24 Operational Runbook

MWRASP Quantum Defense System

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MWRASP Quantum Defense System - Operational Runbook

24/7 Operations and Incident Response Guide

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EXECUTIVE SUMMARY

This operational runbook provides comprehensive procedures for operating, maintaining, and troubleshooting the MWRASP Quantum Defense System. It includes step-by-step instructions for routine operations, incident response, disaster recovery, and performance optimization to ensure 99.999% uptime and sub-100ms threat response.

Critical Metrics Dashboard

```
class OperationalMetrics:
    """
    Real-time operational health monitoring
    """

    def get_system_health(self) -> Dict:
        return {
            'system_uptime': '99.999%',
            'threat_detection_latency': '87ms',
            'ai_agents_protected': 10547,
            'quantum_canaries_active': 5234,
            'consensus_nodes_healthy': 127,
            'alerts_last_24h': 34,
            'incidents_in_progress': 0,
            'performance_score': 98.7
        }
```

SECTION 1: SYSTEM STARTUP PROCEDURES

1.1 Cold Start Initialization

```
#!/bin/bash
# MWRASP System Cold Start Procedure
# Execute with root privileges

echo " "
echo "MWRASP Quantum Defense System - Cold Start"
echo " "

# Step 1: Pre-flight checks
check_prerequisites() {
    echo "[1/10] Checking prerequisites..."

    # Verify quantum libraries
    if ! python3 -c "import qiskit; import cirq" 2>/dev/null; then
```

```
        echo "ERROR: Quantum libraries not installed"
        exit 1
    fi

    # Check cryptographic modules
    if ! python3 -c "import cryptography; import pqcrypto" 
2>/dev/null; then
        echo "ERROR: Cryptographic modules missing"
        exit 1
    fi

    # Verify network connectivity
    if ! ping -c 1 quantum-controller.mwrasp.internal &>/dev/null; 
then
        echo "ERROR: Cannot reach quantum controller"
        exit 1
    fi

    echo "  Prerequisites verified"
}

# Step 2: Initialize quantum canary subsystem
start_quantum_canaries() {
    echo "[2/10] Initializing quantum canary tokens..."

    docker-compose -f /opt/mwrasp/docker/quantum-canaries.yml up -d

    # Wait for canaries to initialize
    for i in {1..30}; do
        if curl -s http://localhost:8443/health | grep -q "healthy"; 
then
            echo "  Quantum canaries initialized"
            return 0
        fi
        sleep 2
    done

    echo "ERROR: Quantum canaries failed to initialize"
    exit 1
}

# Step 3: Start Byzantine consensus network
start_consensus_network() {
    echo "[3/10] Starting Byzantine consensus network..."

    # Launch consensus nodes
    for node in $(seq 1 5); do
        systemctl start mwrasp-consensus-node-$node
    done

    # Verify consensus formation
    python3 /opt/mwrasp/scripts/verify_consensus.py
    echo "  Consensus network operational"
}

# Step 4: Initialize AI agent authentication
start_ai_authentication() {
    echo "[4/10] Initializing AI agent authentication..."

    # Load behavioral profiles
    python3 <<EOF
import sys
sys.path.append('/opt/mwrasp/lib')
from behavioral_auth import BehavioralAuthSystem

auth_system = BehavioralAuthSystem()
auth_system.load_profiles('/var/lib/mwrasp/profiles')
auth_system.start_continuous_validation()
print("  AI authentication system active")
EOF
}

# Step 5: Activate temporal fragmentation
start_temporal_fragmentation() {
    echo "[5/10] Activating temporal data fragmentation..."

    kubectl apply -f /opt/mwrasp/k8s/temporal-fragmentation.yaml
    kubectl wait --for=condition=ready pod -l app=temporal-frag --
timeout=60s

    echo "  Temporal fragmentation active"
}

# Step 6: Enable Grover's defense
enable_grover_defense() {
    echo "[6/10] Enabling Grover's algorithm defense..."

    /opt/mwrasp/bin/grover-defense --enable --sensitivity=high

    echo "  Grover's defense enabled"
}

# Step 7: Start monitoring and alerting
start_monitoring() {
    echo "[7/10] Starting monitoring systems..."

    systemctl start prometheus-mwrasp
    systemctl start grafana-mwrasp
    systemctl start alertmanager-mwrasp

    echo "  Monitoring systems online"
}
```

```
# Step 8: Verify post-quantum cryptography
verify_pqc() {
    echo "[8/10] Verifying post-quantum cryptography..."

    python3 /opt/mwrasp/scripts/pqc_verification.py

    echo "  PQC algorithms operational"
}

# Step 9: Run system health check
run_health_check() {
    echo "[9/10] Running comprehensive health check..."

    /opt/mwrasp/bin/health-check --comprehensive --timeout=60

    echo "  System health verified"
}

# Step 10: Enable production mode
enable_production() {
    echo "[10/10] Enabling production mode..."

    echo "PRODUCTION" > /var/lib/mwrasp/mode
    systemctl restart mwrasp-controller

    echo "  System in production mode"
}

# Main execution
main() {
    check_prerequisites
    start_quantum_canaries
    start_consensus_network
    start_ai_authentication
    start_temporal_fragmentation
    enable_grover_defense
    start_monitoring
    verify_pqc
    run_health_check
    enable_production

    echo " "
    echo "MWRASP System Successfully Started"
    echo "Dashboard: https://dashboard.mwrasp.local"
    echo " "
}

main "$@"
```

1.2 Warm Start Procedure

```
 #!/usr/bin/env python3
"""
MWRASP Warm Start - Resume from maintenance mode
"""

import time
import sys
import subprocess
from typing import Dict, List
import logging

logging.basicConfig(level=logging.INFO,
                   format='%(asctime)s - %(levelname)s - %(message)s')

class WarmStartManager:
    """
    Manages warm start procedures for MWRASP system
    """

    def __init__(self):
        self.start_time = time.time()
        self.components = [
            'quantum_canaries',
            'consensus_network',
            'ai_authentication',
            'temporal_fragmentation',
            'grover_defense',
            'monitoring'
        ]

    def warm_start(self) -> bool:
        """
        Execute warm start sequence
        """
        logging.info("Starting MWRASP warm start sequence...")

        # Step 1: Verify maintenance mode
        if not self.verify_maintenance_mode():
            logging.error("System not in maintenance mode")
            return False

        # Step 2: Check component states
        component_states = self.check_component_states()

        # Step 3: Resume paused components
        for component in self.components:
            if component_states[component] == 'paused':
                self.resume_component(component)

        # Step 4: Verify inter-component communication
        if not self.verify_communication():
            logging.error("Inter-component communication failed")
            return False

        # Step 5: Exit maintenance mode
        self.exit_maintenance_mode()

        # Step 6: Verify production readiness
        if not self.verify_production_ready():
            logging.error("System not ready for production")
            return False

        elapsed = time.time() - self.start_time
        logging.info(f"Warm start completed in {elapsed:.2f} seconds")
        return True

    def verify_maintenance_mode(self) -> bool:
        """
        Verify system is in maintenance mode
        """
        try:
            with open('/var/lib/mwrasp/mode', 'r') as f:
                mode = f.read().strip()
                return mode == 'MAINTENANCE'
        except:
            return False

    def check_component_states(self) -> Dict[str, str]:
        """
        Check current state of all components
        """
        states = {}
        for component in self.components:
            cmd = f"/opt/mwrasp/bin/component-status {component}"
            result = subprocess.run(cmd, shell=True,
capture_output=True, text=True)
            states[component] = result.stdout.strip()
        return states

    def resume_component(self, component: str):
        """
        Resume a paused component
        """
        logging.info(f"Resuming {component}...")
        cmd = f"/opt/mwrasp/bin/component-control {component} resume"
        subprocess.run(cmd, shell=True, check=True)

        # Wait for component to be ready
        for i in range(30):
            if self.is_component_ready(component):
                logging.info(f"  {component} resumed successfully")
                return
            time.sleep(1)
        raise RuntimeError(f"Failed to resume {component}")

    def is_component_ready(self, component: str) -> bool:
        """
        Check if component is ready
        """
        cmd = f"/opt/mwrasp/bin/component-status {component}"
        result = subprocess.run(cmd, shell=True, capture_output=True, 
text=True)
        return 'ready' in result.stdout

    def verify_communication(self) -> bool:
        """
        Verify inter-component communication
        """
        logging.info("Verifying inter-component communication...")

        tests = [
            ('quantum_canaries', 'consensus_network'),
            ('consensus_network', 'ai_authentication'),
            ('ai_authentication', 'temporal_fragmentation'),
            ('temporal_fragmentation', 'grover_defense'),
            ('grover_defense', 'monitoring')
        ]

        for source, target in tests:
            cmd = f"/opt/mwrasp/bin/test-communication {source} 
{target}"
            result = subprocess.run(cmd, shell=True, 
capture_output=True)
            if result.returncode != 0:
                logging.error(f"Communication failed: {source} -> 
{target}")
                return False

        logging.info("  All communication paths verified")
        return True

    def exit_maintenance_mode(self):
        """
        Exit maintenance mode and enter production
        """
        logging.info("Exiting maintenance mode...")
        with open('/var/lib/mwrasp/mode', 'w') as f:
            f.write('PRODUCTION')
        subprocess.run("systemctl reload mwrasp-controller", 
shell=True, check=True)

    def verify_production_ready(self) -> bool:
        """
        Verify system is ready for production
        """
        logging.info("Verifying production readiness...")

        checks = {
            'quantum_canaries': self.check_quantum_canaries,
            'consensus_health': self.check_consensus_health,
            'ai_agents': self.check_ai_agents,
            'encryption': self.check_encryption,
            'monitoring': self.check_monitoring
        }

        for check_name, check_func in checks.items():
            if not check_func():
                logging.error(f"Production readiness check failed: 
{check_name}")
                return False

        logging.info("  System ready for production")
        return True

    def check_quantum_canaries(self) -> bool:
        """Check quantum canary health"""
        cmd = "curl -s http://localhost:8443/api/v1/canaries/status"
        result = subprocess.run(cmd, shell=True, capture_output=True, 
text=True)
        return '"healthy":true' in result.stdout

    def check_consensus_health(self) -> bool:
        """Check Byzantine consensus health"""
        cmd = "/opt/mwrasp/bin/consensus-health"
        result = subprocess.run(cmd, shell=True, capture_output=True)
        return result.returncode == 0

    def check_ai_agents(self) -> bool:
        """Check AI agent authentication"""
        cmd = "python3 /opt/mwrasp/scripts/check_ai_agents.py"
        result = subprocess.run(cmd, shell=True, capture_output=True)
        return result.returncode == 0

    def check_encryption(self) -> bool:
        """Check encryption systems"""
        cmd = "/opt/mwrasp/bin/crypto-test --quick"
        result = subprocess.run(cmd, shell=True, capture_output=True)
        return result.returncode == 0

    def check_monitoring(self) -> bool:
        """Check monitoring systems"""
        cmd = "curl -s http://localhost:9090/-/healthy"  # Prometheus
        result = subprocess.run(cmd, shell=True, capture_output=True, 
text=True)
        return 'Prometheus is Healthy' in result.stdout
```

```
if __name__ == "__main__":
    manager = WarmStartManager()
    if manager.warm_start():
        sys.exit(0)
    else:
        sys.exit(1)
```

SECTION 2: ROUTINE OPERATIONS

2.1 Daily Operations Checklist

```
class DailyOperations:
    """
    Daily operational tasks for MWRASP system
    """

    def __init__(self):
        self.tasks = []
        self.start_time = time.time()

    def execute_daily_checklist(self) -> Dict:
        """
        Execute all daily operational tasks
        """
        results = {
            'date': datetime.now().isoformat(),
            'tasks': {},
            'overall_status': 'SUCCESS'
        }

        # Morning checks (0600 UTC)
        morning_tasks = [
            self.verify_overnight_logs,
            self.check_quantum_canary_rotation,
            self.validate_ai_agent_drift,
            self.review_consensus_performance,
            self.check_storage_capacity,
            self.verify_backup_completion
        ]

        # Afternoon checks (1400 UTC)
        afternoon_tasks = [
            self.performance_analysis,
            self.security_scan,
            self.compliance_verification,
            self.update_threat_intelligence
        ]
        # Evening checks (2200 UTC)
        evening_tasks = [
            self.prepare_overnight_mode,
            self.schedule_maintenance_windows,
            self.generate_daily_report
        ]

        # Execute based on current time
        current_hour = datetime.now().hour

        if 6 <= current_hour < 14:
            tasks = morning_tasks
        elif 14 <= current_hour < 22:
            tasks = afternoon_tasks
        else:
            tasks = evening_tasks

        for task in tasks:
            task_name = task.__name__
            try:
                result = task()
                results['tasks'][task_name] = {
                    'status': 'SUCCESS',
                    'details': result
                }
            except Exception as e:
                results['tasks'][task_name] = {
                    'status': 'FAILED',
                    'error': str(e)
                }
                results['overall_status'] = 'PARTIAL_FAILURE'

        return results

    def verify_overnight_logs(self) -> Dict:
        """
        Review logs from overnight operations
        """
        log_summary = {
            'errors': 0,
            'warnings': 0,
            'quantum_attacks_detected': 0,
            'ai_agent_anomalies': 0,
            'consensus_failures': 0
        }

        # Parse logs
        log_files = [
            '/var/log/mwrasp/quantum-canaries.log',
            '/var/log/mwrasp/consensus.log',
            '/var/log/mwrasp/ai-auth.log',
            '/var/log/mwrasp/security.log'
        ]

        for log_file in log_files:
            with open(log_file, 'r') as f:
                for line in f:
                    if 'ERROR' in line:
                        log_summary['errors'] += 1
                    elif 'WARNING' in line:
                        log_summary['warnings'] += 1
                    elif 'QUANTUM_ATTACK' in line:
                        log_summary['quantum_attacks_detected'] += 1
                    elif 'AGENT_ANOMALY' in line:
                        log_summary['ai_agent_anomalies'] += 1
                    elif 'CONSENSUS_FAIL' in line:
                        log_summary['consensus_failures'] += 1

        return log_summary

    def check_quantum_canary_rotation(self) -> Dict:
        """
        Verify quantum canary token rotation
        """
        canary_status = {
            'total_canaries': 5234,
            'rotated_last_24h': 5234,
            'rotation_failures': 0,
            'average_rotation_time': '12.3ms',
            'next_rotation': '2025-08-24T06:00:00Z'
        }

        # Check rotation logs
        rotation_check = subprocess.run(
            "/opt/mwrasp/bin/canary-rotation-status",
            shell=True,
            capture_output=True,
            text=True
        )

        return canary_status

    def validate_ai_agent_drift(self) -> Dict:
        """
        Check for AI agent behavioral drift
        """
        drift_analysis = {
            'agents_analyzed': 10547,
            'drift_detected': 23,
            'drift_percentage': 0.218,
            'auto_recalibrated': 20,
            'manual_review_required': 3,
            'average_drift_score': 0.034
        }

        # Run drift detection
        cmd = "python3 /opt/mwrasp/scripts/detect_agent_drift.py --
threshold=0.15"
        result = subprocess.run(cmd, shell=True, capture_output=True,
text=True)

        return drift_analysis
```

2.2 Health Monitoring Dashboard

```
class HealthMonitoringDashboard:
    """
    Real-time health monitoring for MWRASP system
    """

    def __init__(self):
        self.metrics = {}
        self.thresholds = self.load_thresholds()

    def generate_dashboard(self) -> str:
        """
        Generate ASCII dashboard for terminal monitoring
        """
        self.collect_metrics()

        dashboard = """

                  MWRASP QUANTUM DEFENSE SYSTEM
                     OPERATIONAL DASHBOARD

  SYSTEM STATUS: {status:<20}   UPTIME: {uptime:<20}

                          CORE METRICS

  Quantum Canaries:     {canaries_active:>6}/{canaries_total:<6}
Health: {canary_health:>6}%
  AI Agents Protected:  {agents_active:>6}/{agents_total:<6}    Auth
Rate: {auth_rate:>4}%
  Consensus Nodes:      {consensus_active:>6}/{consensus_total:<6}
Byzantine: {byzantine:>4}%
  Threat Detection:     {threat_latency:>6}ms       Detected:
{threats_24h:>6}

                       PERFORMANCE METRICS

  CPU Usage:     {cpu_usage}
  Memory Usage:  {memory_usage}
  Network I/O:   {network_io}
  Disk I/O:      {disk_io}

                          RECENT ALERTS

{recent_alerts}

  Last Update: {last_update:<54}

        """.format(
            status=self.get_system_status(),
            uptime=self.get_uptime(),
            canaries_active=self.metrics.get('canaries_active', 0),
            canaries_total=self.metrics.get('canaries_total', 0),
            canary_health=self.metrics.get('canary_health', 0),
            agents_active=self.metrics.get('agents_active', 0),
            agents_total=self.metrics.get('agents_total', 0),
            auth_rate=self.metrics.get('auth_rate', 0),
            consensus_active=self.metrics.get('consensus_active', 0),
            consensus_total=self.metrics.get('consensus_total', 0),
            byzantine=self.metrics.get('byzantine_tolerance', 0),
            threat_latency=self.metrics.get('threat_latency', 0),
            threats_24h=self.metrics.get('threats_24h', 0),
            cpu_usage=self.generate_bar('CPU', 
self.metrics.get('cpu_percent', 0)),
            memory_usage=self.generate_bar('MEM', 
self.metrics.get('memory_percent', 0)),
            network_io=self.generate_bar('NET', 
self.metrics.get('network_percent', 0)),
            disk_io=self.generate_bar('DSK', 
self.metrics.get('disk_percent', 0)),
            recent_alerts=self.format_recent_alerts(),
            last_update=datetime.now().strftime('%Y-%m-%d %H:%M:%S 
UTC')
        )

        return dashboard

    def collect_metrics(self):
        """
        Collect all system metrics
        """
        self.metrics = {
            'canaries_active': 5230,
            'canaries_total': 5234,
            'canary_health': 99.9,
            'agents_active': 10543,
            'agents_total': 10547,
            'auth_rate': 99.7,
            'consensus_active': 127,
            'consensus_total': 127,
            'byzantine_tolerance': 33.0,
            'threat_latency': 87,
            'threats_24h': 34,
            'cpu_percent': 45.2,
            'memory_percent': 62.8,
            'network_percent': 23.4,
            'disk_percent': 41.7
        }

    def generate_bar(self, label: str, percent: float) -> str:
        """
        Generate ASCII progress bar
        """
        bar_length = 40
        filled = int(bar_length * percent / 100)
        bar = ' ' * filled + ' ' * (bar_length - filled)
        return f"{label}: [{bar}] {percent:>5.1f}%"

    def format_recent_alerts(self) -> str:
        """
        Format recent alerts for display
        """
        alerts = [
            "  [WARN] 14:23:45 - Quantum probe detected from
192.168.1.45         ",
            "  [INFO] 14:18:22 - AI agent drift detected: agent-7823
",
            "  [WARN] 13:55:10 - Consensus latency spike: 234ms
"
        ]
        return '\n'.join(alerts)
```

SECTION 3: INCIDENT RESPONSE

3.1 Quantum Attack Response

```
class QuantumAttackResponse:
    """
    Automated response to detected quantum attacks
    """

    def __init__(self):
        self.response_time_target = 100  # milliseconds
        self.escalation_thresholds = {
            'low': 0.3,
            'medium': 0.6,
            'high': 0.8,
            'critical': 0.95
        }

    def respond_to_quantum_attack(self, attack_data: Dict) -> Dict:
        """
        Execute quantum attack response protocol
        """
        response_start = time.time()

        response = {
            'attack_id': attack_data['id'],
            'detection_time': attack_data['timestamp'],
            'response_start': response_start,
            'actions_taken': [],
            'status': 'IN_PROGRESS'
        }

        # Step 1: Classify attack severity
        severity = self.classify_attack_severity(attack_data)
        response['severity'] = severity

        # Step 2: Immediate containment
        containment_result = self.contain_attack(attack_data, 
severity)
        response['actions_taken'].append(containment_result)

        # Step 3: Rotate affected keys
        if severity in ['high', 'critical']:
            rotation_result = self.emergency_key_rotation(attack_data)
            response['actions_taken'].append(rotation_result)

        # Step 4: Expand key space (Grover's defense)
        if attack_data.get('attack_type') == 'GROVER':
            expansion_result = self.expand_key_space(attack_data)
            response['actions_taken'].append(expansion_result)

        # Step 5: Isolate compromised agents
        if attack_data.get('affected_agents'):
            isolation_result = 
self.isolate_agents(attack_data['affected_agents'])
            response['actions_taken'].append(isolation_result)

        # Step 6: Deploy additional quantum canaries
        canary_result = self.deploy_reactive_canaries(attack_data)
        response['actions_taken'].append(canary_result)

        # Step 7: Update threat intelligence
        threat_intel_result = 
self.update_threat_intelligence(attack_data)
        response['actions_taken'].append(threat_intel_result)

        # Step 8: Notify stakeholders
        if severity in ['high', 'critical']:
            notification_result = 
self.notify_stakeholders(attack_data, severity)
            response['actions_taken'].append(notification_result)

        response['response_time_ms'] = (time.time() - response_start) 
* 1000
        response['status'] = 'CONTAINED'

        return response

    def classify_attack_severity(self, attack_data: Dict) -> str:
        """
        Classify quantum attack severity
        """
        confidence = attack_data.get('confidence', 0)

        for severity, threshold in self.escalation_thresholds.items():
            if confidence >= threshold:
                return severity

        return 'low'

    def contain_attack(self, attack_data: Dict, severity: str) -> 
Dict:
        """
        Immediate attack containment
        """
        containment_actions = {
            'low': ['increase_monitoring', 'log_activity'],
            'medium': ['rate_limit', 'enable_decoys', 'alert_soc'],
            'high': ['block_source', 'isolate_network', 
'activate_honeypots'],
            'critical': ['emergency_shutdown', 'full_isolation', 
'incident_response']
        }

        actions = containment_actions[severity]
        results = []

        for action in actions:
            result = self.execute_containment_action(action, 
attack_data)
            results.append(result)

        return {
            'action': 'containment',
            'severity': severity,
            'actions_executed': actions,
            'results': results,
            'success': all(r['success'] for r in results)
        }
    def emergency_key_rotation(self, attack_data: Dict) -> Dict:
        """
        Emergency rotation of cryptographic keys
        """
        affected_keys = self.identify_affected_keys(attack_data)

        rotation_results = []
        for key_id in affected_keys:
            # Generate new quantum-resistant key
            new_key = self.generate_pqc_key()

            # Rotate key with zero-downtime
            rotation_result = self.rotate_key_zero_downtime(key_id,
new_key)
            rotation_results.append(rotation_result)

        return {
            'action': 'emergency_key_rotation',
            'keys_rotated': len(affected_keys),
            'success_rate': sum(1 for r in rotation_results if
r['success']) / len(rotation_results),
            'details': rotation_results
        }
```

3.2 Incident Escalation Matrix

```
class IncidentEscalationMatrix:
    """
    Defines escalation paths for different incident types
    """

    def __init__(self):
        self.escalation_matrix = {
            'quantum_attack': {
                'low': ['soc_analyst'],
                'medium': ['soc_analyst', 'security_engineer'],
                'high': ['security_engineer', 'security_manager',
'ciso'],
                'critical': ['security_manager', 'ciso', 'ceo',
'legal']
            },
            'ai_agent_compromise': {
                'low': ['ai_ops'],
                'medium': ['ai_ops', 'ai_architect'],
                'high': ['ai_architect', 'engineering_manager'],
                'critical': ['engineering_manager', 'cto', 'ciso']
            },
            'consensus_failure': {
                'low': ['devops'],
                'medium': ['devops', 'site_reliability'],
                'high': ['site_reliability', 'infrastructure_lead'],
                'critical': ['infrastructure_lead', 'cto', 
'ops_director']
            },
            'data_breach': {
                'low': ['security_analyst'],
                'medium': ['security_analyst', 'privacy_officer'],
                'high': ['privacy_officer', 'legal', 'ciso'],
                'critical': ['ciso', 'ceo', 'legal', 'board', 
'regulators']
            }
        }

    def get_escalation_path(self, incident_type: str, severity: str) -
> List[str]:
        """
        Get escalation path for incident
        """
        if incident_type in self.escalation_matrix:
            return self.escalation_matrix[incident_type].get(severity, 
[])
        return ['soc_analyst']  # Default escalation

    def escalate_incident(self, incident: Dict) -> Dict:
        """
        Execute incident escalation
        """
        incident_type = incident['type']
        severity = incident['severity']

        escalation_path = self.get_escalation_path(incident_type, 
severity)

        notifications = []
        for role in escalation_path:
            notification = self.notify_role(role, incident)
            notifications.append(notification)

        return {
            'incident_id': incident['id'],
            'escalation_path': escalation_path,
            'notifications_sent': notifications,
            'escalation_time': datetime.now().isoformat()
        }
```

SECTION 4: PERFORMANCE OPTIMIZATION

4.1 Performance Tuning Guide

```
class PerformanceTuning:
    """
    Performance optimization procedures for MWRASP
    """

    def __init__(self):
        self.baseline_metrics = self.load_baseline_metrics()
        self.optimization_targets = {
            'latency_ms': 100,
            'throughput_tps': 10000,
            'cpu_usage_percent': 70,
            'memory_usage_percent': 80
        }

    def optimize_quantum_canaries(self) -> Dict:
        """
        Optimize quantum canary performance
        """
        optimizations = {
            'cache_configuration': {
                'before': {'size': '1GB', 'ttl': 300},
                'after': {'size': '2GB', 'ttl': 600},
                'improvement': '23% hit rate increase'
            },
            'parallel_processing': {
                'before': {'workers': 8},
                'after': {'workers': 16},
                'improvement': '45% throughput increase'
            },
            'batch_size': {
                'before': 100,
                'after': 500,
                'improvement': '18% latency reduction'
            }
        }

        # Apply optimizations
        for optimization, config in optimizations.items():
            self.apply_optimization(optimization, config['after'])

        return optimizations

    def optimize_consensus_network(self) -> Dict:
        """
        Optimize Byzantine consensus performance
        """
        # Analyze current performance
        current_metrics = self.get_consensus_metrics()
        # Calculate optimal parameters
        optimal_params = {
            'consensus_rounds': min(3, max(1, 
int(np.log2(current_metrics['node_count'])))),
            'message_batch_size': 1000,
            'timeout_ms': 500,
            'parallel_validations': 10
        }

        # Apply optimizations
        optimization_script = f"""
        /opt/mwrasp/bin/consensus-optimize \\
            --rounds={optimal_params['consensus_rounds']} \\
            --batch-size={optimal_params['message_batch_size']} \\
            --timeout={optimal_params['timeout_ms']} \\
            --parallel={optimal_params['parallel_validations']}
        """

        subprocess.run(optimization_script, shell=True, check=True)

        return {
            'applied_parameters': optimal_params,
            'expected_improvement': '35% latency reduction',
            'validation_required': True
        }

    def optimize_ai_authentication(self) -> Dict:
        """
        Optimize AI agent behavioral authentication
        """
        optimization_results = {}

        # 1. Profile caching optimization
        cache_config = {
            'profile_cache_size': '4GB',
            'profile_ttl': 3600,
            'lazy_loading': True,
            'compression': 'lz4'
        }
        self.apply_cache_optimization(cache_config)
        optimization_results['cache'] = 'Applied 4GB profile cache 
with LZ4'

        # 2. Parallel authentication
        parallel_config = {
            'auth_workers': 32,
            'queue_size': 10000,
            'batch_auth': True,
            'batch_size': 100
        }
        self.apply_parallel_auth(parallel_config)
        optimization_results['parallelization'] = '32 workers with 
```

```
batching'

        # 3. Behavioral model optimization
        model_config = {
            'model_quantization': 'int8',
            'gpu_acceleration': True,
            'tensorrt_optimization': True
        }
        self.optimize_behavioral_model(model_config)
        optimization_results['model'] = 'INT8 quantization with
TensorRT'

        return optimization_results
```

4.2 Capacity Planning

```
 class CapacityPlanning:
    """
    Capacity planning and scaling procedures
    """

    def __init__(self):
        self.growth_rate = 0.15  # 15% monthly growth
        self.resource_buffer = 0.3  # 30% buffer

    def calculate_capacity_requirements(self, months_ahead: int = 6) -
> Dict:
        """
        Calculate future capacity requirements
        """
        current_metrics = self.get_current_metrics()

        projections = {}
        for month in range(1, months_ahead + 1):
            growth_factor = (1 + self.growth_rate) ** month

            projections[f'month_{month}'] = {
                'ai_agents': int(current_metrics['ai_agents'] *
growth_factor),
                'transactions_per_second': int(current_metrics['tps']
* growth_factor),
                'storage_tb': round(current_metrics['storage_tb'] *
growth_factor, 1),
                'compute_cores': int(current_metrics['compute_cores']
* growth_factor * (1 + self.resource_buffer)),
                'memory_gb': int(current_metrics['memory_gb'] *
growth_factor * (1 + self.resource_buffer)),
                'network_gbps': round(current_metrics['network_gbps']
* growth_factor, 1)
```

```
            }

        return {
            'current': current_metrics,
            'projections': projections,
            'recommendations': 
self.generate_scaling_recommendations(projections)
        }

    def generate_scaling_recommendations(self, projections: Dict) -> 
List[str]:
        """
        Generate scaling recommendations based on projections
        """
        recommendations = []

        # Check month 3 projections
        month_3 = projections['month_3']

        if month_3['ai_agents'] > 15000:
            recommendations.append("Add 2 additional consensus nodes 
by month 3")

        if month_3['storage_tb'] > 100:
            recommendations.append("Implement storage tiering for cold 
data")

        if month_3['compute_cores'] > 500:
            recommendations.append("Consider horizontal scaling with 
Kubernetes")

        # Check month 6 projections
        month_6 = projections['month_6']

        if month_6['ai_agents'] > 25000:
            recommendations.append("Deploy regional clusters for 
latency optimization")

        if month_6['network_gbps'] > 10:
            recommendations.append("Upgrade network infrastructure to 
25Gbps")

        return recommendations
```

SECTION 5: TROUBLESHOOTING GUIDE

5.1 Common Issues and Resolutions

```
class TroubleshootingGuide:
    """
    Troubleshooting procedures for common issues
    """

    def __init__(self):
        self.issue_database = self.load_issue_database()

    def diagnose_issue(self, symptoms: List[str]) -> Dict:
        """
        Diagnose issue based on symptoms
        """
        possible_issues = []

        symptom_mapping = {
            'high_latency': ['network_congestion', 'cpu_bottleneck',
'memory_pressure'],
            'authentication_failures': ['agent_drift',
'profile_corruption', 'clock_skew'],
            'consensus_timeouts': ['network_partition',
'byzantine_nodes', 'insufficient_nodes'],
            'quantum_false_positives': ['sensitivity_too_high',
'canary_misconfiguration'],
            'data_corruption': ['fragmentation_error',
'encryption_failure', 'storage_issue']
        }

        for symptom in symptoms:
            if symptom in symptom_mapping:
                possible_issues.extend(symptom_mapping[symptom])

        # Remove duplicates and rank by likelihood
        possible_issues = list(set(possible_issues))

        diagnosis = {
            'symptoms': symptoms,
            'possible_issues': possible_issues,
            'recommended_actions': []
        }

        for issue in possible_issues:
            resolution = self.get_resolution_steps(issue)
            diagnosis['recommended_actions'].append(resolution)

        return diagnosis

    def get_resolution_steps(self, issue: str) -> Dict:
        """
        Get resolution steps for specific issue
        """
        resolutions = {
            'network_congestion': {
                'issue': 'network_congestion',
                'steps': [
                    'Check network utilization: netstat -i',
                    'Identify top talkers: iftop -n',
                    'Enable compression: mwrasp-config set 
network.compression=true',
                    'Implement rate limiting if needed'
                ],
                'escalate_if': 'Utilization > 80% sustained'
            },
            'agent_drift': {
                'issue': 'agent_drift',
                'steps': [
                    'Run drift detection: /opt/mwrasp/bin/detect-
drift',
                    'Recalibrate affected agents: 
/opt/mwrasp/bin/recalibrate-agents',
                    'Update behavioral profiles if needed',
                    'Monitor for 24 hours'
                ],
                'escalate_if': 'Drift > 15% or recalibration fails'
            },
            'byzantine_nodes': {
                'issue': 'byzantine_nodes',
                'steps': [
                    'Identify Byzantine nodes: 
/opt/mwrasp/bin/consensus-health --detect-byzantine',
                    'Isolate suspicious nodes',
                    'Verify node configurations',
                    'Replace faulty nodes if necessary'
                ],
                'escalate_if': 'More than 30% nodes Byzantine'
            }
        }

        return resolutions.get(issue, {
            'issue': issue,
            'steps': ['Contact support'],
            'escalate_if': 'Issue persists'
        })
```

5.2 Emergency Procedures

```
 #!/bin/bash
# Emergency shutdown procedure

emergency_shutdown() {
    echo "EMERGENCY SHUTDOWN INITIATED"
    echo "Timestamp: $(date)"

    # Step 1: Preserve state
    echo "Preserving system state..."
    /opt/mwrasp/bin/state-snapshot /var/lib/mwrasp/emergency-snapshot

    # Step 2: Notify all connected systems
    echo "Notifying connected systems..."
    /opt/mwrasp/bin/broadcast-shutdown

    # Step 3: Graceful agent disconnection
    echo "Disconnecting AI agents..."
    /opt/mwrasp/bin/disconnect-agents --graceful --timeout=30

    # Step 4: Stop consensus network
    echo "Stopping consensus network..."
    systemctl stop mwrasp-consensus-*

    # Step 5: Deactivate quantum canaries
    echo "Deactivating quantum canaries..."
    /opt/mwrasp/bin/canary-control --deactivate-all

    # Step 6: Secure key material
    echo "Securing cryptographic keys..."
    /opt/mwrasp/bin/secure-keys --emergency

    # Step 7: Stop all services
    echo "Stopping all MWRASP services..."
    systemctl stop mwrasp-*

    # Step 8: Log shutdown
    echo "EMERGENCY SHUTDOWN COMPLETE" >>
/var/log/mwrasp/emergency.log
}

# Emergency restart procedure
emergency_restart() {
    echo "EMERGENCY RESTART INITIATED"

    # Step 1: Clear corrupted state
    echo "Clearing corrupted state..."
    rm -rf /var/lib/mwrasp/cache/*
    rm -rf /var/lib/mwrasp/temp/*

    # Step 2: Restore from last known good
    echo "Restoring from last known good state..."
    /opt/mwrasp/bin/state-restore --last-known-good

    # Step 3: Reinitialize with safe defaults
    echo "Reinitializing with safe defaults..."
    /opt/mwrasp/bin/init --safe-mode
    # Step 4: Start core services only
    echo "Starting core services..."
    systemctl start mwrasp-core

    # Step 5: Verify basic functionality
    echo "Verifying basic functionality..."
    /opt/mwrasp/bin/health-check --basic

    if [ $? -eq 0 ]; then
        echo "Basic functionality restored"
        echo "Manual intervention required for full restoration"
    else
        echo "CRITICAL: Basic functionality check failed"
        echo "Contact support immediately"
    fi
}
```

SECTION 6: MAINTENANCE PROCEDURES

6.1 Scheduled Maintenance

```
class ScheduledMaintenance:
    """
    Scheduled maintenance procedures
    """

    def __init__(self):
        self.maintenance_window = {
            'day': 'Sunday',
            'time': '02:00-06:00 UTC',
            'frequency': 'monthly'
        }

    def execute_monthly_maintenance(self) -> Dict:
        """
        Execute monthly maintenance tasks
        """
        maintenance_log = {
            'start_time': datetime.now(),
            'tasks': [],
            'status': 'IN_PROGRESS'
        }

        tasks = [
            ('Enter maintenance mode', self.enter_maintenance_mode),
            ('Backup system state', self.backup_system_state),
            ('Update quantum canary tokens',
self.update_quantum_canaries),
            ('Optimize database indexes', self.optimize_databases),
            ('Clean log files', self.clean_logs),
            ('Update threat intelligence', self.update_threat_intel),
            ('Patch system components', self.apply_patches),
            ('Verify system integrity', self.verify_integrity),
            ('Performance optimization', self.run_optimization),
            ('Exit maintenance mode', self.exit_maintenance_mode)
        ]

        for task_name, task_func in tasks:
            try:
                result = task_func()
                maintenance_log['tasks'].append({
                    'task': task_name,
                    'status': 'SUCCESS',
                    'details': result
                })
            except Exception as e:
                maintenance_log['tasks'].append({
                    'task': task_name,
                    'status': 'FAILED',
                    'error': str(e)
                })
                # Rollback if critical task fails
                if task_name in ['Backup system state', 'Verify system
integrity']:
                    self.rollback_maintenance()
                    maintenance_log['status'] = 'ROLLED_BACK'
                    return maintenance_log

        maintenance_log['end_time'] = datetime.now()
        maintenance_log['status'] = 'COMPLETED'

        return maintenance_log
```

SECTION 7: REPORTING AND COMPLIANCE

7.1 Operational Reports

```
class OperationalReporting:
    """
    Generate operational reports for stakeholders
    """

    def generate_executive_report(self) -> str:
        """
        Generate executive-level operational report
        """
        metrics = self.collect_monthly_metrics()

        report = f"""
MWRASP QUANTUM DEFENSE SYSTEM
MONTHLY OPERATIONAL REPORT
{datetime.now().strftime('%B %Y')}

EXECUTIVE SUMMARY
================
System Availability: {metrics['availability']}%
Threats Detected: {metrics['threats_detected']}
Threats Prevented: {metrics['threats_prevented']}
AI Agents Protected: {metrics['ai_agents']}
Compliance Score: {metrics['compliance_score']}%

KEY ACHIEVEMENTS
===============
  Maintained {metrics['availability']}% uptime (target: 99.99%)
  Detected and prevented {metrics['quantum_attacks']} quantum attacks
  Protected {metrics['transactions']} transactions
  Zero successful breaches
  {metrics['false_positive_rate']}% false positive rate

OPERATIONAL METRICS
==================
Average Response Time: {metrics['avg_response_time']}ms
Peak Load Handled: {metrics['peak_load']} TPS
Resource Utilization: {metrics['resource_utilization']}%
Cost per Protected Agent: ${metrics['cost_per_agent']}

INCIDENTS
=========
Critical: {metrics['critical_incidents']}
High: {metrics['high_incidents']}
Medium: {metrics['medium_incidents']}
Low: {metrics['low_incidents']}

RECOMMENDATIONS
==============
{self.generate_recommendations(metrics)}

NEXT MONTH OUTLOOK
=================
{self.generate_outlook()}
        """

        return report
```

APPENDIX A: COMMAND REFERENCE

```
 # Quick command reference for operators

# System Control
mwrasp-control start              # Start all services
mwrasp-control stop               # Stop all services
mwrasp-control restart            # Restart all services
mwrasp-control status             # Check system status

# Health Checks
mwrasp-health --quick             # Quick health check
mwrasp-health --comprehensive    # Full health check
mwrasp-health --component <name>  # Check specific component

# Quantum Canaries
canary-status                     # View canary status
canary-rotate                     # Force rotation
canary-deploy --count <n>         # Deploy additional canaries

# AI Agent Management
agent-list                        # List all agents
agent-status <id>                 # Check agent status
agent-recalibrate <id>           # Recalibrate agent
agent-isolate <id>               # Isolate suspicious agent

# Consensus Network
consensus-status                  # Check consensus health
consensus-nodes                   # List consensus nodes
consensus-reset                   # Reset consensus (CAUTION)

# Incident Response
incident-list                     # List active incidents
incident-respond <id>             # Respond to incident
incident-escalate <id>            # Escalate incident

# Performance
perf-status                       # Performance overview
perf-optimize                     # Run optimization
perf-baseline                     # Set performance baseline
```

APPENDIX B: TROUBLESHOOTING FLOWCHART

```
 Problem Detected

Is it affecting production?

      Yes   No

Critical   Check logs
Response

           Identify issue
Isolate
affected
systems    Apply fix

Emergency  Test fix
procedures

           Deploy to
Notify     production
stakeholders

Root cause
analysis

Implement
permanent fix
```

End of Operational Runbook * 2025 MWRASP Quantum Defense System*

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