When the unexpected hits, VANNA fights back

1. Executive Summary

Virtually Autonomous Neural Network Applications (VANNA), developed by DeepFlight, is a contingency flight control system designed to ensure UAV mission survivability following partial system failure. Current UAV flight controllers lack the adaptive intelligence required to respond to real-time damage in contested environments. As adversarial air defense systems grow increasingly sophisticated, so does the need for systems that can detect and recover from mid-flight anomalies such as rotor loss, sensor spoofing, or GPS denial.

VANNA addresses this gap by integrating a neural network-based fallback controller trained to recognize unstable flight dynamics and issue corrective thrust commands. It passively monitors system health, activates upon failure detection, and takes over control to stabilize the aircraft, complete the mission, or initiate an autonomous landing. Through subsystems like thrust reallocation logic, a CFD-guided control system, and transition layers for system overrides, VANNA equips UAVs with intelligent post-failure response—something conventional PID-based systems cannot deliver.

Initial simulation testing has demonstrated VANNA's ability to maintain flight control under conditions that would typically disable standard UAV systems. The system is currently assessed at Technology Readiness Level (TRL) 3, with a development path targeting TRL 5 by Q4 2025. VANNA performs real-time inference on an NVIDIA Jetson Nano and includes a fallback mechanism that reverts control to a Pixhawk Cube in the event of GPU failure, meaning that the system can maintain safe and stable flight even if its AI-based controller fails.

As defense initiatives like Overmatch and the DoD's counter-UAS strategies increasingly emphasize autonomy in disconnected, denied, intermittent, and limited bandwidth (DDIL) environments, VANNA aligns directly with these goals. Over the next 12 months, DeepFlight aims to develop a physical testbed, refine real-time damage recognition, and validate VANNA through flight trials. In the long term, this technology will scale across military and civilian UAV platforms, enabling intelligent autonomy where traditional control systems fail.

DeepFlight is currently seeking defense-aligned sponsors to fund VANNA's transition from simulation to flight readiness. Support will enable sensor integration, hardware fabrication, and formal flight testing across varied aerial platforms to ensure the system is mission ready.

2. Background

Project Short Title: VANNA

Project Title: Virtually Autonomous Neural Network Applications

Project Overview: This project proposes the development of a cost-effective and modular flight algorithm capable of allowing unmanned aerial vehicles (UAVs) to operate despite sudden malfunctions (e.g., propeller loss, sensor failure, etc.) The algorithm aims to leverage artificial intelligence to adapt thrust and control responses to respond to damage detected in real time, with significant implications to the aerospace industry.

Technical Objectives/Deliverables: Demonstrate UAV's ability to maintain flight and autonomously return to base following mid-mission damage (e.g., rotor loss, GPS jamming, or IMU spoofing), with >90% mission completion rate over 20 field trials.

3. Project Rationale

Maintaining operational capability following partial UAV failure is necessary when executing tactical missions, conducting intelligence, surveillance, and reconnaissance operations, and ensuring asset recovery. From joint operations centers to tactical units on the field, all levels of modern military aviation require adaptable systems that can respond to unexpected in-flight damage, particularly in environments where GPS signals, sensor feeds, or external communications may be degraded or denied. This need for real-time autonomous adaptability has been emphasized by the Department of Defense, which stated that “unmanned systems are fundamentally changing how militaries achieve their objectives [1]”. Projects like Overmatch further reinforce that “mission autonomy in disconnected, denied, intermittent, and/or limited bandwidth (DDIL) environments” is no longer optional [2]. Table 4-1 further examines the strengths and weaknesses of current UAV survivability approaches, aiming to weigh the operational tradeoffs and outline whether VANNA addresses the limitations of conventional systems.

4. Introduction

As the air defense systems of adversaries grow more sophisticated, the demands for unmanned aerial vehicles are evolving just as rapidly. While conventional UAV flight controllers are highly optimized for stability and control under normal conditions, they are unreliable when reacting to unpredictable threats. The current technologies such as PID flight controllers, return-to-base logic, etc., systems excel at flying when a mission goes as planned. However, under enemy fire, in GPS-jammed zones, during sensor spoofing attacks, and similar unforeseen scenarios, UAVs may suffer partial failures that render conventional controllers unable to respond.

Table 4-1 – Current Capabilities

Current Technology	Benefits	Limitations
Conventional PID Controllers	• Simple, time-tested • Efficient for nominal flight conditions	• Cannot adapt to damage scenarios • Fail under sensor blackout or actuator failure
Predefined Fail-Safes	• Enables basic safety behaviors (e.g., Return-to-home, Forced Landing)	• Do not account for aerodynamic changes • Often terminate missions prematurely
Redundant Sensor System	• Provides backup data streams for fault tolerance	• Adds system complexity and weight • Does not solve asymmetric control or actuator issues

These architectures lack the capacity to recognize abnormal flight states and adaptability and reconfigure in real time. This limitation turns recoverable damage into total mission loss, which is why a contingency layer to **take over when things go wrong** is not just beneficial, but imperative to ensure mission success.

VANNA (Virtual Autonomous Neural Network Applications) is an auxiliary control system designed to augment existing UAV flight controllers by unlocking real-time adaptability capabilities following partial system failures.

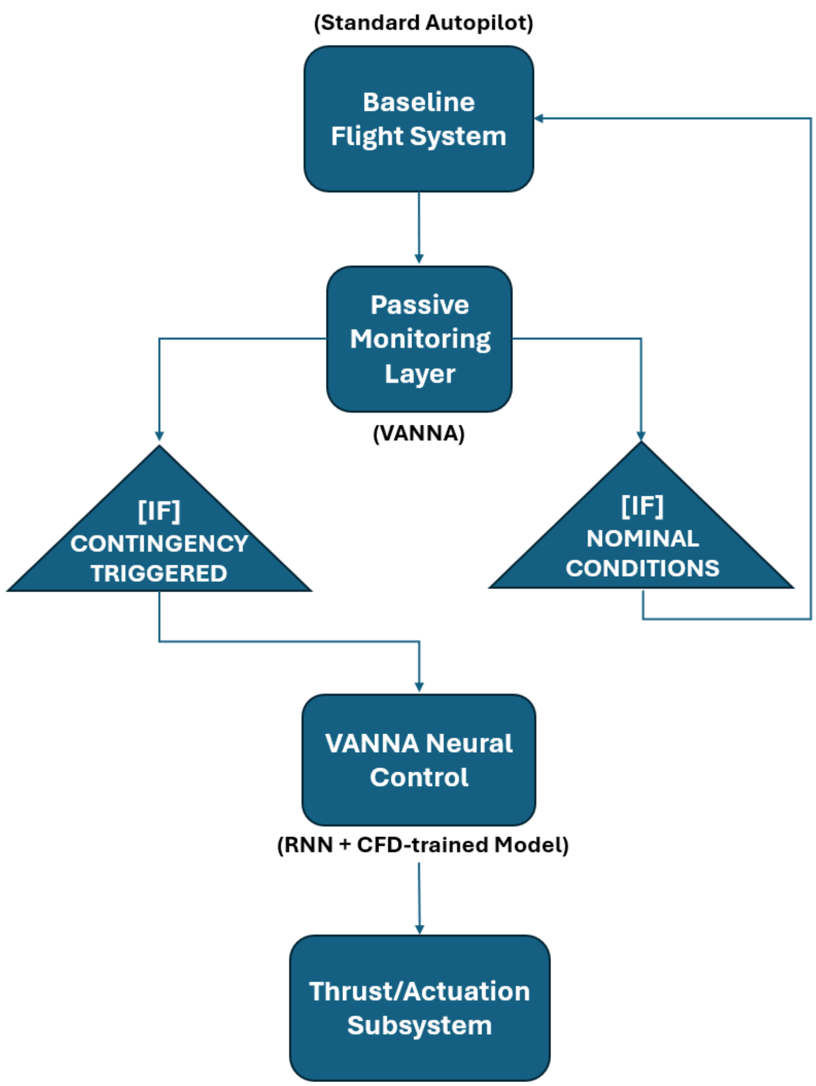
This white paper covers the overall development, architecture, and benefits of VANNA. This document is intended to bridge conceptual design and preliminary research, as detailed in the PDR, with our formal sponsorship proposal, offering prospective defense partners a clear understanding of VANNA's role, value, and technical advantages within the constantly evolving domain of UAVs.

5. Solution Overview

VANNA is a fallback control system designed to extend UAV mission survivability following partial system failure. Operating as a contingency layer, VANNA remains passive under nominal conditions but activates when the UAV suffers critical disruptions. Once engaged, VANNA overrides conventional control logic to stabilize the aircraft and complete the mission or initiate a safe autonomous landing. VANNA utilizes an adaptable engine trained in a high-fidelity simulation environment. This engine allows the system to recognize damage-induced aerodynamic changes and dynamically issue new thrust commands.

Figure 5-1 provides a visual breakdown of the VANNA system architecture, illustrating how to control transitions from the baseline autopilot to VANNA under failure conditions.

Figure 5-1 – VANNA System Diagram



VANNA Integration Strategy & Risks/Mitigations:

To execute this contingency response, VANNA is structured into **five subsystems.** Each component plays a critical role in detecting instability, evaluating conditions, and issuing corrective control outputs.

- **State Monitoring Module:** Detects anomalies by tracking IMU, GPS, and power data for rotor drop, signal loss, etc.
- **CFD-Guided Neural Control:** Predicts control commands using a neural network trained on simulated flight data.
- **Thrust Reallocation Logic:** Redistributes thrust to compensate for asymmetric conditions (e.g., damaged propeller).
- **Control Transition Layer:** Switches control from the default autopilot to VANNA when failure thresholds are passed.
- **Simulation-to-Reality Transfer Pipeline:** Refines VANNA behavior by blending synthetic data with real-world flight feedback.

Table 5-2 – VANNA Risks & Mitigations

Risk	Impact	Mitigation
AI doesn't respond well to unexpected damage	May fail to stabilize the UAV if the damage type wasn't seen during training	Keep improving the AI using real flight data to teach it how to handle more damage types
Triggers fallback mode when there's no real issue	Could override a healthy autopilot and cause instability	Use better thresholds and combine data from multiple sensors to avoid false alarms
Slow reaction time after failure	May not correct the issue fast enough, risking a crash	Optimize code and hardware to reduce delay when switching to fallback mode

6. Future Direction

Although VANNA has demonstrated its core functionality through early-stage testing and simulated demonstrations, the modularity of its neural network-based control pipeline enables major upgrades across both software and hardware systems. These improvements are designed to validate VANNA in real-world contested flight scenarios, especially under conditions that render conventional PID-based controllers ineffective.

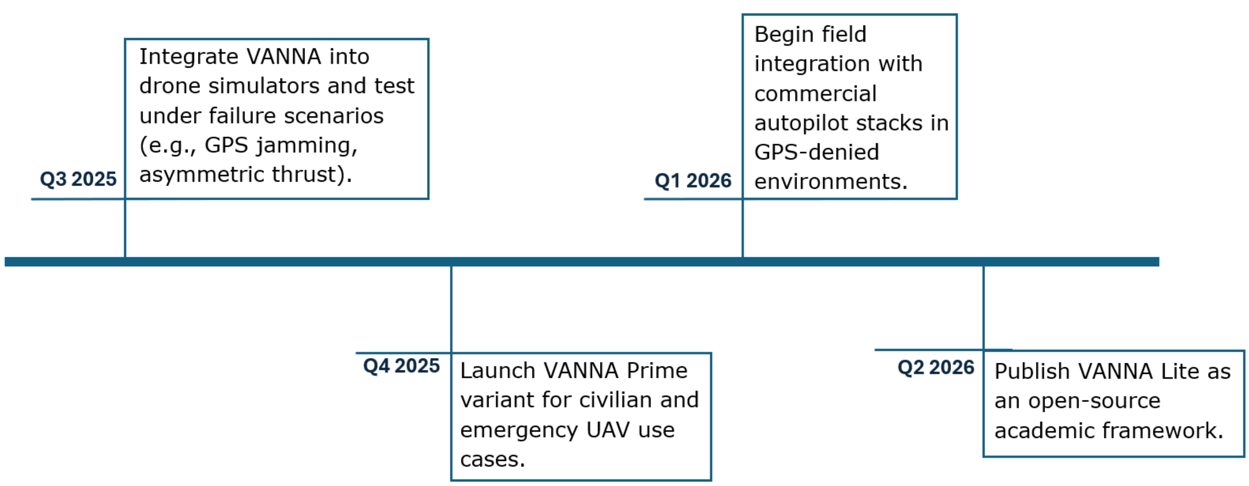
With an estimated budget of $15,000, we can implement the following upgrades and milestones to ensure VANNA reaches operational field-readiness:

Integrating VANNA into **drone simulators** to **test performance** across failure scenarios like **GPS jamming, asymmetric thrust, and mid-flight actuator loss**.

Integration with **Commercial Flight Stacks** (e.g.**, ROS2/MAVLink** compatibility) to **enable** VANNA as a **plug-and-play** fallback module for **existing UAV systems**.

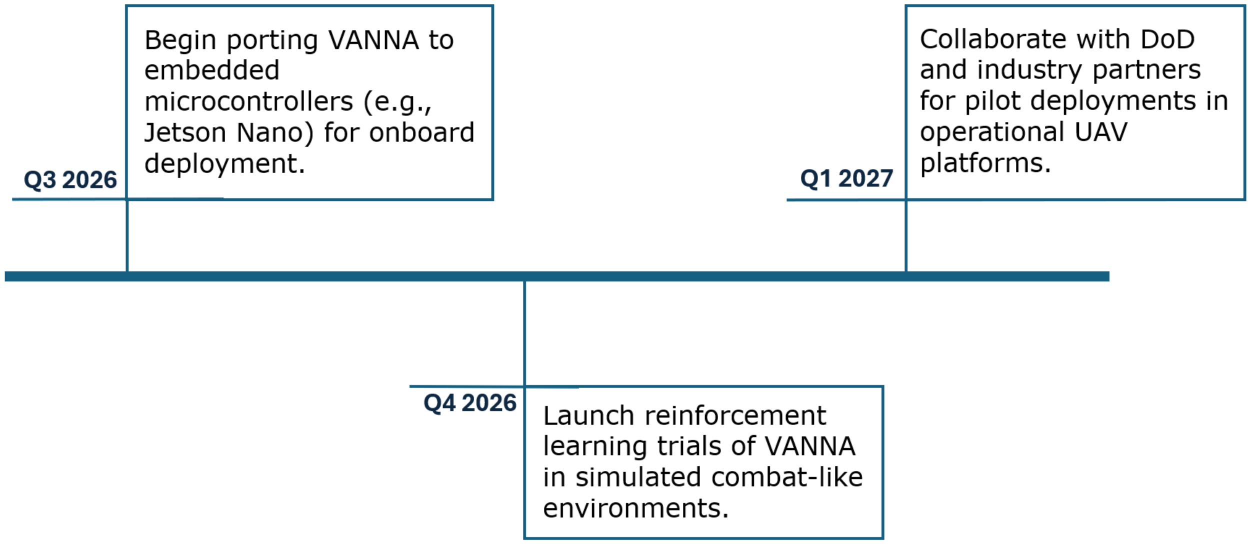
Developing a real-time **flight state classifier** that enables VANNA **to detect abnormal UAV behavior** and **automatically switch to its contingency control layer** when needed.

Figure 6-1: Strategic Timeline (12 months)



Achieving these milestones will position VANNA for early-stage validation and field readiness, laying the groundwork for more advanced autonomy integrations in the following year.

Figure 6-2 - Long-Term Vision (12+ months):



As VANNA transitions beyond prototyping, our long-term efforts will focus on scaling its deployment across defense and civilian UAV platforms in collaboration with key stakeholders.

7. References

1. https://media.defense.gov/2024/Dec/05/2003599149/-1/-1/0/FACT-SHEET-STRATEGY-FOR-COUNTERING-UNMANNED-SYSTEMS.PDF
2. https://www.diu.mil/latest/department-of-defense-successfully-deploys-commercial-ai-solutions-for?utm