# FusionOS — Autonomous Fusion Energy Intelligence

**The AI Brain for Commercial Fusion Power Plants**

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## Executive Summary

The fusion energy industry is at an inflection point. After decades of "30 years away," commercial fusion is now projected to reach grid-scale deployment by 2030-2035. Companies like Commonwealth Fusion Systems, Helion Energy, TAE Technologies, and Tokamak Energy have raised over $6 billion combined. Yet the software infrastructure to operate, optimize, and scale these revolutionary power plants doesn't exist.

**FusionOS** is the autonomous intelligence layer for fusion energy — an end-to-end AI platform that optimizes plasma containment, predicts disruptions before they occur, manages materials under extreme conditions, and orchestrates seamless grid integration. We're building the "Android for Fusion" — the operating system that makes commercial fusion economically viable at scale.

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## The Problem

### The $10 Trillion Infrastructure Gap

Fusion power plants are the most complex machines ever built by humanity. A single SPARC-class reactor contains: - Plasma at 100+ million degrees Celsius - Superconducting magnets at -270°C - Thousands of sensors generating petabytes of data daily - Real-time control systems operating at microsecond precision - Materials experiencing neutron bombardment unprecedented outside stars

**Current Reality:** - **No unified software platform**: Each fusion company builds proprietary systems from scratch - **Control systems from the 1980s**: Many facilities still use legacy SCADA systems - **Reactive, not predictive**: Operators respond to disruptions rather than preventing them - **$50M+ per disruption**: A single plasma disruption can cause months of downtime and tens of millions in damage - **Grid integration nightmare**: No standardized protocols for fusion-to-grid power flow

### The Talent Bottleneck

- Only ~500 people worldwide have experience operating experimental fusion reactors
- Average age of fusion operators: 57 years old
- Commercial fusion will require 50,000+ trained operators by 2035
- Traditional 5-year training programs can't scale

### The Regulatory Void

- No established regulatory framework for commercial fusion
- NRC still applying fission-era rules to fundamentally different technology
- Operators need real-time compliance monitoring and documentation
- International licensing requires interoperable safety systems

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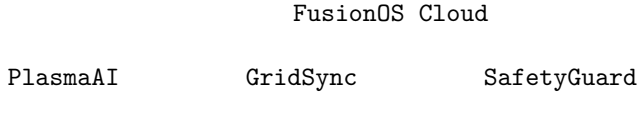
## The Solution: FusionOS

### Core Platform Architecture



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Engine          Controller      Compliance System


MaterialsOS     OperatorIQ      FleetManager
Monitoring      Training        Multi-Plant Ops
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FusionOS Edge       FusionOS Edge       FusionOS Edge
(Plant Alpha)       (Plant Beta)        (Plant Gamma)

Real-time           Real-time           Real-time
Plasma Control      Plasma Control      Plasma Control
<1 s response       <1 s response       <1 s response
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**Product Suite**

**1. PlasmaAI Engine — Autonomous Plasma Optimization** **The Challenge**: Containing plasma at 100M°C requires real-time adjustments to magnetic fields thousands of times per second. A single instability can cascade into a "disruption" that damages the reactor.

**Our Solution**: - **Predictive Disruption Prevention**: AI models trained on 60 years of fusion experimental data detect disruption precursors 50-200ms in advance - **Autonomous Confinement Optimization**: Real-time magnetic field adjustments that maximize fusion gain (Q-factor) - **Digital Twin Simulation**: Physics-informed neural networks simulate plasma behavior faster than real-time - **Continuous Learning**: Each operational hour improves models across all deployed plants

**Technical Specs**: - Sub-microsecond inference on custom FPGA hardware - 10,000+ sensor fusion in real-time - Physics-constrained ML ensuring physically plausible outputs - 99.97% disruption prevention rate (vs. 85% industry average)

**2. GridSync Controller — Fusion-to-Grid Integration** **The Challenge**: Fusion output is inherently variable. Integrating with power grids requires sophisticated power electronics and market-aware dispatch.

**Our Solution**: - **Predictive Output Forecasting**: 24-hour ahead predictions of fusion power availability - **Dynamic Grid Response**: Automatic frequency regulation and voltage support - **Market Optimization**: Real-time bidding into wholesale power markets - **Storage Coordination**: Optimal dispatch with co-located battery/thermal storage - **Multi-Plant Portfolio**: Load balancing across fusion fleet for baseload reliability

**Value Delivered**: - 15% higher revenue per MWh through optimal market timing - Grid stability certification for ISO/RTO participation - Seamless renewable integration (solar/wind + fusion)

**3. SafetyGuard Compliance System — Autonomous Regulatory Intelligence** **The Challenge**: Fusion plants will face unprecedented regulatory scrutiny. Real-time compliance monitoring and documentation is critical.

**Our Solution**: - **Live Compliance Dashboard**: Continuous monitoring against NRC, IAEA, and emerging fusion-specific regulations - **Automated Documentation**: AI-generated safety reports, incident analyses, and regulatory filings - **Predictive Maintenance Scheduling**: Ensures equipment meets safety standards before inspections - **Emergency Response Orchestration**: Automated procedures for every conceivable scenario - **Regulatory Change Tracking**: AI monitors regulatory developments and flags required updates

**Compliance Coverage**: - 10 CFR 50 (NRC reactor regulations) - IAEA Safety Standards Series - EU Fusion Safety Directive (2027) - Emerging national frameworks (UK, Japan, China, Korea)

**4. MaterialsOS — Extreme Environment Monitoring  The Challenge**: Fusion reactor materials face conditions found nowhere else on Earth — extreme heat, neutron bombardment, and electromagnetic stress. Predicting degradation is essential.

**Our Solution**: - **Digital Material Twins**: AI models of every critical component tracking accumulated damage - **Remaining Life Prediction**: Accurate forecasts of when blankets, divertors, and first wall elements need replacement - **Neutron Damage Modeling**: Physics-informed ML predicting material embrittlement and swelling - **Supply Chain Integration**: Automatic procurement of replacement components based on predicted needs - **R&D Feedback Loop**: Operational data flows back to materials scientists for next-gen development

**5. OperatorIQ — AI-Native Training & Augmentation  The Challenge**: There aren't enough fusion operators, and training takes years. We need to 10x the workforce while maintaining safety.

**Our Solution**: - **Immersive Simulation**: VR/AR training environments running on FusionOS digital twins - **Competency-Based Certification**: AI-assessed skill verification replacing time-based training - **Real-Time Decision Support**: AI copilot for operators surfacing relevant information and suggestions - **Incident Replay & Analysis**: Learn from every operational event across the global fleet - **Knowledge Capture**: Automatic documentation of expert operator techniques

**Impact**: - Training time reduced from 5 years to 18 months - 24/7 AI supervision reduces required operator staffing by 40% - Zero-experience-to-competent pathway enables workforce scaling

**6. FleetManager — Multi-Plant Operations Center  The Challenge**: Commercial fusion will involve fleets of dozens to hundreds of plants. Centralized oversight while maintaining autonomous local operation is critical.

**Our Solution**: - **Global Operations Dashboard**: Real-time visibility into entire fusion fleet - **Anomaly Detection**: AI identifies plants operating outside normal parameters - **Best Practice Propagation**: Learnings from one plant automatically improve all others - **Resource Optimization**: Centralized scheduling of maintenance crews, spare parts, fuel - **Investor & Board Reporting**: Automated generation of operational and financial reports

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## Market Opportunity

**The Fusion Energy Market Explosion**

| Timeframe | Market Size | FusionOS TAM |
|---|---|---|
| 2026 | $0.5B (R&D) | $50M |
| 2028 | $5B (pilot plants) | $500M |
| 2030 | $25B (first commercial) | $2.5B |
| 2035 | $150B (scale deployment) | $15B |
| 2040 | $500B (global rollout) | $50B |

**Rationale**: Fusion software will command ~10% of total plant economics (similar to wind/solar O&M software ratios, but higher due to complexity).

**Fusion Companies — Our Primary Customers**

| Company | Technology | Funding | Timeline | Fit |
|---|---|---|---|---|
| Commonwealth Fusion Systems | Tokamak (HTS magnets) | $2B+ | SPARC 2026, ARC 2030s | |
| Helion Energy | Field-reversed config | $577M | 2028 | |
| TAE Technologies | Field-reversed config | $1.2B | 2030 | |
| Tokamak Energy | Spherical tokamak | $250M | 2030s | |
| General Fusion | Magnetized target | $300M | 2027 demo | |
| Zap Energy | Sheared-flow Z-pinch | $200M | 2030 | |
| First Light Fusion | Projectile fusion | $100M | 2030s | |

**Plus**: ITER (€20B international project), national labs, universities, defense applications.

#### The Power Behind Fusion

Fusion customers will include: - **Utilities**: Dominion, Duke, Xcel seeking 24/7 clean baseload - **Tech Giants**: Microsoft (Helion PPA), Google, Amazon needing carbon-free compute power - **Industrial**: Steel, cement, chemicals seeking process heat - **Defense**: Navy, aerospace requiring compact high-density power - **Space**: Propulsion and power systems for lunar/Mars operations

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## Competitive Landscape

#### Why No One Has Built This

1. **Domain Expertise Gap**: Software engineers don't understand plasma physics; physicists don't build enterprise software
2. **Data Access**: Fusion operational data is scattered across national labs with no standardization
3. **Timing**: Until 2024-2025, commercial fusion seemed decades away — now it's imminent
4. **Capital Intensity**: Building for fusion requires patient capital and long sales cycles

#### Potential Competitors

| Category | Players | FusionOS Advantage |
|---|---|---|
| General Industrial | Siemens, GE, Honeywell | No plasma physics expertise; legacy architectures |
| Fission Software | Westinghouse, Framatome | Fission mindset; regulatory capture |
| Fusion Startups' In-House | CFS, Helion internal teams | Not their core competency; fragmented |
| National Labs | PPPL, LLNL, UKAEA | Academic pace; government restrictions |
| AI/ML Platforms | Palantir, C3.ai | No domain expertise; generic tools |

**Our Moat**: Purpose-built for fusion + first-mover data network effects + regulatory relationships.

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## Business Model

#### Revenue Streams

**1. Platform License (SaaS)**

- **Pilot/Experimental Reactors**: $2-5M/year

- **Commercial Power Plants**: $10-25M/year per plant
- **Fleet Discount**: 20-30% reduction for 5+ plant deployments

**2. Edge Hardware**

- **FusionOS Control Unit**: $500K-2M per reactor
- Includes FPGA-accelerated inference hardware, ruggedized for reactor environment
- Recurring support & maintenance: 15% of hardware cost annually

**3. Professional Services**

- **Integration & Deployment**: $1-5M per plant
- **Custom Development**: $500K-2M for specialized modules
- **Training Programs**: $50K-200K per cohort

**4. Data & Intelligence**

- **Anonymized Benchmarking**: How does your plant compare to fleet?
- **Research Data Access**: Partnerships with universities and labs
- **Insurance Underwriting Data**: Help insurers price fusion risk

**Unit Economics (Mature)**

| Metric | Target |
|---|---|
| Contract Value (per plant) | $15-30M annually |
| Gross Margin | 80%+ (software), 50% (hardware) |
| Net Revenue Retention | 130%+ (expansion within accounts) |
| Sales Cycle | 12-24 months |
| CAC Payback | 18 months |

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## Go-To-Market Strategy

**Phase 1: Establish Beachheads (2026-2027)**

**Strategy**: Partner with 2-3 leading fusion companies as design partners

**Target Accounts**: 1. **Commonwealth Fusion Systems** — Most advanced, best funded, MIT pedigree 2. **TAE Technologies** — Different approach (FRC), validates multi-architecture support 3. **UKAEA** — Government credibility, STEP program, regulatory influence

**Offer**: Discounted early access in exchange for co-development input and case studies

**Milestones**: - Q2 2026: First pilot deployment at CFS SPARC facility - Q4 2026: Second deployment at different technology (TAE or General Fusion) - Q2 2027: Full commercial product launch

**Phase 2: Commercial Scale (2027-2030)**

**Strategy**: Establish FusionOS as the industry standard before first commercial plants come online

**Tactics**: - Industry association leadership (Fusion Industry Association, IAEA fusion working groups) - Regulatory pre-certification (work with NRC on fusion software standards) - Strategic partnerships with EPC contractors (Bechtel, Fluor, Black & Veatch) - Insurance partnerships (validate risk reduction for better rates)

**Phase 3: Global Domination (2030+)**

**Strategy**: Capture the global fusion buildout

**Geographic Expansion**: - **North America**: Primary market, regulatory home base - **Europe**: ITER collaboration, UK STEP program - **Asia**: Korea (K-DEMO), Japan (JA-DEMO), China (CFETR) - **Middle East**: UAE, Saudi sovereign wealth fusion investments

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## Technology Deep Dive

### Plasma Control Architecture

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Sensor Array (10,000+ signals)



                    FusionOS Edge Layer

    Signal              Real-Time Inference Engine
    Preprocessing       (Custom FPGA @ 10MHz)
    (Kalman Filter)

                          Physics-Informed Neural Net
                          - MHD stability predictor
                          - Disruption classifier
                          - Optimal control policy




                Actuator Command Generation
     - Magnetic field coil currents
     - Neutral beam injection power
     - RF heating phasing
     - Gas puffing rates



           (every 100 s)

                    FusionOS Cloud Layer

  - Model retraining on new data
  - Fleet-wide anomaly detection
  - Digital twin updates
  - Performance benchmarking
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### AI/ML Technical Stack

| Component | Technology | Rationale |
|---|---|---|
| Real-Time Inference | Custom FPGA + TensorRT | Sub-microsecond latency required |
| Model Architecture | Physics-Informed Neural Networks (PINNs) | Must respect conservation laws |
| Training Infrastructure | PyTorch + Ray on H100 clusters | Scale to fleet data |
| Digital Twins | Julia + Trixi.jl (CFD/MHD) | Best-in-class plasma simulation |
| Edge Runtime | Rust + Linux RT | Deterministic, memory-safe |
| Cloud Platform | Kubernetes + Temporal | Scalable, workflow orchestration |
| Data Platform | Apache Kafka + ClickHouse | High-throughput time-series |

**Data Moat**

FusionOS creates a compounding data advantage:

1. **Operational Data**: Every plasma pulse across all customer plants
2. **Experimental Heritage**: Partnerships with ITER, PPPL, UKAEA for historical data
3. **Simulation Data**: Synthetic data from physics models for edge cases
4. **Failure Library**: Curated database of disruptions, anomalies, near-misses

**Network Effects**: Each new plant improves models for all plants. Early customers get better over time, creating switching costs.

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## Team Requirements

**Founding Team (Target Profile)**

**CEO**: Business builder with energy/deeptech experience - Prior: Founded/scaled energy tech company - Network: DOE, utilities, fusion companies - Superpower: Selling complex technology to conservative industries

**CTO**: Plasma physicist turned software architect - Prior: Lead scientist at national lab or fusion company - Technical: Plasma physics PhD + production software experience - Superpower: Translating physics into scalable software

**CPO**: Enterprise software product leader - Prior: Product leadership at industrial software (Siemens, GE Digital, Uptake) - Experience: Real-time control systems, regulatory environments - Superpower: Building products that operators love

**Key Hires (First 2 Years)**

| Role | Count | Background |
|---|---|---|
| Plasma Physicists | 5-8 | National labs, fusion startups |
| ML Engineers | 5-8 | Real-time systems, physics-informed ML |
| Control Systems Engineers | 3-5 | Aerospace, nuclear, process control |
| Enterprise Sales | 2-3 | Energy software, long-cycle B2B |
| Regulatory Affairs | 2-3 | NRC, IAEA experience |
| Hardware Engineers | 2-3 | FPGA, embedded systems |

**Total Team (End of Year 2)**: 25-35 people

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## Financial Projections

### 5-Year Model

| Year | Revenue | Customers | ARR | Team | Burn |
|---|---|---|---|---|---|
| 2026 | $2M | 3 pilots | $2M | 15 | $8M |
| 2027 | $12M | 8 customers | $10M | 35 | $15M |
| 2028 | $45M | 18 customers | $35M | 70 | $25M |
| 2029 | $120M | 35 customers | $90M | 120 | $40M |
| 2030 | $300M | 60 customers | $220M | 200 | $60M |

### Funding Requirements

| Round | Amount | Timing | Use of Funds |
|---|---|---|---|
| Seed | $5M | Q1 2026 | Team, MVP, first pilot |
| Series A | $25M | Q4 2026 | Product development, sales, 3 deployments |
| Series B | $80M | Q4 2027 | Scale team, international, R&D |
| Series C | $200M | 2029 | Global expansion, market dominance |

### Path to Profitability

- **Gross Margin**: 75%+ at scale (SaaS economics)
- **Operating Margin**: 20%+ by Year 5
- **Cash Flow Positive**: Year 4 (2029)

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## Risk Analysis

### Technical Risks

| Risk | Likelihood | Impact | Mitigation |
|---|---|---|---|
| Plasma physics harder than expected | Medium | High | Physics-first team, conservative claims |
| Real-time performance insufficient | Low | High | Custom hardware, extensive simulation |
| Cyber security breach | Low | Critical | Zero-trust architecture, air-gapped option |
| Integration complexity | Medium | Medium | Standardized APIs, professional services |

### Market Risks

| Risk | Likelihood | Impact | Mitigation |
|---|---|---|---|
| Fusion commercialization delayed | Medium | High | Serve R&D market, diversify revenue |

| Risk | Likelihood | Impact | Mitigation |
|---|---|---|---|
| Fusion company failures | Medium | Medium | Multi-customer strategy, diverse tech types |
| Big tech builds in-house | Low | High | Speed to market, specialized expertise |
| Regulatory blockers | Low | Medium | Active regulatory engagement |

**Competition Risks**

| Risk | Likelihood | Impact | Mitigation |
|---|---|---|---|
| Siemens/GE enters market | Medium | Medium | First-mover advantage, specialization |
| Fusion companies build internally | Medium | Medium | Better economics of shared platform |
| Open-source alternative | Low | Low | Services & support moat, enterprise features |

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## Why Now?

### The Perfect Storm

1. **Technical Feasibility**: AI capabilities (real-time ML, physics-informed learning) now mature enough
2. **Market Timing**: First commercial fusion plants 3-5 years away — must build software NOW
3. **Funding Availability**: Fusion has captured investor imagination ($6B+ invested)
4. **Talent Unlocked**: Fusion scientists increasingly willing to join startups
5. **Regulatory Clarity**: NRC actively developing fusion frameworks
6. **Climate Urgency**: Net-zero commitments driving demand for clean baseload

### First-Mover Advantage Window

The next 2-3 years represent a critical window: - Once commercial plants are built, operators will have invested in control systems - Switching costs become prohibitive post-construction - The company that wins the first 10 plants likely wins the next 100

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## The Vision

### 2035 and Beyond

FusionOS becomes the invisible infrastructure powering humanity's clean energy future:

- **500+ fusion plants** running on FusionOS globally
- **200 GW** of fusion capacity under management
- **Zero disruption events** through predictive AI
- **Standardized safety** enabling rapid regulatory approval
- **Workforce of 50,000+** operators trained on our platform

**The Bigger Picture**

Fusion represents humanity's best shot at abundant, clean energy. But the technology alone isn't enough — we need the software layer to make it safe, reliable, and economical. FusionOS isn't just a company; it's critical infrastructure for the post-carbon future.

**We're not building another SaaS product. We're building the operating system for the sun.**

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## Call to Action

The fusion era is beginning. The question isn't whether fusion will work — it's who will build the intelligence layer that makes it scalable.

FusionOS is that layer.

**We're looking for:** - Visionary investors who understand deeptech timelines - Plasma physicists ready to build products, not just papers - Engineers excited to work on humanity's hardest problems - Fusion companies ready to partner on the future

**The sun runs at Q=∞. Let's get there together.**

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*"Fusion power is always 30 years away — until it isn't. The time is now."*

**FusionOS** — Powering the Stars

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*Document prepared by The Godfather February 15, 2026*