



UK defence · autonomous systems · public case note

Latency-Bounded Perception

Why an autonomous system's reaction time is set by its sensor's physics rather than its resolution — and why that limit is written into almost no requirement. Prepared by Mark Poxton, Independent Analytical Systems Consultant.

Field	Outcome	Readiness	Proposed validation	Application
Autonomous systems and robotic sensing	Reviewed; not taken forward	Concept stage, declared as such	Three-month bench experiment	Thermal perception for autonomous systems

The point of the work

Sensors are bought and specified by what they can see: how far, how finely, how reliably they tell one thing from another. Control loops are limited by something else entirely — **when** the sensor can tell you. A machine that must react cannot act on what the world is doing now, only on the newest picture it has finished forming. That delay is a property of the detector's physics.

The analysis argued that this second limit is missing from the way autonomous perception is specified, tested and accepted; that it is measurable; and that in at least one published requirement it is already the binding constraint while everyone is arguing about resolution.

Position of this document

A public case note describing analytical work and the evidence discipline behind it. The work was produced independently, in response to a requirement the client organisation published openly, and offered to it for consideration; it was not a commissioned engagement. Nothing shared in confidence is reproduced here.

1. The arithmetic that reframes the requirement

A published requirement asks a system to hold a manoeuvre within three metres of a target that is closing at roughly the speed of sound. It is read almost universally as a detection and discrimination problem: see it further away, tell it apart from clutter.

Divide the two numbers the requirement already states and it becomes a timing problem. At that closing speed, three metres is worth under nine milliseconds. Then set the published physics of the sensor normally proposed against that budget.

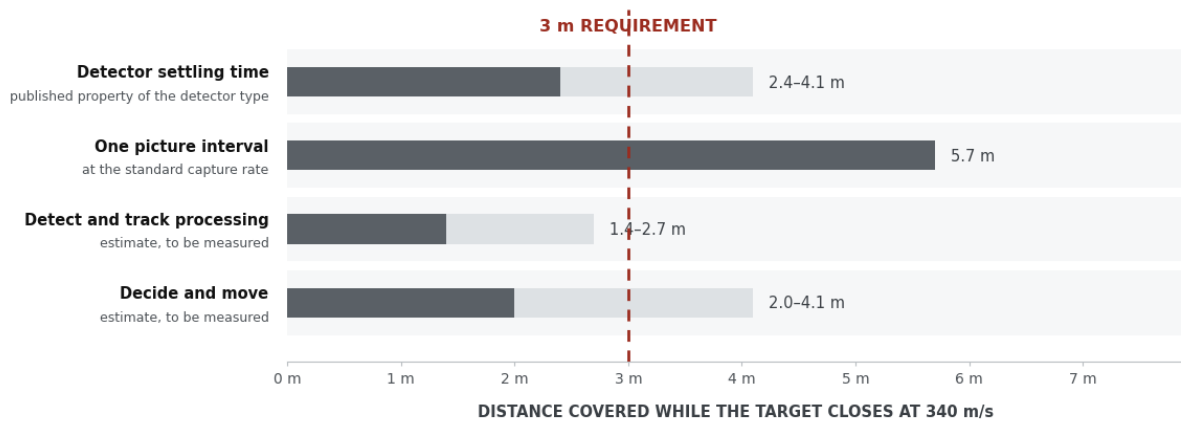


Figure 1 Distance covered by each stage of the sense-to-act chain while a target closes at 340 m/s, set against the three-metre requirement.

Stage of the sense-to-act chain	What it is	Distance consumed before the 3 m budget
Detector settling time	How long the sensing element itself takes to register a change — a published property of the detector type, not a quality of manufacture.	Roughly 2.4 to 4.1 m
One picture interval	The gap between one complete image and the next at the standard capture rate.	Roughly 5.7 m
Detect and track processing	Turning the picture into a usable position estimate.	Roughly 1.4 to 2.7 m — to be measured
Decide and move	Converting that estimate into a physical correction.	Roughly 2.0 to 4.1 m — to be measured

The finding

A single stage of the chain — the detector settling on its own, before one picture has even been completed — can consume the whole three-metre allowance. No improvement in sensitivity, optics or detection software touches this. The requirement, as written, is already spent.



2. Why the usual framing misses it

Perception is described spatially because that is how sensors are sold and compared. Range, resolution and probability of detection all appear on a datasheet. Settling time usually appears too, in the small print, but it is treated as a fixed characteristic of the part rather than as a term in the control budget — so it is never carried through into the requirement, the test plan, or the acceptance criteria.

The consequence is that a programme can meet every stated sensing specification and still be unable to do the thing the specification was written to achieve. The gap is not in anyone's engineering. It is in the shape of the specification.

3. What was proposed — and what is withheld here

The work did not stop at the diagnosis. It proposed that the detector's slowness is not a hard floor but a measurable and correctable property, set out a route to recover usable reaction rate beyond the apparent limit, and specified a three-month bench experiment that would either demonstrate that recovery or kill the idea.

The mechanism is not published in this document. The concept was not taken forward, so it remains unpublished and wholly owned. Setting it out in a portfolio piece would place it in the public domain for no return. What is shown here is the analysis and the evidence discipline; the method is available under discussion.

Why this distinction is the point

A case note exists to show how someone thinks, not to give away the asset. The reasoning above is the transferable part and is published in full. The mechanism is the part a client would be buying, and it is not.



4. The limit is general, not one use case

The interceptor requirement is the sharpest illustration because its tolerance is unforgiving and its numbers are public. The constraint itself is not special to it. Any autonomous system closing a control loop on a detector with a non-trivial settling time inherits the same bound.

Setting	Where the same limit binds
Vessels avoiding collision at speed	Thermal imaging used for obstacle detection: the avoidance decision is only as fresh as the detector allows, and speed shortens the margin.
Ground vehicles in obscured conditions	Navigation on thermal sensing in smoke, dust or darkness, where the same detector physics sets how fast the vehicle can safely move.
Cooperating air systems without communications	Where the loop must be closed on board rather than shared, every platform is individually bounded by its own sensor timing.

If recovery works, it raises the achievable reaction rate of a whole class of platforms without replacing a single detector. That is the reason the idea was worth an experiment rather than an argument.



5. Proposed as an experiment, not a claim

The work was pitched honestly at concept stage. It did not claim a working system, a prototype, or a demonstrated result. It asked for a bench experiment whose purpose was to produce evidence, and it stated in writing what result would end the idea.

Stage	Purpose	What it produces
Characterise	Measure how the detector actually behaves against a controlled, changing heat source.	A measured response model with its uncertainty stated.
Build the reference bench	A moving target observed at the same time by the slow sensor and by an independent, faster position reference.	Physical ground truth to score against — not a visual judgement.
Test and score	Compare recovered timing against that independent reference across conditions.	A measured recovery figure, or a null result.
Falsify	Three named outcomes, written before the experiment, each of which would disprove the concept.	A defensible stop decision either way.

The discipline that matters

Scoring against a physical reference rather than against how the output looks, and naming the disproving results in advance, are what separate an experiment from a demonstration. Both were written down before the work left the desk.



6. Stated limitations

Limitation	Practical meaning
Unproven	The central claim was untested. It was offered as an experiment to run, and was described that way throughout.
Two stages estimated	Two elements of the timing budget were engineering estimates awaiting measurement, and were labelled as estimates rather than presented as findings.
Noise cost not yet quantified	Any recovery of this kind carries a penalty. Its size was a question for the bench, not something the work asserted.
Single practitioner	The product is analysis. The experiment would need a host laboratory, and the document said so rather than implying delivery capability.

7. Outcome

The work was reviewed and not taken forward. No detailed reasoning was provided, so none is inferred here.

That is recorded plainly because it is the honest record. A document is put in front of a reader; the reader decides. What survives the decision is the work, and the work is what this note is for. Intellectual property in the concept is retained in full.



What the work shows

Signal	Evidence in this case note
Problem reframing	A requirement everybody read as a resolution problem was shown, from its own two numbers, to be a timing problem.
Working from published fact	The binding figures were taken from manufacturers' published characteristics and the requirement's own wording, not from assumption.
Bounded claiming	Estimated elements were labelled as estimates; the central claim was framed as untested.
Designed to be disproved	Physical ground truth and three pre-declared failure conditions, written before the work left the desk rather than after it was questioned.
Knowing what to withhold	The reasoning is published; the mechanism that carries the value is not.

Public note: a reworked public case note derived from the author's own work, which is retained in full. It omits the client organisation's brief, all material shared in confidence, and the proposed recovery mechanism.