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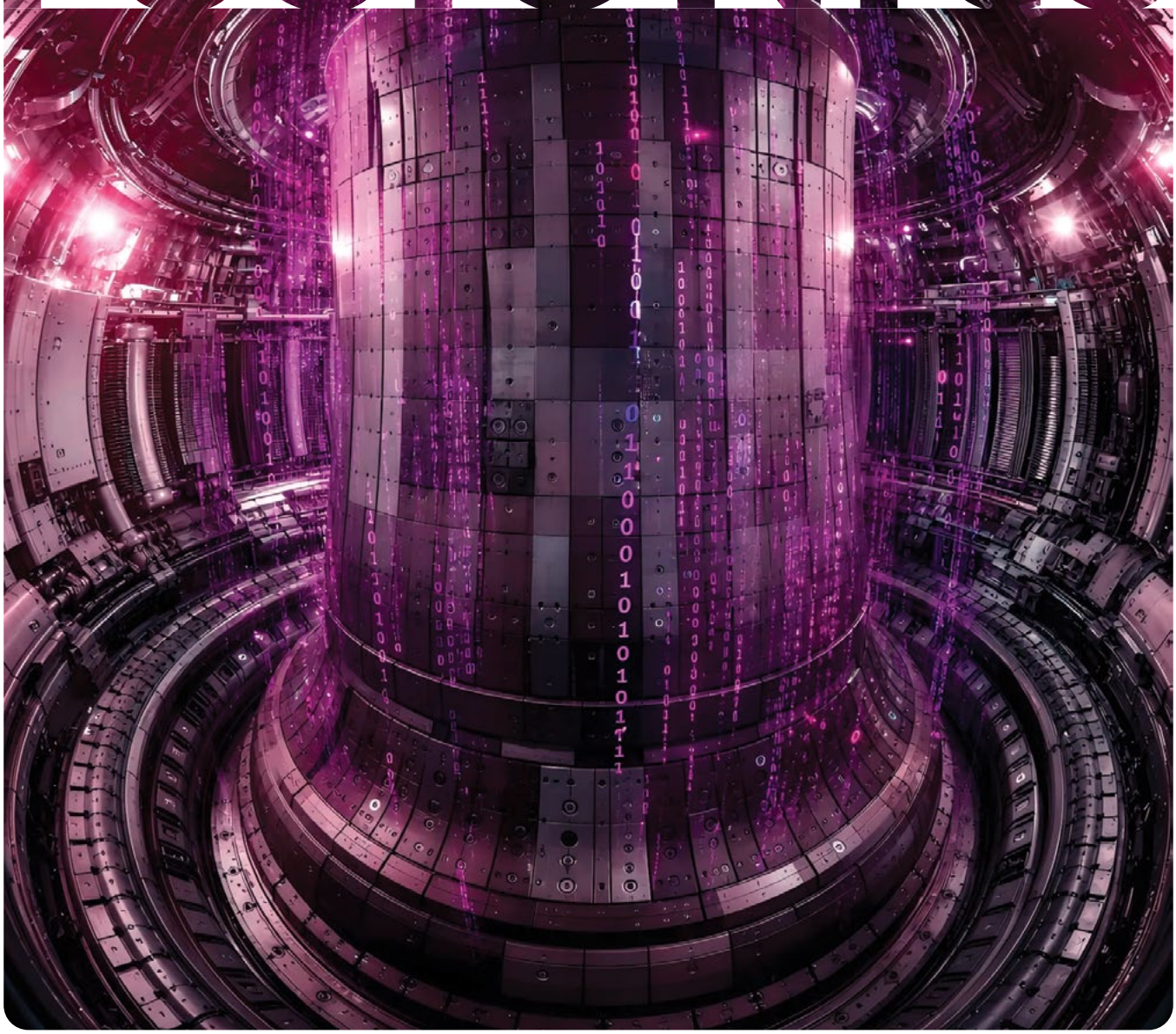
A strategic whitepaper by Cosylab

FUSIONICS



The Control Backbone for Commercial Fusion

How operational discipline, not just physics,
will determine which fusion programmes reach industrial scale

A Note on Terminology

Fusionics is an initiative originated by Adam Stephen at the UK Atomic Energy Authority (UKAEA) to establish the control, protection, and operation of fusion machines as an engineered industrial discipline — what avionics is to aerospace. Its scope is broad, spanning standardisation and solutions across the full fusion control domain. Cosylab has worked alongside UKAEA, over an extended period, on the Instrumentation & Control (I&C) part of that scope. This whitepaper concerns that I&C work specifically — and for brevity uses *Fusionics* throughout to refer to the I&C platform described here, rather than to the wider initiative.

Executive Summary

Fusion programmes worldwide are advancing from laboratory experiments toward integrated prototypes and, increasingly, toward pilot and pre-commercial facilities. As the machines become more advanced, the programmes face a risk that is widely underestimated: the Instrumentation and Control (I&C) infrastructure is not keeping pace with the physics and engineering ambition.

By "fusion control," people, especially magnetic confinement ones, often mean the plasma control system — the real-time algorithms that keep the plasma stable. Those algorithms are the customer's IP, and our platform does not own them: it is the controls backbone they run on — the I&C infrastructure that coordinates every plant system, synchronises timing, archives data, and connects the operator to the machine. This backbone is not the differentiating IP of a fusion company, but it is a necessary condition for operating it safely, repeatably, and credibly. When it is built too late, assembled ad hoc, or treated as a project afterthought, the consequences arrive as integration problems, commissioning delays, fragile operations, timewise uncorrelated data, and a control stack that cannot scale with the programme.

Fusionics is Cosylab's response to that risk. It is a software-first fusion plant I&C platform — designed, built, and maintained by Cosylab, and grounded in the co-development of the overall concept with UKAEA. It is structured as a staged product line — Editions E1 through E4 — that grows with the customer from a first diagnostic testbed to a commercially operated facility. Each edition addresses the operational needs of a specific stage of machine maturity, without requiring the customer to rebuild the I&C programme at each transition.

Fusionics is designed for fusion facilities of all types — magnetic and inertial confinement, as well as other emerging approaches. The platform addresses the operational challenges that are common across these modalities: coordination, timing, data integrity, safety interfaces, and repeatable operation.

This whitepaper explains why the I&C challenge is a genuine business risk, what Fusionics offers at each stage, and what senior decision-makers should consider when planning their programme's control infrastructure. Whatever stage your programme is at, Cosylab's aim is to work from your machine, your goals, and your timeline — and to keep your physics and control IP firmly yours.

1. The Business Challenge: Fusion Programmes Are Underinvesting in Operability

The private fusion sector has matured substantially. Capital is flowing, physics milestones are being set, and timelines are being stated publicly. What has not kept pace is the facility control layer: the systems that make a fusion machine actually runnable as a facility, not just as a physics experiment.

This gap is not caused by negligence. It is caused by a structural bias in how fusion programmes are built. Founding teams are, by design, strong in plasma physics, engineering, and machine design. The I&C layer — the software and integration infrastructure that coordinates every plant system, synchronises every diagnostic, enforces operating procedures, captures data, and connects the operator to the machine — is rarely the team's first priority.

The result is a pattern that repeats across the sector:

- I&C is assembled late from heterogeneous components, open-source tools, and custom scripts.
- Plant systems are individually controlled, but facility-wide orchestration is weak.
- Shot or pulse operations depend on tribal knowledge rather than being repeatable, documented and automated procedures.
- Data quality suffers from timing inconsistencies and incomplete archiving.
- When the machine grows in complexity, the control stack does not grow with it.

Key takeaway:
The I&C problem does not prevent physics breakthroughs in the short term. It prevents commercial scale. Investors, procurement officers, and industrial partners who are evaluating fusion programmes for longer-term commitments are increasingly aware of this.

2. Why This Matters Now

The fusion sector is entering a phase where the commercial question is becoming as important as the technical question. Programmes that have demonstrated physics results are now being evaluated on whether they can operate reliably, scale to a pilot plant, attract industrial partners, and manage long-term operational risk.

In that context, a fusion programme's I&C infrastructure is no longer a purely engineering decision. It is a commercial readiness signal.

Several specific pressures are making this relevant now:

Investor and technical due diligence scrutiny is increasing. Technical due diligence teams are beginning to look beyond physics claims at whether the machine can actually be operated safely, repeatably, and sustainably. A fragile or ad hoc control stack is a visible risk factor.

The transition from prototype to pilot plant is a known failure point. Many programmes discover at this transition that the control stack they built for a laboratory prototype cannot scale to a more serious facility without a significant rebuild. That rebuild is expensive, disruptive, and often arrives at exactly the wrong moment in a programme's funding cycle.

Industrial partners and procurement channels require operational credibility. Utilities, industrial integrators, and government procurement channels are not prepared to engage with a fusion programme that cannot demonstrate disciplined, auditable machine operations.

The talent pressure is real. Fusion programmes cannot afford to have their best engineers absorbed by I&C plumbing, integration cleanup, and lifecycle maintenance. Every engineering hour spent rebuilding custom controls infrastructure is an hour not spent on the machine itself.

Decision-maker question:
At what point in your programme's growth does I&C debt begin to affect schedule, credibility, or partnership readiness?

3. Inside the Fusionics I&C Platform

Fusionics is a software-first fusion plant I&C platform — designed, built, and maintained by Cosylab, and grounded in the co-development of the overall concept with UKAEA.

It is a staged commercial product line, designed to be installed, supported, upgraded, and extended.

At its core, Fusionics is built around the Coordination Platform — the software layer that manages process variables, alarms, operational sequences, operator interfaces, and the integration of all plant systems into a coherent, operable machine. This is where the technical heart of the product sits.

Surrounding the Coordination Platform, Fusionics productises the integration with the other essential building blocks of a modern fusion I&C system:

- **Plant System Controllers** — the local control systems for magnets, vacuum, heating, diagnostics, cooling, power, gas injection, and safety systems
- **Data Archiving and Storage** — pulse/shot metadata, configuration history, time-series data, alarms, waveforms, and export pathways for physics analysis
- **Timing System** — synchronisation and event distribution
- **Machine Protection System** — monitored through constrained, non-overridable interfaces
- **Real-Time Plasma Control Engine** — integrated as a semi-autonomous building block
- **Network Infrastructure** — deployment patterns, zone separation, and access control

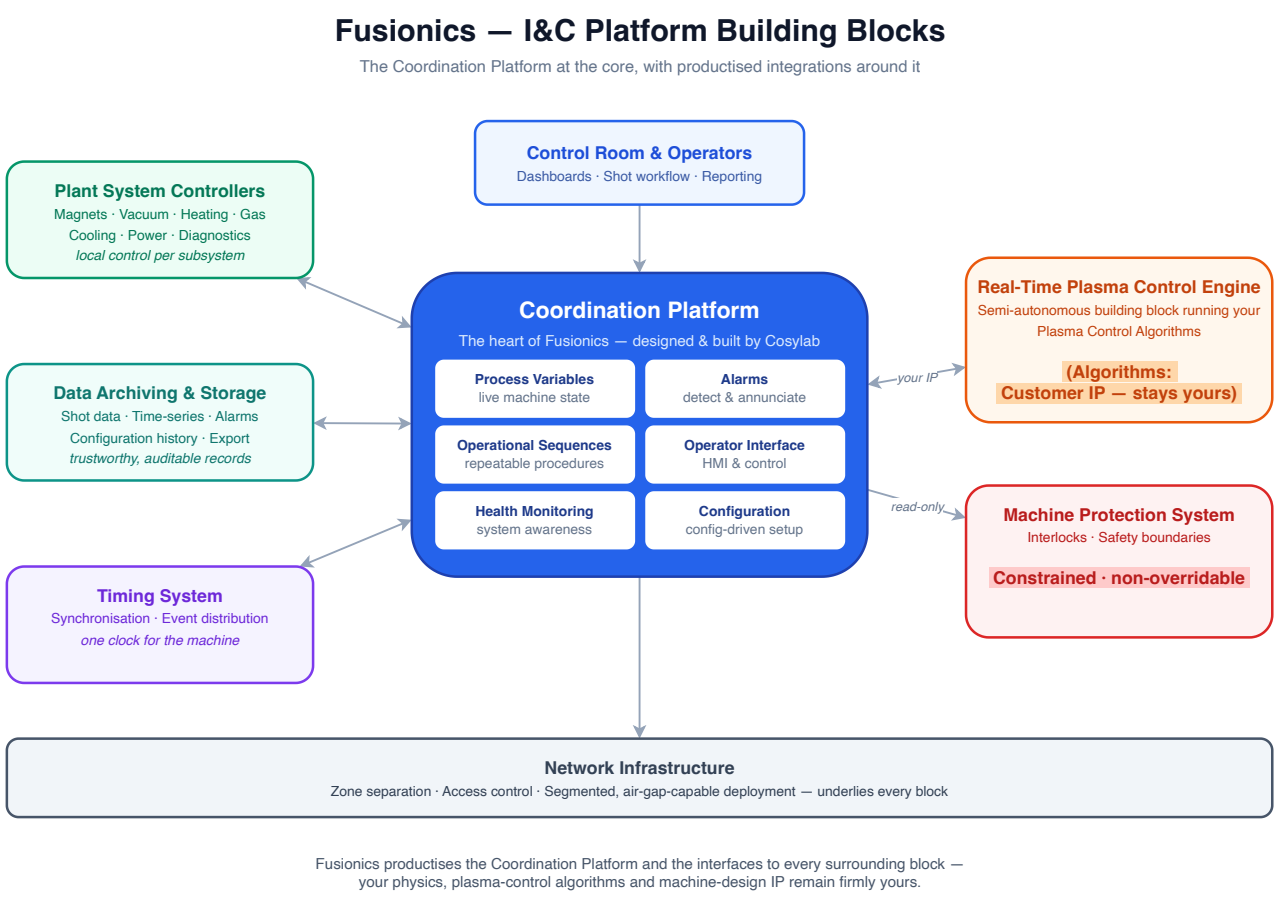


Figure 1: *The Fusionics I&C platform — the Coordination Platform at the core, with productised integrations to every essential building block*

Safety scope. The Fusionics safety architecture addresses both machine protection and personnel safety boundaries. The platform interfaces with primary safety and machine protection systems through constrained, non-overridable channels — receiving status, permissives, and events — without owning or replacing the primary safety implementation. Personnel protection, environmental safety, and machine protection all sit outside the Fusionics operational layer and are treated as inviolable constraints that the platform respects and monitors.

Boundary with adjacent tools. Fusionics is designed as an open operational platform. It does not replace modelling, simulation, digital twin, or AI-assisted tools that programmes increasingly rely on. Instead, it defines the interfaces through which those tools connect to the live I&C system — providing the operational data they need and receiving the setpoints or configurations they generate. This connection is intentional and supported, not an afterthought.

Plant-level boundary. The precise scope of I&C at the facility boundary — which plant systems fall within the platform's integration perimeter and which remain outside — is defined per programme.

Fusionics does not attempt to own the customer's proprietary physics algorithms, laser internals, or machine design IP. It productises and standardises the interfaces and operational layer that allow those proprietary elements to seamlessly connect to the I&C system.

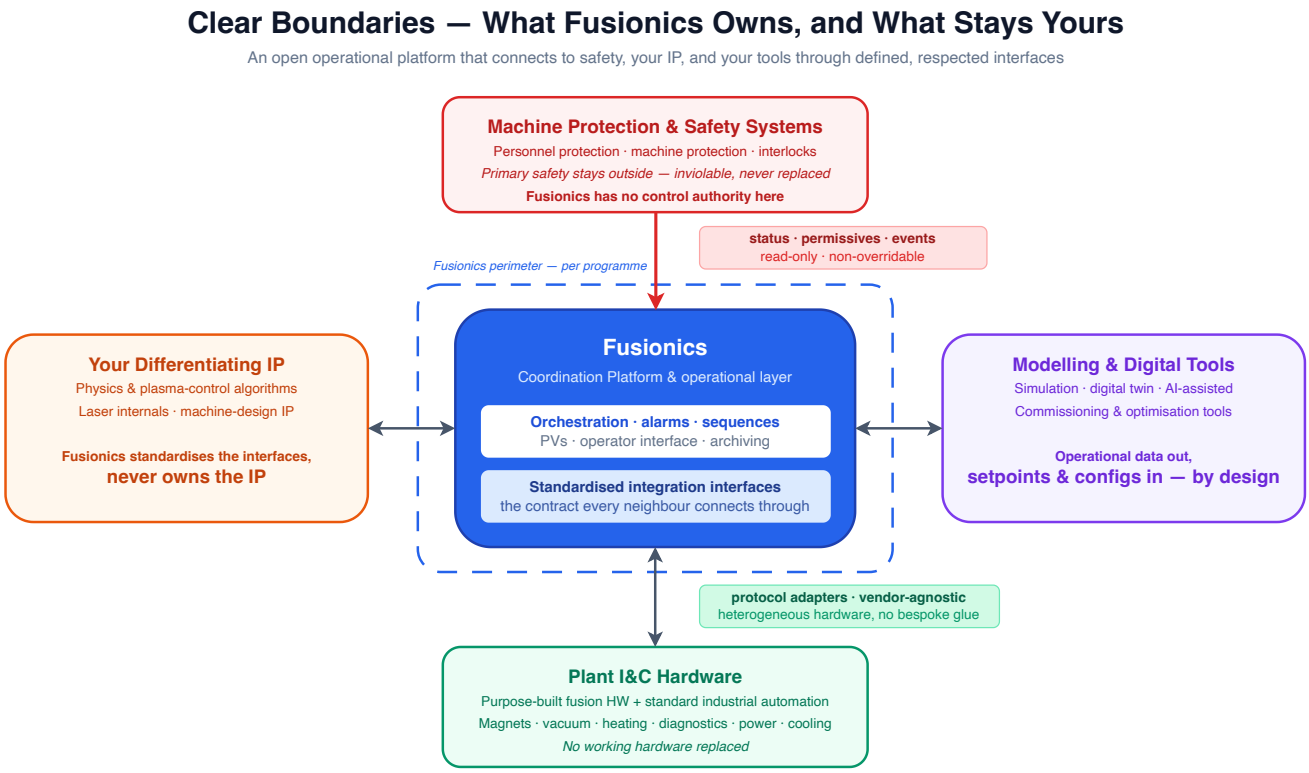


Figure 2: *Clear boundaries — primary safety is monitored through read-only, non-overridable interfaces; customer IP and digital tools connect through standard interfaces and stay under customer ownership*

Key takeaway:

A fusion company's competitive advantage lives in its physics and machine design. Fusionics gives that advantage a platform to operate from — without taking it over.

4. The Product Roadmap: Editions E1 to E4

Fusionics is structured as a single product line with four editions. Each edition addresses the needs of a specific stage of machine maturity. The critical commercial property of this structure is continuity: a customer who starts on Edition E1 does not need to abandon the platform to move to E2, E3, or E4. The platform grows with the programme.

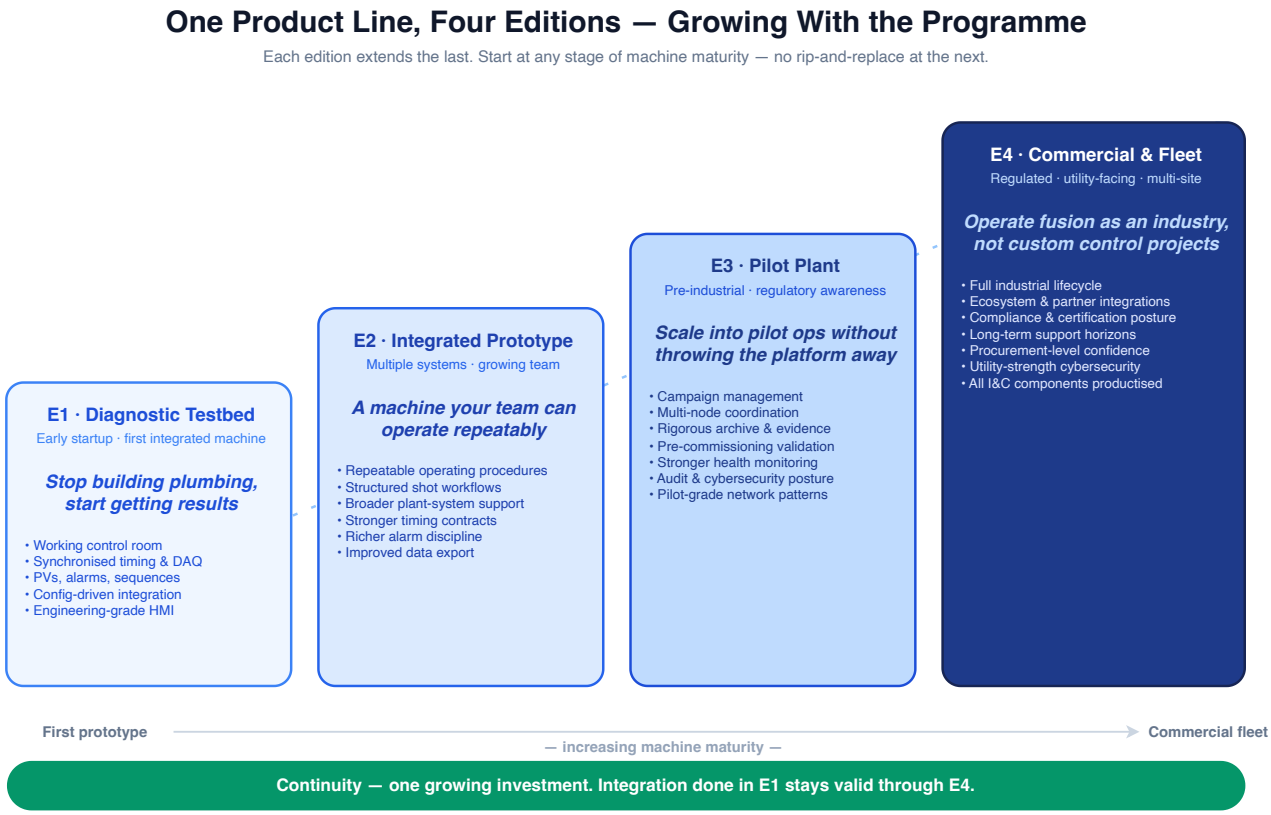


Figure 3: *One product line, four editions — each edition extends the last as the programme matures from first prototype to commercial fleet*

Edition E1 — Diagnostic Testbed and First Integrated Prototype

Target stage: Early-phase startup, first diagnostics, first integrated machine.

What the customer needs at this stage:

- A working control room that produces trustworthy results.
- Centralised control of the whole plant
- Synchronised timing and data acquisition.
- A faster path from hardware assembly to usable experimental operation.

What E1 delivers: A foundational I&C platform covering process variable management, basic alarm handling, sequence execution for startup and pulse/shot operations, and an operator interface sufficient for engineering-grade use. This provides a way to stop depending on ad hoc scripts and isolated tools.

Differentiating capability — configuration-driven integration: A key feature of E1 is the ability to connect new plant systems and define operational behaviour through structured configuration rather than bespoke software development. This significantly reduces the time and engineering effort required to bring a new facility online. It also ensures that integration work done in E1 remains valid and extensible into later editions — the customer is not starting over as the machine grows.

> **Core value proposition:**
> Stop building I&C plumbing and start generating credible experimental results.

Practical implication: Investors and technical reviewers increasingly expect a fusion startup to demonstrate that it can operate its machine systematically. E1 provides that foundation without requiring the full industrial infrastructure that only becomes relevant later.

Edition E2 — Integrated Prototype and First Serious Machine Operations

Target stage: Multiple plant systems online, growing team, rising operational expectations.

What the customer needs at this stage:

- Repeatable operating procedures that do not depend on one expert.
- Structured pulse/shot workflows.
- Broader and more standardised plant system integration.
- Stronger data quality and post-pulse/shot reporting.

What E2 delivers: Expanded operator workflows, richer alarm and sequence discipline, broader support for the full range of

fusion plant system families, complex timing sequences, and improved data export for physics analysis workflows.

Core value proposition:
Turn a first-of-a-kind machine into a facility your team can actually operate repeatedly.

Key takeaway:
The transition from heroic engineering — where one person knows how the machine works — to systematic operation is a significant organisational and commercial milestone. E2 is designed to enable that transition.

Edition E3 — Pilot Plant and Pre-Industrial Operation

Target stage: More formal operations, more personnel, more scrutiny, more regulatory awareness.

What the customer needs at this stage:

- Scaling without rip-and-replace.
- Stronger operational assurance and resilience.
- Better validation before changes touch hardware.
- A stronger auditability and cybersecurity measures.

What E3 delivers: Campaign management, stronger multi-node coordination, more rigorous archive and evidence capabilities, improved pre-commissioning validation capability, stronger health monitoring, and network infrastructure patterns appropriate for a pilot-grade facility.

Core value proposition:
Scale into pilot operations without throwing away the platform you already built around.

Decision-maker question:
Many fusion programmes find at the prototype-to-pilot transition that the control stack they built for the laboratory cannot grow with them. What is the cost to your programme of discovering that at the wrong moment?

Edition E4 — Commercial, Regulated, and Fleet-Ready Operation

Target stage: Commercial plant operators, utility-facing deployments, multi-site programmes.

What the customer needs at this stage:

- Industrial lifecycle behaviour.
- Ecosystem interoperability and approved partner integrations.
- A compliance and certification posture.
- Long support horizons.
- Procurement-level confidence.
- Utility-strength cybersecurity.

What E4 delivers: A fully industrialised version of the platform covering all I&C components, production deployment patterns, long-term lifecycle support policies, compliance-facing evidence, and an approved ecosystem model for hardware and integration partners.

Core value proposition:
Operate fusion as an industry, not as a chain of custom control projects.

Key takeaway:
Commercial operators and utilities will not procure a laboratory script collection. They will procure a supportable operating platform with a credible architecture, a defined lifecycle, and named accountability. E4 is that platform.

5. Four Principles That Underpin the Commercial Case

1. Continuity

Every edition of Fusionics extends the previous one. The customer does not face a forced migration when the machine matures. This is not a small commercial benefit. The alternative — rebuilding the I&C infrastructure at each maturity stage — is a recurring cost, a recurring schedule risk, and a recurring distraction. Fusionics replaces that pattern with a single, growing investment.

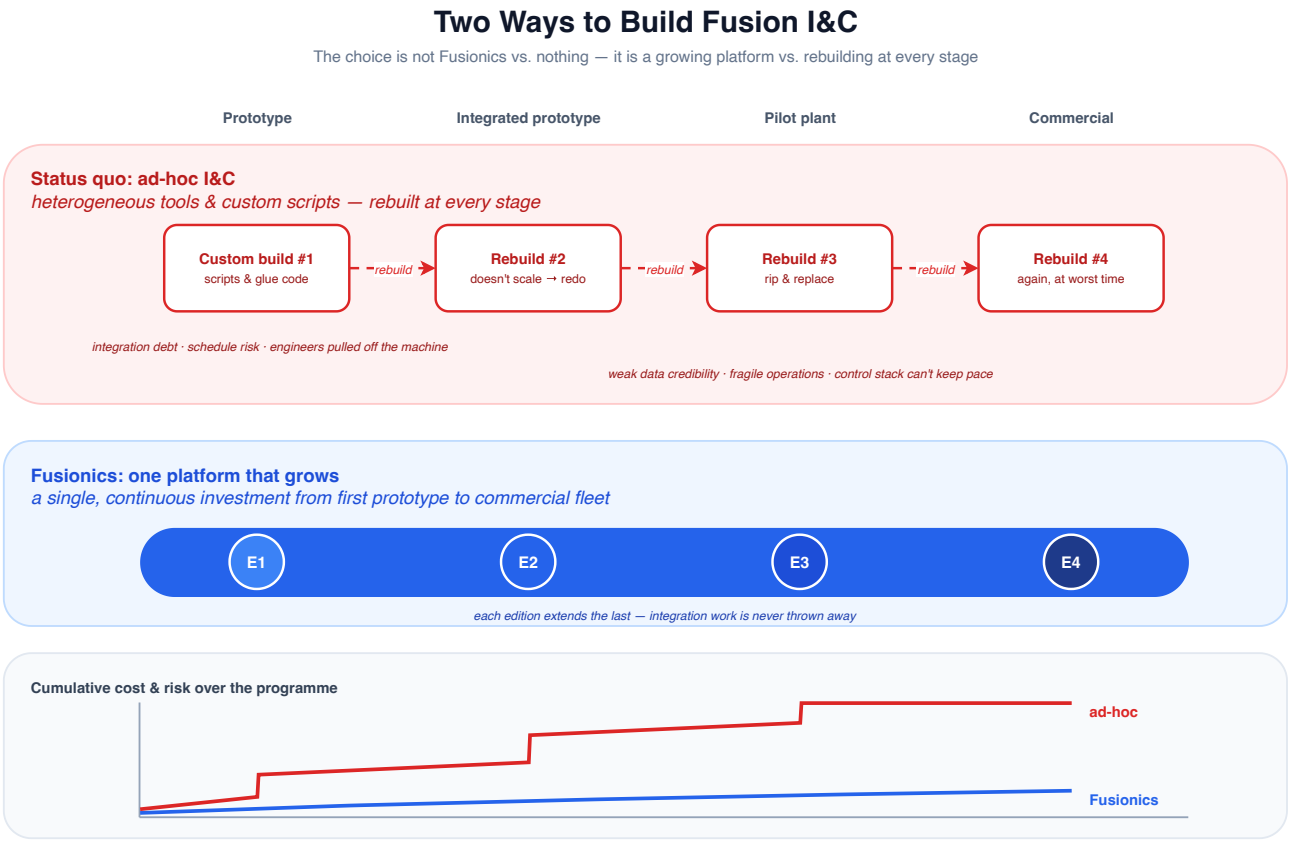


Figure 4: *Two ways to build fusion I&C — repeated ad-hoc rebuilds accumulate cost and risk at every maturity transition; a single growing platform does not*

2. Vendor independence

Fusionics is designed to remain vendor-agnostic at the integration level. The platform integrates with the hardware the customer has, not with a proprietary hardware catalogue. This protects the customer from hardware obsolescence risk and from single-vendor dependency. Over time, hardware choices that were state of the art in Year 1 will require updating. A vendor-agnostic platform absorbs that change without forcing an architectural rebuild.

3. Customer IP protection

Fusionics does not attempt to own or absorb the customer's proprietary science, physics algorithms, laser control logic, or machine design. The platform standardises and productises the interfaces between those proprietary elements and the operational layer. Customers retain full ownership of their differentiating IP while gaining the operational infrastructure around it.

4. Standards alignment

Fusionics is developed in alignment with emerging fusion I&C standards and contributes to the broader effort to establish common interfaces and practices across the sector. Rather than creating proprietary lock-in, the platform is designed to implement and reinforce industry-standard patterns — making it easier for customers to engage with the wider ecosystem of tools, partners, and regulatory frameworks as they mature. For programmes preparing for certification or regulatory scrutiny, working with a platform that is grounded in standards is a material advantage.

6. Practical Considerations for Adoption

Integration with existing plant systems

Fusion facilities sit at the intersection of scientific instrumentation and industrial automation. Fusionics is designed to accommodate both: it integrates with purpose-built fusion hardware where specialist performance is required, and with standard industrial automation components where they are the appropriate and cost-effective choice. The platform does not prescribe a single technology stack. It defines the integration contract and ensures that whichever hardware is used, it connects to the operational platform through a standard, validated interface. This philosophy protects the customer from technology churn and allows the I&C architecture to evolve alongside both the machine and the broader hardware market.

Fusionics does not require replacing working hardware. The standard integration model uses protocol adapters and a defined plant system controller pattern, allowing heterogeneous hardware to connect to the platform without bespoke glue code.

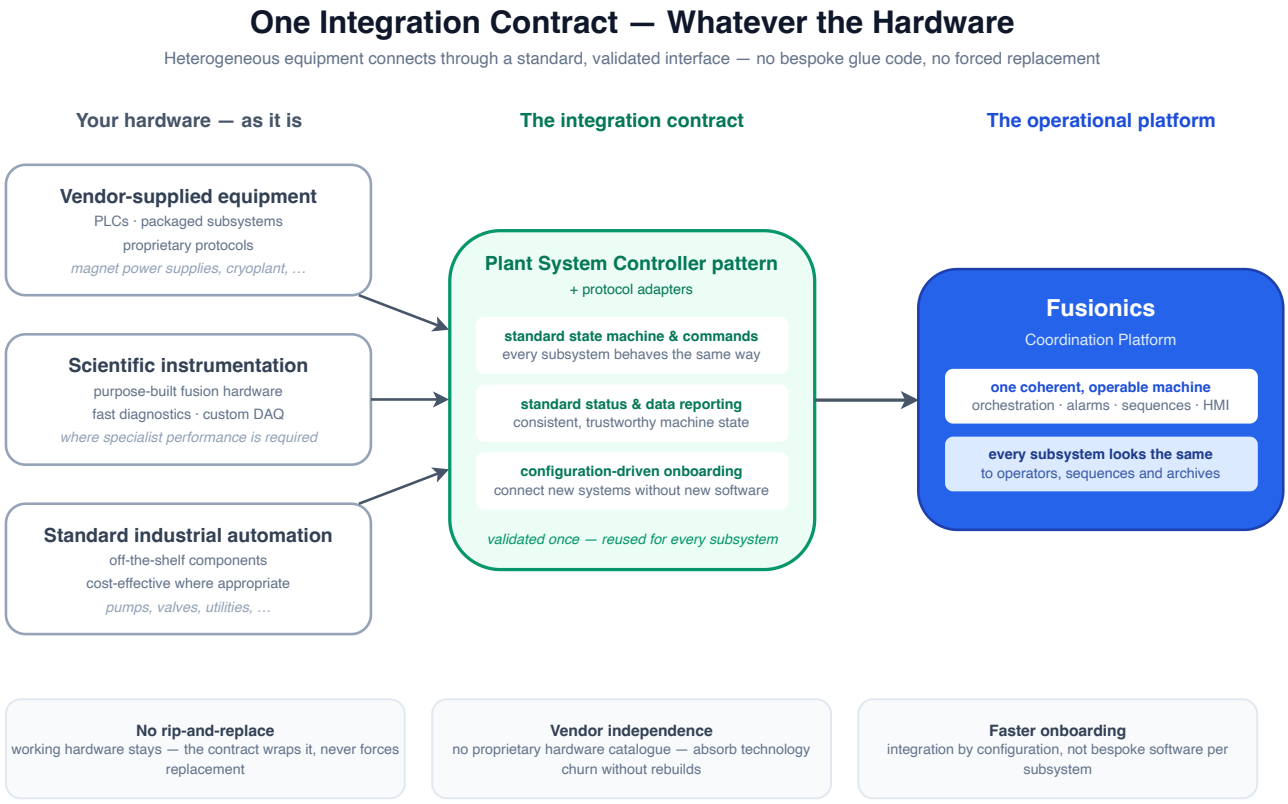


Figure 5: *One integration contract — vendor equipment, scientific instrumentation, and standard industrial automation all connect through the same standard, validated interface*

Cybersecurity

Cybersecurity is treated as a structural requirement across all editions, not a feature to be added later. From E1 onwards, the platform includes network zone separation and access control patterns appropriate to the facility type. These strengthen progressively through E2 and E3 — where a formal cybersecurity posture becomes a procurement and partnership expectation — and reach utility-grade discipline in E4. The deployment architecture is designed from the outset to support air-gapped and segmented network environments.

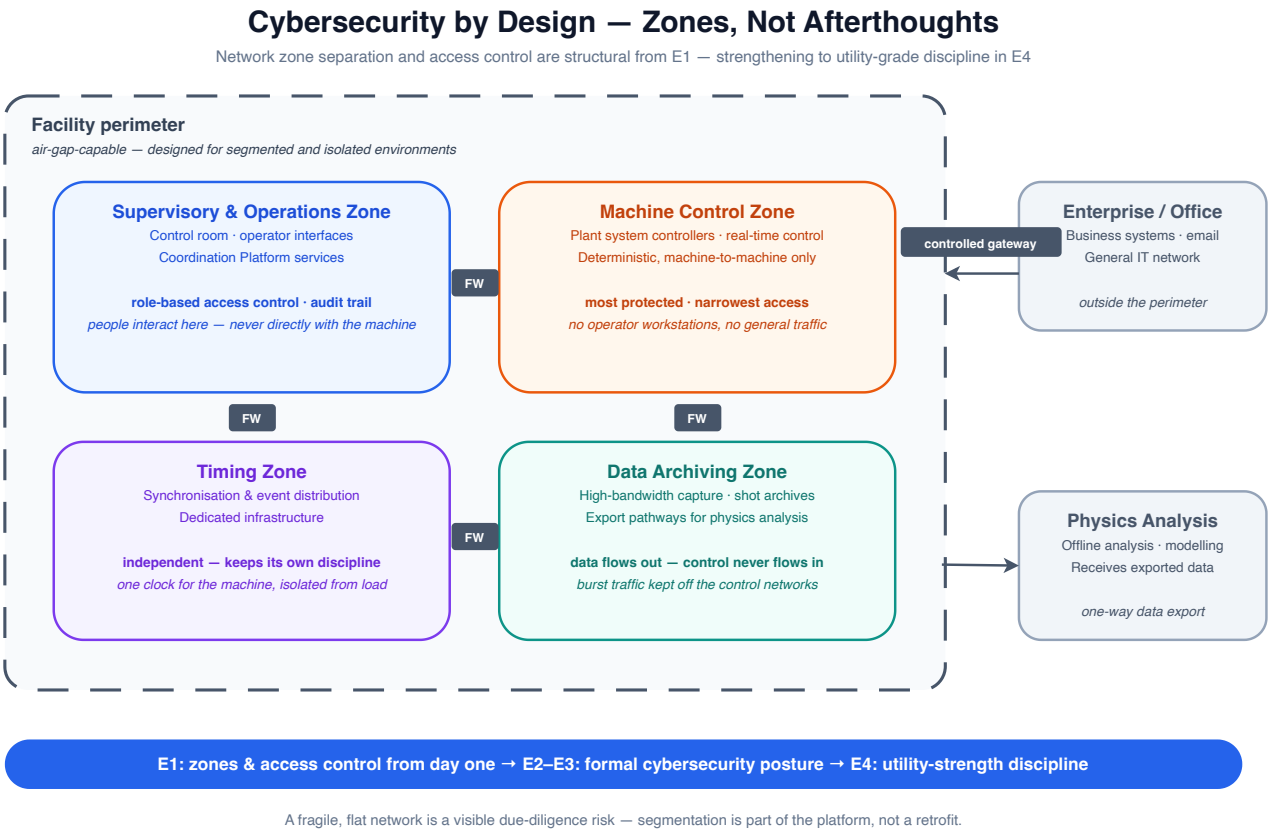


Figure 6: *Cybersecurity by design — zone separation, controlled gateways, and an air-gap-capable perimeter are structural platform properties from E1 onwards*

Interfaces with modelling, simulation, and digital tools

Fusionics provides defined interfaces for connecting to modelling, simulation, digital twin, and AI-assisted tools. These tools are increasingly central to commissioning, validation, and operational optimisation in serious fusion programmes. The platform makes the operational data they need available through standard interfaces and receives the configurations or setpoints they generate — without those tools needing to be part of the I&C platform itself.

Onboarding

For early editions, the onboarding process includes deployment, configuration, and integration services. Cosylab brings experience across the specific plant system families relevant to fusion — magnets, vacuum, plasma heating, diagnostics, cooling, power systems, and safety interfaces — which reduces the integration burden on the customer's team.

Support and lifecycle

Each edition includes a defined support and long-term support (LTS) model. This is relevant commercially because fusion facilities are long-lived investments. A control platform that lacks a credible support horizon introduces lifecycle risk that engineering teams and procurement officers are both capable of identifying.

7. Risks and Constraints to Consider Honestly

The product is still maturing

Fusionics is an actively developing product. Not all capabilities described in the E3 and E4 editions are fully productised today. Customers engaging now are engaging with a product that is growing, not a static catalogue. Early editions (E1 and E2) represent the most mature product offering. This is a relevant factor for programmes that need near-term operational capability.

The fusion market is early

The private fusion sector is growing but is not yet a mature commercial market. Timelines for pilot and commercial plant deployment remain variable across the industry. This affects the commercial velocity of the later editions and means that some features planned for E3 and E4 will be shaped in part by early customer engagements.

Quantified benefits are not yet available

The source materials for this whitepaper do not contain independently verified quantification of time savings, cost reduction, or engineering efficiency gains. Specific metrics —

such as commissioning time saved or reduction in integration engineering effort — would require further scoping against a customer's specific programme context.

Custom integration remains necessary

Fusionics productises the platform, but integrating a specific facility's plant system controllers and configurations requires engineering effort. The platform reduces and standardises that effort, but it does not eliminate the need for programme-specific integration work.

Practical implication:
The strongest near-term commercial fit is with programmes at E1 or E2 maturity — early-stage and integrated prototype facilities — where the pain of ad hoc I&C is most immediate and where the investment in the platform has the longest operational runway ahead of it.

8. Recommended Next Steps for Decision-Makers

If the operational challenge described in this whitepaper is relevant to your programme, the following actions are worth considering:

1. Assess your current I&C maturity. Where does your programme sit today on the E1–E4 maturity arc? What are the operational limitations you are already experiencing, and which ones are likely to appear within the next twelve months?

2. Identify the cost of the status quo. What proportion of your engineering capacity is currently absorbed by I&C integration, maintenance, and firefighting? What is the schedule and credibility cost of that absorption?

3. Evaluate the transition risk. If your programme is currently at E1 or E2 maturity, consider what it would cost — in time, engineering effort, and schedule disruption — to rebuild the I&C infrastructure at the E3 transition. A platform investment made early removes that transition cost.

4. Engage Cosylab for a programme-specific assessment. Cosylab's value lies in deep knowledge of both fusion facility operations and I&C engineering. The most productive conversation begins with the customer's specific machine, plant systems, operational goals, and timeline. A structured engagement can quickly identify where Fusionics provides high-value leverage and where custom engineering effort would be required.

9. Conclusion

Fusion programmes are no longer competing only on physics performance. They are beginning to compete on operational credibility, commercial readiness, and the ability to scale. The I&C infrastructure is central to all three.

Fusionics is built on the premise that the I&C challenge in fusion is not fundamentally different from one programme to the next — and that a product approach to solving it is more efficient, more scalable, and more commercially robust than repeated bespoke engineering. It is grounded in real operational experience, developed in collaboration with UKAEA, and aligned with the standards and practices that the sector is converging on.

The choice is not between Fusionics and doing nothing. It is between a growing product platform that accumulates operational experience and improves with each edition, and a custom-built infrastructure that accumulates technical debt and must be rebuilt each time the programme matures.

For programmes that are serious about reaching commercial scale, that choice is worth examining now.

An Invitation to Collaborate

If the operational challenge described in this whitepaper is one you recognise, we would welcome a conversation — one that starts from your machine, your goals, and your timeline, not from our product. You keep your physics and your control IP; Cosylab brings the I&C experience, and together we work out where the backbone helps most.

To start that conversation, contact Cosylab.

About Cosylab

Cosylab is the leading provider of comprehensive expertise and forward-looking software and electronics for the world's most advanced systems and devices.

It helps commercial fusion companies and research facilities achieve critical milestones faster and with less risk by providing expert control system engineering, integration, support, and a staged product line—without requiring the client to maintain large in-house teams.

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