AetherGrid

Production-Grade Technical Specification

Autonomous Renewable Infrastructure Sentinel

Gemini API Developer Competition Entry

Version 1.0 | January 2026

Executive Summary

AetherGrid is an autonomous agentic system engineered to revolutionize renewable energy operations and maintenance (O&M) through advanced multimodal AI. Built on the Gemini 3 Pro model family, AetherGrid addresses the critical challenge of reactive maintenance in renewable energy infrastructure by enabling predictive, data-driven decision-making that reduces operational costs and maximizes energy yield.

The platform leverages Gemini 3’s 2-million-token context window to fuse years of SCADA (Supervisory Control and Data Acquisition) telemetry data with high-fidelity drone inspection video, creating a comprehensive understanding of asset health that was previously impossible with traditional inspection methods.

Key Value Propositions

- **Reduces unnecessary truck rolls (manual site visits) by 60% through predictive maintenance scheduling**
- **Increases annual energy yield by 1–3% through early detection and remediation of performance-degrading defects**
- **Prevents catastrophic failures by identifying leading edge erosion, delamination, and thermal hotspots before critical thresholds**
- **Automates end-to-end maintenance workflows from anomaly detection to technician dispatch and parts procurement**

Core Platform Features

1. Mission Control Orchestrator

The Mission Control Orchestrator serves as the central intelligence hub of AetherGrid, coordinating all autonomous operations across the renewable energy asset portfolio.

Functionality Overview

- Real-time Data Stream Processing: Continuously ingests and analyzes multimodal data from SCADA systems, drone video feeds, weather APIs, and maintenance logs
- Autonomous Decision Engine: Utilizes Gemini 3 Pro’s advanced reasoning capabilities with thinking_level: high to perform root-cause analysis and distinguish genuine component failures from environmental artifacts
- Workflow Orchestration: Manages complex, multi-step maintenance workflows while maintaining context through Thought Signatures to prevent drift in long-horizon operations
- Priority Management: Dynamically prioritizes maintenance tasks based on severity, business impact, resource availability, and weather constraints

Technical Implementation

System Instructions Configuration:

```
Role: AetherGrid Mission Control Orchestrator Goal: Analyze multimodal data streams to identify structural/electrical anomalies  Operational Protocol: 1. Perception: Process drone video (media_resolution: high) 2. Reasoning: Cross-reference with SCADA JSON logs 3. Planning: Root-cause analysis (thinking_level: high) 4. Action: Tool calling with Thought Signature context preservation
```

User Interface Components

- Live Asset Health Dashboard: Real-time visualization of all monitored assets with color-coded health status indicators (green/yellow/red)
- Active Workflow Monitor: Displays all ongoing maintenance workflows with current status, next actions, and estimated completion times
- Alert Management Console: Centralized view of all system-generated alerts with filtering, sorting, and bulk action capabilities
- Performance Analytics: Historical trend analysis showing truck roll reduction, yield improvements, and cost savings metrics

2. Multimodal Perception Lab

The Multimodal Perception Lab is AetherGrid’s visual intelligence engine, processing high-fidelity drone inspection footage to detect microscopic defects that human inspectors might miss or that are too dangerous to inspect manually.

Functionality Overview

- High-Resolution Video Analysis: Processes drone video at media_resolution: high to detect micro-cracks, surface delamination, and text on equipment labels
- **Defect Classification System:**
    - Wind Turbine Defects: Leading edge erosion, trailing edge damage, lightning strike marks, surface cracks, pitch bearing wear, nacelle vibration patterns
    - Solar Array Defects: Thermal hotspots, cell cracking, snail trails, delamination, PID (potential-induced degradation), soiling patterns
- Temporal Analysis: Compares current inspection footage with historical baselines to track defect progression rates and predict failure timelines
- Environmental Artifact Filtering: Uses advanced reasoning to distinguish between actual defects and false positives caused by shadows, dust, water droplets, or camera artifacts

Technical Implementation

Processing Pipeline:

1. Video Ingestion: Accepts 4K drone footage in standard formats (MP4, MOV) with automatic frame extraction at optimal intervals
2. Frame-by-Frame Analysis: Gemini 3 Pro processes each frame at high resolution to identify visual anomalies
3. Defect Localization: Generates precise spatial coordinates and bounding boxes for each identified defect
4. Severity Classification: Assigns priority levels (Critical/High/Medium/Low) based on defect type, size, location, and growth rate
5. Report Generation: Creates detailed inspection reports with annotated images, defect inventories, and recommended actions

User Interface Components

- Video Player with AI Annotations: Synchronized playback showing detected defects highlighted with bounding boxes and severity labels
- Defect Gallery: Thumbnail view of all identified defects with filtering by type, severity, and asset

- Historical Comparison Slider: Side-by-side view of current vs. previous inspections to visualize defect progression
- 3D Asset Visualization: Interactive 3D model of turbines/arrays with defects mapped to their precise physical locations

3. SCADA Telemetry Analytics

The SCADA Telemetry Analytics module processes continuous sensor data streams to identify performance anomalies and mechanical stress indicators that aren’t visible through visual inspection alone.

Functionality Overview

- Continuous Sensor Monitoring: Ingests real-time data from nacelle accelerometers, temperature sensors, power output meters, pitch sensors, and wind speed anemometers
- Performance Curve Analysis: Compares actual power output against theoretical curves to identify underperformance patterns
- Vibration Pattern Recognition: Detects abnormal nacelle vibration signatures indicating bearing wear, blade imbalance, or structural fatigue
- Cross-Correlation with Visual Data: Automatically links SCADA anomalies with visual defects detected by the Perception Lab to confirm root causes
- Predictive Failure Modeling: Uses historical data patterns to forecast component failure timelines and optimal maintenance windows

Tool Function: analyze_scada_telemetry

Input Schema:

Parameter	Type	Description	Range/Unit
nacelle_vibration	Number	Vibration amplitude measured at nacelle housing	0-100 mm/s
rotor_rpm	Number	Current rotational speed of turbine rotor	0-25 RPM
power_output_kw	Number	Instantaneous electrical power generation	0-5000 kW
blade_pitch_angle	Number	Current pitch angle of turbine blades	0-90 degrees
wind_speed_ms	Number	Wind speed at hub height	0-30 m/s
temperature_c	Number	Gearbox/generator temperature	-40 to 120°C
timestamp	ISO8601	Data point timestamp	ISO 8601 format

Output Schema:

- anomaly_detected: Boolean indicating whether performance deviation exceeds threshold

- anomaly_type: Classification (PowerCurveDrop, VibrationSpike, TemperatureAnomaly, PitchMalfunction)
- severity_score: Numerical severity rating (1-10)
- recommended_action: Suggested next steps (Monitor, Schedule Inspection, Immediate Intervention)
- correlation_confidence: Confidence level if correlated with visual defect (0-100%)

User Interface Components

- Time-Series Visualization: Interactive charts showing sensor trends over configurable time periods (1 hour to 5 years)
- Power Curve Overlay: Scatter plot comparing actual vs. theoretical power output with deviation highlighting
- Vibration Spectrum Analyzer: Frequency domain analysis to identify characteristic failure signatures
- Anomaly Timeline: Chronological log of all detected anomalies with drill-down capabilities

4. Site Supervisor Dashboard (Dynamic View)

The Site Supervisor Dashboard provides decision-makers with actionable insights and strategic repair recommendations through Gemini 3’s Dynamic View capabilities.

Functionality Overview

- Multi-Tier Repair Strategy Generator: Automatically generates three repair approaches (Budget/Balanced/Luxury) based on asset remaining life, business priorities, and budget constraints
- Cost-Benefit Analysis: Calculates ROI for each repair tier including downtime costs, parts expenses, labor hours, and projected yield improvements
- Fleet-Wide Optimization: Prioritizes maintenance across entire portfolio to maximize total energy production and minimize aggregate costs
- What-If Scenario Modeling: Allows supervisors to simulate different maintenance strategies and compare projected outcomes

Repair Tier Definitions

Tier	Approach	Cost Range	Downtime	Warranty	Use Case
Budget	Minimal intervention; temporary fixes using existing parts	$5K-10K	4-6 hours	90 days	End-of-life assets with <3 years remaining
Balanced	Standard OEM parts and procedures	$10K-15K	6-10 hours	2 years	Mid-life assets with 5-10 years remaining
Luxury	Premium materials, extended warranties, preventive upgrades	$15K-25K	10-16 hours	5 years	New assets with >15 years remaining

User Interface Components

- Executive Summary Cards: High-level KPIs including total assets monitored, active alerts, scheduled maintenance, and monthly cost savings
- Repair Comparison Table: Side-by-side view of Budget/Balanced/Luxury tiers with sortable columns and export functionality
- Portfolio Heat Map: Geographic visualization showing asset health status across multiple sites

- Approval Workflow: One-click approval/rejection of AI-recommended maintenance plans with comment capabilities

5. Logistics & Repair Management

The Logistics & Repair Management system automates the entire maintenance execution workflow from parts procurement to technician scheduling, closing the loop between anomaly detection and physical repair.

Functionality Overview

- Intelligent Scheduling: Integrates with Google Calendar API to schedule technician visits based on urgency, weather forecasts, crew availability, and travel optimization
- Parts Inventory Management: Automatically generates parts lists based on defect type and checks inventory availability before creating purchase orders
- Weather-Aware Dispatch: Queries weather forecast APIs to avoid scheduling outdoor work during unsafe wind speeds or precipitation
- Work Order Generation: Creates detailed work orders with defect locations, repair procedures, safety requirements, and estimated labor hours
- Progress Tracking: Monitors repair completion status and updates asset health records upon verification

Tool Function: dispatch_repair_crew

Input Schema:

Parameter	Type	Description	Values
fault_type	String	Classification of detected defect	LeadingEdgeErosion, Delamination, ThermalHotspot, PitchBearing, etc.
priority_level	Integer	Urgency of repair	1 (Critical) to 5 (Routine)
asset_id	String	Unique identifier of affected asset	Alphanumeric
estimated_parts_list	Array	Required components and quantities	[{part_id, quantity, unit_cost}]
preferred_date_range	Object	Desired scheduling window	{start_date, end_date}
crew_size	Integer	Number of technicians required	1-6
estimated_hours	Number	Projected labor duration	0.5-48 hours

Output Schema:

- work_order_id: Unique identifier for created work order

- scheduled_date: Confirmed date/time for repair work
- assigned_crew: Technician names and credentials
- parts_ordered: Confirmation of parts procurement with expected delivery dates
- calendar_event_id: Google Calendar event ID for scheduling integration

User Interface Components

- Work Order Management Board: Kanban-style interface with columns for Pending, Scheduled, In Progress, and Completed work orders
- Technician Calendar View: Interactive calendar showing all scheduled maintenance with filtering by crew, site, and priority
- Parts Inventory Dashboard: Real-time inventory levels with low-stock alerts and reorder point indicators
- Mobile Work Order App: Field technician interface for viewing assignments, uploading completion photos, and updating status

6. Solar Resource Planner

The Solar Resource Planner leverages the Google Maps Solar API to optimize placement of new photovoltaic installations by analyzing rooftop geometry, solar flux patterns, and shading effects.

Functionality Overview

- Rooftop Suitability Analysis: Automatically evaluates building rooftops for solar panel installation based on area, orientation, tilt, and structural capacity
- Annual Solar Flux Mapping: Generates hourly irradiance profiles accounting for seasonal variations, geographic location, and atmospheric conditions
- Shade Impact Modeling: Identifies and quantifies shade from nearby trees, buildings, and structures throughout the year
- Optimal Panel Layout: Uses AI reasoning to determine ideal panel quantities, orientations, and spacing to maximize energy production
- Financial Modeling: Calculates projected energy yield, payback period, ROI, and lifecycle cost savings

Tool Function: query_solar_potential

Input Schema:

Parameter	Type	Description	Example
location_coords	Object	Geographic coordinates	{lat: -1.286389, lng: 36.817223}
building_id	String	Optional building identifier	Building_A42
analysis_period	String	Time range for flux calculation	Annual, Quarterly, Monthly
panel_type	String	Solar panel specifications	Monocrystalline, Polycrystalline

Output Schema:

- total_solar_flux_kwh: Annual energy potential in kilowatt-hours
- hourly_flux_map: 8760-element array with hourly irradiance values
- optimal_panel_count: Recommended number of panels for maximum efficiency
- shade_loss_percentage: Annual energy loss due to shading (0-100%)
- financial_projections: Object containing installation cost, annual savings, and payback period

User Interface Components

- Interactive Site Map: Satellite imagery with overlaid solar potential heat maps and proposed panel placements
- Hourly Flux Visualization: Time-series graphs showing expected solar irradiance throughout typical days across all seasons
- Shade Analysis Timeline: Animated visualization showing shade patterns moving across the day and year
- Financial Calculator: Interactive tool for adjusting variables like electricity rates, incentives, and financing terms

Technical Architecture

Gemini 3 Pro Configuration

AetherGrid is optimized for the Gemini 3 Pro model with specific parameter configurations to ensure reliable, high-quality autonomous operations.

Parameter	Value	Reasoning
Model	gemini-3-pro-preview	Optimized for complex reasoning, coding, and long-horizon planning workflows
Temperature	1.0	Required for Gemini 3 reasoning mode; values <1.0 cause response looping
Thinking Level	high	Essential for distinguishing false-positive environmental factors from genuine component failures
Media Resolution	high	Necessary for detecting micro-cracks on turbine blades and fine text on equipment labels
Context Window	2,000,000 tokens	Enables fusion of years of SCADA logs with current inspection data
Max Output Tokens	8,192	Sufficient for detailed maintenance reports and multi-step reasoning chains

Multi-Agent Architecture (Antigravity Platform)

AetherGrid leverages the Antigravity Agent Manager to run specialized agents in parallel, enabling sophisticated division of labor and concurrent processing.

Agent Roles

- **Perception Agent:** Specializes in processing visual data streams from drone inspections, thermal cameras, and satellite imagery
- **Analytics Agent:** Dedicated to SCADA data analysis, performance curve modeling, and statistical anomaly detection
- **Planning Agent:** Performs root-cause analysis, generates maintenance strategies, and optimizes portfolio-wide scheduling
- **Logistics Agent:** Handles parts procurement, crew scheduling, calendar integration, and work order management

Context Management with Thought Signatures

To prevent context drift in long-horizon maintenance workflows that may span hours or days, AetherGrid implements Gemini 3’s Thought Signatures pattern.

- Every tool-calling operation returns a thoughtSignature token
- Subsequent requests include the previous signature to maintain workflow continuity
- Enables coherent multi-step reasoning across tool calls without losing critical context
- Critical for workflows like: Detect defect → Analyze SCADA → Check weather → Schedule crew → Order parts

Long-Context Caching Strategy

To optimize performance and reduce token costs for repeated operations, AetherGrid caches frequently accessed reference data.

Cached Data Categories

- **Historical SCADA Logs:** Up to 5 years of sensor data for trend analysis and baseline comparisons
- **Maintenance Best Practices:** Industry standard procedures, safety protocols, and manufacturer service manuals
- **Defect Classification Database:** Reference images and descriptions of all known defect types with repair procedures
- **Asset Configuration Data:** Specifications, installation dates, warranty information, and maintenance history for all managed assets

Integration Specifications

External API Integrations

API Service	Purpose	Endpoints Used	Authentication
Google Calendar API	Technician scheduling and availability management	events.insert, events.list, events.patch	OAuth 2.0
Google Maps Solar API	Rooftop solar potential analysis	solarPotential.get, buildingInsights.get	API Key
Weather API (OpenWeather)	7-day forecast for maintenance scheduling	forecast/daily	API Key
Parts Supplier API (Custom)	Inventory checks and procurement	inventory/check, orders/create	API Token
Email (SendGrid)	Notification delivery to stakeholders	mail/send	API Key

Data Input Requirements

Drone Video Specifications

- Minimum Resolution: 4K (3840×2160) for defect detection accuracy
- Supported Formats: MP4, MOV, AVI with H.264/H.265 codecs
- Optimal Flight Parameters: 5-10m distance from blades/panels, 30-60 FPS capture rate
- Metadata Requirements: GPS coordinates, timestamp, asset ID embedded in filename or EXIF

SCADA Data Format

JSON structure with the following schema:

```
{   "asset_id": "TURB_A42",   "timestamp": "2026-01-27T14:30:00Z",
"sensors": {     "nacelle_vibration_mms": 2.3,     "rotor_rpm": 12.5,
"power_output_kw": 1850,     "blade_pitch_angle_deg": 5.2,
"wind_speed_ms": 8.7,     "gearbox_temp_c": 65,     "generator_temp_c": 72
} }
```

Example User Workflows

Workflow 1: Automated Turbine Blade Inspection

Trigger

Operator uploads 10-minute drone inspection video of Wind Turbine #A42 to AetherGrid via the Multimodal Perception Lab interface.

System Prompt

```
"Analyze the attached drone video of Turbine A42. Focus on blade tips for
leading edge erosion. If detected, cross-reference with last 48 hours of
SCADA data for power drops. If both present, generate repair ticket with
optimal timing based on weather forecast."
```

Autonomous Execution Steps

6. **Visual Analysis (Perception Agent):** Processes video at media_resolution: high and detects 3cm×5cm erosion area on Blade 2 at 75% span location. Returns thoughtSignature <Sig_A>
7. **SCADA Correlation (Analytics Agent):** Receives <Sig_A>, calls analyze_scada_telemetry with 48-hour window, identifies 5% power output drop correlated with increased vibration. Returns <Sig_B>
8. **Weather Check (Planning Agent):** Receives <Sig_B>, queries weather API, finds suitable repair window in 3 days (low wind forecast). Returns <Sig_C>
9. **Repair Strategy Generation (Planning Agent):** Using thinking_level: high with <Sig_C>, generates three repair tiers with cost-benefit analysis
10. **Work Order Creation (Logistics Agent):** Calls dispatch_repair_crew with recommended Balanced tier approach, creating work order WO-2026-0127-001
11. **Notification:** Site supervisor receives email with annotated video frames, SCADA charts, repair comparison table, and one-click approval link

Expected Output

Dynamic View dashboard displays repair comparison table with estimated costs ($8,500 Budget / $12,000 Balanced / $18,500 Luxury), downtime hours (6 / 8 / 12), and projected yield recovery (+1.2% / +1.5% / +1.8%). Supervisor approves Balanced tier; technician receives calendar notification for Thursday 9 AM visit.

Workflow 2: Solar Array Thermal Hotspot Detection

Trigger

Scheduled thermal imaging flight over 100kW rooftop solar installation identifies multiple panel hotspots.

Autonomous Execution Steps

12. Thermal Analysis: Perception Agent identifies 4 panels with temperatures >15°C above array average, indicating potential cell failures
13. Performance Verification: Cross-references with inverter data showing 2.3% underperformance on affected strings
14. Root Cause Determination: Planning Agent uses thinking_level: high to rule out shading/soiling, concludes bypass diode failure in 3 panels + cell cracking in 1 panel
15. Warranty Check: Queries cached asset configuration, determines all panels still under manufacturer warranty
16. Automated Claim Filing: Generates warranty claim with thermal images, performance data, and technical analysis documentation

Performance Metrics & Success Criteria

Key Performance Indicators (KPIs)

Metric	Target	Measurement Method	Business Impact
Truck Roll Reduction	60%	Compare pre/post deployment site visit frequency	$200K-500K annual savings per site
Annual Yield Increase	1-3%	Energy output comparison vs. historical baseline	$100K-300K additional revenue per 50MW site
Defect Detection Accuracy	>95%	Manual verification of AI-flagged anomalies	Prevents false positives/missed failures
Maintenance Cost Reduction	30-40%	Total O&M spend comparison year-over-year	Direct operational expense reduction
Workflow Automation Rate	80%	Percentage of anomalies resolved without human intervention	Labor efficiency gains
Mean Time to Repair (MTTR)	-50%	Days from defect detection to repair completion	Minimizes downtime and lost production

Competition Alignment

AetherGrid directly addresses the Gemini API Developer Competition judging criteria through quantifiable, real-world impact.

Value Proposition (40% Weight)

- Solves Critical Industry Problem: Reactive maintenance costs renewable energy operators $50-100B annually worldwide. AetherGrid provides measurable cost reduction and yield improvement.
- Tangible Business Impact: 60% reduction in truck rolls = $200K-500K annual savings per wind farm. 1-3% yield increase = $100K-300K additional revenue per 50MW facility.
- Environmental Benefit: Maximizing renewable energy production directly reduces fossil fuel dependence and carbon emissions.

Technical Implementation (30% Weight)

- Advanced Gemini 3 Features: Leverages 2M token context, Thought Signatures, thinking_level: high, media_resolution: high, and Dynamic View

- Multi-Agent Architecture: Demonstrates sophisticated agent coordination through Antigravity platform
- Production-Grade Engineering: Well-defined function schemas, error handling, context management, and external API integrations

Security & Privacy Considerations

Data Protection

- SCADA Data Encryption: All telemetry data encrypted at rest (AES-256) and in transit (TLS 1.3)
- Role-Based Access Control: Granular permissions for viewing, editing, and approving maintenance decisions
- Audit Logging: Complete trail of all AI decisions, tool calls, and human approvals for regulatory compliance
- Data Retention Policies: Configurable retention periods compliant with industry regulations (NERC CIP, IEC 62443)

Safety Considerations

- Human-in-the-Loop for Critical Decisions: Priority 1 (Critical) repairs require supervisor approval before work order execution
- Safety Protocol Enforcement: Work orders automatically include required PPE, lockout/tagout procedures, and weather constraints
- Fail-Safe Mechanisms: System defaults to conservative recommendations if confidence scores fall below 85% threshold

Roadmap & Future Enhancements

Phase 1: Core Platform (Q1 2026)

- Launch Mission Control Orchestrator, Multimodal Perception Lab, and SCADA Analytics for wind turbines
- Integrate Google Calendar API for basic scheduling automation
- Support for 2-3 wind farm pilot deployments

Phase 2: Solar & Logistics (Q2 2026)

- Add solar array thermal analysis and Solar Resource Planner
- Full Logistics & Repair Management with parts inventory integration
- Mobile app for field technicians

Phase 3: Advanced AI & Scale (Q3-Q4 2026)

- Predictive failure modeling using 5+ years of historical data
- Battery energy storage system (BESS) health monitoring
- Multi-site portfolio optimization for 100+ asset deployments
- API marketplace for third-party integrations (ERP, CMMS, GIS)

Conclusion

AetherGrid represents a paradigm shift in renewable energy operations, transforming reactive maintenance into proactive, AI-driven asset management. By leveraging the full capabilities of the Gemini 3 Pro model family—including its unprecedented 2-million-token context window, advanced reasoning with thinking_level: high, and multimodal analysis at media_resolution: high—AetherGrid delivers measurable business value while accelerating the global transition to clean energy.

The platform’s autonomous agentic architecture, powered by Thought Signatures for context preservation and the Antigravity multi-agent framework, demonstrates sophisticated engineering that goes beyond simple demo applications. AetherGrid solves a real-world problem affecting billions of dollars in renewable energy infrastructure, with quantifiable impact metrics including 60% reduction in truck rolls and 1–3% increase in energy yield.

This production-grade technical specification provides the foundation for a competition-winning entry that showcases the transformative potential of Gemini 3 in critical infrastructure applications. AetherGrid is not just a proof of concept—it’s a deployable solution ready to revolutionize how the renewable energy industry maintains and optimizes its most valuable assets.

Appendix A: Glossary

Term	Definition
SCADA	Supervisory Control and Data Acquisition - industrial control system for monitoring sensors and equipment
Leading Edge Erosion	Degradation of wind turbine blade front edges due to rain, hail, and airborne particles, reducing aerodynamic efficiency
Delamination	Separation of composite material layers in turbine blades or solar panel backing, indicating structural failure
Thermal Hotspot	Localized temperature elevation in solar cells indicating electrical faults or shading damage
Nacelle	Housing at top of wind turbine tower containing gearbox, generator, and control systems
Power Curve	Relationship between wind speed and electrical output; deviations indicate mechanical or electrical issues
Truck Roll	Industry term for dispatching technicians to a physical site for manual inspection or repair
Thought Signature	Gemini 3 feature allowing context preservation across multi-step tool-calling workflows
Dynamic View	Gemini 3 capability for generating interactive UI components within AI responses
Antigravity	Development platform for building and orchestrating multi-agent AI systems

Appendix B: API Reference

Complete API documentation available at: *https://docs.aethergrid.ai/api/v1*

Contact Information:

Technical Support: support@aethergrid.ai
Sales Inquiries: sales@aethergrid.ai
Competition Submission: gemini-competition@aethergrid.ai