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- **Problem Statement ID –** 26169
- **Problem Statement Title –** Development of an AI-Based Virtual Camera Tracking System for Coarse Alignment of Mobile Free Space Optical Communication (FSOC) Terminals
- **Theme –** Smart Automation, Space Technology
- **PS Category –** Software
- **Team ID –** 182144
- **Team Name –** Blank Point



ARGUS

FSOC COARSE-POINTING TRACKER

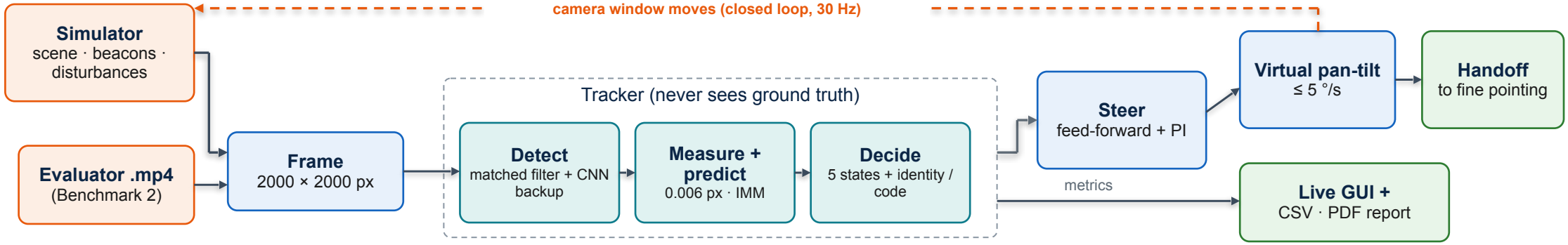
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ARGUS: AI-Assisted Virtual Camera Tracker

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Proposed Solution

A standalone desktop app (plus the same program as a web app) that **renders a 2000 × 2000 px sky with a moving beacon and real-world disturbances**, then detects, measures, predicts and steers a rate-limited 640 × 480 virtual camera to keep that beacon centred, and says when fine pointing can take over. Every run writes its own performance report; evaluator .mp4 files plug into the same pipeline.



How it addresses the problem

OBSERVE — Tracker watches the whole 2000 × 2000 scene every frame (a hard mode limits it to the camera window).

ACQUIRE — Matched filter + noise-adaptive threshold; a spot must hold 3 of 4 frames before lock. Locks in 0.6 to 1.3 s (spec ≤ 2 s).

ESTIMATE — Centre to 0.006 px by a 2D Gaussian fit; an IMM filter predicts line, circle, figure-8 and random paths unaided.

ADJUST — Feed-forward + PI leads the beacon by the gimbal's 1-frame delay, never above 5 °/s: 2.1 to 3.7 px error (spec ≤ 10 px).

Innovation and uniqueness

Physics-ordered, live disturbances
Atmosphere, then sway and jitter, then sensor noise; change any of them mid-run and each phase is scored.

Track-before-detect
Links 3 to 6 σ spots across frames. Faint-beacon lock went from never to 94–98 % (10 seeds).

Self-trained AI safety net
84 k-parameter CNN trained on our own simulator frames with exact labels; no dataset needed.

Identity among look-alikes
Appearance, start cue or click, and a blink code: identical decoys told apart with no cue, 100 % on the beacon.

Provably blind to the truth
Ground truth deleted before tracking gives identical results; `verify` rebuilds every figure from the log.

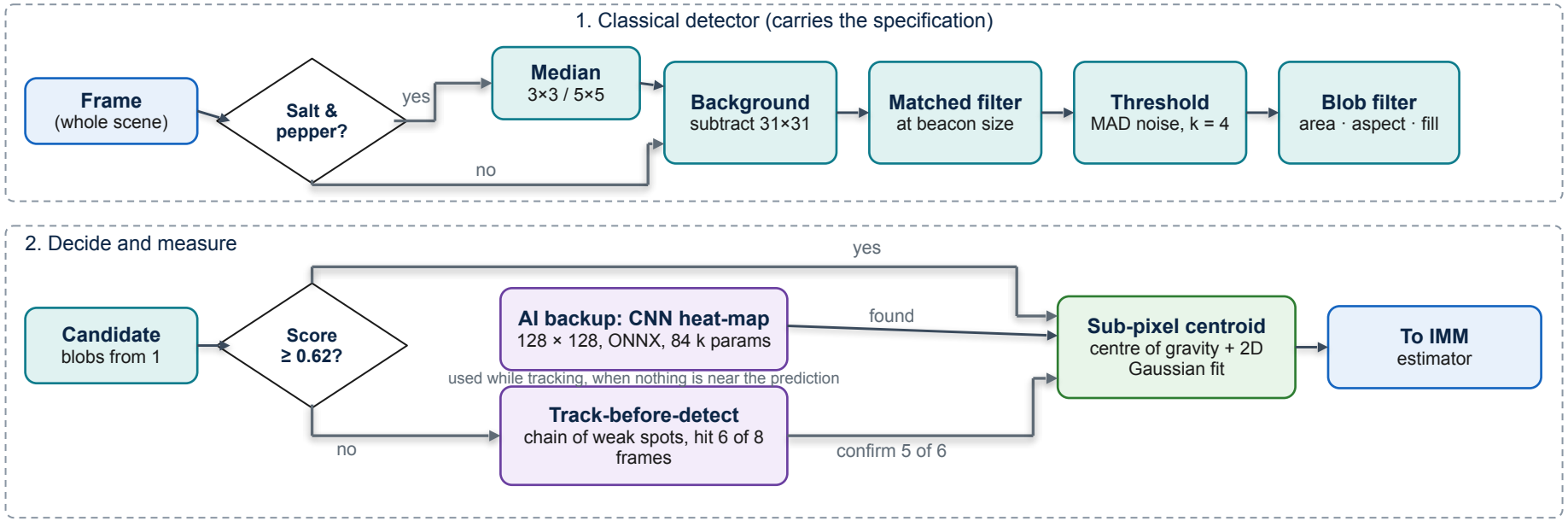
Ready for fine pointing
Declares handoff once lock holds within 10 px for 1 s: 1.7 to 2.5 s after start on clear skies.

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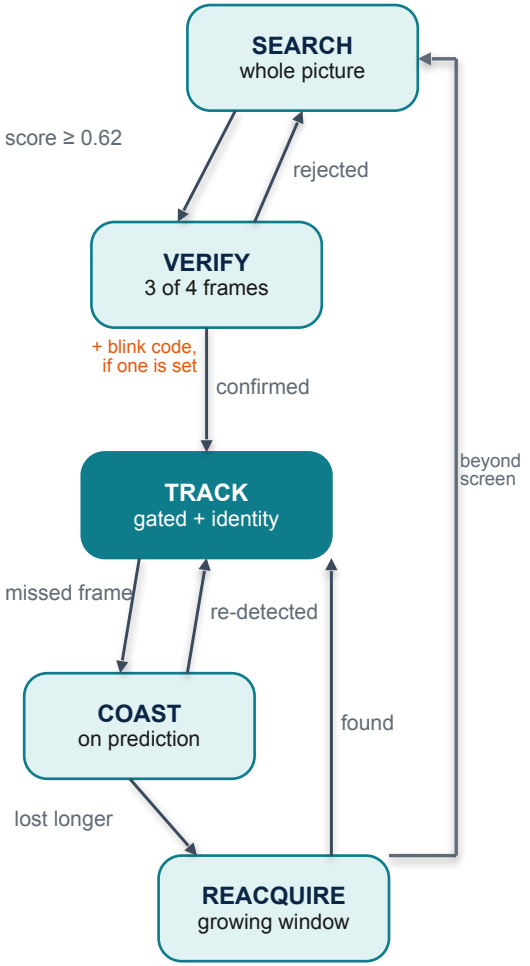
TECHNICAL APPROACH: METHODOLOGY

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Every frame: detect and measure



Tracker states



Then estimate and steer



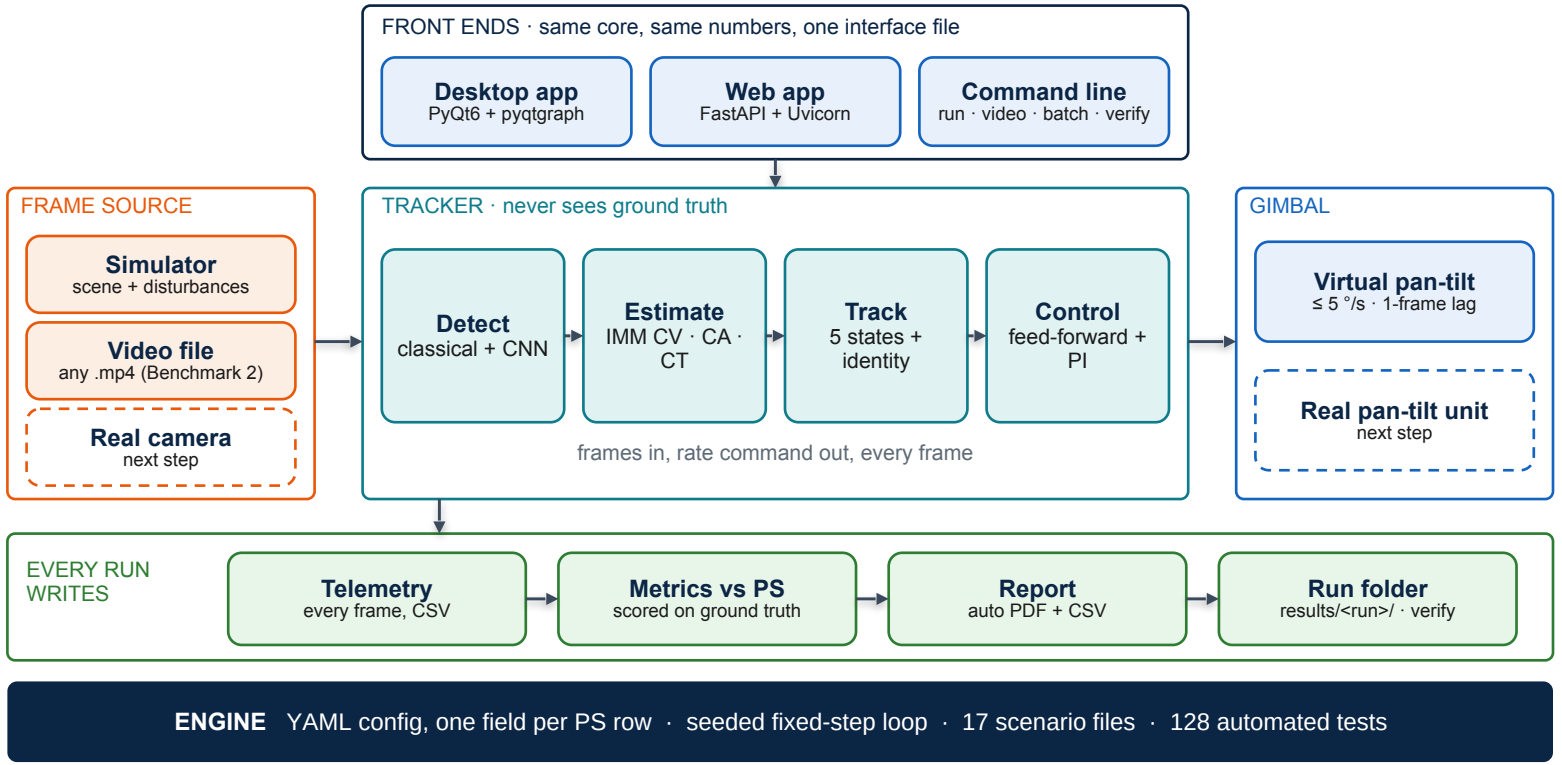
22.5″	26.7 px	0.95 s	50 ms
one pixel (4° / 640 px)	max slew per frame at 5 °/s, 30 Hz	centre to corner, target known	budget at 20 FPS; we use 5 to 14 ms

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TECHNICAL APPROACH: ARCHITECTURE

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Software architecture



Technologies used

LANGUAGE + CORE

Python 3.12 · NumPy · SciPy · PyYAML

COMPUTER VISION

OpenCV · sub-pixel Gaussian fit

AI

PyTorch · ONNX · ONNX Runtime

DESKTOP GUI

PyQt6 · pyqtgraph

WEB APP

FastAPI · Uvicorn · Caddy

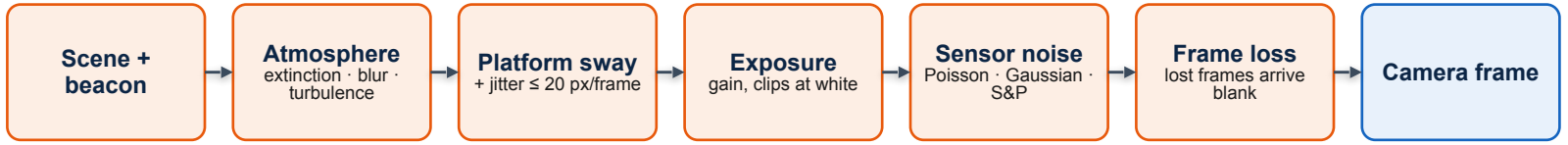
REPORTS

Matplotlib PDF · CSV · JSON

BUILD + QA

PyInstaller · pytest · GitHub Actions

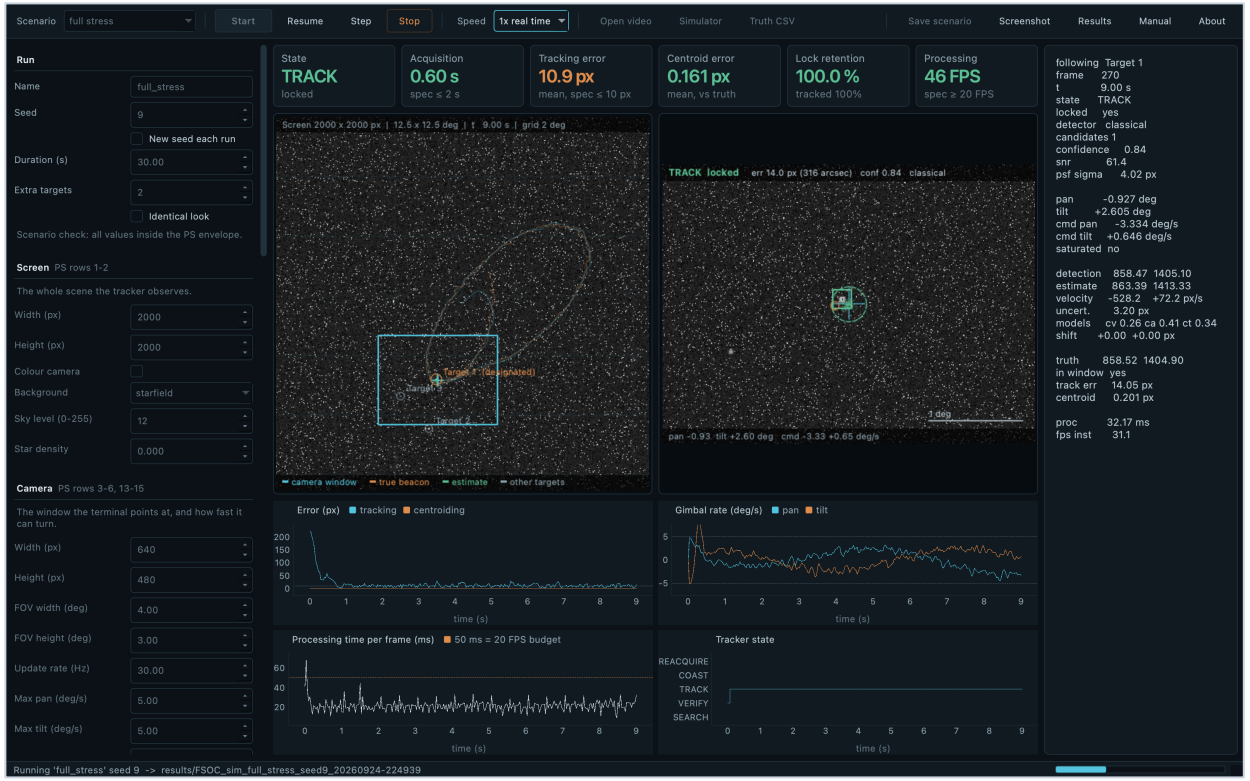
Disturbances in physical order, changeable live



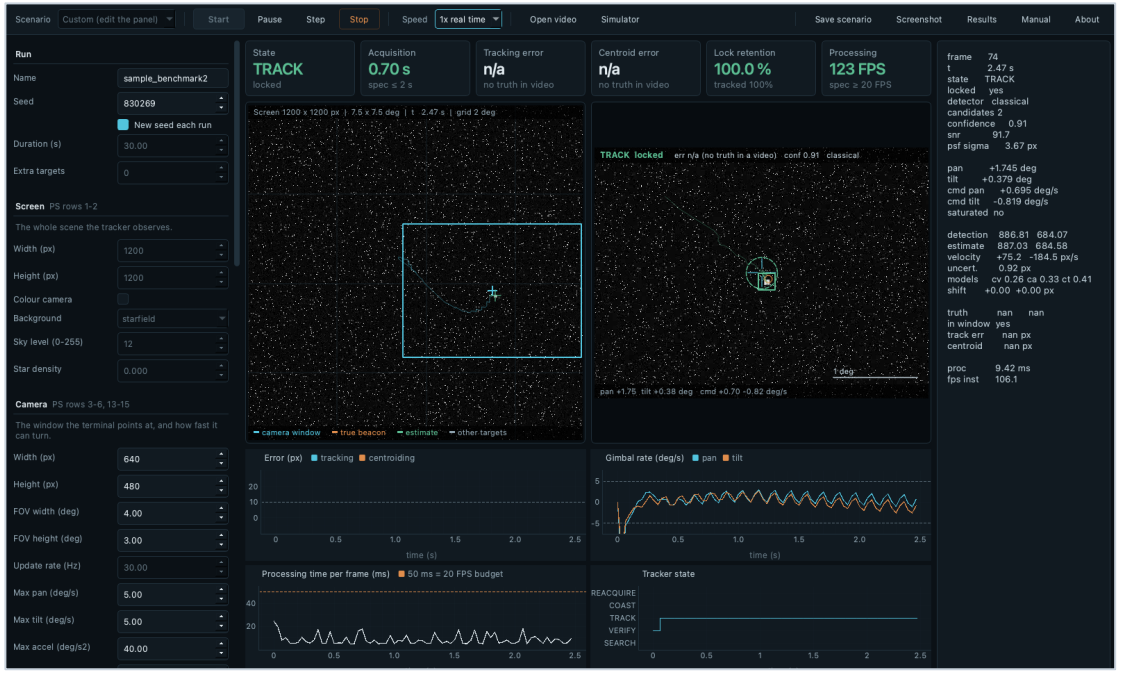
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WORKING PROTOTYPE / DEMO

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Desktop app mid-run, multi-target stress scenario (haze, 3 noise types, sway, jitter, 2 decoys): TRACK locked, 0.60 s acquisition, 100 % lock, centroid 0.161 px; 10.9 px is the injected shake.



Benchmark 2 input: sample_benchmark2.mp4 (1200 × 1200 px, 30 fps) tracked directly, PTZ bypassed: locked in 0.70 s, 100 % lock, 123 FPS with live drawing.

Source code: github.com/tanmayhutt/SIH26169 (private)
Web app and demo video: sih26169.blankpoint.club (login)

Results against the PS targets (51 runs, final code)

0.6–1.3 s	2.1–3.7 px	100 %	0.006 px	≤ 0.27 s	71–211
acquisition spec ≤ 2 s	**tracking error** spec ≤ 10 px	**lock retention** spec: loss < 5 %	**centroid error, clear** 0.19 px heavy noise	**re-acquisition** spec ≤ 1 s	**FPS on a laptop** spec ≥ 20 FPS

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FEASIBILITY AND VIABILITY

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Feasibility: already built and measured

Scenario (15 s runs, 3 seeds)	Acquire	Error	Lock	Verdict
Clear: line, circle, figure 8	0.6–1.3 s	2.1–3.7 px	100 %	Pass
Clear random walk	0.7–1.0 s	5.1–6.3 px	100 %	Pass
Heavy noise (S&P 10 %, σ 20, Poisson)	0.7–1.0 s	2.4–3.7 px	100 %	Pass
Fog and low light	0.6–1.6 s	2.5–3.7 px	100 %	Pass
Faint beacon, 3 to 6 σ, 10 seeds	0.8–2.0 s	2.4–3.5 px	94–98 %	Pass
Identical look-alikes (start cue or code)	0.6–1.9 s	1.9–3.5 px	100 %	Pass
Decoys + haze + noise + sway	0.3–1.0 s	10.3–11.3 px	98–100 %	Identity held
Platform at PS max (20 + 20 px/frame)	0.7–1.0 s	21.7–23.5 px	93–97 %	Physical limit

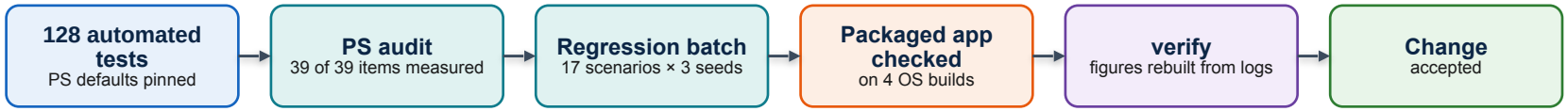
Viability: runs offline on an ordinary laptop CPU, no camera, pan-tilt unit or optics to buy. Same numbers on Windows, Linux and both Macs; every build ships only after its own packaged smoke test.

Against a brightest-spot baseline: ARGUS meets every PS limit in 33 of 48 runs; the baseline in 0.

Challenges, risks and our strategy

Challenge or risk	Our strategy
Random shake at the PS maximum (20 px/frame) cannot be predicted	Report error with shake removed beside the raw number; a 10 °/s motor was tested and does not help
Unseen evaluator videos (60 % of marks)	Never tune to our own clips; read true size, fps and rotation from each file; 19 evaluator-style videos run clean
Beacon too faint for any single frame	Track-before-detect: chain weak spots over 6 of 8 frames, then confirm 5 of 6
Decoys crossing the designated beacon	Appearance signature, start cue or click, and an optional blink code checked all the time
An AI model failing silently or slowly	Classical path carries the spec; CNN only fills gaps, loaded and warmed up at start
A later change quietly making results worse	Every engine change reruns the whole pack × 3 seeds; no run may get worse

How every change is verified



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IMPACT AND BENEFITS

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WHY IT MATTERS NOW
Optical links are already here, and every one starts with coarse pointing.

200 Gbps
NASA TBIRD, space to ground, 2023 [11]

20 Gbps · 20 km
Taara FSO links in Airtel's network, India [15]

1.8 Gbit/s
ESA EDRS relay to satellites 35,000+ km away [13]

Who it helps

ISRO SAC and DoS PAT teams
Try coarse-pointing algorithms before a camera or gimbal is bought; one config field per PS row.

Universities and students
A free, repeatable PAT lab: the PS's own "development and learning" goal.

Indian FSOC, UAV and NewSpace start-ups
Benchmark trackers on the same scenarios and per-frame logs.

Defence and disaster communications
Rapid optical links between vehicles and drones need a fast coarse lock.

What it brings

Economic
One laptop replaces a camera, pan-tilt and optics bench.

Technical
Seeded, repeatable runs; per-frame CSV makes trackers comparable.

Social
Offline on Windows, Linux and macOS; nothing to install.

Environmental
Fewer hardware prototypes; light needs no spectrum licence.

Strategic
Indigenous PAT software for India's optical and quantum links [14].

Hardware-ready
Camera and gimbal are interfaces, so real ones plug straight in.

Path from virtual bench to a real link



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RESEARCH AND REFERENCES

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