Software Requirements Specification (SRS)

NASA Farm Navigators

Document Control

- **Version:** 2.0
- **Date:** September 2025
- **Status:** Final
- **Compliance:** NASA Data Standards, IEEE 830-1998

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1. Introduction

1.1 Purpose

This SRS document defines comprehensive requirements for NASA Farm Navigators, an educational game that transforms NASA's satellite data into actionable farming insights. The document serves as the authoritative reference for developers, testers, NASA stakeholders, and educational partners.

1.2 Document Conventions

- **SHALL**: Mandatory requirement
- **SHOULD**: Recommended requirement
- **MAY**: Optional requirement
- Priority Levels: Critical (C), High (H), Medium (M), Low (L)

1.3 Intended Audience

- Development team implementing the system
- NASA technical reviewers
- Educational institution evaluators
- Quality assurance teams
- Agricultural domain experts

1.4 Product Scope

NASA Farm Navigators bridges the gap between complex satellite data and practical farming applications through gamified education. The system SHALL:

- Integrate multiple NASA data sources at various resolutions (30m-11km)
- Demonstrate soil moisture depth variations (surface vs root zone)

- Adapt to different farming contexts (industrial vs smallholder)
- Operate offline for rural accessibility
- Measure educational effectiveness and behavioral change

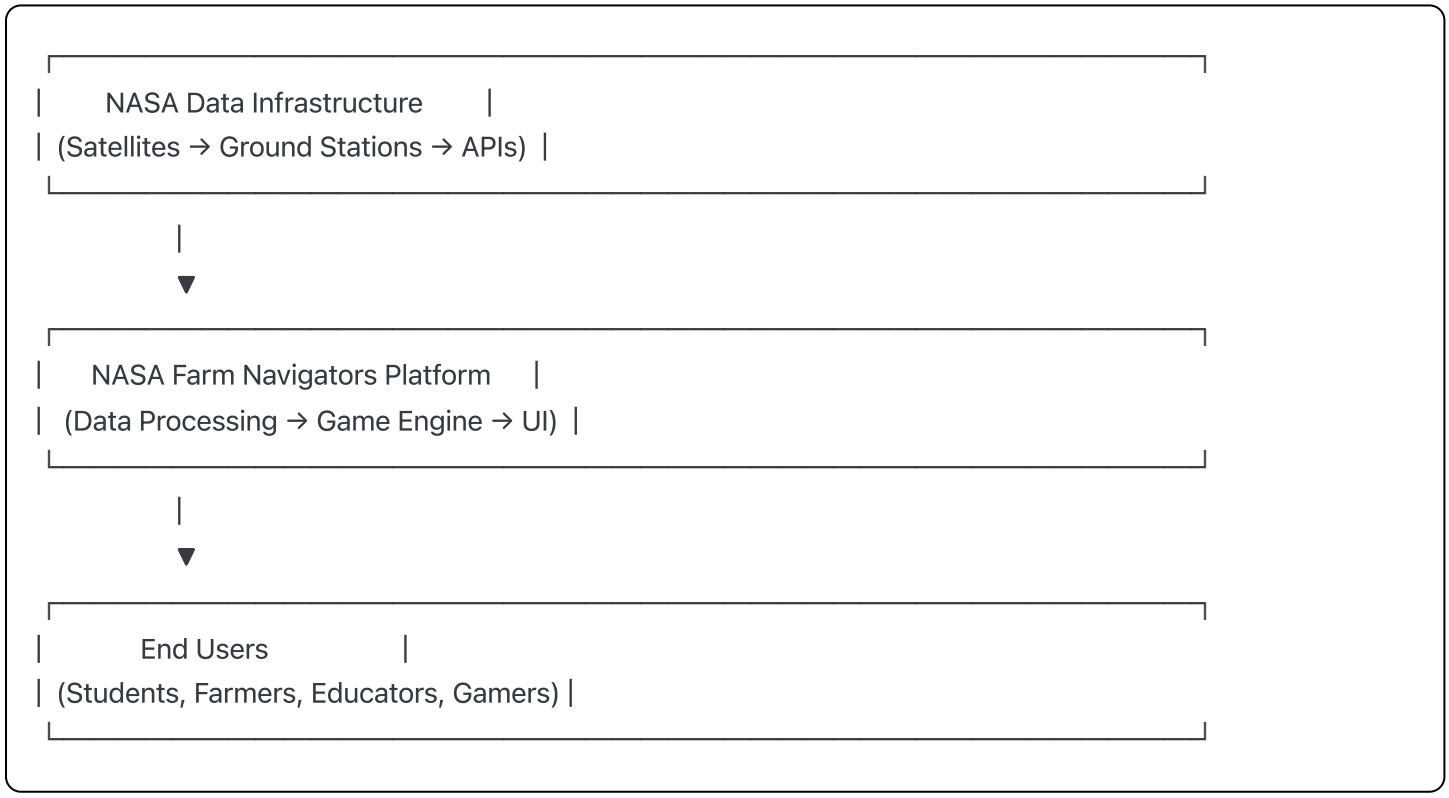
1.5 References

- NASA Earthdata API Documentation v2.0
- AppEEARS User Guide
- Crop-CASMA Technical Specifications
- SMAP Data Products Specification Document
- MODIS User Guide
- GPM Data Product Documentation
- OGC Web Services Standards
- WCAG 2.1 Accessibility Guidelines

2. Overall Description

2.1 Product Perspective

The system operates within the NASA Earth observation ecosystem:



2.2 Product Functions

Core Educational Functions

1. **Resolution Awareness Training**: Demonstrate 30m vs 375m detection capabilities

2. **Depth Understanding**: Differentiate surface (0-5cm) vs root zone (0-100cm) moisture
3. **Context Adaptation**: Adjust gameplay for farm scale and resources
4. **Data Limitation Education**: Teach accuracy, latency, and coverage constraints
5. **Practical Application**: Connect data insights to farming decisions

Gaming Functions

1. Farm management simulation
2. Crop lifecycle modeling
3. Resource optimization challenges
4. Scenario-based learning
5. Achievement and progression systems

2.3 User Classes and Characteristics

User Class	Age Range	Technical Skill	Domain Knowledge	Primary Goal
Agricultural Students	16-25	Medium-High	Low-Medium	Learn precision agriculture
Small-scale Farmers	25-65	Low-Medium	High	Apply data to operations
Industrial Farmers	30-60	Medium	High	Optimize efficiency
Educators	25-65	Medium	Medium	Teach data concepts
Casual Gamers	13-35	High	Low	Entertainment + learning
Agricultural Advisors	25-65	High	High	Understand tools

2.4 Operating Environment

Client Requirements

- **Browsers**: Chrome 90+, Firefox 88+, Safari 14+, Edge 90+
- **Mobile OS**: iOS 14+, Android 10+
- **Hardware**: 2GB RAM minimum, 4GB recommended
- **Storage**: 500MB available space
- **Network**: 256 kbps minimum (after initial load)

Server Requirements

- **Runtime**: Node.js 20 LTS
- **Database**: PostgreSQL 15+, TimescaleDB 2.0+
- **Cache**: Redis 7+
- **Container**: Docker 20+, Kubernetes 1.25+

2.5 Design and Implementation Constraints

1. **NASA API Limitations**: 100 requests/hour per endpoint
2. **Data Resolution**: Must accurately represent pixel sizes
3. **Offline Operation**: 72-hour minimum without connectivity
4. **Educational Integrity**: No oversimplification of science
5. **Accessibility**: WCAG 2.1 AA compliance mandatory

2.6 Assumptions and Dependencies

- NASA data APIs remain publicly accessible
- Earthdata login system continues operation
- Users have basic device and internet access
- Educational standards remain stable
- Agricultural practices follow established science

3. Specific Requirements

3.1 External Interface Requirements

3.1.1 User Interfaces

UI-REQ-001: Resolution Comparison Interface [Priority: C]

The system SHALL provide side-by-side visualization comparing data at different resolutions:

- Display same geographic area at multiple resolutions simultaneously
- Show pixel grid overlay with actual dimensions
- Highlight features visible/invisible at each resolution
- Include interactive resolution slider (30m → 11km)

UI-REQ-002: Depth Profile Visualizer [Priority: C]

The system SHALL display soil moisture at multiple depths:

- Surface layer (0-5cm) with SMAP L3 data
- Root zone (0-100cm) with SMAP L4 data
- Visual cross-section showing moisture gradient
- Crop root depth overlay for context

UI-REQ-003: Context Switcher [Priority: H]

The system SHALL adapt interface based on farming context:

- Smallholder mode: Simplified controls, essential data only
- Industrial mode: Advanced analytics, bulk operations
- Resource constraints indicator
- Appropriate tool availability

3.1.2 Hardware Interfaces

HW-REQ-001: Input Device Support [Priority: H]

- Mouse/trackpad with hover states
- Touch screen with gesture support
- Keyboard with full navigation
- Gamepad support (optional)

3.1.3 Software Interfaces

SW-REQ-001: NASA AppEEARS Integration [Priority: C]

The system SHALL interface with AppEEARS API:

- Authentication via Earthdata Login
- Submit area extraction requests
- Download processed data bundles
- Handle job queue management
- Timeout handling: 5-minute maximum wait

SW-REQ-002: Crop-CASMA WMS/WCS Integration [Priority: C]

The system SHALL consume Crop-CASMA services:

```
WMS Endpoint: https://crop-casma.nasacrsmap.org/wms
WCS Endpoint: https://crop-casma.nasacrsmap.org/wcs
Layers:
  - smap_l3_sma_9km
  - smap_l4_rwc_11km
  - modis_ndvi_250m
Update Frequency: Daily
Format: GeoTIFF, PNG
```

SW-REQ-003: Worldview GIBS Integration [Priority: H]

The system SHALL display NASA Worldview imagery:

- GIBS tile service integration

- Time-enabled layer support
- 1000+ layer catalog access
- Temporal animation capability

3.1.4 Communications Interfaces

COM-REQ-001: API Communication [Priority: C]

- Protocol: HTTPS/TLS 1.3
- Authentication: OAuth 2.0 + JWT
- Format: JSON, GeoJSON, COG
- Compression: gzip, brotli
- Rate limiting: Exponential backoff

3.2 Functional Requirements

3.2.1 Data Integration Requirements

FR-DI-001: Multi-Resolution Data Handling [Priority: C]

The system SHALL process data at multiple resolutions:

Dataset	Resolution	Update	Use Case
SMAP L3	9km	2-3 days	Surface moisture
SMAP L4	11km	Daily	Root zone moisture
MODIS NDVI	250m	8 days	Vegetation health
Landsat	30m	16 days	Field precision
GPM IMERG	10km	30 min	Precipitation

FR-DI-002: Resolution Education [Priority: C]

The system SHALL teach resolution impacts through gameplay:

- Demonstrate feature detection limits
- Show aggregation effects
- Explain mixed pixel problem
- Visualize uncertainty bounds
- Test understanding with challenges

FR-DI-003: Depth-Aware Processing [Priority: C]

The system SHALL differentiate soil moisture depths:

- Parse SMAP L3 surface moisture (0-5cm)

- Parse SMAP L4 root zone moisture (0-100cm)
- Calculate depth-specific irrigation needs
- Display multi-layer moisture profile
- Teach depth importance for different crops

FR-DI-004: Data Accuracy Validation [Priority: H]

The system SHALL validate data accuracy:

- Check value ranges per dataset specifications
- Flag suspicious anomalies
- Display confidence intervals
- Explain uncertainty sources
- Provide quality flags

3.2.2 Game Mechanics Requirements

FR-GM-001: Farm Creation with Scale Context [Priority: C]

The system SHALL enable context-appropriate farm creation:

Smallholder Context (< 2 hectares):

- Manual field delineation
- Limited equipment options
- Rainfall dependence emphasis
- Community resource sharing
- Mobile-first interface

Industrial Context (> 100 hectares):

- Automated field mapping
- Full equipment catalog
- Irrigation infrastructure
- Precision agriculture tools
- Desktop-optimized interface

FR-GM-002: Adaptive Crop Modeling [Priority: C]

The system SHALL simulate crop growth using NASA data:

```
python
```

```
crop_growth_model = {
    "inputs": {
        "temperature": "GLDAS 3-hourly",
        "moisture": "SMAP L3/L4",
        "radiation": "MODIS",
        "precipitation": "GPM IMERG"
    },
    "parameters": {
        "phenology": "GDD accumulation",
        "water_stress": "FAO-56 method",
        "nutrient": "QUEFTS model"
    },
    "outputs": {
        "biomass": "kg/ha",
        "yield": "tonnes/ha",
        "quality": "grade"
    }
}
```

FR-GM-003: Precision Agriculture Actions [Priority: H]

The system SHALL implement variable-rate applications:

- Zone management based on NDVI variability
- Prescription map generation
- Application rate optimization
- Cost-benefit analysis
- Environmental impact scoring

FR-GM-004: Livestock Integration [Priority: M]

The system SHALL include basic livestock management:

- Pasture quality from NDVI
- Water requirement calculations
- Heat stress from temperature data
- Rotational grazing optimization
- Feed planning based on forecasts

3.2.3 Educational Requirements

FR-ED-001: Progressive Complexity System [Priority: C]

The system SHALL implement three complexity levels:

Beginner Level:

- Single resolution view (9km SMAP)
- Surface moisture only
- Binary decisions (irrigate/don't irrigate)
- Visual indicators only
- Guided tutorials

Intermediate Level:

- Multiple resolutions (30m-9km)
- Surface + root zone moisture
- Graduated decisions (how much to irrigate)
- Numerical data display
- Scenario challenges

Expert Level:

- All resolutions available
- Full depth profile
- Optimization problems
- Raw data access
- Research mode

FR-ED-002: Resolution Reality Check [Priority: C]

The system SHALL demonstrate resolution limitations:

- "Pixel Hunt" mini-game: Find features at different resolutions
- Before/after comparisons
- Detection capability matrix
- Real-world examples
- Common misconception corrections

FR-ED-003: Depth Diving Education [Priority: C]

The system SHALL teach soil moisture depth concepts:

- Interactive soil profile cutaway
- Root growth animation
- Water infiltration simulation

- Crop-specific depth requirements
- Surface vs deep irrigation trade-offs

FR-ED-004: Context Awareness Training [Priority: H]

The system SHALL educate on farming contexts:

- Scale impact demonstrations
- Resource constraint simulations
- Technology accessibility lessons
- Economic reality checks
- Cultural consideration discussions

3.2.4 Offline Functionality Requirements

FR-OF-001: Progressive Web App Implementation [Priority: C]

The system SHALL function as a PWA:

```javascript
service_worker_config = {
    cache_strategy: "network-first",
    offline_duration: "72 hours",
    data_sync: "background",
    conflict_resolution: "last-write-wins",
    storage_quota: "500MB"
}
```

FR-OF-002: Intelligent Data Caching [Priority: H]

The system SHALL cache data strategically:

- Priority 1: Current season data
- Priority 2: Historical averages
- Priority 3: Tutorial content
- Priority 4: Achievement data
- Automatic cache management

FR-OF-003: Offline Feature Set [Priority: H]

The system SHALL provide offline capabilities:

Feature	Online	Offline
Farm management	✓	✓
Historical data view	✓	✓
New NASA data fetch	✓	×
Tutorial access	✓	✓
Progress saving	✓	✓ (local)
Multiplayer	✓	×
Certification	✓	×

3.3 Performance Requirements

3.3.1 Speed and Latency

PR-001: Initial Load Time [Priority: H]

- Target: < 3 seconds on 3G connection
- Critical render: < 1 second
- Time to interactive: < 2 seconds
- Lighthouse score: > 90

PR-002: API Response Times [Priority: H]

- NASA data fetch: < 5 seconds
- Game state update: < 100ms
- UI interaction: < 50ms
- Data processing: < 500ms

PR-003: Frame Rate [Priority: M]

- Target: 60 FPS
- Minimum: 30 FPS
- No drops below 24 FPS
- Smooth animations required

3.3.2 Capacity

PR-004: Concurrent Users [Priority: H]

- Minimum: 10,000 simultaneous
- Target: 50,000 simultaneous
- Peak handling: 100,000/hour
- Graceful degradation required

PR-005: Data Processing [Priority: M]

- Process 100 fields simultaneously
- Handle 1GB satellite imagery
- Support 5-year historical data
- Real-time calculations for 20 crops

3.4 Safety Requirements

SR-001: Data Accuracy Safety [Priority: C]

The system SHALL prevent dangerous misinterpretation:

- Display confidence intervals
- Flag uncertain data
- Prevent action on bad data
- Require confirmation for critical decisions
- Provide disclaimer on limitations

3.5 Security Requirements

SEC-001: Authentication Security [Priority: C]

- NASA Earthdata OAuth 2.0
- JWT token management
- Session timeout: 30 minutes
- MFA support
- Password complexity enforcement

SEC-002: Data Protection [Priority: H]

- TLS 1.3 for all transmissions
- AES-256 encryption at rest
- PII data minimization
- COPPA compliance for minors
- GDPR compliance for EU users

3.6 Software Quality Attributes

3.6.1 Reliability

- Uptime: 99.9% (excluding maintenance)

- MTBF: > 720 hours
- MTTR: < 1 hour
- Data integrity: 100%

3.6.2 Maintainability

- Code coverage: > 80%
- Documentation: 100% of public APIs
- Modular architecture
- Automated deployment

3.6.3 Portability

- Cross-platform compatibility
- Browser agnostic
- Cloud provider independent
- Data format standards compliance

4. Verification and Validation

4.1 Data Accuracy Validation

V&V-001: Resolution Accuracy [Priority: C]

Verify correct representation of pixel sizes:

```python
test_cases = [
    {"dataset": "SMAP L3", "resolution": 9000, "tolerance": 100},
    {"dataset": "MODIS", "resolution": 250, "tolerance": 10},
    {"dataset": "Landsat", "resolution": 30, "tolerance": 1}
]
```

V&V-002: Depth Accuracy [Priority: C]

Validate soil moisture depth differentiation:

- Compare SMAP L3 vs L4 values
- Verify depth labels
- Check irrigation recommendations
- Validate root zone calculations

4.2 Educational Effectiveness

V&V-003: Learning Assessment [Priority: H]

- Pre/post knowledge tests
- Skill application tracking
- Behavioral change measurement
- Long-term retention studies

5. Supporting Information

5.1 Appendices

Appendix A: NASA Data Product Specifications

Detailed specifications for each integrated dataset.

Appendix B: Educational Standards Alignment

Mapping to NGSS, Common Core, and agricultural education standards.

Appendix C: Accessibility Compliance Checklist

WCAG 2.1 AA requirements and implementation.

Appendix D: Sample Lesson Plans

Educator resources for classroom integration.