NEXUS-PRIME Development Specifications

Complete Technical Implementation Guide

Project: NEXUS-PRIME Adaptive AI Integration Platform
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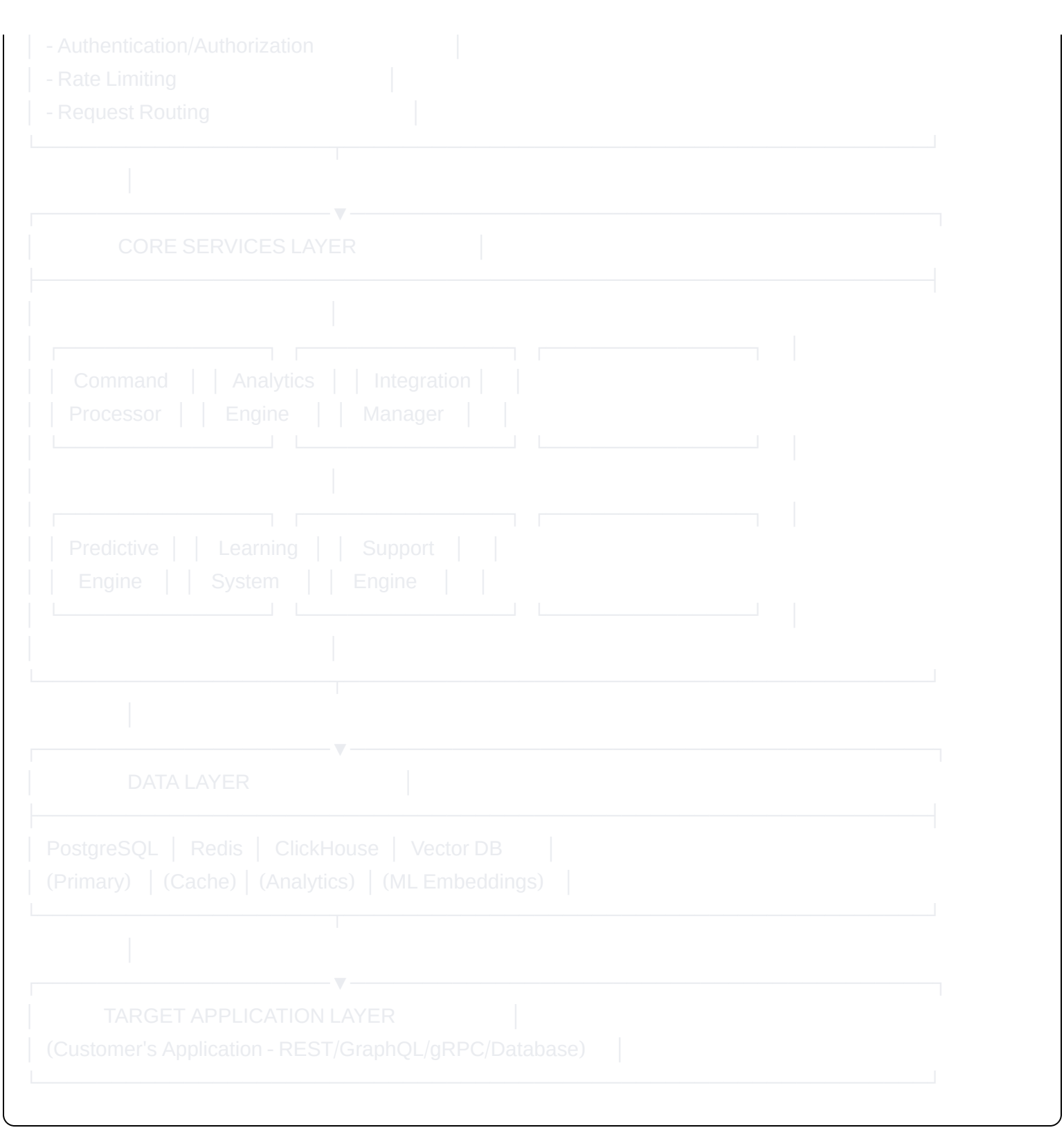
SYSTEM ARCHITECTURE OVERVIEW

High-Level Architecture



Component Responsibilities

API Gateway

- Single entry point for all requests
- JWT token validation
- Rate limiting per customer

- Request logging and monitoring

Command Processor

- Natural language parsing (NLP)
- Intent classification
- Command execution orchestration
- Safety validation

Analytics Engine

- Real-time metrics aggregation
- Anomaly detection
- Insight generation
- Report creation

Integration Manager

- Application discovery
- Connection management
- Adapter generation
- Health monitoring

Predictive Engine

- ML model inference
- Pattern recognition
- Recommendation generation
- Forecasting

Learning System

- Continuous model training
- Feature extraction
- Behavior analysis
- Knowledge graph updates

Support Engine

- Context-aware assistance
- Friction detection
- Automated responses
- Escalation management

TECHNOLOGY STACK

Backend Services

Primary Language: Python 3.11+

- **Why:** Rich ML ecosystem, async support, rapid development

Web Framework: FastAPI

- **Why:** Modern, fast, automatic API documentation, async native

Additional Languages:

- **Node.js 20+:** Real-time features (WebSockets, event streaming)
- **Go:** High-performance workers and connectors

Databases

Primary Database: PostgreSQL 15+

- User data, application metadata, configurations
- JSONB support for flexible schemas
- Full-text search capabilities

Cache Layer: Redis 7+

- Session management
- Real-time analytics buffers
- Rate limiting
- Job queues (with Bull/Celery)

Analytics Database: ClickHouse

- Time-series data
- Event tracking
- Log aggregation
- High-volume metrics

Vector Database: Pinecone or Weaviate

- ML embeddings storage
- Semantic search
- Similarity matching

Graph Database: Neo4j (optional)

- Application relationship mapping
- Dependency tracking
- Knowledge graph

ML/AI Stack

Framework: PyTorch 2.0+

- Neural network models
- Custom architectures

NLP: Hugging Face Transformers

- Pre-trained models (BERT, GPT)
- Text classification
- Named entity recognition

Additional Libraries:

- scikit-learn: Classical ML algorithms
- pandas/numpy: Data processing
- spaCy: Advanced NLP

Infrastructure

Containerization: Docker

- Consistent environments
- Easy deployment

Orchestration: Kubernetes

- Auto-scaling
- Service discovery
- Load balancing

Message Queue: RabbitMQ or Apache Kafka

- Event streaming
- Async task processing
- Service decoupling

Monitoring:

- Prometheus: Metrics collection
- Grafana: Visualization
- ELK Stack: Log aggregation
- Sentry: Error tracking

Frontend (Dashboard)

Framework: React 18+ with TypeScript

- Component-based architecture
- Type safety

State Management: Zustand or Redux Toolkit

- Centralized state
- Predictable updates

UI Library: Tailwind CSS + shadcn/ui

- Consistent design
- Accessibility

Data Visualization: Recharts or D3.js

- Interactive charts
- Real-time updates

DATABASE SCHEMA

PostgreSQL Schema

```sql
```

```sql
-- Organizations (customers)
CREATE TABLE organizations (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    name VARCHAR(255) NOT NULL,
    slug VARCHAR(100) UNIQUE NOT NULL,
    subscription_tier VARCHAR(50) NOT NULL,
    api_key VARCHAR(255) UNIQUE NOT NULL,
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

-- Users
CREATE TABLE users (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    organization_id UUID REFERENCES organizations(id) ON DELETE CASCADE,
    email VARCHAR(255) UNIQUE NOT NULL,
    password_hash VARCHAR(255) NOT NULL,
    full_name VARCHAR(255),
    role VARCHAR(50) NOT NULL DEFAULT 'user',
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    last_login TIMESTAMP WITH TIME ZONE
);

-- Integrated Applications
CREATE TABLE applications (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    organization_id UUID REFERENCES organizations(id) ON DELETE CASCADE,
    name VARCHAR(255) NOT NULL,
    description TEXT,
    base_url VARCHAR(500),
    application_type VARCHAR(50), -- 'saas', 'mobile', 'web', 'enterprise'
    status VARCHAR(50) NOT NULL DEFAULT 'learning', -- 'learning', 'active', 'paused', 'error'
    learning_progress INTEGER DEFAULT 0, -- 0-100
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    last_scanned TIMESTAMP WITH TIME ZONE,
    metadata JSONB DEFAULT '{}'::jsonb
);

-- Application Connections (APIs, DBs)
CREATE TABLE application_connections (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
```

```
    application_id UUID REFERENCES applications(id) ON DELETE CASCADE,
    connection_type VARCHAR(50) NOT NULL, -- 'rest_api', 'graphql', 'database', 'grpc'
    connection_name VARCHAR(255),
    endpoint_url VARCHAR(500),
    auth_type VARCHAR(50), -- 'bearer', 'api_key', 'oauth', 'basic'
    credentials JSONB, -- encrypted
    configuration JSONB DEFAULT '{}'::jsonb,
    status VARCHAR(50) DEFAULT 'active',
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    last_tested TIMESTAMP WITH TIME ZONE
);

-- Discovered API Endpoints
CREATE TABLE api_endpoints (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    connection_id UUID REFERENCES application_connections(id) ON DELETE CASCADE,
    method VARCHAR(10) NOT NULL, -- GET, POST, PUT, DELETE, etc.
    path VARCHAR(500) NOT NULL,
    description TEXT,
    parameters JSONB DEFAULT '[]'::jsonb,
    response_schema JSONB,
    usage_count INTEGER DEFAULT 0,
    avg_response_time FLOAT,
    discovered_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    last_called TIMESTAMP WITH TIME ZONE
);

-- Database Tables/Collections Discovered
CREATE TABLE discovered_tables (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    connection_id UUID REFERENCES application_connections(id) ON DELETE CASCADE,
    table_name VARCHAR(255) NOT NULL,
    schema_name VARCHAR(255),
    row_count BIGINT,
    columns JSONB DEFAULT '[]'::jsonb, -- column definitions
    relationships JSONB DEFAULT '[]'::jsonb, -- foreign keys, etc.
    discovered_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    last_analyzed TIMESTAMP WITH TIME ZONE
);

-- Command History
```

```
CREATE TABLE command_history (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    organization_id UUID REFERENCES organizations(id) ON DELETE CASCADE,
    user_id UUID REFERENCES users(id) ON DELETE SET NULL,
    application_id UUID REFERENCES applications(id) ON DELETE CASCADE,
    command_text TEXT NOT NULL,
    intent VARCHAR(100), -- classified intent
    status VARCHAR(50) NOT NULL, -- 'pending', 'executing', 'completed', 'failed'
    execution_time_ms INTEGER,
    result JSONB,
    error_message TEXT,
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    completed_at TIMESTAMP WITH TIME ZONE
);

-- Predictive Insights
CREATE TABLE insights (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    application_id UUID REFERENCES applications(id) ON DELETE CASCADE,
    insight_type VARCHAR(100) NOT NULL, -- 'performance', 'churn', 'feature', 'security'
    severity VARCHAR(50) NOT NULL, -- 'low', 'medium', 'high', 'critical'
    title VARCHAR(500) NOT NULL,
    description TEXT NOT NULL,
    recommendation TEXT,
    confidence_score FLOAT, -- 0.0 to 1.0
    impact_score FLOAT, -- estimated impact
    status VARCHAR(50) DEFAULT 'new', -- 'new', 'acknowledged', 'resolved', 'dismissed'
    generated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    acknowledged_at TIMESTAMP WITH TIME ZONE,
    data JSONB DEFAULT '{}'::jsonb
);

-- Analytics Events (high volume - consider partitioning)
CREATE TABLE analytics_events (
    id BIGSERIAL PRIMARY KEY,
    application_id UUID REFERENCES applications(id) ON DELETE CASCADE,
    event_type VARCHAR(100) NOT NULL,
    event_name VARCHAR(255),
    user_identifier VARCHAR(255), -- user ID from customer app
    session_id VARCHAR(255),
    properties JSONB DEFAULT '{}'::jsonb,
```

```
    timestamp TIMESTAMP WITH TIME ZONE DEFAULT NOW()
) PARTITION BY RANGE (timestamp);

-- Create partitions (example for monthly)
CREATE TABLE analytics_events_2026_02 PARTITION OF analytics_events
    FOR VALUES FROM ('2026-02-01') TO ('2026-03-01');

-- Support Interactions
CREATE TABLE support_interactions (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    application_id UUID REFERENCES applications(id) ON DELETE CASCADE,
    user_identifier VARCHAR(255),
    interaction_type VARCHAR(50), -- 'automated', 'escalated', 'proactive'
    question TEXT,
    response TEXT,
    resolved BOOLEAN DEFAULT FALSE,
    resolution_time_seconds INTEGER,
    satisfaction_score INTEGER, -- 1-5
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    resolved_at TIMESTAMP WITH TIME ZONE
);

-- Learning Models Metadata
CREATE TABLE ml_models (
    id UUID PRIMARY KEY DEFAULT gen_random_uuid(),
    model_type VARCHAR(100) NOT NULL, -- 'churn_prediction', 'friction_detection', etc.
    version VARCHAR(50) NOT NULL,
    application_id UUID REFERENCES applications(id) ON DELETE CASCADE,
    model_path VARCHAR(500), -- storage location
    accuracy FLOAT,
    trained_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    training_data_size INTEGER,
    hyperparameters JSONB,
    status VARCHAR(50) DEFAULT 'training' -- 'training', 'deployed', 'deprecated'
);

-- Indexes
CREATE INDEX idx_applications_org ON applications(organization_id);
CREATE INDEX idx_connections_app ON application_connections(application_id);
CREATE INDEX idx_endpoints_connection ON api_endpoints(connection_id);
CREATE INDEX idx_commands_org ON command_history(organization_id);
```

```
CREATE INDEX idx_commands_created ON command_history(created_at);
CREATE INDEX idx_insights_app ON insights(application_id);
CREATE INDEX idx_insights_status ON insights(status);
CREATE INDEX idx_events_app_time ON analytics_events(application_id, timestamp);
CREATE INDEX idx_support_app ON support_interactions(application_id);
```

Redis Schema Design

```
# Session Management
session:{session_id} -> Hash {
  user_id: UUID,
  organization_id: UUID,
  expires_at: timestamp
}
TTL: 24 hours

# Rate Limiting
rate_limit:{organization_id}:{endpoint} -> String (count)
TTL: 1 hour

# Real-time Metrics Cache
metrics:{application_id}:active_users -> Sorted Set (score: timestamp)
metrics:{application_id}:recent_events -> List (max 1000)

# Command Processing Queue
queue:commands -> List (command job IDs)

# Application Learning Cache
learning:{application_id}:endpoints -> Hash (discovered endpoints)
learning:{application_id}:tables -> Hash (discovered tables)
```

ClickHouse Schema

```sql
```

```sql
-- Time-series events table
CREATE TABLE events (
    timestamp DateTime64(3),
    application_id UUID,
    event_type LowCardinality(String),
    event_name String,
    user_id String,
    session_id String,
    properties String, -- JSON string
    metric_value Float64
) ENGINE = MergeTree()
PARTITION BY toYYYYMM(timestamp)
ORDER BY (application_id, event_type, timestamp);

-- Aggregated metrics materialized view
CREATE MATERIALIZED VIEW metrics_hourly
ENGINE = SummingMergeTree()
PARTITION BY toYYYYMM(timestamp)
ORDER BY (application_id, event_type, hour)
AS SELECT
    application_id,
    event_type,
    toStartOfHour(timestamp) as hour,
    count() as event_count,
    uniq(user_id) as unique_users,
    avg(metric_value) as avg_value
FROM events
GROUP BY application_id, event_type, hour;

-- Performance metrics
CREATE TABLE performance_metrics (
    timestamp DateTime64(3),
    application_id UUID,
    endpoint_path String,
    response_time_ms UInt32,
    status_code UInt16,
    error_type LowCardinality(String)
) ENGINE = MergeTree()
PARTITION BY toYYYYMM(timestamp)
ORDER BY (application_id, endpoint_path, timestamp);
```

API SPECIFICATIONS

Authentication

All API requests require authentication via JWT token or API key.

Headers:

```
Authorization: Bearer <jwt_token>
X-API-Key: <api_key>
```

Base Endpoints

Base URL: `https://api.nexus-prime.io/v1`

Core API Endpoints

1. Application Management

```
POST /applications
Create new application integration

Request:
{
  "name": "My SaaS App",
  "description": "Customer management platform",
  "base_url": "https://myapp.com",
  "application_type": "saas"
}

Response:
{
  "id": "uuid",
  "name": "My SaaS App",
  "status": "learning",
  "learning_progress": 0,
  "created_at": "2026-02-10T12:00:00Z"
}
```

```
GET /applications/{application_id}
Get application details and learning status

Response:
{
  "id": "uuid",
  "name": "My SaaS App",
  "status": "active",
  "learning_progress": 100,
  "connections": [
    {
      "id": "uuid",
      "type": "rest_api",
      "endpoint_count": 47,
      "status": "active"
    }
  ],
  "discovered_endpoints": 47,
  "discovered_tables": 23,
  "last_scanned": "2026-02-10T12:00:00Z"
}
```

2. Connections

```
POST /applications/{application_id}/connections
Add new connection (API, database, etc.)

Request:
{
  "connection_type": "rest_api",
  "endpoint_url": "https://api.myapp.com",
  "auth_type": "bearer",
  "credentials": {
    "token": "encrypted_token"
  }
}

Response:
{
  "id": "uuid",
  "connection_type": "rest_api",
  "status": "testing",
  "created_at": "2026-02-10T12:00:00Z"
}
```

```
POST /connections/{connection_id}/scan
Trigger discovery scan

Response:
{
  "scan_id": "uuid",
  "status": "in_progress",
  "started_at": "2026-02-10T12:00:00Z"
}
```

3. Command Processing

```
POST /commands
Execute natural language command

Request:
{
  "application_id": "uuid",
  "command": "Show me why conversions dropped yesterday",
  "context": {
    "user_id": "optional_context"
  }
}

Response:
{
  "command_id": "uuid",
  "status": "processing",
  "estimated_completion": "2026-02-10T12:00:05Z"
}
```

```
GET /commands/{command_id}
Get command execution status and result

Response:
{
  "command_id": "uuid",
  "status": "completed",
  "intent": "analyze_conversion_drop",
  "result": {
    "analysis": "Conversions dropped 23% yesterday...",
    "root_cause": "Checkout page load time increased...",
    "recommendation": "Rollback database changes..."
  },
  "execution_time_ms": 1247,
  "completed_at": "2026-02-10T12:00:05Z"
}
```

4. Analytics

GET /applications/{application_id}/metrics
Get real-time metrics

Query Parameters:
- timeframe: "1h", "24h", "7d", "30d"
- metrics: "active_users,conversions,response_time"

Response:

```
{
  "timeframe": "24h",
  "metrics": {
    "active_users": {
      "current": 1247,
      "change_percent": 15.3,
      "trend": "up",
      "data_points": [...]
    },
    "conversion_rate": {
      "current": 3.2,
      "change_percent": -2.1,
      "trend": "down"
    }
  }
}
```

```
POST /applications/{application_id}/analytics/query
Custom analytics query using natural language

Request:
{
  "query": "What are the top 5 features used this month?",
  "filters": {
    "date_range": "last_30_days"
  }
}

Response:
{
  "query_id": "uuid",
  "results": {
    "features": [
      {"name": "Dashboard", "usage_percent": 94, "sessions": 8234},
      {"name": "Search", "usage_percent": 87, "sessions": 7123}
    ]
  },
  "visualization_url": "https://cdn.nexus-prime.io/viz/..."
}
```

5. Insights

GET /applications/{application_id}/insights
Get predictive insights and recommendations

Query Parameters:
- severity: "high", "medium", "low"
- type: "performance", "churn", "feature", "security"
- status: "new", "acknowledged", "resolved"

Response:

```
{
  "insights": [
    {
      "id": "uuid",
      "type": "performance",
      "severity": "high",
      "title": "Predicted Performance Issue",
      "description": "Database query performance will degrade...",
      "recommendation": "Add indexes on user_events table",
      "confidence_score": 0.89,
      "impact_score": 0.75,
      "generated_at": "2026-02-10T12:00:00Z"
    }
  ],
  "total_count": 5,
  "new_count": 3
}
```

```
PUT /insights/{insight_id}
Update insight status

Request:
{
  "status": "acknowledged",
  "notes": "Will implement recommended indexes"
}

Response:
{
  "id": "uuid",
  "status": "acknowledged",
  "acknowledged_at": "2026-02-10T12:00:00Z"
}
```

6. Support

```
POST /applications/{application_id}/support/query
Query support system (can be triggered by end users)

Request:
{
  "user_identifier": "user_123",
  "question": "How do I export my data?",
  "context": {
    "current_page": "/dashboard",
    "session_id": "session_456"
  }
}

Response:
{
  "interaction_id": "uuid",
  "answer": "To export your data, click the Export button...",
  "confidence": 0.95,
  "related_articles": [
    {"title": "Data Export Guide", "url": "..."}
  ],
  "escalated": false
}
```

7. Webhooks

```
POST /webhooks
Configure webhooks for events

Request:
{
  "url": "https://myapp.com/nexus-webhook",
  "events": ["insight.generated", "command.completed", "alert.triggered"],
  "secret": "webhook_secret"
}

Response:
{
  "id": "uuid",
  "url": "https://myapp.com/nexus-webhook",
  "events": ["insight.generated", "command.completed"],
  "created_at": "2026-02-10T12:00:00Z"
}
```

Webhook Payload Example:

```json
{
  "event": "insight.generated",
  "timestamp": "2026-02-10T12:00:00Z",
  "data": {
    "insight_id": "uuid",
    "application_id": "uuid",
    "type": "churn",
    "severity": "high",
    "title": "Churn Risk Detected",
    "description": "127 users show early churn signals..."
  }
}
```

CORE MODULES

Module 1: Application Discovery Engine

Purpose: Automatically scan and map target applications

File: `src/discovery/scanner.py`

```python
```

```python
from typing import Dict, List, Optional
import asyncio
import httpx
from urllib.parse import urljoin

class ApplicationScanner:
    """Discovers application structure, APIs, and databases"""

    def __init__(self, application_id: str, base_url: str, credentials: Dict):
        self.application_id = application_id
        self.base_url = base_url
        self.credentials = credentials
        self.endpoints_discovered = []

    async def scan_rest_api(self) -> List[Dict]:
        """Discover REST API endpoints"""
        discovered_endpoints = []

        # Strategy 1: Check for OpenAPI/Swagger docs
        swagger_urls = ['/swagger.json', '/api-docs', '/openapi.json']
        for url in swagger_urls:
            spec = await self._fetch_openapi_spec(urljoin(self.base_url, url))
            if spec:
                discovered_endpoints.extend(self._parse_openapi_spec(spec))
                return discovered_endpoints

        # Strategy 2: Common endpoint discovery
        common_paths = [
            '/api/users', '/api/v1/users',
            '/api/products', '/api/v1/products',
            '/api/orders', '/api/v1/orders',
            '/api/analytics', '/api/v1/analytics'
        ]

        async with httpx.AsyncClient() as client:
            tasks = [self._probe_endpoint(client, path) for path in common_paths]
            results = await asyncio.gather(*tasks, return_exceptions=True)

        for path, result in zip(common_paths, results):
            if isinstance(result, dict):
                discovered_endpoints.append(result)
```

```
    return discovered_endpoints

async def _fetch_openapi_spec(self, url: str) -> Optional[Dict]:
    """Attempt to fetch OpenAPI specification"""
    try:
        async with httpx.AsyncClient() as client:
            response = await client.get(url, timeout=5.0)
            if response.status_code == 200:
                return response.json()
    except Exception:
        pass
    return None

async def _probe_endpoint(self, client: httpx.AsyncClient, path: str) -> Optional[Dict]:
    """Probe an endpoint to see if it exists"""
    try:
        url = urljoin(self.base_url, path)
        response = await client.get(
            url,
            headers=self._get_auth_headers(),
            timeout=5.0
        )

        if response.status_code in [200, 401, 403]:  # Exists but may need auth
            return {
                'method': 'GET',
                'path': path,
                'status_code': response.status_code,
                'response_schema': self._infer_schema(response)
            }
    except Exception:
        pass
    return None

def _parse_openapi_spec(self, spec: Dict) -> List[Dict]:
    """Parse OpenAPI specification into endpoint list"""
    endpoints = []
    paths = spec.get('paths', {})

    for path, methods in paths.items():
```

```
        for method, details in methods.items():
            if method.upper() in ['GET', 'POST', 'PUT', 'DELETE', 'PATCH']:
                endpoints.append({
                    'method': method.upper(),
                    'path': path,
                    'description': details.get('summary', ''),
                    'parameters': details.get('parameters', []),
                    'response_schema': details.get('responses', {})
                })

    return endpoints

def _get_auth_headers(self) -> Dict[str, str]:
    """Generate authentication headers"""
    if self.credentials.get('type') == 'bearer':
        return {'Authorization': f"Bearer {self.credentials['token']}"}
    elif self.credentials.get('type') == 'api_key':
        return {self.credentials.get('header', 'X-API-Key'): self.credentials['key']}
    return {}

def _infer_schema(self, response: httpx.Response) -> Dict:
    """Infer response schema from actual response"""
    try:
        data = response.json()
        return self._analyze_json_structure(data)
    except Exception:
        return {'type': 'unknown'}

def _analyze_json_structure(self, data) -> Dict:
    """Recursively analyze JSON structure"""
    if isinstance(data, dict):
        return {
            'type': 'object',
            'properties': {k: self._analyze_json_structure(v) for k, v in data.items()}
        }
    elif isinstance(data, list):
        if len(data) > 0:
            return {
                'type': 'array',
                'items': self._analyze_json_structure(data[0])
            }
```

```
    return {'type': 'array', 'items': {}}
elif isinstance(data, bool):
    return {'type': 'boolean'}
elif isinstance(data, int):
    return {'type': 'integer'}
elif isinstance(data, float):
    return {'type': 'number'}
elif isinstance(data, str):
    return {'type': 'string'}
else:
    return {'type': 'unknown'}
```

Database Discovery:

```python
```

```python
from sqlalchemy import create_engine, inspect
from typing import Dict, List

class DatabaseScanner:
    """Discovers database schema and structure"""

    def __init__(self, connection_string: str):
        self.engine = create_engine(connection_string)

    def scan_schema(self) -> List[Dict]:
        """Scan database for tables and columns"""
        inspector = inspect(self.engine)
        tables = []

        for table_name in inspector.get_table_names():
            columns = []
            for column in inspector.get_columns(table_name):
                columns.append({
                    'name': column['name'],
                    'type': str(column['type']),
                    'nullable': column['nullable'],
                    'default': column.get('default')
                })

            # Get foreign keys
            relationships = []
            for fk in inspector.get_foreign_keys(table_name):
                relationships.append({
                    'referenced_table': fk['referred_table'],
                    'columns': fk['constrained_columns']
                })

            # Estimate row count (sample query)
            with self.engine.connect() as conn:
                result = conn.execute(f"SELECT COUNT(*) FROM {table_name}")
                row_count = result.scalar()

            tables.append({
                'table_name': table_name,
                'columns': columns,
                'relationships': relationships,
```

```
            'row_count': row_count
        })

    return tables
```

Module 2: Natural Language Command Processor

File: `src/nlp/command_processor.py`

```python
```

```python
from transformers import pipeline
from typing import Dict, Optional
import re

class CommandProcessor:
    """Process natural language commands and extract intent"""

    def __init__(self):
        # Use pre-trained model for text classification
        self.classifier = pipeline(
            "zero-shot-classification",
            model="facebook/bart-large-mnli"
        )

        self.intent_labels = [
            "analyze_metrics",
            "generate_report",
            "export_data",
            "add_feature",
            "modify_ui",
            "query_database",
            "troubleshoot_issue",
            "predict_trend"
        ]

    def process_command(self, command_text: str, application_context: Dict) -> Dict:
        """Process command and return structured intent"""

        # Classify intent
        result = self.classifier(command_text, self.intent_labels)
        intent = result['labels'][0]
        confidence = result['scores'][0]

        # Extract entities
        entities = self._extract_entities(command_text)

        # Extract parameters
        parameters = self._extract_parameters(command_text, intent)

        return {
            'intent': intent,
```

```
            'confidence': confidence,
            'entities': entities,
            'parameters': parameters,
            'original_text': command_text
        }

    def _extract_entities(self, text: str) -> Dict:
        """Extract named entities from text"""
        entities = {
            'dates': self._extract_dates(text),
            'metrics': self._extract_metrics(text),
            'features': self._extract_features(text),
            'numbers': self._extract_numbers(text)
        }
        return entities

    def _extract_dates(self, text: str) -> list:
        """Extract date references"""
        date_patterns = [
            r'yesterday', r'today', r'last week', r'last month',
            r'last (\d+) days', r'\d{4}-\d{2}-\d{2}'
        ]
        dates = []
        for pattern in date_patterns:
            matches = re.findall(pattern, text, re.IGNORECASE)
            dates.extend(matches)
        return dates

    def _extract_metrics(self, text: str) -> list:
        """Extract metric names"""
        metric_keywords = [
            'conversion', 'revenue', 'users', 'traffic',
            'engagement', 'churn', 'retention', 'response time'
        ]
        metrics = []
        for metric in metric_keywords:
            if metric.lower() in text.lower():
                metrics.append(metric)
        return metrics

    def _extract_features(self, text: str) -> list:
```

```
    """Extract feature names or UI elements"""
    feature_patterns = [
        r'dark mode', r'export button', r'dashboard',
        r'search bar', r'navigation menu'
    ]
    features = []
    for pattern in feature_patterns:
        if re.search(pattern, text, re.IGNORECASE):
            features.append(pattern)
    return features

def _extract_numbers(self, text: str) -> list:
    """Extract numeric values"""
    return re.findall(r'\d+\.?\d*', text)

def _extract_parameters(self, text: str, intent: str) -> Dict:
    """Extract intent-specific parameters"""
    params = {}

    if intent == "analyze_metrics":
        # Extract timeframe
        if "yesterday" in text.lower():
            params['timeframe'] = 'yesterday'
        elif "last week" in text.lower():
            params['timeframe'] = 'last_week'
        elif "last month" in text.lower():
            params['timeframe'] = 'last_month'

        # Extract specific metric
        if "conversion" in text.lower():
            params['metric'] = 'conversion_rate'
        elif "revenue" in text.lower():
            params['metric'] = 'revenue'

    elif intent == "export_data":
        # Extract data type
        if "users" in text.lower():
            params['data_type'] = 'users'
        elif "orders" in text.lower():
            params['data_type'] = 'orders'
```

```
        # Extract format
        if "csv" in text.lower():
            params['format'] = 'csv'
        elif "json" in text.lower():
            params['format'] = 'json'

    return params
```

Module 3: Predictive Analytics Engine

File: src/analytics/predictor.py

python

```python
import numpy as np
from sklearn.ensemble import RandomForestRegressor, GradientBoostingClassifier
from datetime import datetime, timedelta
from typing import Dict, List, Tuple

class PredictiveAnalytics:
    """Generate predictions and insights"""

    def __init__(self):
        self.churn_model = GradientBoostingClassifier()
        self.performance_model = RandomForestRegressor()

    def predict_churn_risk(self, user_features: Dict) -> Tuple[float, List[str]]:
        """Predict user churn probability and reasons"""

        # Feature engineering
        features = self._extract_churn_features(user_features)

        # Predict (assumes model is trained)
        churn_probability = self.churn_model.predict_proba([features])[0][1]

        # Feature importance for explanation
        feature_importance = self.churn_model.feature_importances_
        top_factors = self._get_top_factors(feature_importance, features)

        return churn_probability, top_factors

    def _extract_churn_features(self, user_data: Dict) -> List[float]:
        """Extract features for churn prediction"""
        return [
            user_data.get('days_since_last_login', 0),
            user_data.get('session_count_last_week', 0),
            user_data.get('feature_usage_diversity', 0),  # 0-1 score
            user_data.get('support_tickets_count', 0),
            user_data.get('error_encounters', 0),
            user_data.get('days_since_signup', 0),
            user_data.get('subscription_value', 0),
        ]

    def _get_top_factors(self, importance: np.ndarray, features: List) -> List[str]:
        """Get top contributing factors"""
```

```
        feature_names = [
            'inactivity', 'low_engagement', 'limited_feature_use',
            'support_issues', 'errors', 'account_age', 'value'
        ]

        # Get top 3 most important features
        top_indices = np.argsort(importance)[-3:][::-1]
        return [feature_names[i] for i in top_indices]

    def detect_anomalies(self, metric_history: List[float]) -> List[int]:
        """Detect anomalies in time series data"""
        if len(metric_history) < 7:
            return []

        # Simple moving average with standard deviation
        window_size = 7
        anomalies = []

        for i in range(window_size, len(metric_history)):
            window = metric_history[i-window_size:i]
            mean = np.mean(window)
            std = np.std(window)
            current = metric_history[i]

            # If value is more than 2 standard deviations away
            if abs(current - mean) > 2 * std:
                anomalies.append(i)

        return anomalies

    def forecast_metric(self, historical_data: List[Dict], days_ahead: int = 7) -> List[float]:
        """Forecast metric values"""

        # Extract values and timestamps
        values = [d['value'] for d in historical_data]

        # Simple linear regression for demo (replace with better model)
        x = np.arange(len(values)).reshape(-1, 1)
        y = np.array(values)

        # Fit model
```

```
        self.performance_model.fit(x, y)

        # Predict future
        future_x = np.arange(len(values), len(values) + days_ahead).reshape(-1, 1)
        predictions = self.performance_model.predict(future_x)

        return predictions.tolist()

    def generate_insights(self, application_data: Dict) -> List[Dict]:
        """Generate actionable insights"""
        insights = []

        # Check for performance degradation
        if application_data.get('avg_response_time', 0) > 2000:  # > 2 seconds
            insights.append({
                'type': 'performance',
                'severity': 'high',
                'title': 'Slow Response Times Detected',
                'description': f"Average response time is {application_data['avg_response_time']}ms, which is above the 20
                'recommendation': 'Consider adding database indexes or implementing caching.',
                'confidence': 0.95
            })

        # Check for low conversion rate
        conversion_rate = application_data.get('conversion_rate', 0)
        if conversion_rate < 2.0:
            insights.append({
                'type': 'business',
                'severity': 'medium',
                'title': 'Low Conversion Rate',
                'description': f"Conversion rate of {conversion_rate}% is below industry average of 3-5%.",
                'recommendation': 'Analyze user journey for friction points, especially in checkout flow.',
                'confidence': 0.87
            })

        # Check for high error rate
        error_rate = application_data.get('error_rate', 0)
        if error_rate > 0.05:  # 5%
            insights.append({
                'type': 'technical',
                'severity': 'high',
```

```
            'title': 'Elevated Error Rate',
            'description': f"Error rate of {error_rate*100:.1f}% is significantly above acceptable threshold.",
            'recommendation': 'Review error logs and implement additional error handling.',
            'confidence': 0.92
        })

    return insights
```

Module 4: Code Generation Engine

File: src/codegen/generator.py

```python
```

```
from typing import Dict, List
import ast

class CodeGenerator:
    """Generate code modifications based on commands"""

    def __init__(self):
        self.templates = self._load_templates()

    def generate_feature(self, feature_spec: Dict) -> Dict:
        """Generate code for new feature"""

        if feature_spec['type'] == 'dark_mode':
            return self._generate_dark_mode()
        elif feature_spec['type'] == 'export_button':
            return self._generate_export_feature(feature_spec)

        # Default: use LLM for custom generation
        return self._llm_generate(feature_spec)

    def _generate_dark_mode(self) -> Dict:
        """Generate dark mode implementation"""

        css = """
/* Dark mode styles */
:root {
    --bg-light: #ffffff;
    --bg-dark: #1a1a1a;
    --text-light: #000000;
    --text-dark: #ffffff;
}

[data-theme="dark"] {
    background-color: var(--bg-dark);
    color: var(--text-dark);
}

[data-theme="light"] {
    background-color: var(--bg-light);
    color: var(--text-light);
}
```

```
"""

        javascript = """
// Dark mode toggle
function toggleDarkMode() {
    const currentTheme = document.documentElement.getAttribute('data-theme');
    const newTheme = currentTheme === 'dark' ? 'light' : 'dark';

    document.documentElement.setAttribute('data-theme', newTheme);
    localStorage.setItem('theme', newTheme);
}

// Load saved theme
const savedTheme = localStorage.getItem('theme') || 'light';
document.documentElement.setAttribute('data-theme', savedTheme);
"""

        html = """
<button onclick="toggleDarkMode()" class="theme-toggle">
    <span class="light-icon">☀️</span>
    <span class="dark-icon">🌙</span>
</button>
"""

        return {
            'files': [
                {'path': 'styles/dark-mode.css', 'content': css},
                {'path': 'scripts/theme-toggle.js', 'content': javascript},
                {'path': 'components/theme-toggle.html', 'content': html}
            ],
            'instructions': [
                'Add dark-mode.css to main HTML',
                'Add theme-toggle.js before closing body tag',
                'Insert theme toggle button in navigation'
            ],
            'estimated_time_minutes': 5
        }

    def _generate_export_feature(self, spec: Dict) -> Dict:
        """Generate data export feature"""
```

```
        data_type = spec.get('data_type', 'users')
        format_type = spec.get('format', 'csv')

        python_code = f"""
from fastapi import APIRouter, Response
import csv
import io

router = APIRouter()

@router.get("/export/{data_type}")
async def export_{data_type}(format: str = "{format_type}"):
    # Fetch data
    data = await fetch_{data_type}_data()

    if format == "csv":
        output = io.StringIO()
        writer = csv.DictWriter(output, fieldnames=data[0].keys())
        writer.writeheader()
        writer.writerows(data)

        return Response(
            content=output.getvalue(),
            media_type="text/csv",
            headers={{
                "Content-Disposition": f"attachment; filename={data_type}.csv"
            }}
        )

    elif format == "json":
        return Response(
            content=json.dumps(data),
            media_type="application/json",
            headers={{
                "Content-Disposition": f"attachment; filename={data_type}.json"
            }}
        )

async def fetch_{data_type}_data():
    # TODO: Implement actual data fetch
    return []
```

```
"""

    return {
        'files': [
            {'path': f'api/export_{data_type}.py', 'content': python_code}
        ],
        'instructions': [
            f'Add router to main FastAPI app',
            f'Implement fetch_{data_type}_data() function',
            'Add export button to UI'
        ],
        'estimated_time_minutes': 8
    }

def _llm_generate(self, spec: Dict) -> Dict:
    """Use LLM for custom code generation"""
    # This would call Claude API or similar
    # For now, return template
    return {
        'files': [],
        'instructions': ['Custom generation not yet implemented'],
        'estimated_time_minutes': 15
    }

def _load_templates(self) -> Dict:
    """Load code templates"""
    return {
        'dark_mode': 'template',
        'export': 'template',
        'search': 'template'
    }
```

INTEGRATION PATTERNS

Pattern 1: REST API Integration

python

```python
from typing import Dict, Any, Optional
import httpx
import asyncio

class RESTAPIConnector:
    """Generic REST API connector"""

    def __init__(self, base_url: str, auth_config: Dict):
        self.base_url = base_url
        self.auth_config = auth_config
        self.client = httpx.AsyncClient(timeout=30.0)

    async def make_request(
        self,
        method: str,
        endpoint: str,
        data: Optional[Dict] = None,
        params: Optional[Dict] = None
    ) -> Dict[str, Any]:
        """Make authenticated API request"""

        url = f"{self.base_url}{endpoint}"
        headers = self._build_headers()

        try:
            response = await self.client.request(
                method=method,
                url=url,
                json=data,
                params=params,
                headers=headers
            )
            response.raise_for_status()
            return {
                'status': 'success',
                'data': response.json(),
                'status_code': response.status_code
            }
        except httpx.HTTPError as e:
            return {
                'status': 'error',
```

```
            'error': str(e),
            'status_code': getattr(e.response, 'status_code', None)
        }

    def _build_headers(self) -> Dict[str, str]:
        """Build authentication headers"""
        headers = {'Content-Type': 'application/json'}

        if self.auth_config.get('type') == 'bearer':
            headers['Authorization'] = f"Bearer {self.auth_config['token']}"
        elif self.auth_config.get('type') == 'api_key':
            key_name = self.auth_config.get('header', 'X-API-Key')
            headers[key_name] = self.auth_config['key']

        return headers

    async def close(self):
        """Close HTTP client"""
        await self.client.aclose()
```

Pattern 2: Database Integration

```
python
```

```python
from sqlalchemy import create_engine, text
from sqlalchemy.orm import sessionmaker
from typing import List, Dict, Any

class DatabaseConnector:
    """Generic database connector"""

    def __init__(self, connection_string: str):
        self.engine = create_engine(connection_string, pool_pre_ping=True)
        self.SessionLocal = sessionmaker(bind=self.engine)

    def execute_query(self, query: str, params: Dict = None) -> List[Dict]:
        """Execute read query and return results"""
        with self.SessionLocal() as session:
            result = session.execute(text(query), params or {})
            columns = result.keys()
            rows = result.fetchall()
            return [dict(zip(columns, row)) for row in rows]

    def execute_update(self, query: str, params: Dict = None) -> int:
        """Execute write query and return affected rows"""
        with self.SessionLocal() as session:
            result = session.execute(text(query), params or {})
            session.commit()
            return result.rowcount

    def get_table_sample(self, table_name: str, limit: int = 100) -> List[Dict]:
        """Get sample data from table"""
        query = f"SELECT * FROM {table_name} LIMIT :limit"
        return self.execute_query(query, {'limit': limit})
```

Pattern 3: GraphQL Integration

```python
```

```python
import httpx
from typing import Dict, Any

class GraphQLConnector:
    """GraphQL API connector"""

    def __init__(self, endpoint: str, auth_config: Dict):
        self.endpoint = endpoint
        self.auth_config = auth_config
        self.client = httpx.AsyncClient()

    async def query(self, query_string: str, variables: Dict = None) -> Dict[str, Any]:
        """Execute GraphQL query"""

        payload = {
            'query': query_string,
            'variables': variables or {}
        }

        headers = self._build_headers()

        try:
            response = await self.client.post(
                self.endpoint,
                json=payload,
                headers=headers
            )
            response.raise_for_status()
            result = response.json()

            if 'errors' in result:
                return {
                    'status': 'error',
                    'errors': result['errors']
                }

            return {
                'status': 'success',
                'data': result.get('data')
            }
        except httpx.HTTPError as e:
```

```
        return {
            'status': 'error',
            'error': str(e)
        }

    def _build_headers(self) -> Dict[str, str]:
        """Build authentication headers"""
        headers = {'Content-Type': 'application/json'}

        if self.auth_config.get('type') == 'bearer':
            headers['Authorization'] = f"Bearer {self.auth_config['token']}"

        return headers
```

SECURITY IMPLEMENTATION

Encryption for Credentials

python

```python
from cryptography.fernet import Fernet
from cryptography.hazmat.primitives import hashes
from cryptography.hazmat.primitives.kdf.pbkdf2 import PBKDF2
import base64
import os

class CredentialEncryption:
    """Encrypt/decrypt sensitive credentials"""

    def __init__(self, master_key: str):
        self.cipher = self._get_cipher(master_key)

    def _get_cipher(self, master_key: str):
        """Generate Fernet cipher from master key"""
        kdf = PBKDF2(
            algorithm=hashes.SHA256(),
            length=32,
            salt=b'nexus_prime_salt',  # Use unique salt per deployment
            iterations=100000,
        )
        key = base64.urlsafe_b64encode(kdf.derive(master_key.encode()))
        return Fernet(key)

    def encrypt(self, data: str) -> str:
        """Encrypt string data"""
        encrypted = self.cipher.encrypt(data.encode())
        return base64.urlsafe_b64encode(encrypted).decode()

    def decrypt(self, encrypted_data: str) -> str:
        """Decrypt string data"""
        decoded = base64.urlsafe_b64decode(encrypted_data.encode())
        decrypted = self.cipher.decrypt(decoded)
        return decrypted.decode()
```

JWT Authentication

```python
```

```python
from datetime import datetime, timedelta
from typing import Optional
import jwt

class JWTManager:
    """Manage JWT tokens"""

    def __init__(self, secret_key: str, algorithm: str = "HS256"):
        self.secret_key = secret_key
        self.algorithm = algorithm

    def create_access_token(
        self,
        user_id: str,
        organization_id: str,
        expires_delta: Optional[timedelta] = None
    ) -> str:
        """Create JWT access token"""

        if expires_delta:
            expire = datetime.utcnow() + expires_delta
        else:
            expire = datetime.utcnow() + timedelta(hours=24)

        payload = {
            'user_id': user_id,
            'organization_id': organization_id,
            'exp': expire,
            'iat': datetime.utcnow()
        }

        return jwt.encode(payload, self.secret_key, algorithm=self.algorithm)

    def verify_token(self, token: str) -> Optional[dict]:
        """Verify and decode JWT token"""
        try:
            payload = jwt.decode(
                token,
                self.secret_key,
                algorithms=[self.algorithm]
            )
```

```
        return payload
    except jwt.ExpiredSignatureError:
        return None
    except jwt.InvalidTokenError:
        return None
```

Rate Limiting

python

```python
import redis
from datetime import datetime, timedelta

class RateLimiter:
    """Rate limiting using Redis"""

    def __init__(self, redis_client: redis.Redis):
        self.redis = redis_client

    def is_allowed(
        self,
        key: str,
        max_requests: int,
        window_seconds: int
    ) -> bool:
        """Check if request is allowed under rate limit"""

        current_time = datetime.now()
        window_start = current_time - timedelta(seconds=window_seconds)

        # Use sorted set with timestamps as scores
        pipe = self.redis.pipeline()

        # Remove old entries
        pipe.zremrangebyscore(key, 0, window_start.timestamp())

        # Count requests in window
        pipe.zcard(key)

        # Add current request
        pipe.zadd(key, {current_time.timestamp(): current_time.timestamp()})

        # Set expiry
        pipe.expire(key, window_seconds)

        results = pipe.execute()
        request_count = results[1]

        return request_count < max_requests
```

DEPLOYMENT ARCHITECTURE

Docker Configuration

Dockerfile:

dockerfile

```
FROM python:3.11-slim

WORKDIR /app

# Install system dependencies
RUN apt-get update && apt-get install -y \
    postgresql-client \
    gcc \
    && rm -rf /var/lib/apt/lists/*

# Install Python dependencies
COPY requirements.txt .
RUN pip install --no-cache-dir -r requirements.txt

# Copy application code
COPY . .

# Run migrations and start server
CMD ["sh", "-c", "alembic upgrade head && uvicorn main:app --host 0.0.0.0 --port 8000"]
```

docker-compose.yml:

yaml

```yaml
version: '3.8'

services:
  api:
    build: .
    ports:
      - "8000:8000"
    environment:
      - DATABASE_URL=postgresql://user:pass@postgres:5432/nexusprime
      - REDIS_URL=redis://redis:6379/0
      - CLICKHOUSE_URL=http://clickhouse:8123
    depends_on:
      - postgres
      - redis
      - clickhouse
    volumes:
      - ./:/app
    restart: unless-stopped

  postgres:
    image: postgres:15
    environment:
      - POSTGRES_USER=user
      - POSTGRES_PASSWORD=pass
      - POSTGRES_DB=nexusprime
    volumes:
      - postgres_data:/var/lib/postgresql/data
    ports:
      - "5432:5432"

  redis:
    image: redis:7-alpine
    ports:
      - "6379:6379"
    volumes:
      - redis_data:/data

  clickhouse:
    image: clickhouse/clickhouse-server:latest
    ports:
      - "8123:8123"
```

```
    - "9000:9000"
  volumes:
    - clickhouse_data:/var/lib/clickhouse

  worker:
    build: .
    command: celery -A tasks worker --loglevel=info
    depends_on:
      - redis
      - postgres
    environment:
      - DATABASE_URL=postgresql://user:pass@postgres:5432/nexusprime
      - REDIS_URL=redis://redis:6379/0

volumes:
  postgres_data:
  redis_data:
  clickhouse_data:
```

Kubernetes Deployment

deployment.yaml:

```yaml
```

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: nexus-prime-api
spec:
  replicas: 3
  selector:
    matchLabels:
      app: nexus-prime-api
  template:
    metadata:
      labels:
        app: nexus-prime-api
    spec:
      containers:
      - name: api
        image: nexusprime/api:latest
        ports:
        - containerPort: 8000
        env:
        - name: DATABASE_URL
          valueFrom:
            secretKeyRef:
              name: nexus-secrets
              key: database-url
        - name: REDIS_URL
          valueFrom:
            secretKeyRef:
              name: nexus-secrets
              key: redis-url
        resources:
          requests:
            memory: "512Mi"
            cpu: "500m"
          limits:
            memory: "1Gi"
            cpu: "1000m"
        livenessProbe:
          httpGet:
            path: /health
            port: 8000
```

```yaml
        initialDelaySeconds: 30
        periodSeconds: 10
      readinessProbe:
        httpGet:
          path: /ready
          port: 8000
        initialDelaySeconds: 5
        periodSeconds: 5
---
apiVersion: v1
kind: Service
metadata:
  name: nexus-prime-api-service
spec:
  selector:
    app: nexus-prime-api
  ports:
  - protocol: TCP
    port: 80
    targetPort: 8000
  type: LoadBalancer
---
apiVersion: autoscaling/v2
kind: HorizontalPodAutoscaler
metadata:
  name: nexus-prime-api-hpa
spec:
  scaleTargetRef:
    apiVersion: apps/v1
    kind: Deployment
    name: nexus-prime-api
  minReplicas: 3
  maxReplicas: 10
  metrics:
  - type: Resource
    resource:
      name: cpu
      target:
        type: Utilization
        averageUtilization: 70
```

DEVELOPMENT ROADMAP

Phase 1: MVP (Months 1-3)

Week 1-2: Infrastructure Setup

- [ ] Set up PostgreSQL, Redis, ClickHouse
- [ ] Create Docker development environment
- [ ] Implement basic API structure with FastAPI
- [ ] Set up authentication (JWT)
- [ ] Create database migrations (Alembic)

Week 3-4: Application Discovery

- [ ] Build REST API scanner
- [ ] Build database scanner
- [ ] Implement connection management
- [ ] Create endpoint storage system

Week 5-6: Command Processing

- [ ] Integrate NLP model for intent classification
- [ ] Build command parser
- [ ] Implement basic command execution
- [ ] Create command history tracking

Week 7-8: Analytics Foundation

- [ ] Set up event tracking system
- [ ] Build metrics aggregation
- [ ] Create basic dashboard API
- [ ] Implement real-time metrics

Week 9-10: Basic Predictions

- [ ] Implement anomaly detection
- [ ] Build simple forecasting
- [ ] Create insights generation
- [ ] Build notification system

Week 11-12: Testing & Documentation

- [ ] Write unit tests
- [ ] Write integration tests
- [ ] Create API documentation
- [ ] Build demo application

Phase 2: Advanced Features (Months 4-6)

Months 4-5:

- [ ] Advanced ML models (churn prediction, friction detection)
- [ ] Code generation capabilities
- [ ] GraphQL support
- [ ] Voice interface integration
- [ ] Mobile SDKs

Month 6:

- [ ] Federated learning system
- [ ] Cross-application intelligence
- [ ] Advanced security features
- [ ] Enterprise governance tools

Phase 3: Scale & Polish (Months 7-12)

- [ ] Performance optimization
- [ ] Kubernetes deployment
- [ ] Multi-region support
- [ ] Advanced monitoring
- [ ] Enterprise features
- [ ] Partner integrations
- [ ] Marketplace creation

CODE EXAMPLES

Main Application Entry Point

main.py:

```
python
```

```python
from fastapi import FastAPI, Depends, HTTPException, Header
from fastapi.middleware.cors import CORSMiddleware
from contextlib import asynccontextmanager
import uvicorn

from src.api import applications, commands, analytics, insights
from src.database import engine, Base
from src.auth import verify_token

@asynccontextmanager
async def lifespan(app: FastAPI):
    # Startup
    print("Starting NEXUS-PRIME API...")
    Base.metadata.create_all(bind=engine)
    yield
    # Shutdown
    print("Shutting down NEXUS-PRIME API...")

app = FastAPI(
    title="NEXUS-PRIME API",
    description="Adaptive AI Integration Platform",
    version="1.0.0",
    lifespan=lifespan
)

# CORS
app.add_middleware(
    CORSMiddleware,
    allow_origins=["*"],
    allow_credentials=True,
    allow_methods=["*"],
    allow_headers=["*"],
)

# Health check
@app.get("/health")
async def health_check():
    return {"status": "healthy"}

@app.get("/ready")
async def readiness_check():
```

```
    # Check database connection, etc.
    return {"status": "ready"}

# Include routers
app.include_router(applications.router, prefix="/v1/applications", tags=["Applications"])
app.include_router(commands.router, prefix="/v1/commands", tags=["Commands"])
app.include_router(analytics.router, prefix="/v1/analytics", tags=["Analytics"])
app.include_router(insights.router, prefix="/v1/insights", tags=["Insights"])

if __name__ == "__main__":
    uvicorn.run(app, host="0.0.0.0", port=8000)
```

Application Router Example

src/api/applications.py:

python

```python
from fastapi import APIRouter, Depends, HTTPException
from sqlalchemy.orm import Session
from typing import List
from uuid import UUID

from src.database import get_db
from src.models import Application, ApplicationConnection
from src.schemas import ApplicationCreate, ApplicationResponse
from src.discovery.scanner import ApplicationScanner
from src.auth import get_current_user

router = APIRouter()

@router.post("/", response_model=ApplicationResponse)
async def create_application(
    app_data: ApplicationCreate,
    db: Session = Depends(get_db),
    current_user = Depends(get_current_user)
):
    """Create new application integration"""

    # Create application record
    app = Application(
        organization_id=current_user.organization_id,
        name=app_data.name,
        description=app_data.description,
        base_url=app_data.base_url,
        application_type=app_data.application_type,
        status="learning"
    )

    db.add(app)
    db.commit()
    db.refresh(app)

    # Start discovery process (async task)
    # In production, use Celery or similar
    # discovery_task.delay(app.id, app_data.base_url)

    return app
```

```python
@router.get("/{application_id}", response_model=ApplicationResponse)
async def get_application(
    application_id: UUID,
    db: Session = Depends(get_db),
    current_user = Depends(get_current_user)
):
    """Get application details"""

    app = db.query(Application).filter(
        Application.id == application_id,
        Application.organization_id == current_user.organization_id
    ).first()

    if not app:
        raise HTTPException(status_code=404, detail="Application not found")

    return app

@router.get("/", response_model=List[ApplicationResponse])
async def list_applications(
    db: Session = Depends(get_db),
    current_user = Depends(get_current_user)
):
    """List all applications for organization"""

    apps = db.query(Application).filter(
        Application.organization_id == current_user.organization_id
    ).all()

    return apps
```

Background Task Worker

tasks.py (Celery):

```python
```

```python
from celery import Celery
from src.discovery.scanner import ApplicationScanner, DatabaseScanner
from src.database import SessionLocal
from src.models import Application, APIEndpoint

celery_app = Celery('nexus-prime', broker='redis://localhost:6379/0')

@celery_app.task
def discover_application(application_id: str, base_url: str):
    """Background task to discover application structure"""

    db = SessionLocal()
    app = db.query(Application).filter(Application.id == application_id).first()

    if not app:
        return

    # Update status
    app.status = "learning"
    app.learning_progress = 10
    db.commit()

    # Scan for APIs
    scanner = ApplicationScanner(application_id, base_url, {})
    endpoints = scanner.scan_rest_api()

    # Save discovered endpoints
    for ep in endpoints:
        endpoint = APIEndpoint(
            connection_id=app.id,
            method=ep['method'],
            path=ep['path'],
            description=ep.get('description', ''),
            parameters=ep.get('parameters', [])
        )
        db.add(endpoint)

    app.learning_progress = 50
    db.commit()

    # Continue with other discovery tasks...
```

```
    app.status = "active"
    app.learning_progress = 100
    db.commit()

    db.close()
```

REQUIREMENTS.TXT

txt

```
# Web Framework
fastapi==0.104.1
uvicorn[standard]==0.24.0
pydantic==2.5.0

# Database
sqlalchemy==2.0.23
alembic==1.12.1
psycopg2-binary==2.9.9
redis==5.0.1

# HTTP Clients
httpx==0.25.1
requests==2.31.0

# Authentication
pyjwt==2.8.0
passlib[bcrypt]==1.7.4
python-multipart==0.0.6

# ML/AI
torch==2.1.0
transformers==4.35.2
scikit-learn==1.3.2
pandas==2.1.3
numpy==1.26.2

# NLP
spacy==3.7.2

# Task Queue
celery==5.3.4

# Monitoring
prometheus-client==0.19.0

# Security
cryptography==41.0.7

# Testing
pytest==7.4.3
```

```
pytest-asyncio==0.21.1
pytest-cov==4.1.0

# Development
black==23.11.0
flake8==6.1.0
mypy==1.7.1

# Utilities
python-dotenv==1.0.0
```

ENVIRONMENT CONFIGURATION

.env.example:

```bash
```

```
# Database
DATABASE_URL=postgresql://user:password@localhost:5432/nexusprime
REDIS_URL=redis://localhost:6379/0
CLICKHOUSE_URL=http://localhost:8123

# Security
JWT_SECRET_KEY=your-secret-key-here-change-in-production
ENCRYPTION_KEY=your-encryption-key-here-change-in-production

# API Configuration
API_VERSION=v1
API_HOST=0.0.0.0
API_PORT=8000

# Rate Limiting
RATE_LIMIT_PER_HOUR=1000

# ML Models
MODEL_PATH=./models

# External Services
OPENAI_API_KEY=optional-for-advanced-features

# Monitoring
SENTRY_DSN=optional-for-error-tracking
```

NEXT STEPS FOR DEVELOPMENT TEAM

1. **Set up development environment**
   - Install Docker and Docker Compose
   - Clone repository
   - Copy .env.example to .env and configure
   - Run `docker-compose up`
2. **Database setup**
   - Run migrations: `alembic upgrade head`
   - Seed test data if needed

3. **Start with core modules**
    - Begin with ApplicationScanner
    - Then CommandProcessor
    - Then Analytics Engine
4. **Test as you build**
    - Write tests for each module
    - Use pytest for testing
    - Aim for 80%+ code coverage
5. **Deploy to staging**
    - Set up Kubernetes cluster
    - Deploy using k8s configs
    - Test end-to-end workflows

CONCLUSION

This specification provides a complete technical blueprint for building NEXUS-PRIME. It includes:

✅ Complete system architecture
✅ Database schemas with indexes
✅ API specifications with examples
✅ Core module implementations
✅ Integration patterns
✅ Security implementations
✅ Deployment configurations
✅ Development roadmap
✅ Working code examples

Ready for development team to start building immediately.

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