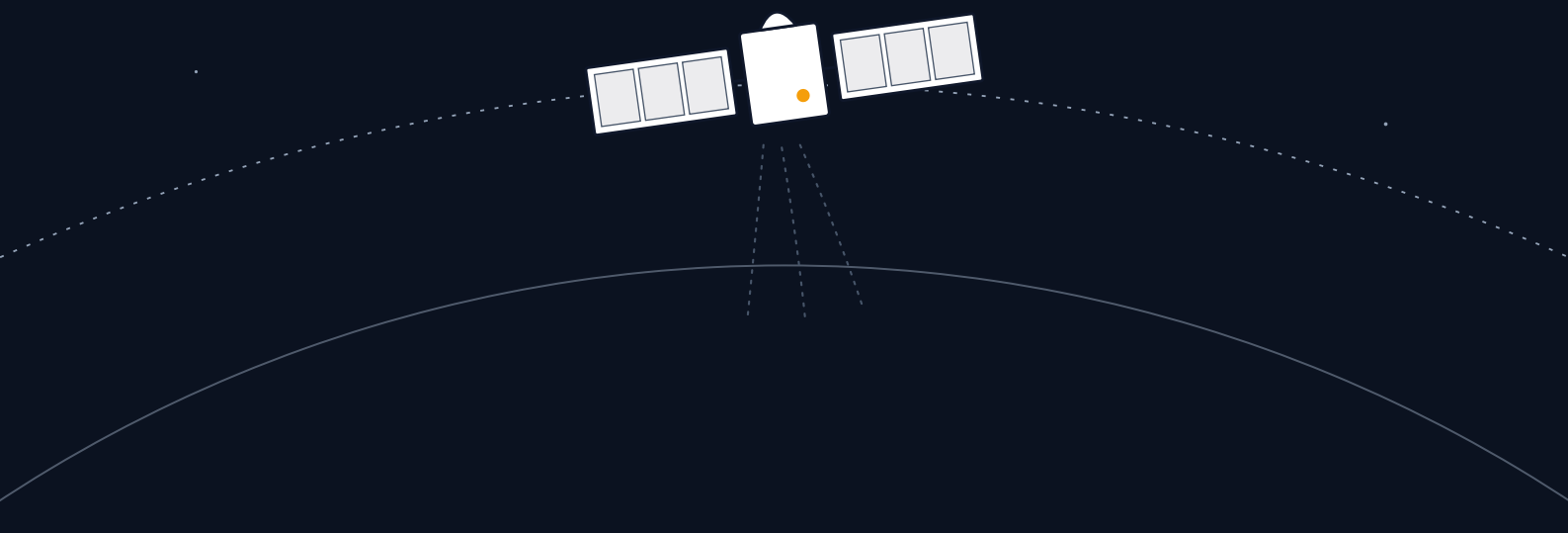
TupleTrace

Your spacecraft is already telling you.

Anomaly detection for spacecraft telemetry that explains every alert, and learns from your operators.



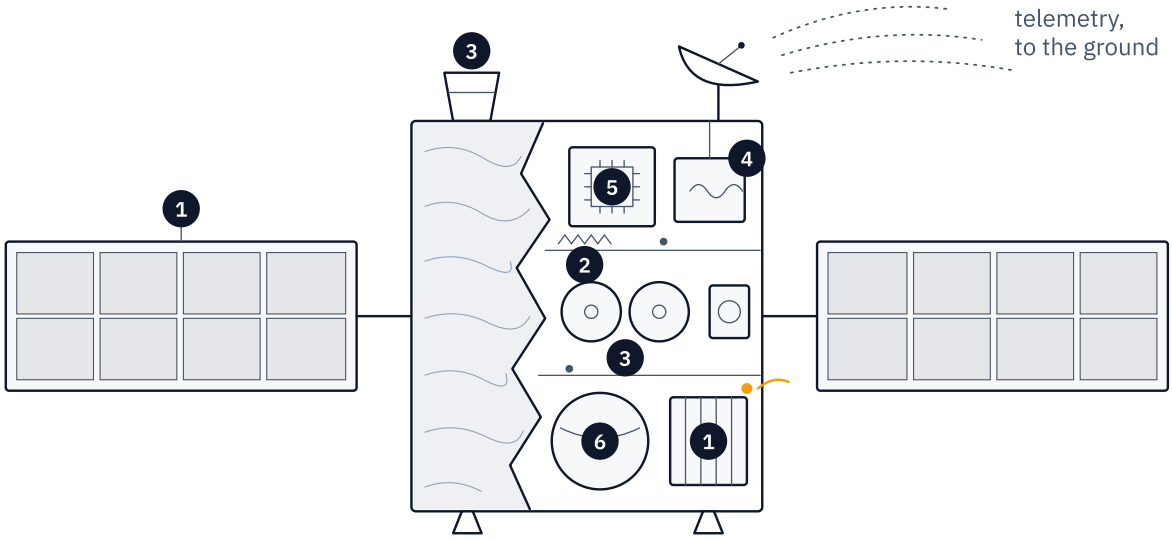
Detection you can audit. Diagnosis you can read.

WHERE THE DATA COMES FROM

A satellite never stops reporting on itself

Every few seconds to a minute, each part of a typical satellite sends readings to the ground: voltages, temperatures, wheel speeds, signal levels. Thousands of parameters, for the whole life of the mission.

This is housekeeping telemetry: the satellite's own account of how it is doing. Everything TupleTrace does starts here.



1 **Power**
Solar arrays and battery: voltages, currents, state of charge.

2 **Thermal**
Heaters and temperature sensors: temperatures, heater duty cycles.

3 **Attitude**
Reaction wheels, gyros, star tracker: wheel speeds, rotation rates, pointing.

4 **Communications**
Radio and antenna: signal levels, link status.

5 **On-board computer**
Memory errors, resets, processor load.

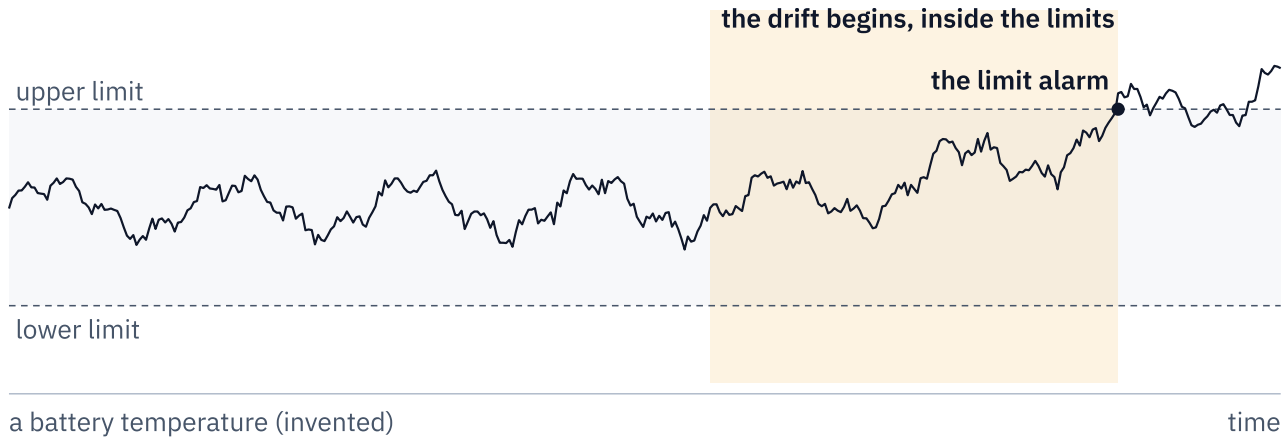
6 **Propulsion**
Propellant tank: pressure, temperature.

Not every platform carries all of these. The amber dot is a battery sensor starting to drift: the next page follows it.

THE PROBLEM

Faults rarely arrive all at once

A heater weakens, a bearing wears, a battery ages. The readings start to drift, often while they are still inside their limits.



An invented example. The limit alarm fires only once the reading crosses the line.

Fixed limits are blunt. Set them tight and they ring all day; set them loose and they speak up late.

Either way, the scarce thing is the same: your operators' time and attention. An alarm that is usually noise teaches people to ignore alarms.

> **What operators need** is to hear about a developing fault early, with a reason they can check, and without being buried in false alarms.

HOW TUPLETRACE WORKS

Four steps, every parameter

TupleTrace sits beside your mission control and watches each parameter on its own terms.



01

Learns what normal looks like

From your own history, for each parameter.



02

Flags what departs from it

Including drifts that stay inside the limits.



03

Explains every alert

What it was compared with, and why it stood out.



04

Learns from your operators

Their verdicts teach it what matters on your mission.

It is advisory: a person judges every alert, and nothing is closed without one.

FEWER, BETTER ALARMS

From about 40 false alarms a week to fewer than one

Measured on two missions of ESA's public anomaly detection benchmark (ESA-ADB), against a fixed alert threshold.



Fixed threshold: 41 to 48 false alarms a week across the two missions. TupleTrace sets a threshold for each parameter instead.

The trade-off is yours to set

Quiet comes at a price, and we say so up front. At its default setting, TupleTrace caught about a third of one mission's anomalies. Turned up, it caught 51 of 55, at about 7 false alarms a week.

Sensitivity is a dial your operators own: as quiet as your team needs, or as watchful as the mission phase demands.

Full results for both missions, every run included, are available on request.

EVERY ALERT EXPLAINS ITSELF

An alert nobody can explain is an alert nobody trusts

Each TupleTrace alert says what its score was compared with, and why it stood out.

For any alert, a triage report: correlated parameters, similar past events and the relevant passage of your documentation, each statement citing its source.

Battery temperature 2 ILLUSTRATIVE

window	One hour, ending 09:00 UTC
why	The window's mean, against its last 30 windows, pushed it towards an alert. Its minimum did the same.
correlated	Heater 2 duty cycle rising over the same days[1]
past events	No similar event in this parameter's history[2]
documentation	Thermal control manual, section 4.2: battery heater control[3]
sources	[1] telemetry, heater 2, last 14 days [2] event history [3] your documentation

Nominal Anomaly

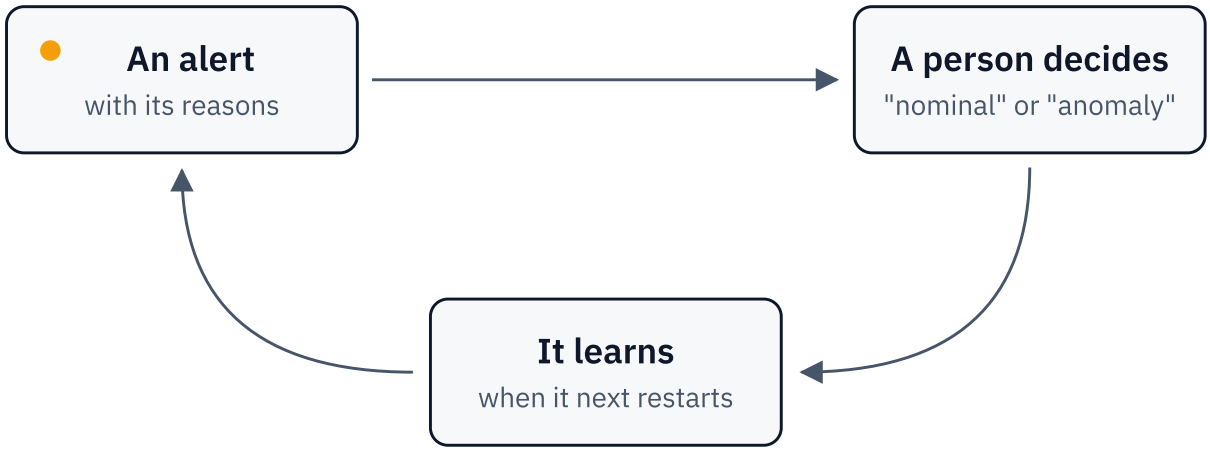
- **Facts are computed.** A language model, running on your premises, only drafts the prose.
- **A person decides.** Nothing is acted on without one.

> Turning the sensitivity up only pays if a false alarm is cheap to dismiss. A reason you can check makes it cheap, and every dismissal teaches TupleTrace something, as the next page shows.

IT LEARNS FROM YOUR OPERATORS

Every verdict teaches it something

Your operators already know which alarms matter. TupleTrace listens.



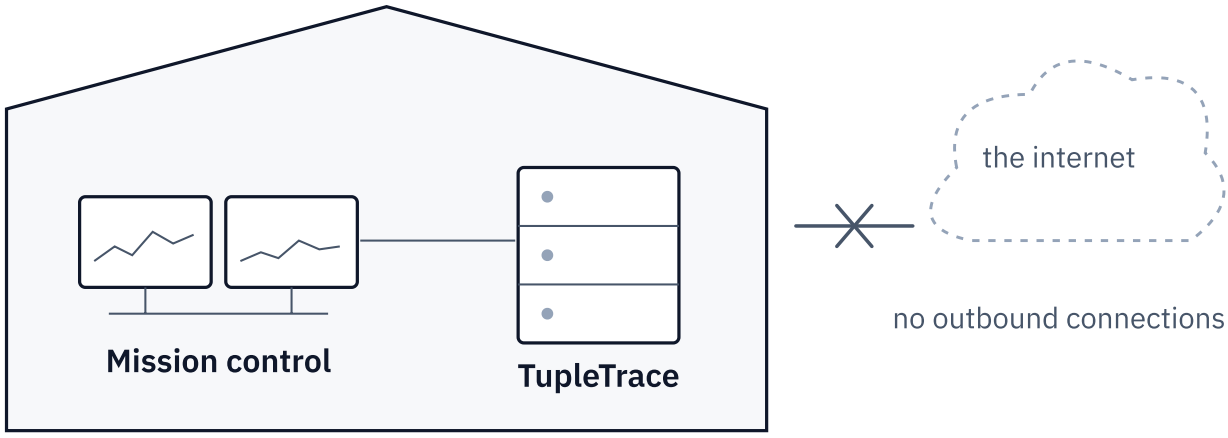
- **"Nominal"** teaches it that this behaviour is normal, so the same thing stops alerting.
- **"Anomaly"** becomes a label for that parameter.
- Each parameter starts without labels, and switches to a detector trained on your operators' labels once it has enough.
- Changes take effect when it next restarts, at a time your team chooses. Nothing is closed without a person.

> The more your team uses it, the more it reflects their judgement about your mission.

BUILT FOR YOUR PREMISES

Your telemetry stays in your building

TupleTrace runs next to your mission control on a single server, air-gapped if you need it.



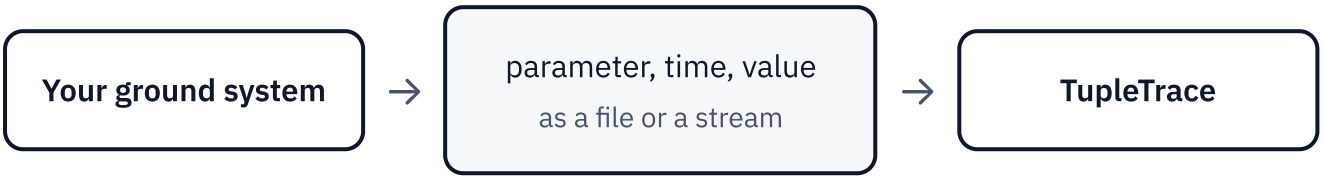
- Installs from one bundle, **verified in one command**.
- **No outbound connections.**
- Your telemetry is **mounted read-only**.
- Every third-party image pinned by digest; the bundle is checksummed and ships with a **software bill of materials**.

It runs on a single server today.

CONNECTING YOUR TELEMETRY

Three things per reading

TupleTrace needs to know which parameter, when, and the value. Any ground system that can export that, as a file or a stream, can feed it.



Connecting your specific system is part of our job.

WHAT IT MEASURES FOR YOU

The numbers your budget asks about

alerts per day

2.6



time to verdict

12 min, median



verdict mix

64% nominal



alerts avoided

35 this week

against your old threshold

hours avoided

23 this week

at your 40 min per investigation

open alerts

1

waiting for a verdict

ILLUSTRATIVE Made-up numbers. "Hours avoided" always uses your own figure for what an investigation costs.

HOW WE MEASURE

In our research we write the test down before running it, report every run, and use public benchmarks under their own rules. The false-alarm figures in this brochure come from studies run that way.

GETTING STARTED

See it on your own telemetry first

FIRST STEP, NO COST

A first look

Two CSV exports from one platform: a normal period, and the window you want looked at. We show what our detection found next to what your monitoring flagged. No commitment, and it can run as a container on your side.

FOUR TO SIX WEEKS

A pilot

One mission, one subsystem, historical telemetry, inside your environment: your telemetry stays on your site. We install, verify, learn normal behaviour from a known-good period, run, and review the results with your operators.

WHAT YOU GET

Evidence you can check

The system running, a findings report (each episode, its evidence, against your limits) and a review session.

AFTER THAT

Live

A live connection to your telemetry, with your operators' verdicts teaching it as they go.

Want to see it on your telemetry?

Tell us about your mission, and we'll set up the first look.

tupletrace.com/#contact

Contact form

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