

Test Case Document

NASA Farm Navigators

Document Information

- **Version:** 2.0
 - **Date:** September 2025
 - **Test Levels:** Unit, Integration, System, Acceptance
 - **Compliance:** NASA Quality Standards
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1. Test Strategy Overview

1.1 Testing Objectives

1. **Verify Data Accuracy:** Ensure NASA data is correctly processed at all resolutions
2. **Validate Educational Effectiveness:** Confirm learning objectives are achieved
3. **Test Resolution Understanding:** Verify users comprehend pixel size implications
4. **Confirm Depth Differentiation:** Validate surface vs root zone distinction
5. **Assess Context Adaptation:** Ensure appropriate farming scale adjustments
6. **Verify Offline Functionality:** Confirm 72-hour offline capability

1.2 Testing Scope

In Scope:

- └── NASA data integration accuracy
- └── Resolution comparison features
- └── Depth visualization tools
- └── Context switching mechanisms
- └── Educational content delivery
- └── Offline functionality
- └── Performance requirements
- └── Accessibility compliance

Out of Scope:

- └── Third-party API reliability
- └── NASA satellite operations
- └── Internet connectivity issues
- └── Device manufacturing defects

1.3 Test Environment Requirements

Environment	Purpose	Configuration
Development	Unit testing	Local Docker containers
Integration	API testing	AWS staging environment
System	E2E testing	Production-like setup
Performance	Load testing	AWS with auto-scaling
UAT	User acceptance	Beta environment

2. NASA Data Integration Test Cases

2.1 Multi-Resolution Data Testing

TC-RES-001: SMAP 9km Resolution Accuracy

Priority: Critical

Category: Data Accuracy

Preconditions:

- NASA AppEEARS API accessible
- Test farm location: 40.0°N, 100.0°W (Nebraska)

Test Steps:

- Request SMAP L3 data for test location
- Verify pixel size = 9km × 9km
- Display pixel grid overlay on map
- Check value range: 0.0–0.6 m³/m³
- Validate timestamp within 2–3 days

Expected Results:

```
json
{
  "pixel_size": 9000,
  "unit": "meters",
  "value": 0.25,
  "unit_value": "m³/m³",
  "confidence": 0.85,
  "timestamp": "2025-09-15T12:00:00Z"
}
```

Validation: Cross-reference with NASA Earthdata portal

TC-RES-002: Resolution Comparison Display

Priority: Critical

Category: Educational Feature

Preconditions: Multiple datasets loaded

Test Steps:

1. Load same 100-hectare field
2. Display at 30m resolution (Landsat)
3. Display at 250m resolution (MODIS)
4. Display at 9km resolution (SMAP)
5. Activate comparison mode

Expected Results:

Resolution	Pixels in Field	Features Detectable
30m	1,111	Individual fields, roads
250m	16	Field boundaries
9km	0.01	Regional average only

Pass Criteria: User correctly identifies detection limitations

TC-RES-003: Mixed Pixel Problem Demonstration

Priority: High

Category: Educational

Preconditions: Field with mixed land use

Test Steps:

1. Select field with 60% crops, 40% forest
2. Show 30m resolution view
3. Show 9km resolution view
4. Display averaging effect
5. Quiz user on actual crop area

Expected Results:

- 30m: Distinguishes crop from forest
- 9km: Shows averaged value

- User understands aggregation error
-

2.2 Depth Differentiation Testing

TC-DEPTH-001: Surface vs Root Zone Moisture

Priority: Critical

Category: Data Processing

Preconditions: SMAP L3 and L4 data available

Test Steps:

1. Fetch SMAP L3 surface moisture (0-5cm)
2. Fetch SMAP L4 root zone moisture (0-100cm)
3. Display both values for same location
4. Show depth profile visualization
5. Recommend irrigation based on crop type

Test Data:

```
python

test_scenarios = [
    {
        "surface": 0.15, # Dry surface
        "root_zone": 0.35, # Adequate root zone
        "crop": "corn",
        "recommendation": "No irrigation needed"
    },
    {
        "surface": 0.30, # Moist surface
        "root_zone": 0.15, # Dry root zone
        "crop": "corn",
        "recommendation": "Deep irrigation required"
    }
]
```

Pass Criteria: Correct irrigation recommendation for each scenario

TC-DEPTH-002: Crop-Specific Root Depth Application

Priority: High

Category: Game Mechanics

Preconditions: Various crops planted

Test Steps:

- 1. Plant shallow-rooted lettuce
- 2. Plant deep-rooted corn
- 3. Apply same surface moisture stress
- 4. Observe different responses
- 5. Test irrigation effectiveness

Expected Results:

Crop	Root Depth	Surface Impact	Deep Impact
Lettuce	15cm	High	Low
Corn	150cm	Low	High
Wheat	100cm	Medium	High

2.3 Context Adaptation Testing

TC-CONTEXT-001: Smallholder Farm Mode

Priority: High

Category: UI/UX

Preconditions: New game start

Test Steps:

- 1. Select "Smallholder" context
- 2. Create 2-hectare farm
- 3. Verify simplified interface
- 4. Check limited equipment options
- 5. Test mobile responsiveness

Expected Results:

Features Available:

- ✓ Manual field drawing
- ✓ Basic irrigation
- ✓ Rainfall dependence
- ✗ Precision equipment
- ✗ Variable rate application
- ✗ Advanced analytics

TC-CONTEXT-002: Industrial Farm Mode

Priority: High

Category: UI/UX

Preconditions: New game start

Test Steps:

1. Select "Industrial" context
2. Create 500-hectare farm
3. Verify advanced interface
4. Check full equipment catalog
5. Test desktop optimization

Expected Results:

Features Available:

- ✓ Automated field mapping
- ✓ Center pivot irrigation
- ✓ Variable rate technology
- ✓ Prescription maps
- ✓ Yield monitors
- ✓ Financial analytics

3. Educational Feature Test Cases

3.1 Tutorial System Testing

TC-EDU-001: Resolution Tutorial Effectiveness

Priority: Critical

Category: Learning

Preconditions: New user account

Test Steps:

1. Start resolution tutorial
2. Complete pixel size demonstration
3. Practice feature detection
4. Take assessment quiz
5. Track time and accuracy

Assessment Questions:

1. "Can a 9km pixel detect a 50m pond?" [Answer: No]
2. "What resolution needed for 10m wide road?" [Answer: $\leq 10\text{m}$]
3. "How many 30m pixels in 1 hectare?" [Answer: ~ 11]

Pass Criteria:

- 80% quiz accuracy
 - <10 minutes completion
 - Positive feedback rating
-

TC-EDU-002: Depth Understanding Assessment

Priority: Critical

Category: Learning

Preconditions: Completed depth tutorial

Test Steps:

1. Present moisture scenario
2. User selects appropriate depth
3. User chooses irrigation strategy
4. System provides feedback
5. Repeat with 5 scenarios

Test Scenarios:

```
javascript
```

```
scenarios = [  
  {  
    crop: "tomatoes",  
    surface: "dry",  
    deep: "moist",  
    correct_action: "light_surface_irrigation"  
  },  
  {  
    crop: "corn",  
    surface: "moist",  
    deep: "dry",  
    correct_action: "deep_irrigation"  
  }  
]
```

Pass Criteria: 4/5 correct decisions

3.2 Scenario Challenge Testing

TC-SCEN-001: California Drought Scenario

Priority: High

Category: Applied Learning

Preconditions: Unlocked scenarios

Test Steps:

- 1. Load "2023 California Drought" scenario
- 2. Provide 50% water allocation
- 3. Player manages almond orchard
- 4. Use SMAP data for decisions
- 5. Complete growing season

Success Metrics:

Outcome	Score	Achievement
>70% yield, <50% water	100	Gold Medal
>50% yield, <50% water	75	Silver Medal
Completed season	50	Bronze Medal
Crop failure	0	Retry prompt

4. System Performance Test Cases

4.1 Load Testing

TC-PERF-001: Concurrent User Load

Priority: Critical

Category: Performance

Tool: Apache JMeter

Test Configuration:

```
yaml

test_plan:
  users: 10000
  ramp_up: 300 seconds
  duration: 3600 seconds

user_actions:
  - login: weight 1
  - view_dashboard: weight 5
  - fetch_nasa_data: weight 3
  - update_field: weight 4
  - save_game: weight 2
```

Expected Results:

- Response time p95 < 200ms
- Error rate < 0.1%
- Server CPU < 80%
- Memory usage < 4GB

TC-PERF-002: NASA API Rate Limit Handling

Priority: High

Category: Integration

Preconditions: Rate limit = 100 req/hour

Test Steps:

1. Generate 150 API requests rapidly
2. Observe rate limit response
3. Verify exponential backoff

- 4. Check cache serving
- 5. Monitor user experience

Expected Behavior:

```
python
for attempt in range(5):
    if response.status == 429:
        wait_time = 2 ** attempt
        cache.serve_data()
        sleep(wait_time)
    else:
        break
```

4.2 Offline Functionality Testing

TC-OFF-001: 72-Hour Offline Operation

Priority: Critical
Category: PWA
Preconditions: Game fully cached

Test Steps:

- 1. Play online for 1 hour
- 2. Disconnect network
- 3. Continue playing for 72 hours
- 4. Test all offline features
- 5. Reconnect and sync

Offline Feature Matrix:

Feature	Hour 1	Hour 24	Hour 72
Farm management	✓	✓	✓
Historical data	✓	✓	✓
Tutorials	✓	✓	✓
New NASA data	×	×	×
Achievements	✓	✓	✓

TC-OFF-002: Offline Data Sync

Priority: High

Category: Data Integrity

Preconditions: Offline changes made

Test Steps:

1. Make changes offline:
 - Plant 5 fields
 - Irrigate 3 times
 - Complete 2 harvests
2. Reconnect to internet
3. Verify sync process
4. Check data integrity
5. Confirm no data loss

Validation:

```
sql

SELECT COUNT(*) FROM actions
WHERE sync_status = 'pending'
-- Should be 0 after sync
```

5. Security Test Cases

5.1 Authentication Security

TC-SEC-001: NASA Earthdata OAuth Flow

Priority: Critical

Category: Security

Preconditions: Valid Earthdata account

Test Steps:

1. Click "Login with NASA"
2. Redirect to Earthdata
3. Enter credentials
4. Authorize application
5. Receive JWT token

Security Checks:

- TLS 1.3 encryption
 - State parameter validation
 - Token expiration (30 min)
 - Refresh token handling
 - CSRF protection
-

TC-SEC-002: Input Validation

Priority: High

Category: Security

Tool: OWASP ZAP

Test Vectors:

```
javascript

malicious_inputs = [
  "<script>alert('XSS')</script>",
  "' OR '1'='1",
  "../../../etc/passwd",
  "{{7*7}}",
  "%00",
  "; DROP TABLE users;--"
]
```

Expected Results: All inputs sanitized, no execution

5.2 Data Protection

TC-SEC-003: PII Encryption

Priority: High

Category: Compliance

Preconditions: User data exists

Test Steps:

1. Check database encryption
2. Verify transmission encryption
3. Test data masking
4. Validate access controls

5. Audit log review

Validation Queries:

```
sql

-- Check encryption
SELECT encryption_status FROM pg_stat_ssl;

-- Check PII access
SELECT has_table_privilege('public_user', 'users', 'SELECT');
```

6. Accessibility Test Cases

6.1 WCAG Compliance

TC-ACC-001: Screen Reader Navigation

Priority: High

Category: Accessibility

Tool: NVDA, JAWS

Test Steps:

1. Enable screen reader
2. Navigate main menu
3. Play tutorial
4. Manage farm
5. Access help

Success Criteria:

- All elements have labels
- Logical reading order
- Skip links available
- ARIA landmarks present
- Focus indicators visible

TC-ACC-002: Keyboard Navigation

Priority: High

Category: Accessibility

Preconditions: No mouse available

Test Steps:

- 1. Tab through interface
- 2. Activate controls with Enter/Space
- 3. Use arrow keys for selection
- 4. Escape to close modals
- 5. No keyboard traps

Key Mappings:

Key	Action
Tab	Next element
Shift+Tab	Previous element
Enter	Activate
Space	Select
Escape	Cancel/Close
Arrow keys	Navigate

7. User Acceptance Test Cases

7.1 Educational Effectiveness

TC-UAT-001: Knowledge Transfer Validation

Priority: Critical
Category: Learning Outcomes
Participants: 100 students

Test Protocol:

- 1. Pre-assessment (20 questions)
- 2. 5 hours gameplay
- 3. Post-assessment (same questions)
- 4. 30-day retention test
- 5. Practical application survey

Success Metrics:

- Knowledge improvement: >80%
- Retention rate: >60%
- Application rate: >40%
- Satisfaction: >4.0/5.0

TC-UAT-002: Real-World Application

Priority: High

Category: Behavioral Change

Participants: 50 farmers

Test Protocol:

1. 2-week game training
2. Return to actual farming
3. 3-month follow-up survey
4. Document changes made
5. Measure outcomes

Expected Outcomes:

- 40% adopt precision techniques
- 30% report water savings
- 25% improve yields
- 90% find value in training

8. Regression Test Suite

8.1 Critical Path Tests

Must pass before any release:

```
yaml
critical_tests:
  - user_registration_login
  - nasa_data_fetch
  - resolution_comparison
  - depth_visualization
  - context_switching
  - offline_mode
  - tutorial_completion
  - assessment_scoring
  - data_sync
  - save_game_state
```

8.2 Automated Test Coverage

Component	Unit Tests	Integration	E2E	Coverage
Data Pipeline	85%	75%	60%	80%
Game Engine	80%	70%	65%	75%
Education System	75%	80%	70%	75%
UI Components	70%	65%	75%	70%
Overall	78%	73%	68%	75%

9. Test Data Management

9.1 Test Data Sets

NASA Data Samples

```
json
{
  "test_locations": [
    {"name": "Nebraska", "lat": 40.0, "lon": -100.0},
    {"name": "California", "lat": 36.7, "lon": -119.8},
    {"name": "Kenya", "lat": -0.5, "lon": 37.0}
  ],
  "date_ranges": [
    "2025-01-01 to 2025-01-31",
    "2025-06-01 to 2025-06-30",
    "2025-09-01 to 2025-09-30"
  ],
  "resolutions": [30, 250, 9000, 11000]
}
```

Test Users

```
yaml
```


test_accounts:
 student:
 age: 18
 experience: beginner
 context: educational

smallholder:
 age: 45
 experience: expert
 context: small_farm

industrial:
 age: 35
 experience: intermediate
 context: large_farm

10. Defect Management

10.1 Severity Classification

Severity	Description	Response Time	Example
Critical	System unusable	4 hours	Data corruption
High	Major feature broken	24 hours	Can't save game
Medium	Minor feature issue	72 hours	UI glitch
Low	Cosmetic/enhancement	Next release	Typo

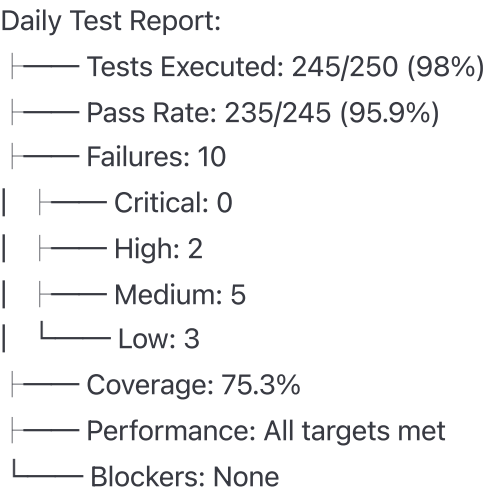
10.2 Defect Tracking

yaml

defect_template:
 id: "NFN-BUG-XXXX"
 title: "Brief description"
 severity: "Critical|High|Medium|Low"
 category: "Data|Game|Education|UI"
 steps_to_reproduce: []
 expected_result: ""
 actual_result: ""
 environment: ""
 attachments: []
 assigned_to: ""
 status: "Open|In Progress|Fixed|Closed"

11. Test Reporting

11.1 Test Metrics Dashboard



11.2 Exit Criteria

Release Criteria:

- All critical tests pass
- No critical/high defects
- 95% pass rate
- Performance targets met
- Security scan clean
- Accessibility compliant
- Educational objectives validated

Appendices

Appendix A: Test Environment Setup

Detailed configuration for each test environment.

Appendix B: Test Data Generation Scripts

Automated scripts for test data creation.

Appendix C: Performance Baselines

Historical performance metrics for comparison.

Appendix D: Accessibility Checklist

Complete WCAG 2.1 AA compliance checklist.

