Day 5 — Assembly

18 JULY · RANA, EVAN · CAPSTONE

Design an interferometer, then commission it. Build its noise model, then find where the machine disagrees with it.

Day 5 · the capstone

Phase 1 · Design the model `pygwinc`

Build the **GWINC** fundamental-noise floor — quantum, thermal, seismic, Newtonian, gas — then **overlay the week's loop noises** on top.

GWINC is the floor; your loops add technical noise; commissioning pushes it under the floor. The floor slide is that one `pygwinc` call — `gwinc.load_budget("aLIGO").run()`, times the 4 km arm to get metres. Measured performance and the noise that actually limited O4: Capote et al., PRD 111, 062002 (2025).

Phase 2 · Commission (find the discrepancies)

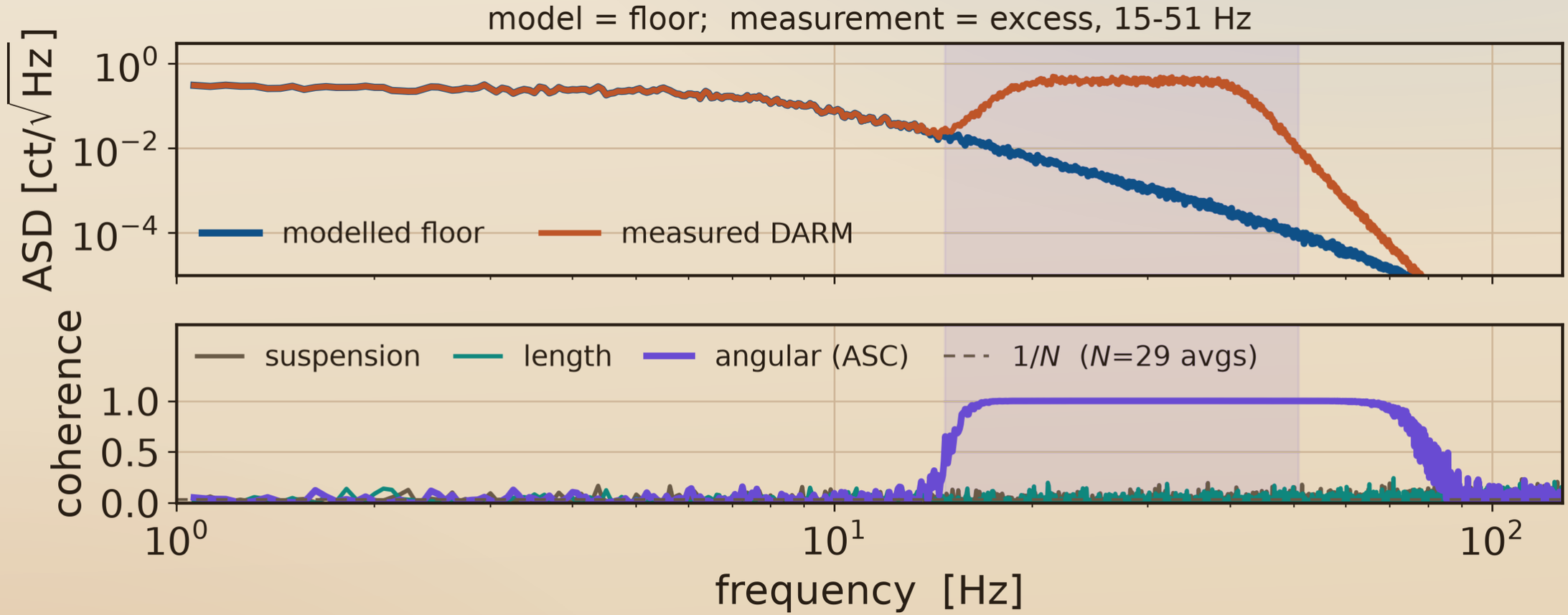
> SEVERAL INJECTED DISCREPANCIES
> Noisy OSEM · a suspension a little off · extra optical loss · a noisy ISC sensor. Each shows up as a disagreement between the machine and your model — the model is the prior, the measurement updates it.

Apply the whole method: measure, localize on the matrix, prioritize by budget.

`Deliverable · a ranked list of discrepancies — each localized, its cost, fix-first / defer — i.e. a commissioning plan`

Localize — which block, from coherence

Coherence of DARM with each witness you already record: the one riding to ≈ 1 in the excess band names the block.

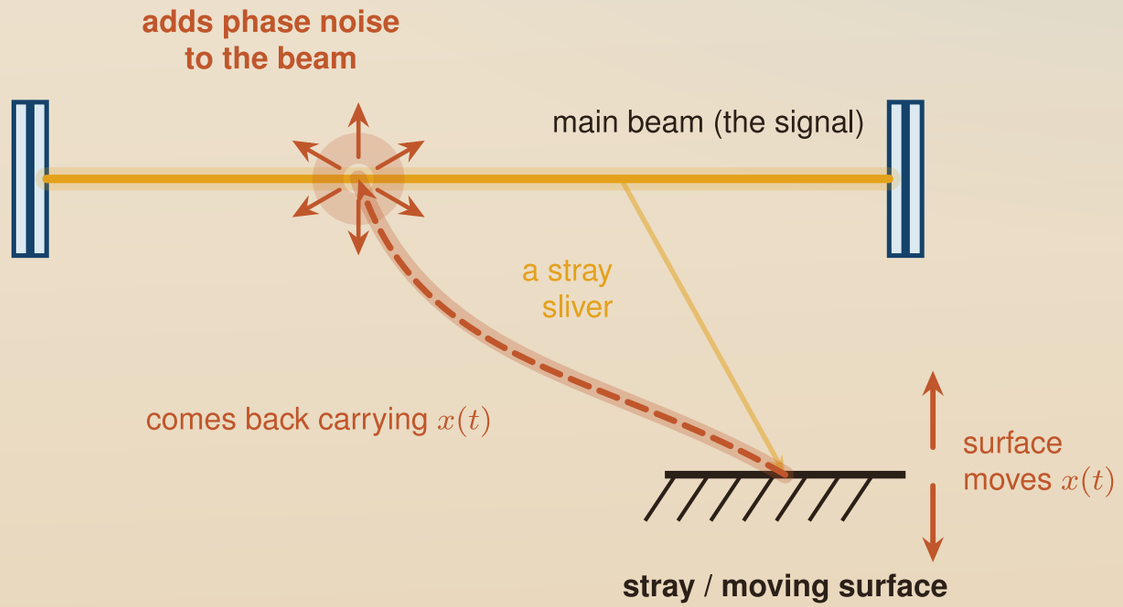


Synthetic, illustrative units; a term is ranked only with enough averages **and** good coherence.

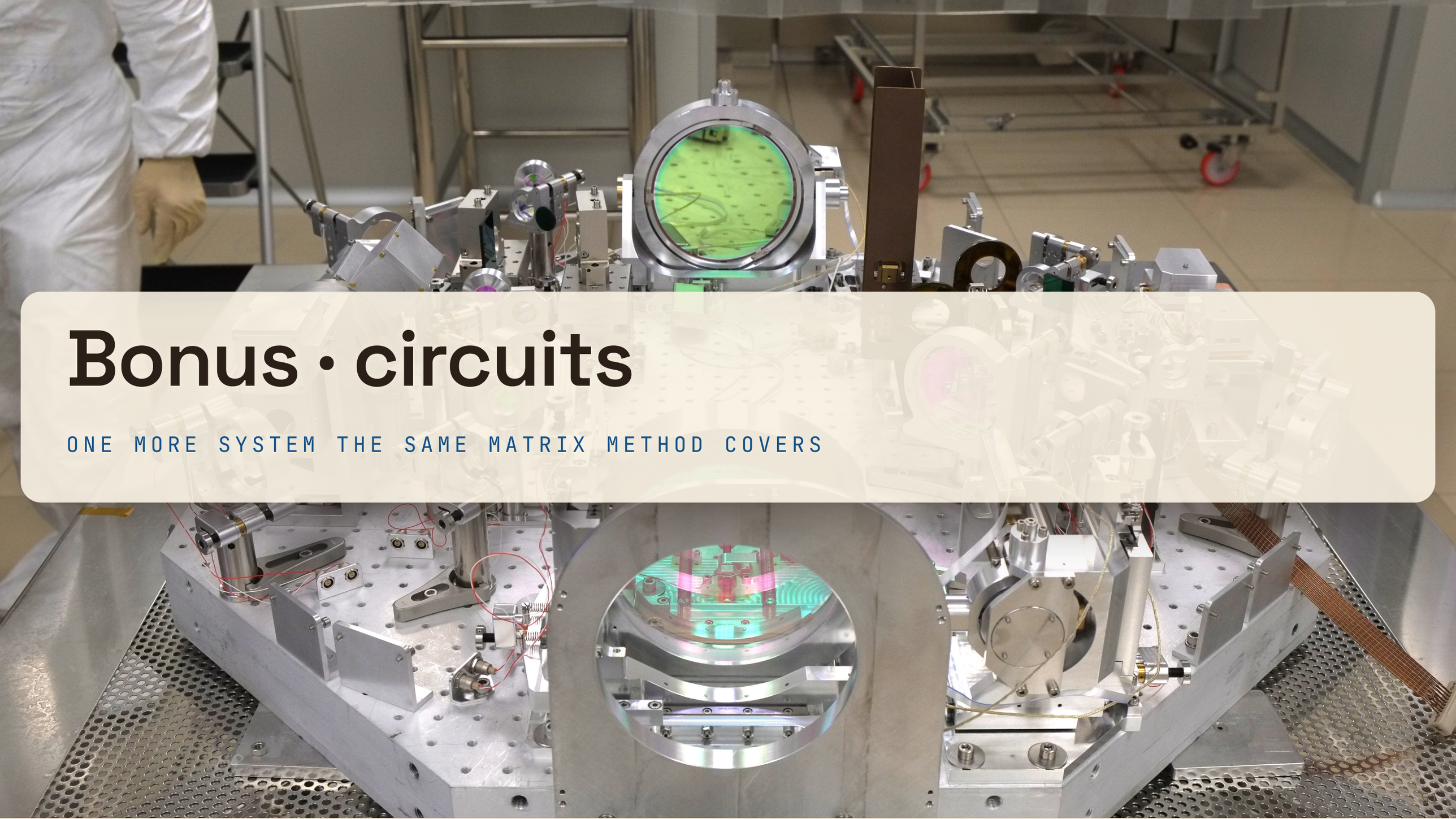
What the linear model misses

scattered light: a little light touches a moving wall and comes back dirty

big low-frequency wall motion ⇒ up-converted, fringe-wrapped noise in the band



Lock acquisition is **nonlinear** before the loop linearizes; **scattered light** up-converts low-frequency motion into the band — a surface moving at v paints a shelf up to $f \simeq 2v/\lambda$, about 2 Hz for $v \approx 1\ \mu\mathrm{m/s}$ at 1064 nm, tracking the microseism. Saturations, drifts and timing bite too. The fixes are feedforward, gain scheduling, dither and glitch vetoes.

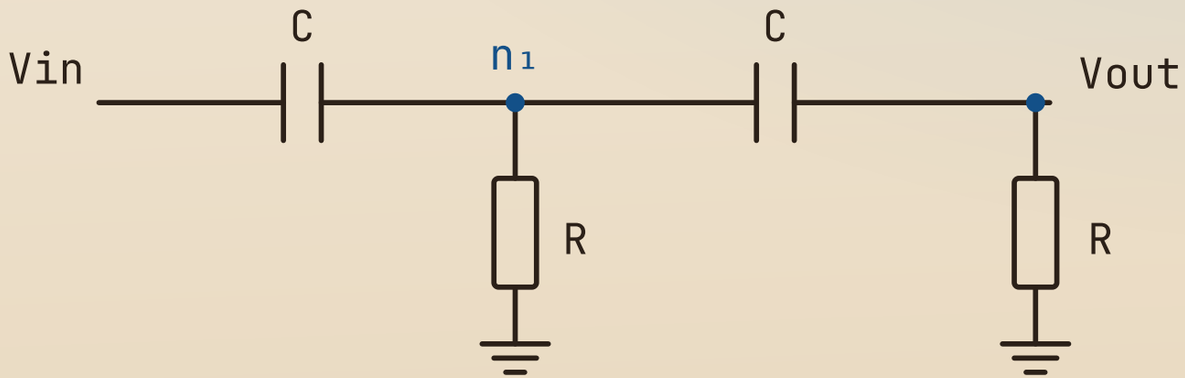


Bonus · circuits

ONE MORE SYSTEM THE SAME MATRIX METHOD COVERS

A circuit is the same matrix

Same matrix as the Day-1 loop and cavity — now a two-stage **RC high-pass**.



Modified nodal analysis, by inspection: diagonal = the admittances at a node, off-diagonal = the shared edge.

$$\begin{bmatrix} 2y+g & -y \\ -y & y+g \end{bmatrix}\begin{bmatrix} V_1 \\ V_{\text{out}} \end{bmatrix} = \begin{bmatrix} y\,V_{\text{in}} \\ 0 \end{bmatrix}, \quad y = j\omega C,\ g = \tfrac{1}{R} \ \Rightarrow\ x = G^{-1}\,b$$

The arc

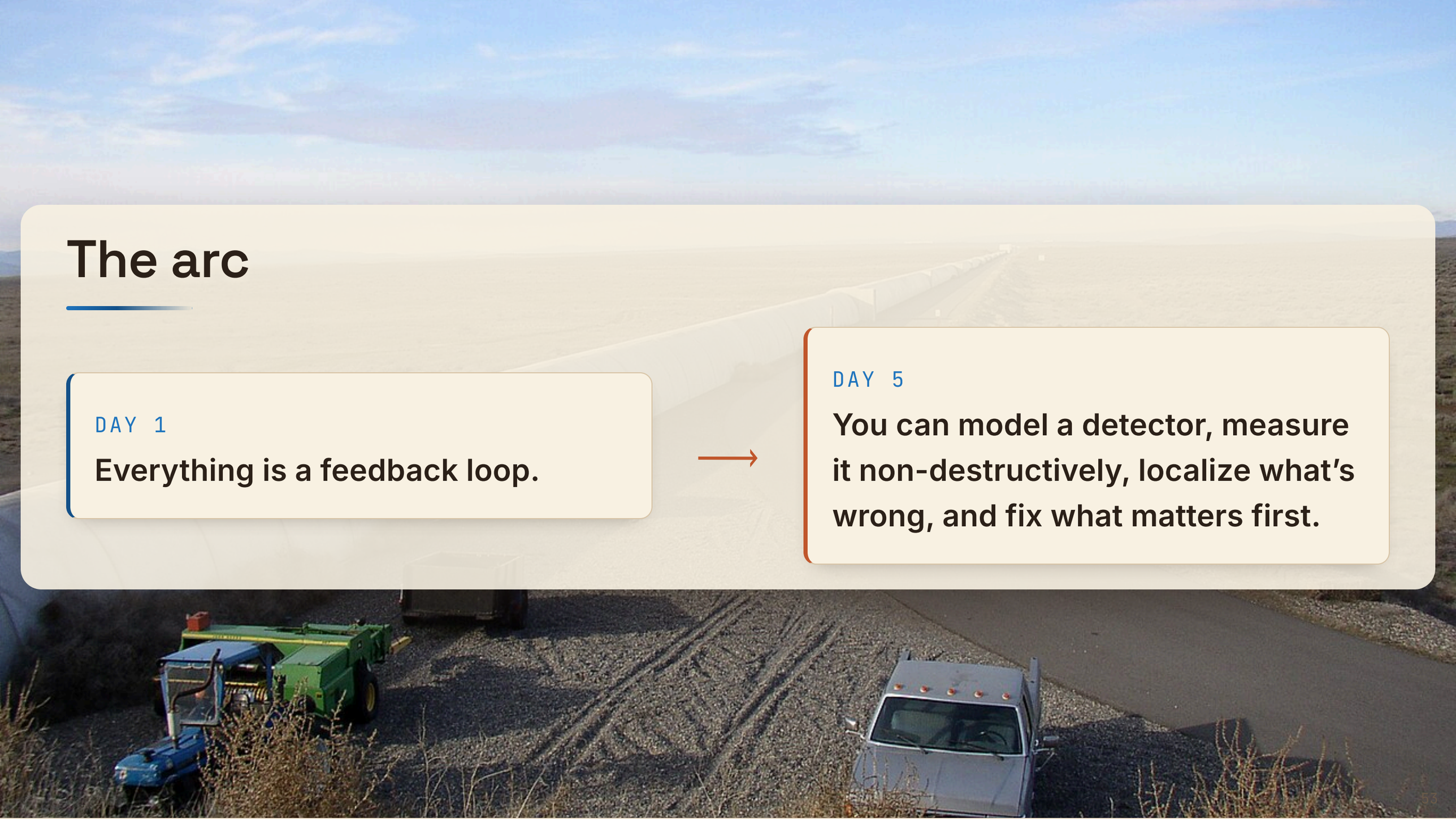
DAY 1

Everything is a feedback loop.

→

DAY 5

You can model a detector, measure it non-destructively, localize what's wrong, and fix what matters first.



Everything is a feedback loop.

POPULATE · CLOSE · BUDGET

14–18 JULY 2026 · IUCAA, PUNE

You now have the method.

Take it to LIGO-India.

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