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Failure Mode and Effects Analysis

Reference Design — Fischer 26 / 26E / Lisa 26 / MANET C2

STATUS — REFERENCE DESIGN / CONCEPT DOCUMENT. This document is a design contribution, not a programme deliverable. It describes a proposed approach, structure, or analysis that researchers at FOI, FMV, Försvarsmakten, or defence industry partners may adapt when building their own prototypes or running their own programmes. FSG-A does not operate a UAS programme at the scale or maturity this document describes; no organisational roles, test schedules, logistics facilities, or maintenance processes named within are currently active. Any dates, RPN scores, MTBF values, budget figures, or organisational structures are **illustrative examples** intended to show how a real programme might approach the subject — they are not commitments, plans, or claims of current capability.

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Revision History

Version	Date	Author	Description
0.1 DRAFT	2026-04-19	FSG-A	Initial draft reference design. Illustrative FMEA structure showing how a formal programme might analyse the proposed UAS architecture. Mitigation columns describe design intent, not implemented controls. Suitable as a starting point for real FMEA work by a funded development programme.

1. Scope and Intent

This reference-design FMEA illustrates how a formal failure-mode analysis might be structured for the proposed FSG-A UAS architecture: Fischer 26 baseline airframe, Fischer 26E tier-2 variant, Lisa 26 command-and-control system, and the MANET communications backbone. The structure follows MIL-STD-1629A methodology and is compatible with SAE J1739.

For each failure mode the analysis sketches: (a) a plausible physical or procedural cause, (b) an observable effect on a hypothetical mission, (c) illustrative scores for Severity (S, 1-10), Occurrence (O, 1-10), and Detection (D, 1-10), and (d) the design-level mitigation concept that the FSG-A architecture documents in the wiki.

What this document is not. The scores below are illustrative. The mitigation column describes design intent visible in the wiki and SDK, not controls that have been physically tested, certified, or deployed. No physical prototype exists; no flight-test data underlies any occurrence score. A funded development programme adopting this architecture would re-score every row based on its own analysis, component choices, and test data — this reference simply shows the structure such an analysis would take.

The composite Risk Priority Number RPN = S × O × D is used here illustratively to rank design attention. Rows where RPN ≥ 100 in this reference are shaded grey to indicate where the architectural concept places the most engineering weight.

2. Scoring Guide (illustrative)

Severity (S): 1 = negligible (no mission impact); 3 = minor (degraded performance); 5 = significant (mission objective at risk); 7 = major (mission failure, no injuries); 9 = critical (mission failure + possible injury); 10 = catastrophic (loss of airframe or life-threatening).

Occurrence (O): 1 = extremely unlikely; 3 = rare; 5 = occasional; 7 = likely; 10 = near-certain. In this reference, O scores are design-intent estimates — they are what a programme adopting this architecture should expect to measure, not values FSG-A has measured.

Detection (D): 1 = immediately detected; 3 = detected within seconds; 5 = detected during debrief; 7 = detected only on subsequent failure; 10 = latent, essentially undetectable before mission loss.

3. Fischer 26 Baseline — Illustrative Failure Modes

Twelve failure modes covering airframe structure, propulsion, avionics, and payload for the Fischer 26 baseline concept. Shaded rows (RPN ≥ 100 in this reference scoring) indicate where the architectural concept places concentrated engineering attention. The mitigation column describes design intent as documented in the FSG-A wiki; no claim is made that any mitigation has been physically validated.

Item	Failure Mode	Effect	Cause	S	O	D	RPN	Mitigation
Wing spar	Spar fracture at root	Uncontrolled descent, hull loss	Exceeded 3.8g ultimate load in turbulence	10	2	3	60	Design intent: STANAG 4671 §21 compliance; V_NE limiter in ArduPlane; turbulence envelope check pre-flight.
Main battery	Cell thermal runaway	In-flight fire, hull loss	Damaged cell + mechanical stress + cold-soak cycling	10	2	4	80	Design intent: thermal shutdown at 80°C; ceramic-backed battery tray; pre-flight IR imaging of battery pack.

Item	Failure Mode	Effect	Cause	S	O	D	RPN	Mitigation
Brushless motor	Bearing seizure	Loss of propulsion, forced landing	Dust ingestion + moisture freezing in Arctic conditions	7	3	5	105	Design intent: IP54-sealed motor housing; pre-heat cycle below -15°C; motor-current anomaly detection in firmware.
Electronic Speed Controller	MOSFET failure	Motor stop, forced landing	Thermal cycling + cold starts + peak current	7	3	6	126	Design intent: derated MOSFETs (40% safety margin); conformal coating; temperature monitoring in ArduPlane logs.
Autopilot (Cube Orange)	EKF failsafe trip	Auto-RTL initiation	Magnetic anomaly (Aurora) + GPS glitch + IMU drift	5	5	2	50	Design intent: EKF3 with multi-IMU; Aurora-aware EKF parameters for Norrbotten; SLAM fallback when GPS reliability < 0.6.
GPS receiver	Total signal loss	Degraded navigation accuracy	Russian GNSS jamming or spoofing	5	6	3	90	Design intent: CRPA antenna with null-steering; SLAM-based dead reckoning; barometric altitude hold; RTL via pre-loaded terrain waypoints.
Radio link (Silvus)	Link loss beyond horizon	Data link outage	Terrain obstruction + no mesh node in coverage	4	6	2	48	Design intent: Fresnel-zone-aware altitude adjust; mesh relay via other F26 airframes; pre-mission LOS analysis.
Pitot tube	Icing blockage	Invalid airspeed reading	Supercooled droplet icing at freezing levels	6	3	4	72	Design intent: heated pitot (12V element); dual pitot with cross-check; GPS ground-speed fallback in EKF.
Landing parachute	Failure to deploy	Hard landing, airframe damage	Packing error or deployment mechanism failure	6	2	5	60	Design intent: dual pyro-cartridge activation; pre-flight rig inspection procedure; RTL with controlled belly landing as backup.
IMU (ICM-42688-P)	Temperature-drift bias	Attitude estimate error	Cold soak at -30°C exceeding factory calibration range	5	4	4	80	Design intent: extended temp cal to -40°C; EKF innovation-gate rejects out-of-spec; heater element on IMU PCB for pre-launch warm-up.

Item	Failure Mode	Effect	Cause	S	O	D	RPN	Mitigation
SD card (telemetry log)	Write failure mid-flight	Lost telemetry	Cold-induced read error or full card	2	3	2	12	Design intent: industrial-grade SD card (-40°C rated); pre-flight space check; redundant telemetry buffer in flash.
Receiver (ELRS)	Link fade on climb	Command delay or loss	Airframe antenna shadowing + low elevation	4	4	2	32	Design intent: diversity receiver with two antennas; FastLock FHSS; auto-RTL on link-loss timer.

4. Fischer 26E Tier-2 — Illustrative Failure Modes

Six failure modes unique to the Fischer 26E concept (SDR, CRPA, passive radar, SLAM, H.265 encoder, mesh relay). As above, scores and mitigations are reference-design illustrations.

Item	Failure Mode	Effect	Cause	S	O	D	RPN	Mitigation
SDR (AD9361)	DMA buffer overrun	Momentary spectrum blindness	High-rate hop schedule combined with CPU load spike	3	5	4	60	Design intent: DMA watchdog reset; lower-priority tasks interruptible; fallback to fixed frequency if SDR fails.
CRPA array	Single element failure	Degraded null-steering	Connector corrosion or physical damage to one element	3	4	3	36	Design intent: 4-element array degrades gracefully to 3-element; MVDR weights recomputed in firmware on element loss detection.
Passive radar receiver	Illuminator lost mid-mission	GMTI capability lost	FM transmitter taken offline or jammed	3	3	3	27	Design intent: multi-illuminator scoring auto-selects next best; fallback to active sensors (EO/IR); mission degraded but continues.
SLAM stack	Feature-point tracking lost	Position drift	Uniform terrain (snow field, forest monoculture) with no features	4	4	4	64	Design intent: GPS + EKF re-acquisition; pre-flight terrain analysis flags feature-sparse areas; operator warned.
H.265 encoder (Raspberry Pi CM4)	Encoder stall	Video feed lost	Thermal throttling at Arctic temperatures (cold start) or power dip	3	3	3	27	Design intent: pre-heat cycle for CM4; degraded resolution fallback (1080p → 720p); telemetry continues independently of video.

Item	Failure Mode	Effect	Cause	S	O	D	RPN	Mitigation
Fischer 26E relay network	Multi-node loss	Cascading coverage gap	EW barrage attack targeting multiple nodes simultaneously	7	3	4	84	Design intent: distributed mesh topology; dynamic role reassignment; ground-station redundancy (2-3 anchors).

5. Lisa 26 C2 — Illustrative Failure Modes

Seven failure modes covering the proposed command-and-control chain from AI detection through L3 gate and IFF deconfliction. The L3 gate entry warrants particular attention in any real FMEA: any failure mode leading to autonomous engagement of non-threat is inherently high-severity, which is why the Lisa 26 wiki design documents hard gating on category, confidence, and time-to-impact.

Item	Failure Mode	Effect	Cause	S	O	D	RPN	Mitigation
Detection pipeline (YOLOv8)	False-positive surge	L1 alert storm	Unusual visual pattern (snow glare, camouflage scheme)	3	5	3	45	Design intent: Dempster-Shafer fusion requires 2+ sensor agreement; operator triage workflow; training data augmented with edge cases.
Fusion module	Hypothesis collapse	Wrong target class fused	Conflicting high-confidence detections from EO vs IR	5	3	3	45	Design intent: conflict-mass threshold triggers manual review; confidence cap at 0.95 forces operator confirmation before L2 action.
L3 gate	Erroneous air-target classification	Autonomous engagement of non-threat	Adversarial ML attack or misidentified civil aircraft	9	2	5	90	Hard gate (design intent): L3 requires confidence ≥ 0.85 AND time-to-impact < 8s AND category in AIR_UAV/AIR_MUNITION/AIR_ROTARY/AIR_FIXED; Article 36 IHL review embedded in decision logic.
IFF heartbeat	Blue force flagged HOSTILE	Fratricide risk	Transmitter failure or HMAC key rotation mismatch	10	2	3	60	Design intent: MISSING status treated as friendly unknown (not hostile); 100 m safety radius; trajectory corridor deconfliction; operator confirmation required.
Lisa 26 database	Sync corruption	COP divergence across nodes	Packet loss + concurrent write conflict	4	3	3	36	Design intent: CRDT-based state; last-write-wins with timestamp; manual reconcile procedure documented in SOP.

Item	Failure Mode	Effect	Cause	S	O	D	RPN	Mitigation
Operator terminal	Tablet battery depletion	Local COP blackout	Cold-induced capacity loss below 20% SOC	3	4	2	24	Design intent: spare tablet with hot-handoff; vehicle-powered standby; Ra 180 radio fallback for critical alerts.
TAK Server integration	CoT message dropped	Track invisible to ATAK	Network partition or TAK Server overload	3	3	3	27	Design intent: retry with exponential backoff; local queue persists through outage; primary C2 channel remains SLB (JC3IEDM).

6. MANET Communications — Illustrative Failure Modes

Four failure modes for the Silvus StreamCaster mesh and associated cryptographic concepts. The Silvus supply chain item illustrates how a strategic-level concern (ITAR-dependent component in a peer-adversary scenario) can legitimately appear alongside engineering-level items in the same register.

Item	Failure Mode	Effect	Cause	S	O	D	RPN	Mitigation
Silvus mesh	Spanning-tree convergence delay	Temporary path loss	Rapid topology change (node movement) triggering re convergence	3	5	2	30	Design intent: pre-computed alternate paths cached; mesh settles within 30 s; application-layer retry masks most occurrences.
Frequency coordination	Co-channel interference spike	Throughput drop	Adjacent friendly unit on overlapping channel	3	4	3	36	Design intent: pre-mission frequency plan; real-time spectrum monitor; automatic hop to alternate channel (30 s settle).
HMAC signing	Key rotation failure mid-mission	Authentication loss	Daily key derivation failure (clock skew, PRNG failure)	5	2	4	40	Design intent: previous day's key accepted for 5 min window during rotation; graceful degradation to unsigned mode with operator alert.
Silvus supply chain	US export block (ITAR)	No replacement radios	Geopolitical change affecting US defence export	8	2	5	80	Design intent: strategic stockpile (3-year operational reserve) for a programme adopting this architecture; European alternatives evaluated (Rohde&Schwarz; SDTR, Bittium); fallback to ELRS 900-MHz-band + custom relay for austere operations.

7. How to Use This Reference

Total failure modes sketched in this reference: 29.

A funded development programme adopting the FSG-A architecture can use this reference as a starting skeleton for its own FMEA. Expected adaptations:

• Replace every Occurrence score with a value derived from the programme's own component choice, supplier reliability data, and environmental test profile.

• Replace every Detection score based on what monitoring, BIT (Built-In Test), or field inspection the programme actually implements.

• Expand the mitigation column from design-intent statements to specific engineering drawings, test procedures, and inspection criteria.

• Add programme-specific failure modes not in this reference (for example, interaction modes unique to a specific host-platform integration).

• Re-score after each test campaign and re-issue the FMEA at each TRL milestone.

The highest-attention concepts in this reference (wing-spar fracture, battery thermal runaway, L3 gate misclassification, IFF fratricide, supply-chain disruption) are places where FSG-A's architectural documentation goes into the most depth; they are the items most worth cross-referencing when adapting this structure.

8. References

MIL-STD-1629A — Procedures for Performing a Failure Mode, Effects and Criticality Analysis (US DoD, 1980).

SAE J1739:2021 — Potential Failure Mode and Effects Analysis in Design (Design FMEA) and Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA) (SAE International).

STANAG 4671 Ed. 1 — UAV Systems Airworthiness Requirements (USAR) (NATO Standardization Office).

FSG-A wiki — individual component analyses referenced per failure mode (https://fsg-a.com/).