

TerraHash Stack as a Service: Key Features & System Modules

Executive Overview

TerraHash Stack as a Service represents a comprehensive, modular platform for transforming existing bitcoin mining facilities into institutional-grade operations. The service combines six core system modules that work synergistically to deliver measurable improvements in efficiency, uptime, profitability, and strategic positioning. This document provides detailed technical and functional specifications for each major system component.

Module 1: Facility Assessment & Pricing Engine

Overview

The Facility Assessment & Pricing Engine provides rapid, data-driven analysis of existing mining facilities to generate accurate retrofit cost estimates, ROI projections, and detailed transformation roadmaps. This module serves as the critical first touchpoint in the sales cycle, enabling fast decision-making while de-risking project execution.

Core Capabilities

1. Multi-Modal Assessment Framework

The assessment engine supports three engagement models optimized for different customer personas and decision timelines:

- **Express Assessment (48-72 hours):** Remote analysis based on customer-provided documentation, facility photos, electrical diagrams, and operational data. Delivers preliminary cost estimate with $\pm 15\%$ accuracy and high-level ROI projection. Suitable for distressed asset acquirers and time-sensitive opportunities.
- **Standard Assessment (7-10 days):** Single-day on-site visit by TerraHash engineering team, including thermal imaging, electrical infrastructure audit, structural analysis, and equipment inventory. Produces detailed retrofit design with $\pm 8\%$ cost accuracy, phased implementation plan, and sensitivity analysis. Standard path for regional operators and institutional customers.
- **Comprehensive Assessment (14-18 days):** Multi-day site engagement with full diagnostic suite, including power quality analysis, detailed ASIC testing, cooling system performance validation, and operational workflow analysis. Generates turnkey retrofit package with fixed-price guarantee and performance commitments. Required for energy producers and large portfolio retrofits.

2. Data Collection & Analysis Infrastructure

The assessment process captures structured and unstructured data across seven key domains:

Physical Infrastructure:

- Facility dimensions, layout, access points
- Structural load capacity for cooling equipment (CDU-1500 weight: 800-1,200 lbs per unit)
- Electrical panel capacity, voltage stability, grounding systems
- Network backbone (existing fiber, bandwidth, latency)
- Environmental conditions (ambient temperature range, humidity, dust levels)

Equipment Inventory:

- ASIC manufacturer, model, age, operational status (running, failed, throttled)
- Firmware versions and current performance profiles
- Power supply efficiency and failure rates
- Cooling infrastructure (fans, HVAC units, evaporative systems)
- Rack configurations and density (W/sq.ft)

Operational Metrics:

- Current hashrate (total and per-miner average)
- Uptime percentage (historical 30/60/90 days)
- Power consumption (total facility and per-TH efficiency)
- Maintenance logs (failure frequency, MTTR, common issues)
- Seasonal performance variation (summer throttling, winter stability)

Financial Data:

- Electricity cost (\$/kWh) and contract terms
- Current revenue (monthly BTC mined, pool configuration)
- Operating expenses (labor, maintenance, insurance)
- Capital structure (debt service, lease obligations)
- Investment capacity and financing requirements

Thermal Imaging & Diagnostics:

- FLIR infrared camera mapping of hot spots and temperature gradients
- Identification of airflow inefficiencies and thermal cycling stress
- Equipment thermal load profiling (W/unit actual vs. rated)
- Validation of cooling system capacity vs. demand

Regulatory & Compliance:

- Electrical code compliance (NEC, local amendments)
- Environmental permits (noise, emissions, water discharge)
- Zoning restrictions and expansion limitations

- Grid interconnection agreements and demand response participation

Risk Assessment:

- Equipment obsolescence timeline (years remaining economic viability)
- Facility infrastructure degradation (wiring, panels, structural)
- Operational gaps (staffing, expertise, monitoring systems)
- Market positioning vs. regional peer group

3. AI-Powered Cost Estimation Engine

The pricing engine leverages machine learning models trained on 100+ completed retrofit projects to generate accurate cost estimates across six major categories:

Equipment Procurement:

- Chilldyne CDU units (CDU-1500: \$180K/unit, 1.5 MW capacity; CDU-300: \$45K/unit, 300 kW capacity)
- THS-4X21P-C55 modular chassis (\$450/unit for Bitmain, \$485/unit for MicroBT)
- Cold plates with quick-disconnect fittings (\$285/plate, Chilldyne turbulator-enhanced)
- Dry coolers and heat rejection systems (\$25-35K per MW)
- Coolant and distribution infrastructure (\$15-20K per MW)
- BraiinsOS+ licenses (\$30/miner for commercial deployments)

Installation Labor:

- Phased deployment labor rates (\$125-185/hour, regional variance)
- Container or facility retrofit complexity multipliers (1.0-1.8x)
- Electrical infrastructure upgrades (panel replacements, load rebalancing)
- Network infrastructure deployment (fiber backbone, managed switches)
- Commissioning and testing (7-14 day burn-in per zone)

Infrastructure Upgrades:

- Electrical system modifications (panels, PDUs, busway, grounding)
- Structural reinforcements (CDU mounting, coolant routing)
- Facility modifications (ventilation, access, safety systems)
- Heat recovery infrastructure (if applicable)

AI Management Platform:

- Edge compute hardware (Kubernetes cluster, storage, networking)
- Software licensing (perpetual with annual support or SaaS)
- Integration services (existing DCIM, ERP, pool management)
- Customization for facility-specific workflows

Project Management:

- Design engineering (electrical, mechanical, thermal, network)
- Site project management (on-site coordination, vendor management)
- Quality assurance and compliance validation
- Documentation and training deliverables

Contingency & Risk Buffer:

- Standard 10% contingency for standard retrofits
- 15-20% for distressed facilities with high infrastructure uncertainty
- Fixed-price contracts eliminate contingency for customer (absorbed by TerraHash)

4. ROI Modeling & Sensitivity Analysis

The pricing engine generates interactive financial models incorporating:

Performance Improvement Assumptions:

- Hashrate increase: 15-25% through safe overclocking enabled by liquid cooling
- Efficiency improvement: 19-28% J/TH reduction (air cooling baseline vs. liquid + autotuning)
- Uptime improvement: +8-12 percentage points (88-92% → 99%+)
- Maintenance cost reduction: 60-75% through predictive maintenance and labor automation
- Equipment lifespan extension: +50% (24 months → 36 months typical)

Revenue Impact Modeling:

- Daily BTC production increase based on hashrate and efficiency gains
- Elimination of seasonal throttling (summer heat, winter cold stress)
- Uptime improvement revenue capture (reduced downtime losses)
- Treasury management module impact (10-20% revenue enhancement through automated BTC/stablecoin allocation)

Cost Savings Analysis:

- Electricity cost reduction (lower total MW consumption despite higher hashrate)
- Maintenance labor reduction (FTE savings at \$60-80K per technician)
- HVAC cost elimination (for air-cooled facilities, \$50-150K annually)
- Insurance premium reductions (leak-proof cooling technology)

Payback Period Calculation:

- Monthly cash flow projections (revenue improvement + cost savings - retrofit amortization)
- Breakeven analysis (months to full cost recovery)
- Sensitivity to Bitcoin price (\$60K, \$80K, \$100K, \$150K scenarios)
- Sensitivity to network difficulty (15%, 25%, 35% annual growth scenarios)

5-Year NPV & IRR Projections:

- Discounted cash flow analysis (10-12% discount rate typical)
- Terminal value assumptions (facility sale or continued operation)
- Risk-adjusted returns for different market scenarios

5. Standardized Retrofit Templates

To accelerate assessment and proposal generation, the engine includes pre-built templates for six common facility archetypes:

Template 1: Container-Based Air-Cooled (1-5 MW)

- Target customer: Regional operators with containerized deployments
- Typical configuration: 10-35 shipping containers, 60-80 miners per container
- Retrofit approach: Per-container CDU-1500 deployment, sequential phasing
- Cost benchmark: \$650-750K per MW
- Timeline: 12-16 weeks for full fleet

Template 2: Warehouse Hot/Cold Aisle (3-20 MW)

- Target customer: Institutional operators with traditional data hall layouts
- Typical configuration: 5,000-15,000 miners in hot/cold aisle containment
- Retrofit approach: Zone-by-zone conversion, centralized cooling plant
- Cost benchmark: \$500-600K per MW
- Timeline: 16-24 weeks for phased deployment

Template 3: Existing Immersion (2-15 MW)

- Target customer: Early immersion adopters needing standardization
- Typical configuration: Non-standard tanks, single-phase dielectric fluid
- Retrofit approach: Standardize to Fog Hashing C6 or equivalent, integrate AI management
- Cost benchmark: \$280-380K per MW (lower than direct-to-chip)
- Timeline: 12-18 weeks

Template 4: Hybrid (Mixed Cooling, 5-25 MW)

- Target customer: Institutional operators with heterogeneous infrastructure
- Typical configuration: Mix of air-cooled and basic liquid across zones
- Retrofit approach: High-density zones get direct-to-chip, legacy zones optimized air
- Cost benchmark: \$450-550K per MW blended
- Timeline: 18-24 weeks

Template 5: Data Hall / Colocation (10-50 MW)

- Target customer: Large institutional operators or energy producers

- Typical configuration: Purpose-built data center with existing HVAC infrastructure
- Retrofit approach: Centralized cooling tower, modular CDU deployment, HVAC decommissioning
- Cost benchmark: \$400-500K per MW (economies of scale)
- Timeline: 20-28 weeks

Template 6: Greenfield / Legacy (1-50 MW)

- Target customer: Unique configurations requiring custom design
- Typical configuration: Varies widely (outdoor yards, pole barns, etc.)
- Retrofit approach: Fully custom engineering and implementation
- Cost benchmark: \$500-700K per MW (depends on baseline conditions)
- Timeline: 20-32 weeks

6. Proposal Generation & Contract Templates

The pricing engine auto-generates professional proposals incorporating:

Executive Summary:

- Current facility performance vs. post-retrofit projections
- Total investment requirement and financing options
- Payback period and 5-year ROI
- Key risks and mitigation strategies

Technical Approach:

- Detailed retrofit design with equipment specifications
- Phased implementation timeline with critical path analysis
- Integration plan for existing systems (power, network, management)
- Performance guarantees and SLA commitments

Financial Analysis:

- Itemized cost breakdown with transparent pricing
- Cash flow projections under multiple scenarios
- Sensitivity analysis tables
- Financing alternatives (cash, equipment financing, revenue share)

Statement of Work:

- Scope of services (what TerraHash delivers vs. customer responsibilities)
- Acceptance criteria and performance validation process
- Warranty terms (equipment, workmanship, performance guarantees)
- Payment schedule tied to milestones

Contract Terms:

- Fixed-price vs. time-and-materials options
- Change order process for scope modifications
- Force majeure and delay provisions
- Dispute resolution and arbitration framework

Technology Stack

Assessment Platform:

- Frontend: React-based web application with interactive facility modeling
- Backend: Python (Flask) with PostgreSQL database
- ML models: Scikit-learn for cost estimation, TensorFlow for thermal modeling
- GIS integration: Google Maps API for site location and logistics analysis

Data Collection Tools:

- Mobile app: iOS/Android for on-site data capture (photos, measurements, equipment serial numbers)
- FLIR thermal camera integration: Automated hot spot detection and analysis
- ASIC diagnostic scripts: Remote or USB-based performance testing and logging
- Network scanning tools: Nmap, iperf for bandwidth and latency validation

Document Generation:

- Proposal templates: Jinja2 with LaTeX for professional formatting
- Interactive financial models: Excel export with dynamic scenario analysis
- CAD integration: AutoCAD exports for electrical and cooling system diagrams
- CRM integration: Salesforce for proposal tracking and pipeline management

Key Differentiators

Speed to Proposal:

- Express assessments delivered in 48-72 hours (vs. industry standard 2-3 weeks)
- Standard assessments completed in 7-10 days with fixed-price quotes
- Eliminates extended evaluation paralysis common in retrofit decisions

Accuracy & Transparency:

- $\pm 8\%$ cost estimation accuracy validated across 100+ projects
- Transparent itemized pricing (no hidden fees or surprise markups)
- Performance guarantees backed by contractual remedies

Risk Mitigation:

- Fixed-price contracts eliminate customer exposure to cost overruns

- Performance guarantees ensure minimum efficiency and uptime improvements
- Phased milestone payments tie cash outlay to delivered value

Customer Experience:

- Self-service assessment portal for initial scoping
- Interactive ROI calculators allow real-time scenario modeling
- Digital proposal presentation with embedded video walkthroughs

Module 2: Modular Cooling System Retrofit

Overview

The Modular Cooling System Retrofit module represents the core physical transformation of air-cooled facilities into high-efficiency liquid-cooled operations. Leveraging Chilldyne's patented negative-pressure direct-to-chip cooling technology, the module delivers 19-28% efficiency improvements, eliminates seasonal throttling, and extends equipment lifespan by 50%+.

Core Technology: Chilldyne Negative Pressure Cooling

Revolutionary Design Principle:

Traditional liquid cooling systems use positive pressure (pumps push coolant through pipes), creating catastrophic leak risk when fittings fail. Chilldyne's negative pressure architecture operates at -25 to -4 Hg (vacuum), meaning any fitting failure results in air ingress rather than coolant leakage—eliminating the primary risk factor that has historically limited liquid cooling adoption in mining.

CDU (Cooling Distribution Unit) Product Line:

CDU-1500 (Primary for Mining Retrofits):

- Cooling capacity: 1.5 MW (1,500 kW)
- Flow rate: 400 GPM (gallons per minute)
- Operating pressure: -25 to -4 Hg (vacuum)
- Coolant: 30% ethylene glycol / 70% deionized water
- Approach temperature: 3°C at full load (industry-leading)
- Dimensions: 72" W x 36" D x 84" H
- Weight: 800-1,200 lbs (requires structural assessment)
- Power consumption: 8-12 kW (pumps, controls, monitoring)
- Redundancy: Dual pump configuration with N+1 failover
- Monitoring: Real-time flow, pressure, temperature sensors with Modbus/BACnet integration

CDU-300 (For Smaller Deployments or Zone-Specific):

- Cooling capacity: 300 kW

- Flow rate: 80 GPM
- All other specifications proportional to CDU-1500
- Ideal for: Small operators (<1 MW), zone-specific retrofits, pilot deployments

Cold Plate Technology:

Turbulator-Enhanced Design:

- Micro-channel copper construction with turbulator inserts for maximum heat transfer
- Direct mounting to ASIC chips via thermal interface material (TIM)
- Quick-disconnect fittings: Tool-less installation and hot-swap capability
- Corrosion-resistant coating for long-term glycol compatibility
- Pressure drop: <0.5 PSI per plate (minimal impact on pump requirements)

Chassis Integration:

- THS-4X21P-C55 modular chassis (Bitmain S19/S21 series): 3 hashboards per 4U rack unit
- THS-4X5M-C55 chassis (MicroBT M30S/M50S series): 4 hashboards per 4U rack unit
- Integrated manifolds with quick-disconnect for rack-level coolant distribution
- Hot-swap capability: Replace miners without system shutdown
- Standard 19" rack mount: Compatible with existing data center infrastructure

Retrofit Implementation Process

Phase 1: Pre-Deployment Preparation

Site Readiness:

- Electrical panel upgrades (if required) for CDU power distribution
- Structural reinforcement for CDU weight (800-1,200 lbs per unit)
- Coolant distribution routing (overhead or underfloor)
- Heat rejection system placement (dry coolers, cooling towers, or adiabatic systems)

Equipment Staging:

- CDU units delivered and positioned with 0.6m service clearance on all sides
- Cold plates and manifolds inventoried and organized by rack/zone
- Coolant pre-mixed and staged (30% glycol/water, pH-balanced)
- Network upgrades deployed (10Gb fiber backbone for AI management integration)

Phase 2: Miner Migration & Chassis Integration

ASIC Extraction & Preparation:

- Power down target zone/container (phased to maintain 70-90% facility hashrate)
- Remove miners from stock air-cooled enclosures

- Extract hashboards, power supplies, and control boards
- Clean hashboards (remove dust, verify solder joint integrity)
- Test hashboards (validate functionality before migration)

Chassis Assembly & Cold Plate Installation:

- Mount hashboards into THS-4X21P-C55 chassis (3 boards per chassis)
- Install Chilldyne cold plates onto ASIC chips
 - Apply thermal interface material (TIM) to chip surface
 - Secure cold plate with spring-loaded mounting bracket
 - Connect quick-disconnect fittings to chassis manifold
- Install power supplies and control boards (Braiiins BCB100 or stock controller)
- Mount chassis into rack (12-15 chassis per rack, 60-90 miners per rack)

Phase 3: Coolant System Integration

Primary Loop Installation:

- Connect CDU to rack-level manifolds via flexible plastic tubing (overhead or underfloor routing)
- Install flow sensors and pressure sensors at key distribution points
- Configure manifold quick-disconnects for each chassis (tool-less attachment)
- Fill and pressurize coolant loop
 - Achieve -25 to -4 Hg vacuum pressure
 - Validate leak-proof operation (no coolant leakage, air ingress only on fitting failure)
 - Purge air from system (automated via CDU)

Heat Rejection Configuration:

- Roof-mounted dry coolers (ambient air heat rejection)
- Cooling towers (evaporative cooling for hot climates)
- Adiabatic systems (mist-assisted dry cooling for efficiency)
- Heat recovery (industrial co-generation, district heating, greenhouse integration)

Phase 4: Commissioning & Performance Validation

System Startup:

- Energize CDU and establish coolant flow (400 GPM target)
- Power on miners in staged sequence (10-20% increments to validate thermal response)
- Monitor junction temperatures (target: 50-60°C under full load)
- Validate approach temperature (3°C delta between coolant and chip)

24-48 Hour Burn-In:

- Full load operation to validate thermal stability

- Monitor for anomalies (flow restrictions, hot spots, pump performance)
- Calibrate AI management platform sensors and alerts
- Document baseline performance (hashrate, power, temperature, efficiency)

Performance Acceptance:

- Validate minimum 20% J/TH efficiency improvement vs. air-cooled baseline
- Confirm elimination of thermal throttling under full load
- Achieve 99%+ uptime target within first 30 days
- Customer sign-off and transition to operations

Heat Rejection & Recovery Options

Standard Heat Rejection (Dry Coolers):

- Roof-mounted or adjacent pad installation
- Ambient air cooling (no water consumption)
- Modular sizing: 25-50 kW per unit
- Fan speed modulation based on ambient temperature and coolant demand
- Low maintenance: Annual cleaning, fan bearing inspection

High-Efficiency Heat Rejection (Cooling Towers):

- Evaporative cooling for hot climates (Texas, Arizona, Middle East)
- 30-40% more efficient than dry coolers in high ambient conditions
- Water consumption: 0.5-1.0 gallons per kW-hour rejected
- Requires water treatment (scale inhibitors, biocides)
- Higher maintenance: Quarterly cleaning, water quality monitoring

Heat Recovery for Revenue Generation:

- **Industrial Co-Generation:** Supply waste heat to adjacent facilities (food processing, chemical plants, lumber drying)
- **District Heating:** Integrate with municipal or campus heating systems
- **Greenhouse Integration:** Year-round climate control for agricultural operations (target: 70-85°C heat delivery)
- **Aquaculture:** Fish farming temperature regulation
- **Desalination:** Multi-effect distillation for water purification

Revenue Potential:

- Heat sales pricing: \$12-25 per MMBtu (depends on offtake agreement and market)
- Annual revenue (5 MW facility): \$500K-2.5M depending on utilization and pricing
- Payback on heat recovery infrastructure: 18-36 months

Retrofit Cost Breakdown (Per MW)

Component	Unit Cost	Quantity (1 MW)	Total
CDU-1500 units	\$180,000	0.67	\$120,000
THS chassis	\$450	285	\$128,250
Cold plates & fittings	\$285	285	\$81,225
Coolant system	\$15,000	1 MW	\$15,000
Dry coolers	\$30,000	1 MW	\$30,000
Installation labor	\$35,000	1 MW	\$35,000
Network upgrades	\$12,000	1 MW	\$12,000
Total per MW	-	-	\$421,475

Volume Discounts (5+ MW):

- Equipment: 8-12% discount on CDU and cold plates
- Installation: 15-20% labor efficiency from crew learning curve
- Total cost reduction: \$380-400K per MW for large deployments

Performance Guarantees

Efficiency Improvement:

- Minimum 20% J/TH improvement vs. documented air-cooled baseline
- Typical achievement: 25-35% improvement
- Contractual remedy: Performance fee waiver or equipment upgrade if target missed

Uptime Guarantee:

- 99% annual facility uptime within 90 days of retrofit completion
- Measured as percentage of hours at $\geq 95\%$ target hashrate
- Excludes customer-caused downtime (power outages, network failures, operator error)
- Remedy: SLA credits applied to monthly support fees

Thermal Stability:

- Junction temperatures maintained at 50-65°C under full load
- No thermal throttling under normal operating conditions (ambient $< 35^{\circ}\text{C}$)
- Validation through 30-day continuous operation monitoring

Module 3: Firmware & Automation Upgrade (AI Management)

Overview

The Firmware & Automation Upgrade module transforms mining operations from manual, reactive management to autonomous, predictive optimization. Integrating BraiinsOS+ per-chip autotuning with the TerraHash AI Management Platform, this module delivers 8-15% efficiency gains through firmware optimization, 80%+ failure prediction accuracy 3-14 days in advance, and 95%+ automated incident resolution without human intervention.

Component 1: BraiinsOS+ Firmware Deployment

Overview:

BraiinsOS+ is the industry-leading open-source mining firmware developed by Braiins (operators of the longest-running Bitcoin mining pool, Slush Pool). The platform enables per-chip voltage/frequency tuning, dynamic power scaling, and Stratum V2 support—delivering measurable efficiency improvements over stock manufacturer firmware.

Core Features:

Per-Chip Autotuning:

- ASIC chips within a single miner exhibit 10-20% performance variance due to manufacturing tolerances
- BraiinsOS+ calibrates individual chip voltage/frequency curves to optimize each chip independently
- Result: 8-15% efficiency improvement (J/TH reduction) vs. stock firmware
- Safe overclocking: Enabled by liquid cooling thermal headroom, increases hashrate 15-25% without compromising stability

Dynamic Power Scaling:

- Automatically adjusts miner power consumption based on real-time conditions:
 - Thermal feedback: Reduce power if junction temps approach limits (prevents thermal throttling)
 - Grid demand response: Scale down during peak pricing or curtailment events
 - Pool failover: Maintain hashrate during primary pool outages
- Integrates with TerraHash AI platform for fleet-wide coordination

Stratum V2 Protocol Support:

- Next-generation mining pool protocol with:
 - 40-60% bandwidth reduction (encrypted, compressed communication)
 - Job negotiation: Miners can customize block templates (future feature)
 - Enhanced security: Encrypted communication prevents hashrate hijacking

- Positions facility for future protocol migration as pools adopt Stratum V2

Dev Fee Structure:

- BraiinsOS+ Standard: 2% dev fee (2% of hashrate contributed to Braiins)
- BraiinsOS+ Commercial: \$30 per miner perpetual license, 0% dev fee
- TerraHash licensing: Negotiated bulk pricing for fleet deployments (typically \$20-25/miner)

Deployment Process:

Phase 1: Pre-Deployment Validation (Week 1)

- Test firmware on 5-10% of fleet (pilot miners)
- Validate thermal stability, hashrate performance, pool connectivity
- Document baseline performance vs. post-firmware efficiency gains
- Refine tuning profiles for facility-specific conditions

Phase 2: Fleet-Wide Rollout (Weeks 2-4)

- Batch firmware deployment: 50-100 miners per batch, staged over 2-3 weeks
- Automated deployment via TerraHash management platform (remote flashing)
- Per-miner autotuning calibration: 24-48 hours per miner for optimal profile generation
- Continuous monitoring for anomalies or regression to stock firmware

Phase 3: Optimization & Fine-Tuning (Weeks 5-8)

- Analyze 30-day performance data across fleet
- Adjust tuning profiles for outlier miners (underperformers or overly aggressive settings)
- Integrate with AI platform for dynamic power scaling triggers
- Document final efficiency improvement vs. baseline

Expected Outcomes:

- Efficiency improvement: 8-15% J/TH reduction
- Hashrate increase: 10-20% through safe overclocking (liquid cooling enables higher power limits)
- Pool connectivity: <0.1% reject/stale rate (vs. 0.5-1.5% with stock firmware)
- Uptime: 99.9% firmware stability (vs. 98-99% stock firmware crash rate)

Component 2: TerraHash AI Management Platform

Architecture Overview:

The TerraHash AI Management Platform is a comprehensive, cloud-native application deployed on edge compute infrastructure (Kubernetes cluster) within or adjacent to the mining facility. The platform aggregates real-time telemetry from miners, cooling systems, power distribution, and network infrastructure—applying machine learning models for predictive maintenance, automated remediation, and performance optimization.

System Architecture:

Edge Compute Cluster:

- Hardware: 3-node Kubernetes cluster (bare metal or VM)
 - CPU: 16-32 cores per node (AMD EPYC or Intel Xeon)
 - RAM: 64-128 GB per node
 - Storage: 2-4 TB NVMe SSD per node (time-series data, ML models)
 - Network: 10Gb fiber backbone, 1Gb to miners
- Software: Kubernetes (K8s), Rancher for cluster management, Prometheus/Grafana for monitoring

Data Ingestion Layer:

- Miner telemetry: BraiinsOS API (hashrate, temperature, power, rejects, firmware version)
- Cooling system: Chillydyne CDU sensors (flow rate, pressure, temperature, pump speed, alarms)
- Power monitoring: PDU API (current, voltage, power factor, energy consumption)
- Network monitoring: Switch SNMP (bandwidth, latency, packet loss, errors)
- Environmental: Temperature/humidity sensors, HVAC controls

Time-Series Database:

- InfluxDB or TimescaleDB for high-frequency telemetry storage
- Retention: 90 days real-time data, 2 years aggregated hourly data, 5 years daily summaries
- Query performance: <100ms for dashboard queries, <5s for complex analytics

ML Inference Engine:

- TensorFlow or PyTorch models for anomaly detection and predictive maintenance
- Models trained on 100+ facility-years of operational data
- Inference latency: <500ms for real-time alerts

Automation Engine:

- Rule-based automation: If/then logic for common issues (miner reboot, pool failover)
- ML-driven automation: Predictive actions based on failure probability (e.g., schedule maintenance before predicted failure)
- Human-in-loop: Escalation to NOC for complex issues or low-confidence predictions

Frontend Dashboard:

- React-based web application (desktop and mobile responsive)
- Role-based access control: Operator, Engineer, Finance, Executive views
- Real-time updates: WebSocket for live data streaming

Core AI Capabilities:

1. Predictive Maintenance

Failure Prediction Models:

- **Dashboard Degradation:** Detects gradual performance decline (chip failures, solder joint fatigue)
 - Features: Temperature history, power consumption trend, reject rate increase
 - Prediction horizon: 7-14 days before critical failure
 - Accuracy: 85-90% after 90-day training period
- **Fan Failures:** Predicts bearing wear and motor burnout
 - Features: Vibration (inferred from temperature oscillations), RPM variance, current draw anomalies
 - Prediction horizon: 3-7 days before failure
 - Accuracy: 80-85%
- **Power Supply Failures:** Detects capacitor aging and voltage instability
 - Features: Output voltage variance, ripple current, temperature, efficiency degradation
 - Prediction horizon: 5-10 days before failure
 - Accuracy: 75-80%
- **Cooling System Issues:** Identifies pump wear, flow restrictions, coolant degradation
 - Features: Flow rate trend, differential pressure, pump current draw, coolant temperature delta
 - Prediction horizon: 7-14 days before failure
 - Accuracy: 85-90%

Maintenance Scheduling:

- Automated work order generation integrated with CMMS (Computerized Maintenance Management System)
- Parts inventory tracking and automated RMA initiation
- Technician dispatch scheduling to minimize downtime
- Spare parts forecasting based on predicted failure rates

2. Automated Incident Remediation

Common Issue Auto-Resolution (95%+ success rate):

Miner Stuck/Unresponsive:

- Detection: No hashrate reported for >5 minutes, no API response
- Remediation: Automated power cycle via PDU API or BMC (Baseboard Management Controller)
- Success rate: 98% (2% require physical intervention)
- Resolution time: <2 minutes

Pool Connection Loss:

- Detection: Miner reports "pool disconnected" or excessive rejects
- Remediation: Automatic failover to backup pool, re-establish Stratum connection
- Success rate: 99%
- Resolution time: <30 seconds

Thermal Throttling:

- Detection: Junction temperature >75°C, hashrate drops >10%
- Remediation: Increase coolant flow (CDU pump speed), reduce miner power (dynamic scaling), alert for cooling system diagnostics
- Success rate: 95% (5% indicate cooling system failure requiring human intervention)
- Resolution time: <1 minute

Firmware Crash/Reboot:

- Detection: Miner unexpectedly reboots or reports firmware error
- Remediation: Automated firmware re-flash or rollback to stable version
- Success rate: 90%
- Resolution time: <5 minutes

Network Connectivity Issues:

- Detection: Miner cannot reach pool or management API
- Remediation: Network diagnostics (ping, traceroute), automated switch port bounce, VLAN reconfiguration
- Success rate: 85% (15% require physical cable inspection)
- Resolution time: <3 minutes

High Reject/Stale Rate:

- Detection: Reject rate >1.5% (vs. normal <0.3%)
- Remediation: Pool failover, network diagnostics, firmware tuning adjustment
- Success rate: 90%
- Resolution time: <2 minutes

3. Performance Optimization

Fleet-Wide Efficiency Tuning:

- Continuous analysis of per-miner efficiency (J/TH) vs. fleet average
- Automatic tuning profile adjustments for underperforming miners
- A/B testing of tuning profiles to identify optimal settings
- Result: 3-5% efficiency improvement over initial firmware deployment

Thermal Management Optimization:

- Coordinated control of cooling system and miner power to maintain optimal temperature
- Predictive ambient temperature compensation (weather forecast integration)
- Heat recovery optimization (balance between mining efficiency and heat sales value)

Pool Strategy Optimization:

- Automatic pool selection based on latency, luck, and fee structure
- Stratum V2 job negotiation configuration (future)
- Variance reduction through multi-pool distribution

Power Cost Optimization:

- Curtailment event participation (automatically scale down during demand response events)
- Time-of-use pricing optimization (reduce hashrate during peak pricing, increase during off-peak)
- Grid frequency regulation participation (future revenue stream)

4. Financial Analytics & Reporting

Real-Time Cost Per Bitcoin Tracking:

- Aggregate electricity cost, maintenance, labor, pool fees
- Calculate effective cost per BTC mined (daily, weekly, monthly)
- Compare to market BTC price for profitability visibility

Cohort Analysis:

- Track ROI and payback period by equipment cohort (ASIC model, purchase date)
- Identify underperforming cohorts for replacement prioritization
- Forecast equipment refresh timing based on profitability trends

Scenario Modeling:

- "What-if" analysis: Impact of BTC price changes, difficulty increases, electricity cost changes
- Reinvestment modeling: Optimal timing and sizing for capacity expansion
- Sensitivity analysis: Identify key drivers of profitability

Treasury Integration:

- Interfaces with Automated Treasury Management Module (Module 4)
- Provides mining revenue data for BTC/stablecoin allocation decisions
- Tracks HODL ratio compliance and runway metrics

Dashboard Views by User Role

Operator View (NOC/Technician):

- Real-time facility status: Miners online/offline, total hashrate, power consumption
- Active alerts and incidents with resolution steps

- Miner health heatmap (color-coded by performance vs. baseline)
- Cooling system status: CDU flow, temperature, pressure, alarms

Engineer View (Mining Engineer/Manager):

- Efficiency trends: Fleet-wide J/TH over time, per-miner efficiency scatter plot
- Predictive maintenance queue: Upcoming failures and recommended actions
- Firmware deployment status: Miners on latest version, tuning profile distribution
- Performance benchmarking: Facility vs. regional peers, cohort vs. cohort

Finance View (CFO/Controller):

- Cost per BTC: Real-time and historical trends
- Revenue vs. forecast: Actual BTC mined vs. projections
- Cash flow: Mining revenue, operational expenses, net profit
- Cohort ROI: Payback period and IRR by equipment purchase

Executive View (CEO/Board):

- High-level KPIs: Uptime, efficiency, cost per BTC, net profit
- Strategic positioning: Facility competitiveness vs. industry benchmarks
- Investment performance: Retrofit ROI, NPV, IRR
- Risk dashboard: Top risks and mitigation status

Integration & Ecosystem

Pool Management Integration:

- Native support for all major pools: Braiins, Luxor, Foundry, F2Pool, Hive OS
- API integration for pool metrics: Luck, earnings, worker status
- Automated pool failover and load balancing

ERP & Accounting Systems:

- QuickBooks, Xero, SAP connectors for financial data sync
- Automated journal entries for mining revenue, electricity cost, maintenance expenses
- Tax reporting: Cost-basis tracking, depreciation schedules

CMMS (Maintenance Management):

- Integration with UpKeep, Fiix, or similar platforms
- Automated work order creation for predicted failures
- Parts inventory tracking and reorder triggers

SCADA/Facility Management:

- Modbus/BACnet integration with building management systems (BMS)

- Coordination with facility HVAC, security, fire suppression

Custody & Treasury:

- API integration with institutional custody providers (Fortris, Fireblocks, Coinbase Prime)
- Real-time balance tracking for hot, warm, and cold wallets
- Automated treasury rebalancing signals (feeds Module 4)

Key Performance Indicators (KPIs)

Operational Excellence:

- Uptime: 99%+ facility-level availability
- Mean Time To Resolution (MTTR): <30 minutes for critical incidents
- Automated resolution rate: 95%+ of incidents resolved without human intervention

Efficiency Optimization:

- Fleet J/TH: Track continuous improvement (baseline → firmware → AI tuning)
- Hashrate per MW: Measure density improvements
- PUE (Power Usage Effectiveness): Facility power / miner power (target <1.10)

Predictive Maintenance:

- Failure prediction accuracy: 80%+ at 3-14 day horizon
- Unplanned downtime reduction: 80%+ vs. pre-AI baseline
- Maintenance cost reduction: 60-75% through predictive vs. reactive maintenance

Financial Performance:

- Cost per BTC: Decrease 25-35% through efficiency gains and labor reduction
- Profitability margin: Increase 15-25 percentage points
- ROI on AI platform investment: 18-24 month payback

Module 4: Automated Treasury Management Module

Overview

The Automated Treasury Management Module addresses the unique challenge of bitcoin mining operations: How to maximize long-term wealth accumulation while maintaining operational liquidity and protecting against extreme market volatility. This module automates BTC/stablecoin allocation, profit reinvestment, and risk management—delivering 10-20% revenue enhancement through strategic asset allocation and reducing manual treasury decision-making by 90%+.

Core Problem Statement

Bitcoin mining operations generate revenue in a highly volatile asset (BTC) but incur expenses in stable fiat currencies (electricity, labor, maintenance). This creates three critical treasury management challenges:

1. **Operational Runway Risk:** Holding 100% BTC exposes operations to cash flow crises during bear markets (e.g., 70%+ BTC drawdowns)
2. **Opportunity Cost:** Selling 100% of mined BTC to cover fiat expenses sacrifices long-term wealth accumulation (BTC appreciation over 5-10 year horizons)
3. **Manual Decision-Making:** Ad-hoc treasury decisions are emotionally driven, poorly timed, and lack systematic risk management

The Automated Treasury Management Module solves these challenges through rule-based, data-driven allocation policies that balance liquidity, growth, and risk management.

Core Capabilities

1. Dynamic Allocation Engine

Allocation Bands by Market Regime:

The module implements **regime-based allocation** that automatically adjusts BTC vs. stablecoin holdings based on market conditions:

Bear Regime (BTC <\$60K, 30% drawdown from recent high):

- BTC Holdings: 70-80% (higher HODL ratio—buy low, accumulate)
- Stablecoin Holdings: 20-30% (elevated cash reserves for operational runway)
- Rationale: Bear markets offer best accumulation opportunity; protect against further downside with cash buffer

Base Regime (BTC \$60-120K, normal volatility):

- BTC Holdings: 50-70% (balanced approach)
- Stablecoin Holdings: 30-50% (standard operational runway)
- Rationale: Maintain exposure to BTC upside while ensuring 6-12 month operational runway

Bull Regime (BTC >\$150K, >50% rally from recent low):

- BTC Holdings: 30-50% (reduce exposure near cycle peaks)
- Stablecoin Holdings: 50-70% (lock in profits, de-risk portfolio)
- Rationale: Reduce risk at elevated prices; secure fiat for capital expenditures (equipment upgrades, facility expansion)

Allocation Rebalancing:

- Frequency: Daily rebalancing to maintain target allocation bands
- Execution: Automated via API integration with exchange (Coinbase, Kraken, OTC desk)

- Slippage management: Smart order routing to minimize market impact (<0.3% slippage target)
- Tax efficiency: LIFO (Last In, First Out) cost-basis tracking to optimize capital gains

2. Operational Runway Management

Runway Calculation:

- **Definition:** Number of months of operational expenses covered by stablecoin holdings
- **Target:** 6-12 months depending on risk tolerance and market regime
- **Formula:** $\text{Runway (months)} = \text{Stablecoin Balance} / \text{Monthly OpEx}$

Dynamic OpEx Forecasting:

- Historical 90-day average operational expenses (electricity, labor, maintenance, insurance)
- Seasonal adjustments (e.g., summer cooling costs +20%, winter heating credits)
- Expansion planning (account for planned capacity increases)

Runway Alerts & Triggers:

- **Green Zone (12+ months):** All systems normal, can increase BTC allocation
- **Yellow Zone (6-12 months):** Standard operations, monitor for deterioration
- **Orange Zone (3-6 months):** Elevated risk, increase stablecoin allocation, defer non-critical CapEx
- **Red Zone (<3 months):** Emergency mode, sell BTC to restore runway, halt expansion plans

Automated Runway Protection:

- If runway drops below 6 months, automatically allocate 80% of new mining revenue to stablecoins
- If runway falls below 3 months, initiate emergency BTC liquidation (up to 25% of holdings per week)
- Notify management for approval on large liquidations (>\$500K single transaction)

3. Profit Reinvestment Optimization

Reinvestment Decision Framework:

The module determines optimal allocation of profits between:

1. **Holding BTC (Passive Appreciation):** Accumulate BTC for long-term wealth
2. **Cash Distributions (Shareholder Returns):** Distribute profits to owners/investors
3. **Equipment Refresh (Active Reinvestment):** Purchase new miners to maintain competitiveness
4. **Facility Expansion (Growth CapEx):** Scale capacity to increase absolute hashrate

Reinvestment Rate by Regime:

- **Bear Market:** 10-20% reinvestment (focus on survival, preserve cash, accumulate BTC)
- **Base Market:** 25-40% reinvestment (balanced growth, equipment refresh cycles)
- **Bull Market:** 15-25% reinvestment (avoid peak-cycle equipment purchases, lock in profits)

Capital Allocation Priorities:

1. **Energy Efficiency First:** Prioritize CapEx that reduces J/TH (firmware, cooling upgrades, PPA negotiations) before adding hashrate
2. **Replace Weakest Cohorts:** Target oldest/least-efficient equipment for replacement (e.g., S9 → S21 upgrade)
3. **Expand Only at Attractive Economics:** Add capacity only when marginal ROI exceeds holding BTC under modeled difficulty projections

Scenario-Based Reinvestment Modeling:

- Conservative scenario (15% annual difficulty growth, \$80K BTC): 15% reinvestment rate
- Moderate scenario (25% difficulty, \$120K BTC): 30% reinvestment rate
- Aggressive scenario (40% difficulty, \$200K BTC): 20% reinvestment rate (avoid peak purchases)

4. Risk Management & Hedging

Hedging Instruments:

Hashprice Hedges:

- **What:** Derivatives that lock in minimum revenue per terahash regardless of BTC price/difficulty
- **When:** During bull markets to protect against future revenue declines
- **Example:** 6-month hashprice collar at \$70/PH/day (current \$90/PH/day)—guarantees minimum revenue floor

Difficulty Futures:

- **What:** Contracts that pay out based on future network difficulty levels
- **When:** During periods of rapid hashrate growth to hedge against profitability compression
- **Example:** Difficulty swap at 150 exahash—pays if difficulty exceeds target, protects profit margins

BTC Options:

- **What:** Put options that protect against severe BTC price declines
- **When:** Large BTC holdings in bull markets to protect unrealized gains
- **Example:** 3-month 80% OTM puts—insurance against black swan events

Stablecoin Yield Generation:

- **What:** DeFi protocols or CeFi platforms offering yield on stablecoin balances
- **When:** Always (idle cash should earn yield)
- **Options:** Coinbase USD (USDC) at 4-5% APY, Aave/Compound DeFi lending at 6-8% APY (higher risk)
- **Risk management:** Limit DeFi exposure to 30% of stablecoin holdings (smart contract risk)

5. Custody Integration

Multi-Tier Custody Architecture:

Hot Wallet (Daily Operations):

- Balance target: 3-7 days of mining revenue (~\$50-150K for 5 MW facility)
- Purpose: Pool payouts, immediate operational liquidity
- Custody: Self-hosted with multi-sig (2-of-3) or exchange API
- Security: Hardware security module (HSM), IP whitelist, 2FA

Warm Wallet (Weekly Sweep):

- Balance target: 1-2 months of operational expenses + allocation buffer (~\$500K-1M)
- Purpose: Treasury rebalancing, BTC/stablecoin swaps, medium-term reserves
- Custody: Institutional multi-sig (Fortris, Fireblocks) or qualified custodian (Coinbase Prime)
- Security: Multi-sig (3-of-5), geographic key distribution, time-locks

Cold Wallet (Long-Term Holdings):

- Balance target: 80-90% of total BTC holdings (multi-million dollar balances)
- Purpose: HODL strategy, long-term wealth preservation
- Custody: Cold storage (hardware wallets, multi-sig vaults) with geographic redundancy
- Security: Air-gapped signing, multi-sig (5-of-7 or higher), geographic key distribution, time-locks on withdrawals

Automated Wallet Management:

- Daily sweep: Hot wallet → Warm wallet when balance exceeds 7-day target
- Weekly allocation: Warm wallet rebalancing to maintain target BTC/stablecoin allocation
- Monthly consolidation: Excess warm wallet BTC → Cold wallet for long-term storage

6. Tax Optimization & Reporting**Cost-Basis Tracking:**

- Per-transaction cost basis logging (mining date, BTC amount, USD value at receipt)
- LIFO, FIFO, or specific identification methods supported
- Automated 1099-MISC generation for mining income (US tax compliance)

Capital Gains Optimization:

- Prefer long-term capital gains (BTC held >1 year) for liquidity events
- Tax-loss harvesting: Realize losses during bear markets to offset gains
- Quarterly tax payment estimates based on realized income

Reporting & Audit Trails:

- Monthly treasury reports: Holdings, allocations, rebalancing activity, realized gains/losses
- Quarterly board reports: Treasury performance vs. benchmark, risk metrics, runway status
- Annual audit package: Complete transaction history, cost-basis records, custody attestations

Implementation & Integration

Phase 1: Policy Definition (Week 1-2)

- Define allocation bands for each market regime (bear/base/bull)
- Set operational runway targets (6, 9, or 12 months)
- Establish reinvestment priorities and approval thresholds
- Configure risk management rules (hedging triggers, stablecoin yield allocation)

Phase 2: Custody Setup (Week 2-4)

- Establish hot/warm/cold wallet infrastructure
- Integrate with institutional custody provider (Fortris, Fireblocks, Coinbase Prime)
- Configure multi-sig policies and signing authorities
- Test wallet sweeps and rebalancing flows

Phase 3: Exchange Integration (Week 3-5)

- API integration with primary exchange (Coinbase, Kraken, or OTC desk)
- Configure automated trading bot for rebalancing
- Test slippage management and order routing
- Establish backup liquidity providers

Phase 4: Dashboard & Reporting (Week 4-6)

- Deploy treasury dashboard with real-time holdings, allocation, runway metrics
- Configure automated alerts (runway warnings, allocation drift, large transactions)
- Set up monthly/quarterly reporting templates
- Integrate with ERP system for financial consolidation

Phase 5: Pilot & Optimization (Week 7-12)

- Run pilot allocation cycle with small percentage of holdings (10-20%)
- Monitor rebalancing execution, slippage, and policy adherence
- Refine allocation bands based on observed volatility and market conditions
- Full rollout after pilot success validation

Key Performance Metrics

Allocation Accuracy:

- Target: Maintain allocation within $\pm 5\%$ of policy bands 95%+ of the time
- Measure: Daily snapshot of actual vs. target allocation

Runway Compliance:

- Target: Never fall below 6-month runway threshold

- Measure: Minimum runway observed during each month

Revenue Enhancement:

- Target: 10-20% total revenue improvement through strategic allocation vs. naive 100% BTC HODL or 100% sell strategies
- Measure: Cumulative value of (BTC holdings + stablecoin holdings + distributed profits) vs. baseline strategies

Rebalancing Efficiency:

- Target: <0.3% average slippage on rebalancing trades
- Measure: Executed price vs. mid-market at time of order

Tax Optimization:

- Target: Maximize long-term capital gains percentage vs. short-term
- Measure: Percentage of realized gains taxed at long-term rates (>1 year holding)

User Interface & Control

Treasury Dashboard:

- **Current Holdings:** BTC balance, stablecoin balance, total USD value
- **Allocation Status:** Current allocation vs. target, drift percentage
- **Runway Meter:** Visual gauge showing months of operational coverage
- **Rebalancing Queue:** Pending trades and execution status
- **Historical Performance:** Portfolio value over time vs. benchmark strategies

Manual Override:

- **Pause Automation:** Temporarily disable automatic rebalancing (e.g., during major market events)
- **Force Rebalance:** Trigger immediate rebalancing outside of scheduled daily execution
- **Adjust Allocation Bands:** Update target allocations in response to changing risk tolerance or market conditions

Approval Workflows:

- **Small Transactions (<\$50K):** Fully automated, no approval required
- **Medium Transactions (\$50-500K):** Email notification to CFO, auto-execute unless paused within 1 hour
- **Large Transactions (>\$500K):** Require explicit CFO approval before execution

Risk Management & Safeguards

Position Limits:

- Maximum single-day BTC liquidation: 10% of total holdings
- Maximum stablecoin yield exposure: 30% of stablecoin holdings (DeFi protocols)
- Maximum exchange balance: 20% of total holdings (avoid counterparty risk)

Circuit Breakers:

- Pause all automated trading during:
 - BTC price volatility >30% in 24 hours (potential market manipulation or oracle failure)
 - Exchange API downtime >1 hour (risk of stale pricing data)
 - Major security incidents (exchange hacks, custody breach)
- Resume only after manual review and approval

Multi-Sig & Time-Locks:

- All large transactions (>\$500K) require 3-of-5 multi-sig approval
- Cold storage withdrawals have 48-hour time-lock (allows detection and cancellation of unauthorized transactions)
- Warm wallet has 24-hour withdrawal limit (caps damage from compromised hot wallet)

Module 5: Tiered SLA Support Packages

Overview

The Tiered SLA Support Packages provide flexible, outcome-based service levels tailored to different customer needs and risk tolerances. From self-service monitoring to white-glove managed services, the packages ensure customers receive the appropriate level of support while aligning costs with value delivered.

SLA Tier Structure

Feature	Silver (Self-Service)	Gold (Standard)	Platinum (Premium)	Platinum Enterprise
Target Customer	Technical operators, <10 MW	Regional miners, 10-30 MW	Institutional, 30-100 MW	Public companies, 100+ MW
Annual Cost (Base)	\$30K + \$2.5K/MW/month	\$50K + \$5K/MW/month	\$150K + \$10K/MW/month	Custom (typically \$500K-2M)
Uptime SLA	98% (best-effort)	99% (guaranteed)	99.5% (guaranteed)	99.9% (guaranteed)
Incident Response	4 hours (business hours)	30 minutes (24/7)	15 minutes (24/7)	5 minutes (24/7)
On-Site Support	Annual inspection	Semi-annual visits	Quarterly visits + on-demand	Dedicated on-site tech

Feature	Silver (Self-Service)	Gold (Standard)	Platinum (Premium)	Platinum Enterprise
AI Platform	Standard dashboards	Full platform + custom views	Priority ML model training	Custom AI development
Treasury Module	Basic (manual)	Automated (standard policies)	Automated + hedging	Fully customized
Firmware Updates	Self-service	Managed rollout	Priority access to beta	Co-development with Braiins
Financial Penalties	None	\$25-50/TH/month (SLA miss)	\$50-100/TH/month (SLA miss)	Custom (typically 2-5% revenue)
Dedicated Support	Email/ticket only	Shared account manager	Dedicated account manager	Executive account team

Detailed SLA Tier Descriptions

Silver Tier: Self-Service

Target Customer: Technical operators with in-house mining expertise, budget-conscious operations, small-scale deployments (<10 MW).

Included Services:

- **AI Management Platform Access:** Standard dashboards, real-time monitoring, automated alerts
- **Incident Response:** Email/ticket support during business hours (M-F 8am-6pm local time), 4-hour initial response target
- **Firmware Management:** Self-service firmware deployment tools, documentation, and community support
- **Treasury Module:** Basic cost tracking and reporting, manual BTC/stablecoin allocation
- **Annual Facility Inspection:** On-site visit (1 day) for performance validation, optimization recommendations, equipment health assessment

Exclusions:

- No after-hours emergency support (customer responsible for critical incident management)
- No financial penalty for underperformance (SLA is best-effort, not guaranteed)
- No dedicated account management (support via ticketing system)

Use Cases:

- Experienced operators comfortable managing day-to-day operations
- Facilities with strong internal technical teams
- Cost-sensitive operations prioritizing low fixed costs

Pricing:

- Base: \$30,000 annually
- Per-MW: \$2,500/MW/month

- Example: 5 MW facility = \$30K + (\$2.5K x 5 x 12) = \$180K annually

Gold Tier: Standard

Target Customer: Regional mining operators, institutional investors with moderate technical expertise, facilities 10-30 MW.

Included Services:

- **99% Uptime Guarantee:** Financial penalties (\$25-50/TH/month) if uptime falls below 99% in any calendar month
- **24/7 NOC Support:** Remote monitoring and incident response within 30 minutes
- **Semi-Annual On-Site Visits:** Performance optimization, equipment health assessments, cooling system maintenance, firmware updates
- **Automated Treasury Management:** Standard allocation policies (bear/base/bull regimes), automated rebalancing, operational runway management
- **Managed Firmware Rollouts:** TerraHash-managed firmware updates with staged deployment and rollback capability
- **Predictive Maintenance:** 80%+ accuracy failure prediction with 3-7 day advance warning, automated maintenance scheduling
- **Monthly Reporting:** Performance reports (uptime, efficiency, cost per BTC), financial analytics, optimization recommendations

Financial Guarantee:

- SLA Credit: If monthly uptime <99%, customer receives \$25-50/TH credit against next month's service fee
- Example: 10 MW facility (2,850 miners, 570,000 TH) with 97% uptime (2% shortfall) = \$285K credit

Dedicated Support:

- Shared account manager (1 manager per 5-8 customers)
- Quarterly business reviews (remote)
- Priority email/phone support (response within 2 hours)

Use Cases:

- Operators seeking balance between cost and support level
- Facilities without 24/7 internal staff
- Operations requiring guaranteed uptime for investor confidence

Pricing:

- Base: \$50,000 annually
- Per-MW: \$5,000/MW/month
- Example: 15 MW facility = \$50K + (\$5K x 15 x 12) = \$950K annually

Platinum Tier: Premium

Target Customer: Institutional mining companies, publicly-traded miners, energy producers, facilities 30-100 MW.

Included Services:

- **99.5% Uptime Guarantee:** Financial penalties (\$50-100/TH/month) if uptime falls below 99.5%
- **15-Minute Incident Response:** Dedicated NOC with priority escalation path, 24/7/365
- **Quarterly On-Site Visits + On-Demand Support:** Regular optimization visits plus emergency dispatch (technician on-site within 24-48 hours)
- **Advanced Treasury Management:** Automated allocation + hedging (hashprice, difficulty futures), stablecoin yield optimization
- **Priority Firmware Access:** Beta firmware testing, early access to new features, priority bug fixes
- **Custom AI Model Training:** Facility-specific ML models trained on 60-90 days of historical data for maximum prediction accuracy
- **Board-Ready Reporting:** Monthly executive summaries, quarterly board presentations, investor relations support

Financial Guarantee:

- SLA Credit: \$50-100/TH for each percentage point below 99.5% uptime
- Example: 40 MW facility (11,400 miners, 2.28M TH) with 99% uptime (0.5% shortfall) = \$1.14M credit

Dedicated Support:

- Dedicated account manager (1:1 relationship)
- Quarterly on-site business reviews
- Direct phone/SMS access to account manager and senior engineers
- Priority escalation to CTO/CEO for critical issues

Additional Benefits:

- **White-Glove Onboarding:** 30-day intensive support during retrofit commissioning
- **Integration Services:** Custom integrations with customer ERP, accounting, investor portals
- **Regulatory Compliance Support:** Assistance with SOC2, ISO27001, environmental audits

Use Cases:

- Public mining companies requiring institutional-grade uptime and reporting
- Energy producers with limited internal mining expertise
- Facilities with complex integration requirements (SCADA, heat recovery, demand response)

Pricing:

- Base: \$150,000 annually

- Per-MW: \$10,000/MW/month
- Example: 50 MW facility = \$150K + (\$10K x 50 x 12) = \$6.15M annually

Platinum Enterprise Tier: Fully Customized

Target Customer: Large public mining companies (100+ MW), multi-site portfolios, strategic partnerships requiring co-development.

Included Services:

- **99.9% Uptime Guarantee:** Financial penalties custom-negotiated (typically 2-5% of monthly gross mining revenue)
- **5-Minute Incident Response:** Dedicated NOC with direct line to senior engineering team
- **Dedicated On-Site Technician(s):** Full-time TerraHash employee embedded at customer facility(ies)
- **Fully Customized Treasury & Risk Management:** Bespoke policies, institutional custody integration, advanced hedging strategies
- **Co-Development Partnership:** Joint product development (firmware features, AI models, hardware integration)
- **24/7 Executive Support:** Direct access to TerraHash executive team (CEO, CTO, CFO) for strategic decisions

Financial Guarantee:

- Revenue-Based SLA: If uptime <99.9%, TerraHash pays 2-5% of gross monthly mining revenue as penalty
- Example: 150 MW facility generating \$20M monthly revenue with 99.5% uptime (0.4% shortfall) = \$400K-1M penalty (at 2-5% rate)

Dedicated Support:

- Executive account team: Account director, lead engineer, finance liaison
- Monthly executive business reviews (on-site or remote)
- Annual strategic planning sessions with TerraHash C-suite

Additional Benefits:

- **White-Label Services:** TerraHash management platform branded with customer logo for investor/tenant presentations
- **Investor Relations Support:** Custom reporting packages, quarterly earnings call prep, analyst Q&A support
- **M&A Integration Services:** Rapid integration of acquired facilities into TerraHash standard

Use Cases:

- Public mining companies (MARA, Riot, CleanSpark, TeraWulf)
- Large private portfolios (100+ MW across multiple sites)

- Strategic partnerships (ServerDomes hosting TerraHash-managed facilities)

Pricing:

- Custom negotiation (typically \$500K-2M annually + per-MW fees)
- Example: 200 MW portfolio across 8 sites = \$2M base + (\$8K x 200 x 12) = \$21.2M annually

SLA Performance Measurement

Uptime Calculation:

- **Definition:** Percentage of time facility operates at $\geq 95\%$ of target hashrate
- **Measurement:** Hourly snapshots of actual hashrate vs. theoretical maximum (accounting for operational miners)
- **Exclusions:** Customer-caused downtime (power outages, network failures, operator error), scheduled maintenance (pre-approved 48+ hours in advance), force majeure events (natural disasters, grid failures)

Formula:

$$\text{Uptime \%} = (\text{Hours at } \geq 95\% \text{ hashrate}) / (\text{Total hours} - \text{Excluded downtime}) \times 100$$

Reporting:

- Monthly uptime report delivered within 5 business days of month-end
- Itemized downtime log: Incident description, root cause, resolution time, exclusion justification
- Customer right to dispute: 10-day window to challenge uptime calculation or exclusions

SLA Credits:

- Automatically applied to next month's invoice (no customer action required)
- For Platinum Enterprise (revenue-based penalties), credits paid via wire transfer within 15 days

Escalation & Incident Management

Incident Severity Levels:

Severity 1 (Critical):

- **Definition:** $>50\%$ facility hashrate offline or total facility outage
- **Response:** Immediate escalation to on-call engineer (within 5-15 minutes depending on tier)
- **Resolution Target:** 2 hours for initial mitigation, 24 hours for full restoration

Severity 2 (High):

- **Definition:** 10-50% hashrate degradation or critical system failure (cooling, power, network)
- **Response:** 15-30 minutes (tier-dependent)
- **Resolution Target:** 4 hours for mitigation, 48 hours for full resolution

Severity 3 (Medium):

- **Definition:** <10% hashrate impact, non-critical equipment failures, performance anomalies
- **Response:** 1-4 hours (tier-dependent)
- **Resolution Target:** 24-72 hours for full resolution

Severity 4 (Low):

- **Definition:** Single miner failures, cosmetic issues, feature requests
- **Response:** Next business day
- **Resolution Target:** 1-2 weeks

Escalation Path:

- Tier 1: NOC technician (initial diagnosis and automated remediation)
- Tier 2: Senior engineer (complex troubleshooting, on-site dispatch)
- Tier 3: Engineering manager (facility-wide issues, vendor escalation)
- Tier 4: CTO (strategic decisions, major incidents, customer executive engagement)

Module 6: Project Management & Execution Framework**Overview**

The Project Management & Execution Framework ensures predictable, on-time, on-budget retrofit delivery through standardized processes, experienced teams, and transparent communication. This module leverages 100+ completed projects to de-risk execution and deliver consistent customer satisfaction.

Execution Methodology**Phase-Gate Approach:**

TerraHash employs a modified Agile methodology with five phase gates:

Phase Gate 0: Assessment & Proposal (Weeks 0-2)

- **Deliverables:** Facility assessment report, detailed retrofit design, fixed-price proposal
- **Approval:** Customer signs Statement of Work (SOW) and provides deposit (typically 20-30%)
- **Exit Criteria:** Contract executed, deposit received, long-lead equipment ordered

Phase Gate 1: Engineering & Procurement (Weeks 1-4)

- **Deliverables:** Finalized electrical/mechanical/thermal designs, equipment ordered, site preparation plan
- **Approval:** Customer approves final design drawings, confirms equipment specifications
- **Exit Criteria:** Long-lead equipment delivery scheduled, site ready for mobilization

Phase Gate 2: Installation & Integration (Weeks 5-16)

- Deliverables: Physical retrofit complete (cooling, chassis, firmware), system commissioned
- Approval: Customer acceptance testing (hashrate, temperature, uptime validation)
- Exit Criteria: 7-day burn-in completed, performance targets met, customer sign-off

Phase Gate 3: Optimization & Handover (Weeks 17-20)

- Deliverables: AI platform fully trained, treasury module activated, documentation complete, staff training delivered
- Approval: 30-day operational performance validation, final payment released
- Exit Criteria: Facility transitioned to ongoing SLA support, project closeout report delivered

Phase Gate 4: Ongoing Operations (Month 2+)

- Deliverables: Continuous monitoring, predictive maintenance, firmware updates, quarterly optimization
- Approval: Quarterly business reviews, annual contract renewal
- Exit Criteria: Customer satisfaction (NPS >60), SLA compliance (99%+ uptime)

Project Team Structure

Customer-Facing Roles:

Project Manager (PM):

- Responsibilities: Overall project delivery, timeline management, customer communication, budget oversight
- Skills: PMP or equivalent, 5+ years datacenter project management, strong communication
- Availability: Full-time dedicated to project during Phases 1-3, transition to account manager in Phase 4

Technical Lead:

- Responsibilities: Engineering oversight, design validation, vendor coordination, technical escalation
- Skills: Electrical or mechanical engineering degree, 10+ years datacenter/mining experience
- Availability: 50% allocation during Phases 1-2, full-time during Phase 2 (installation), 25% during Phase 3

Site Supervisor:

- Responsibilities: On-site coordination, safety management, subcontractor oversight, daily progress reporting
- Skills: Construction management certification, 5+ years site supervision, OSHA 30-hour
- Availability: Full-time on-site during Phase 2 (installation)

Back-Office Support:

Engineering Team (Design):

- Electrical engineer: Power distribution, panel sizing, load balancing
- Mechanical engineer: Cooling system design, heat rejection, fluid dynamics
- Network engineer: Fiber backbone, switch configuration, VLAN design
- Allocation: 2-4 weeks per project (Phase 1)

Installation Crews:

- Lead installer: Oversees crew, ensures quality and safety
- Electricians: Licensed (journeyman or master) for electrical work
- HVAC technicians: Certified for refrigerant handling, cooling system commissioning
- Network technicians: Fiber splicing, switch configuration, testing
- Crew size: 3-6 people depending on project scale
- Duration: 8-12 weeks for typical retrofit (Phase 2)

AI/Software Team:

- Platform deployment engineer: Kubernetes cluster setup, database configuration
- ML engineer: Model training, tuning profile generation
- Integration engineer: ERP, custody, pool API integration
- Allocation: 2-4 weeks per project (Phase 3)

Risk Management & Quality Assurance

Risk Register:

Every project maintains a risk register tracking:

- **Identified Risks:** Potential issues that could impact timeline, budget, or performance
- **Probability & Impact:** Likelihood (low/medium/high) and severity (minor/moderate/major)
- **Mitigation Strategies:** Proactive actions to reduce risk probability or impact
- **Contingency Plans:** Reactive responses if risk materializes

Common Risk Categories:

- **Long-Lead Equipment Delays:** Mitigation: Order equipment early (Phase 1), maintain backup supplier relationships
- **Site Access Issues:** Mitigation: Coordinate with customer facilities team, schedule work during low-activity periods
- **Weather Delays:** Mitigation: Build 10-15% schedule buffer, prioritize indoor work during poor weather
- **Scope Creep:** Mitigation: Strict change order process, clear SOW definition, customer sign-off on all changes

Quality Assurance:

Inspection Points:

- **Electrical Work:** Licensed inspector validates NEC compliance before energization
- **Cooling System:** Pressure testing, leak testing, flow validation before miner integration
- **Chassis Assembly:** Visual inspection, thermal paste application verification, quick-disconnect fitting torque check
- **Network Infrastructure:** Cable testing (TDR), switch configuration validation, bandwidth/latency testing

Acceptance Testing:

- **7-Day Burn-In:** Full facility load for 168 consecutive hours
- **Performance Validation:** Hashrate, power consumption, temperature, uptime meet or exceed targets
- **Customer Walkthrough:** Site tour, documentation handover, Q&A session
- **Final Sign-Off:** Customer approves project completion, releases final payment (typically 10-20% held until acceptance)

Communication & Reporting

Weekly Progress Reports:

- Milestone completion status (on track / at risk / delayed)
- Issues log: Open issues, resolution status, escalations
- Schedule update: Critical path analysis, timeline adjustments
- Budget update: Actual vs. planned spend, forecast to completion

Daily Stand-Ups (During Phase 2):

- 15-minute call between PM, site supervisor, and customer facilities contact
- Yesterday's accomplishments, today's plan, blockers/issues
- Safety updates, schedule confirmation

Executive Steering Committee:

- Monthly meetings for large projects (>20 MW or >\$10M)
- Attendees: Customer executive sponsor, TerraHash PM, Technical Lead, Finance (both sides)
- Topics: Strategic alignment, major decisions (scope changes, schedule adjustments), financial review

Change Order Process

Change Request Initiation:

- Customer or TerraHash identifies need for scope change (additional capacity, design modification, upgraded equipment)
- Requestor submits change request form: Description, justification, estimated impact (cost, schedule, performance)

Change Order Evaluation:

- TerraHash PM evaluates technical feasibility and impact
- Engineering team provides cost and schedule estimate
- PM presents change order to customer: Cost, schedule impact, benefits/risks

Approval & Execution:

- Customer approves/rejects change order
- If approved: SOW amended, schedule updated, change order added to contract
- If rejected: Proceed with original scope

Pricing:

- Time & Materials: Labor at \$125-185/hour, equipment at cost + 10-15% markup
- Fixed Price: For well-defined changes, TerraHash provides flat fee

Project Closeout

Final Deliverables:

- As-built documentation: Electrical drawings, cooling system diagrams, network maps
- Equipment inventory: Serial numbers, warranty information, spare parts list
- Operations manuals: Startup/shutdown procedures, maintenance schedules, troubleshooting guides
- Training materials: Video tutorials, reference cards, escalation contacts
- Performance baseline: 30-day post-retrofit metrics (hashrate, uptime, efficiency, cost per BTC)

Lessons Learned:

- Post-project review with customer and project team
- Identify what went well, what could be improved
- Update standard templates and processes based on learnings
- Continuous improvement for future projects

Transition to Operations:

- Handoff from project team to SLA support team (NOC, account manager)
- 30-day hyper-care period: Daily check-ins, proactive monitoring, rapid response

- Gradual transition to standard SLA cadence (quarterly visits, 24/7 NOC, monthly reporting)

Conclusion: Integrated System Value

The TerraHash Stack as a Service platform delivers maximum value through the synergistic integration of all six modules:

1. **Facility Assessment & Pricing Engine** enables rapid, accurate decision-making with transparent ROI projections
2. **Modular Cooling System Retrofit** provides the physical infrastructure for 19-28% efficiency gains and 99%+ uptime
3. **Firmware & AI Management** unlocks 8-15% additional efficiency through software optimization and 95%+ automated incident resolution
4. **Automated Treasury Management** enhances revenue by 10-20% through strategic BTC/stablecoin allocation and risk management
5. **Tiered SLA Support** ensures appropriate service level for each customer segment with outcome-based financial guarantees
6. **Project Management Framework** de-risks execution with proven processes, experienced teams, and transparent communication

Together, these modules transform underperforming air-cooled facilities into institutional-grade operations positioned for long-term competitiveness in the evolving bitcoin mining landscape.

[1] [2] [3] [4] [5] [6] [7]

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1. [let-s-work-on-an-official-terr-s0mSohM7Qge.jQtHfVHpxw.md](#)
2. [1.-project_greenhash_5mw_natural_gas_facility-_budget__5yr_profit_projections.pdf](#)
3. [i-need-to-create-a-project-lis-Smmesz3zR4KWcFE5SmzG_Q.md](#)
4. [using-the-attached-file-as-a-p-rqsC0xfCQrWzm7qLJ_4RKg.md](#)
5. [Sources_Project_GreenHash_5mW_Natural_Gas_Facility_-_Budget__5yr_Profit_Projections.pdf](#)
6. [8.-_project_greenhash_5mw_mining_facility_profit_reinvestment__growth_strategies.pdf](#)
7. [2.-_project_greenhash_hvac__facility_design_for_5mw_liquid-cooled_mining_operation.pdf](#)