NATO OTAN
Science & Technology Organization (STO)

Hypersonics

Briefing paper

5/9

Hypersonic systems are defined by their ability to travel at speeds greater than 1715 metres per second (or five times the speed of sound/Mach 5). The rapid development of hypersonic systems – in conjunction with the inability of legacy systems to defend against future hypersonic threats – draws attention to a range of considerable deterrence and defence issues.

Implications

Economic Implications – The most immediate impact of advances in hypersonics will be felt in the defence industry and, for the time being, less so on civilian transportation applications. Due to the very high up-front investments required, the number of commercial actors is limited, and progress is primarily driven by government investments motivated by security needs. Nevertheless, significant investments are being made, with possible secondary economic applications in the transport and logistics sectors likely to take off in the medium to long term.

Military Implications – Hypersonic capabilities would make some weapons' designs less complex by harnessing the power of kinetic impact energy rather than explosive warheads. Furthermore, hypersonic speeds reduce early-warning and response times further, as their non-ballistic trajectory poses further challenges to detection and effective defence, since hypersonics spend less time in general above the atmosphere.

Societal Implications – The social implications of hypersonic systems are limited. However, given the substantive investments needed for a country to successfully design, develop and deploy these systems, they may lead to second-order effects on government spending, and subsequently cause impacts on economic and social security frameworks.

Key Technology Areas

Vehicles and Propulsion – Hypersonic vehicles encompass a range of technologies including aircrafts, missiles, projectiles or spacecrafts. They are divided into four main types of system:

- Boost glide vehicles, which are launched by rocket but then manoeuvred in the atmosphere at altitudes of 40-100 km, have made remarkable progress and research is currently focusing on reducing the cost of this technology .

- Hypersonic cruise missiles (HCM) are typically air-launched and powered by scramjets (supersonic combusting ramjets) that need to reach Mach 3 or 4 to become operational. These missiles fly at altitudes of 20-30 km.

- Rail guns are systems that use an electromagnetic field to accelerate projectiles at hypersonic speeds. They are intended to engage time-critical targets over longer ranges, augment surface-to-air capabilities against very fast-moving targets, and intercept ballistic missiles. They have a major advantage in their relative affordability, and have no reliance on chemical energy sources.

- Hypersonic aircraft have shown encouraging results, with dual-mode ramjet systems potentially enabling transformational aircraft and RAS capabilities.

Counter-Hypersonic Systems – The speed, manoeuvrability and trajectory of hypersonic systems, coupled with the possibility of large swarms of hypersonic effectors, pose noteworthy challenges to defensive efforts. Countermeasures include both soft-kill approaches such as jamming or decoys, and hard-kill ones, such as directed energy weapons or physical interceptors. These systems will need to be refined and operationalised to maintain the current deterrent framework in a future era of strategic hypersonic capabilities.

Technology Convergence

Space, Quantum and Artificial Intelligence – Countering hypersonic threats will require an advanced space-based sensor network for detection, identification and tracking of such threats, which, with the support of terrestrial sensors, can then provide navigation and control for successful interception. Such sensors and control functions will be further enhanced by quantum technologies and AI applications, thereby enabling shorter response times.

Propulsion and Materials – The speed of hypersonic vehicles can cause their surface temperatures to exceed 1000°C. As a result, the development of mechanically strong and heat-tolerant materials is necessary for the implementation of these vehicles. There are promising research activities being conducted for these materials, considering both novel materials and advanced manufacturing. Advances in the underlying propulsion technologies, such as supersonic combustion ramjets (scramjets) or dual-mode engines that can switch from fuel-efficient turbine operation to ramjet mode, will support transformational changes for civil and military applications.