tax and replacement allowance, subject to quotations. Imputed applicant effort: 276 h × $60/h = $16,560; total economic planning envelope up to $19,060. A future educational kit or integration service could be sold only after demand and unit costs are validated; no sales price or margin is asserted.

Path to market

Publish a reproducible synthetic-data bench demo, solicit feedback through TeraOpenScience and engineering/academic networks, then offer a scoped paid pilot after documenting customer data rights, hardware safety boundaries, software licenses, ownership and acceptance criteria. Any flight-ready claim requires a separate assurance program.

4 Capacity to deliver | 15%

Your background

BS Electrical Engineering (2004) and MS Electrical Engineering (2012), Wright State University; current doctoral studies in Electrical and Systems Engineering at the University of Dayton. Relevant experience includes embedded programming, Python, aerospace autonomy, modeling and verification. Coauthor of Intelligent Autonomous Drones by Cognitive Deep Learning (Apress, 2022).

Skill area	Owner / proposed support	Responsibility
Embedded hardware / firmware	David Allen Blubaugh	MCU bring-up, buses, deterministic firmware, bench tests

Skill area	Owner / proposed support	Responsibility
Estimation / datasets / TinyML	David Allen Blubaugh	Algorithms, labeling, evaluation, error analysis
Safety / MBSE / documentation	David Allen Blubaugh	Requirements, hazard controls, traceability and reports
Academic technical review	Dr. Thomas Ford (potential)	Review only if agreed; no challenge commitment assumed
Vendor / specialized radar expertise	Not secured	Consult TI documentation/support; radar scope remains optional

Time and support

Proposed 12 h/week, 276 h total including contingency, subject to confirmation. Existing PC and test instruments must be inventoried; no committed institutional funding, TI donation, vendor engineering support, laboratory access or paid assistance is presumed. The TI board may be contest-awarded, but procurement plans must work if it is not.

5 Real-world impact | 10%

What need does this address, and what evidence?

Low-cost inertial systems drift when GNSS fixes are absent, and inconsistent sensor measurements can compromise estimators. These are established engineering limitations. The posted E6B-AI NAV project identifies potential integrity and resilience applications, but no measured improvement, customer interview or completed prototype is represented in the source.

What could it lead to?

Reproducible embedded-AI navigation benchmarks, sensor-fault datasets, teaching laboratories, a small navigation-integrity evaluation board and research extensions to terrain/radar fusion. Marine, industrial and field-robotics transfer would need separate observability and sensor validation.

Who benefits?

Students, researchers and small robotics/UAS teams may gain a transparent, affordable method for comparing physical checks and learned anomaly assessment. Potential safety benefit is earlier recognition of suspect sensor evidence, not proven accident reduction. Regulatory flight approval and quantified societal impact are not claimed.

6 Confirmation

“All work will follow applicable university, platform, consumer-safety, consent, and privacy requirements.”

Full name	Date
David Allen Blubaugh	November 6, 2026

Before submission: verify board availability and precise electrical interfaces, procurement prices, access to instruments, software terms, expected hours, project rights and organizer dates. This document is a proposed jury summary, not a representation that the applicant has signed or formally submitted the challenge confirmation.

Reference basis and accuracy notes

Prepared from the applicant’s E6B-AI NAV public project text (provided Markdown, November 6, 2026) and the supplied six-page BIRE Project Plan Summary as a format and jury-question reference only. Product specifics, cost bands, milestones, targets and suggested hardware examples in this E6B plan are new planning assumptions and require supplier and bench verification. Source project: https://www.teraopenscience.com/project/11765-e6b-ai-nav-ai-assisted-physics-constrained-gps-denied-navigation-co-processor/

E6B-AI NAV | SUPPLEMENTAL DOCUMENTATION

MASTER ENGINEERING PROJECT PLAN AND SCHEMATICS

ADDITIONAL SUPPLEMENTAL INFORMATION FOR THE JURORS

The following master plan, engineering review, and schematics are provided if the jurors require critical, in-depth technical information.

Primary submission: 5-page Project Plan Summary
Supplemental reference: 32-page reviewed engineering package

E6B-AI NAV | INDEPENDENT DOCUMENT CROSS-CHECK

Engineering verification addendum | 6 November 2026 | Disposition: **CONDITIONALLY ALIGNED — NOT DESIGN-VERIFIED**

This addendum precedes the unmodified 20-page Master Plan Rev A and the unmodified 10-sheet Conceptual Engineering Schematic Rev A. It records checks that can be made from the two documents alone. It does not certify hardware, flight performance, statistical integrity, or toolchain support.

1. Document-level synchronization

Both sources identify MSPM0G5187/TinyEngine as a candidate, use deterministic E6B plausibility checking plus learned sensor-health scoring, reserve the autopilot as the sole flight-control authority, and defer radar processing, terrain matching and factor-graph smoothing to optional external processors. Their four comparison variants, advisory-only outputs, fault handling, and proposed acceptance gates are consistent. The master plan expands, rather than electrically implements, the schematic.

2. Independently checked mathematical example

For a desired northbound ground track, true airspeed 20 m/s and a wind vector of 5 m/s toward east, the required westward air-velocity component is -5 m/s. Heading offset = -asin(5/20) = -14.477512 degrees, hence heading 345.522488 degrees true. Along-track ground speed = sqrt(20^2 - 5^2) = 19.364917 m/s. The plan’s rounded values 345.52 degrees and 19.365 m/s are correct for its stated two-dimensional, negligible-sideslip assumptions.

Boundary correction: The exact course can be held when |wind cross-track| <= TAS in idealized 2-D geometry, but equality yields zero air-relative along-track component. Whether progress is possible then depends on along-track wind. An actual mission should require a positive minimum ground-speed margin and use a well-defined infeasible/no-progress status. Total wind speed exceeding TAS does not by itself make every desired course infeasible.

3. Mathematical and physical limitations

The vector equation v_ground = v_air + v_wind is physically consistent, but pitot-derived scalar TAS alone does not specify the air-relative velocity vector. AoA, sideslip, flow disturbance, density, attitude and reference frames must be measured or explicitly bounded. The E6B relationship cannot independently restore Earth-referenced position. A barometer is not an AGL sensor; a magnetometer is not a reliable heading reference near interference. IMU bias causes drift. Covariance is a model-based uncertainty description, not a certified absolute error bound.

An EKF needs defined state, transition and observation functions, Jacobians (or equivalent), units, process/measurement noise, covariance stabilization and observable aiding. Normalized innovation tests require appropriate residual covariance and justified thresholds. AI-derived quality weights must be bounded, calibrated and protected against correlated evidence. These definitions are planned but not completely specified in either source.

4. Electrical and computational gates

The hardware sheet has no pin/net list, supply rail tolerances, regulator sizing, logic-voltage matrix, connector pinout, interrupt allocation, bus pull-up values, decoupling values, or EMC evidence. The master plan correctly calls for these before PCB design. The actual MSPM0G5187 orderable board, memory capacity, available pins, TinyEngine compiler/runtime, model tensor arena, firmware stack, CPU load, inference latency, sensor rates and power must be verified on the exact device. Radar range/Doppler features cannot be assumed to provide full ground velocity without adequate geometry.

5. Operational and drone-integration gates

The Holybro X500 V2 / Pixhawk 6C-class quadrotor is an illustrative candidate, not a verified BOM or tested aircraft. Quadrotor body heading does not determine translational airspeed direction, and pitot readings may be distorted by rotor downwash. Thus fixed-wing E6B cases should be demonstrated separately with validated simulation or an appropriate

air-data platform. Phase-1 drone use should remain telemetry-only; offline removal of GNSS from E6B replay must not be confused with disabling GNSS on the aircraft.

6. Sheet-by-sheet cross-reference

Sheet	Master-plan coverage	Finding
01 System	Master pp. 1,4,11–13	Aligned: advisory boundary
02 Hardware	Master pp. 5–6,15	Conditional: electrical verification absent
03 Timing	Master pp. 6–7,11	Conditional: latency and sync unmeasured
04 E6B	Master pp. 7–8	Math example verified; boundary nuance
05 Firmware	Master pp. 5,11	Conditional: resource/WCET proof absent
06 AI	Master pp. 10–11	Conditional: NPU deployment unproven
07 Fusion	Master pp. 8–10	Conditional: full estimator unspecified
08 Radar/DTED	Master pp. 5,7,9	Aligned as deferred; observability gate
09 MAVLink	Master pp. 4,11–13	Conditional: interface acceptance untested
10 Verification	Master pp. 3,14,17–20	Aligned as future tests, not results

7. Release and claim-control decision

Document synchronization: PASS WITH OPEN ITEMS. The two artifacts are not in direct architectural conflict. **Mathematical verification: PARTIAL.** The worked wind example and basic vector physics pass; complete estimator and numerical correctness cannot be established without executable equations and tests. **Electrical/embedded verification: HOLD.** No validated pin-level schematic, tested board integration, or resource measurements are supplied. **Flight readiness: HOLD.** No flight-safety case or experimental evidence is supplied. Do not describe the combined package as certified, proven GPS-denied navigation, or a verified manufacturable design.

Priority closure sequence: (1) exact TI board/SKU and vendor NPU demo; (2) controlled interface and power matrix; (3) executable E6B test vectors and unit conversions; (4) bounded filter with measurement equations; (5) on-target timing/memory/power; (6) disjoint held-out anomaly evaluation and covariance coverage; (7) SITL/MAVLink contract; (8) supervised physical integration only after safety approval.

Source provenance: appended Master Engineering Project Plan Rev A (20 pages) and Conceptual Engineering Schematic Rev A (10 sheets). Original pages are preserved unchanged. This addendum is a document review, not a vendor datasheet audit or hardware laboratory verification.

E6B-AI NAV

MASTER ENGINEERING PROJECT PLAN | REVISION A

AI-Assisted, Physics-Constrained GPS-Denied Navigation Integrity Co-Processor

Prepared for the TeraOpenScience Idea, Innovation, Business: A Science Challenge | 6 November 2026

Document control	Value
Applicant	David Allen Blubaugh
Posted project	E6B-AI NAV: AI-Assisted, Physics-Constrained GPS-Denied Navigation Co-Processor
Public project	https://www.teraopenscience.com/project/11765-e6b-ai-nav-ai-assisted-physics-constrained-gps-denied-navigation-co-processor/
Baseline inputs	5-page Project Plan Summary (6 Nov 2026); 10-sheet Conceptual Engineering Schematic Rev A (31 Oct 2026)
Planning window	16 Nov 2026–23 Apr 2027; 276 h total proposed
Status	Proposal, not completed hardware, qualified avionics, or verified circuit schematic

Document interpretation

This plan expands the supplied summary and audits all ten schematic sheets. Where exact pinouts, component variants, TI software support, airframe availability, costs, or empirical results are unknown, the text labels them as verification gates rather than established facts. All targets and budgets are estimates, not performance claims.

Safety boundary: the flight controller retains guidance and actuator authority. E6B-AI NAV starts in advisory/logging mode; any later external-navigation injection is separately gated and evaluated.

01 | Executive summary and jury alignment

E6B-AI NAV investigates whether a small MCU with a neural accelerator can improve the transparency of navigation evidence during GNSS degradation. A deterministic E6B-inspired model, lightweight inertial estimation, bounded innovation tests and a compact learned anomaly classifier are combined on the Texas Instruments MSPM0G5187 candidate platform. The core deliverable is a reproducible laboratory demonstrator and comparative evidence package by 23 April 2027.

Jury criterion	Weight	Evidence delivered
Innovation	25%	Physics/AI separation; explicit confidence and failure evidence
Technical plan	25%	Reference equations, constrained firmware, fault-injection tests
Execution	25%	Gates, BOM, resource limits, schedule and risks
Capacity	15%	Owner skills, labor plan and uncommitted support
Impact	10%	Research/education use, customer discovery, honest limitations

Primary deliverables

• Versioned host reference E6B solver with units, sign conventions and edge-case tests.

• Target MCU firmware for acquisition, health monitoring, estimation, deterministic acceptance and advisory telemetry.

• At least one measured on-device TinyEngine-compatible inference example, conditional on exact device/toolchain support.

• Four controlled baseline comparisons with ground truth, failure scenarios and uncertainty calibration.

• Reproducible data, test scripts, logs, resource measurements, requirements matrix and presentation.

Non-goals

No claim of indefinite accurate dead reckoning, autonomous flight-control authority, certified navigation integrity, military-grade performance, or complete aircraft integration within the core schedule.

02 | Innovation, prior art and falsifiable hypotheses

E6B wind triangles, INS, EKFs, sensor fault detection and neural classifiers are established techniques. The proposed research contribution is the measured low-resource integration of these techniques with explicit evidence provenance, a deterministic veto, and a conservative external-navigation validity contract.

Hypotheses

• H1: In a pre-registered degraded-sensor scenario, TinyML-informed fusion reduces median navigation error by at least 15% against conventional gated fusion without degrading empirical uncertainty coverage.

• H2: A compact classifier detects at least 90% of pre-defined anomaly events on held-out scenarios, with false-positive rate and confidence intervals disclosed.

• H3: The safety monitor rejects all enumerated malformed/stale/physically impossible inputs and prevents invalid fixes from being published as valid.

• H4: All required real-time tasks meet measured worst-case timing and memory limits during a one-hour replay.

Fair comparisons

Variant	What is enabled
A	IMU propagation only
B	A + E6B physics plausibility checks (not an absolute position fix)
C	Conventional validated sensor fusion and innovation gating
D	C + learned quality scores with bounded weighting and deterministic veto

Use identical timestamped datasets, initial states, fault injections and evaluation windows. Pre-register thresholds before evaluating the held-out test set. Report negative results and scenarios where D is worse than C.

03 | Requirements, boundaries and interfaces

ID	Requirement / acceptance method
REQ-01	Time-stamp every observation; log source ID, frame, units, age, quality and sequence number.
REQ-02	Reject malformed, stale, out-of-range and nonfinite values; enumerate test cases.
REQ-03	Implement wind-from/heading/course conventions and handle infeasible crosswind.
REQ-04	Deterministic monitor can veto AI-favored measurements.
REQ-05	No actuator commands or autonomous mode transitions from the co-processor.
REQ-06	Advisory telemetry must include validity, fault codes and uncertainty metadata.
REQ-07	Measure CPU, flash, SRAM, inference latency, power and deadlines on exact board.
REQ-08	No GPS-like position fix published without a supported observation and acceptance gate.
REQ-09	Dataset splits separate runs, vehicles and fault regimes to reduce leakage.
REQ-10	Three repeatable builds/replays and independent clean restore recorded.

Operational modes

INIT (configuration check), CALIBRATING (sensors not yet valid), MONITOR (normal advisory outputs), DEGRADED (partial aiding), INVALID (no usable navigation claim), and FAULT (latched critical failure). Transitions require documented conditions and a safe stale-output policy.

System-of-systems boundary

Onboard sensors and optional radar send time-tagged measurements to E6B-AI NAV; the optional companion processor provides heavier map/radar functions; the PX4/ArduPilot flight controller retains all flight authority. Logging and telemetry are advisory until a separate approved integration gate.

04 | Hardware partition and MCU feasibility

Candidate target: TI MSPM0G5187 development board with Arm Cortex-M0+ and TinyEngine NPU. The exact orderable board, revision, electrical characteristics, usable SRAM/flash and supported model compilation path must be confirmed from TI documentation and a running vendor example at Gate G1. Do not infer full peripheral pin availability from the chip block diagram.

Processing element	Assigned workload
MSPM0G5187 CPU	Driver acquisition, monotonic timestamps, E6B equations, bounded estimator, gating, watchdog, serial advisory output.
TinyEngine NPU	Compact quantized anomaly or motion-state classifier only after on-target feasibility proof.
Radar SoC (optional)	Chirp acquisition, range/Doppler/beam processing; outputs validated features, not raw chirps to MCU.
Companion SBC (optional)	Terrain map matching, fixed-lag factor graph, visualization, storage and complex numerical processing.
Pixhawk-class FC	Vehicle stabilization, failsafes, actuator outputs and independent navigation stack.

Resource gate

Reserve explicit SRAM for stack, driver buffers, feature windows, estimator covariance, neural tensors and fault logs. Produce a link map, stack-watermark measurement and measured worst-case execution time. If the full EKF cannot fit, reduce state size or move it off-board; do not silently overcommit 32 KB-class SRAM.

05 | Electrical design and instrument requirements

Interface	Engineering check
Power	Confirm board input rail and all breakout supply voltages; common ground, decoupling, reverse-polarity/current limits, brownout response.
I2C	Check pull-up voltage, total bus capacitance, addresses, cable length, startup and recovery after stuck SDA.
SPI	Verify 3.3 V logic, CS routing, clock polarity/phase, interrupt levels, DMA and maximum wire length.
UART	Confirm voltage levels, ground reference, pin mapping, baud, isolation and no 5 V direct connection.
Analog pressure	Check sensor output transfer curve, ADC reference, full scale, anti-alias filter and overpressure protection.
SWD	Preserve debugger/reset access, test pads and documented board pin conflicts.
Radar (optional)	Dedicated regulator and processing board; assess antenna placement, EMC and mechanical vibration.

Minimum bench equipment

Host PC, USB/debug cable, ESD-safe workspace, digital multimeter, regulated/current-limited bench supply, USB logic analyzer, UART adapter, jumper wiring, test connectors, controlled pressure source or pressure fixture, temperature logging and repeatable motion/vibration stimulus. Shared oscilloscope is preferable to buying one solely for the first phase.

Electrical gate

A pin-level schematic, netlist, connector map, verified logic-voltage table, power tree and component datasheets are required before custom PCB fabrication. The supplied ten sheets are functional diagrams, not a wiring-ready circuit.

06 | Sensors, measurement models and calibration

Sensor	Observable / principal limitations
6-axis MEMS IMU	Angular rate and specific force; gyro/accelerometer bias, vibration, temperature drift; no absolute position.
Barometer	Pressure altitude with atmospheric/QNH bias; not independent AGL without terrain or ranging.
Magnetometer	Magnetic field / heading aid only after hard/soft iron calibration and interference checks.
Differential pitot	Dynamic pressure; TAS from air density and calibrated pressure, with low-speed sensitivity and port blockage.
Temperature	Air-density correction; distinguish ambient, sensor and total-air-temperature assumptions.
Radar (optional)	Range and line-of-sight Doppler; geometry and multiple independent looks needed for full velocity vector.
GNSS reference	Ground-truth comparison / test initialization; never treat withheld GNSS as an active aiding source.

Calibration records

For every channel, store part number, revision, serial/lot if available, axis orientation, scale, bias, temperature range, time delay, units, uncertainty model, calibration date and raw data. IMU rotation into body and navigation frames must use an explicitly tested quaternion/rotation convention.

Critical qualification

Airspeed magnitude alone does not determine a 3D air-relative velocity vector. Sideslip and angle of attack must be measured, estimated with uncertainty or bounded by an explicit operating assumption.

07 | E6B physics and numerical implementation

Define NED navigation axes, heading clockwise from north, true course as desired ground-track direction, and meteorological wind-from direction. Convert wind-from angle to the wind-to vector before vector addition. With desired course chi, airspeed V, and wind components along/cross track, solve the crosswind cancellation using arcsin only when absolute crosswind does not exceed V; ground speed is the along-track airspeed projection plus along-track wind.

Worked check case

Example: TAS = 20 m/s, desired true course north, wind blowing east at 5 m/s (meteorological wind from west). Required aircraft air-vector heading is about 345.52 degrees (14.48 degrees west of north), and ground speed is sqrt(20 squared minus 5 squared) = 19.365 m/s. If crosswind magnitude exceeds TAS, the demanded course is infeasible. This check assumes negligible sideslip/AoA and horizontal motion.

Embedded math

• Implement host double-precision oracle and compare target Q-format or floating-point routines over deterministic test vectors.

• Use 64-bit intermediate multiplication for Q31 products, explicit rounding/saturation and finite/domain guards.

• Test angle wraparound, zero TAS, maximum representable values, negative speeds, near-singular geometry and exact crosswind limit.

• ETA and endurance estimates must state speed, wind and power/fuel assumptions and must not be used as position corrections.

Cross-reference: schematic sheet 04 correctly distinguishes heading from course and flags wind exceeding TAS; the master plan adds explicit reference-frame and sign-convention tests.

08 | Estimator design, observability and uncertainty

Begin with a bounded attitude complementary filter and short-term inertial propagation; advance to a small error-state Kalman filter only if measured resources permit. Define state x, process f, covariance P, observation h, measurement covariance R, and residual r = z - h(x). Apply normalized innovation gating with pre-registered thresholds.

Suggested development state

A lightweight attitude/bias filter may use attitude-error, gyro-bias and selected accelerometer-bias states. Wind components and airspeed constraints may be handled by a separate low-rate filter. A full position/velocity/attitude/wind/bias covariance is not assumed feasible on the MCU until profiled.

Observability rules

• IMU-only position uncertainty grows with bias and integration; covariance is a statistical model, not a certified error bound.

• E6B wind-triangle consistency is not an independent Earth-referenced position measurement.

• Barometer constrains pressure altitude, not longitude/latitude; magnetometer helps yaw only when valid.

• Radar radial Doppler is one velocity projection; full planar ground velocity requires sufficient independent geometry.

• ZUPT/ZARU is allowed only after verified Earth-stationary conditions; hover is not stationary in the required sense.

Record consistency using empirical coverage, innovation distributions and NEES/NIS where ground truth and modeling permit.

09 | TinyEngine model, confidence and deterministic veto

Train a compact model on windows of IMU magnitude, variance, spectral vibration features, pressure changes and selected sensor-quality statistics. Candidate classes: normal, vibration, sensor dropout, injected bias and stationary candidate. The selected network must be quantized and supported by the exact TI compiler/runtime; a successful vendor example is a prerequisite.

Data hygiene

- Partition train, validation and test by recording session and scenario, not random adjacent windows.
- Label fault onset/offset, severity, sensor identity and ground truth; retain negative/ambiguous examples.
- Report class-specific precision, recall, false alarm per hour, latency, confusion matrix and model calibration.
- Treat raw softmax outputs as scores until calibrated on independent data; monitor out-of-distribution behavior.

Fusion contract

The AI output may request bounded measurement downweighting, but never force acceptance, decrease covariance below a physically justified floor, override an innovation rejection, or directly command actuators. If AI and physics reuse the same sensor window, do not treat their scores as independent evidence. If the classifier fails, the system falls back to deterministic baseline C.

10 | Firmware tasks, telemetry and safety

Task	Candidate cadence / measured gate
IMU acquisition	100–200 Hz candidate; measured sensor ODR, bus budget and latency govern final value.
Physics and estimator	25–100 Hz candidate; benchmark actual execution and covariance stability.
TinyML inference	5–20 Hz candidate; bound feature-window age and NPU contention.
Health monitor	At least as fast as output publication; watchdog and freshness checks.
Advisory telemetry	5–10 Hz candidate; include time, frames, units, status, faults and uncertainties.

MAVLink policy

Phase 1 uses serial logs or custom diagnostic messages to a ground station. For PX4/ArduPilot, review the exact firmware version and accepted message semantics before sending external vision/odometry or GPS-like messages. Covariance, frame transforms, timestamp age, estimator source selection and EKF rejection behavior must be tested in SITL before any bench HIL. Do not present stale or unobservable positions as valid fixes.

Fail-closed behavior

On reset, clock discontinuity, invalid units, model failure, estimator divergence or watchdog fault, clear validity and publish a fault/status event; never reuse last valid position without explicit age and invalidity. Flight controller continues its independent safe behavior.

11 | Suitable drone example: PX4 research quadrotor

Candidate integration vehicle: a Holybro X500 V2-class quadrotor with a Pixhawk 6C-class controller running PX4, or an equivalent commercially available 450–500 mm research quadrotor. This is a representative procurement example, not a verified kit configuration or supplier endorsement. Confirm payload margin, flight-controller firmware, power outputs, connector voltage, telemetry port availability and flight-test permissions before purchase.

Physical integration concept

Aircraft component	Role
Pixhawk/PX4	Independent stabilization, flight control, primary navigation and failsafes.
E6B-AI NAV enclosure	Isolated 3.3 V-compatible board, IMU and optional sensors; vibration-controlled mounting.
Pitot/static	Forward-facing air-data experiment; meaningful mainly with adequate relative airflow; multirotor downwash can corrupt readings.
Ground station	Receives E6B health/uncertainty log, time-synced to PX4 ULog.
Companion computer (optional)	Receives radar features and map data; optional replay/HIL bridge.

Why a quadrotor?

A quadrotor is a convenient, repeatable research platform for stationary/turn/vibration tests and PX4 SITL. However, E6B wind-triangle assumptions are less directly useful than for fixed-wing aircraft because multirotor airspeed and attitude do not imply a simple forward flight-path vector. For early E6B performance demonstrations, use simulated fixed-wing air-data trajectories alongside the quadrotor sensor-health case.

12 | Drone mission vignette and test sequence

Scenario: a small research quadrotor performs a supervised 8-minute inspection circuit near a test field. PX4 maintains flight authority and its own navigation. E6B-AI NAV logs IMU, heading and barometric evidence, observes a simulated GNSS outage flag, and classifies vibration and injected pressure/heading anomalies. No co-processor position is injected into the autopilot during initial flights.

Phase	Behavior / evidence
0: Preflight	Check wiring, power, sensor orientation, props-off diagnostics, mode and log timestamps.
1: Nominal flight	Collect synchronized reference PX4 data and E6B advisory outputs.
2: Simulated GNSS dropout	Offline replay removes GNSS aiding from E6B estimator; PX4 remains independently controlled.
3: Fault injection	In replay, inject IMU bias, magnetic disturbance, stale packet and pressure anomaly.
4: Evaluate	Compare four estimators against withheld ground-truth/reference trajectory; plot error, coverage and alarms.
5: Review	Document missed detections, false alarms, MCU load, sensor interference and integration faults.

How the system helps

It may recognize when a sensor becomes inconsistent, downweight suspect evidence and report lower confidence earlier than a baseline. It cannot guarantee continued accurate position in a featureless environment without suitable external fixes. Airborne GNSS-denied experiments require separate safety approvals and should not be attempted until bench, SITL and HIL gates pass.

13 | Verification strategy and experimental statistics

Test family	Evidence and acceptance
E6B math	Reference oracle; zero/head/tail/crosswind, infeasible cases, wrap, overflow and unit conversions.
Sensor transport	I2C/SPI/UART dropouts, stale data, CRC where available, timestamp reorder and resets.
Estimator	Known trajectory with bias, noise, turns, outages; RMSE, 95th percentile, NIS/coverage.
TinyML	Held-out scenarios, confusion matrix, calibration, OOD and timing.
Safety	Deterministic veto; invalid output gate; watchdog reset; no actuation interface.
Integration	SITL MAVLink frames and ages; then HIL only after pass; clean restore.

Statistical reporting

Define evaluation unit (event, time window or independent run), report denominators and uncertainty intervals, avoid mixing training and test windows from the same continuous trace, and disclose tuning after test-set exposure. The 90% recall and 15% improvement goals are stretch targets. A failure to reach them must not be hidden or redefined after the experiment.

Release gate

Three reproducible replays, a one-hour timing soak, frozen code/dataset hashes, test report and unresolved-risk register. Any critical failure produces HOLD, not PASS.

14 | Detailed equipment and procurement plan

Core equipment	Planning USD	Purchase gate
MSPM0G5187 board	25–60	Exact SKU, on-target NPU demo, debug support
6-axis IMU breakout	15–45	Voltage, axes, ODR, SPI/I2C compatibility
Barometer + magnetometer	20–50	Addresses, calibration and library support
Differential pressure + pitot/tubing	60–180	Range, calibration fixture, low-speed behavior
Serial/prototyping/connectors	40–100	Level-safe UART, secure connectors
Bench supply/current measurement	80–250	Use shared equipment where possible
Logic analyzer + multimeter	60–180	Sufficient voltage/timing resolution
Oscilloscope (shared preferred)	0–400	Purchase only if needed
PC/storage	0–150	Assume existing suitable workstation

Optional, explicitly deferred

PX4 flight controller $100–250; radar evaluation board $150–450; companion SBC/terrain storage $80–200. A complete drone airframe, motors, ESCs, radio, batteries, charger, spare parts, safety enclosure and test-site costs are not included in the $2,500 research ceiling. Quote separately before any flight expansion.

Prices are 2026 planning ranges from the supplied summary, not live supplier quotations. Tax, shipping, duties, replacement and actual availability require confirmation.

15 | Budget reconciliation, supply chain and labor

The source summary states a $1,500 target for core bench cash, $330–900 optional radar/flight-controller/companion expansion, and a $2,500 total research cash ceiling. These are compatible only if selected purchases, shared tools, shipping/tax and contingency remain inside the ceiling; the full upper end of every listed range would exceed it.

Allocation	Proposed cap
Core MCU, sensors, connectors, pressure fixture	$550
Instrumentation / shared-lab allowance	$450
Software, storage, replacement, shipping and tax	$300
Core contingency	$200
Core subtotal	$1,500
Optional FC/radar/SBC expansion (prioritized)	$700
Additional research contingency	$300
Total cash ceiling	$2,500

This is a recommended envelope, not a vendor quote or purchase order. The full $700 expansion cannot necessarily buy all three optional items at their high prices. A suitable PC and borrowed oscilloscope are assumptions; if unavailable, scope and budget must be revised.

Economic labor

276 h at an illustrative $60/h = $16,560 imputed, unpaid applicant effort. Full economic planning envelope is up to $19,060 including $2,500 cash. A contest-awarded TI board would reduce cash needs but is not assumed.

16 | Milestones, dependencies and reporting

Window / effort	Deliverable and exit criterion
16 Nov–15 Dec 2026 | 50 h	G1: verify TI board/NPU example, source rights, quotes, host E6B oracle, sensor data contract and hazards.
16 Dec–15 Jan 2027 | 50 h	G2: MCU bring-up, timestamped IMU, E6B execution, power/latency profile, first progress report.
16 Jan–15 Feb 2027 | 55 h	G3: baseline estimator and quantized classifier on target; memory/timing and data-split report.
16 Feb–15 Mar 2027 | 50 h	G4: four matched baseline replays, fault detection, uncertainty calibration, second progress report.
16 Mar–23 Apr 2027 | 45 h	G5: freeze by Mar 19, draft by Apr 9, restore/replay by Apr 16, defense Apr 19–23.
Distributed contingency | 26 h	Documented recovery only; if critical gate fails, reduce scope and disclose.

Critical path

Vendor NPU runtime example → IMU/clock acquisition → deterministic physics and baseline estimator → trained classifier → bounded fusion → held-out evaluation → reproducible final package. Optional radar, terrain and airframe flight tests cannot displace core evidence. Organizer reporting and defense dates must be independently confirmed.

17 | Risk register and go/no-go decisions

Risk	Consequence	Mitigation / fallback
NPU toolchain unavailable	No on-device inference	G1 vendor demo; use CPU classifier with clearly labeled deviation; no NPU claim.
RAM/CPU exhaustion	Deadline misses	Profile early; simplify estimator/model; move heavy tasks to host/SBC.
Air-data unobservable on quadrotor	Invalid E6B assumption	Use fixed-wing synthetic cases; avoid treating attitude as TAS direction.
Sensor interference / vibration	False faults and bias	Calibration, physical separation, recorded test conditions.
AI score miscalibration	Overconfident fusion	Deterministic veto, covariance floors, held-out calibration.
Radar geometry insufficient	No ground velocity vector	Radial-only use; no radar velocity claim until geometry validated.
Unreliable GNSS-denied position	Misleading output	Validity gate; publish diagnostic uncertainty rather than false fix.
Hardware costs / delays	Schedule slip	Use shared instruments, synthetic replay and staged procurement.
Flight safety / permissions	Physical hazard	Bench/SITL/HIL first; flight only under separate authorization.

Each risk has an owner (applicant), trigger, evidence record and explicit HOLD decision when a safety-critical assumption fails.

18 | Schematic-to-master-plan cross-reference audit

Sheet	Assessment	Master plan / required closure
01 System context	Aligned	§§3,10–12: advisory only; autopilot authority preserved.
02 Hardware	Conditional	§§4–6: actual MCU pinout, voltage and power tree absent; must verify.
03 Acquisition	Aligned / incomplete	§§6–7: timestamps; quantify capture delay, latency and sensor clocks.
04 E6B physics	Aligned / assumption	§8: wind-from convention, heading/course, TAS vector/AoA/sideslip.
05 Firmware	Aligned / unproven	§§5,11: memory map, WCET, task priorities and measured load.
06 TinyEngine	Aligned / unproven	§10: exact NPU toolchain and calibration/OOD validation.
07 Bayesian fusion	Aligned / scope risk	§9: MCU filter must be small; covariance is not certified integrity.
08 Radar/terrain	Aligned / optional	§§5,7,9: single beam radial only; DTED needs AGL/map uniqueness.
09 Safety/MAVLink	Aligned / integration risk	§11: message semantics, frames, timestamp, rejection and failsafe.
10 Verification	Aligned / future evidence	§14: no demonstrated metrics yet; controlled datasets needed.

Audit disposition

No direct architectural contradiction was found between the supplied 10-sheet Rev A conceptual diagrams and the 5-page summary. However, “synchronous” means consistent in scope and intent, not electrically validated or proven executable. The gaps above are open verification items. This master plan does not retroactively revise the uploaded Rev A schematic; a future Rev B should include electrical and interface detail, testable requirements and exact board identifiers.

19 | Deliverables, traceability and final decision

Evidence package index

- D01 requirements register and source-to-requirement mapping (REQ-01–REQ-10).
- D02 component selection and verified pin/voltage/power matrix; revision-controlled BOM.
- D03 host E6B oracle, target code, test vectors and numeric comparison report.
- D04 sensor calibration and timestamp logs; environmental/fault metadata.
- D05 on-target AI runtime, model checksum, data splits and calibration report.
- D06 estimator comparison A/B/C/D with raw metrics, uncertainty coverage and limitations.
- D07 fault-injection and safety-gate test evidence; MAVLink/SITL contract where implemented.
- D08 timing, memory, energy and reproducibility report; clean rebuild and replay.
- D09 drone integration feasibility assessment (no flight-readiness claim).
- D10 jury defense slides, summary and archive manifest with hashes.

Revision and synchronization rule

The summary remains the controlling contest scope and budget baseline. The 10-sheet schematic Rev A is the functional architecture baseline. This 20-page Master Rev A expands both without claiming a completed circuit or validated navigation performance. Changes to MCU, data contract, sensor measurement model, acceptance target, cost cap or flight authority require a recorded change request and updates to all three artifacts.

Final acceptance

PASS requires documented core bench functions and independent test evidence. CONDITIONAL means partial success with explicitly listed missing tests. HOLD means an unresolved critical safety, validity or reproducibility defect. The final report must preserve unsuccessful trials.

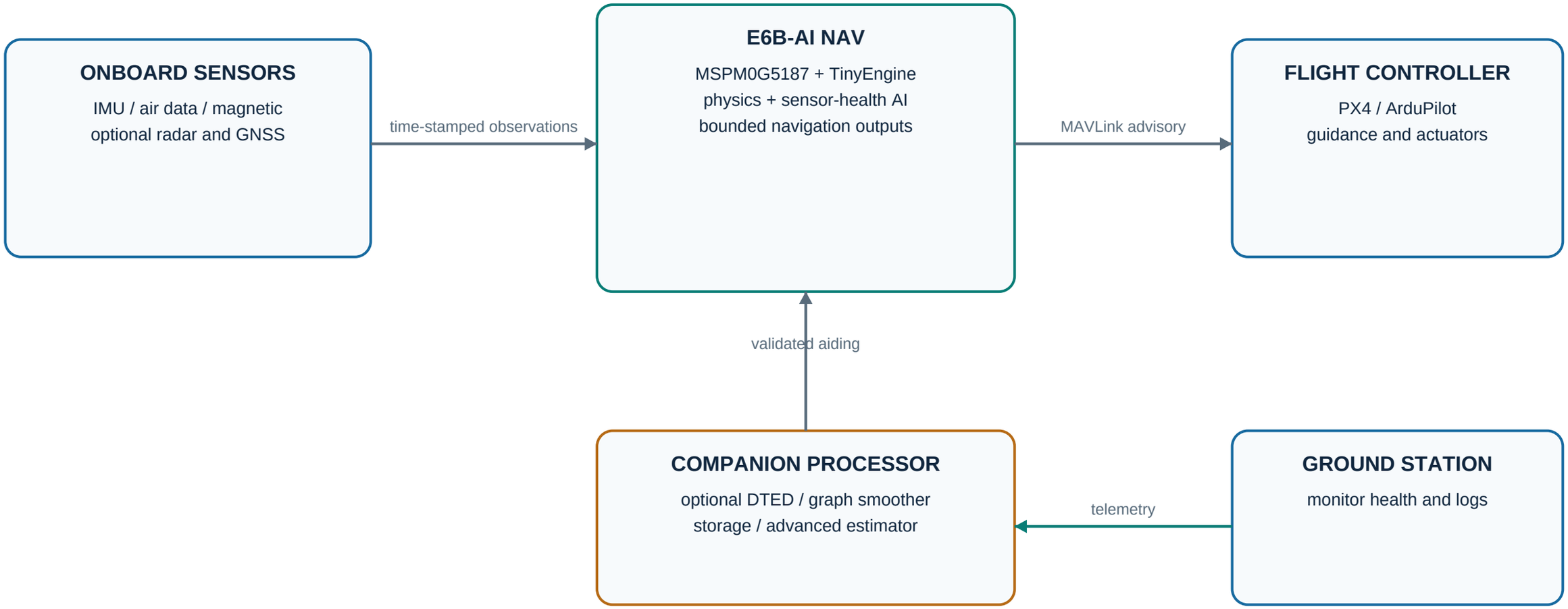
Source and verification note

Sources: applicant-supplied 5-page E6B-AI NAV Project Plan Summary (6 Nov 2026), 10-sheet Conceptual Engineering Schematic Rev A (31 Oct 2026), and the applicant-posted TeraOpenScience project. Example airframe, cost allocations, model structure and numerical check case are new planning illustrations, not independently vendor-verified specifications.

Confirmation: “All work will follow applicable university, platform, consumer-safety, consent, and privacy requirements.” Applicant: David Allen Blubaugh | Prepared: 6 November 2026. This is a draft master plan, not evidence of formal organizer acceptance.

SYSTEM CONTEXT / UAS INTEGRATION

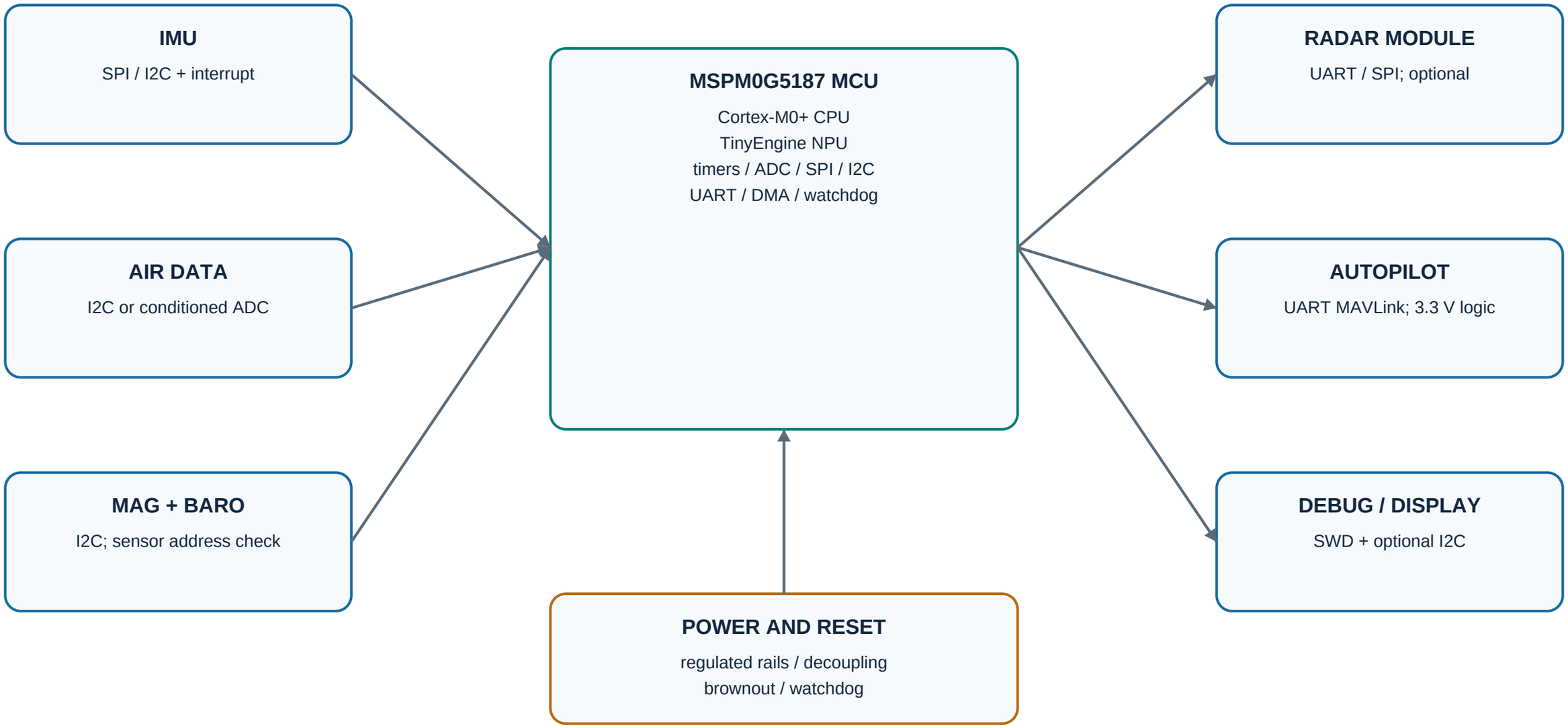
System boundaries and advisory-only information exchange



Solid arrows: proposed data flow. Dashed links on later sheets: optional future interfaces.
Navigation integrity does not imply an absolute GPS position fix; autopilot retains flight-control authority.

HARDWARE BLOCK SCHEMATIC

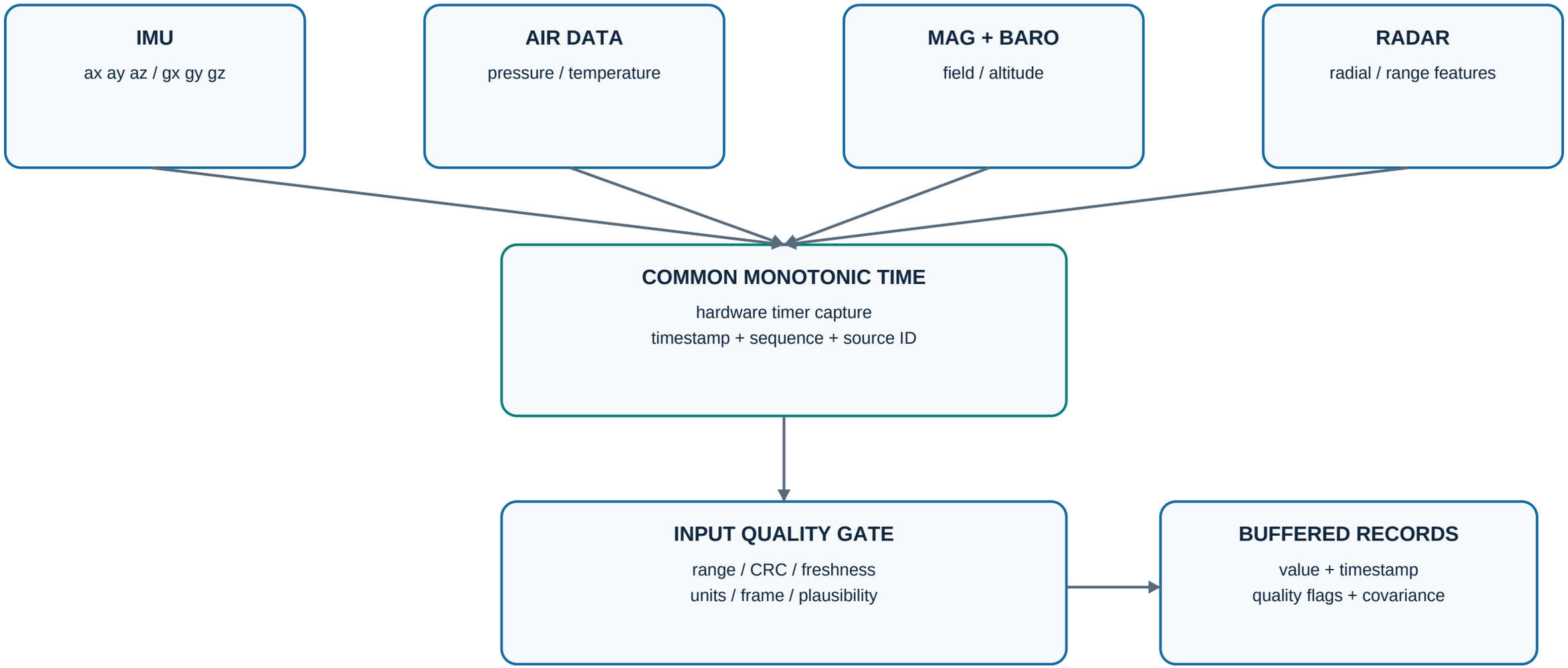
Functional electrical interfaces - pinout and voltage levels are to be verified



Do not connect 5 V signals directly to 3.3 V-only MCU pins without verified level shifting.
External radar has its own processing and power requirements; this sheet is not a PCB wiring diagram.

SENSOR ACQUISITION AND TIMEBASE

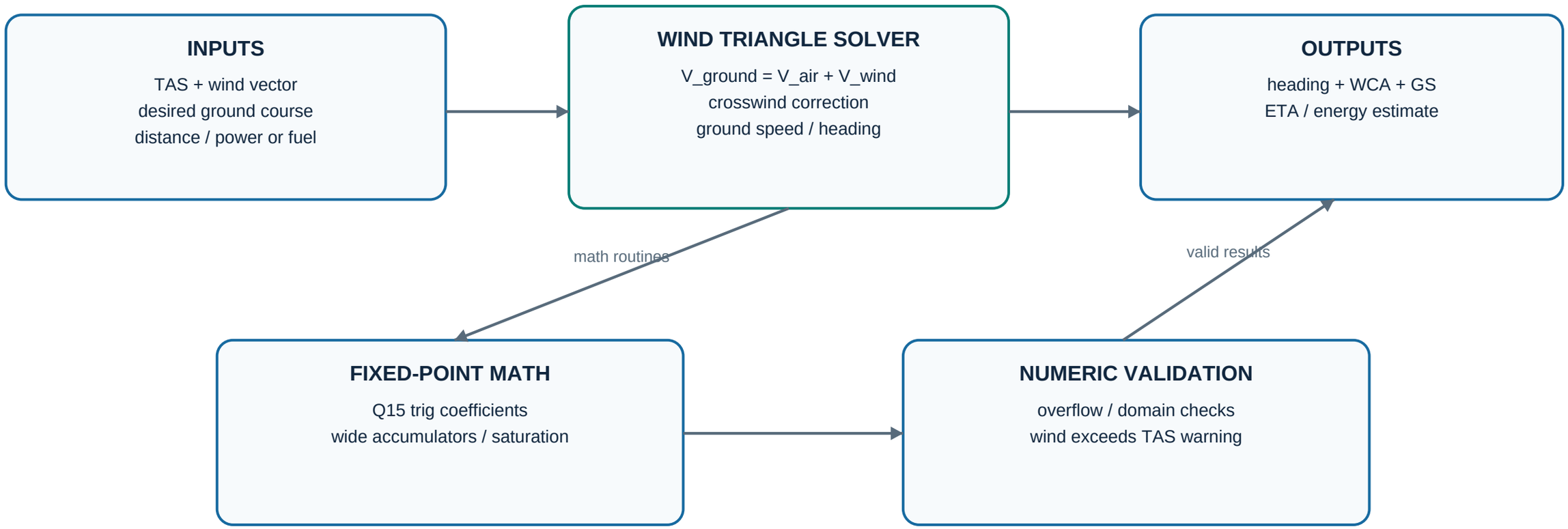
Timestamp each measurement before fusion; reject stale or malformed data



Sensor time alignment matters more than a nominally expensive clock if acquisition latency is unmeasured.
Optional TCXO/CSAC only if supported by actual hardware clock tree and a validated timing budget.

E6B PHYSICS COMPUTATION

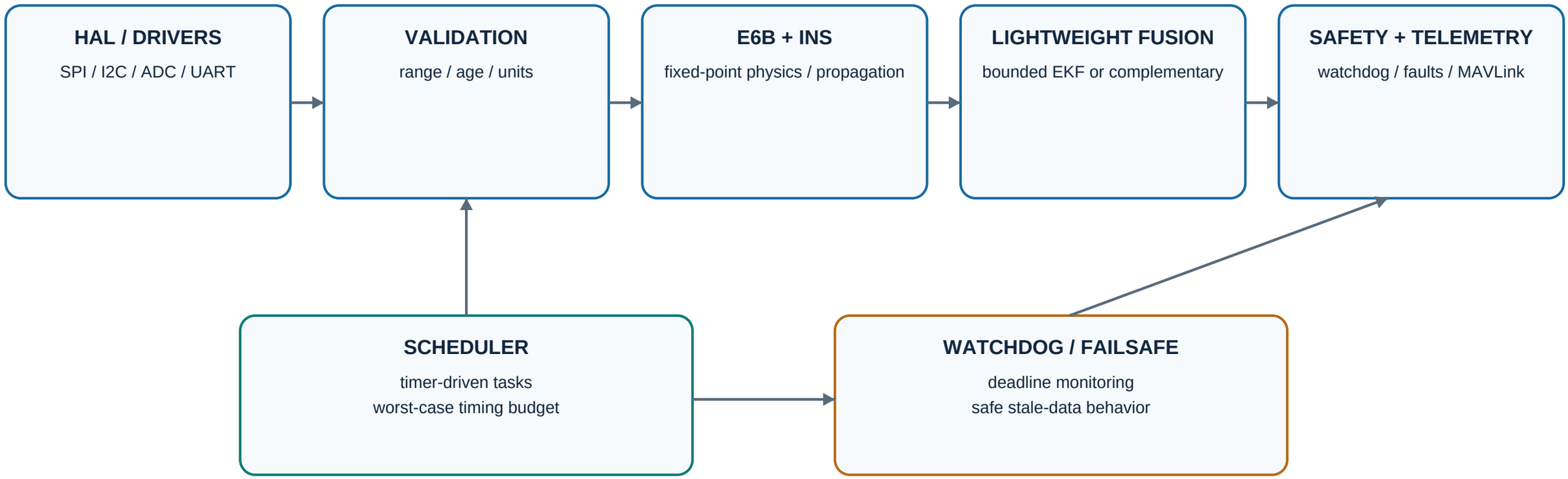
Wind triangle and time / distance / energy relationships



For desired ground track, solve the crosswind cancellation before deriving heading; do not equate course with heading.
Air-data scalar TAS is not necessarily aligned with fuselage heading under sideslip; represent assumptions explicitly.

DETERMINISTIC FIRMWARE ARCHITECTURE

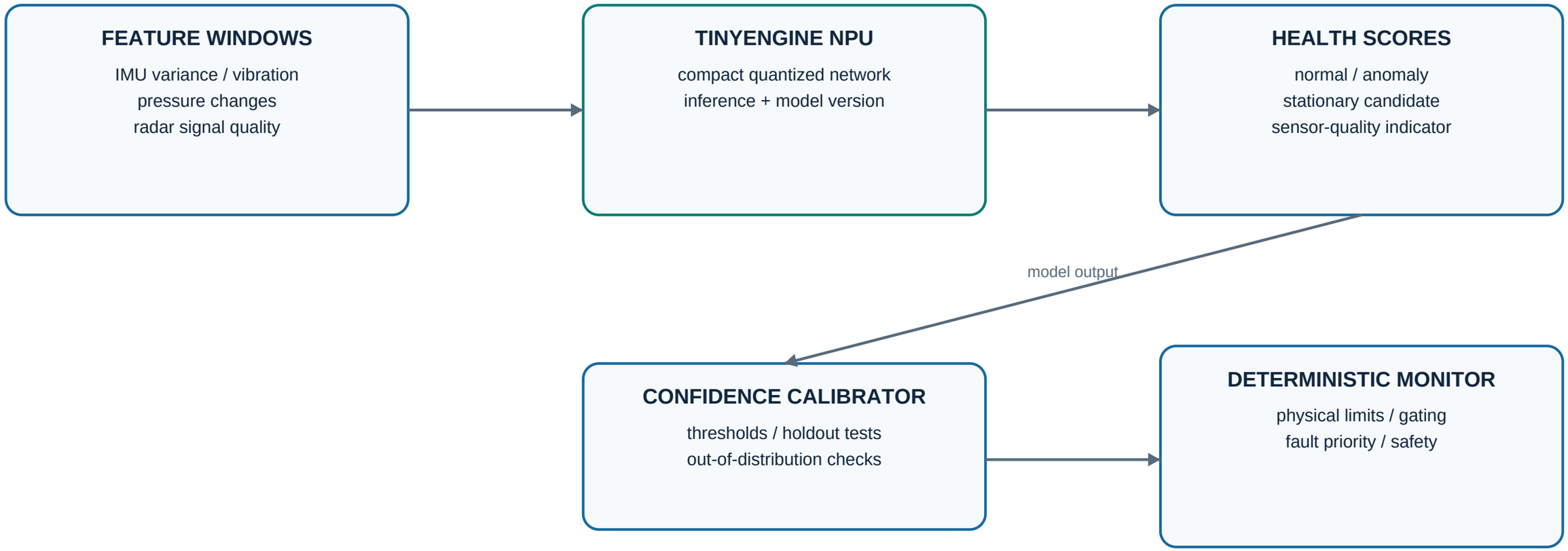
MSPM0G5187 real-time functions and bounded execution



Example scheduling periods are design candidates, not demonstrated timing guarantees.
Advanced factor-graph smoothing and full DTED search should run on an optional companion processor.

TINYENGINE NPU / AI HEALTH MONITOR

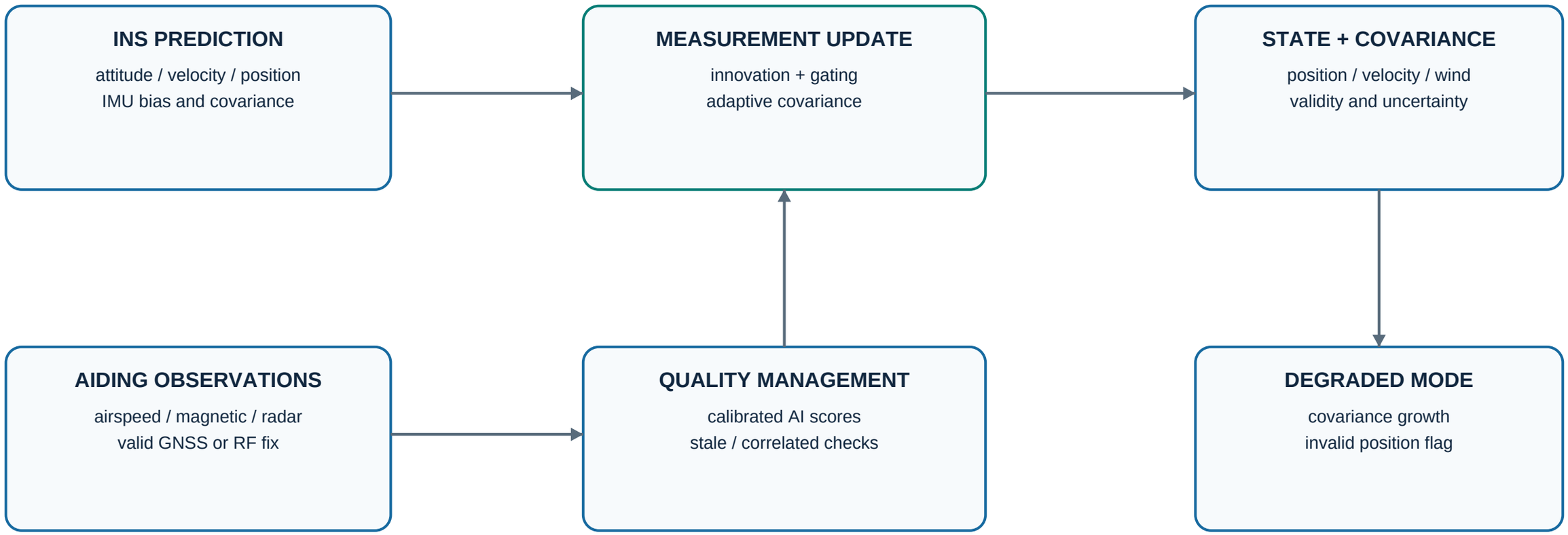
Learned classification supplements - never overrides - deterministic checks



Model outputs are scores until calibration against held-out datasets supports probability interpretation.
AI features and residuals may share sensor data: avoid double-counting correlated evidence.

BAYESIAN NAVIGATION FUSION

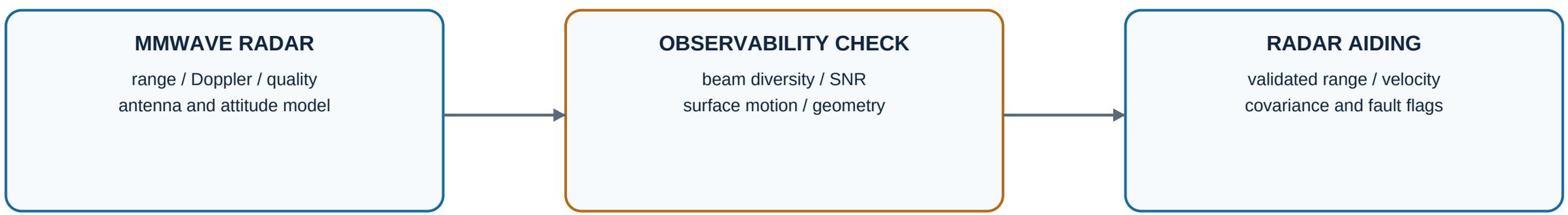
INS prediction, external measurements, and calibrated uncertainty



E6B constraints are not independent absolute-position measurements. Position remains unobservable without suitable external fixes.
ZUPT requires true zero Earth-frame velocity; hover alone is insufficient.

OPTIONAL RADAR / TERRAIN / MARITIME AIDS

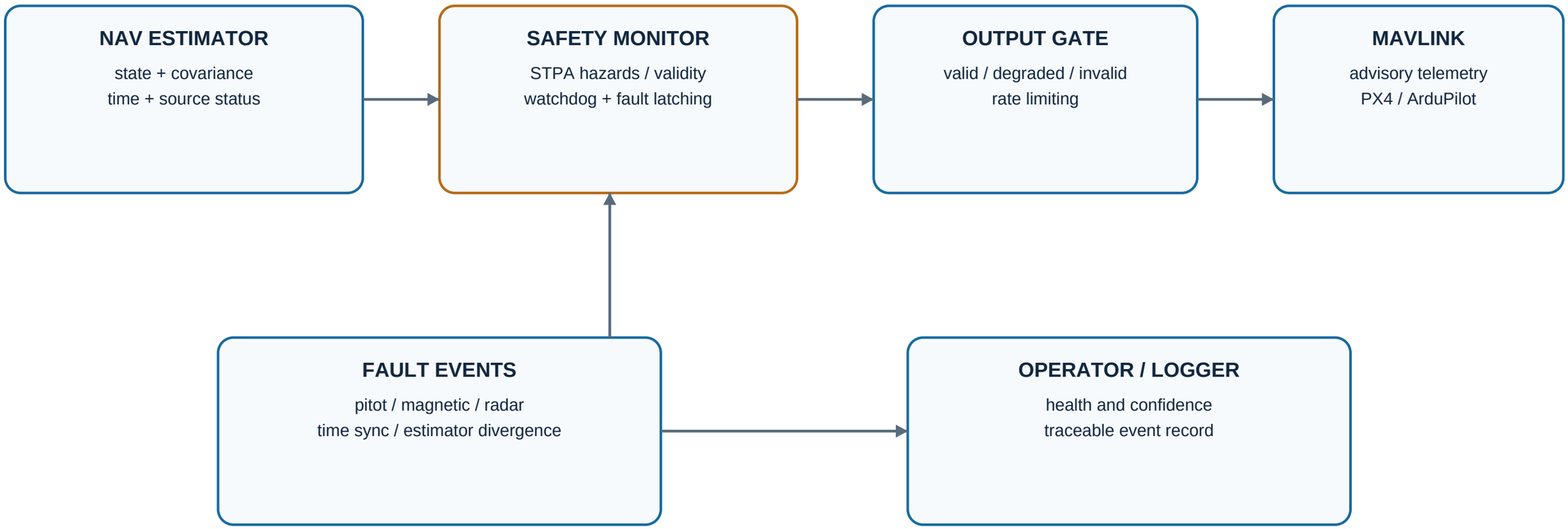
External aiding can constrain drift only when its measurements are informative



Single-beam Doppler observes radial speed, not complete horizontal velocity. Water surface motion and clutter complicate interpretation.
Terrain matching requires distinctive topography, a usable elevation map, and independent altitude-above-ground information.

SAFETY, INTEGRITY AND MAVLINK

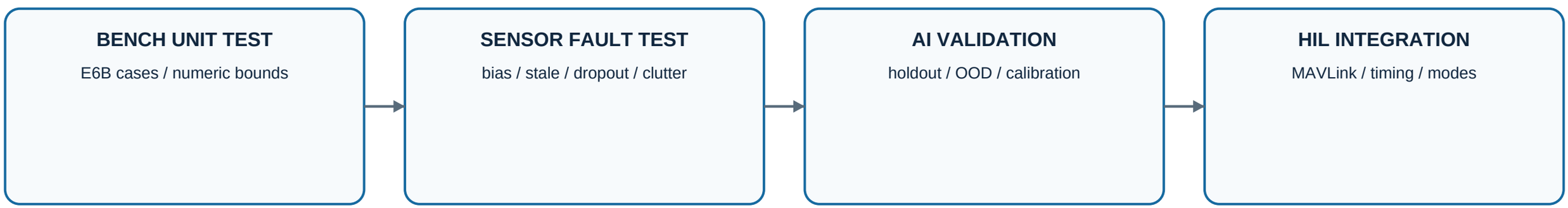
Fail closed on invalid data; preserve autopilot authority

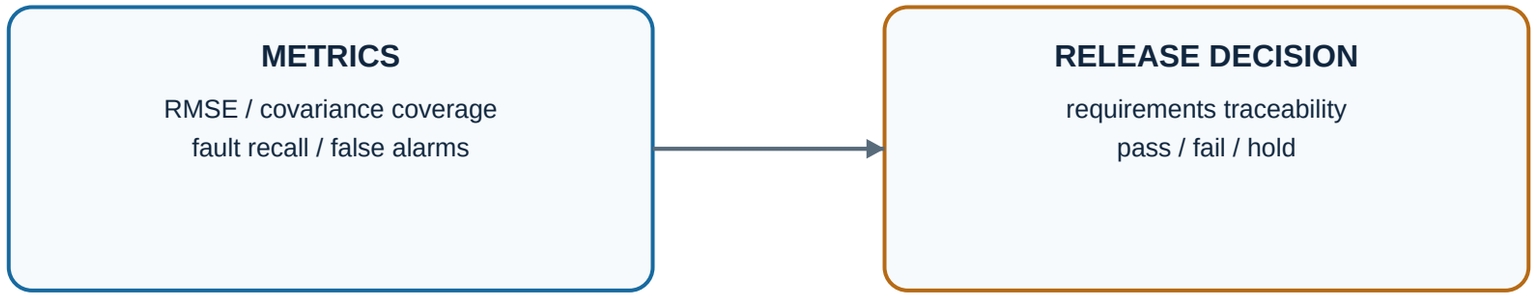


Never publish an unbounded or stale position as a valid external navigation fix.
MAVLink frame conventions, timestamp age, covariance encoding, and autopilot acceptance must be integration-tested.

VERIFICATION AND RELEASE GATES

Evidence needed before experimental aircraft integration





Baseline comparisons: INS-only | INS + E6B | Bayesian fusion | Bayesian + TinyML

Status: design proposal only. No verified electrical schematic, qualified flight hardware, or measured navigation performance is asserted.
Acceptance requires controlled datasets, independent truth reference, documented limits, and recorded pass/fail evidence.