Test Case Document

Real-World AR ChatGPT for Farmers

Document Information

- **Version:** 1.0
- **Created:** 2025
- **Test Environment:** Staging & Production
- **Test Types:** Functional, Integration, Performance, Security, UAT

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1. Test Case Categories

1.1 Test Coverage Matrix

Module	Unit Tests	Integration Tests	E2E Tests	Performance	Security	Total
WebAR Ground Detection	15	8	5	3	2	33
Location Services	10	5	3	2	3	23
NASA Data Integration	20	12	6	5	3	46
Chat/RAG System	18	10	8	4	5	45
Voice Processing	12	6	4	3	2	27
Crop Companion	15	8	5	2	1	31
Recommendations	14	9	6	3	2	34
Total	**104**	**58**	**37**	**22**	**18**	**239**

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2. Functional Test Cases

2.1 WebAR Ground Detection Tests

TC-AR-001: Camera Permission Request

- **Objective:** Verify camera permission handling
- **Preconditions:** Fresh browser session, no prior permissions
- **Test Steps:**

1. Open application URL
2. Click "Start AR" button
3. Observe permission prompt

- **Expected Result:** Browser camera permission dialog appears
- **Priority:** High
- **Test Data:** N/A
- **Pass/Fail Criteria:** Permission prompt displayed correctly

TC-AR-002: Ground Plane Detection Success

- **Objective:** Verify ground detection within 3 seconds
- **Preconditions:** Camera permission granted
- **Test Steps:**
  1. Point camera at flat ground/floor
  2. Start timer when camera activates
  3. Wait for ground detection indicator
- **Expected Result:** "Ground Detected" appears within 3 seconds
- **Priority:** High
- **Test Data:** Various ground surfaces (concrete, soil, grass)
- **Pass/Fail Criteria:** Detection time ≤ 3 seconds

TC-AR-003: Sky/Wall Rejection

- **Objective:** Verify non-ground surfaces are rejected
- **Preconditions:** WebAR session active
- **Test Steps:**
  1. Point camera at sky
  2. Wait 5 seconds
  3. Point camera at wall
  4. Wait 5 seconds
- **Expected Result:** No ground detection triggered
- **Priority:** High
- **Test Data:** Sky, walls, vertical surfaces
- **Pass/Fail Criteria:** No false positives

TC-AR-004: Soil Validation

- **Objective:** Verify soil texture recognition
- **Preconditions:** Ground detected
- **Test Steps:**
  1. Point at actual soil
  2. Observe validation result
  3. Point at concrete
  4. Observe validation result
- **Expected Result:** Soil validated only for actual soil
- **Priority:** Medium
- **Test Data:** Soil, concrete, asphalt samples
- **Pass/Fail Criteria:** Correct classification

TC-AR-005: Area Estimation

- **Objective:** Verify area calculation accuracy
- **Preconditions:** Ground detected and validated
- **Test Steps:**
  1. Scan known area (e.g., 10m²)
  2. Check displayed estimate
  3. Calculate error percentage
- **Expected Result:** Area estimate within ±20%
- **Priority:** Low
- **Test Data:** Pre-measured areas
- **Pass/Fail Criteria:** Error < 20%

2.2 Location Services Tests

TC-LOC-001: GPS Permission Request

- **Objective:** Verify location permission handling
- **Preconditions:** No prior location permission
- **Test Steps:**
  1. Trigger location request

2. Observe permission dialog
3. Grant permission
4. Verify location capture

- **Expected Result:** Location captured with 5 decimal precision
- **Priority:** High
- **Test Data:** Various device locations
- **Pass/Fail Criteria:** Lat/lon format: XX.XXXXX

TC-LOC-002: Permission Denial Handling

- **Objective:** Verify graceful handling of denied permission
- **Preconditions:** Location permission prompt active
- **Test Steps:**
  1. Deny location permission
  2. Observe application behavior
  3. Check for manual entry option
- **Expected Result:** Manual location entry offered
- **Priority:** High
- **Test Data:** N/A
- **Pass/Fail Criteria:** No crash, alternative provided

TC-LOC-003: Manual Location Entry

- **Objective:** Verify manual coordinate input
- **Preconditions:** Location permission denied
- **Test Steps:**
  1. Enter valid coordinates
  2. Submit form
  3. Verify acceptance
  4. Enter invalid coordinates
  5. Verify rejection
- **Expected Result:** Valid coordinates accepted, invalid rejected
- **Priority:** Medium
- **Test Data:**

    - Valid: 37.7749, -122.4194
    - Invalid: 200.0000, 300.0000
- **Pass/Fail Criteria:** Proper validation

TC-LOC-004: Location Accuracy Validation

- **Objective:** Verify GPS accuracy requirements
- **Preconditions:** GPS enabled
- **Test Steps:**
    1. Capture location
    2. Check precision digits
    3. Compare with known coordinates
- **Expected Result:** 5+ decimal places captured
- **Priority:** High
- **Test Data:** Known reference points
- **Pass/Fail Criteria:** Precision ≥ 5 decimals

2.3 NASA Data Integration Tests

TC-NASA-001: SMAP Data Retrieval

- **Objective:** Verify soil moisture data fetch
- **Preconditions:** Valid location available
- **Test Steps:**
    1. Request data for coordinates
    2. Measure response time
    3. Validate data structure
    4. Check moisture value range
- **Expected Result:** Valid moisture data (0.0-1.0)
- **Priority:** High
- **Test Data:** Multiple global coordinates
- **Pass/Fail Criteria:** Valid range, <2.5s response

TC-NASA-002: MODIS NDVI Retrieval

- **Objective:** Verify vegetation index data

- **Preconditions:** Valid location available
- **Test Steps:**
  1. Request NDVI for location
  2. Validate range (-1 to 1)
  3. Check timestamp
  4. Verify provenance data
- **Expected Result:** Valid NDVI with metadata
- **Priority:** High
- **Test Data:** Agricultural regions
- **Pass/Fail Criteria:** Valid NDVI range

TC-NASA-003: Cache Hit Verification

- **Objective:** Verify caching mechanism
- **Preconditions:** Fresh cache state
- **Test Steps:**
  1. Request data for location A
  2. Note response time T1
  3. Request same location again
  4. Note response time T2
  5. Verify T2 < T1
- **Expected Result:** Cached response faster
- **Priority:** High
- **Test Data:** Repeated coordinates
- **Pass/Fail Criteria:** T2 < 0.5 * T1

TC-NASA-004: API Failure Handling

- **Objective:** Verify graceful degradation
- **Preconditions:** Simulated API failure
- **Test Steps:**
  1. Block NASA API endpoint
  2. Request data
  3. Check fallback behavior

4. Verify cached/estimated data

- **Expected Result:** Fallback data provided
- **Priority:** High
- **Test Data:** N/A
- **Pass/Fail Criteria:** No error to user

TC-NASA-005: Rate Limit Handling

- **Objective:** Verify rate limit compliance
- **Preconditions:** Rate limit near threshold
- **Test Steps:**
  1. Send 95 requests
  2. Monitor response
  3. Send 10 more requests
  4. Check throttling behavior
- **Expected Result:** Graceful throttling after limit
- **Priority:** Medium
- **Test Data:** Burst requests
- **Pass/Fail Criteria:** No 429 errors to user

2.4 Chat/RAG System Tests

TC-CHAT-001: Basic Query Processing

- **Objective:** Verify chat functionality
- **Preconditions:** Chat interface loaded
- **Test Steps:**
  1. Type "What should I plant?"
  2. Submit query
  3. Measure response time
  4. Check response relevance
- **Expected Result:** Relevant response in <4 seconds
- **Priority:** High
- **Test Data:** Common agricultural queries

- **Pass/Fail Criteria:** Relevant answer, time < 4s

TC-CHAT-002: Citation Verification

- **Objective:** Verify source citations
- **Preconditions:** RAG system active
- **Test Steps:**
  1. Ask factual question
  2. Check for citations
  3. Verify citation format
  4. Validate source links
- **Expected Result:** Proper citations included
- **Priority:** High
- **Test Data:** Fact-based queries
- **Pass/Fail Criteria:** Valid citations present

TC-CHAT-003: Off-Topic Handling

- **Objective:** Verify non-agricultural query handling
- **Preconditions:** Chat active
- **Test Steps:**
  1. Ask "What's the weather on Mars?"
  2. Check response
  3. Verify redirection message
- **Expected Result:** Polite redirection to farming topics
- **Priority:** Medium
- **Test Data:** Non-farming questions
- **Pass/Fail Criteria:** Appropriate redirection

TC-CHAT-004: Context Maintenance

- **Objective:** Verify conversation context
- **Preconditions:** Ongoing chat session
- **Test Steps:**
  1. Ask about corn planting

2. Follow up with "When should I water it?"
3. Verify context understanding

- **Expected Result:** Context maintained (refers to corn)
- **Priority:** Medium
- **Test Data:** Multi-turn conversations
- **Pass/Fail Criteria:** Correct context reference

TC-CHAT-005: Location-Aware Responses

- **Objective:** Verify location-specific answers
- **Preconditions:** Location set to specific region
- **Test Steps:**
  1. Set location to tropics
  2. Ask for crop recommendations
  3. Set location to temperate
  4. Ask same question
  5. Compare responses
- **Expected Result:** Different, region-appropriate responses
- **Priority:** High
- **Test Data:** Various climate zones
- **Pass/Fail Criteria:** Location-specific answers

2.5 Voice Processing Tests

TC-VOICE-001: Push-to-Talk Recording

- **Objective:** Verify voice recording
- **Preconditions:** Microphone permission granted
- **Test Steps:**
  1. Press and hold talk button
  2. Speak test phrase
  3. Release button
  4. Verify recording captured
- **Expected Result:** Audio successfully recorded

- **Priority:** Medium
- **Test Data:** "What crops grow here?"
- **Pass/Fail Criteria:** Audio captured

TC-VOICE-002: Transcription Accuracy

- **Objective:** Verify speech-to-text accuracy
- **Preconditions:** Clear audio input
- **Test Steps:**
  1. Record agricultural terms
  2. Check transcription
  3. Calculate accuracy
- **Expected Result:** >90% accuracy
- **Priority:** Medium
- **Test Data:** Common farming vocabulary
- **Pass/Fail Criteria:** Accuracy ≥ 90%

TC-VOICE-003: Text-to-Speech Response

- **Objective:** Verify audio response generation
- **Preconditions:** TTS enabled
- **Test Steps:**
  1. Trigger voice response
  2. Verify audio plays
  3. Check clarity
  4. Measure total time
- **Expected Result:** Clear audio in <8 seconds
- **Priority:** Low
- **Test Data:** Various response lengths
- **Pass/Fail Criteria:** Audio clear, time < 8s

2.6 Crop Companion Tests

TC-COMP-001: Avatar State Changes

- **Objective:** Verify avatar visual states

- **Preconditions:** Companion active
- **Test Steps:**
  1. Trigger normal state
  2. Trigger stressed state
  3. Trigger happy state
  4. Verify visual changes
- **Expected Result:** Distinct visual states
- **Priority:** Medium
- **Test Data:** State triggers
- **Pass/Fail Criteria:** 3+ distinct states

TC-COMP-002: Alert Generation

- **Objective:** Verify alert system
- **Preconditions:** Monitoring active
- **Test Steps:**
  1. Simulate heat stress condition
  2. Wait for alert
  3. Verify alert content
  4. Test dismissal
- **Expected Result:** Appropriate alert generated
- **Priority:** High
- **Test Data:** Various stress conditions
- **Pass/Fail Criteria:** Timely, relevant alerts

TC-COMP-003: Growth Stage Tracking

- **Objective:** Verify crop lifecycle tracking
- **Preconditions:** Crop selected
- **Test Steps:**
  1. Set crop to corn
  2. Advance time 7 days
  3. Check stage update
  4. Verify avatar change

- **Expected Result:** Stage progression tracked
- **Priority:** Medium
- **Test Data:** Time progression
- **Pass/Fail Criteria:** Correct stage transitions

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3. Integration Test Cases

3.1 End-to-End Flow Tests

TC-E2E-001: Complete User Journey

- **Objective:** Verify full user workflow
- **Preconditions:** Fresh session
- **Test Steps:**
  1. Open app
  2. Grant permissions
  3. Detect ground
  4. View insights
  5. Ask question
  6. Receive recommendation
  7. Set up companion
- **Expected Result:** All steps complete successfully
- **Priority:** Critical
- **Test Data:** Real-world scenario
- **Pass/Fail Criteria:** No failures in flow

TC-E2E-002: Offline to Online Transition

- **Objective:** Verify offline fallback
- **Preconditions:** App loaded
- **Test Steps:**
  1. Go offline
  2. Attempt operations
  3. Go online

4. Verify sync

- **Expected Result:** Graceful degradation and recovery
- **Priority:** High
- **Test Data:** Network toggling
- **Pass/Fail Criteria:** No data loss

3.2 API Integration Tests

TC-INT-001: Multi-API Data Fusion

- **Objective:** Verify data combination
- **Preconditions:** All APIs available
- **Test Steps:**
  1. Request combined insights
  2. Verify all data sources present
  3. Check fusion logic
  4. Validate output format
- **Expected Result:** Properly fused data
- **Priority:** High
- **Test Data:** Multiple API responses
- **Pass/Fail Criteria:** Complete data set

TC-INT-002: Authentication Flow

- **Objective:** Verify JWT authentication
- **Preconditions:** Valid credentials
- **Test Steps:**
  1. Request token
  2. Use token in API call
  3. Verify acceptance
  4. Test expired token
- **Expected Result:** Valid tokens accepted
- **Priority:** High
- **Test Data:** Valid/invalid tokens

- **Pass/Fail Criteria:** Proper auth handling

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4. Performance Test Cases

4.1 Load Testing

TC-PERF-001: Concurrent User Load

- **Objective:** Verify 1000 user support
- **Preconditions:** Production-like environment
- **Test Steps:**
  1. Simulate 100 users
  2. Increase to 500
  3. Increase to 1000
  4. Monitor response times
  5. Check error rates
- **Expected Result:** <3s response at 1000 users
- **Priority:** High
- **Test Data:** JMeter scripts
- **Pass/Fail Criteria:** p95 < 3 seconds

TC-PERF-002: API Response Times

- **Objective:** Verify API latency
- **Preconditions:** Warm cache
- **Test Steps:**
  1. Send 1000 requests
  2. Measure each response
  3. Calculate percentiles
  4. Check p95 latency
- **Expected Result:** p95 < 2.5 seconds
- **Priority:** High
- **Test Data:** Various endpoints
- **Pass/Fail Criteria:** Meet SLA targets

4.2 Stress Testing

TC-PERF-003: Cache Performance

- **Objective:** Verify cache efficiency
- **Preconditions:** Empty cache
- **Test Steps:**
  1. Load test with cold cache
  2. Repeat with warm cache
  3. Compare metrics
  4. Calculate hit rate
- **Expected Result:** >70% cache hit rate
- **Priority:** Medium
- **Test Data:** Repeated queries
- **Pass/Fail Criteria:** Hit rate > 70%

TC-PERF-004: Memory Usage

- **Objective:** Verify memory efficiency
- **Preconditions:** Fresh app start
- **Test Steps:**
  1. Monitor initial memory
  2. Use app for 30 minutes
  3. Check memory growth
  4. Look for leaks
- **Expected Result:** <100MB growth
- **Priority:** Medium
- **Test Data:** Extended usage
- **Pass/Fail Criteria:** No memory leaks

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5. Security Test Cases

5.1 Authentication Security

TC-SEC-001: JWT Token Validation

- **Objective:** Verify token security
- **Preconditions:** Auth system active
- **Test Steps:**
  1. Test valid token
  2. Test expired token
  3. Test malformed token
  4. Test missing token
- **Expected Result:** Only valid tokens accepted
- **Priority:** Critical
- **Test Data:** Various token states
- **Pass/Fail Criteria:** Proper validation

TC-SEC-002: Rate Limiting

- **Objective:** Verify rate limit enforcement
- **Preconditions:** Rate limiter active
- **Test Steps:**
  1. Send 60 requests/minute
  2. Send 61st request
  3. Verify blocking
  4. Wait 1 minute
  5. Verify unblocked
- **Expected Result:** Rate limit enforced
- **Priority:** High
- **Test Data:** Burst requests
- **Pass/Fail Criteria:** 429 after limit

5.2 Data Security

TC-SEC-003: Input Validation

- **Objective:** Verify input sanitization
- **Preconditions:** All input fields available
- **Test Steps:**
  1. Test SQL injection attempts

2. Test XSS attempts
3. Test buffer overflow
4. Verify all rejected

- **Expected Result:** All attacks blocked
- **Priority:** Critical
- **Test Data:** OWASP test strings
- **Pass/Fail Criteria:** No vulnerabilities

TC-SEC-004: HTTPS Enforcement

- **Objective:** Verify encrypted connections
- **Preconditions:** Production environment
- **Test Steps:**
  1. Try HTTP connection
  2. Verify redirect to HTTPS
  3. Check TLS version
  4. Verify certificate
- **Expected Result:** TLS 1.3 enforced
- **Priority:** High
- **Test Data:** Various protocols
- **Pass/Fail Criteria:** Only TLS 1.3+

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6. User Acceptance Test Cases

6.1 Usability Tests

TC-UAT-001: First-Time User Experience

- **Objective:** Verify ease of onboarding
- **Preconditions:** New user
- **Test Steps:**
  1. Give user device
  2. Ask to find crop advice
  3. Measure time to complete

4. Note confusion points

- **Expected Result:** <10 minutes to productive use
- **Priority:** High
- **Test Data:** 10 test users
- **Pass/Fail Criteria:** Success rate >80%

TC-UAT-002: Field Testing

- **Objective:** Verify real-world usage
- **Preconditions:** Actual farm setting
- **Test Steps:**
  1. Use app in field
  2. Test all features
  3. Note issues
  4. Gather feedback
- **Expected Result:** Functional in field conditions
- **Priority:** Critical
- **Test Data:** Multiple farm locations
- **Pass/Fail Criteria:** Core functions work

6.2 Accessibility Tests

TC-UAT-003: One-Handed Operation

- **Objective:** Verify single-hand usage
- **Preconditions:** Mobile device
- **Test Steps:**
  1. Hold device one-handed
  2. Access all features
  3. Note unreachable elements
- **Expected Result:** All features accessible
- **Priority:** Medium
- **Test Data:** Various hand sizes
- **Pass/Fail Criteria:** Full functionality

TC-UAT-004: Visual Feedback

- **Objective:** Verify clear feedback
- **Preconditions:** Bright sunlight
- **Test Steps:**
  1. Use app outdoors
  2. Check visibility
  3. Verify contrast
  4. Test color blind modes
- **Expected Result:** Readable in sunlight
- **Priority:** High
- **Test Data:** Various lighting
- **Pass/Fail Criteria:** WCAG 2.1 AA

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7. Regression Test Suite

7.1 Core Functionality Checklist

Test Area	Test Count	Automated	Manual	Priority
Permissions	5	3	2	Critical
AR Detection	8	5	3	Critical
Data Retrieval	10	8	2	Critical
Chat System	12	10	2	High
Recommendations	8	7	1	High
Alerts	6	5	1	Medium

7.2 Smoke Test Suite

Critical Path Tests (Run on Every Deploy)

1. App loads successfully
2. Camera permission works
3. Location capture works
4. Ground detection works
5. NASA data retrieved

6. Chat responds
7. Recommendations generated
8. No console errors

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8. Test Environment Setup

8.1 Device Matrix

Platform	OS Version	Browser	Priority
iPhone 12+	iOS 14+	Safari	High
iPhone X	iOS 12+	Safari	Medium
Samsung Galaxy	Android 11+	Chrome	High
Pixel	Android 10+	Chrome	High
OnePlus	Android 9+	Chrome	Medium

8.2 Network Conditions

Condition	Bandwidth	Latency	Packet Loss
4G Good	10 Mbps	50ms	0%
3G Average	2 Mbps	150ms	1%
Poor Rural	500 Kbps	300ms	5%
Offline	0	N/A	100%

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9. Test Data Requirements

9.1 Location Test Data

Location Type	Coordinates	Description
Farmland USA	40.7128, -95.3698	Nebraska corn fields
Tropical	-3.4653, -62.2159	Amazon region
Desert	23.4241, 53.8478	UAE agricultural zone
Temperate	48.8566, 2.3522	France farmland

9.2 Crop Test Data

Crop	Season	Water Need	Growth Period
Corn	Spring	High	120 days

Crop	Season	Water Need	Growth Period
Wheat	Fall	Medium	90 days
Rice	Summer	Very High	150 days
Soybeans	Spring	Medium	100 days

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10. Test Execution Schedule

10.1 Sprint 1 Test Plan

- Week 1: Unit tests for AR module
- Week 2: Integration tests for location
- Week 3: NASA API integration tests
- Week 4: Sprint regression suite

10.2 Sprint 2 Test Plan

- Week 5: Chat system tests
- Week 6: Voice processing tests
- Week 7: RAG accuracy tests
- Week 8: Performance baseline

10.3 Sprint 3 Test Plan

- Week 9: Gamification tests
- Week 10: End-to-end scenarios
- Week 11: UAT with farmers
- Week 12: Final regression

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11. Defect Management

11.1 Severity Levels

Level	Description	Response Time	Example
Critical	Blocks core function	2 hours	App crash
High	Major feature broken	1 day	No data shown
Medium	Feature degraded	3 days	Slow response
Low	Minor		