

Neuromorphic ASCENT: Revolutionising Aircraft Stores Compatibility and Intelligent & Autonomous Systems

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Abstract

Aircraft stores separation techniques have long relied on traditional methodologies such as wind tunnel testing, computational fluid dynamics (CFD), modelling and simulation, and flight testing, as outlined in MIL-HDBK-1763 [1] and STANAG 7068 [2]. While these approaches have proven effective, they are often costly, time-intensive, and constrained by outdated assumptions. This paper introduces Neuromorphic Aircraft Stores-Centric Employable and returnable Networked Technology (ASCENT), a groundbreaking innovation that leverages neuromorphic event cameras, advanced instrumentation, and neural networks to redefine aircraft stores compatibility and interoperability. [3] By integrating physics-informed neural networks (PINNs) and combinatorial test techniques, Neuromorphic ASCENT significantly reduces certification timelines and costs while enhancing operational safety and efficiency.

Neuromorphic ASCENT employs event-driven processing inspired by human neural functions, enabling real-time decision-making and adaptability across diverse platforms. Neuromorphic event cameras focus on significant changes in the environment, providing precise imagery and reducing computational overhead. These cameras, combined with instrumented measurement units (IMUs) and PINNs, allow for tailored ejection forces and trajectories, minimizing structural stress on aircraft and ensuring safe autonomous separation of stores. Unlike traditional stores, which rely on high ejection velocities and onboard cameras, neuromorphic stores autonomously "know" their position relative to the aircraft and safely navigate away at lower velocities. This capability eliminates the need for platform-mounted cameras and enhances operational flexibility. [3], [4]

The paper explores operational implications of Neuromorphic ASCENT, including its role in enabling returnable aircraft stores for refuelling, rearming, reprogramming, and secure analysis. This shift supports reuse of stores, reducing costs and promoting sustainability. Additionally, Neuromorphic ASCENT enhances the F2T2EA kill chain process by introducing enhanced continuous "Assess" and "Abort" criteria, potentially transforming it into an F2T2E2A2 framework. Forward-facing cameras on stores capture real-time data to refine abort/assess decisions, enabling dynamic mission adjustments and safe return of stores to other platforms. [5], [6]

Neuromorphic ASCENT also addresses critical challenges in aircraft stores compatibility and interoperability. By leveraging advanced CFD models and simulation tools, the technology ensures aerodynamic, structural, electrical, and functional compatibility across legacy and next-generation systems. Combinatorial test techniques further optimize certification processes, reducing sample sizes while improving fault detection rates. This approach supports multi-platform and multi-weapon integration, enabling accurate predictions across diverse flight conditions and scenarios.

The paper highlights the broader implications of Neuromorphic ASCENT for modern warfare. Its neuromorphic architecture facilitates real-time coordination of distributed assets, enhancing mission success rates and operational safety. The technology's adaptability and reusability align with the evolving needs of military

operations, offering scalable and sustainable solutions. By overcoming limitations in traditional testing methods and operational trade-offs, [4] Neuromorphic ASCENT paves the way for smarter, safer, more efficient military systems and represents a transformative leap in aircraft stores technology, combining brain-inspired computing with advanced neural networks to redefine compatibility, interoperability, and operational efficiency. This innovation not only reduces costs and development timelines but also lays the foundation for a more adaptable and sustainable future in military technology. By integrating cutting-edge neuromorphic capabilities, Neuromorphic ASCENT is poised to revolutionize the science and engineering underpinning aircraft stores compatibility, ensuring mission success in the complexities and character of modern warfare. [5]

Keywords: aircraft stores compatibility, active separation control, neuromorphic event cameras

1. Introduction

This paper introduces a cutting-edge technology that's poised to transform how we approach aircraft stores[1], drones, and intelligent and autonomous systems.

Neuromorphic Aircraft Stores Centric Expendable, returnable Networked Technology (ASCENT) is set to become a superpower in both the Systems Engineering and the Test and Evaluation (SETE) communities and not just a technological advancement; it's a leap forward in how we think about imagery as well as command and control in modern military and complex systems operations.

This paper investigates the use of Neuromorphic Event-based Cameras (NECs) and Physics Informed Neural Networks (PINNs) for determining real time tracking and analysis of aircraft stores separation dynamics during the safe separation and jettison of store(s) or armament(s) from aircraft or aerial launch vehicles including drones. These event cameras and instrumentation provide a digital history of the trajectory for data processing to guide the stores' control surfaces and to provide near real time service life. Ultimately, the investigations and research should also consider the safe return of the store(s) or armament(s) using neuromorphic event cameras, separately or in conjunction with other instrumentation. Such developments are critical for determining suitability and applicability to the T&E, ground and flight test, and Model-Based Systems Engineering and T&E (MBSETE) communities for Aircraft Stores Compatibility[2] (ASC) focusing on stores separation and Network-Enabled Weapons (NEW)[3] and Intelligent and Autonomous Systems (IAS) of the future. This is vitally important as we head into such IAS ostensibly dominating the battlefields and spaces today with lethal Autonomous Weapon Systems (AWS),[4] [7], [8].

Store separation techniques for military applications, including wind tunnel testing, computational fluid dynamics, modelling and simulation, flight testing, and interoperability, are well established in MIL-HDBK-244 (1990) [9], MIL-STD/HDBK-1763 (1998) [1] for ASC and STANAG 7068 (2001) [2] for Armament Systems Compatibility and Interoperability (ASCI) respectively. This paper examines

[1] An 'aircraft store' is traditionally: any device intended for internal or external carriage and mounted on aircraft suspension and release equipment, whether or not the item is intended to be separated in flight from the aircraft or the store separated. They are classified as Non-expendable (Carriage Only) and Expendable (Carriage and Separation from an aircraft is acceptable within Employment and Jettison operating envelopes), MIL-HDBK-1763 (1998) [1] and STANAG 7068 (2001) [2].

[2] *Ibid,* The ability of each element of specified aircraft stores configuration(s) to coexist without unacceptable effects on the physical, aerodynamic, structural, electrical, electromagnetic, optical or functional characteristics of each other under specified ground and flight conditions.

[3] A class of precision-guided munitions derived from GPS-aided weapons, which are guided to a specific coordinate entered prior to release and have the ability to have targeting coordinates updated in flight through the use of a common datalink, and be tracked by aircraft and other platforms logged into the same network. [8]

[4] There is no internationally agreed definition of the term 'autonomous weapon system'. The term refers broadly to any weapon system that, once activated, can select and engage targets without further intervention by an operator. Thus, "AWS include systems with varying degrees of autonomy. These practices are not intended to be limited to 'lethal AWS' [in] a concept used by the [UN] GGE [Group of Government Experts on Lethal AWS].' Importantly, the International Committee of the Red Cross understands the term 'AWS' as 'a weapon system that is designed to select and engage one or more targets without the need for human intervention after activation." ICRC notes "that the process by which AWS function entails loss of human control and judgement in the use of force, bringing risks for civilians, challenges for IHL compliance and fundamental ethical concerns for humanity." [17] p13

the implications of over a century of experience in these methods for future applications, such as Neuromorphic ASCENT, and explores the use of analogies instead of "grandfathering" to reduce simulation and flight test costs while maximising experimental and testing outcomes. The focus is on certifying employment and jettison envelopes for operational use. Case studies will highlight lessons learned from F/A-18 and F-16 aircraft stores compatibility projects conducted under NATO Research and Technology Organisation and the Five Eyes TTCP nations in NATO RTO AGARDograph 300 Vol 29 [10] and associated SCI 277 series of lectures. These studies aim to advance the science and engineering of future aircraft stores, enhance integration with network-enabled weapons, and support emerging approaches to higher-level ASCI.

The paper briefly examines the challenges of modern complex Systems of Systems (SoS) and families of SoS, particularly in military and safety-critical contexts such as lethal AWS. These systems are increasingly integrated, complex, and interdependent, often exhibiting emergent properties or unpredictable behaviours even without considering human involvement. As software-intensive systems advance to perform higher-order human-like functions, such as strategy and decision-making beyond basic control, defining system requirements becomes more difficult. This highlights the importance of incorporating representative human agency and decision-making to adapt these systems during development, [7], [11], [12].

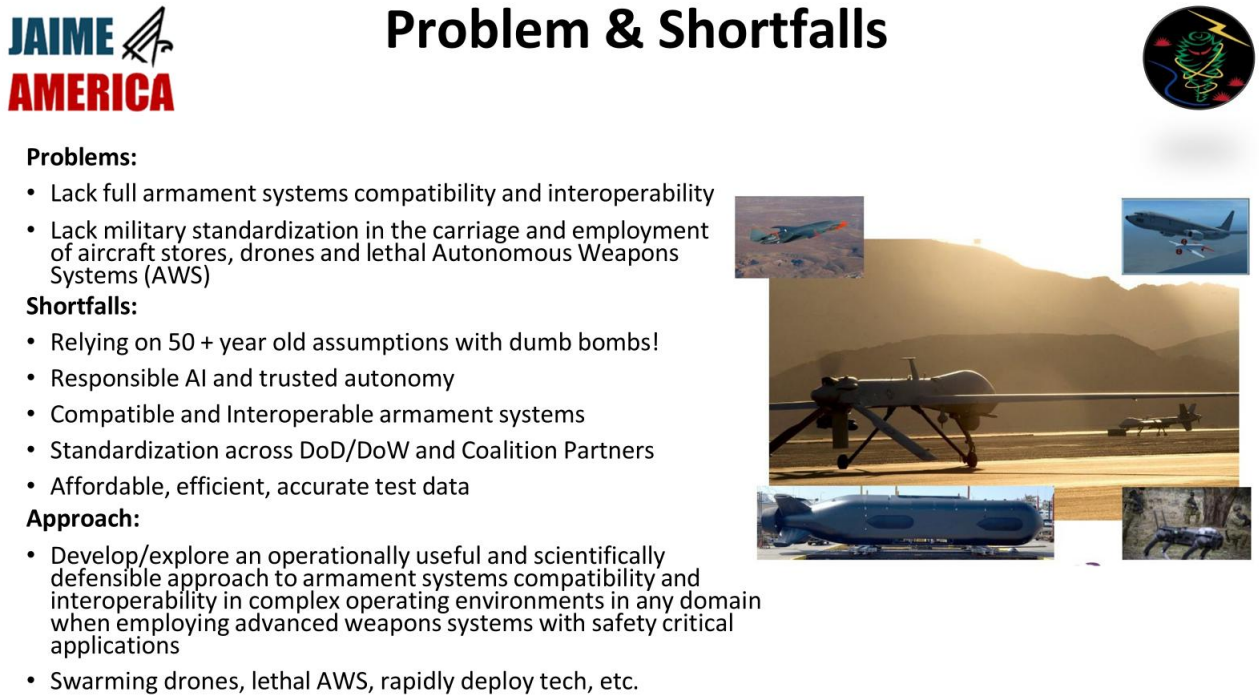


Figure 1. Problems and shortfalls with "dumb" unguided bombs and the wide-spread use of poorly conceived lethal AWS if not addressed scientifically and in doctrine, [5].

1.1 The Problem: Legacy Systems in a Modern Battlespace

To contextualise the challenge facing contemporary military organisations, consider the absurdity of attempting to run modern smartphone applications on a mobile phone from four decades ago. The hardware, software architecture, and underlying assumptions are so fundamentally misaligned that the endeavour would be entirely futile. This analogy, whilst seemingly reductive, accurately captures the operational reality confronting many of today's defence forces. Despite the rapid and accelerating evolution of military technologies, a significant proportion of existing systems continue to operate on outdated assumptions and methodologies. Critically, these legacy frameworks are being relied upon to manage sophisticated modern weapons systems, Unmanned Aerial Vehicles (UAVs), and lethal AWS, a mismatch that carries profound operational and strategic consequences, [4], [5].

The specific challenges that arise from this technological misalignment are multifaceted and deeply

interconnected. Current systems frequently lack full compatibility and interoperability across platforms, creating dangerous seams in operational capability. Compounding this, many testing and deployment methodologies continue to rely on approaches developed decades ago, originally designed for comparatively rudimentary unguided "dumb" bombs that bear little resemblance to the precision-guided, network-enabled munitions of today. The emergence of Artificial Intelligence (AI) introduces an additional layer of complexity, most notably the critical imperative for responsible AI governance and trusted autonomy within military systems. Furthermore, despite numerous technological advances across the defence sector and advances in military experimentation through use of the GUIDEx (2004) [13], existing experimentation and testing methodologies remain prohibitively costly, operationally inefficient, and frequently fail to generate data of sufficient accuracy or granularity to support informed decision-making. These compounding challenges demand a solution that is not merely innovative in isolation, but fundamentally adaptable to the multidimensional complexities of modern warfare and should be addressed scientifically considering our evolving 'socially contract' to use DG DASA's point of view, [5].

1.2 Traditional Testing Limitations and Operational Trade-offs

Within the specific domain of aircraft stores separation testing, the inadequacies of conventional approaches are particularly pronounced. Traditional techniques such as photogrammetry and aircraft camera triangulation, whilst representing the state of the art at the time of their development, are demonstrably ill-suited to accurately reflecting real-world operational conditions. These methods struggle to achieve the precise measurements required for modern weapons integration and are largely incapable of replicating the complex, flexible wing dynamics observed during actual flight operations. The result is a persistent gap between laboratory or range-based test data and the conditions encountered in operational environments as shown in Figure 2.

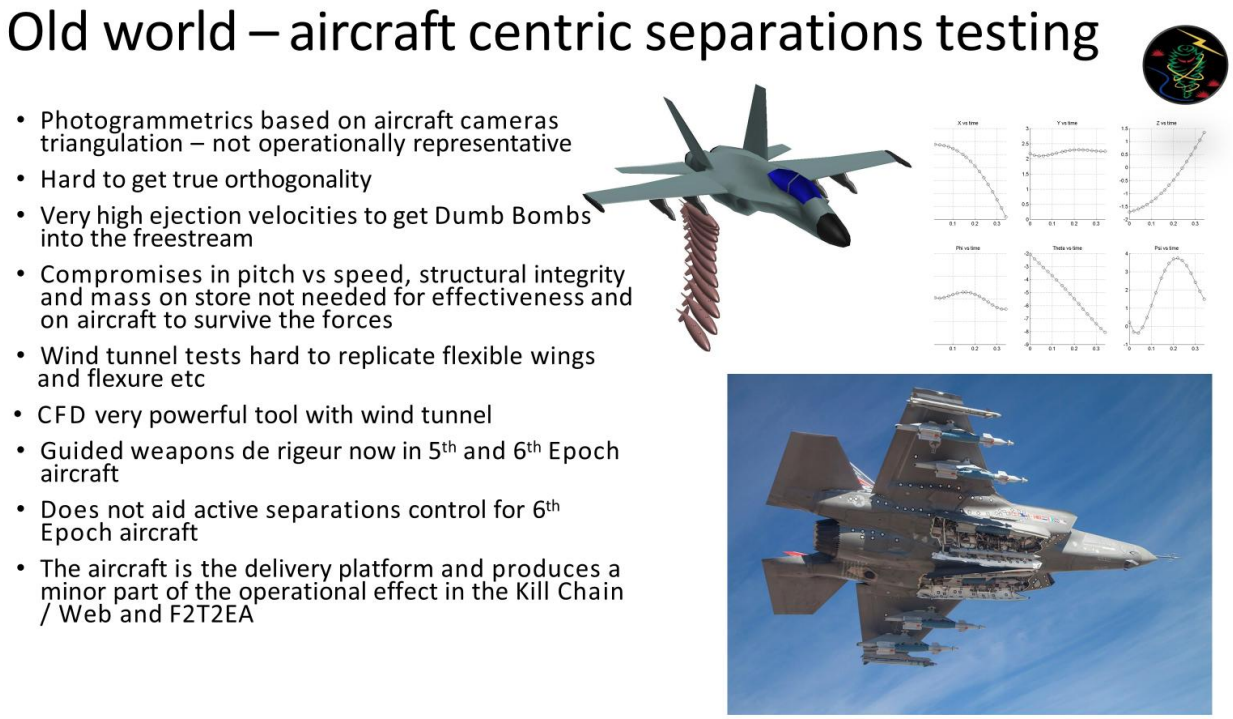


Figure 2. Platform centricity for integration and separations, [5]

Operational trade-offs associated with conventional stores deployment further exacerbate these limitations. Current practice necessitates the use of extremely high ejection velocities to ensure safe weapon separation from the aircraft. However, these high ejection speeds impose significant penalties on aircraft structural integrity and contribute unnecessary weight to the overall system. Moreover, such methods offer only limited support for the advanced separation control mechanisms that will be essential for sixth-epoch aircraft platforms. Perhaps most fundamentally, this conventional approach conceptualises the aircraft as merely a delivery platform or passive vehicle, rather than as

an integrated and active component of the broader weapon system. This framing fails to account for the aircraft's role in achieving mission success across the full extent of the mission and kill chain, representing a significant conceptual limitation that Neuromorphic ASCENT is specifically designed to address.

1.3 Introducing Neuromorphic ASCENT

Neuromorphic ASCENT represents a genuinely transformative development in the field of armament and C2 technologies. Whilst the nomenclature may initially evoke associations with science fiction, the technology is grounded in rigorous scientific principles and constitutes a rapidly maturing area of applied research. At its conceptual core, Neuromorphic ASCENT can be understood as endowing military systems with a form of artificial cognition, one inspired by the architecture and operational principles of the human brain.

More precisely, Neuromorphic ASCENT represents a paradigm shift not only in range data capture but also in the broader domain of C2 technologies. It leverages brain-inspired, or neuromorphic, computing to deliver human-analogous decision-making capabilities for aircraft stores, UAVs, and LAWS. The technology integrates three principal technical components. First, Neuromorphic Event Cameras (NECs) emulate human neural and ocular functions by responding only to significant and meaningful changes in the visual field, thereby providing highly precise imagery whilst dramatically reducing redundant data processing. Second, Physics-Informed Neural Networks (PINNs) are trained to adhere to universal physical laws, ensuring that the system's predictive and adaptive capabilities remain valid across any aircraft platform without requiring platform-specific reprogramming. Third, the system facilitates real-time coordination through a neuromorphic architecture that integrates data streams from multiple distributed sources, enabling rapid decision-making and the seamless coordination of distributed assets across complex operational environments.

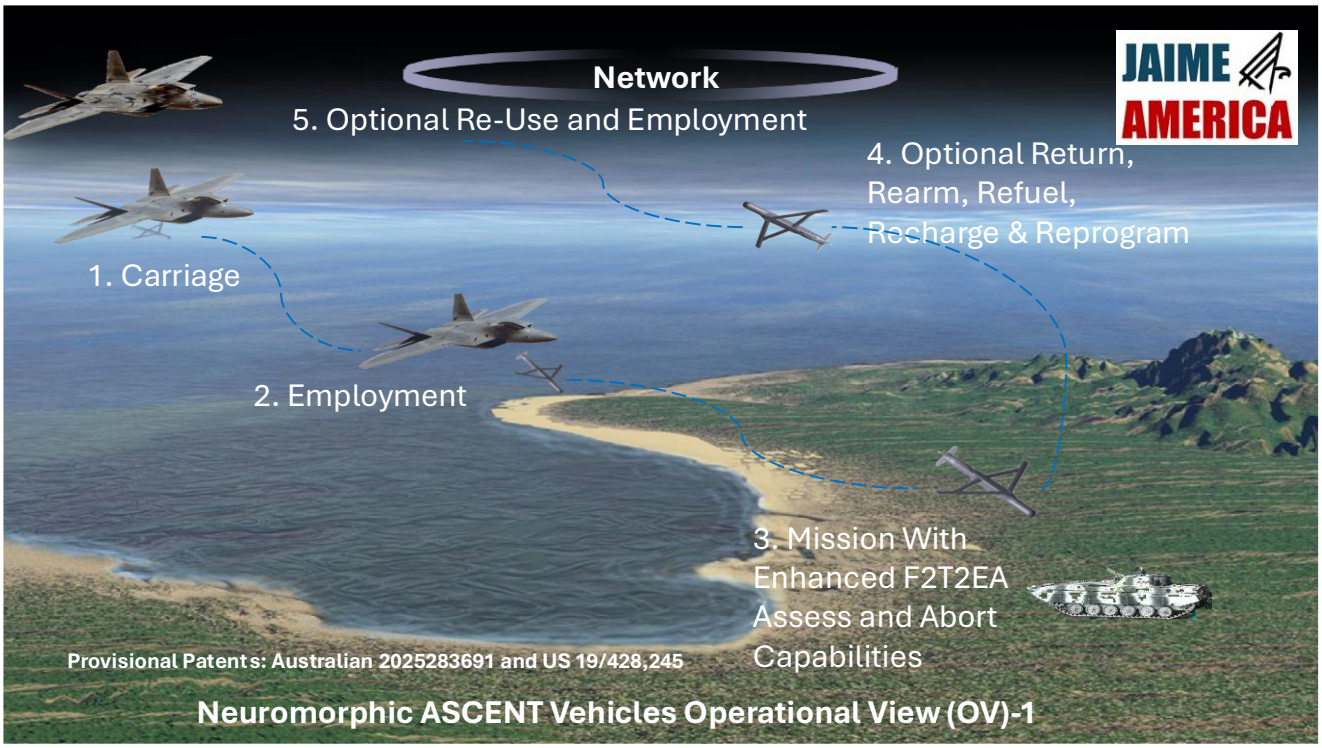


Figure 3. Operational View 1 for the future of weapons separations and missions using the Kill Chain F2T2EA, [5].

2. Operational Benefits of Neuromorphic ASCENT

The advantages conferred by Neuromorphic ASCENT extend considerably beyond its technical specifications, addressing critical operational requirements whilst simultaneously establishing the foundations for a more efficient and sustainable defence capability. In terms of interoperability, the

system functions seamlessly across heterogeneous platforms, conferring a degree of versatility that is largely unattainable with legacy approaches. Its efficiency gains derive from the event-driven processing architecture of NECs, which focuses computational resources exclusively on significant changes rather than processing continuous, largely redundant data streams. From a safety perspective, the system provides high-speed, autonomous corrections to ensure the safe carriage and employment of stores under a wide range of conditions as shown in Figure 3 Phases 1 and 2.

The system's adaptability is perhaps its most strategically significant attribute: Neuromorphic ASCENT learns and evolves autonomously in response to dynamic environments, without requiring manual reprogramming during Figure 3 Phase 3, a capability that is essential in the fluid and unpredictable contexts of modern warfare. Finally, the system's design explicitly supports the reusability of assets, enabling the retrieval and redeployment of stores and platforms in a manner analogous to the transition from single-use disposable cameras to reusable high-resolution digital imaging systems, Figure 3 Phases 4 and 5. This reusability paradigm supports rapid capability enhancements at substantially reduced per-item costs for both stores and platforms, whilst simultaneously enhancing aircraft stores compatibility across aerodynamic, structural, electrical, and functional characteristics for both flight and ground conditions.

To illustrate the operational implications of these capabilities, consider a lethal AWS or drone that can autonomously adjust its trajectory in real time to avoid obstacles or recalibrate its mission parameters in response to changing conditions. Neuromorphic ASCENT renders this possible through the integration of advanced sensors and neural networks that are demonstrably better than their old frame based forebears. Extending this further, envision a collaborative fleet of UAVs sharing data via neural networks in real time, adapting to mission changes without human intervention, and doing so safely, flexibly, and at reduced cost. This level of operational efficiency and adaptability represents a transformative potential that Neuromorphic ASCENT introduces to the contemporary battlespace.

2.1 Aircraft Stores Compatibility and Interoperability

A critical application domain for Neuromorphic ASCENT lies in the enhancement of aircraft stores compatibility and interoperability. Aircraft stores compatibility, in its conventional definition, focuses on ensuring that weapons systems can be safely and effectively integrated onto specific aircraft platforms. Armament systems interoperability extends this concept further, enabling seamless interaction between different platforms in pursuit of a unified operational objective. Neuromorphic ASCENT addresses both dimensions simultaneously.

With respect to compatibility, the system ensures the physical fit, functional integration, and safe escape of stores from the host platform. Interoperability is addressed through the facilitation of data sharing, task coordination, and cybersecurity protocols across heterogeneous platforms. Enhanced testing capabilities combine advanced modelling, simulation, and wind tunnel testing to improve both the accuracy and efficiency of the aircraft stores certification process. The vision enabled by Neuromorphic ASCENT is one in which multiple compatible and interoperable aircraft and UAVs coordinate their actions with precision, sharing intelligence and executing complex, multi-domain missions seamlessly, a future that the technology is actively working to realise.

2.2 Emergent Properties and Stores Deployment

Neuromorphic ASCENT introduces a range of emergent properties that fundamentally alter the parameters of stores deployment. When extending the operational envelope for munitions employment by increasing ranges and deployment parameters, the technology yields a materially higher probability of mission success. Neuromorphic stores utilise two primary data sources to guide separation from the host aircraft: Neuromorphic Event Cameras (NECs) and Instrumented Measurement Units (IMUs), including accelerometers embedded in nose or tail fuzes, which capture trajectory data and vibration signatures with high fidelity.

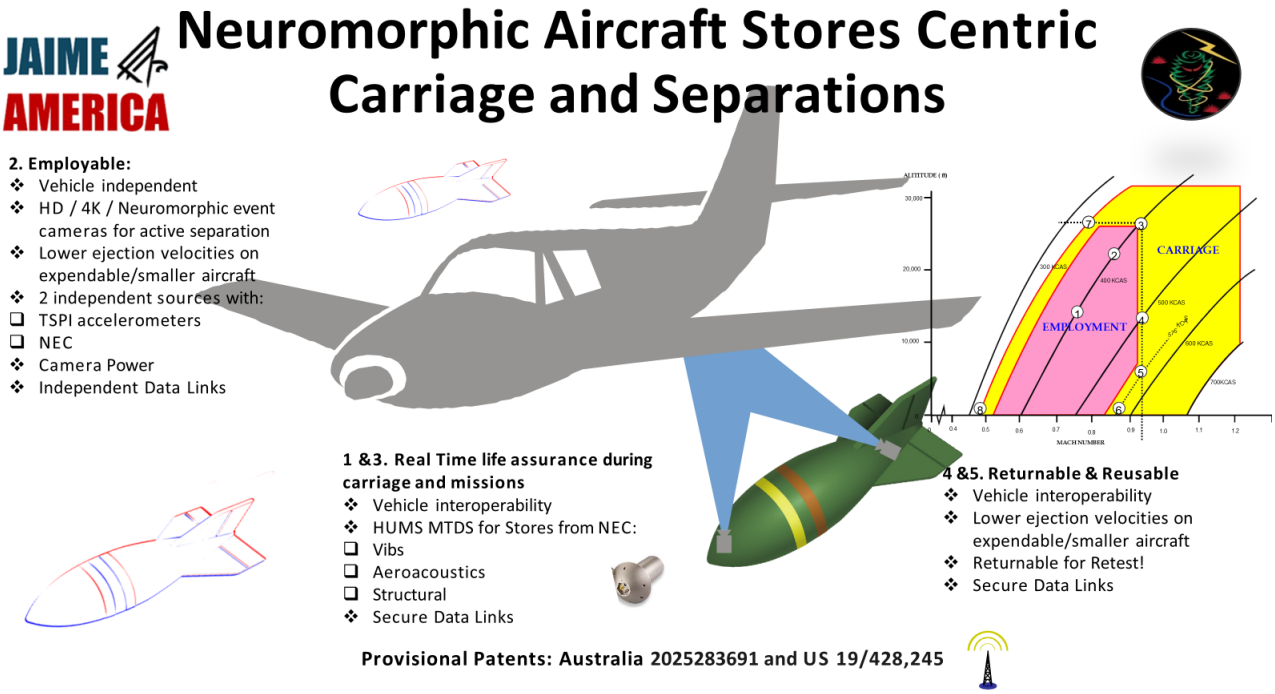


Figure 4. Aircraft Stores Centric perspective with neuromorphic event cameras guiding the weapon from and to compatible aircraft, [5]

A particularly significant operational advantage is that Neuromorphic stores are guided away from the aircraft at substantially lower ejection velocities than their conventional counterparts, as shown in Figure 4 Phase 2. The stores possess autonomous situational awareness of the host aircraft's position and are capable of safely manoeuvring away from it without the need for onboard platform cameras. This capability eliminates a significant source of system weight and complexity. Modelling and simulation, supported by high-fidelity Computational Fluid Dynamics (CFD), underpin the analysis required to train the PINNs. CFD modelling examines fluid flow characteristics to determine force and trajectory parameters with a level of precision and speed that far exceeds conventional methods. To contextualise the cost implications, current Defence Science and Technology Group (DSTG) and US Air Force Research Laboratory (AFRL) methodologies for solving a single trajectory cost approximately one million dollars and have required approximately one week of computation time, [6]. Furthermore, as velocities approach Mach 1, the associated shockwave phenomena become exceedingly difficult to replicate at scale in wind tunnel environments. CFD offers a pathway to resolving these challenges more rapidly and cost-effectively.

2.3 Camera Technology: Frame Cameras versus Neuromorphic Event Cameras

The distinction between traditional frame cameras and Neuromorphic Event Cameras is instructive in understanding the technological leap that Neuromorphic ASCENT represents. As shown in Figure 5a, conventional frame cameras capture images at fixed intervals, generating large volumes of data, much of which is redundant, and introducing latency that is incompatible with the demands of high-speed stores separation and autonomous decision-making. Neuromorphic Event Cameras, by contrast, operate on an event-driven paradigm, responding only to changes in the visual scene as they occur. This approach is directly analogous to the functioning of the human visual system and the neural architecture of the brain.

The underlying computational framework leverages Artificial Neural Networks (ANNs) that emulate brain function and specifically employs Spiking Neural Networks (SNNs) or architectures that process information through discrete spikes, mirroring the brain's own signaling mechanisms, rather than through continuous value streams. This enables intelligent agents to perform complex tasks in real time, with enhanced interpretability and reliability. The integration of PINNs, as shown at Figure 5b, are being trained to adhere to universal physical laws, ensures adaptability across any aircraft platform. When these neural network architectures are combined with neuromorphic algorithms, the

resultant capability represents a qualitative leap beyond what either component could achieve in isolation.

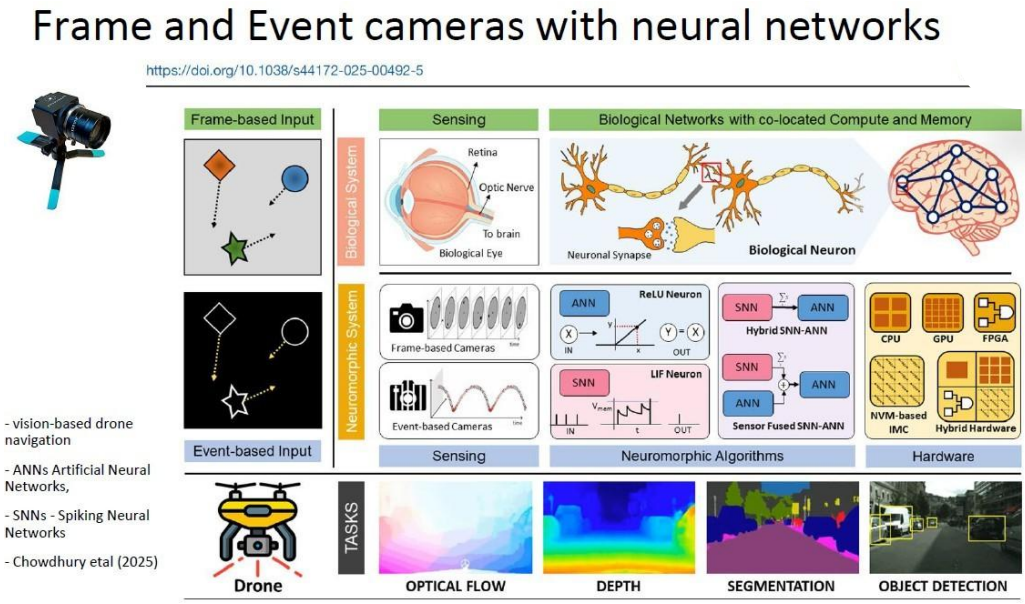


Figure 5a. Classic Frame and Neuromorphic event camera with neural networks, [14]

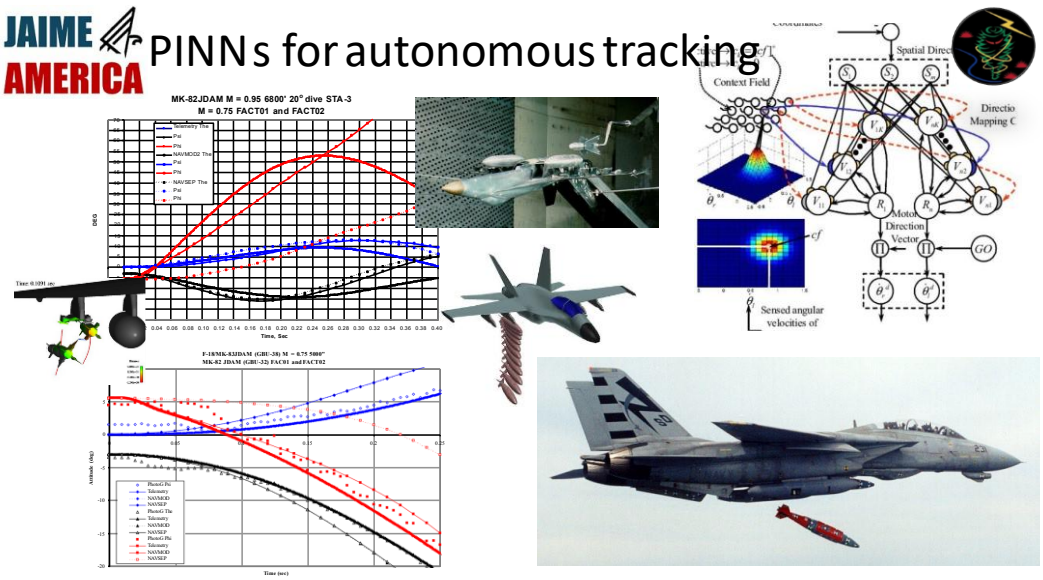


Figure 5b. Physics Informed Neural Networks using neuromorphic event cameras to train the active separation control, [5]

2.4 Combinatorial Testing Techniques

Neuromorphic ASCENT employs combinatorial testing techniques to substantially reduce both the time and cost associated with certifying military aircraft systems. By decreasing the sample sizes required whilst simultaneously improving fault detection rates, the approach delivers significant efficiency gains, particularly in the context of complex, multi-parameter testing scenarios associated with the integration of external stores. Multi-weapons and multi-platform-trained neural networks and models enable accurate predictions across a wide variety of flight conditions and operational scenarios.

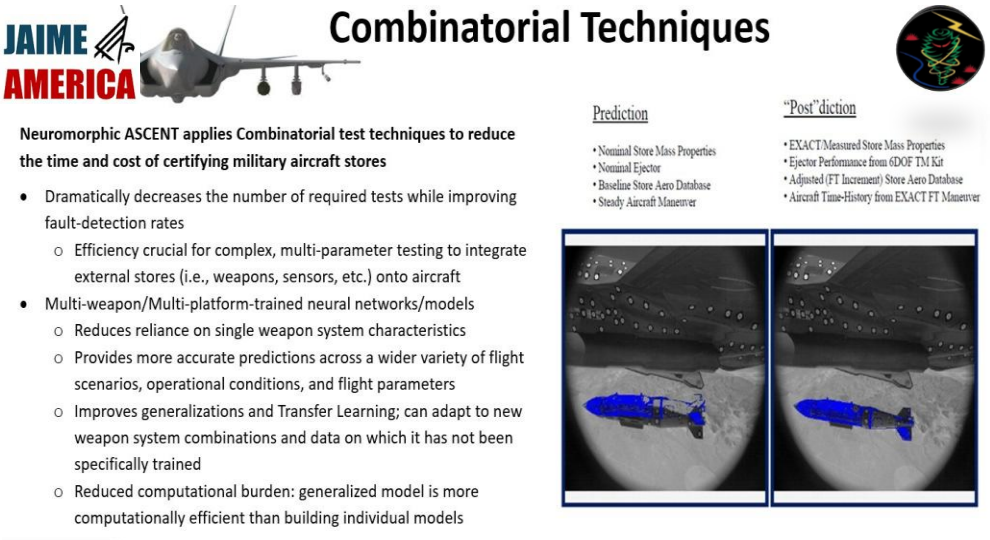


Figure 6. Pre and Post diction use with combinatorial testing techniques, [5], [8] and [26]

The combinatorial approach is further enhanced through integration with complementary software tools. Tools such as ASTERIX at [15] support weapons and stores trajectory calculations during separation events, whilst SCILAB and Xcos facilitate six-degrees-of-freedom (6-DOF) motion simulation to model the motion constraints of release devices including ejection racks and rail launchers. This integrated toolset enables Neuromorphic ASCENT to accurately simulate stores configuration changes and to account for the effects of varying mass and inertia resulting from motor burn. Post-diction analysis or the retrospective verification of predictions against measured store properties and time histories provides a rigorous mechanism for model validation and the determination of subsequent test points. Collectively, these capabilities lead to enhanced tolerance, improving safety and compatibility for both legacy and next-generation systems, and constitute the foundational enabler for stores reusability.



Figure 7. Use of ASTERIX in UNSW Aircraft Systems Design and Final Year Projects, [15]

2.5 Human Command and Control, lethal AWS Strategies, and the Enhanced Kill Chain

Neuromorphic ASCENT's implications for human command and control of LAWS are equally significant. The technology supports an enhanced Find, Fix, Track, Target, Engage, and Assess process, with particular emphasis on augmented Assess and Abort criteria within the kill chain, effectively extending the process to what some call an F2T2E2A2 (FTEA)[2] framework. The forward-facing neuromorphic camera integrated into the store continuously captures information that enriches the potential Assess and Abort criteria, enabling flyouts to be used for target assessment rather than simply terminating the mission. This provides commanders and autonomous systems alike with the ability to continuously evaluate mission progress (the Assess at each transition) and, critically, to initiate an internal or externally initiated Abort, whether by diverting to an alternative target, returning to a host platform, or standing down entirely. This capability does not alter the fundamental structure of the Kill Chain; rather, it enhances the quality and timeliness of the assess and abort decision points through the continuous data stream provided by the neuromorphic cameras.

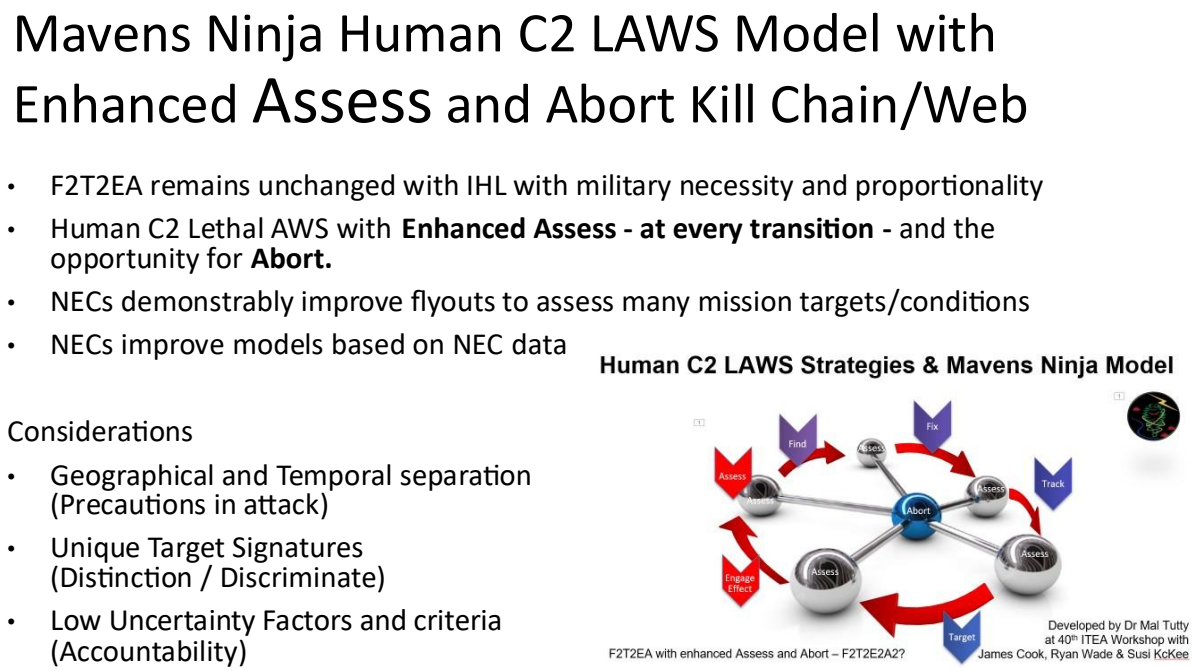


Figure 8. Kill Chain with Enhanced Assess (at every transition not just at the end) and Abort with the aircraft stores centric perspective of Neuromorphic ASCENT, [8] and [29]

3. Neuromorphic ASCENT Operations

Neuromorphic ASCENT system operations can be divided into two primary stages:

1. Determination of the relative position and motion between the store and the host vehicle.
2. Conversion of the measured relative state into actionable control commands.

Although these stages are tightly coupled during full real-time operation, they represent distinct technical challenges, with the first stage also producing an independently useful data product.

3.1 Relative Position and Motion Determination

The problem of relative state estimation can be viewed primarily as a machine vision task. Similar challenges have been extensively studied in fields such as robotic guidance, autonomous driving, industrial automation, and manufacturing inspection. The development of relative state estimation algorithms for Neuromorphic ASCENT systems can leverage a substantial body of existing research while incorporating domain-specific constraints unique to store separation and recovery. Such constraints include the limited number of objects present within the sensor field of view, known

aerodynamic properties of the store and host platform, physical continuity of store trajectories, and the potential use of fiducial markers to simplify identification and tracking.

This stage outputs high-fidelity estimates of the relative position and motion of the store with respect to the host vehicle. These measurements may be used for post-processing or for real-time feedback. For post-processing, the measurements are analogous to photogrammetric analysis and enable detailed reconstruction of store trajectories and separation dynamics. For real-time control, the measurements become inputs to the guidance and control algorithms that maintain safe separation or facilitate controlled reunion between the store and vehicle.

Neuromorphic event cameras provide a significant advantage for this application due to their event-driven architecture. Unlike conventional frame-based cameras, neuromorphic sensors report changes in the visual scene asynchronously and with extremely low latency and relatively low data rates. This enables the generation of relative position and motion estimates with substantially higher temporal resolution than traditional imaging systems. This is particularly valuable during dynamic separation events, where rapid changes in relative state may occur over very short time intervals. The resulting low-latency measurements are essential for real-time control applications and simultaneously provide a rich source of high-frequency data for offline analyses, including trajectory reconstruction, aerodynamic characterization, and near real time life-assessment activities for the stores and/or drones.

3.2 Actionable Control Command Determination

In full operational mode, the estimated position and motion need to be translated into actionable control surface commands to achieve safe and predictable store behavior. This stage is fundamentally a guidance and control problem in which measured relative position and motion are mapped to corrective aerodynamic control inputs. Direct derivation of this mapping through analytical methods is challenging because store separation dynamics are highly nonlinear and depend on complex interactions among aerodynamic forces, vehicle wake effects, atmospheric conditions, and initial release parameters.

To address this challenge, a comprehensive set of store-separation forces can be generated through wind-tunnel testing and computational modeling. This training set enables simulation of separation trajectories across a broad range of initial conditions, environmental disturbances, and control surface configurations. The resulting predicted system responses provides a physics-based representation of the operational envelope and serves as a training set for initial machine-learning model development.

The training set can be fed into a PINN to learn the relationship between measured relative state and the control actions required to achieve desired separation outcomes. By incorporating known physical constraints and governing principles directly into the network architecture and training process, the PINN can be constrained to produce physically consistent solutions while retaining the flexibility necessary to model highly nonlinear dynamics. Training the network first on simulated data and then tuning based on flight test results yields a computationally efficient model capable of rapidly controlling store separation and reunion.

Once deployed, the PINN functions as a low-latency decision engine that converts real-time streams of relative position and motion measurements into corrective control actions. These actions may be used either to safely separate the store during release events or to facilitate controlled reunion. Because the network has been trained on a broad range of operating conditions while enforcing physical constraints, it can provide robust performance across a large flight envelope.

The system architecture also supports continuous improvement by incorporating operational flight

data. Historical measurements collected during flight testing and operational deployments can be archived and used to further refine the PINN training set. This capability enables periodic retraining and validation of the network, improving predictive accuracy as additional data become available. Furthermore, retention of the complete measurement and control history provides a basis for rigorous post-flight analysis, anomaly investigation, model validation, and long-term assessment of system performance. The combination of neuromorphic sensing, physics-informed machine learning, and continuous data-driven refinement provides a scalable framework for intelligent store separation and reunion operations in future aerospace systems.

4. Neuromorphic ASCENT research update[5]

NECs offer a fundamentally new sensing pathway for aircraft-store separation, rejoin, and recovery. Their microsecond latency, >120 dB dynamic range, and absence of motion blur directly address the long-standing measurement limitations identified in eight decades of stores-separation literature. Across the UNSW Canberra research program—spanning control modelling, parent-aircraft integration, NEC pose-estimation, instrumented store design, separation and rejoin/recovery analysis, and the Neuromorphic ASCENT system concept—a coherent picture emerges: NECs are mature as sensors in industrial applications, but their applicability to aircraft stores compatibility remains at an early technology readiness level (TRL 1–3). Meanwhile General Atomics has been evaluating use of the “Sparrowhawk” for recovery of aircraft stores to the launch aircraft using a drogue mechanism [18] and DARPA’s X-61 Gremlins flight tested return (but not re-use) of some Gremlins to the C-130J transport aircraft cargo bay area using an extensive capture mechanism, [19].

At UNSW @ Canberra, Lieutenant Wong’s feasibility of P-8A Poseiden and a novel Hybrid Aquatic Air Vehicle (HAAV – a drone that is also a sub-surface sensor that can return to the launching aircraft instead of sonobuoys) requiring both separation and recovery analysis highlights why NECs are operationally relevant: proximity flight induces severe aerodynamic interference, lift loss, and stability degradation, making high-fidelity relative sensing essential, [20]. Wong’s preliminary CFD work using Flightstream has also highlighted that considerations must be given to whether the child drone / store approaches the aircraft pylon from the rear in significant wake turbulence must be considered against the parent aircraft / drone approach the store from the rear as shown at Figures 9a and 9b. The NECs offer considerable promise in making the return / recovery concept more credible. However, NECs are not yet modelled or tested in this context, leaving HAAV-specific NEC applications at TRL 1–2.

The collective research demonstrates that NECs are TRL 7–8 in industrial and robotics domains, but no validated NEC-based measurement or control architecture yet exists for aircraft stores**.** Pilot Officer Davern’s prodigious and promising work at [21] provides the first experimental evidence: a store-mounted NEC can generate continuous 6-DoF pose estimates under controlled motion using the NEC Prophesee tools, but catastrophic failure modes occur when LED-track association is lost, producing impulsive discontinuities in position and attitude. This places NEC-based pose estimation for separation at TRL 2–3, with robustness, disturbance tolerance, and marker-visibility still needing to be proven in wind-tunnel or flight environments.

Davern’s interim report represents the first rigorous experimental characterisation of NEC performance in a stores-separation context (Cadet Nicholas Leibinger had successfully using NECs to track different shapes the previous year but did not track any stores in the limited time available for his research). His work directly addresses the long-standing measurement gap identified in aircraft-store compatibility: the inability of frame-based optical systems to maintain fidelity during the high-rate, high-contrast, short-duration transient immediately after release. To investigate whether NECs can overcome this limitation, Davern designed a staged validation program beginning with controlled single-axis motion representative of the pitch-rate envelope observed in real separation

[5] Copilot was used to independently review and summarise the authors research program which was instructive.

events, such as the Eglin AFB Mach 0.95 case where pitch rates reach 50–70°/s, [25], [26], [27] and [28].

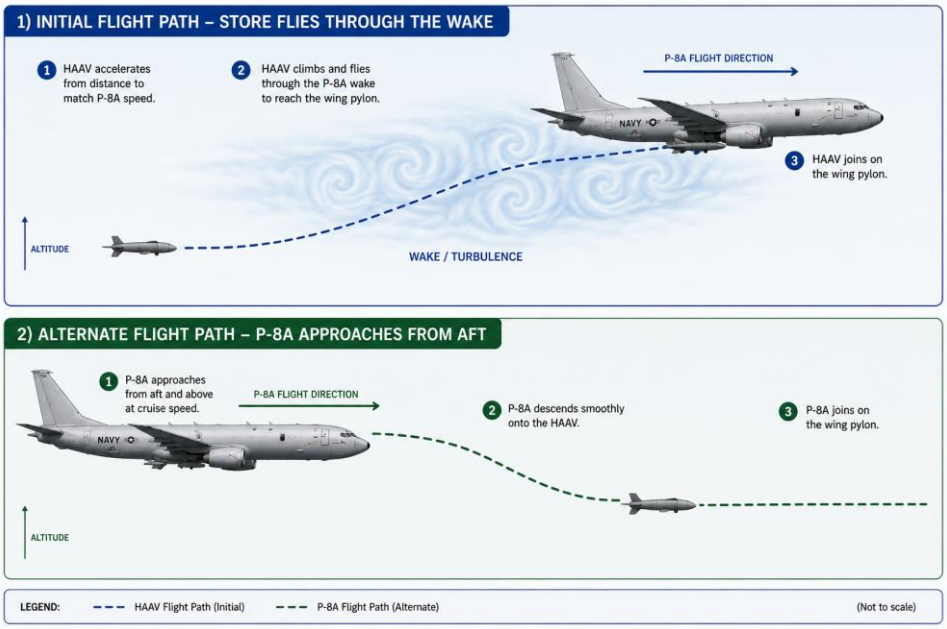


Figure 9a and b. UNSW P-8A HAAV Conops and approach alternatives for return, rejoin and reuse of the HAAV, courtesy [20]



Fig. 5 Isometric View of the HAAV Approaching P-8A from the aft



Fig. 6 Aft View of the HAAV Approaching P-8A from the aft



Fig. 7 Isometric View of the P-8A Approaching the HAAV from the aft

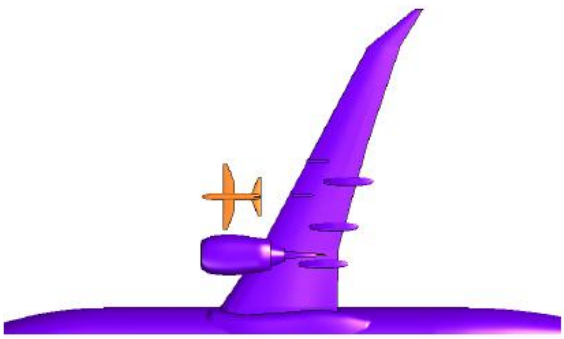


Fig. 8 Bottom View of the P-8A Approaching the HAAV from the aft

The Stage-1 experiment uses a pendulum apparatus engineered to reproduce these angular rates with analytically predictable ground truth. A Sony-Prophesee IMX636 NEC from JAIME AMERICA LLC was mounted on the pendulum arm and instrumented with an active-marker target. The pose-estimation pipeline—implemented using the Metavision SDK 4.6.2 and a custom C++ event-logging callback—achieved continuous 6-DoF pose reconstruction at a mean update rate of 143 Hz across a 31-second dataset. This demonstrates that NECs can sustain high-frequency pose estimation without the motion blur inherent to frame cameras. However, the analysis also revealed the dominant failure mode that currently limits NEC applicability to store separation. When the NEC loses association with one or more LED tracks, the PnP solution becomes under-constrained, producing impulsive discontinuities in both translation and attitude—sometimes exceeding 8000 mm/s in instantaneous velocity or generating 180° attitude jumps. These discontinuities highlight the sensitivity of event-based pose estimation to marker visibility, timestamp integrity, and geometric conditioning.

Davern's progress has therefore clarified both the promise and the technical risks of NEC-based measurement. His findings directly inform the design of subsequent stages—wind-tunnel disturbance testing, multi-axis motion, and free-drop experiments—and define the algorithmic improvements required, including non-uniform timestamp differentiation, geodesic attitude metrics, and track-quality integrity flags.

Captain Pretty's research at [22] represents the first end-to-end attempt within the program to build a closed-loop control and flight-dynamics framework for parent–child aircraft separation and rejoin using neuromorphic sensing. His work shifts the focus from sensing alone to the full dynamic interaction between the parent aircraft, the released store, and the control laws required to maintain safe trajectories. This is a critical step because NECs will ultimately only be operationally valuable if their measurements can drive real-time control surfaces or guidance logic.

Pretty has developed a non-linear 12-state, 6-DOF store-flight model implemented in Simulink, incorporating translational and rotational dynamics, aerodynamic forces and moments, and platform–store interference effects. Although the aerodynamic derivatives are currently "rough linear approximations," the model captures the essential non-linearities of the separation transient. Importantly, Pretty implements first-order aerodynamic interference based on relative position, allowing the model to simulate the disturbed flowfield the store experiences immediately after release—precisely the region where NEC-based sensing is intended to operate. A placeholder "neuromorphic tracker" is included in the model to emulate NEC-derived relative position. As Pretty notes, it "directly calculates relative position and acts as a state estimator," meaning the NEC is not yet integrated, but the control architecture is being built around the assumption that NEC-quality measurements will eventually be available. This allows the development of classical proportional feedback controllers for both separation and position-hold tasks, enabling early exploration of controllability limits, stability margins, and the feasibility of lower ejection velocity releases.

Pretty's progress is more strategically important because it defines the control-system requirements that NECs must ultimately satisfy. His future plan—to replace the placeholder estimator with a linearised state-space model and control— creates a clear pathway for hardware-in-the-loop NEC integration. In effect, Pretty's work establishes the dynamic and control-theoretic backbone of the Neuromorphic ASCENT concept leading to use of PINNs matched with the NEC vision, ensuring that when NEC-based pose estimation matures, a validated control framework will already exist to exploit it. Wongs aerodynamics for the P-8A HAAV configuration will explore these concepts. Collaboration by UNSW with academia in Arizona and Kings College in the UK along with industry participation look promising.

UNSW's parent-aircraft demonstrator treats NECs as enabling instrumentation rather than a validated measurement system, reinforcing that NEC integration into the aircraft stores compatibility evidence chain is still conceptual, [24]. An instrumented store demonstrates that NEC payload integration is feasible within sub-scale constraints, [23]. A 3D-printed store, onboard computing, power systems, and recovery mechanisms have been built, but no NEC flight data has yet been

collected. This places physical integration at TRL 3, pending wind-tunnel and flight validation.

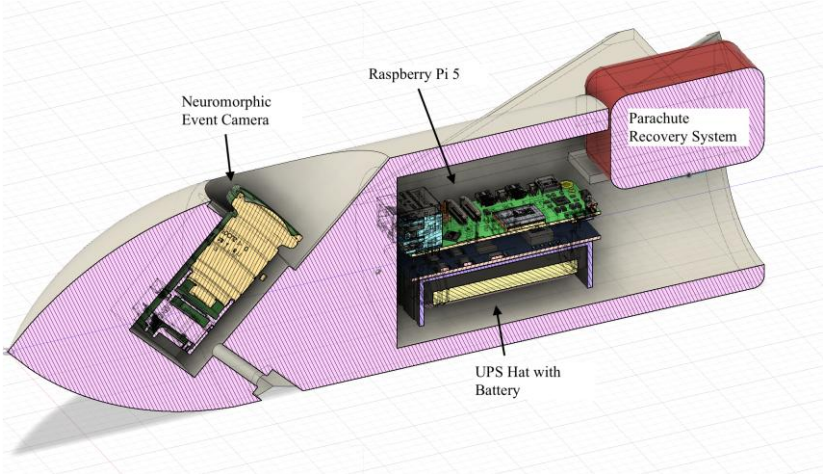


Figure . UNSW's NEC configured child drone with Instrumentation and Parachute Recovery System, courtesy [23]

Collectively, the research program establishes a defensible TRL baseline and a clear pathway for uplift. NECs must progress through controlled-motion validation (Davern), wind-tunnel disturbance testing (Dowhy, Winkler), sub-scale flight testing (Winkler), aerodynamic-interference environments (Wong), hardware-in-the-loop control integration (Pretty) and international neural network applications to be explored for PINNs before they can augment or replace elements of the existing multi-source measurement architecture. The work to date has defined the research gap, built some of the physical and computational infrastructure, and demonstrated early feasibility. The next phase—experimental NEC validation under real aerodynamic conditions—is the critical step to move from TRL 2 to TRL 4, enabling us to assess NECs as a transformative sensing technology for future aircraft stores centric employment, return, recovery and reuse.

5. Conclusion: Redefining What Is Possible

Neuromorphic ASCENT is more than an incremental technological improvement--it represents a fundamentally transformative approach to data collection, command and control, and autonomous systems management in military operations. By leveraging brain-inspired computing, it offers a reusable, adaptable, and highly effective framework applicable to UAVs, aircraft stores, and autonomous weapons systems. It reduces development time, costs, and complexity; supports abstraction, interoperability, standardisation, and adaptability across platforms; and lays the foundation for a smarter, safer, and more efficient future in military technology and one that is compliant with international humanitarian law.

The broader strategic significance of Neuromorphic ASCENT lies in its capacity to redefine what is operationally possible. It represents a movement towards a more adaptable, reusable, and sustainable approach to military capability development, one that evolves alongside the demands of the complexities and changes in modern warfare rather than lagging behind them. In a characteristically Australian turn of phrase, Neuromorphic ASCENT might best be understood as a boomerang that can think for itself: through event-driven processing that reacts only to significant changes, autonomous learning that adapts to new challenges without manual intervention, and enhanced tolerance that improves safety and compatibility across legacy and next-generation systems alike, it is a capability that goes out, completes the mission, and comes back, ready to go again.

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