

A vintage typewriter is the central focus, positioned on a wooden desk. To its left, a brass lamp with a warm, glowing light sits on a small stand. Further left, a brown leather suitcase is partially visible. A sheet of paper with typed text is emerging from the typewriter. The scene is dimly lit, with the lamp providing the primary light source, creating a nostalgic and scholarly atmosphere.

CORA

What an experiment can be asked and who is asking

Doğa Gürsoy · Argonne National Laboratory

Advanced Photon Source · 2026

Four parts

1 The questions YOU ARE HERE

What is asked about an experiment.

2 The machinery

What the record is made of.

3 At a beamline

What runs at 2-BM today.

4 Proposed next steps

Where this path goes.



When the questions arise

A run of questions

BEFORE

weeks of getting ready

“What did we propose to measure?”

“Is the instrument as we left it?”

“Has this sample been run before?”

“Who may change the setup?”

DURING

a few days of beam

—————

“Is this working, or wasting the shift?”

“Are we measuring what we came for?”

“When did it fail, and why?”

“Do we keep going, or re-plan?”

AFTER

for as long as the data is used

“What settings produced this file?”

“Can I compare these two runs?”

“Which of these runs are usable?”

“Could anyone reproduce this in a year?”

Answered today by a system or by a person still here.

Who is asking

One run of beam time

DIVISION MANAGEMENT	<i>"How much of that beam time was science?"</i>	What the next allocation is worth.
BEAMLINE SCIENTIST	<i>"Which runs used the old detector distance?"</i> <i>"Is this fault expected?"</i>	What has to be re-taken and by whom.
THE USER	<i>"What exactly produced the figure in the paper?"</i>	Whether the result survives a referee.
DOWNSTREAM ANALYSIS	<i>"Which frames can go in the training set?"</i>	Whether the model can be defended.
AN AGENT, AT 3AM	<i>"Am I allowed to change the plan right now?"</i> <i>"Has this condition occurred before, in any earlier run?"</i> <i>"Do earlier runs on this material support what I see?"</i> <i>"Which of my last ten decisions would a person have refused?"</i>	Whether it acts or waits for a person. The last one can be asked only by the thing that decided and answered only by a record.

The last of these askers is not a person.

The same asker, a different setup

The asker held constant

THE INSTRUMENT

TOMOGRAPHY	<i>"Did the sample move between projections?"</i>
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PTYCHOGRAPHY	<i>"Was the probe the same across the scan?"</i>
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HOLOGRAPHY	<i>"Were the propagation distances the same?"</i>
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SPECTROSCOPY	<i>"Was the energy calibrated the same way?"</i>
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THE SAMPLE AND THE RUN

IN SITU	<i>"What was the cell doing at this frame?"</i>
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OPERANDO	<i>"Was the device working while we measured?"</i>
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LARGE SAMPLES	<i>"Which tile is this, and how did they line up?"</i>
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THROUGHPUT	<i>"Which of the four thousand runs are usable?"</i>
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Any instrument with any run type in any combination.

The same setup, a different science

Instrument and run type held constant

BATTERIES

"Where did the lithium go, and on which cycle?"

CATALYSIS

"Was the reaction running when this scan was taken?"

BONE AND TISSUE

"Is this feature the specimen, or the preparation?"

PRINTED METAL

"Were these pores there before the load, or after?"

ROCK AND FLOW

"Did the flow path change as the pressure ramped?"

SO FAR

When: before, during, after.

Who: management, staff, users, analysis, software.

Which: every instrument on the floor.

How: every way a run can be shaped.

What: every science those setups serve.

These combinations cannot be listed in advance. Next year's science arrives with questions nobody has written down yet.

Ordinary questions answered today by a person.

How it is answered today

One question recorded in twelve places

THE PROPOSAL

What science was approved and what it aimed to show.

THE SAFETY APPROVAL

What is permitted with this sample and until when.

THE SCHEDULE

Who held the beam that week and in which shift.

THE STORAGE RING

What the source was doing while the frames were taken.

THE CONTROL SYSTEM ARCHIVE

Every value second by second, including that distance.

THE SCAN SOFTWARE

Which scans ran with which parameters into which files.

THE ELECTRONIC LOGBOOK

Detector settings and alignments as they were typed.

DATA MOVEMENT AND STORAGE

Where those files went and what was kept.

THE RECONSTRUCTION

Which settings turned those frames into a volume.

THE ANALYSIS CODE

What the group ran on it afterwards and in which version.

A NOTEBOOK, OR PAPER

What was written down at the time but never typed up.

A PERSON

Why the distance was changed and on which day, often known only here.

A person can complete that join in an afternoon. An agent at three in the morning cannot complete it at all.

Why I built this

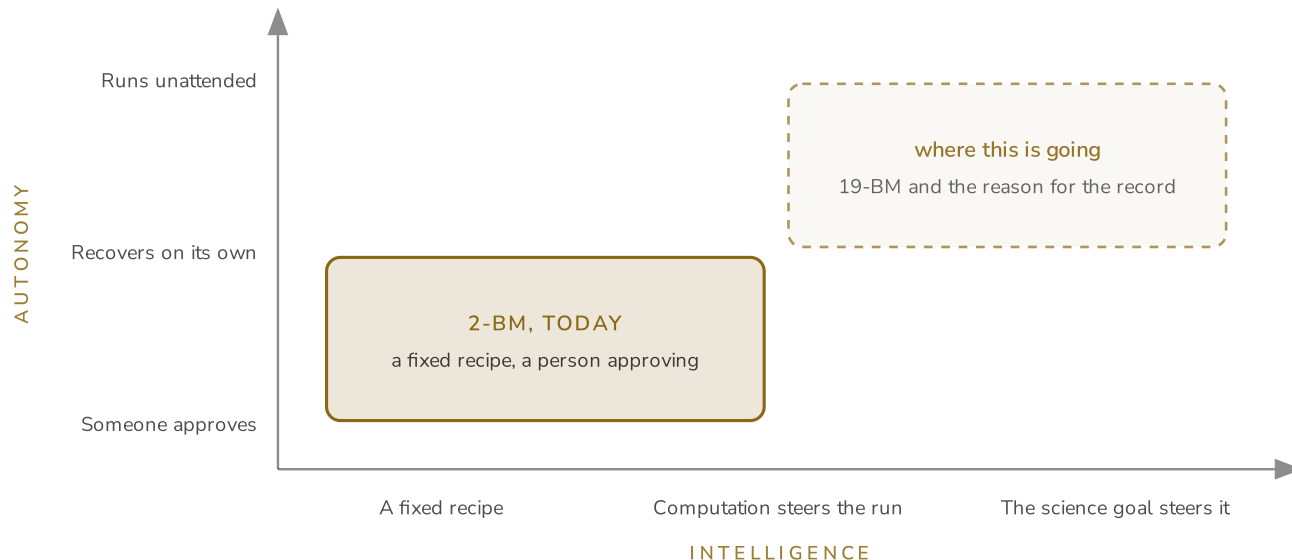
Where I came in

AUTONOMY, THE PREREQUISITE

"An experiment that gets through the night alone has to meet its own failures. What has to be on record for it to recover from them?"

INTELLIGENCE, WHAT IT UNLOCKS

"Once the science goal is steering the run, what has to be on record for the next move to be defensible?"



The machinery

- 1 The questions
What is asked about an experiment.

- 2 **The machinery** YOU ARE HERE
What the record is made of.

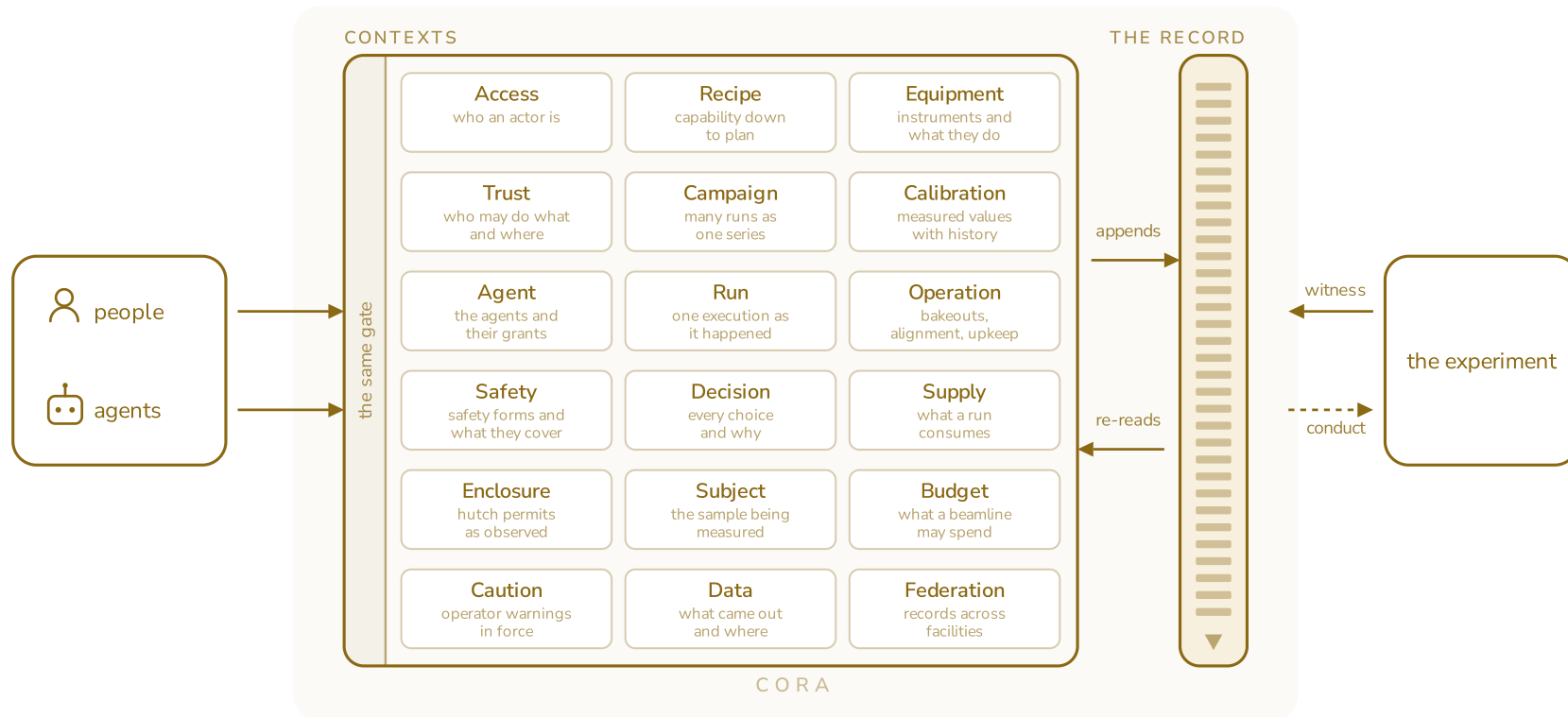
- 3 At a beamline
What runs at 2-BM today.

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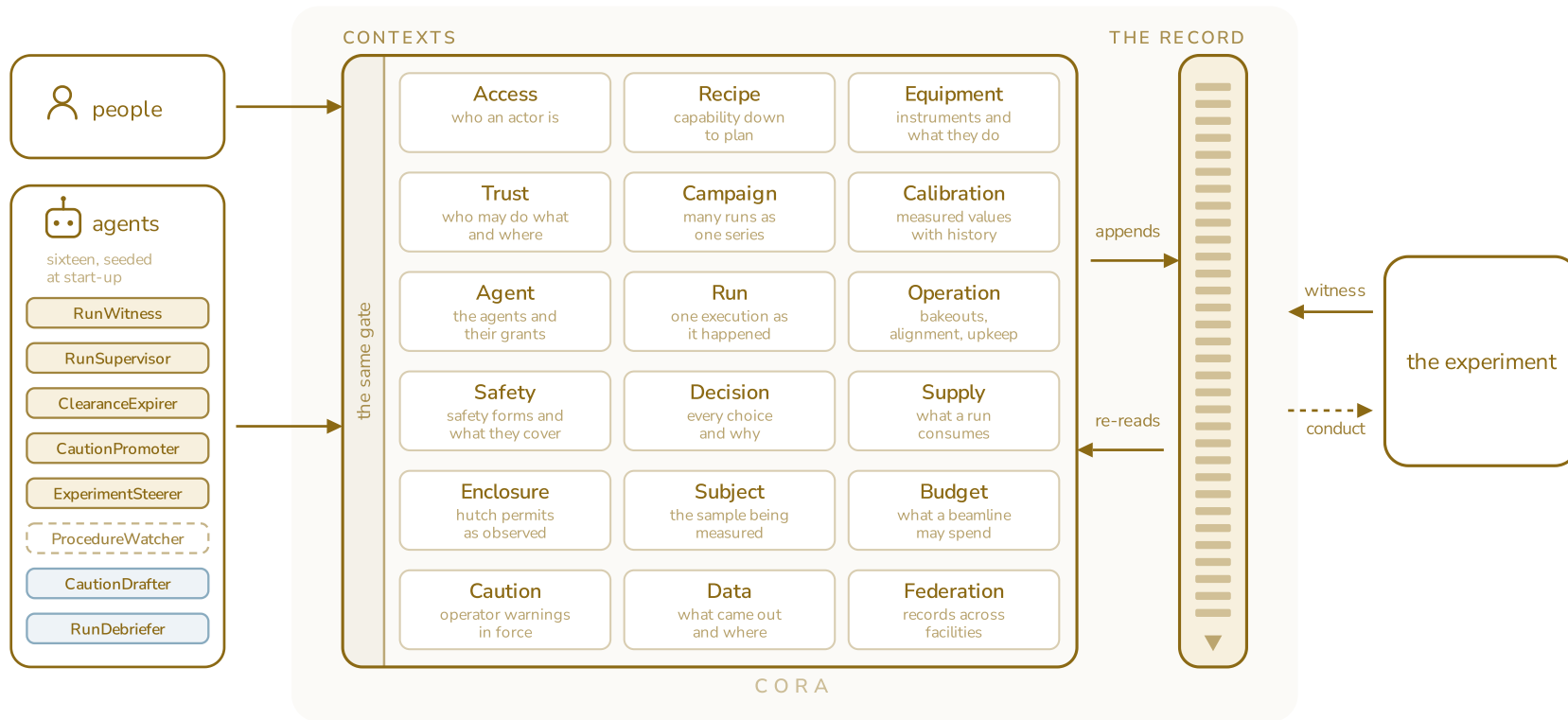
Inside the record

One record across many contexts



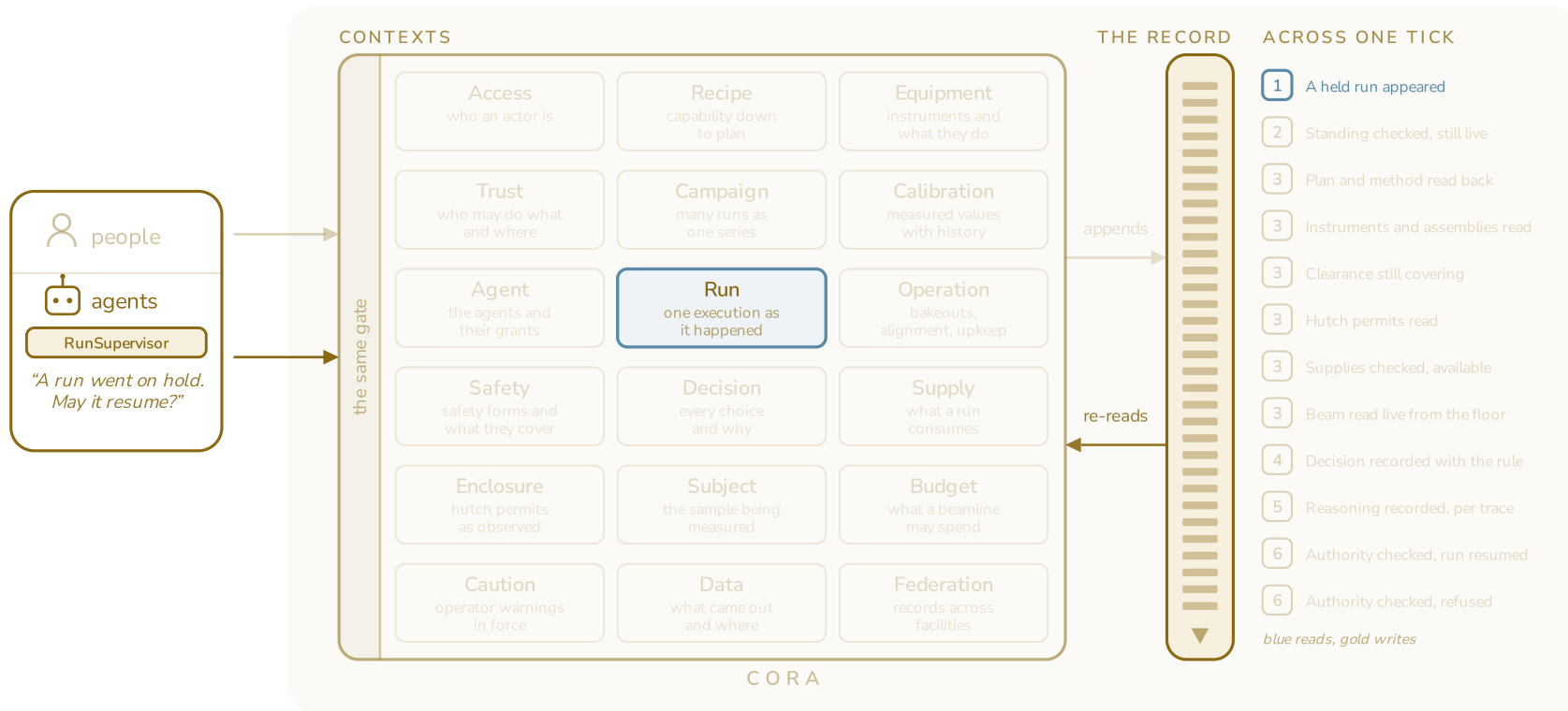
The agents, named

Where people stop and agents begin



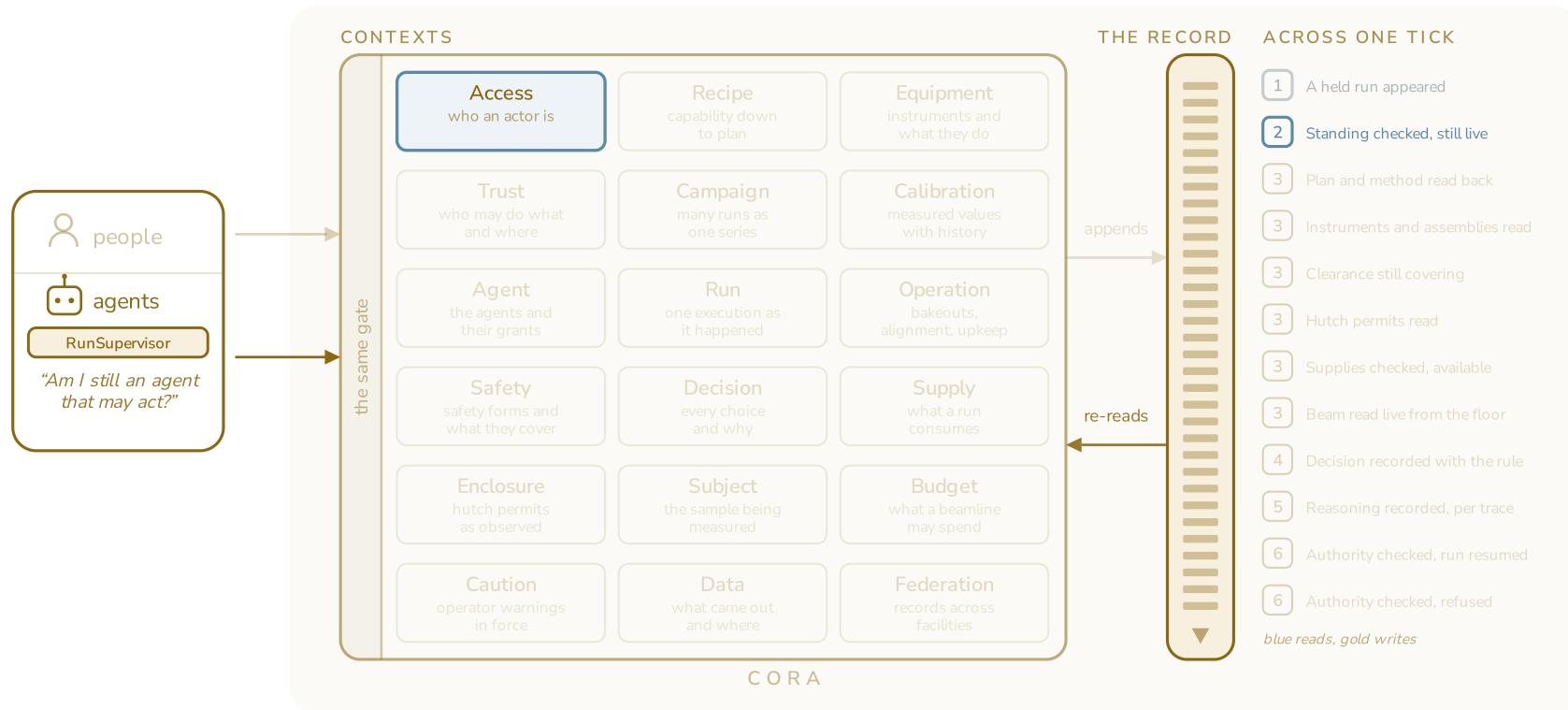
It wakes

One agent is listening for the entry that says a run went on hold



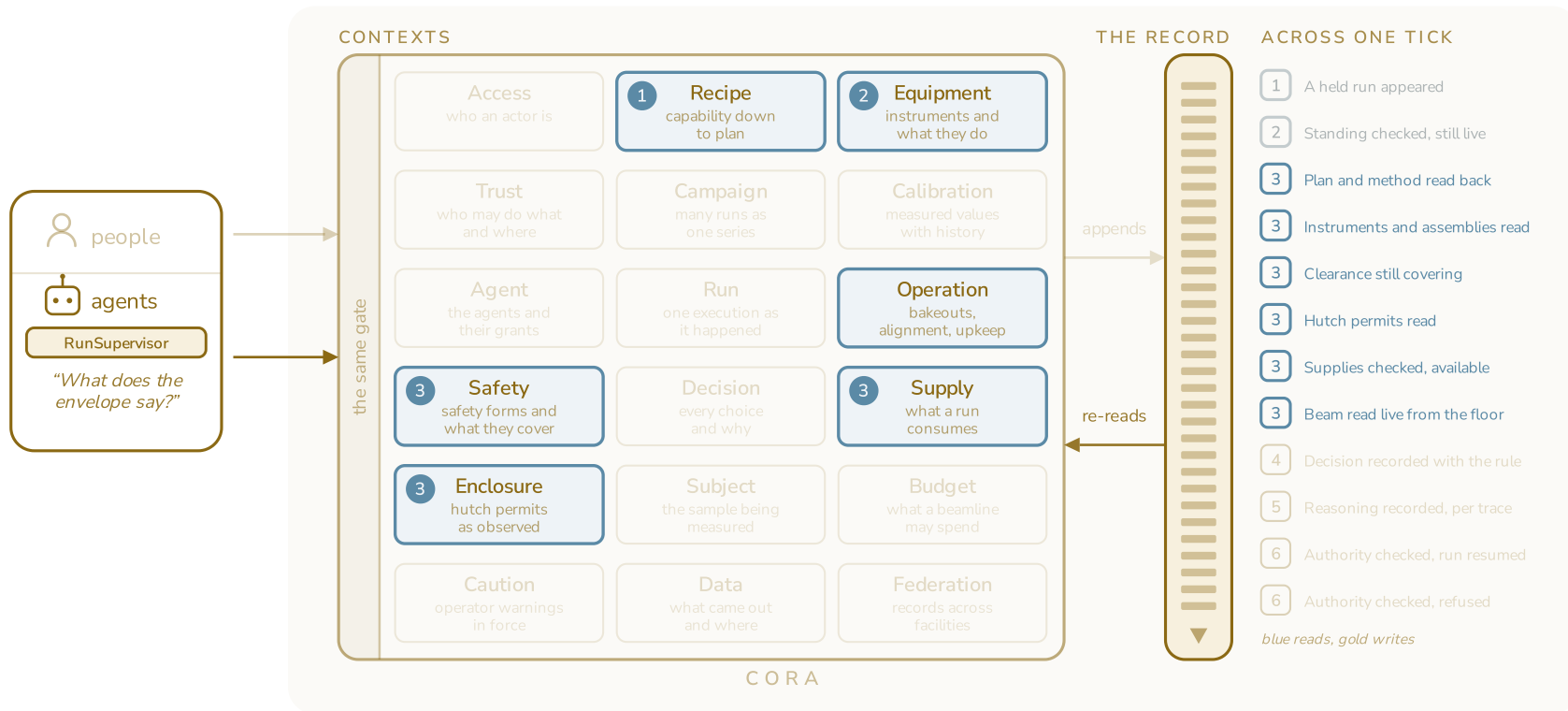
Is it stood down?

It checks first that it may still act at all



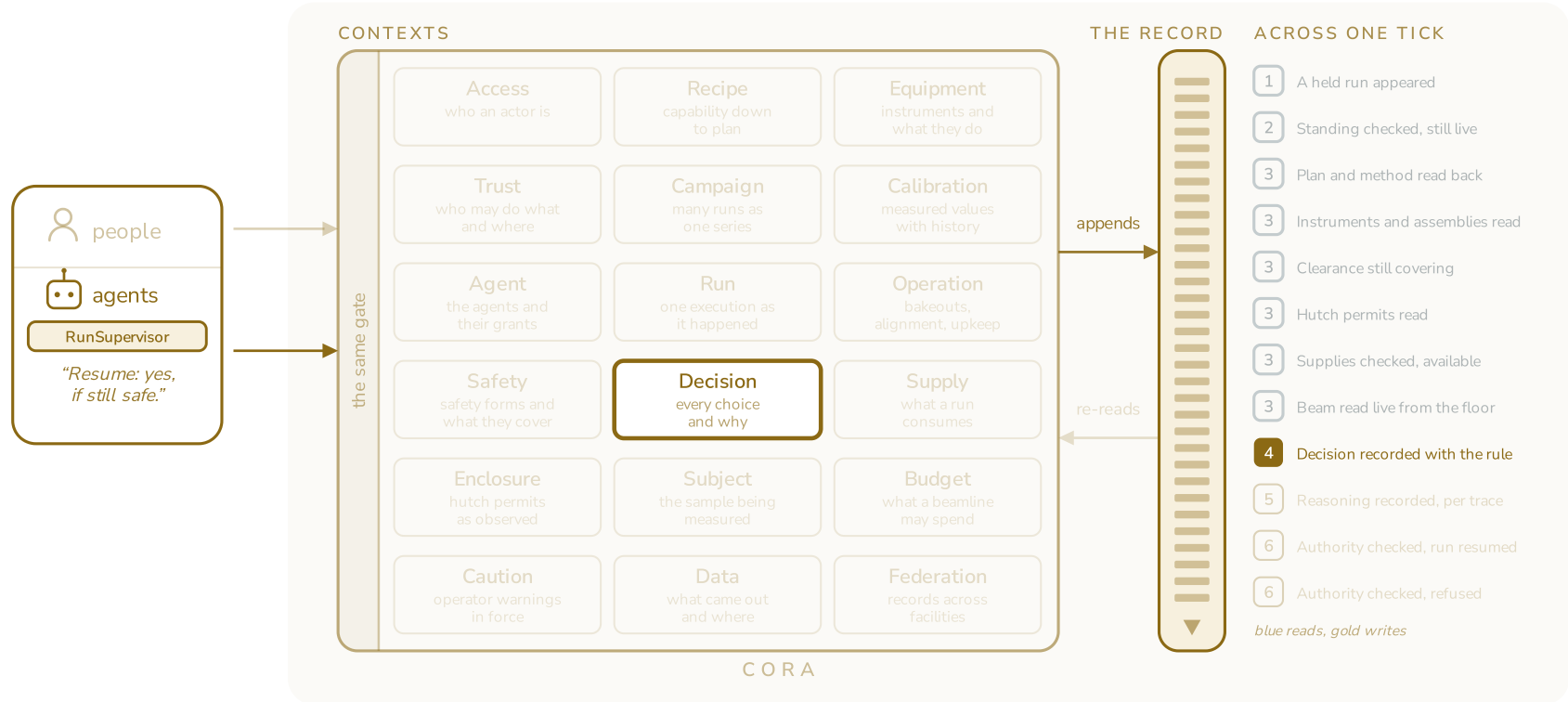
It reads

Six contexts answer without a single entry being written



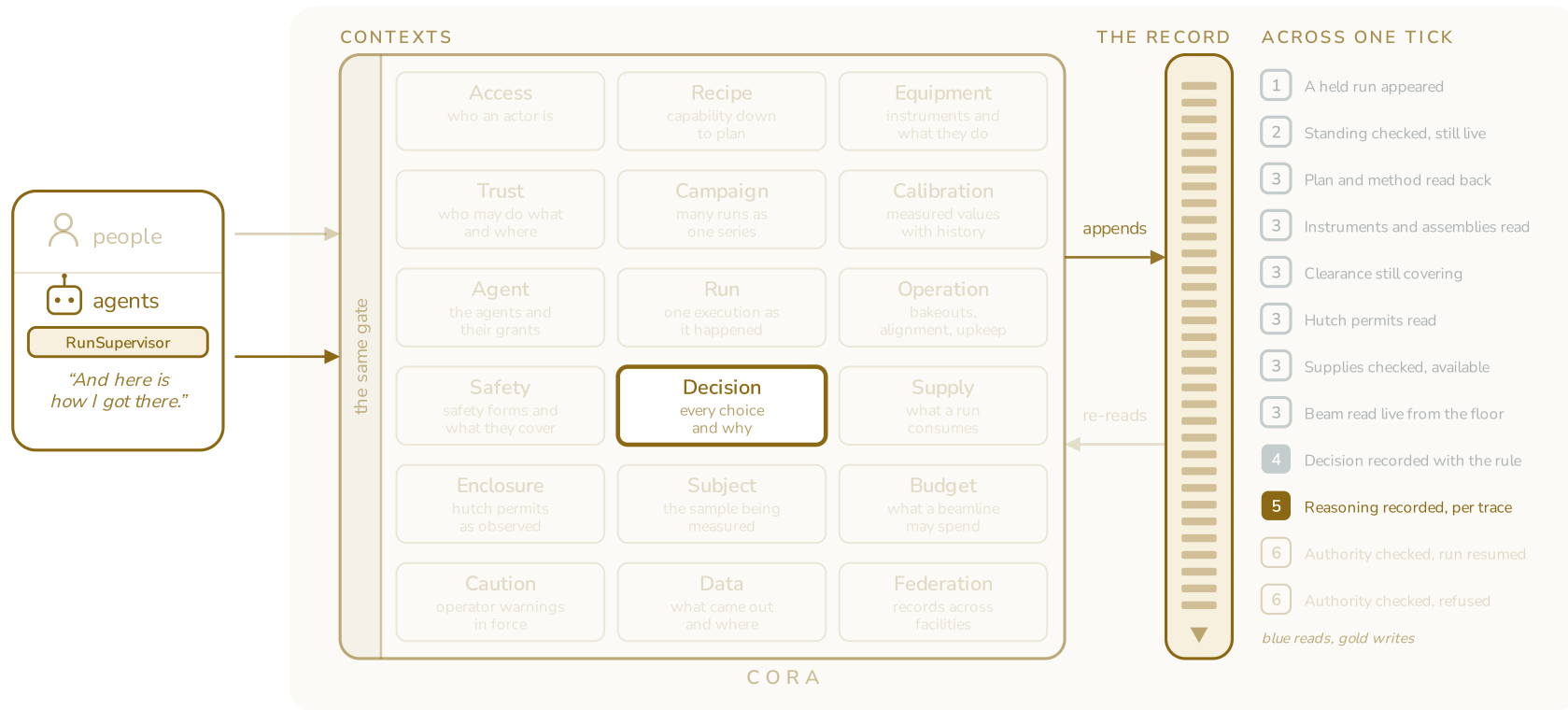
It concludes

The choice is written down before anything is acted on



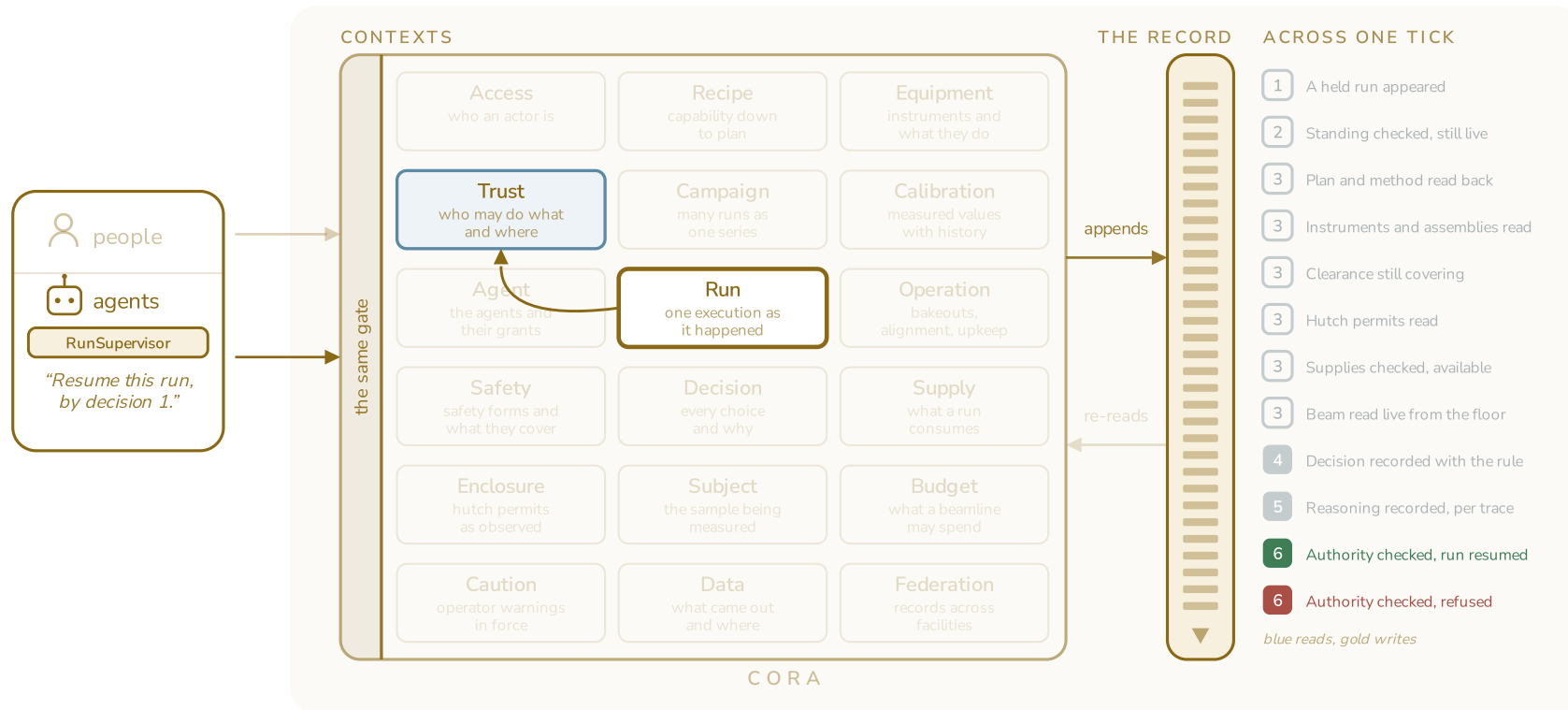
It says why

The reasoning is recorded beside the choice rather than behind it



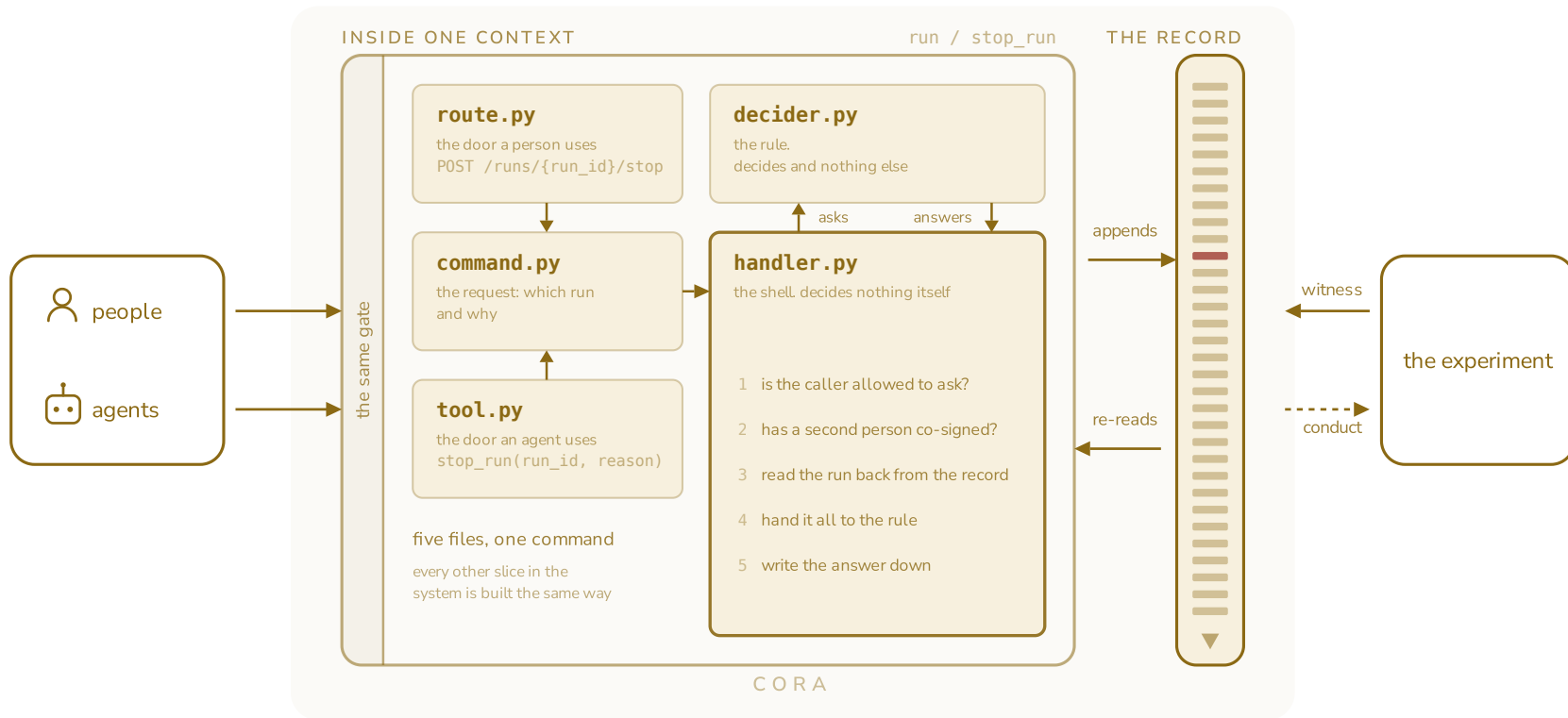
It acts

Through the gate to the one context the command belongs to



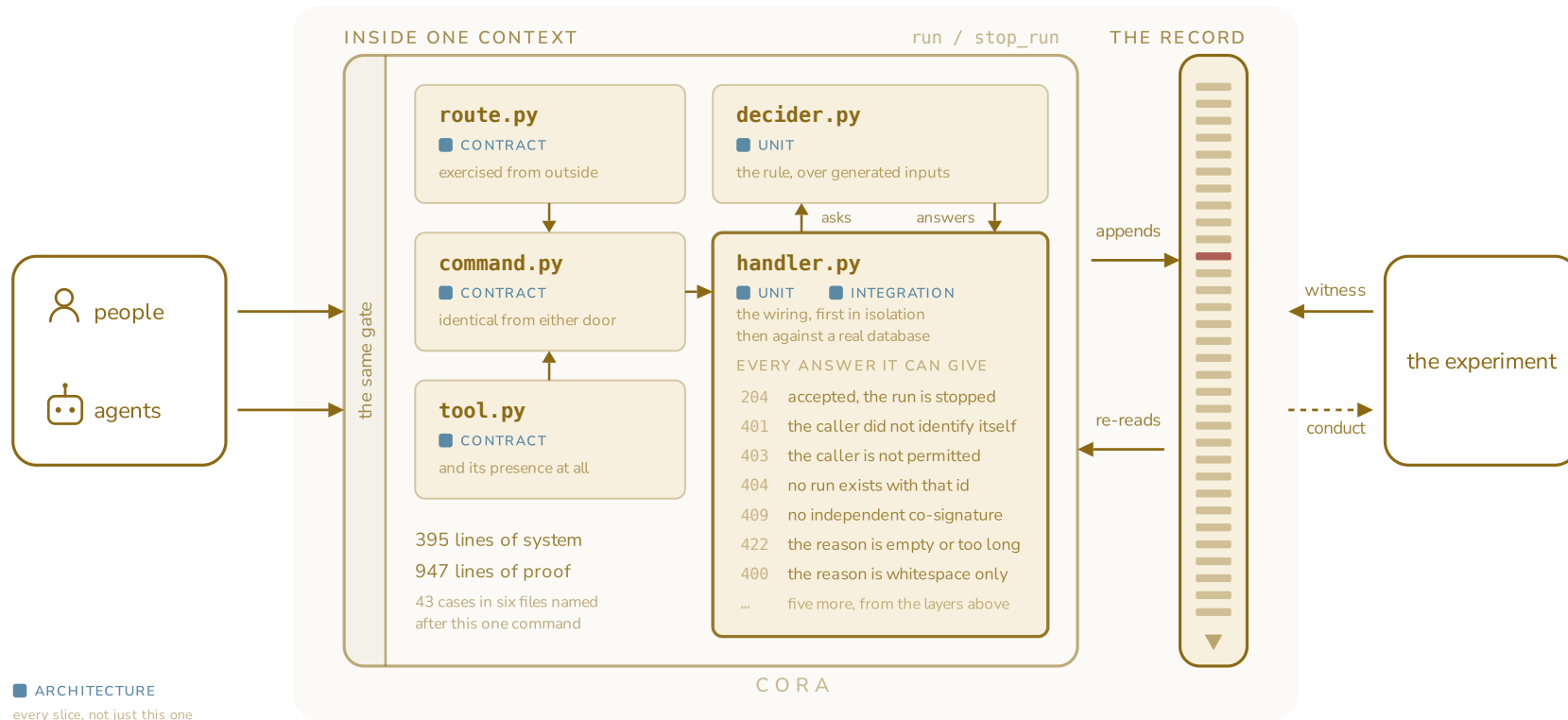
The anatomy of one command

From the door to the record in five files



And how it is proved

The same five files with what pins each one



Every context is built the same way

One slice measured against the whole system

The same slice, now measured. Line counts include docstrings.

run / stop_run

command.py	31
the intent, which run and on what grounds	
decider.py	83
the rule in isolation, neither reading nor writing	
handler.py	138
authorises, checks the co-signature, then appends	
route.py · tool.py	143
two entry points, one handler behind both	

395 lines in total. The system holds **297** such slices averaging about 460 lines. Every context is assembled from nothing else.

THE SYSTEM

310,310 39%



Feature slices, x297	136,020
one folder per command or query, five files each	
Domain internals	124,579
what each context is, shared by all its slices	
Infrastructure, API, kernel	40,836
event store, permissions, database, start-up	
Schema migrations	8,875
171 numbered steps, the database's own history	

THE PROOF

484,129 61%



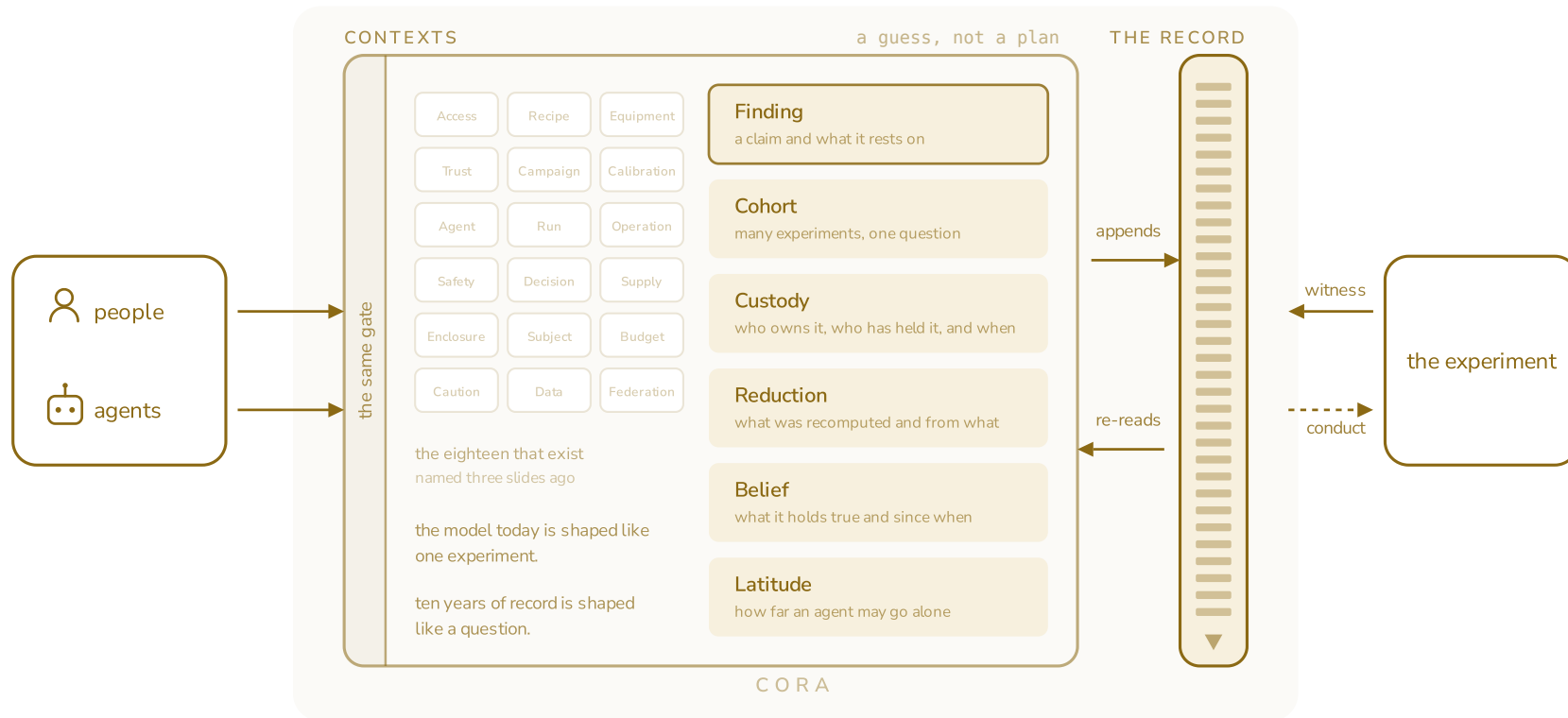
Unit	289,034
one piece alone, no database	
Integration	98,000
several pieces against a real Postgres	
Contract	74,836
both doors tested from outside, REST and MCP	
Architecture + end to end	22,259
the shape of the code, not its behaviour	

1.56 lines of test for every line of system

794,439 lines total. Inline docstrings counted where they live, inside the code.

What a decade would add

Each of these is a question that ten years of record would force



At a beamline

1 The questions
What is asked about an experiment.

2 The machinery
What the record is made of.

3 **At a beamline** YOU ARE HERE
What runs at 2-BM today.

4 Proposed next steps
Where this path goes.



An agent is tuned on history

Autonomy is granted in increments against evidence

IN A DEMONSTRATION

The record is assembled for the agent

The agent is tuned to that record

It is judged on data it helped shape

It begins on the day it is shown

IN A DEPLOYMENT

The record is written by ordinary operation

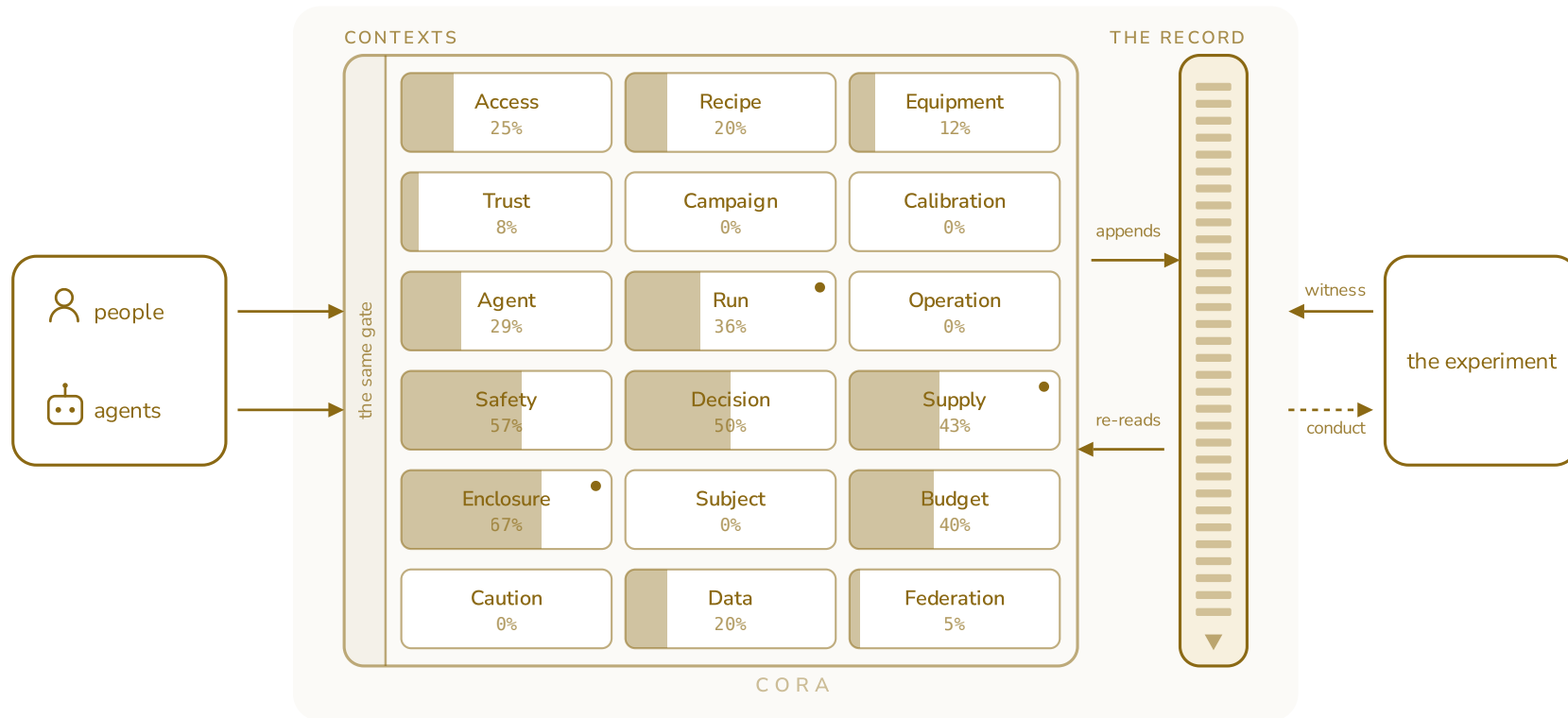
The agent meets what it finds

It is judged on data that predates it

It has been recording since 9 August

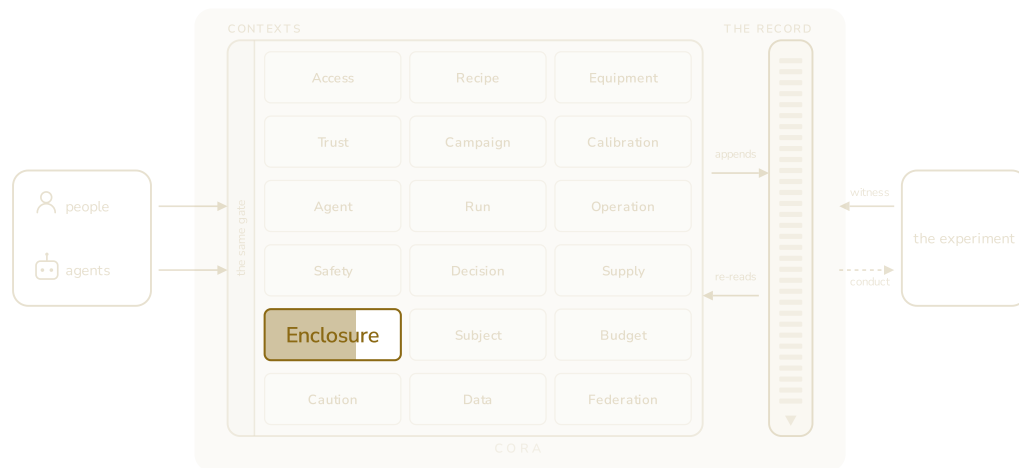
What a deployment means

How much of each context is in use today



Enclosure

The hutch permits as CORA observed them



IN THE RECORD

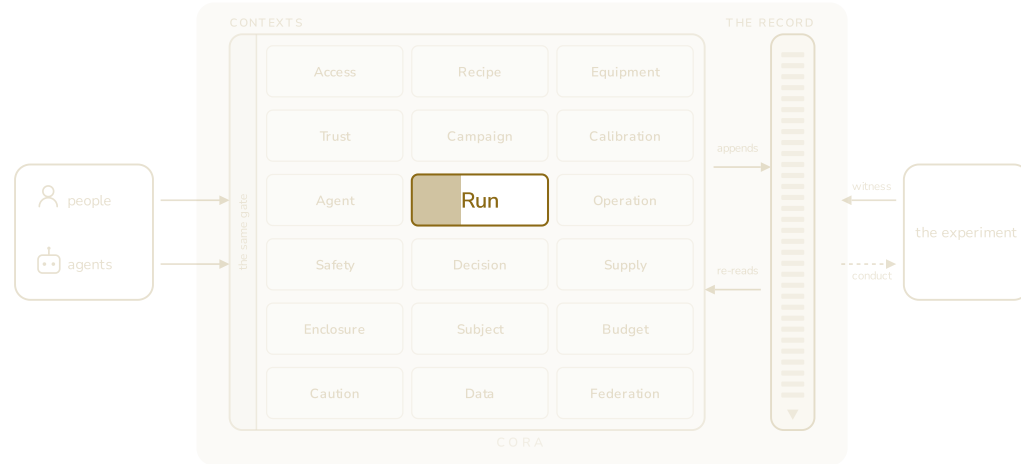
A hutch exists with its two stations	twice, 9 Aug, by hand
The permit reads locked and what said so	86,649, by the interlock

NOT IN THE RECORD

A hutch has been taken out of service	once a decade, if ever
---------------------------------------	------------------------

Run

One execution recorded as it happened



IN THE RECORD

A run started and whose it was	2,024 times
A logbook opened to hold what was seen	1,950 times
A run finished	2,021 times
A run was abandoned	3 times
An agent was asked to explain it	2,190 times

NOT IN THE RECORD

A run was paused and later resumed	CORA would have to drive it
A run was changed, cut short, or halted	CORA would have to drive it
A standing warning was acknowledged	no warning exists to accept
A run joined a series or left one	no series exists to join
What was being measured	the Subject box, 0 of 2,024

Supply

What a run consumes



IN THE RECORD

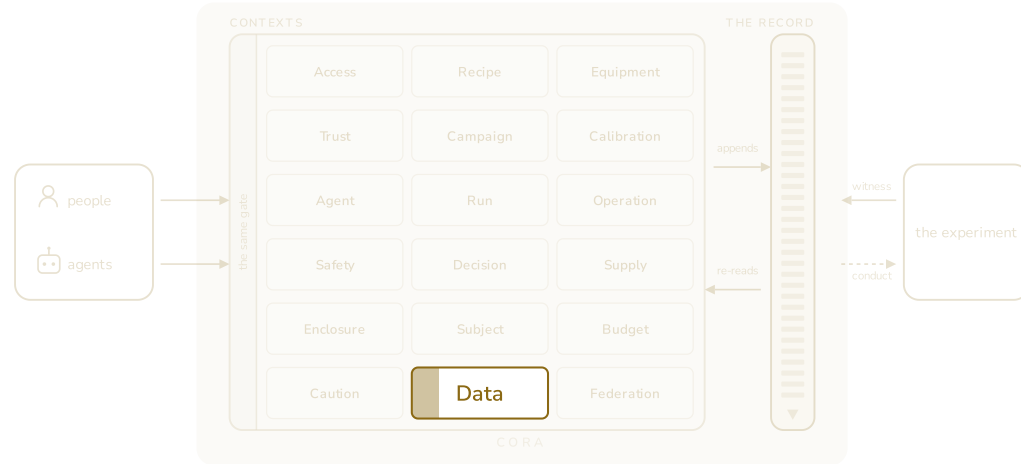
A supply was registered and named	5: water, vacuum, disk
A supply went unavailable	twice
A supply came back	once

NOT IN THE RECORD

A supply was degraded or recovering	the trip bit is yes or no
A supply was restored by an operator	nobody has been asked
A supply was deregistered	none has been retired

Data

What each run produced



IN THE RECORD

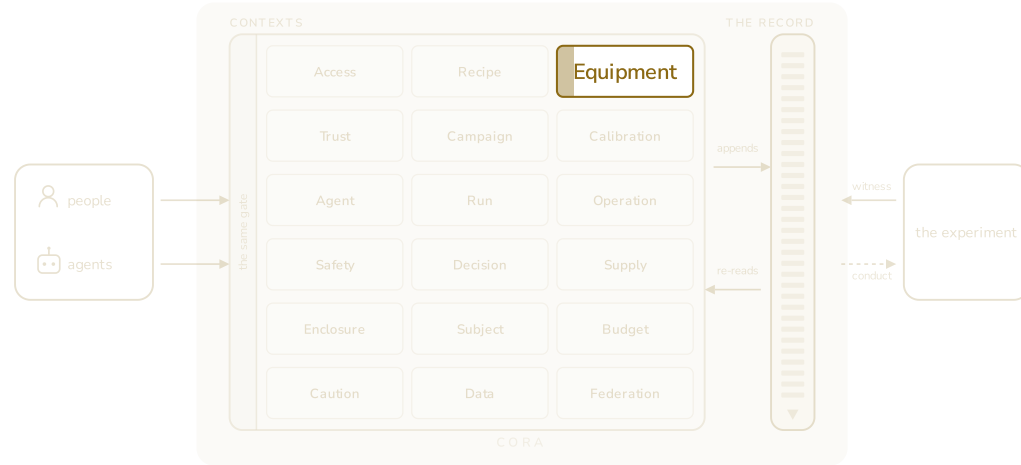
A scan was acquired and what made it	315 times
A dataset exists and this is what it is	315 datasets
A copy exists and this is where it lies	315 copies

NOT IN THE RECORD

A second durable copy was registered	the sweep is on, no beam
A dataset was promoted or discarded	nothing has been judged
An edition was sealed and published	0 of 315 shareable

Equipment

What each instrument can do



IN THE RECORD

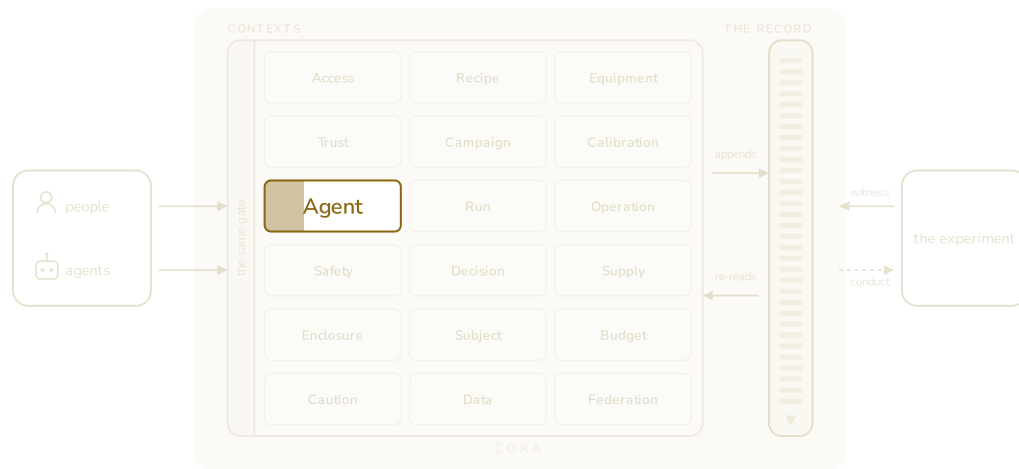
A kind of device was defined (Camera)	46 families
A device was registered (Camera_HighRes)	7 assets
A device was decommissioned	twice
A role was defined (Detector, Positioner)	6 roles

NOT IN THE RECORD

It moved, faulted, or went for repair	none has, yet
Its model, mount, frame or fixture	never materialised
It gained an owner or a citable id	nothing to cite yet
Its settings or its version changed	nothing has drifted

Agent

What each agent may do



IN THE RECORD

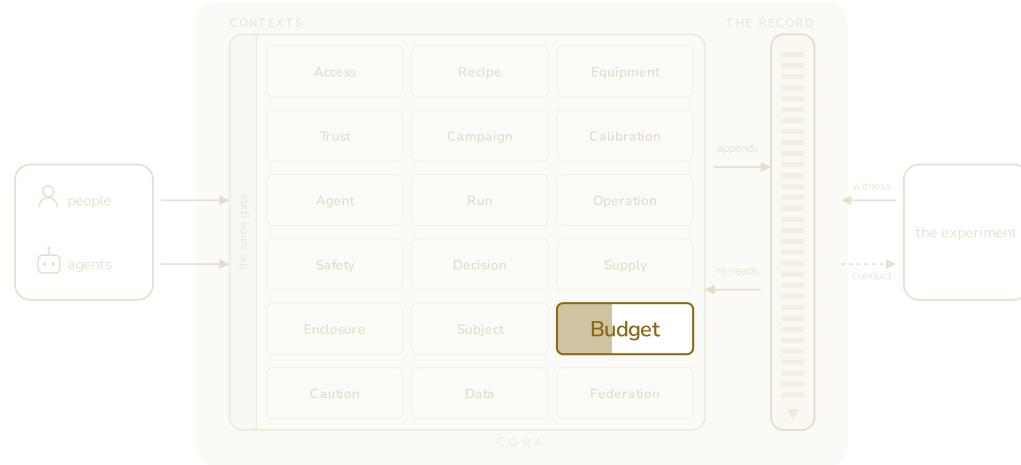
An agent was defined with its limits	20 agents
An agent was given a new version	4 times
A language model was declared	5 models
A model was approved for use here	5 times

NOT IN THE RECORD

An agent was suspended or resumed	nothing has gone wrong
Its budget or its plan was changed	set once, not revised
A tool was granted or taken back	these agents hold none
A model was retired or announced for it	no model has aged out

Budget

What a beamline may spend



IN THE RECORD

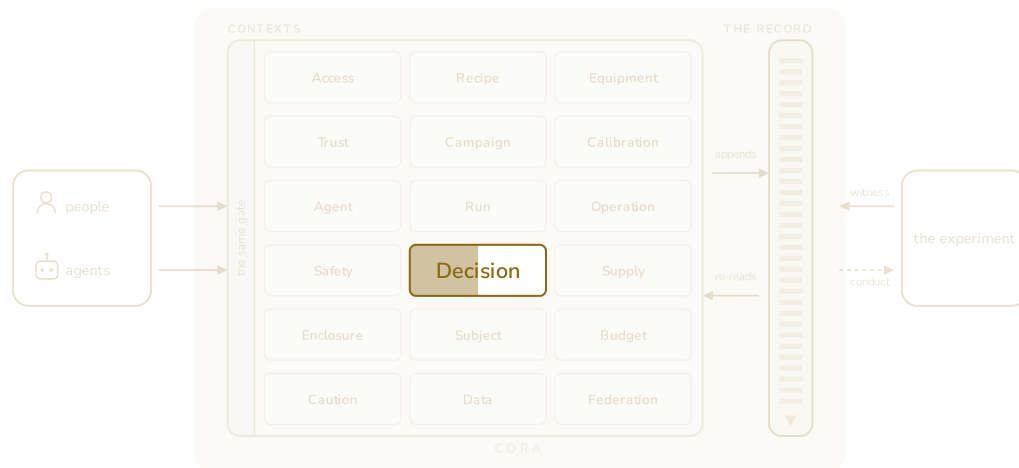
An envelope was granted with a ceiling	25 dollars
The envelope was activated	0.1s later

NOT IN THE RECORD

The ceiling was raised or lowered	never needed
The envelope was voided	never revoked
It was sealed with what it cost	the period has not ended

Decision

Why each choice was made



IN THE RECORD

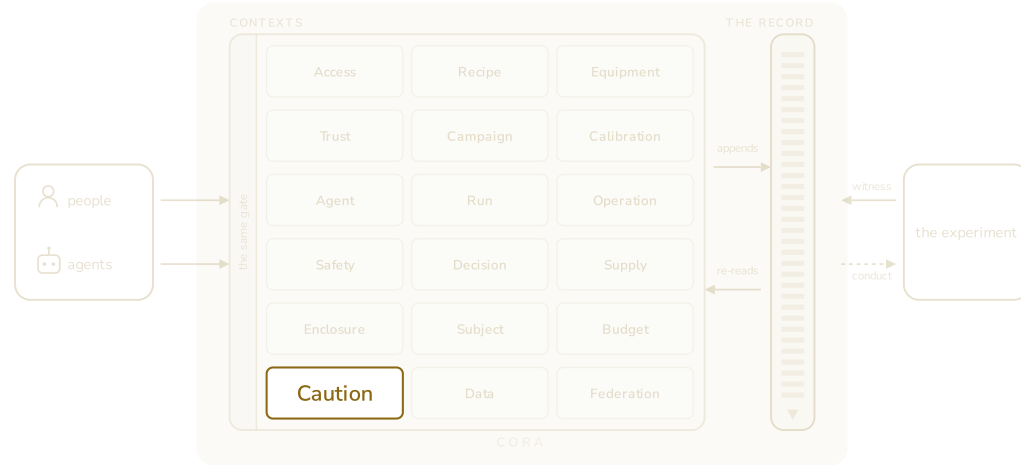
A decision with what it saw and why	2,193 times
A logbook holds the reasoning behind it	2,191 times

NOT IN THE RECORD

Anyone said whether a decision was useful	0 of 2,193
A logbook was closed	nothing writes this yet

Caution

The operator warnings in force



IN THE RECORD

Nothing. This box has never held a single entry.

NOT IN THE RECORD

A warning was registered	6 proposed by CautionDrafter
A warning was retired	nothing to retire
A warning was superseded	nothing to supersede

Deployment is the beginning

Two questions follow from a record that is filling

What else is worth recording?

Is this enough for an agent to do science?

The agents with a model behind them

Both agents run the same model under the same rules

WHAT THEY SHARE

Model	phi-4, run on the beamline's own GPU no text leaves the building
Dials	An output cap each and no sampling settings nothing else was set, so nothing else was recorded
Registered	Five models across three routes the local pool, the laboratory gateway, the vendor
Metering	A monthly dollar cap and a daily token cap priced per token from a vendor, measured in GPU time in house
Standing	An operator can stand either down each reads that before it does anything else
Wakes	On every run that ends both of them, independently
Confidence	A number each states about itself recorded as self-reported, with nothing acting on it

WHAT EACH ONE DOES

RunDebriefer

Reads	The run and the frame counts it declared
Writes	One verdict on that run NominalCompletion, DataSuspect, DegradedCompletion, DebriefDeferred

CautionDrafter

Reads	The run, its plan, and the warnings in force
Writes	One proposal or nothing NoAction, ProposeNotice, ProposeCaution, ProposeWarning, ProposeSupersede



a proposal



approve?

When it started

Francesco asked on 19 August when the missing frames began

“I noticed we had the missing frame problem. It would be good to know when (from which measurement) it started to show up.”

Francesco, 19 August, 12:34:13. Ten seconds later a restart produced a clean run



WHAT IT WAS HANDED

```
run_name · run_status · plan_id · subject_id · campaign_id ·  
terminal_event_type · terminal_event_reason ·  
terminal_event_occurred_at · adjustment_count · effective_parameters  
· frames_saved · frames_saved_expected · frames_collected ·  
frames_collected_expected · reading_age_seconds
```

WHAT IT SAID BACK

“1528 frames saved against an expected count of 1541, leaving a shortfall of 13 frames. The saved frames shortfall suggests possible data loss that warrants further investigation.”

DataSuspect, confidence 0.82

What else the record has answered

It found four faults in software CORA does not own

A scan stopped early still reported that it had finished.

The instrument corrected the record four times

A reading with no clock time was being stored as 1 January 1990.

- - It records its own gaps

For three days the abort signal was unreachable, recorded once per attempt.

The record can be checked by an outsider

Every kind travels with a row count and a fingerprint, even the kinds with no rows.

It cannot change anything at the beamline

There is no code path from CORA to a motor, a shutter, or a detector.

What a deployment needs

The five inputs as each looked at 2-BM

- 1  **Describe the beamline.** One file, source to detector.
- 2  **Say what it may read.** Writing stays off.
- 3  **Name the hutches.** Each with its safety signal.
- 4  **Run it once for APS.** Not once per beamline.
- 5  **Seed, then switch on.** One observer at a time.

DEPLOYMENTS/2-BM/BEAMLINE.YAML

```
- name: Camera
  family: Camera
  model: flir_oryx
  sensor: Sony IMX250 CMOS, 2448 x 2048 pixel
  pv: "2bmSP1:"
- name: Hexapod
  family: Hexapod
  pv: "2bmHXP:"
- name: MirrorTable
  family: Table
  pv: "2bma:table1"
```

Three of 38 devices. The file is 834 lines.

Proposed next steps

1 The questions
What is asked about an experiment.

2 The machinery
What the record is made of.

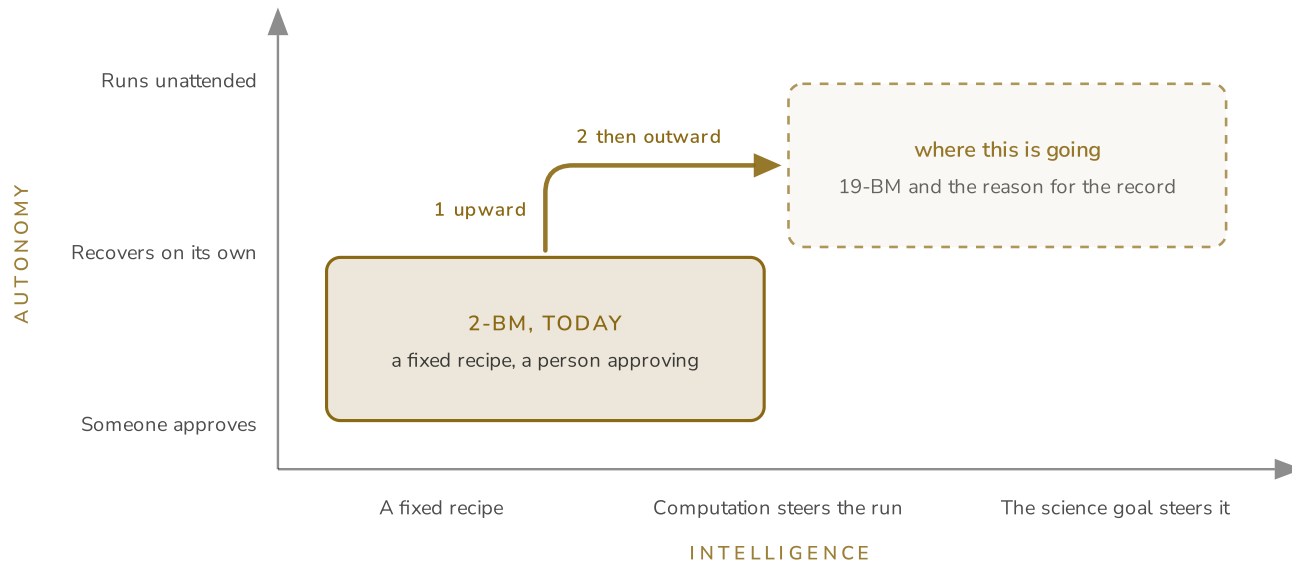
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4 **Proposed next steps** YOU ARE HERE
Where this path goes.



Beyond 2-BM

Upward before outward



1 · UPWARD, AND THIS IS OURS

A record makes an unattended decision authorizable in the first place and reviewable afterwards.

2 · OUTWARD, AND THIS IS A COLLABORATION

Every steering brain is somebody else's work, so CORA offers a single seam for all of them. BoTorch is wired in, and EAA here at APS and gpCAM at Berkeley fit that same seam.

A survey

Two informal series open across APS



Autonomous science

“What would this beamline have to be able to answer before it could run itself?”



Agentic beamlines

“Who is building agents here, what may they do, and who is there when they do it?”

What the record cannot answer yet

“Show me 2-BM and 12-ID side by side, live.”

Designed but not hardened, with no live link between instances.

“Show me the beamline as it was understood last March.”

The model holds it but no endpoint serves it.

“What did CORA decide to do?”

Nothing at 2-BM, where the deployment is read only.

“How did it behave while driving a beamline?”

It never has. That is the most important row on this slide.

So: what would you ask it?

A vintage typewriter is the central focus, positioned on a wooden desk. A sheet of paper with typed text is emerging from the carriage. To the left, a brass desk lamp with a warm glow sits on the desk. Further left, a brown leather suitcase is partially visible. The scene is dimly lit, creating a nostalgic atmosphere. The text "Thank you" is overlaid in white on the left side of the image.

Thank you