Track Surveillance Drone - System Requirements Document

Project: Track Surveillance Drone
Version: 1.0
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1. Introduction

1.1 Purpose

This System Requirements Document (SRD) defines the technical system requirements for the Track Surveillance Drone system, derived from the User Requirements Document (URD) version 1.0. The document establishes the technical foundation for design, development, and verification activities in accordance with CENELEC standards for railway applications.

1.2 Scope

This document covers all technical aspects of the Track Surveillance Drone system including hardware, software, interfaces, safety, security, and operational requirements. The system shall operate as an autonomous inspection platform for railway track infrastructure.

1.3 Definitions and Abbreviations

- **CENELEC**: European Committee for Electrotechnical Standardization
- **RaSTA**: Safe Transport Protocol for Railway Applications
- **GNSS**: Global Navigation Satellite System
- **EMC**: Electromagnetic Compatibility
- **MTBF**: Mean Time Between Failures
- **MTTR**: Mean Time To Repair
- **SIL**: Safety Integrity Level
- **THR**: Tolerable Hazard Rate
- **LRU**: Line Replaceable Unit
- **BIT**: Built-In Test
- **FMECA**: Failure Mode, Effects and Criticality Analysis

1.4 Requirements Obligation Levels

- **Requirement**: Mandatory requirements (equivalent to Shall/Must)
- **Recommendation**: Recommended requirements (equivalent to Should)
- **Info**: Informative statements (equivalent to Will)

2. Referenced Documents

2.1 CENELEC Standards

- EN 50126: Railway Applications - Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS)
- EN 50128: Railway Applications - Communication, Signalling and Processing Systems - Software for Railway Control and Protection Systems
- EN 50129: Railway Applications - Communication, Signalling and Processing Systems - Safety Related Electronic Systems for Signalling
- EN 50155: Railway Applications - Electronic Equipment used on Rolling Stock
- EN 50701: Railway Applications - Cybersecurity

2.2 Other Standards

- IEC 61508: Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems
- DO-178C: Software Considerations in Airborne Systems and Equipment Certification
- ISO 26262: Road Vehicles - Functional Safety
- 2011/65/EU: RoHS Directive

2.3 Project Documents

- Track Surveillance Drone URD v1.0
- System Architecture Document
- Safety Plan
- Verification and Validation Plan

3. General Description

3.1 System Overview

The Track Surveillance Drone system consists of an autonomous unmanned aerial vehicle equipped with inspection sensors, communication systems, and ground-based control infrastructure for railway track monitoring and defect detection.

3.2 System Architecture

The system architecture comprises:

- Aerial Platform (drone hardware)
- Sensor Suite (cameras, LIDAR, thermal imaging)
- Flight Control System
- Communication Subsystem

- Ground Control Station
- Data Processing and Analysis System
- Asset Management Interface

4. System Requirements

ID	Requirement	Obligation	URD Source
SR-001	**Technical Requirements**	Info	-
SR-002	The following section defines the technical requirements for the drone system including environmental, hardware, functional, and navigation specifications.	Info	-
SR-003	The drone flight control system shall operate continuously at altitudes from 0 to 2000 meters above sea level without performance degradation.	Requirement	UR-01
SR-004	The barometric pressure compensation system shall maintain flight stability across the operational altitude range with accuracy of ±1 meter.	Requirement	UR-01
SR-005	All electronic components shall maintain specified performance parameters within the temperature range of -20°C to +50°C during operation.	Requirement	UR-02
SR-006	The thermal management system shall maintain critical component temperatures within 5°C of optimal operating range during maximum performance operations.	Requirement	UR-02
SR-007	Battery performance shall maintain minimum 80% capacity throughout the operational temperature range.	Requirement	UR-02
SR-008	The drone shall maintain stable flight operations in precipitation up to 2.5 mm/hour and wind speeds up to 40 km/h (11 m/s).	Requirement	UR-03
SR-009	Water ingress protection shall prevent operational degradation during 30 minutes of continuous light rain exposure.	Requirement	UR-03
SR-010	The flight control system shall automatically compensate for wind gusts up to 60 km/h (17 m/s) peak velocity.	Requirement	UR-03
SR-011	All system components shall survive storage temperatures from -40°C to +60°C without permanent damage or performance degradation.	Requirement	UR-04
SR-012	Storage humidity tolerance shall extend from 5% to 95% relative humidity without condensation effects.	Requirement	UR-04
SR-013	The weather monitoring subsystem shall measure and report wind speed (±1 m/s accuracy), temperature (±2°C accuracy), humidity (±5% accuracy), and precipitation intensity every 10 seconds.	Requirement	UR-05
SR-014	Weather data shall be transmitted to ground control station with maximum 5-second latency.	Requirement	UR-05
SR-015	The flight control system shall automatically abort mission and execute safe landing procedure when weather conditions exceed operational limits.	Requirement	UR-05
SR-016	Weather monitoring sensors shall self-calibrate every 24 hours of operation.	Requirement	UR-05

ID	Requirement	Obligation	URD Source
SR-017	All electronic components and materials shall comply with EU RoHS Directive 2011/65/EU with maximum concentrations: Lead (0.1%), Mercury (0.1%), Cadmium (0.01%), Hexavalent chromium (0.1%), PBB (0.1%), PBDE (0.1%).	Requirement	UR-06
SR-018	Material certificates shall be maintained for all components with hazardous substance declarations.	Requirement	UR-06
SR-019	The drone shall support hot-swappable battery packs with standardized electrical and mechanical interfaces.	Requirement	UR-07
SR-020	Battery pack electrical interface shall provide reverse polarity protection and over-current protection.	Requirement	UR-07
SR-021	Battery packs shall provide minimum 45 minutes flight time at maximum payload configuration.	Requirement	UR-07
SR-022	Battery management system shall monitor individual cell voltages, temperatures, and charge/discharge currents.	Requirement	UR-07
SR-023	Battery pack mechanical interface shall withstand 1000 insertion/removal cycles without degradation.	Requirement	UR-07
SR-024	The primary housing shall achieve minimum IP54 rating with ingress protection against dust and water splashing from any direction.	Requirement	UR-08
SR-025	Critical electronic components shall be housed in IP67 rated enclosures.	Requirement	UR-08
SR-026	Housing materials shall demonstrate UV resistance for minimum 5 years outdoor exposure.	Requirement	UR-08
SR-027	Gasket and seal materials shall maintain integrity through 500 thermal cycles from -20°C to +50°C.	Requirement	UR-08
SR-028	The drone shall display high-visibility markings compliant with aviation regulations including registration number, weight class, and emergency contact information.	Requirement	UR-09
SR-029	Marking materials shall maintain visibility and adhesion for minimum 2 years outdoor exposure.	Requirement	UR-09
SR-030	Emergency contact information shall be displayed in characters minimum 10mm height.	Requirement	UR-09
SR-031	The emergency shut-off switch shall be accessible within 5 seconds and shall immediately terminate all motor functions and enable emergency landing mode.	Requirement	UR-10
SR-032	Emergency shut-off shall be operable with protective gloves and in low-light conditions.	Requirement	UR-10

ID	Requirement	Obligation	URD Source
SR-033	Emergency shut-off activation shall be logged with timestamp and transmitted to ground control.	Requirement	UR-10
SR-034	The defect detection system shall identify track irregularities including: rail breaks, bolt failures, ballast displacement, vegetation encroachment, and surface defects with 95% detection accuracy.	Requirement	UR-11
SR-035	Track defect classification shall distinguish between severity levels: Critical (immediate attention), Major (within 24 hours), Minor (scheduled maintenance).	Requirement	UR-11
SR-036	The defect detection algorithm shall process imagery at minimum 30 frames per second with real-time analysis.	Requirement	UR-11
SR-037	False positive rate for defect detection shall not exceed 5% under normal operating conditions.	Requirement	UR-11
SR-038	The system shall detect rail surface defects as small as 5mm in any dimension.	Requirement	UR-11
SR-039	Defect location accuracy shall be within ±0.5 meters along track centerline.	Requirement	UR-11
SR-040	The autonomous navigation system shall follow pre-programmed flight paths with ±2 meter lateral accuracy using GNSS and visual odometry.	Requirement	UR-12
SR-041	The flight path planning system shall automatically generate optimized routes considering track geometry, obstacles, and restricted airspace.	Requirement	UR-12
SR-042	Navigation system shall maintain position accuracy during GNSS signal loss for minimum 2 minutes using inertial navigation.	Requirement	UR-12
SR-043	Flight path deviation alerts shall be generated when lateral position exceeds ±5 meters from planned route.	Requirement	UR-12
SR-044	The system shall automatically adjust flight altitude to maintain constant clearance above track infrastructure.	Requirement	UR-12
SR-045	Navigation waypoints shall be updatable during flight without interrupting autonomous operation.	Requirement	UR-12
SR-046	Real-time data transmission shall deliver video streams at minimum 1080p resolution with maximum 500ms latency to the control center.	Requirement	UR-13
SR-047	Sensor data transmission shall include GPS coordinates, timestamps, and sensor readings with 100ms maximum latency.	Requirement	UR-13
SR-048	Data transmission shall maintain 99.9% packet delivery rate under normal operating conditions.	Requirement	UR-13
SR-049	The system shall automatically adjust data transmission quality based on available bandwidth.	Requirement	UR-13

ID	Requirement	Obligation	URD Source
SR-050	Transmitted data shall include integrity checksums and error correction codes.	Requirement	UR-13
SR-051	The manual control interface shall provide full flight control authority with maximum 200ms response time from operator input to drone response.	Requirement	UR-14
SR-052	Manual override shall be available within 2 seconds from any autonomous flight mode.	Requirement	UR-14
SR-053	Manual control inputs shall be validated for safety limits before execution.	Requirement	UR-14
SR-054	The system should provide haptic feedback for manual control operations.	Recommendation	UR-14
SR-055	Manual control authority shall be transferred seamlessly without flight disruption.	Requirement	UR-14
SR-056	All inspection data shall be geo-referenced with accuracy better than 1 meter using GNSS and inertial navigation systems.	Requirement	UR-15
SR-057	Time synchronization accuracy shall be within ±10 milliseconds of UTC.	Requirement	UR-15
SR-058	Geo-referencing data shall include altitude, heading, and roll/pitch attitude information.	Requirement	UR-15
SR-059	The return-to-home function shall activate automatically when battery level reaches 25% remaining capacity or communication loss exceeds 30 seconds.	Requirement	UR-16
SR-060	Return-to-home shall execute a pre-programmed safe landing sequence at the designated home position with ±5 meter accuracy.	Requirement	UR-16
SR-061	Multiple return-to-home locations shall be programmable with automatic selection based on current position.	Requirement	UR-16
SR-062	Return-to-home flight path shall avoid known obstacles and restricted airspace.	Requirement	UR-16
SR-063	The system shall support redundant controller levels for availability with automatic failover capability.	Requirement	UR-17
SR-064	Controller redundancy switching shall occur within 50ms without loss of flight control.	Requirement	UR-17
SR-065	Redundant controllers shall continuously synchronize state information.	Requirement	UR-17
SR-066	Health monitoring shall detect controller failures within 100ms.	Requirement	UR-17

ID	Requirement	Obligation	URD Source
SR-067	**Interface Requirements**	Info	-
SR-068	The following section defines the interface requirements for communication protocols, data exchange, and user interfaces.	Info	-
SR-069	The transport protocol for communication with the interlocking shall be RaSTA compliant with EN 50159.	Requirement	UR-18
SR-070	RaSTA communication shall implement safety code SC-1 with 32-bit CRC and sequence numbering for data integrity.	Requirement	UR-18
SR-071	RaSTA protocol stack shall support message authentication and replay attack prevention.	Requirement	UR-18
SR-072	The system shall support remote diagnosis for any component fault with detailed fault isolation.	Requirement	UR-19
SR-073	Remote diagnostic access shall be secure with multi-factor authentication.	Requirement	UR-19
SR-074	Diagnostic data shall be transmitted in real-time during flight operations.	Requirement	UR-19
SR-075	The system shall include redundant communication links to prevent data loss using different frequency bands.	Requirement	UR-20
SR-076	Communication range shall extend to minimum 5 kilometers line-of-sight with automatic handover between base stations.	Requirement	UR-20
SR-077	Redundant communication systems shall automatically switch within 1 second of primary link failure.	Requirement	UR-20
SR-078	The system shall support secure over-the-air updates using encrypted channels with digital signature verification.	Requirement	UR-21
SR-079	Update packages shall be cryptographically signed and verified before installation with rollback capability.	Requirement	UR-21
SR-080	Software updates shall not interrupt ongoing flight operations.	Requirement	UR-21
SR-081	Update verification shall include integrity checks and compatibility validation.	Requirement	UR-21
SR-082	The operator shall be provided with a user-friendly interface for mission planning and monitoring with graphical map display.	Requirement	UR-32
SR-083	Mission planning interface shall support waypoint editing, flight path visualization, and restricted area management.	Requirement	UR-32
SR-084	The interface should provide flight simulation capability for mission validation before execution.	Recommendation	UR-32

ID	Requirement	Obligation	URD Source
SR-085	The interface shall show live status and alerts including battery level, GPS position, altitude, speed, weather conditions, and system health indicators.	Requirement	UR-33
SR-086	Alert notifications shall be presented with visual and audible indicators for critical conditions.	Requirement	UR-33
SR-087	Status information shall be updated with maximum 1-second refresh rate.	Requirement	UR-33
SR-088	The system shall log operator actions for traceability including timestamps, user identification, and command details.	Requirement	UR-34
SR-089	Operator action logs shall be tamper-evident and maintain complete audit trail.	Requirement	UR-34
SR-090	The interface shall support multi-user access with role-based permissions including Administrator, Operator, and Viewer roles.	Requirement	UR-35
SR-091	User authentication shall require minimum 8-character passwords with complexity requirements and session timeout after 30 minutes of inactivity.	Requirement	UR-35
SR-092	**RAMS Requirements**	Info	-
SR-093	The following section defines the Reliability, Availability, Maintainability, and Safety requirements for the drone system.	Info	-
SR-094	The overall system shall achieve minimum Mean Time Between Failures (MTBF) of 2000 flight hours for all mission-critical components.	Requirement	UR-23
SR-095	The flight control system shall implement dual-redundant processors with hot-standby switching capability within 50ms.	Requirement	UR-17
SR-096	Power systems shall provide triple redundancy with automatic load balancing and fault isolation.	Requirement	UR-17
SR-097	The system shall maintain 99.5% operational availability during scheduled inspection periods.	Requirement	UR-17
SR-098	Planned maintenance activities shall not exceed 2% of total operational time.	Requirement	UR-23
SR-099	The system shall support condition-based maintenance with predictive algorithms for component life estimation.	Requirement	UR-23
SR-100	Component replacement procedures shall be completed within maximum 15 minutes for field-replaceable units.	Requirement	UR-07
SR-101	Built-in test equipment shall provide fault isolation to Line Replaceable Unit (LRU) level with 95% accuracy.	Requirement	UR-26
SR-102	The drone system shall comply with Safety Integrity Level (SIL) 2 requirements per EN 50129 for safety-critical functions.	Requirement	UR-31

ID	Requirement	Obligation	URD Source
SR-103	Emergency landing procedures shall be executable within 60 seconds from fault detection to safe touchdown.	Requirement	UR-29
SR-104	The system shall implement fail-safe behavior for all safety-critical functions with automatic transition to safe state.	Requirement	UR-29
SR-105	Propulsion system failures shall not result in uncontrolled flight or ground impact with kinetic energy exceeding 79 Joules.	Requirement	UR-29
SR-106	The drone shall include obstacle detection and collision avoidance using LIDAR and stereo cameras.	Requirement	UR-28
SR-107	Obstacle detection shall identify objects larger than 10cm at distances up to 50 meters.	Requirement	UR-28
SR-108	Collision avoidance shall execute automatic evasive maneuvers maintaining minimum 5-meter clearance from detected obstacles.	Requirement	UR-28
SR-109	The system shall detect and avoid power lines, communication cables, and other overhead hazards.	Requirement	UR-28
SR-110	Emergency landing shall be controllable to avoid populated areas and critical infrastructure.	Requirement	UR-29
SR-111	The drone shall have geofencing to prevent entry into restricted airspace with 10-meter buffer zones.	Requirement	UR-30
SR-112	Geofencing boundaries shall be updateable remotely and during flight operations.	Requirement	UR-30
SR-113	The system shall automatically execute return-to-home when approaching geofence boundaries.	Requirement	UR-30
SR-114	The system shall comply with aviation safety regulations for unmanned flights including DO-178C Level C for flight-critical software.	Requirement	UR-31
SR-115	**Security Requirements**	Info	-
SR-116	The following section defines the cybersecurity requirements for the drone system in accordance with railway security standards.	Info	-
SR-117	The system shall comply with railway cybersecurity requirements EN 50701 including network segmentation, access controls, and intrusion detection.	Requirement	UR-22
SR-118	All communication channels shall use AES-256 encryption with perfect forward secrecy and mutual authentication.	Requirement	UR-22
SR-119	The system shall maintain security event logs with tamper-evident storage and automatic alerting for suspicious activities.	Requirement	UR-22
SR-120	Security patches shall be deployable within 24 hours of availability through the secure update mechanism.	Requirement	UR-22

ID	Requirement	Obligation	URD Source
SR-121	Physical security measures shall prevent unauthorized access to flight control systems and data storage devices.	Requirement	UR-22
SR-122	Network intrusion detection shall monitor all communication interfaces continuously.	Requirement	UR-22
SR-123	Security key management shall implement automatic key rotation every 30 days.	Requirement	UR-22
SR-124	The system shall implement certificate-based authentication for all secure communications.	Requirement	UR-22
SR-125	Security audit logs shall be forwarded to a centralized security monitoring system in real-time.	Requirement	UR-22
SR-126	The system shall implement secure boot procedures with verified signatures for all firmware components.	Requirement	UR-22
SR-127	**Manufacturing Requirements**	Info	-
SR-128	The following section defines the manufacturing requirements for quality control, testing, and production processes.	Info	-
SR-129	Manufacturing processes shall comply with ISO 9001 quality management standards with full traceability of components and assemblies.	Requirement	UR-06
SR-130	All safety-critical components shall undergo 100% functional testing and burn-in procedures before integration.	Requirement	UR-36
SR-131	Environmental stress screening shall be performed on all electronic assemblies including thermal cycling, vibration, and humidity testing.	Requirement	UR-02, UR-03, UR-04
SR-132	Component marking and labeling shall include part numbers, serial numbers, manufacturing dates, and compliance certifications.	Requirement	UR-09
SR-133	Manufacturing documentation shall maintain complete configuration control with version management and change tracking.	Requirement	UR-36
SR-134	Production testing shall verify all functional requirements before final assembly.	Requirement	UR-36
SR-135	Quality control inspection points shall be established at each critical manufacturing stage.	Requirement	UR-36
SR-136	Manufacturing equipment shall be calibrated and maintained according to documented procedures.	Requirement	UR-36
SR-137	Non-conforming products shall be identified, segregated, and processed according to quality control procedures.	Requirement	UR-36

ID	Requirement	Obligation	URD Source
SR-138	Manufacturing records shall be maintained for minimum 10 years for traceability purposes.	Requirement	UR-36
SR-139	**Diagnosis and Maintenance Requirements**	Info	-
SR-140	The following section defines the requirements for system diagnosis, maintenance planning, and asset management.	Info	-
SR-141	No periodical or preventive maintenance shall be necessary under normal conditions for minimum 1000 flight hours.	Requirement	UR-23
SR-142	Maintenance intervals shall be automatically calculated based on actual usage patterns and environmental conditions.	Requirement	UR-23
SR-143	All relevant information related to asset management shall be accessible remotely by a centralized asset management system.	Requirement	UR-24
SR-144	Asset management interface shall provide real-time status updates and historical trend analysis.	Requirement	UR-24
SR-145	Configuration management data shall be synchronized with the asset management system automatically.	Requirement	UR-24
SR-146	The system shall log all flight and inspection data for at least 12 months with automatic archival.	Requirement	UR-25
SR-147	Data storage shall provide redundancy and error correction to prevent data loss.	Requirement	UR-25
SR-148	Historical data shall be searchable and retrievable within 30 seconds for any specific flight or time period.	Requirement	UR-25
SR-149	The system shall generate automatic diagnostic reports after each flight mission.	Requirement	UR-26
SR-150	Diagnostic reports shall include component health status, performance metrics, and anomaly detection.	Requirement	UR-26
SR-151	The diagnostic system shall monitor all safety-critical parameters continuously with real-time health assessment and trend analysis.	Requirement	UR-19
SR-152	Remote diagnostic capabilities shall provide access to all system parameters, fault codes, and performance metrics without physical access to the drone.	Requirement	UR-19
SR-153	Automated diagnostic reports shall be generated after each flight mission and transmitted to the asset management system within 5 minutes of landing.	Requirement	UR-26
SR-154	The diagnostic system shall predict component failures with minimum 100-flight-hour advance warning for scheduled replacement.	Requirement	UR-27

ID	Requirement	Obligation	URD Source
SR-155	The system shall provide alerts for upcoming component replacements with minimum 7-day advance notice.	Requirement	UR-27
SR-156	Component life prediction shall be based on usage patterns, environmental exposure, and manufacturer specifications.	Requirement	UR-27
SR-157	Maintenance scheduling shall optimize component replacement timing to minimize operational disruption.	Requirement	UR-27
SR-158	The maintenance planning system shall automatically schedule preventive maintenance based on flight hours, calendar time, and condition monitoring data.	Requirement	UR-23, UR-27
SR-159	Maintenance alerts shall be issued with minimum 7-day advance notice for scheduled maintenance and immediate notification for unscheduled repairs.	Requirement	UR-27
SR-160	The system shall maintain spare parts inventory recommendations based on failure rates and lead times.	Requirement	UR-27
SR-161	Diagnostic data correlation shall identify patterns and trends across multiple system components.	Requirement	UR-19
SR-162	The system shall support remote firmware updates for diagnostic and maintenance systems.	Requirement	UR-21
SR-163	Maintenance procedures shall be documented and accessible through the asset management interface.	Requirement	UR-24
SR-164	The system shall track component serial numbers and revision levels throughout the operational lifecycle.	Requirement	UR-24
SR-165	**Verification Requirements**	Info	-
SR-166	The following section defines the verification requirements for system validation and compliance testing.	Info	-
SR-167	All requirements shall be verifiable by test, analysis, or inspection in compliance with the V-Model (EN 50126).	Requirement	UR-36
SR-168	The supplier shall deliver a Verification and Validation plan with complete traceability matrix.	Requirement	UR-37
SR-169	Safety-critical functions shall undergo independent verification and validation by qualified third-party assessors.	Requirement	UR-36
SR-170	Performance testing shall demonstrate compliance with all operational requirements under specified environmental conditions.	Requirement	UR-36
SR-171	Integration testing shall verify all interface requirements and system-level functionality.	Requirement	UR-36

ID	Requirement	Obligation	URD Source
SR-172	Environmental testing shall validate operation across full temperature, humidity, and altitude ranges.	Requirement	UR-02, UR-03, UR-04
SR-173	EMC testing shall demonstrate compliance with railway electromagnetic compatibility requirements.	Requirement	UR-06
SR-174	Software verification shall comply with DO-178C Level C requirements for flight-critical functions.	Requirement	UR-31
SR-175	Hardware verification shall include worst-case analysis and derating verification.	Requirement	UR-36

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