Strategic Investment Memorandum: Distributed Aerial Search and Rescue (DAS-SAR) Swarm System

1. Executive Summary

The global aerospace and defense sector is currently witnessing a paradigm shift of historical magnitude, transitioning from monolithic, human-piloted platforms toward distributed, autonomous systems. Within this broad transformation, the domain of Search and Rescue (SAR) and tactical aerial logistics stands at a critical inflection point. The convergence of high-performance edge computing, novel electric propulsion technologies, and safety-critical software architectures has rendered the traditional "single-airframe" heavy-lift model increasingly obsolete for rapid response applications in complex terrain.

This Investment Memorandum presents a rigorous, exhaustive analysis of the **Distributed Aerial Search and Rescue (DAS-SAR)** project—a pioneering engineering initiative designed to disrupt the status quo of aerial evacuation. Historically, the extraction of human casualties or high-value assets from inaccessible environments has been the exclusive purview of manned rotary-wing aircraft or massive, trailer-deployed Unmanned Aerial Vehicles (UAVs). These legacy solutions are capital-intensive, logistically rigid, and vulnerable to single-point mechanical failures.

The DAS-SAR project proposes a fundamental architectural pivot: a **Distributed Lift System (DLS)**. Instead of relying on a single, massive aircraft to generate lift, this system utilizes a coordinated swarm of smaller, man-portable drones physically tethered to a single payload. By decoupling the lift capacity from the size of individual agents, the system achieves a level of modularity, transportability, and redundancy previously unattainable in aerospace engineering. A team of ground operators can hike into a remote alpine environment, deploy a "backpack-portable" swarm, and execute a heavy-lift extraction of a 100kg+ payload without the need for prepared landing zones or heavy transport infrastructure.[1]

The project is structured around a two-phase development roadmap designed to de-risk the technology iteratively. **Phase 1** focuses on a scaled prototype ("Micro" Swarm) comprising four quadcopters to validate the complex distributed control algorithms required to stabilize a coupled slung load. **Phase 2** escalates to a full-scale "Macro" Swarm utilizing six coaxial octocopters, capable of lifting a 115kg payload (human casualty + stretcher) with **fail-operational** redundancy. Crucially, the system architecture supports "Hot-Swap" logic, allowing individual drones to be replaced mid-mission without grounding the payload—a capability that theoretically extends flight endurance indefinitely, limited only by the availability of charged reserve units.[3]

Technologically, the project rejects the industry-standard academic robotics stack (C++/ROS 1) in favor of a production-grade, safety-critical architecture built on **Rust**, **ROS 2**, and **Eclipse Zenoh**. This strategic choice addresses the fundamental vulnerabilities of modern autonomous systems: memory safety, real-time determinism, and communication bandwidth saturation in contested wireless environments.[4]

Financially, the venture requires a seed investment of approximately **€1.31 million** to reach full-scale human extraction capability over a 12-month timeline. This capital requirement is driven by the high premium on specialized engineering talent—specifically Rust embedded systems engineers and AI computer vision specialists—and the procurement of industrial-grade aerospace hardware. The projected return on investment is validated by a global Search and Rescue drone market forecast to reach **$677.34 billion by 2035**, growing at a CAGR of 10.72%.[5]

This document serves as a complete due diligence package for potential investors. It details the technical specifications, dissects the competitive landscape (including analysis of incumbents like Malloy Aeronautics and Griff Aviation), investigates historical failure modes of similar ventures (such as Facebook's Project Aquila), and provides a complex risk analysis grounded in the EASA Specific Operations Risk Assessment (SORA) framework.

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2. Operational Context and Market Imperative

2.1 The "Golden Hour" and the Logistical Gap

The operational efficacy of emergency medical services and combat casualty care is universally measured against the "Golden Hour"—the critical sixty-minute window following a traumatic injury during which prompt medical treatment offers the highest likelihood of preventing death. In traditional SAR paradigms, this window is frequently eroded by logistical friction. Ground teams, limited by human physiology and terrain roughness, often move at speeds below 3 km/h in dense vegetation, snow, or steep inclines. Manned helicopters, while significantly faster, are constrained by landing zone (LZ) availability, weather minimums (ceiling and visibility), and the inherent risk of endangering aircrew in hazardous environments.[1]

The integration of small UAVs has effectively digitized the "battlefield for life," acting as flying binoculars that extend the sensor range of rescue teams. However, a critical logistical gap remains: **physical extraction**. Once a victim is located by a reconnaissance drone, the rescue team must still physically traverse the terrain to retrieve them. Current heavy-lift drone solutions capable of lifting a human typically rely on massive, single-airframe designs with a Maximum Take-Off Mass (MTOM) exceeding 300kg. These platforms suffer from the same transportability issues as manned helicopters, requiring trailers or flatbed trucks to reach the staging area, effectively negating the rapid-response advantage of UAVs in remote areas.[1]

The DAS-SAR system addresses this gap by offering a solution that is **backpack-deployable**. A team of six rescuers can each carry one drone component of the heavy-lift swarm, hike to a remote location (e.g., a narrow ridge or a dense forest clearing), and assemble the system on-site. This capability opens up new operational concepts for mountain rescue organizations (such as GOPR/TOPR in Poland), special forces extraction, and maritime man-overboard recovery where deck space for large helicopters is unavailable.[6]

2.2 Global Drone Market Dynamics and Growth Vectors

The global drone market is undergoing a significant bifurcation. While the consumer segment approaches saturation, the commercial and industrial segments are experiencing explosive growth, particularly in heavy-lift and autonomous applications. This divergence is driven by the realization that drones are no longer just flying cameras but are evolving into sophisticated logistical tools capable of physical work.

Search and Rescue Market Expansion:
The global Search and Rescue drone market was valued at approximately $220.96 billion in 2024. It is projected to grow to $244.64 billion in 2025 and reach an staggering $677.34 billion by 2035, exhibiting a compound annual growth rate (CAGR) of 10.72%.5 This robust growth is fueled by increasing government allocations for public safety modernization, the rising frequency of climate-related disasters (floods, wildfires) requiring rapid response, and the need to reduce risk to human responders.
Autonomous Drones and AI Integration:
The broader autonomous drone market is forecast to grow from $20.74 billion in 2024 to $25.12 billion in 2025, with a CAGR of 21.1%.7 This indicates a strong market appetite for systems that reduce human-in-the-loop dependencies. The integration of AI for visual search (using tools like YOLOv8) and autonomous flight control is a key value driver. The DAS-SAR project leverages this trend by utilizing NVIDIA Jetson Orin Nano modules for onboard edge computing, enabling the swarm to navigate and identify targets without continuous operator input.1
Service Model Viability (RaaS):
While the "Drone Services" segment is expected to remain the largest revenue generator, hardware sales are growing fastest.9 This suggests that a business model combining proprietary hardware sales (the DAS-SAR swarm) with a recurring service or training contract (Rescue as a Service - RaaS) aligns perfectly with current market trends. Clients are looking for turnkey solutions that include not just the airframe, but the entire operational ecosystem.

2.3 The Demand for Redundancy and Safety

A key driver in the heavy-lift market is safety. In the defense and industrial sectors, the loss of a payload—whether a soldier, a casualty, or a $500k sensor package—due to a single motor failure is unacceptable. Traditional multicopters (quadcopters) lack redundancy; if one motor fails, the aircraft crashes. Octocopters offer some redundancy but remain single monolithic targets that are difficult to transport and repair in the field.

The DAS-SAR's **Distributed Lift System** offers a higher tier of survivability. It creates a "Fail-Operational" architecture where the system can sustain the complete loss of one or even two agents (depending on load factors) without catastrophic failure. This aligns with the stringent safety requirements of EASA's **Specific Assurance and Integrity Level (SAIL)** IV-VI, which are mandatory for operations over populated areas or involving human transport.[1] The market is actively seeking solutions that can meet these high regulatory bars, and DAS-SAR's redundancy-first approach positions it favorably against less robust competitors.

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3. Technical Architecture and Engineering Innovation

The DAS-SAR project is not merely an integration of off-the-shelf components; it is a fundamental re-engineering of how aerial lift is generated, controlled, and managed. The architecture is defined by three pillars: **Distributed Physics**, **Safety-Critical Software**, and **Resilient Communication**.

3.1 Pillars of Cooperative Aerial Manipulation

The core engineering challenge lies in the physics of **coupled slung load systems**. Unlike formation flight, where drones fly in a shape without physical interaction, a distributed lift system couples the dynamics of all agents through the payload. The payload is not rigidly attached; it is suspended by flexible tethers, creating a chaotic multi-pendulum system if not actively damped.

3.1.1 The Physics of the 6-Agent Configuration

The project plan explicitly pivots to a **6-drone configuration** for Phase 2. This is a decision rooted in control theory, specifically **Geometric Authority**.

- **Degrees of Freedom (DOF):** A rigid body (the stretcher/payload) has 6 degrees of freedom: translation in x, y, z and rotation in pitch, roll, yaw.
- **Actuation:** To fully control a rigid body in 3D space, one requires at least 6 independent actuators (force vectors). A tether provides force only in tension (pulling), not compression (pushing). Therefore, a minimum of 6 tethers is required to fully constrain and control the payload's position and orientation.
- **Redundancy Calculation:** With 6 drones, the system is fully actuated. If one drone fails (loss of an actuator), the system technically becomes under-actuated relative to full 6-DOF control unless the remaining 5 drones can reconfigure their geometry to compensate. The DAS-SAR architecture specifies a "nominal load" of ~19kg per drone. In a failure state, the remaining 5 drones must instantly increase thrust to ~24kg each. Given that the selected propulsion systems (T-Motor U15 or Hobbywing X9) are rated for ~40kg

of lift, the system maintains a safety factor of nearly **2:1** even after losing an agent.[1]

3.1.2 Admittance vs. Impedance Control

Standard commercial autopilots (like those on DJI drones) use Impedance Control (High Stiffness), fighting external forces to hold a specific GNSS coordinate. In a tethered swarm, this is disastrous. If Drone A drifts 10cm left and Drone B holds position rigidly, the tether tension spikes, causing the drones to fight each other until motors overheat or the tether snaps.
The DAS-SAR system employs Admittance Control (Low Stiffness). The drone is modeled as a virtual mass-spring-damper system. If the tether pulls the drone—due to wind acting on the payload or the movement of another drone—the drone "admits" this force and complies by moving slightly in the direction of the pull. This minimizes internal stress accumulation within the swarm and mimics biological cooperative transport (e.g., ants moving food). The drone's onboard computer runs a non-linear Model Predictive Control (MPC) solver to calculate the optimal thrust vector that stabilizes the payload while respecting these admittance constraints.1

3.2 The Modern Safety-Critical Software Stack

The project rejects the traditional academic robotics stack (ROS 1/Python) in favor of a production-grade, safety-certified architecture. This selection is the project's most significant "moat" against low-cost competitors and provides the reliability necessary for human transport certification.

3.2.1 The Paradigm Shift to Rust

The safety-critical control loops are implemented in **Rust**.

- **Memory Safety:** C++ allows for memory management errors (buffer overflows, dangling pointers) that cause segmentation faults (crashes). In a flying robot carrying a human at 100 meters, a software crash is fatal. Rust’s ownership model guarantees memory safety at compile time, eliminating entire classes of bugs before the code ever flies.
- **Real-Time Determinism:** Unlike Python or Java, Rust does not have a Garbage Collector (GC). GC pauses can cause unpredictable latency spikes (jitter), which destabilize flight control loops running at 400Hz. Rust ensures consistent execution times, essential for the millisecond-level synchronization required for distributed lift. The project utilizes ros2_rust client libraries and the MAVSDK-Rust wrapper to interface with the flight controller.[1]

3.2.2 Eclipse Zenoh: Solving the "Discovery Storm"

Standard ROS 2 uses DDS (Data Distribution Service) as its middleware. DDS relies on multicast for node discovery. In a swarm of 6 drones, each with 50+ topics (sensors, states, logs), the discovery traffic grows exponentially (N^2). This creates a "Discovery Storm" that can saturate the limited bandwidth of WiFi or Mesh Radio links, causing packet loss and loss of control.

The project implements Eclipse Zenoh, a next-generation middleware that reduces discovery overhead by up to 99%. Zenoh uses a routed, peer-to-peer architecture optimized for constrained networks (high latency, low bandwidth). It allows the swarm to share critical state data (Force Consensus) without clogging the network with administrative traffic. A zenoh-bridge-ros2dds acts as a gateway on each drone, bridging internal ROS 2 traffic to the external swarm network.1

3.3 Hardware Specification and Roadmap

The hardware strategy is bifurcated into two phases to manage capital risk and allow for iterative testing.

Phase 1: Scaled Prototype ("Micro" Swarm)

- **Objective:** Software validation at low cost/risk. Validating the "brain" before building the "muscle."
- **Airframe: Holybro X500 V2**. A rigid carbon fiber frame minimizes flex, which reduces noise in the IMU data—critical for the sensitive admittance controllers.
- **Compute: NVIDIA Jetson Orin Nano (8GB)**. Provides 40 TOPS of AI performance for Visual Inertial Odometry (VIO) and MPC solvers. It handles high-level logic while the flight controller handles stability.
- **Sensors:**
  - **Luxonis OAK-D Pro:** Selected for its active IR laser projector, allowing depth perception in textureless environments (snow, grass) where passive cameras fail.
  - **CubePilot Here 4:** Provides RTK GNSS for centimeter-level positioning, essential for collision avoidance within the swarm.
  - **Intel RealSense D435i:** Used for Visual Inertial Odometry (VIO) as a GPS-denied navigation backup.[1]

Phase 2: Full-Scale Heavy Lift ("Macro" Swarm)

- **Objective:** Human extraction (115kg total payload).
- **Airframe:** Custom Carbon Coaxial Octocopters (X8). The X8 configuration provides motor redundancy on each arm; if a motor fails, the coaxial partner compensates.
- **Propulsion: T-Motor U15 II** or **Hobbywing XRotor X9 Plus**. These industrial motors generate ~36-40kg of thrust *each*. A 6-drone swarm provides a total theoretical lift of >1,000kg (at max throttle), ensuring the system operates in the efficient 50% throttle range even with a heavy load.
- **Mechanisms:** Active winch systems for tether length control and quick-release hooks for emergency detachment. These allow the swarm to manipulate the payload's orientation and altitude independently of the drones' altitude.[3]

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4. Competitive Landscape and Alternative Solutions

The DAS-SAR project enters a niche but highly competitive market dominated by two opposing approaches: massive single-airframe drones ("flying trucks") and emerging swarm logistics. Understanding this landscape is vital for positioning the investment.

4.1 Heavy-Lift Incumbents (Single Airframe)

These companies build massive multicopters designed to lift heavy loads using a single, rigid airframe.

- **Malloy Aeronautics (BAE Systems):** The T-150 and T-650 are industry benchmarks. The T-650 can lift 300kg.
  - *Analysis:* Malloy was recently acquired by BAE Systems [10], validating the market demand. However, Malloy drones are massive (3m+ diameter). They require flatbed trucks and cranes for transport and deployment. DAS-SAR competes on **deployability** (backpack portable) rather than raw lift.
- **Griff Aviation:** A Norwegian company building "aviation-grade" heavy lifters (Griff 135/300).
  - *Analysis:* Griff focuses on certified, extremely robust platforms. They have raised ~$12M and focus on construction/offshore markets.[11] Like Malloy, their weakness is the lack of portability for remote SAR operations.
- **Volocopter (VoloDrone):** A spin-off of their air taxi work, capable of lifting 200kg.
  - *Analysis:* The VoloDrone is designed for urban logistics (pallet delivery) and is physically huge (9m diameter).[12] It is essentially a flying car and is not a competitor for rugged terrain SAR or backpack deployment.

4.2 Emerging Swarm & Distributed Lift Players

- **Parallel Flight Technologies:** Uses hybrid-electric powertrains for extreme endurance and heavy lift.
  - *Analysis:* Their "Firefly" drone is a hybrid monster focused on long-duration flight (hours), not swarm redundancy. It is a single point of failure system.[13]
- **Flowcopter:** Uses hydraulic motors for heavy lift.
  - *Analysis:* Extremely novel and robust technology, but heavy and mechanically complex. It does not solve the transportability problem.[14]
- **Academic Competitors: TU Delft** and **ETH Zurich** are the global leaders in cooperative aerial manipulation research. They have published the foundational algorithms for multi-drone transport.[15]
  - *Threat:* The DAS-SAR project relies on algorithms similar to those developed by TU Delft. If TU Delft spins out a commercial entity (as ETH did with Verity), they would be a direct technological competitor with deep IP roots.

4.3 Why "Distributed Lift" Wins in SAR

The competitive advantage of DAS-SAR is **Logistical Flexibility**.

- **Scenario:** A climber breaks a leg on a ridge at 2,500m. Weather prevents a helicopter rescue.

- **Malloy/Griff Approach:** Cannot be deployed. You cannot drive a truck to the ridge, and the drone is too big to carry.
- **DAS-SAR Approach:** A team of 6 rescuers hikes up, each carrying one 20kg drone component in a backpack. They assemble the swarm on a small ledge, tether the climber, and fly them down to the valley floor.
- **Conclusion:** DAS-SAR creates a new market segment: **Man-Portable Heavy Lift**. It does not compete directly with Malloy for base-to-base logistics; it competes for the "last mile" extraction in denied terrain.

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5. Failure Analysis: Lessons from the Graveyard

The graveyard of drone startups is filled with companies that underestimated the complexity of physics and regulation. Understanding why similar projects failed is crucial for DAS-SAR's risk mitigation strategy.

5.1 Facebook Aquila (Structural & Control Failure)

Project Aquila aimed to use massive solar drones for internet connectivity. It failed due to **structural failure induced by wind gusts** on final approach that the autopilot could not compensate for.[16]

- **Lesson for DAS-SAR:** A tethered swarm carrying a human acts like a giant sail. Wind gusts on the payload will transmit shockwaves up the tethers to the drones. The **Admittance Control** logic must be robust enough to dampen these gusts without inducing a divergent oscillation (where the drones fight the wind and each other until failure). The simulation phase in Gazebo Harmonic must specifically stress-test wind gust scenarios.

5.2 Zipline Platform 2 (Alternative Approach)

Zipline's P2 drone uses a tether, but instead of lifting the payload *with* the tether, it lowers a "droid" down to the ground.[17]

- **Lesson:** Zipline realized that precision hovering with a fixed-wing aircraft is hard and dangerous. They solved the "last 100 feet" problem by moving the active control to the payload (the droid). DAS-SAR could adopt a similar philosophy by putting active control surfaces or small thrusters on the stretcher itself to help stabilize it, rather than relying solely on the drones above. This "active payload" concept should be explored in Phase 2.

5.3 Early "Delivery Swarms" (Regulatory Hell)

Many startups promised drone swarms for delivery but failed due to regulations (Beyond Visual Line of Sight - BVLOS).

- **Lesson:** Regulatory approval is the "Great Filter." Projects that ignored EASA/FAA certification pathways burned through cash and died. DAS-SAR's explicit focus on **SORA SAIL IV-VI** compliance from Day 1 is the correct strategy. The "Fail-Operational" architecture is not just a technical feature; it is a regulatory necessity to lower the Ground Risk Class (GRC) and obtain flight permission.[6]

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6. Financial Analysis and Business Plan

6.1 Cost Structure and Budget Recalculation

The financial requirements for DAS-SAR are driven by the high cost of specialized engineering talent and industrial-grade aerospace hardware. The following budget estimates are based on 2025 European market rates.

Phase 1: Prototype Budget (Hardware)

The cost to build the 4-drone scout swarm is relatively low, allowing for iterative testing.

- **Per Unit Cost:** ~€2,490.
  - *Airframe:* Holybro X500 V2 Kit (€380).
  - *Compute:* Jetson Orin Nano 8GB (€450).
  - *FCU:* Pixhawk 6C (€215).
  - *Sensors:* RealSense D435i (€415) + Here 4 RTK (€285).
  - *Comms/Power:* SiYi MK15 / Matek BEC / Batteries (€745).
- **Total Swarm (4 Units + Spares): ~€12,000**.[2]
- **Strategic Note:** This low cost allows for "destructive testing"—flying the drones to failure to validate the safety code without significant financial loss.

Phase 2: Heavy Lift Budget (Hardware)

The cost jumps significantly for the human-rated system due to the need for custom fabrication and industrial components.

- **Propulsion:** 48 motors (6 drones x 8 motors) + spares = ~€16,800.
- **Frames:** Custom carbon fiber manufacturing = ~€13,200.
- **Compute:** Industrial Jetson AGX Orin modules (ruggedized) = ~€9,600.
- **Batteries:** Massive 12S 22,000mAh packs (x24 for the swarm) = ~€18,000.
- **Tether System:** Active winches + load cells = ~€12,000.
- **Comms:** Long-range mesh radio (Silvus/Microhard) = ~€9,000.
- **Ground Station:** Rugged laptop + antenna array = ~€5,000.
- **Total Hardware: ~€86,300 - €95,000**.[1]

Labor Costs (The Real Cost Driver)

Building a safety-critical Rust flight stack requires top-tier talent. Rates are based on 2025

European contractor data.

- **Senior Rust/Embedded Engineer:** €115/hr x 1600 hrs = **€184,000**.
- **Computer Vision/AI Engineer:** €130/hr x 1600 hrs = **€208,000**.
- **Mechatronics Engineer:** €95/hr x 1600 hrs = **€152,000**.
- **Full Stack Devs (GCS/App):** 2 x €85/hr = **€272,000**.
- **Total Labor (1 Year): ~€816,000**.[3]

Total Seed Requirement

Combining hardware, labor, and a 20% operational contingency (insurance, travel, legal, facilities):

- Total Hardware: ~€94,580
- Total Labor: ~€998,400 (High Estimate)
- Contingency: ~€218,000
  Total Ask: ~€1.31 Million.1

6.2 Business Model: From R&D to Revenue

The project should adopt a **B2G (Business to Government)** model initially, transitioning to specialized B2B sectors.

1. **Product Sales (Capex):** Selling the hardware swarm systems to National Guard units, Mountain Rescue Services (e.g., TOPR, Alpine Rescue), and Coast Guard units.
   - *Estimated Price Point:* €250,000 per swarm system. This offers a high margin on the ~€95k BOM, factoring in the IP value of the software.
2. **Training & Support (Opex):** Recurring revenue for pilot training certifications, simulator licenses (using the Gazebo digital twins), and annual maintenance contracts.
   - *Strategic Value:* This locks in customers with the proprietary software ecosystem and ensures long-term revenue visibility.
3. **RaaS (Rescue as a Service):** Leasing systems to private ski resorts, offshore oil rigs, or remote mining operations on a standby retainer basis. This lowers the barrier to entry for commercial clients who need the capability but do not want to manage the asset.

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7. Comprehensive Risk Analysis (SORA Framework)

The project's viability hinges entirely on navigating the **Specific Operations Risk Assessment (SORA)** methodology mandated by EASA. This is the single biggest hurdle for the project.

7.1 Regulatory Risk (The "Red" Zone)

- **Risk:** Carrying a human places the operation in the **"Certified"** category (SAIL VI) by default, which requires airworthiness certification comparable to manned aircraft. This

process is prohibitively expensive and slow for a startup.
- **Mitigation:** The "Fail-Operational" 6-drone architecture lowers the **Ground Risk Class (GRC)**. By proving via the "Digital Twin" simulations and Phase 1 testing that the system can lose a motor, a battery, or an entire drone and still descend safely (controlled crash or soft landing), the project can argue for a lower SAIL level (e.g., SAIL IV) within the "Specific" category. The **Emergency Detach** protocol (dropping the failing drone, not the human) is a critical mitigation strategy here. The system is designed so that the swarm never flies over uninvolved people, further reducing GRC.[1]

7.2 Technical Risk: The "Multi-Pendulum" Instability

- **Risk:** 6 drones tethered to one payload create a chaotic coupled system. Wind gusts or sensor drift can cause "fighting"—drones pulling against each other—leading to rapid battery exhaustion or structural failure of the airframe.
- **Mitigation:**
  - **Admittance Control:** Drones are programmed to "give" to tension rather than fighting it, damping the system naturally.
  - **Force Consensus:** Drones share tension data via Zenoh to agree on the payload's state in real-time.
  - **Simulation First:** The "Zero-Hardware" strategy validates these physics in Gazebo Harmonic before a single propeller spins, preventing expensive hardware crashes during development.[4]

7.3 Communication Risk: "Discovery Storms"

- **Risk:** In a SAR scenario, drones might operate over mesh WiFi or LTE. Standard ROS 2 (DDS) floods the network with discovery packets, killing bandwidth. Loss of comms = loss of swarm cohesion.
- **Mitigation:** The adoption of **Eclipse Zenoh** is a "hard" technical requirement. It reduces discovery traffic by 99% and supports routed networks, ensuring the swarm stays connected even in RF-hostile environments. The system is designed to be tolerant of temporary packet loss via the **Raft consensus algorithm** for mission state.[1]

7.4 Market Risk: Adoption Inertia

- **Risk:** Rescue organizations are conservative. They trust helicopters. They may be skeptical of a "swarm of toys" lifting a person.
- **Mitigation:** Phase 1 (Micro Swarm) serves as a technology demonstrator. By showing the swarm carrying 5-10kg dummy loads with perfect stability and recovering from induced failures, the project builds trust. The marketing must emphasize **redundancy**—"A helicopter has one engine; we have 48."

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8. Strategic Roadmap and Milestones

- **Q1 2025: The Digital Twin.**
  - *Focus:* Zero hardware. Build the full 6-drone physics simulation in Gazebo Harmonic. Validate the Rust control logic and Zenoh mesh networking.
  - *Key Milestone:* "Virtual Rescue" demonstration showing the swarm successfully recovering from a single-drone failure in simulation.[3]
- **Q2 2025: The Micro Swarm.**
  - *Focus:* Build 4 x X500 drones. Field test the distributed control algorithms with 5kg payloads.
  - *Key Milestone:* Outdoor flight demonstration of cooperative transport and coordinated maneuvering.
- **Q3 2025: Fail-Safe Testing.**
  - *Focus:* Intentionally "kill" a drone mid-flight in the Micro Swarm to validate the recovery logic and emergency detach protocols. This data is essential for the SORA safety case submission.
  - *Key Milestone:* SORA package submission to the Civil Aviation Authority (CAA/ULC).
- **Q4 2025: The Heavy Lifter.**
  - *Focus:* Fabricate the Phase 2 custom carbon frames and integrate the 40kg thrust motors.
  - *Key Milestone:* Static heavy lift test (lifting sandbags).
- **Q1 2026: Full Scale Demonstration.**
  - *Focus:* Full-scale human extraction demo.
  - *Key Milestone:* Successful extraction of a mannequin (and subsequently a human) in a controlled environment.

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9. Conclusion

The DAS-SAR project represents a high-risk, high-reward venture into the frontier of aerospace robotics. It addresses a genuine humanitarian need—rapid extraction in inaccessible terrain—with a novel technological solution that leverages the asymmetric cost advantages and redundancy of drone swarms.

While the engineering challenges of cooperative aerial manipulation are immense, the project's rigorous focus on **memory-safe software (Rust)**, **resilient networking (Zenoh)**, and **physics-based redundancy (6-agent DLS)** provides a robust framework for success. Unlike failed predecessors that relied on single monolithic airframes or ignored regulatory realities, DAS-SAR's modular, fail-operational architecture is specifically designed to navigate the EASA SORA landscape.

For investors, this is not just a drone play; it is an investment in the next generation of **Safety-Critical Autonomous Systems**. The IP generated—specifically the distributed control algorithms and the Rust-based flight stack—has value far beyond SAR, extending into industrial logistics, construction, and defense. We recommend a full seed investment of **€1.31 million** to execute the 12-month roadmap, contingent on the successful validation of the "Digital Twin" simulation in Q1.

Metric	Value
Total Funding Ask	**€1.31 Million**
Project Duration	12-15 Months to MVP
Primary Market	Search and Rescue (SAR) / Defense Logistics
Technology Stack	Rust, ROS 2, Eclipse Zenoh, NVIDIA Jetson
Key Differentiator	Backpack-Deployable Heavy Lift via Swarm
Regulatory Framework	EASA SORA (Specific Category)

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