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SPACE–HYPERSONIC CONVERGENCE:
REDEFINING STRATEGIC AIRPOWER IN THE 21ST CENTURY

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The advent of hypersonic systems, capable of sustained flight at speeds exceeding Mach 5, presents both unique opportunities and profound challenges for global defence and security. Their extreme velocity, manoeuvrability, and ability to operate within or elude traditional air defence systems necessitate a paradigm shift in strategic airpower. This paper explores the challenges of "Space-Hypersonic Convergence", arguing that the seamless integration of space-based platforms with hypersonic capabilities is not merely an incremental improvement but the next transformative leap for military efficacy. The core argument posits that effective ISR, resilient missile defence, and credible deterrence in the hypersonic era fundamentally depend on a unified air-and-space operational domain. We examine how sensor fusion, leveraging a constellation of orbital assets, can overcome the inherent challenges of detecting and tracking hypersonic threats, providing real-time situational awareness critical for decision-making. Furthermore, the concept of orbital queuing for precision strikes is analysed, highlighting its potential to enable rapid, global response capabilities and complicate adversary anti-access/area-denial (A2/AD) strategies. Finally, the significant command-and-control (C2) challenges posed by hypersonic speeds are addressed, including the necessity for advanced automation, artificial intelligence, and resilient communication networks to evolve the legacy Observe-Orient-Decide-Act (OODA) loop and ensure effective operational response in high-tempo contested environments. This convergence promises to redefine the operational landscape, demanding parallel developments in technologies and operational concepts across the air and space domains.

Keywords
Space Systems, Hypersonic Systems, Defence Systems, Space-Based Platforms, Strategic Airpower, ISR (Intelligence, Surveillance, Reconnaissance).

1. Introduction

The global security environment of the twenty-first century is undergoing profound transformation, driven in large part by the rapid development and proliferation of hypersonic systems. These systems, defined by their ability to sustain flight at speeds exceeding Mach 5, introduce a new dimension to strategic airpower, offering both unprecedented opportunities and formidable challenges (Schmisseur, 2015). Unlike conventional ballistic missiles, hypersonic weapons exhibit exceptional manoeuvrability throughout their trajectories, rendering their flight paths unpredictable and significantly complicating interception efforts (Belous & Saladukha, 2020). Moreover, many hypersonic systems exploit a critical detection gap

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by operating at altitudes below conventional early-warning radars yet above typical air defence systems (Little, 2024). Figure 1 illustrates the classification of hypersonic platforms within the speed–altitude domain, highlighting their operational envelopes relative to conventional systems. Figure 2 depicts representative hypersonic vehicles. This unique combination of extreme velocity, manoeuvrability, and stealth necessitates a fundamental re-evaluation of existing defence architectures and strategic doctrines (Finabel, 2025; Little, 2024).

This work hypothesises that the seamless integration of space-based platforms with hypersonic capabilities, herein termed Space-Hypersonic Convergence, constitutes not merely an incremental technological advance but a transformative leap in military utility. Such convergence is vital for enhancing intelligence, surveillance, and reconnaissance (ISR), enabling resilient missile defence systems, and sustaining credible deterrence in an era increasingly defined by hypersonic threats. The central argument advanced here is that the establishment of a unified air-and-space operational domain, analogous to the multi-domain traffic management (MDTM) frameworks proposed for integrated air and space operations (Thangavel et al., 2025a; Thangavel et al., 2021b), is indispensable for confronting the distinctive challenges posed by these advanced weapons systems.

This analysis, therefore, posits that Space-Hypersonic Convergence has the potential to redefine the operational landscape, necessitating innovative doctrinal development, technological innovation, and integrated operational concepts across the air and space domains to safeguard strategic stability and superiority. To this end, the study synthesises existing knowledge and emerging concepts on space-hypersonic convergence. Methodologically, it employs a comprehensive literature review and conceptual synthesis, drawing upon publicly available academic, scientific, and defence-related publications. This approach integrates diverse sources to construct a coherent argument regarding the strategic implications and technological requirements of convergence. By grounding its conceptual arguments in existing

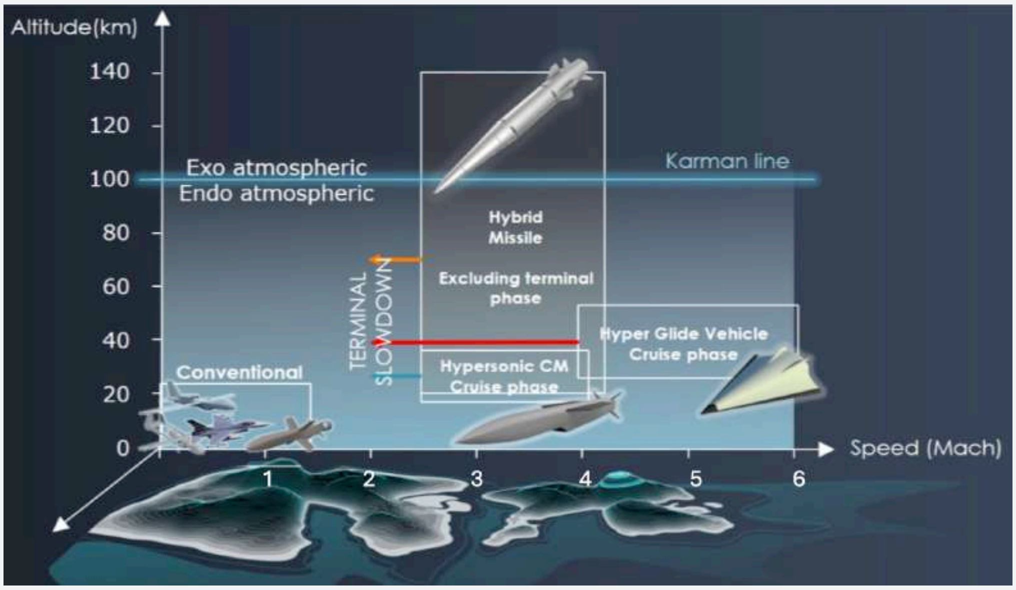

Figure 1: *Flight profiles and operational envelopes of different hypersonic platform types (Thales Group, 2024).*

(Credit: AIAA High-Speed Task Force - All images taken from the Internet)

Figure 2: High-speed endoatmospheric flight vehicle concepts (Sabatini et al., 2024).

scholarship while also identifying future trajectories, the study aims to advance understanding of the emerging paradigm of Space-Hypersonic Convergence.

2. Hypersonic Systems: Capabilities and Challenges

Hypersonic systems represent a significant leap in military technology, characterised by their ability to achieve sustained flights at speeds exceeding Mach 5. The primary capabilities of hypersonic systems encompass extreme velocity, high manoeuvrability, low-altitude flight profiles, and precision-strike potential (Finabel, 2025; Little, 2024). These systems enable rapid coverage of vast distances and severely constrain adversarial response times. Unlike conventional ballistic missiles with predictable parabolic trajectories, hypersonic glide vehicles (HGV) and hypersonic cruise missiles (HCM) exhibit manoeuvrability throughout their flight paths, rendering interception highly complex and enhancing survivability. HGVs, launched via rocket boosters into the outer atmosphere, can glide unpowered with satellite-guided precision, while HCM, powered by scramjet engines, operate at lower atmospheric altitudes and can be deployed from air, land, or sea platforms. Their typical operational altitudes—20–30 km for HCMs and 40–100 km for HGV—exploit a detection gap by flying below ballistic-missile warning radars yet above conventional air-defence coverage. Furthermore, their ability to deliver conventional or nuclear payloads with high accuracy amplifies their lethality and strategic significance. This extreme velocity,

Table 1: Key milestones in hypersonic systems.

Milestone	Year/Decade	Significance	Related Vehicle/ Program
First Manned Hypersonic Flight	1959	Achieved by X-15, proving human capability and gathering critical data on high-Mach aerodynamics, thermal manage-ment, and control.	X-15
Ramjet Propulsion Testing	1950s	Early efforts with programs like Navaho contributed to understanding ramjet operation and limitations at high speeds.	Navaho
Advanced Re-entry Vehicle Design	1960s	Research into ballistic missile re-entry vehicles (AS-BM) led to significant advancements in thermal protection systems for objects entering the atmosphere at hypersonic speeds.	AS-BM
Scramjet Ground Test-ing	1980s-1990s	Extensive ground testing and theoretical work laid the foundation for practical scramjet designs, addressing challenges of supersonic combustion.	NASP, X-43A
First Scramjet Sustained Flight	2004	X-43A achieved Mach 9.6, unequivocally proving the viability of airbreathing scramjet propulsion and reigniting significant investment in the field.	X-43A
Boost-Glide Aerodynamic Validation	2000s-2010s	Flight tests of vehicles like HTV-2 demonstrated the feasibility of highly maneuverable hypersonic glide, validat-ing advanced aerodynamic shapes and thermal protection systems.	HTV-2
Maneuverable HGV Opera-tion	2010s	The emergence of systems like DF-ZF and Avangard showcased the successful integration of advanced GNC, materials, and aerodynamics to create highly maneuverable operational glide vehicles capable of evading traditional defenses.	DF-ZF, Avangard
Operational Scramjet Cruise Missile	2020s	Deployment of Zircon and HAWC demonstrates the successful transition of scramjet technology from experimental proof-of-concept to deployable, sustained atmospheric hypersonic weapon systems.	Zircon, HAWC

combined with advanced manoeuvrability, fundamentally alters the dynamics of strategic airpower and presents unique challenges for existing defence architectures. Key technological milestones in hypersonic vehicles/missiles development are presented in Table 1.

Despite their advanced capabilities, hypersonic systems introduce several critical challenges for global security and strategic stability (Finabel, 2025; Little, 2024; Shepard, 2025):

- **Detection limitations:** Existing early-warning systems are primarily optimised for ballistic-missile trajectories and struggle to detect the unpredictable flight paths of manoeuvring hypersonic weapons. Their low-altitude flight profiles further hinder radar's ability to spot launches and provide early warnings.

- **Tracking difficulties:** The combination of extreme speed, manoeuvrability, and atmospheric flight creates persistent tracking challenges for current sensor systems. Maintaining a continuous track on such agile targets is a complex task.

- **Compressed decision cycles:** The unprecedented speed of hypersonic attacks drastically compresses decision-making timelines for leaders, potentially reducing response windows from hours to mere minutes. This imposes immense pressure on military establishments.

- **Interception windows:** The severely compressed timelines between detection and impact significantly limit opportunities for successful interception by existing defensive systems. No country currently possesses a fully operational anti-hypersonic missile-defence and detection system.

- **Misinterpretation risks:** The difficulty in determining the payload type (conventional versus nuclear) of a launched hypersonic weapon could lead to dangerous misinterpretations of intentions, potentially escalating a conventional conflict to a nuclear one. The blurring of lines between conventional and strategic weapons increases the risk of nuclear escalation and pre-emptive wars.

- **"Use it or lose it" pressures:** Concerns about pre-emptive strikes against hypersonic arsenals could create incentives for early use during crises, further destabilising conflict scenarios.

- **Cost-exchange ratio:** Developing defensive systems capable of countering hypersonic threats typically incurs substantially higher costs than the offensive systems they are designed to counter, creating an unfavourable cost-exchange ratio.

- **Proliferation concerns:** The rapid development and deployment of hypersonic weapons by major powers (e.g., the United States, Russia, China) are triggering a global arms race, with middle powers also increasing investments. This raises concerns about the proliferation of these technologies to additional states and potentially non-state actors, further undermining strategic stability.

Addressing these challenges requires innovative approaches that transcend traditional air and missile-

Table 2: Key Characteristics of hypersonic weapon systems.

Characteristic	Description	Strategic Implication
Extreme Velocity	Speeds exceeding Mach.	Dramatically compresses deci-sion-making timelines for adver-saries, reducing response win-dows to minutes.
High Maneuverability	Ability to change course throughout flight, unlike ballistic missiles.	Unpredictable trajectories compli-cate detection and interception ef-forts, increasing survivability.
Low Altitude Flight Profile	Operates at altitudes below early warning systems but above conventional air defenses.	Exploits a detection gap, hindering radar's ability to provide early warning.
Precision Strike Capability	Delivers conventional or nuclear warheads with high accuracy.	Enhances lethality and potential for strategic impact, blurring lines between conventional and strate-gic weapons.
Propulsion Types	Hypersonic Glide Vehicles (HGVs) launched by rocket boost-ers, then glide. Hypersonic Cruise Missiles (HCMs) use air-breathing engines (scramjets).	HGVs offer long range and preci-sion; HCMs offer lower altitude flight but shorter range.

defence paradigms, emphasising the critical role of space-based assets and key characteristics of hypersonic systems, as presented in Table 2.

3. Space-Based Platforms: Enabling Strategic Airpower

Space-based platforms serve as essential assets for modern military operations, providing a wide array of capabilities that underpin strategic advantage. These orbital systems act as the “extended eyes, ears, and communication relays” for nations, profoundly influencing strategic decisions and operational effectiveness. Military satellites and other space systems offer crucial capabilities (Table 3) across several domains (NewSpace Economy, 2025):

- **Intelligence, surveillance, and reconnaissance (ISR):** Reconnaissance and Earth-observation satellites provide imagery intelligence (optical, radar, infrared), monitoring, surveillance, mapping, and battle-damage assessment. Signals intelligence (SIGINT) satellites intercept and analyse foreign electronic signals for intelligence gathering. These capabilities are vital for creating a comprehensive picture of the operating environment (Naval Information Warfare Center Pacific, 2025).

Table 3: Key Capabilities of Military Space-Based Platforms

Satellite Type	Primary Function(s)	Typical Orbit(s)	Strategic Relevance
Reconnaissance/ Earth Observation	Imagery intelligence (optical, radar, infrared), monitoring, surveillance, mapping, and battle damage assessment.	LEO, GEO	Provides comprehen-sive situational awareness and intelli-gence for strategic decision-making.
Communications (MILSATCOM)	Secure voice/data/video transmission, Command and Control (C2), global connec-tivity for deployed forces.	GEO, MEO, LEO.	Ensures resilient and secure communica-tion for deployed forces and command echelons.
Navigation (PNT)	Precise positioning, naviga-tion, and timing; guidance for precision munitions; synchronization for networks.	MEO	Critical for guiding precision weapons and coordinating complex military op-erations.
Early Warning	Detection of ballistic and hypersonic missile launches, trajectory tracking, strate-gic/tactical warning.	GEO, MEO, HEO	Provides crucial early warning against missile threats, enabling defensive responses.
Signals Intelligence (SIGINT)	Interception and analysis of foreign electronic signals (communications, radar, te-lemetry) for intelligence gathering.	LEO, MEO, GEO.	Enhances intelligence collection and understanding of adversary capabilities.
Space Situational Awareness (SSA)/Space Domain Awareness (SDA)	Tracking satellites and de-bris, monitoring the space environment, characterizing space objects, and intent.	GEO, LEO, MEO	Protects space assets and provides under-standing of the orbital domain for strategic planning.
Weather (Meteorologi-cal)	Monitoring weather patterns, cloud cover, atmospheric conditions, ocean states to support military operations.	LEO, GEO	Supports military operations by providing essential environmen-tal data for planning and execution.

- **Missile warning:** Early-warning satellites are designed to detect ballistic and hypersonic missile launches, track their trajectories, and provide strategic and tactical warnings.

- **Environmental monitoring:** Weather satellites monitor weather patterns, cloud cover, atmospheric conditions, and ocean states, supporting military operations by providing critical environmental data.

- **Satellite CommunicationsSatellite communications (SATCOM):** MILSATCOM systems provide secure voice, data, and video transmission, enabling robust command-and-control (C2) and global connectivity for deployed forces. Systems like the Mobile User Objective System (MUOS) and Protected Tactical Waveform (PTW) offer increased communications capabilities, resiliency, and efficient bandwidth utilisation (Naval Information Warfare Center Pacific, 2025).

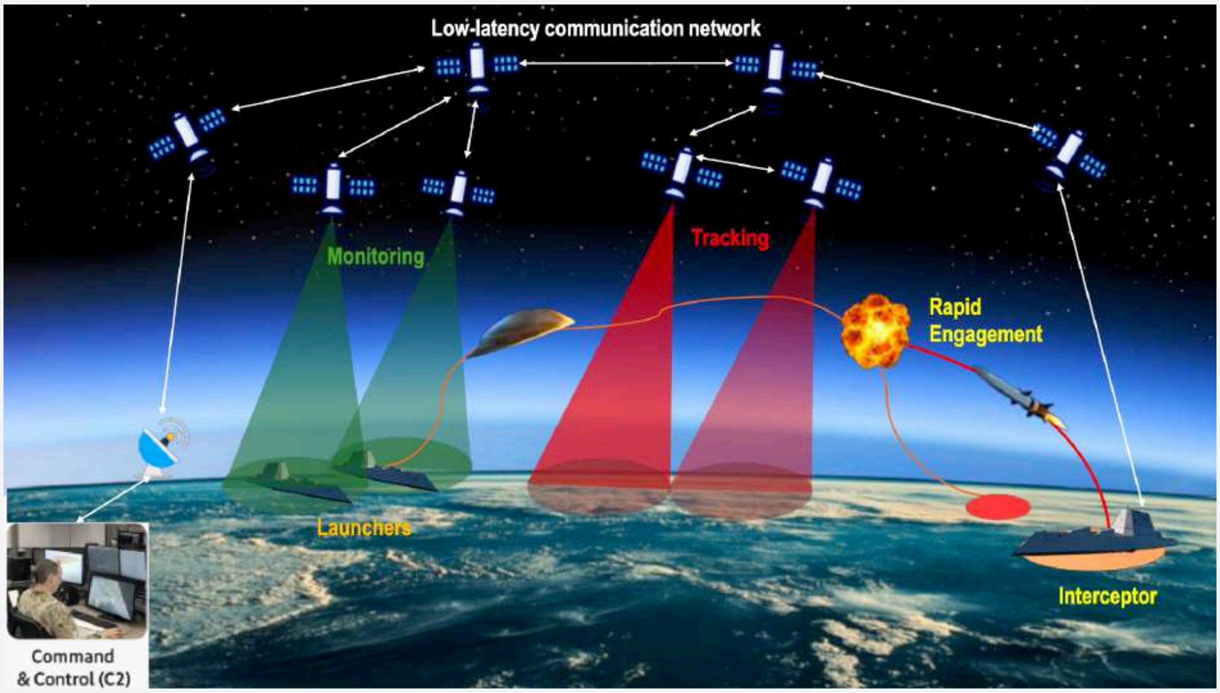

Figure 3: Layered hypersonic defense architecture comprising a monitoring layer, a tracking layer, and a low-latency communication network layer.

- **Position, navigation, and timing (PNT):** PNT satellites, such as the NAVSTAR Global Positioning System (GPS), allow military forces to determine location accurately, navigate effectively across land, sea, and air, and synchronise operations with high precision. This data is essential for guiding precision munitions and coordinating troop movements.

- **Space situational awareness (SSA) / space domain awareness (SDA):** These satellites track other satellites and debris, monitor the space environment, and characterise space objects and their intent, which is crucial for protecting space assets and understanding the orbital battlespace.

These diverse capabilities collectively form the backbone of modern strategic airpower, providing the foundational data and connectivity required for effective military operations across all domains (Naval Information Warfare Center Pacific, 2025).

4. Space-Hypersonic Convergence: A Transformative Leap

The convergence of space-based platforms with hypersonic capabilities constitutes a transformative development in military effectiveness, surpassing incremental advancements to fundamentally redefine the operational landscape. This integration is essential not only for mitigating the unique challenges posed by hypersonic threats but also for generating novel strategic advantages. Figure 3 depicts a three-tiered hypersonic-defence architecture consisting of a monitoring layer, a tracking layer, and a low-latency communication-network layer. The monitoring layer provides persistent, wide-area surveillance, enabling the detection of hypersonic threats and the maintenance of situational awareness during the critical early phases of flight.

The tracking layer ensures high-precision, continuous target tracking through subsequent phases, supporting accurate trajectory prediction. The low-latency communication-network layer, formed by interconnected satellites with inter-satellite links and laser downlinks to ground-based receivers, enables rapid, resilient data transfer between space-based sensors and terrestrial C2 centres. The C2 system processes this data in real time to coordinate timely intercept operations, ensuring an integrated, rapid-response capability against the extreme speed, manoeuvrability, and short warning times associated with hypersonic vehicles.

4.1. Sensor Fusion for Hypersonic Threat Detection and Tracking

Detecting and tracking hypersonic threats, with their extreme speed and manoeuvrability, is a formidable challenge for traditional defence systems (Little, 2024). Space-hypersonic convergence addresses this through advanced sensor fusion, leveraging a multi-layered network of orbital and terrestrial assets. A comprehensive suite of high-performance sensors in orbit, including optical sensors, radar, and infrared, is essential. These space-based sensors not only detect objects but also provide the necessary data for classification (e.g., missile type) and identification (e.g., friend, enemy, neutral). Visual and infrared optical sensors are combined to identify shapes and heat signatures, enabling classification, while identification friend or foe (IFF) transponders can be used for identification.

The Hypersonic and Ballistic Tracking Space Sensor (HBTSS) satellite system exemplifies this approach (Shepard, 2025). HBTSS is designed to be a critical component of a multi-layered overhead-persistent-infrared (OPIR) constellation (Chaplain et al., 2014). It provides continuously updated, high-quality tracks for targeting hypersonic threats and offers near-global coverage when cued by other OPIR systems (Northrop Grumman, 2025). HBTSS satellites use multi-spectral imaging to enhance performance in challenging conditions and can provide continuous tracking data.

Sensor fusion is vital because each sensor type has limitations. For instance, while infrared sensors are useful for target acquisition, space-based radar can track trajectories. A combination of both, supported by high-speed processing, enables continuous sensor fusion. If radar loses a fix on the target, the infrared sensor can aid in reacquisition (Zhang et al., 2015). Further complication arises from the plasma sheath that forms around hypersonic vehicles due to extreme aerodynamic heating during high-speed flights. This ionised layer can attenuate or block radio-frequency (RF) signals, leading to intermittent tracking and degraded communication performance, particularly during the mid-course and terminal phases. Space-based sensors, operating above this plasma envelope, are less susceptible to such interference and thus play a pivotal role in maintaining persistent tracking and data continuity. The fusion of optical and infrared sensing with advanced radar and predictive analytics helps mitigate plasma-induced blackout periods and ensures resilience in the sensor-to-decision pipeline.

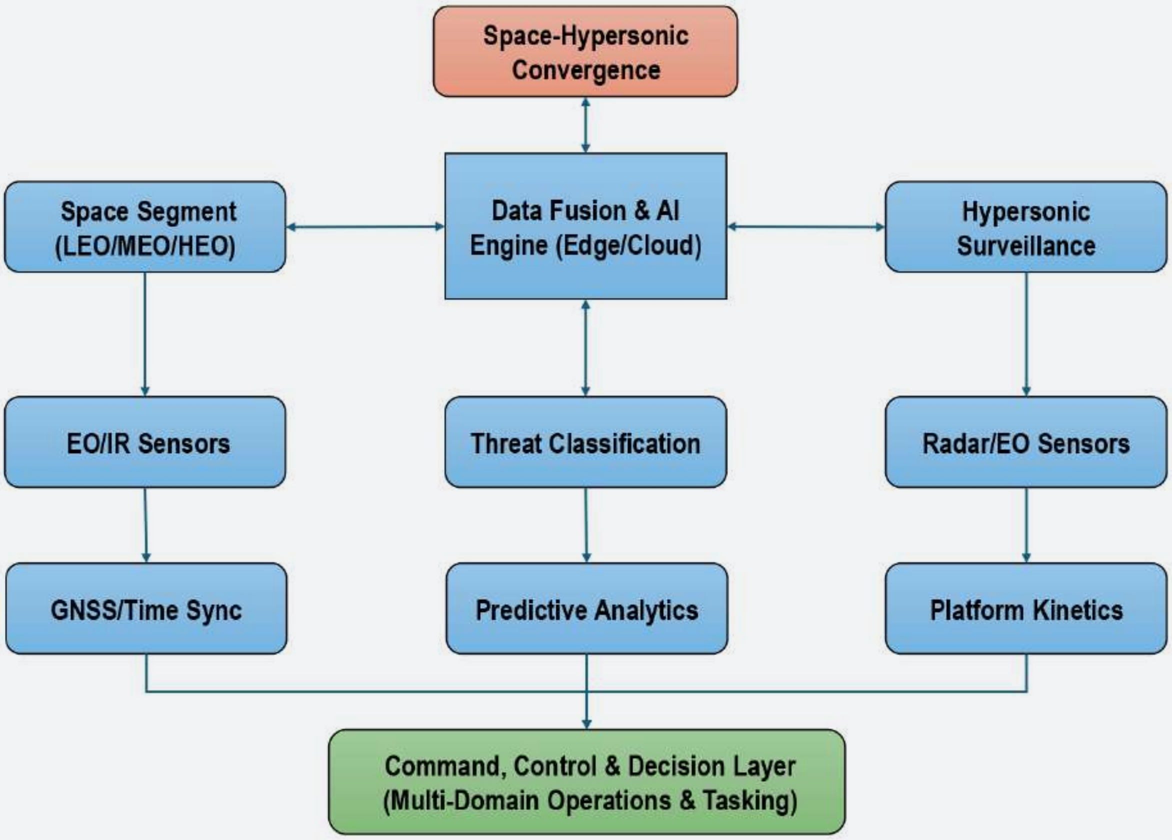

Figure 4: Conceptual framework of Space-Hypersonic convergence for threat detection.

Ground-based radar systems also play a role in layered architecture. While conventional ground radar struggles with low-altitude hypersonic missiles due to line-of-sight limitations, over-the-horizon (OTH) radar (Headrick & Skolnik, 1974) can detect targets at long distances. Advanced active electronically scanned array (AESA) radar, such as the Lower-Tier Air and Missile Defense Sensor (LTAMDS), can simultaneously detect and track multiple threats from any direction, using gallium-nitride (GaN) power devices for longer range and higher resolution. The integration of these diverse space- and ground-based sensors through sensor fusion is indispensable for effective hypersonic-missile defence (Shepard, 2025).

The conceptual framework presented in Figure 4 delineates a multi-tiered architecture that integrates space-based and hypersonic-domain capabilities for enhanced threat detection and situational awareness. At the apex, the convergence layer orchestrates bidirectional data exchange between the space segment comprising LEO, MEO, and HEO satellite platforms and hypersonic surveillance systems. Sensor-derived data from electro-optical (EO), infrared (IR), and radar systems are transmitted through hierarchical processing stages, including time synchronisation via GNSS, and ingested into a centralised data-fusion and artificial-intelligence (AI) engine. This engine performs real-time threat classification and forwards the results to predictive-analytics modules for trajectory estimation and behavioural forecasting. The processed intelligence from both domains converges in the Command, Control, and Decision Layer (C2DL), which synthesises a coherent multi-domain operational picture and facilitates autonomous or human-in-the-loop tasking. The directionality of the data flow, represented through vertically and horizontally oriented arrows, underscores the sequential, recursive, and synchronised nature of sensor-to-decision pipelines across the architecture.

4.2. Orbital Queuing for Precision Strikes

The concept of orbital queuing for precision strikes leverages the global reach and responsiveness of space assets to enable rapid, global response capabilities, thereby complicating adversary anti-access/area-denial (A2/AD) strategies (National Defense University, 2025). This capability is embodied in initiatives such as the United States’ Conventional Prompt Strike (CPS) programme (Woolf, 2019; Bunn & Manzo, 2011). CPS, formerly known as Prompt Global Strike (PGS), is a military effort to develop a system capable of delivering a precision-guided conventional weapon strike anywhere in the world within one hour (Watts, 2013). This system is intended to complement existing rapid-response forces, which typically measure response times in days or weeks. Potential delivery systems for CPS warheads include air- or submarine-launched hypersonic cruise missiles and kinetic weapons launched from orbiting space platforms.

The integration of hypersonic weapons with space-based PNT and ISR capabilities allows for unprecedented speed and precision in targeting. Hypersonic boost-glide missiles, such as those under development in the CPS programme, offer longer range, shorter flight times, and high survivability against enemy defences (Lockheed Martin, 2025). This capability can force adversaries to operate at greater distances, reducing the effectiveness of their A2/AD strategies, particularly in contested regions such as the South China Sea (Little, 2024; National Defense University, 2025). The ability to deliver a precision strike globally within an hour, enabled by orbital queuing and hypersonic delivery, provides a critical tool for deterring and, if necessary, defeating potential strategic competitors (Lockheed Martin, 2025). It also offers a conventional alternative to nuclear weapons for certain targets during a conflict, potentially reducing the risk of nuclear escalation. However, the challenge remains in ensuring that such a system, particularly if launched via ICBM-like trajectories, is not misinterpreted as a nuclear attack by countries with advanced launch-detection systems. This underscores the need for careful doctrinal development and strategic signalling.

5. Command and Control (C2) Challenges in the Hypersonic Era

The extreme speeds and unpredictable trajectories of hypersonic systems impose unprecedented demands on command-and-control (C2) systems, necessitating a fundamental re-evaluation of decision-making processes. The traditional Observe-Orient-Decide-Act (OODA) loop, while foundational, faces significant compression challenges in a hypersonic environment.

5.1. Compressing the OODA Loop

The OODA loop, a metaphorical decision-making cycle, emphasises rapid observation, orientation, decision, and action (CSIS Nuclear Network, 2025; Johnson, 2022). In the context of hypersonic operations, the time available for each stage of this loop is drastically reduced. Leaders may have only minutes, rather than hours, to determine appropriate responses to detected launches (Little, 2024). This compression necessitates:

- **Advanced automation:** To process vast amounts of data and present actionable intelligence rapidly, automation is crucial. This includes automated data collection, initial analysis, and threat assessment.
- **Artificial intelligence (AI):** AI-enabled capabilities, particularly machine-learning techniques such as image recognition, pattern recognition, and natural-language processing, can inductively fill gaps in missing information, identify patterns and trends, and significantly increase the speed and accuracy of certain standardised military operations. AI can inform predictions by using heuristics derived from vast training datasets (CSIS Nuclear Network, 2025).

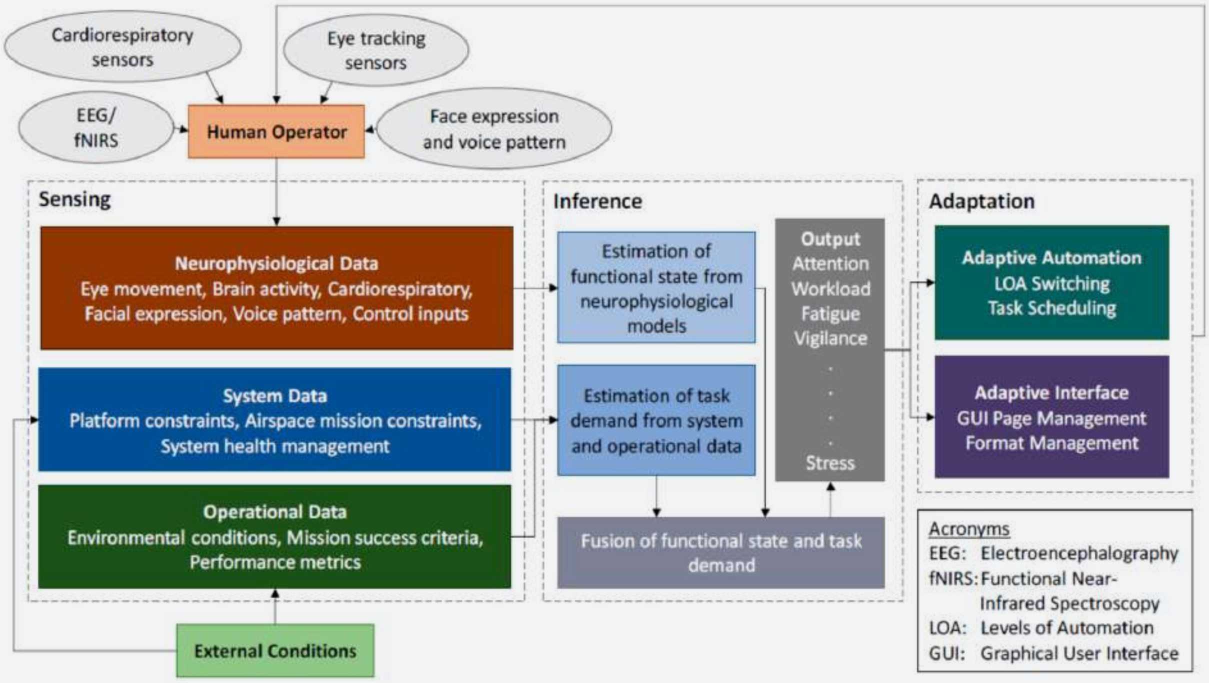

Figure 5: CHMI² framework, Lim et al. (2021).

- **Resilient communication networks:** High-tempo contested environments demand communication networks that are not only fast but also highly resilient to disruption. These networks must ensure low-latency data transfer between sensors, C2 nodes, and effector systems.

5.2. The Role of Human-Machine Teaming

While AI and automation are essential for accelerating the OODA loop, the role of human involvement in C2 decision-making remains critical, and arguably becomes even more important. Critics of an over-emphasis on speed in the OODA loop argue that, beyond granular tactical considerations, it has minimal utility at a strategic level, such as managing nuclear brinkmanship. Human cognition, encompassing perception, emotion, experience, and intuition, is vital for understanding the broader strategic environment, especially in non-linear, complex adaptive organisational systems. Machines, lacking intrinsically human traits such as intentions, ethical and moral leadership, and the ability to predict outcomes in human-centric environments, cannot effectively or reliably replace humans in making strategic judgements (CSIS Nuclear Network, 2025; Johnson, 2022).

Emerging cognitive human–machine systems (CHMS) offer a potential solution by facilitating shared decision-making authority between human operators and AI-enabled agents. These systems incorporate layered cognitive architectures that support perception, knowledge representation, reasoning, and learning, enabling machines to process complex data and adapt their behaviour to evolving mission demands. However, effective implementation of CHMS necessitates human supervisory control and contextual interpretation to avoid over-reliance on automation and maintain system resilience. As emphasised by Sabatini (2024), Safwat et al. (2024), and Safwat et al. (2025), effective human–machine teaming requires cognitive compatibility, mutual predictability, and adaptive trust calibration, ensuring that machines serve as collaborative teammates rather than deterministic tools.

To operationalise these principles, the Cognitive Human–Machine Interfaces and Interactions (CHMI^2) system provides a robust framework for adaptive human–machine decision-making. Within this system, intelligent agents act as cognitive amplifiers that process multi-modal sensor inputs and generate synthesised situational assessments to support human decisions. As illustrated in Figure 5, the CHMI^2 architecture integrates neurophysiological and behavioural sensing modalities with system telemetry and environmental parameters to infer the functional cognitive state of the human operator. This inference process captures critical indicators such as workload, attention, fatigue, and stress, and fuses them with task-demand estimations to drive real-time adaptive-automation strategies and interface-configuration adjustments.

In the hypersonic C2 context, cognitive-adaptive systems such as CHMI^2 are essential to manage the high operational tempo and data volume while preserving the commander's situational awareness, cognitive bandwidth, and ethical responsibility. Adaptation mechanisms—such as levels-of-automation (LOA) switching, dynamic task reallocation, and graphical user-interface (GUI) adjustments—modulate the level of machine autonomy according to operator state and mission complexity. The overarching objective is to establish a symbiotic human–machine teaming paradigm, where AI augments the speed and fidelity of data interpretation, while strategic decision authority remains under human control, governed by ethical principles, operational intent, and established rules of engagement.

Table 4: Command and control challenges and solutions in the hypersonic era.

Challenge	Description	Proposed Solution (Space-Hypersonic Convergence)
Compressed Decision Cycles	Hypersonic speeds reduce response time from hours to minutes.	**Advanced Automation & AI:** AI-enabled capabilities for rapid data processing, pattern recognition, and threat assessment.
Unpredictable Trajectories	Maneuverability of hyper-sonic weapons makes flight paths difficult to predict.	**Sensor Fusion:** Integration of diverse space-based (optical, infrared, radar) and ground-based sensors for continuous, high-precision tracking.
Data Overload & Ambiguity	Vast amounts of data from multiple sensors, coupled with uncertainty about payload type.	**AI-driven Information Synthesis:** AI to fill missing information gaps, identify trends, and present actionable intelligence to human decision-makers.
Maintaining Human Control	Pressure to delegate launch authority due to speed, risk of unintended escalation.	**Human-Machine Teaming:** AI augments human decision-making, but critical strategic judgments remain with human commanders, emphasizing intuition, ethics, and rules of engagement.
Communication Latency & Resilience	Need for rapid, secure, and uninterrupted data flow in contested envi-ronments.	**Resilient Communication Networks:** Leveraging military SATCOM systems (e.g., MUOS, PTW) for low latency, protected global connectivity.

Therefore, the future of C2 in the hypersonic era lies in a blurred human–machine decision-making continuum, where intelligent machines analyse and synthesise data to inform human judgement. Commanders' intuition, latitude, and flexibility will be increasingly demanded to mitigate unintended consequences in an environment driven by rapid technological diffusion. The challenge (Table 4) is to leverage AI for speed and data processing while ensuring that critical decisions—particularly those with strategic implications—remain firmly within human control, guided by ethical considerations and rules of engagement (CSIS Nuclear Network, 2025; Johnson, 2022).

6. Conclusion

The emergence of hypersonic systems has fundamentally reshaped the character of strategic airpower, offering unique capabilities while posing significant challenges to global security. Space-Hypersonic Convergence—i.e., integration of space-based platforms with hypersonic weapon systems—is not an incremental development but a transformative paradigm for sustaining military efficacy and strategic stability in the twenty-first century. Leveraging orbital constellations and advanced sensor fusion, this convergence can mitigate the inherent difficulties of detecting and tracking manoeuvrable, high-speed targets, thereby enabling real-time situational and domain awareness with timely decision-making. The concept of orbital queuing, as demonstrated by initiatives such as Conventional Prompt Strike, further underlines the potential for rapid, global precision-strike capabilities, complicating adversarial anti-access/area-denial strategies and reinforcing deterrence.

However, the integration of hypersonic capabilities requires an evolution of the Observe–Orient–Decide–Act (OODA) cycle, introducing acute command-and-control challenges. While artificial intelligence, automation, and resilient communication networks are critical for accelerating information flows, human judgement and ethical leadership remain necessary, pushing the boundaries of human–machine teaming approaches. The successful realisation of Space-Hypersonic Convergence will largely depend on policy, continuous technological development, and integrated operational concepts across air and space domains. These efforts are vital to ensuring that the future of strategic airpower is defined by resilience, adaptability, and global reach.

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