8-Month Milestone Timeline for Military UGV Electronics & Software Development

This comprehensive development plan provides a structured roadmap for delivering a military-grade autonomous unmanned ground vehicle (UGV) system with advanced electronics and software capabilities. The timeline accounts for procurement lead times, technical development phases, integration, testing, and compliance with Indian defense standards.

Executive Summary

The 8-month development timeline is structured into six distinct phases, beginning with requirements finalization and culminating in system delivery with complete JSS:0251-01:2015 documentation. **Critical long-lead items including LiDAR sensors, thermal cameras, and gimbal systems must be ordered within the first two weeks (T+0)** to ensure timely delivery by Month 3-4. The plan incorporates contingency buffers (T+1 to T+2 weeks) for uncertain elements such as EMI/EMC testing lab availability, import clearances, and BFL (Bharat Electronics Limited or equivalent) support for defense documentation standards.

Phase 0: Planning & Design (Month 0-1)

System Architecture and Requirements Finalisation

The foundational phase establishes the technical framework for the entire project. The team must work closely with army stakeholders to finalise system requirements, particularly the map format specification that will be provided for autonomous navigation[1][2]. Modern military UGVs require sophisticated sensor fusion architectures combining multiple modalities for robust operation.

Key Activities:
- Finalise System Requirements Document (SRD) including detailed specifications for autonomous mode (≥50 km range), remote control mode (≥15 km range), and payload integration
- Design system architecture for ROS2-based autonomous stack with edge computing capabilities
- Create detailed block diagrams for power management, navigation, surveillance, and communication subsystems
- Establish design-for-manufacturability (DFM) guidelines for defence-grade PCB production

Critical Procurement Actions:

Within the first two weeks, purchase orders must be issued for components with 12-16 week lead times:

- **LiDAR sensor** (automotive/industrial grade): 12-16 weeks lead time, estimated arrival Month 3.5
- **Thermal imaging camera** (cooled, 8km detection range): 10-14 weeks, arrival Month 3
- **High-precision IMU** (tactical grade): 8-10 weeks, arrival Month 2.5
- **GPS/GNSS receiver** (GPS, GLONASS, NavIC compatible): 6-8 weeks, arrival Month 1.5
- **Battery pack** (fire-safe, military grade): 10-14 weeks, arrival Month 3
- **APU system** (12+ hour continuous operation): 14-18 weeks, arrival Month 4 (T+2 contingency)

Deliverables:
- System Requirements Document (SRD)
- System architecture diagrams (hardware and software)
- Component selection matrix with vendor details
- Purchase orders for long-lead items
- Risk register with mitigation strategies

Phase 1: Procurement & Early Development (Month 1-2.5)

PCB Design and Software Architecture

This phase focuses on detailed design work while critical components are in procurement. Defence-grade PCB manufacturing requires 3-5 weeks for multi-layer boards with stringent quality requirements.

Electronics Design Activities:
- **Power Management PCB**: Design integrated power management system (IPMS) with dual power rails for payload and drive systems, reverse polarity protection, and fire-safe battery telemetry
- **Sensor Interface PCB**: Multi-layer board design for LiDAR, GPS, IMU, camera interfaces with proper EMI/EMC considerations per MIL-STD-461E/F
- **APU Interface Electronics**: Remote start/stop control, continuous operation monitoring for 12+ hour missions

Software Architecture Development:
- Set up ROS2 development environment with real-time operating system (RTOS) support
- Design autonomous navigation stack architecture using SLAM (LiDAR + GPS + IMU fusion)
- Develop geo-fencing framework with live zone mapping capabilities
- Create software architecture for "Return to Home" with mission continuation fallback
- Design point A-to-B autonomous mission planner with radio loss fallback logic

Additional Procurement:

- **2-axis stabilised gimbal** (PTZ for Day/TI cameras): Order Month 1, 12-16 weeks lead time, arrival Month 4
- **Long-range radio system** (15km, AES-256 encryption): Order Month 1.5, 8-12 weeks, arrival Month 3.5
- **Drive cameras** (6x IP-based): Order Month 1, 4-6 weeks, arrival Month 2
- **Telescopic mast system** (≥2 meter elevation): 8-10 weeks, arrival Month 3

Ground Control Station (GCS) Design:
- Design user interface for 10" FHD rugged touch panel (≥400 nits brightness)
- Create mission planning interface with GPS/GLONASS/NavIC/DSM map integration
- Design operator dashboard for navigation control, payload management, and system diagnostics
- Plan two-way audio-video communication system

Documentation Standards Setup:
Engage support for JSS:0251-01:2015 compliance early[29][30][31][32]. This Indian Ministry of Defence standard mandates specific formats for technical publications, user handbooks, and technical manuals for defense equipment. Multiple OEMs contributing to complex systems must follow identical documentation structures to ensure consistency for operators and maintainers[33][34][35].

Deliverables:
- Complete PCB schematics and layouts (ready for fabrication)
- Software architecture document with ROS2 node structure
- GCS UI/UX mockups with user workflows
- Component tracking sheet with delivery schedules
- JSS:0251-01:2015 documentation template

Phase 2: Core Development (Month 2.5-4)

Hardware Fabrication and Software Development

PCB Fabrication and Assembly:
Manufacturing defence-grade multi-layer PCBs requires specialised facilities with MIL-spec certification. Lead times vary by complexity:
- 2-layer boards: 1-2 days

Allow **3-5 weeks** total for fabrication, assembly, and initial testing of defence-grade boards. Order PCBs by Month 2 for delivery by Month 3.

Autonomous Navigation Development:
- Implement SLAM algorithms using LiDAR point cloud processing and IMU pre-integration
- Develop GPS/IMU sensor fusion with Dynamic Time Warping (DTW) for

temporal alignment
- Create real-time path re-planning and dynamic obstacle avoidance algorithms
- Implement AI-based visual tracking for "Follow Me" mode
- Develop geo-fencing engine with boundary enforcement

Sensor Integration:
Upon delivery of LiDAR (Month 3.5), GPS (Month 1.5), and IMU (Month 2.5), begin intensive integration testing:
- Calibrate LiDAR-IMU extrinsic parameters[3][20]
- Validate GPS/GNSS multi-constellation reception (GPS, GLONASS, NavIC)
- Test sensor fusion algorithms with real sensor data
- Characterise IMU drift and implement correction algorithms

Gimbal and Payload Electronics:
When gimbal system arrives (Month 4), develop:
- Twin-axis PTZ control interface for Day/TI cameras
- Auto-orientation algorithms with AI-based visual tracking
- Optical zoom control (≥10x) and digital zoom processing
- Integration with Laser Range Finder (LRF) for ≥8km range, ±5m accuracy
- Real-time audio streaming (20Hz-20kHz, 30 dB sensitivity)

Video Processing Pipeline:
- Develop 6-camera image stitching algorithm (2 front, 2 side, 2 rear)
- Implement real-time video encoding for transmission
- Create metadata overlay system (GPS coordinates, timestamp, telemetry)
- Design SSD-based 1TB onboard recording system with external logging

Deliverables:
- Fabricated and tested PCB Rev-1 boards
- Autonomous navigation software (alpha version)
- Sensor fusion module with real sensor validation
- Gimbal control interface software
- Video stitching and processing pipeline

Phase 3: System Integration (Month 4-5.5)

Electronics Integration and Communication Systems

Full Electronics System Integration:
With all major electronic subsystems developed and most hardware components delivered (LiDAR by Month 3.5, Gimbal by Month 4, Radio by Month 3.5), begin comprehensive integration on the vehicle platform.

Power Management Integration:
- Integrate IPMS with vehicle battery pack and APU interface
- Implement remote start/stop control for APU (12+ hour continuous operation capability)

- Set up 4-port output system (2×240V AC, 2×variable DC) with reverse polarity protection
- Configure fire-safe battery telemetry to control station
- Test dual power rail distribution for payload and drive systems

Communication System Setup:
Long-range radio systems for military UGVs require robust NLOS (non-line-of-sight) performance and high security. The communication architecture must support:

- **Remote Control Mode**: 15km range at 20-30 kmph vehicle speeds with high-bandwidth, low-latency data link
- **Autonomous Mode**: Secure bi-directional telemetry for mission monitoring over 50km range
- **Security Implementation**: AES-256 encrypted radio data with secure bootloader and firmware lock
- **Fail-safe Logic**: Automatic switch to autonomous mode upon communication loss, with reconnection attempts

Ground Control Station Development:
- Integrate control software with mission planning, navigation, and payload control interfaces
- Implement real-time video streaming with metadata overlay
- Create diagnostic logging system for navigation, payload, and system health data
- Develop operator alert system for critical faults and communication status
- Add battery backup (≥2 hours) with AC/DC charging capability

Mode Switching Controller:
Implement seamless transitions between:
- Autonomous mode (point A-to-B with pre-defined plan)
- Remote control mode (operator commanded)
- Communication loss fallback (automatic continuation of mission in autonomous mode with reconnection attempts)
- Return to Home (RTH) emergency mode

Deliverables:
- Fully integrated electronics system on vehicle
- IPMS with APU interface (tested)
- GCS software beta version with full functionality
- Encrypted bidirectional communication link (validated)
- Mode switching and fail-safe controller

Phase 4: Testing & Validation (Month 5.5-7)

EMI/EMC Testing and Field Validation

MIL-STD-461E/F and 464C Compliance Testing:
Defense electronics must undergo rigorous electromagnetic compatibility testing. **Book test lab slots T+2 weeks in advance** to ensure availability.

Required tests include:
- **Conducted Emissions (CE101, CE102)**: Verify emissions on power leads (30 Hz to 10 MHz)
- **Radiated Emissions (RE102)**: Verify electric field emissions (10 kHz to 18 GHz)
- **Conducted Susceptibility (CS101, CS114)**: Test immunity to power line disturbances and bulk cable injection
- **Radiated Susceptibility (RS103)**: Test immunity to electric fields (2 MHz to 18 GHz for ground applications)

Testing timeline: 1.5-2 weeks for complete EMI/EMC test suite.
Contingency: T+2 weeks buffer for re-testing if failures occur.

Autonomous Navigation Field Testing:
- Test 50km autonomous mission with pre-planned waypoints
- Validate geo-fencing with live zone boundary enforcement
- Test "Return to Home" functionality with various trigger conditions
- Validate mission continuation after communication loss and reconnection
- Test dynamic obstacle avoidance and real-time path re-planning
- Verify SLAM performance across varied terrain (as per army map format)

Remote Control Mode Testing:
- Validate 15km range operation with secure data link
- Test vehicle control responsiveness at 20-30 kmph speeds
- Verify telemetry accuracy and update rates
- Test fail-safe transition to autonomous mode upon link loss
- Validate redundant communication systems

Payload and Surveillance Testing:
- Verify Day/TI camera DRI (Detection, Recognition, Identification) ranges: 8km/5km/2.5km
- Test gimbal stabilisation during vehicle movement
- Validate LRF accuracy (±5m) at ≥8km range
- Test audio sensor performance (20Hz-20kHz, 30 dB sensitivity)
- Verify telescopic mast operation (≥2 meter elevation)
- Test 6-camera image stitching quality and frame rate

Security and Fail-safe Testing:
- Penetration testing of AES-256 encrypted communication
- Test secure boot loader and firmware lock mechanisms
- Validate remote wipe and auto-destruct of storage on command
- Test single-point failure isolation in LRU (Line Replaceable Unit) architecture

- Verify reverse polarity protection on all power lines

Built-In Test Equipment (BITE) Validation:
Test diagnostic capabilities for field replacement and maintenance.

Deliverables:
- EMI/EMC test reports per MIL-STD-461E/F and 464C
- Autonomous navigation field test reports (50km validation)
- Remote control range test reports (15km validation)
- Payload performance validation reports (DRI ranges confirmed)
- Fail-safe and security test reports
- BITE diagnostic test results

Phase 5: Final Integration & Delivery (Month 7-8)

System Optimisation and Documentation

System Optimisation:
Based on field testing feedback from Phase 4, implement:
- Performance optimizations for autonomous navigation algorithms
- Communication system tuning for maximum range and reliability
- Power management refinements for extended mission duration
- User interface improvements based on operator feedback
- Bug fixes and stability enhancements

JSS:0251-01:2015 Documentation Preparation:
This is **critical for defence delivery**. The standard requires comprehensive technical publications including:

1. **Design Specifications**: Detailed technical specifications for all electronic and electrical equipment
2. **User Handbook (UHB)**: Operator-focused manual for system operation
3. **Technical Manual (TM)**: Maintenance and troubleshooting guide for technicians
4. **Procurement Drawings**: Detailed drawings for spare part procurement
5. **List of Components**: Complete bill of materials with part numbers
6. **List of Spares**: Installation spares and carried spares inventory
7. **Engineering Support Package**: Technical data for system support
8. **Special Tools and Test Equipment List**: Required maintenance equipment

Documentation must follow specific formatting requirements:
- Standardised cover page design with code number, date, title
- Consistent section structure across all documents
- Proper illustrations and diagrams
- Safety warnings and precautions highlighted
- Appendices for additional technical data

Allow **3-4 weeks** for comprehensive documentation preparation with BFL support agency.

Final Acceptance Testing:
- Complete system validation against SRD requirements
- Demonstrate all operational modes to customer
- Verify compliance with all specifications
- Final quality assurance checks

Training and Handover:
- Conduct operator training sessions for vehicle control and GCS operation
- Provide maintenance training for technical personnel
- Deliver training materials and user documentation
- Complete knowledge transfer and system handover

Deliverables:
- Production-ready UGV system with all optimisations
- Complete JSS:0251-01:2015 compliant documentation package
- Final acceptance test certificate
- Training materials and session records
- System delivery and customer acceptance

Critical Procurement Timeline Summary

Component Category	Order Month	Lead Time	Delivery Month	Contingency
LiDAR Sensor	M0	12-16 weeks	M3.5	T+1 month backup vendor
Thermal Camera	M0	10-14 weeks	M3.0	Alternative FLIR models
Day Camera (EO)	M0	8-12 weeks	M2.5	Multiple vendors
IMU (Tactical)	M0	8-10 weeks	M2.5	Alternative suppliers
GPS/GNSS Module	M0	6-8 weeks	M1.5	NavIC capable priority
Battery Pack	M0	10-14 weeks	M3.0	Fire-safe certification
APU System	M0	14-18 weeks	M4.0	T+2 week buffer
Gimbal System	M1	12-16 weeks	M4.0	Critical path item
Radio System (15km)	M1	8-12 weeks	M3.5	Silvus/Persistent options
LRF (8km range)	M0	10-12 weeks	M3.0	Military spec required