OSRA Defence Technology Taxonomy v2.0

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Document Information

Classification

This document is unclassified.

Conditions of release

This document is delivered by the European Defence Agency to the EU Defence Community.

Version history

HISTORY OF CHANGES	
Publication date	**Change**
08.04.2008	First edition: *EDA Technology Taxonomy*
08.12.2021	Second edition: *OSRA Defence Technology Taxonomy*

Planned update cycle

The OSRA Defence Technology Taxonomy will be reviewed constantly within the EDA's CapTechs with formal delivery cycles of five years. Full review and update will be done every ten years.

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Foreword

Taxonomy finds its roots in the Greek language *τάξις*, taxis (meaning 'order', 'arrangement') and *νόμος*, nomos ('law' or 'science'), in this sense, the OSRA Defence Technology Taxonomy constitutes a European effort to provide a scheme of classification for the technologies relevant to the military and defence context.

The purpose of the OSRA Defence Technology Taxonomy is to support the management of military capability-oriented research programs by enabling the identification of synergies between different research areas and programmes and creating to a certain extent, a homogeneity of interpretation for the discussion of specific research topics. From the research and technology perspective, and in connection with the Overarching Strategic Research Agenda (OSRA) methodology, OSRA Defence Technology Taxonomy supports EDA in its role to manage military capability-oriented research programs and to be able to analyse and connect possible areas of research with Capability Development Plan (CDP) priorities. The OSRA Defence Technology Taxonomy will enable a top-down as well as bottom-up approach analysis in the OSRA framework and will be suitable for analysis of technology categories with a wide variety and different levels of detail.

OSRA Defence Technology Taxonomy originates from the technology taxonomy of *Western European Armaments Group (WEAG)*. The first version was delivered by the EDA in 2008 and was the first attempt to list a number of technology areas and categories relevant to the military and defence context. In this first edition, not only the technologies were clustered and listed but also additional descriptions were included. The 2008 version was utilised until the development of OSRA as a key element in defining the Areas of Responsibility (AoR) of the CapTechs including their respective technological domains.

Since 2008 significant changes have been taking place around the globe, especially in the defence context. New disruptive and emerging technologies such as: Hypervelocity Defence Systems, Variable Cycle Engine, Supersonic and Hypersonic Designs, Combat Cloud, Nanosensors, Human Machine Teaming, Space Traffic Management, 3D printed materials and structures, Multi-Disciplinary Design and Analysis Framework, Space Defence System, Autonomous Air/Land/Maritime Systems, Hyperconnected Defence Systems, Biosensors, Energy Storage, Sustainable and Synthetic Fuels, Cyber Defence, Quantum computing Technologies, Flow Control Technologies, Electromagnetic Launch/Railgun, CBRN Applications, Digital Twin, Ethics – Rules of Engagement, have shaken the ground of current and future defence systems.

These changes have motivated a full taxonomy update, with the main objective being to cover all technologies and techniques in order to complete the current technology landscaping. Making the taxonomy usable as a tool to identify synergies between different application areas has also been a driver for this update cycle. The 2021 edition took the 2008 one as the starting point, from this, a full review of the taxonomy items was undertaken by the CapTech members. A detailed review completed in 2017 with the support of an EDA contractor, and a dedicated Artificial Intelligence taxonomy delivered by EDA have also been key sources of information during the full update.

The full update resulted in a document structured into five *chapters*. The first three (A, B and C) cover the Underpinning Technologies, the System-related Technologies, and the Systems-level Technologies respectively. Chapter D, describes the Supplementary Technology Areas which cannot be categorized in the hierarchical structure covered by Chapters A, B and C. For clarity, and to facilitate the integration of emerging technologies, a fifth Chapter (E) has been included to incorporate *Specialized Technology*

Taxonomies. In this version, special attention has been given to 'Artificial Intelligence for Defence' (AI). The approach adopted by EDA is to focus on AI in Defence and to define it from a functional perspective, establishing the boundaries of what can be understood by this term and to limit its scope. Describing what AI does from a functional perspective at the highest abstract level and what should be included under this term will help the dialogue at the European level on its applications in defence and to facilitate cooperation.

OSRA Defence Technology Taxonomy aims to support the definition of the technologies covered today by EDAs CapTechs and can be readily updated with emerging or future technologies. Practically speaking, the taxonomy is the corner stone for the CapTechs as it defines the different AoR of the CapTechs and it is used as input in the EDA Technology Watch tool for developing the dedicated queries/information pages per CapTech. In this sense, the objective for the update of the taxonomy is to be able to support the definition of the technologies covered today by the CapTechs, but also flexible enough to be able to describe any emerging or future technology. Vis-à-vis the Technology Building Blocks (TBBs) detailed at OSRA, this Technology Taxonomy has the same role as the Generic Military Tasks (GMTL), i.e. hierarchical lists which are used to position and describe the TBBs. Both the Technology Taxonomy and the GMTL are external to the TBBs. They are, however, both used by the TBBs as the main references.

The European Defence Agency would like to thank all the actors involved in the update of this document which is now delivered to the EU Defence Community as a glossary of commonly used terms with a view to establishing a harmonised understanding of the key technologies relevant for the military and defence context.

Jean-François RIPOCHE

EDA's Research, Technology and Innovation Director

Guide to the reader

This version is structured into 5 different chapters (A; B; C; D and E) and one annex (i). Chapters A, B and C are related in a hierarchical manner.

Chapter A addresses the *underpinning technologies* from the Structural and Smart Materials; Electronic Materials; Photonic/Optical Materials to Fuels, Energetic Materials and Plasma Technology and Chemical, Biological & Medical Materials.

Chapter B contains the *system-related technologies* covering (among other) Lethality & Platform Protection; Propulsion and Powerplants; Guidance and Control Systems for Weapons and Platforms; Electronic Warfare and Directed Energy Technologies.

Chapter C focuses on the *system-level technologies* from two perspectives, Integrated Platforms and Weapons and Effectors.

Chapter D describes the *Supplementary Technology Areas* which cannot be categorised in the hierarchical structure such as Defence Functions and Policy Support; Manufacturing Processes, Design Tools and Techniques; Installations and Facilities.

Finally, for clarity and to facilitate the integration of emerging technologies, Chapter E groups *Specialized Technology Taxonomies* such as Artificial Intelligence.

A list of the new topics included in this edition and topics with relevant changes, as compared to the 2008 edition, can be found in the *Annex i. Main changes from v1 (2008) to v2 (2021*).

Detailed tables of contents are provided at the beginning of each chapter to facilitate the navigation through the document for the reader.

Acronyms List

Chapter A. Underpinning Technologies

Chapter A. Table of Contents

A01 – Structural and Smart Materials and Structural Mechanics

A01.01 – Metals and Metal Matrix Composite Technology

Research to determine the properties and characteristics of Metallic alloys (all types including intermetallics and high entropy alloys), Metal matrix composites (all types of MMCs), and materials used as Fibre and Particulate reinforcements in MMCs. Microstructural analysis of all types of samples, as prepared, heat treated or fractured (as in e.g. failure diagnosis) and corrosion effects. Research leading to improved processes for making novel Metallic alloys or MMCs or metal laminates and new processes for shaping metallic materials, such as casting, powder, vapour deposition, forging, superplastic forming, additive manufacturing etc., for applications in all service. Includes research to develop computer aided multi-scale material modelling, thermodynamic modelling and kinetic modelling to improve alloy design and understand alloy behaviour. Also includes research to understand relationships between microstructure, manufacturing and performance.

A01.02 – Ceramics, Ceramic Matrix Composite and Glass Technologies

Research to determine the properties and characteristics of structural ceramic materials, including ceramic matrix composites (CMCs), and glass ceramics, fibre and particulate reinforcements, microstructural analysis, etc. Research leading to improved processes for making and shaping new structural ceramic materials, etc., for applications in armour and propulsion systems including aeroengines. Also includes application of ceramic technologies for high performance device packaging. Includes research to develop material modelling to improve ceramic material design and understand the behaviour of ceramic materials.

A01.03 – Polymers and Polymer Matrix Composite Technologies

Research to determine the properties and characteristics of organic materials for structural purposes, including, polymers and polymer matrix composites (PMCs), thermosets, thermoplastics, elastomers, and materials used as reinforcing elements in PMCs such as fibres, particulates and laminates. Also includes work to understand the structural properties of biomimetic composite materials. Research leading to improved processes for making novel fibres or matrices, or for total composite manufacture, and new processes for shaping conventional composite materials, etc. Also includes identifying polymers for binders in LO paints and coatings. Also includes research to improve all sealants based on polymeric materials. Includes research to develop material modelling to improve design of materials based on polymers, including polymer composites, and understanding of the behaviour of such materials, particularly mechanical properties.

A01.04 – Structural Materials Processing - Joining Technology

Research to determine the properties and characteristics of joints between metallic, or ceramic or polymer-based materials, or between dissimilar combinations of these material types, etc. Research to improve joining/bonding processes used for any of the above cases, such as adhesive, diffusion, welded, interlayer, pre- and post-joining treatments, etc. Also includes the application of cost-effective joints in all service environments. Includes joining technology for high temperature materials and intermetallics.

A01.04.01 – Welding

Research to determine the properties and characteristics of welded joints in metals and polymers, including microstructure and non-destructive testing. Research into techniques including gas, arc, friction-stir and explosive welding.

A01.04.02 – Brazing/Soldering

Research to determine the properties of soldered or brazed joints including lead-free solders for electronics and brazing materials including amorphous brazing foils for ceramics and high temperature alloys.

A01.04.03 – Bolted Joints

Research to determine the properties of bolted joints including mechanical design and bolt torque, including joints between dissimilar materials such as carbon-fibre composites and metals.

A01.04.04 – Adhesive Joints

Research to determine the properties of adhesive joints including pre-bonding surface treatments, cleaning, etc. Includes research into techniques to ensure joint integrity.

A01.04.05 – Explosive Joining

Research to determine the properties of explosive welded joints including joining dissimilar materials.

A01.05 – Structural Materials Processing - Surface Protection Technologies

Research to determine the properties and characteristics of surfaces on structural materials, and which increases understanding of wear and corrosion mechanisms and prevention, thermal barriers, and other protective techniques to increase the lives of structures and components. Research to improve processes to control surface behaviour and increase lives of components and structures in service environments using advanced coating processes such as metal arc and flame spray, suspension and conventional plasma spray, cold spray coating, chemical vapour deposition, electroplating, diffusion processes, specialised paint formulations, and other protective coatings including multifunctional coatings. Research into developing environmentally benign substitutes for cadmium and hard chromium surface coatings and chromate primers.

A01.05.01 – Painting

Research to determine the properties of painted surfaces including pre-treatment and quality control of the painted surface. Research into environmentally benign solvents (especially water-based), and substitutes for chromate primers.

A01.05.02 – Wear Resistant Surface Protection Technologies

Research into technologies to improve the wear resistance of surfaces by e.g. nitriding, surface hardening, thermal spraying with hard coatings, environmentally benign substitutes for hard chromium plating.

A01.05.03 – Corrosion resistant

Research into technologies for corrosion resistant surface coatings including environmentally benign coatings for anti-fouling.

A01.05.04 – Thermal barrier

Research into materials and technologies for thermal barrier coatings for high temperature engine components, missiles and other high speed systems. Also research into ablative coatings.

A01.06 – Non-Destructive Evaluation and Life Prediction of Structural Materials

Research to determine the properties and characteristics of defects in structural materials using non-destructive tests and techniques of all types to detect flaws and cracks. Also work to develop inspection procedures through to service applications. Understand the limitations of techniques like ultrasonic, radiography, acoustic emission, optical and eddy current procedures. Research studies to develop innovative techniques (e.g. Digital Twin) to predict service life of structures and individual components under the influence of mechanical, thermal and chemical environments, singly and conjointly, etc. and from theoretical and materials behaviour data including studies to understand internal microstructures and the effects of flaws.

A01.07 – Corrosion and Wear Control Technology

Research to understand corrosion mechanisms including stress corrosion, pitting and crevice corrosion, electrochemical corrosion and high temperature corrosion. Research to understand wear mechanisms including abrasion and erosion and cavitation. Research to develop procedures to reduce wear and corrosion, such as surface hardening, shot peening, laser surface glazing, nitriding, etc.

A01.08 – Structural Mechanics

Research studies to determine the effects of vibration fatigue and shock on structures and components, using practical dynamic and static structural analysis methods/techniques or employing finite element analysis and other computerised simulation techniques to understand the response of structures to a variety of conjoint mechanical environment influences. Analysis and evaluations of fracture mechanics, and fracture resistance as applied to airworthiness and other safety issues. Also includes work to exploit life extension technology. Also includes research supporting determinations of static, dynamic and hydrodynamic performance of marine and aircraft structures, and the structural design of land vehicles, and marine platforms, especially those, which may undergo explosive and fire loadings. Also includes research to aid the assessments of design options for and safety margins of future military satellites. Also includes research in the fields of aeroelasticity, hydroelasticity and structural dynamics and structural acoustics. Also includes supporting work to aid structural integrity studies.

A01.09 – Structural Materials - Forming

Research to understand new forming processes and improve scaled-up industrial processes required to shape all forms of structural materials to near-net shape and size with appropriate microstructures, cost effectively. Research to understand forming processes and their relation to microstructure and performance, including additive manufacturing.

A01.10 – Structural Materials - Materials Removal

Research to understand and improve all mechanical and other types of physical techniques employed to remove material accurately and without microstructural damage during the manufacture of close tolerance components used in defence equipment. Research to understand processes such as drilling and high-speed machining and how machined surfaces affect properties such as corrosion, fatigue and friction.

A01.11 – Smart/Functional Materials for Structural Uses

Research to understand optical fibres, conducting wires, electro-active polymers, electroactive ceramics and shape memory alloys as either sensing elements or actuators in "smart/functional"

structural materials. Also includes materials aspects of application of embedded silicon micro-sensors for in-service in-situ monitoring of composite structures. Also includes studies on Biomimetic materials which may have structural applications in defence equipment. Also includes research on morphing materials for structural uses.

A01.12 – Textiles and Woven Materials

Research to understand textiles and woven materials of natural and artificial fibres including nanofibres. Includes research for coating fibres including plasma and chemical coating, conducting, insulating and multifunctional coatings for water, wind, light, flame, IR, chemical and biological resistance. Includes ballistic fibres. Also includes research to integrate power and data cables in textiles. Research to understand signature management including pattern printing and dynamic signature management.

A02 – Signature Related Materials

A02.01 – Acoustic & Vibration Absorbing Materials

Research to determine the properties and characteristics of materials which can be used to attenuate/dampen the transmission and reflection of sound energy in military equipment, for example, ships, submarines, torpedoes, and other UUVs. Research and development of designs aimed at improving the vibration dumping, in order to reduce crew fatigue and enhance weapon system accuracy. Also includes support for applications requiring reduced signature materials. Also includes medical acoustic materials, flesh simulants, and materials for machinery isolation and blast protection, including active (smart) materials for control of vibration and noise. Research into processes which shape such materials and which lead to improved bonding to underlying structures. Includes relevant frequency selective or responsive materials.

A02.02 – IR Signature Control Materials

Research to determine the properties and characteristics of materials which absorb infra-red radiation and which can be used to reduce the IR. signature of military equipment. Also includes tailoring properties like reflectivity and emissivity (all types). Includes supporting the environmental and multispectral requirements for Land vehicle applications for improved IR. absorbing materials. Also includes materials which change properties (e.g. IR reflectivity) for application in stealth coatings. Includes relevant frequency selective or responsive materials.

A02.03 – Radar Absorbing Materials and Coatings

Research to understand materials which serve as electromagnetically active constituents in coatings for use on low radar cross section structures. Also includes such materials for signature reduction applications, including frequency selective or responsive RAM, switchable conductors and tailored dielectrics. Evaluations of RAM, and multispectral materials for use in missile systems, missile detection and platform stealth applications. Also includes research into materials for high temperature RAM.

A02.04 – Structural Radar Absorbing Materials

Research to understand the radar absorbing characteristics of modified fibre reinforced polymer composites and associated conducting and absorbing sealants. Also includes non-invasive loss layers and frequency selective or responsive surfaces in material terms. Also includes materials issues when

integrating structural RAM into warship designs, and the environmental and mechanical applications of structural RAM in Land vehicle applications.

A02.04.01 – Chromic/Tunable Materials

Research to understand mechanisms and materials to allow dynamically tunable visible and IR reflectivity and absorption including electrochromic materials, thermochromic materials, and thermoelectric materials.

A02.04.02 – Metamaterials and Metasurfaces

Research to understand the materials, design and manufacturing of metamaterials metamaterials and metasurfaces including how to control bandwidth and tunability of these materials. Metamaterials consist of bulk materials hosting three-dimensional sub-wavelength arrays of scatterers that modify the electrical constitutive parameters of the hosting media. Metasurfaces, on the contrary, consists of bi-dimensional arrays (surfaces) of scatterers that can impose very abrupt changes of amplitude, phase and polarization of the impinging electromagnetic waves.

A03 – Electronic Materials Technology

A03.01 – Silicon-based Materials

Research to characterise new silicon materials which offer advances in low-cost thermal detectors and low power high performance electronic devices. Also work to improve growth and control of epitaxy for Si and SiGe alloys and improve understanding and growth of porous silicon for quantum and bio-compatible devices. Also research on silicon carbide for use in microwave and high temperature electronic devices.

A03.02 – III-V Compounds

Research to improve the growth and control of III-V compounds such as GaAs, InAs, InSb, GaSb, AlSb, AlN, InP and GaN for use in passive sensing, ECM sub-systems, radar and active imaging. Research to understand and evaluate the electronic characteristics of the III-V materials and their use for Defence systems. For instance, military and space applications could benefit as GaN devices have shown stability in radiation environments. Because GaN transistors can operate at much higher temperatures and work at much higher voltages than gallium arsenide (GaAs) transistors, they make ideal power amplifiers at microwave frequencies. In addition, GaN offers promising characteristics for THz devices.

A03.03 – Other Semiconducting Materials

Research to improve CMT technology applied to high performance and elevated temperature detectors. Also includes research to characterise II-VI compounds.

A03.04 – Insulating & Dielectric Materials

Research to evaluate applications of I (both electrical & thermal) & Ds to integrated circuits, thermal detectors, to pigments in LO coatings and as IR absorbing materials. Research to improve the growth of ferroelectric materials at low temperatures for applications in room temperature detectors. Also includes understanding application of I&D devices in high power RF systems.

A03.05 – Carbon-based Materials

Research to understand the electronic characteristics of carbon60, carbon suspensions, diamonds and diamond coatings which may benefit defence systems. Research to identify and understand organic semiconductors and optical polymer matrices for electronic and optoelectronic effects.

A03.06 – Superconducting Materials

Research to evaluate thin films for microwave sensing and signal processing. Research to understand wire fabrication technologies for electric power applications. Also includes developing superconducting materials for mine-CM magnetic sweeping and for high power RF systems. Also includes research to develop HTS materials for ESM-Comms, and ESM-non Comms.systems.

A03.07 – Magnetic Materials

Research to understand magnetic behaviour of thin film magnetic materials for use in sensors and in signature reducing applications. Also includes "smart" magnetic materials which may find application in HF acoustic transducers used for MCM sonars.

A03.08 – 1D & 2D Materials

Research to understand and evaluate the electronic characteristics of the materials such as unidimensional (1D) carbon nanotubes (CNTs) and two-dimensional (2D) like graphene due to their superior electrical properties (exhibiting room temperature ballistic transport) which allow for fabrication of faster and more power-efficient electronics.

A04 – Photonic/Optical Materials & Device Technology

A04.01 – Optical Materials & Devices

Research to evaluate and analyse optical components, splitters and couplers. Also includes work on optical materials for wideband RF fibre optic links and fibre optics for communications, in particular with UUVs, underwater weapons, anti-tank missiles, hydrophone arrays and in data transmission systems. Also includes research to understand design and fabrication of optics for use in demanding defence applications, and materials for both lenses and their coatings.

A04.02 – IR/Visible/UV Detector Materials & Devices

Research to evaluate and analyse high performance photon detectors, wide field detectors (small pixels, large number of pixels), highly sensitive detection (for high SNR and low light illumination). Also includes optical devices for high-speed detection, optical switching, and infrared detection on SiGe, ferroelectrics and InSb arrays.

A04.03 – Non-Linear Optical Materials & Devices

Research to understand optical materials capable of fast switching, or for tuneable filters, optical limiters and those showing non-linearities in liquid crystals, polymers and polar organic materials. Also includes evaluations of NLOs for personnel protection systems. Also includes studies of non-linear optical characteristics and susceptibility, harmonic generations, and devices for applications in waveguides and tuneable lasers.

A04.04 – Display Materials & Devices

Research to understand nanophase polydisperse tuneable filters, other novel liquid crystal materials and new technologies like OLED, micro-LED offering benefits for future military display applications. Research to evaluate the benefits in terms of DRI of new devices like head-up displays, small screens with high resolution, high contrast and high brightness.

A04.05 – Lasers -all Types

Research to produce (in particular miniaturize – proposition of new architectures) and characterize laser sources (from UV to FIR) for applications in active imaging, laser countermeasure and laser weapons systems, optical telecommunications. Research to evaluate the benefit for these latter applications of new technologies like semi-conductor lasers (laser diodes), fibre lasers.

A04.06 – Non-Laser Devices

Research to understand certain specific structures in III-V materials and in porous silicon for light emitting diodes, and structures in other types of LEDs .

A04.07 – Transparent Materials

Research to understand diamond and sapphire windows and coatings, and other materials which are transparent to optical radiation and other electromagnetic radiation. Also includes studies of the characteristics of materials which serve the above purpose and which are also capable of sustaining mechanical and/or thermal loads, in applications like aircraft canopies, missile radomes, and sonar domes. Also includes relevant frequency selective or responsive surfaces.

A04.08 – Quantum Optics

Research to understand the application of quantum optics to precision measurement. The use of coherence of atomic pulses can be used for measurements of inertial accelerations, gravity and rotation. Quantum technology will be essential in designing the next generation of accelerometers and gyroscopes.

A05 – Electronic, Electrical & Electromechanical Device Technology

A05.01 – Device Concepts and Fabrication

Research to evaluate and analyse technologies for application in novel IR and EO devices like displays. Also includes process technologies required to fabricate flexible and stretchable devices to be seamlessly integrated with soft and curvilinear human skin or clothes (such as electronic devices capable of storing and processing data – wearable computing devices), and characterisation of device structures, including hybrid structures and nanotechnology developments. Also includes studies of micro-structured and deformable surfaces to control the scattering direction of incident radiation for stealth purposes. Also includes devices for applications in high power RF systems. Also includes MEMS fabrication technology and device developments which give rise to novel luminescence effects.

A05.02 – Device Packaging

Research to understand application of new technologies to package system-on-chips, ASIC, ASSP and RFCMOS devices as well as MMICs and other RF power components at the prototype stage, and also

when applied to multichip modules. It includes novel wafer-level-packaging (WLP), 2.5D and 3D integration, opto / MEMS integration. Also includes novel packaging requirements for bio-compatible Si and micro-sensors. Work to improve ruggedization of devices is also included.

A05.03 – Device Integration/Reliability

Research to evaluate and analyse defects in electronic components, device obsolescence tracking processes, specifications, and tests for reliability, quality and fitness for purpose. Also includes integration of discrete devices in silicon-based materials and in other types of semiconductors. Also includes work to understand the requirements for devices in applications like high power RF systems and ASIC devices handling large amounts of sonar data.

A05.04 – Electrochemical Energy Conversion Fuel Cells

Research to understand fuel cell systems, fuel reforming, fuel storage (hydrogen or alternatives like methanol, ammonia or ethanol) and system integration issues (including necessary conversion of electrical power), related to all types of integrated hybrid and all-electric propulsion applications and for all other types of power systems (e.g. high power pulsed systems). Also includes fuel cell technology for man-portable systems. Research on this topic should be done in close connection withA05.13 – Electrochemical Energy Storage - Batteries, as Fuel Cells generate the electrical energy that will be stored in Batteries. Experiences of Fuel Cell Technologies for submarines should also be considered.

A05.05 – Solar Cells

Research to understand organic solar cells for affordable, lightweight, flexible integrated power supplies, and to underpin capability to evaluate and analyse solar cells for satellite applications. Also includes research into photovoltaic cells for defence applications for storing, conserving and dispatching energy produced with solar energy generation technologies using innovative energy management systems. In addition, thermal Energy Storage Systems (solar collectors, heat pumps, hot water production) should be considered.

A05.06 – RF Power Sources & Devices

Research to give ability to evaluate and analyse solid state materials (like SiC) and RF power devices e.g. amplifiers and circuits (from UHF/VHF to microwave and millimetre wave, and THz), novel architectures for application in radar, communication and ECM systems.

A05.07 – Acoustic Power Sources & Devices

Research to understand acoustic power sources with high power and wide bandwidth as well as compact acoustic sources for application in active sonar systems.

A05.08 – Other Electrical Power Systems & Devices

Energy harvesting and scavenging, address the challenge of eliminating or reducing the power source or wiring requirements and lowering the logistic burden from supplying power (including batteries) to remote or on the move equipment and devices. In this context, this refers to research to understand developments of innovative electrical power converting devices, such as power electronics and complete electrical energy systems, for incorporation into a variety of mobile defence equipment requiring standalone energy sources. This includes associated test activities, predictive modelling and simulation and standardization. Also includes research and improvement of all dedicated electrified systems and components, power electronics such as inverter technology or DC-DC converters, as well

as energy management systems (electrical machines are considered under topic A05.09 – Electric Machines and Actuators). Research on the digitization and increasing interconnection of electrical vehicle systems and their sub-systems, taking into account redundancy aspects as well as condition monitoring and status reporting (the specifics regarding weapon systems are considered in section B03.08) Also includes the work on safety, reliability and maintainability of electrified ground vehicle systems with higher voltage levels (beyond ELV). Also includes the research on new materials (SiC, GaN on SiC, GaN on diamond), components and manufacturing processes related to electrical power systems.

A05.09 – Electric Machines and Actuators

Research to understand and evaluate technology for electric machines (motors and generators) and other electromechanical actuators required in a wide range of demanding military applications. Also includes associated test activities, predictive modelling and simulation and standardization. This also includes the improvement of electrical power generation systems based on stationary and vehicle-integrated generators (e.g. for hybrid vehicles), start-stop and starter-generator systems and their system integration. Also includes the research and improvement of servo drives and electromechanical actuators and their system integration. Also includes the research on new materials and manufacturing processes (e.g. additive manufacturing of magnetics and coil windings etc.). Also includes research for alternatives to permanent magnet stator avoiding rare earths. Electric Motors are already in use in several classes of Naval Combatants. Further R+D should focus on power efficiency and scaling effects (smaller size of motors, but in higher quantity).

A05.10 – Inertial/Gravitational Devices

Research to understand and develop inertial and gravitational devices, particularly detectors, for use in a variety of military applications such as guidance systems. Also includes work to apply silicon microsystems technology for micro-accelerometers and micro-gyros, including embedded control and signal processing electronics.

A05.11 – Energy Efficient Technologies

Energy efficiency is closely linked to security with issues such as security of supply, import independence and safe production. As set out in the EU Global Strategy, given the changing security and operating environment, the defence sector is likely to be deployed to increasingly harsh environments with possible energy and water shortages. This will have implications for equipment and personnel function, possibly resulting in increased power requirements because of climatic change and average environmental limits being exceeded with greater frequency. Therefore Smart Grids solutions integrating RES energy efficient technologies and legacy systems to increase and manage the grid efficiently should be taken into consideration.

A05.12 – Energy Storage

Energy storage technologies should be investigated for appropriate use in military camps' power supply and demand management as part of intelligent energy management as well as in military platforms including for hybrid power systems. The research should include hydrogen storage systems, solid oxide fuel cell generating both electricity and hydrogen and fully integrated model of hydrogen production, storage, transportation and utilisation for heat, power and mobility. Future energy storage technologies research shall include supercapacitors (Ultra-capacitors, Lithium-ion Capacitors), to highly constrained applications with requirements for high energy density.

A05.13 – Electrochemical Energy Storage - Batteries

Research on the integration of effective, powerful, high density and reliable energy storage systems and any power charging systems. Research on rechargeable batteries for the improvement of their versatility and interchangeability across system boundaries within the scope of military use and their simultaneous use in different mobile and stationary deployment scenarios, for dismounted, land, maritime and air applications. This includes the improvement of battery management systems and innovative system approaches (including hybrid technologies) to increase the lifetime of the batteries (high number of cycles and calendar life). Also includes work on testing and standardisation of energy storage systems. Also includes evaluation and analysis of power source integration using microsensors for autonomous operation to monitor all issues relating to battery performance. Also includes the analysis of innovative civil-developing energy storage technologies and their suitability for military requirements (environments, robustness, safety, logistics etc.). Includes the research for the new generation of supercapacitors. If applicable outgassing of batteries is also to be taken into account.

A05.14 – On Board High Energy Storage and Distribution System

There are a number of technologies requiring research for military applicability for more compact, more efficient and reliable propulsion/drive systems, such as internal combustion engine optimisation, turbocharging and engine downsizing, higher pressure ratio engines, hybrid engines and electric engine systems. On-board high-power distribution electromagnetic management. Compact power conversion technologies with wide band gap devices for higher voltage shipboard power distribution systems. Power dense and efficient electrical backbone with dynamic reaction times. Dielectric materials for bidirectional power control modules and development of power converters and power management controllers. Components and methods to quickly detect and clear electrical faults and replace slow-acting circuit breakers and protective relays (thus enabling safer operation, reducing arc faults, and increasing the power density of the electrical system and overall power for mission loads). High-power solid-state circuit breakers for shipboard power. Advanced power generation and energy storage technologies for lithium-ion batteries, fuel cells, and ultracapacitors. Multifunction and reconfigurable energy storage solutions for buffering pulse loads. Compact, large-format, module-level, high-density tactical energy storage technologies. Development of hybrid polymer/ ceramic dielectric materials and devices, supercapacitors, and electrochemical capacitors for auxiliary power applications. Phase change heat transfer and materials with increased thermal conductivity for thermal management. Hybrid polymer/ ceramic dielectric materials and devices, supercapacitors, and electrochemical capacitors for auxiliary power applications. boron carbide, boron nitride, and graphene for power electronics to enable higher voltages, frequencies, and temperatures. Identification/development of new materials with higher thermal conductivity and a lower cost than standard wide band gap semiconductor materials. Manufacturing techniques that process materials to modify their surface structure to enable tailored heat transfer properties. New phase change substances that absorb heat by changing the phase of the material. Artificial intelligent controls using deep learning neural networks for load-levelling and high-power switches and controls. Photonic crystals and plasmonic sensors for diagnostic systems for high-temperature systems. Modelling and simulation of the power and thermal management and controls systems as part of the platform. Includes research on superconducting engines.

A05.15 – BioMEMS / Bio Sensors

Research to understand developments of innovative BioMEMS / bio sensors devices including pressure sensors, microphones, inertial MEMS, microfluidic chips, microdispensers, optical MEMS, MUT flow meters, gas and humidity sensors integrated or used in the life science, healthcare and environmental domains and applicable for defence (like for CBRN applications).

A06 – Fuels, Energetic Materials and Plasma Technology

A06.01 – Propellants

Research to understand, evaluate and analyse propellant materials for weapons systems applications and for compliance with OB and CINO policy on handling and use of propellant materials. Also includes use of predictive modelling in the characterisation of new propellants. Also includes research leading to improved fuels for ramjets. Also includes technologies applicable to environmentally-friendly disposal procedures at end of service life.

A06.02 – Conventional Fuels

Research to aid the evaluation and analysis of fuels used in all defence equipment, for compliance with OB and CINO policy/EU Green Deal aspects. Also includes work to understand problems relating to fuel faults and failures, and hazard management processes. Research to improve capability to specify, conduct approval and quality assessments, and evaluate products and equipment during working life.

A06.03 – Non-Conventional Fuels

Research includes biofuels, artificial leaf from the sun light and carbon dioxide, the production of biofuels using enzymes, bacteria or algae, flying wind power and other new ways to produce wind energy, piezoelectrical energy sources, harvesting of kinetic energy, hybrid/alternative energy sources.

A06.04 – Explosives

Research to aid the evaluation and analysis of explosive materials used in weapons systems and armour applications, and for compliance with OB and CINO policy on the handling and use of energetic materials for defence purposes. Also includes research to improve understanding of detonics and use of predictive modelling. Also includes modelling of blast and shrapnel effects. Also includes research needed to address disposal issues at end of service life.

A06.05 – Pyrotechnics

Research to understand application of pyrotechnics and nano-thermites in weapons systems, countermeasures, underwater mine disposal, and for compliance with OB and CINO policy for handling and use of pyrotechnic materials. Also includes behavioural studies of materials used for initiators and as obscurants, and the use of predictive modelling of pyrotechnics. Also includes research to address disposal issues relevant to pyrotechnics at end of their service life.

A06.06 – Plasma Techniques

Research to understand plasmas which have potential defence uses, such as in ETC gun systems. Also includes research to understand intense light propagation, absorption and scattering effects in plasmas, and interactions of plasmas with all forms of matter. Also includes research to address plasma techniques for explosives and plasma techniques for inert materials.

A06.07 – Explosives Detection Techniques

Includes research using active optical sensing and surface enhanced Raman effects for chemical detection purposes. Also includes research on Nuclear Quadrupole Resonance (NQR), Magnetic Resonance, THz technologies, Mid-infrared Spectroscopy and Radar to enhance detection capability

applied to both bulk and trace detection techniques for explosives. Also includes work on bio-engineered organisms for use in explosive detection systems and related degradation determination activities. Also includes research on IED detection thorough Ground Penetrating Radars (GPRs), mechanical components and through techniques based on electromagnetic effects, neutron generation, directed energy detonation, etc.

A06.08 – Ignition Techniques

Includes research to address igniters, EBW, EFI, ignition trains, fuse, primary explosive, detonation cord blasting cap, electrical ignition, optical ignition and novel ignition methods.

A06.09 – Energetic Materials Production Technique

Research addressing new production techniques for Energetic Materials, such as additive manufacturing (3D printing), flow chemistry, continuous (co-)extrusion of gun propellants, Resonant Acoustic Mixing (RAM), among others. Also includes research on safer and improved control of production methods.

A06.10 – Characterization of Energetic Materials

Research to improve methods and techniques to characterize energetic materials concerning safety, sensitivity, combustion, detonation, thermal properties, etc.

A06.11 – Sustainable and Synthetic Fuels

Research to aid the replacement of conventional fossil fuels such as hydrocarbon fuels refined from fossil sources (e.g. gasoline, diesel and kerosene) by synthetic fuels (biofuels, and e-fuels), Ammonia (NH3), On board Hydrogen production (bioethanol reforming, methanol reforming, metal hydrure hydrogen storage) with equal physical properties but produced sustainably (green fuels) and with minimum CO2 emission footprint.

A06.12 – Novel Energetic Materials

Research of new energetic materials formulation, aiming at improved performance, less toxicity and more environmentally friendly (green), while maintaining a certain level of insensitivity towards external stimuli. Also includes investigation of alternative substances, to replace those limited by legal regulations.

A07 – Chemical, Biological & Medical Materials

A07.01 – Chemical Agent Defence, Precursors & Related Materials

Research to aid the ability to identify, analyse and evaluate chemical materials which might be used as a threat against the EU. Also includes research to understand toxicity, producibility and properties of chemicals, and analyses of how such agents might be used, and to maintain the ability to predict the consequences of their use. Research to maintain expertise to specify detection, protection and medical countermeasures. Also includes work to understand pathology and handling of supertoxic chemicals.

A07.02 – Biological Agent Defence, Precursors & Related Materials

Research to aid the ability to identify, analyse and evaluate biological materials which might be used as a threat against the EU. Also includes research to understand toxicity, producibility and properties of biological materials, and analyses of how such agents might be used, and to maintain the ability to predict the consequences of their use. Research to maintain expertise to specify detection, protection and medical countermeasures. Also includes work to understand in vitro, pathology and handling of highly infectious pathogens.

A07.03 – Mid-Spectrum Agent Defence

Research to aid the ability to identify, analyse and evaluate those materials that are produced from biological sources, such as biotoxins and bioregulators, which have severe toxic effects on personnel, and may be used as threat against the EU Also research to maintain the capability to predict the probable consequence of their use in the military environment. Also research to maintain expertise to specify detection of MSA, protection from MSA and appropriate medical countermeasures.

A07.04 – Chemical & Biological Detection Techniques

Research to maintain expertise in CB agent materials and toxic chemicals detection techniques, particularly monitoring levels of hazard, identifying the agent and establishing the exposure period retrospectively. Also includes research into the physics of aerosol collection and characterisation, and application of MS and IMS techniques to the analysis process. Also research to support capabilities in genetic engineering and amplification, antibody/antigen interactions, gene probes and biosensor transduction. Also includes work using novel silicon sensor devices, such as bio-compatible (more applications at topic A05.15 – BioMEMS / Bio Sensors) porous silicon sensors, and the use of optical sensing and surface enhanced Raman effects.

A07.05 – Chemical Research for non-CBD Applications

Research to understand toxicology and safety issues relating to non-CB chemicals used in a wide range of defence equipment. Also includes work on the behaviour of fire protection coatings and maintaining abilities to specify fire resistant materials employed in ships, aircraft and AFVs. Also includes research to aid the analysis and evaluation of new materials to be used as alternatives to halons and other materials prohibited by the Montreal Protocol. Includes research into monitoring techniques for submarine atmospheres, and research into advanced chemical analysis techniques applicable to defence-related materials.

A07.06 – Medical Products and Materials

Research to evaluate and analyse blood products and other important medical materials, including biomimetics and other bio-inspired materials for medical purposes. Also includes work on vaccines, prophylaxis, other disease controlling substances and portable medical diagnostic devices. Also includes work on synthetic biology to produce personalized antibiotics.

A07.07 – Synthetic Biology Technologies

Research and development of biological parts, devices and systems, including synthetic cartilage in human joints, biobots, artificial muscles, artificial & self-renewing skin, tissue engineering and other complex gene networks.

A07.08 – CBRN and Nanotechnology Developments

Research to evaluate and analyse nanotechnology advances for application in novel devices, decontamination techniques, protection equipment's, and other relevant themes regarding to CBRN safety. Also includes process technologies required to fabricate advanced products and protection equipment with innovative properties (self-sensing, self-healing, self-cleaning, self-decontaminating, antifouling and others), and their characterisation.

A07.09 – Medical Research and MedTech

Research to understand the requirements regarding medical devices in current and future battlefields. This includes research on new technology improving military medical care and medical training as well as technology for autonomous medical capability support. This also includes autonomous medical evacuation and medical robotics for combat casualty care.

A08 – Computing Technologies & Mathematical Techniques

A08.01 – Software Engineering

Research to understand software systems engineering, coupled with diverse domain understanding in order to advise on software integration processes, Quality Assessment (QA), COTS product integration, development of algorithms, techniques, models and software engineering processes applicable for radar, and guidance and control applications. Research to understand simulation language developments and their benefits to military systems. Research on algorithms for automatic target detection, tracking, recognition and identification. Research on software systems that implement models of neural systems (for perception, motor control or multisensory integration) - Neuromorphic computing. Also includes work to understand the behaviour of relevant types of embedded software and time-critical aspects of middleware, also for edge processing.

A08.02 – Protocol Technology

Research to understand protocols for satellite and terrestrial communications systems management and control, relevance of civil protocols and their interaction with military networks, including LANs and WANs. Research on Internet Protocols technologies and next generation networks, also includes migration technologies. Research to aid evaluation and analysis of protocols relevant to communications and communications design for battlefield use. Also includes research into Distributed Interactive Simulation protocols. Also includes research to understand the role of middleware (transaction managers) in defence networked information systems.

A08.03 – COTS and OSS Assessment

Research to understand the implications, behaviour and integration of Commercial Off-The-Shelf (COTS) and Open-Source Software (OSS) components in defence systems. This includes release management ensuring functionality as well as freedom of risks (backdoors, viruses, restriction of functionalities, data transfer to the vendors or developers etc.). Also includes compliance and licensing, maintenance and help on make or buy/use decisions.

A08.04 – Architectures

Research to understand architecture systems and parallel computing developments. Research on emerging paradigms that seamlessly integrates large number of smart objects with the internet, interlinking the physical and the cyber worlds and keeping them in a tight and continuous interaction (by example IoT - internet of things). Research on framework developments that allows data to be shared and reused across application, enterprise, and community boundaries (by example semantic web). Also includes the design of Distributed systems. Research also includes the military Multi-domain Operations Clouds (combat cloud).

A08.05 – High Integrity and Safety Critical Computing

Research to understand high integrity hardware and software and their applications in defence equipment. Includes new developments in safety critical software (SCS), particularly new tools and methodologies used to investigate fault tolerance/detection, atomicity and liveness. Also includes work on software quality and reliability issues in SCS and also work to improve knowledge of fault tolerant computing and fault tolerant software.

A08.06 – Secure Computing Techniques

Research to understand secure operational procedures and secure segregation of information, including infosec and vulnerabilities at all hardware and software levels of communications and information systems, and understanding the nature of Information Warfare (IW), high integrity software, open systems integration, architectures and standards. Research to ensure compliance with international standards and best practices. Also includes quantum computing techniques, malware detection techniques and methods through different tools and their implementation, and other intrusion detection systems.

A08.07 – Encryption / Crypto Technologies

Research on different data encryption / decryption methods (by example quantum technologies, homomorphic encryption) in the context of information warfare processes and INFOSEC. It includes the understanding of quantum optical processing for secure communications systems, system vulnerabilities, and encryption work. Also work to understand interaction of communications systems design and encryption techniques.

A08.08 – Mathematical Modelling Development

Research to understand and develop new modelling techniques which advance a wide range of defence applications. For example, new approaches to hydrocode and analytical modelling to underpin CE warhead research and attack of future targets. Includes new modelling approaches in/for synthetic environments, human factors, communications networks and related issues. Also includes work to improve the modelling of risk assessment techniques. Also includes work on Artificial Intelligence (AI), Machine Learning (ML) and autonomous decision methods with and without human in the loop approach.

A08.09 – OA Tools and Techniques

Research to aid the evaluation and analysis of OA/OR techniques for application to security or defence issues, particularly those which allow more effective provision of advice to MoD. Also includes the exploitation of object-oriented techniques within a modelling framework applied to all levels of

communications, information systems networks and management, and to provide rapid prototyping and cost-effective re-use of validated model elements.

A08.10 – Cyber Defence

Research on novel concepts to improve interoperability, capabilities and test and validate concepts through experimentation. Research to understand technical vulnerabilities in systems and software. Also includes emergent and changing properties of cyberspace itself. Research on systematic properties of cyberspace. Research on security standards and tools via promoting those already in existence or developing specific ad-hoc standards. Also includes information on equipment solutions and pooling and sharing for cyber defence capabilities. Also includes to research on generate automate actions to cyber-attacks. Also includes cyber hardening

A08.11 – Software Verification and Accreditation Techniques

Research on the verification and accreditation of software, but not the validation of models which should be carried out within the appropriate technology area.

A08.12 – Quantum Computing Technologies

Research to understand the use of quantum physics, also called quantum mechanics, to perform calculations in a manner radically different than conventional models of computation. Also includes novel concepts related to advancing quantum computing technologies, secure computing, and cryptography and quantum key distribution. Also includes understanding laws of quantum mechanics to process information. Also includes quantum nanotechnologies.

A08.13 – High Power Computing

Full description planned for the next update cycle.

A08.14 – Multicore Systems

Research on transition from monocore, over dual-core, to modern multicore systems for safety-critical aviation applications/computer technology, according to EU supply chain needed (chips, networks). Furthermore, distributed electronics and computing/distributed control system are included in this topic.

A09 – Information and Signal Processing Technology

A09.01 – Data & Information Management Technology

Research to understand data mining (from homogenous and heterogeneous information sources) and automatic image retrieval based on content addressed coding. Also includes work to understand ILS and CALS techniques and to maintain archival and current information databases concerning trials, equipment and manufacturing. Also includes work to understand international standards and codification bodies requirements. Also includes research to address the requirements of military mission simulators in the air environment, and real-time database structures. Includes new data and information storage techniques, including data warehousing technologies. Includes research into new data and information compression techniques. Also includes work on information management and information compression techniques, and application of IM techniques to knowledge-based

engineering designs. Also includes research to support the exploitation of middleware in defence database management systems.

A09.02 – Digital Signal Processing Technology

Research to understand DSP for high-throughput MCM sonars and UUVs., underwater weapon homing and countermeasure algorithms and systems. Also includes DSP techniques in relation to radar systems, weapon dynamics, guidance and weapon/target interactions. Also includes work to understand application of DSP to Satcom EPM and multifunction RF modems, to future software radio concepts, EPM and adaptive systems concepts for tactical communications. Research to understand novel mathematical techniques and to aid the evaluation and analysis of DSP in systems involving PAR, sonar, and communications hardware. Also includes fast DSP techniques, signal correlation, single flux quantum logic in high temperature superconducting devices, and Focal Plane Processing techniques. Also includes data compression/decompression techniques for video and other applications. Also includes research on processing methods of spectrum sensing and digital signal processing steps for cognitive radio networks.

A09.03 – Optical Signal Processing Technology

Research to understand pattern and target recognition for repeaters, and jammers, signal generation. Research to aid evaluation and analysis of adaptive optics and distributed apertures. Also includes work to understand use of novel components for implementation in optical processing algorithms. Also includes Optical Surveillance Platform Optical Signal Processing in the context of prototyping ground stations. Also includes data compression and decompression techniques for video and other applications and compressive sensing algorithms to enhance DRIT capabilities. Also includes study and optimization of coding and link modulation to reduce fading due to propagation effects.

A09.04 – Image/Pattern Processing Technology

Research to understand IR focal plane arrays and passive mm wave imaging, making use of advanced super resolution algorithms. Also includes relevant mathematical techniques, and hardware and software implementation. Also includes work to understand HF sonar imaging, and real time image processing to support unmanned vehicles, machine vision and AFV crew aids. Also includes research to improve understanding of algorithms used for target detection, recognition and identification purposes in weapon and countermeasure system applications, and also used for weapon dynamics, guidance and weapon/target interactions. Radar/optical/IR image processing from satellites for observation purposes is also included.

A09.05 – Speech & Natural Language Processing Technology

Research to understand novel mathematical techniques, requirement assessment, fast prototyping, language modelling, hardware and applications evaluation. Research to aid the development of speech/voice recognition systems for the air environment and for AFV crew station applications.

A09.06 – Optimisation & Decision Support Technology

Research to understand AI and expert techniques for support of data fusion, decision support techniques and their application to satcom system management. Also includes AI/ET in the context of information management, MCM sonar classification systems, combat management systems and planning aids, torpedo homing and simulations, and in wargames supporting analysis of security or other defence issues. Also includes machine intelligence developments, and decision planning aids. Also includes research to develop techniques to aid better situational awareness. Research to

understand optical processing components and algorithms for neural network implementation. Also includes work to understand the uses of Neural Nets in HUMS, for example, fatigue and load exceedance monitoring. Also includes work to understand application of novel mathematical techniques specific to NNs used in a range of weapons systems, simulations and wargames. Also includes work on neuro-fuzzy systems and recurrent NNs.

A09.07 – Information & Data Fusion Technology

Research to understand applications of I&DF techniques in multispectral sensor systems, sensor integration and picture compilation, anti-stealth and target identification, and various weapons systems issues such as guidance, dynamics, and weapon/target interactions. Research to aid evaluation and analysis of data fusion applied to combat aircraft and sensor systems, including software, simulation and flight trial techniques. Also includes work to understand human factors requirements for data fusion. Also includes work to support CALS and CIRPLS activities. Also includes work on decentralised architectures and emergent behaviour.

A09.08 – Cognitive Systems Computing

Research on technology platforms which are based on scientific disciplines such as artificial intelligence or signal processing. Also includes machine learning, big data analytics, language processing, deep learning systems, predictive analytics based on self-organizing data. Also includes self-learning systems that use data mining, pattern recognition and natural language processing. Also includes creating automated IT systems that are capable of solving problems without requiring human assistance. Also includes machine learning algorithms

A09.09 – Other Information Processing Technology

Research to understand applications of OIPT to all aspects of weapon systems, simulations and wargames, and to aid the evaluation and analysis of non-spatial recognition algorithms as applied to long range targeting systems, and to model the optical properties of complex pigments and binders. Also includes fuze algorithms.

A10 – Human Sciences

A10.01 – Human Information Processing

Studies of human sensory, perceptual and cognitive processes. Includes work on modelling of the human visual system; human error and reliability; studies of workload reduction for crew systems in military platforms and installations; hypothesis formation; human decision making and situational awareness; and principles of human interaction with systems. Research on the effects of the Augmented Reality (AR) in the improvement of the situational awareness and its influence on the decision-making process. Research on human information processing based on data gathered through manned and unmanned teaming. Research on multi modal Human-Machine interfaces (HMI).

A10.02 – Military Human Resources

Development of techniques for the recruitment, selection and retention of personnel. Includes work on the management of equal opportunities; aptitude, personal qualities, and physical characteristics; manpower modelling; and systems complementing.

A10.03 – Teams, Organisations & Cultures

Studies of groups ranging from small teams to complete societies. Includes work on team process and effectiveness; impact of command and leadership style on organisational behaviour; human determinants of collective performance - e.g. morale; studies of the impact of cultural norms on social behaviour; and studies of influences on social perception, such as work underpinning Psychological Operations.

A10.04 – Human Survivability, Protection & Stress Effects

Studies relating to the impact of stressors on human performance, behaviour and well-being. Includes work on the impact of irregular duty schedules; sleep loss; physical and mental fatigue; impact of thermal strain; clothing assemblies; decompression and diving studies; post-traumatic stress effects; fear; head impact modelling; prevention of musculo-skelatal injuries; and studies of the human performance implications of protection against environmental and weapon threats.

A10.05 – Individual & Team Training

Studies of skills and physical training techniques. Includes management of skill acquisition and skill fade; Crew Resource Management techniques; training needs analysis; and physical fitness training. (Excludes Skills Training systems B08.01 – Skills Training systems).

A10.06 – Human Factors Integration

Development of methods, tools, and processes to support the integration of people with complex systems. Includes modelling of human performance; development of design standards; kinetic body modelling and anthropometry; and techniques for the allocation of functions to systems. Includes research into applications to integration of speech, performance of MCM sonar, and visual displays. Also includes work on human-interface design and evaluation, such as vision modelling studies, ergonomics and interfaces that provide a direct communication between brain and computerized devices for the identification and assessment of (i.e. CBRN) threats. Moreover, to consider neurotechnologies which are explicitly related to cognitive functions such as communication, memory, decision making, attention, situation awareness, social interactions, complex problem solving, which are all and specifically relevant in the military domain both in offensive and defensive scenarios, by using Brain Machine Interface technologies and invasive/no-invasive brain stimulation.

A10.07 – Collective Training

Studies of techniques for training collective performance. Includes collective non-real-time training; after action review; and metrics of collective performance. This will allows to form teams that be capable to be fully immersed in their mission and to work effectively as a team with a good understanding of the tasks required.

A10.08 – Human Performance Enhancement

Studies of interventions excluding training (A10.05 – Individual & Team Training and A10.07 – Collective Training) and protection (A10.04 – Human Survivability, Protection & Stress Effects), that enhance individual physical and mental performance. Includes work on nutrition; pharmacological agents; ergogenic aids; and other treatments for to enhance human performance, including full understanding of risks to health through continuous personal health monitoring. Also includes research on biometrics applications, simulation and mapping of brain to detect changes in soldiers' physiology and predict humans and groups behaviour from background data. Also to consider tools to

improve wellbeing and alertness referring to devices either to maintain or to enhance the vital functions (first and second order), such as respiration, blood circulation and consciousness as well as water-electrolyte and acid-base balance, kidney function and heat balance (wellbeing); and devices to establish or enhance either the self-awareness or sensory perception with regards to the recognition of vital signs and the surrounding environment. Includes research on smart textiles equipped with sensors monitoring vital human performance data of persons (i.e. wearing CBRN-individual protective equipment (IPE)) with the aim to extend the mission time through physical support (e.g. exoskeletons) and improved mental performance (e.g. neuroenhancement).

A10.09 – Medical Sciences and Capabilities

The science of medical conditions and their treatment, as well as capabilities allowing diagnostics, treatment, and decision support. This topic includes telemedicine and neurosciences.

A10.09.01 – Telemedicine

Medical decision support using telecommunication systems, algorithms or AI. Research to improve telemedicine systems integrated in military platforms and infrastructures: communication solutions, augmented reality for casualty assistance support, etc.
Medical staffing is an identified need in most countries. Enabling medical capabilities with decision support based on telemedicine or artificial intelligence could improve first-responder care, triage, and evacuation decisions. European interoperable medical decision support systems must be based on national and European legislation as well as medical evidence and best practice.

A10.09.02 – Neuroscience

The science of the nervous system. It includes the study of neurological anatomy, the physiology and pharmacology of nervous signal transmission, the biological neuronal network, as well as biological cognitive sciences. Cognitive warfare (CW) neurosciences play an important role in the research of cognitive resilience and neuroweapons.

A10.10 – Robotics in Medicine

Research on the use autonomous platforms could serve as vehicles of opportunity for Casualty Evacuation (CASEVAC). Development of a common European autonomous CASEVAC standard would allow the specification of CASEVAC capabilities for the procurement of future autonomous platforms. Longer term developments should include dedicated Robotics Assisted Medical Evacuation (RASEVAC), where autonomous platforms with medical robotics capabilities may start life-saving treatment during the transport process. This should include robotic surgery and robotic prosthetics

A10.11 – Molecular Biology Technologies

Studies to evaluate the threat level from biological pathogens generated through DNA engineering, bacterial transformation, transfection, chromosome integration, molecular hybridization, rewriting DNA: mutations, random mutagenesis, point mutation, chromosome mutation.

A10.12 – Surgical Techniques and Medical Procedures

Research to evaluate and analyse non-CB medical defence issues such as treatment of battlefield casualties affected by either conventional or novel weapons, using surgical and medical skills, operating theatres, and mathematical modelling. Also includes work to understand ballistic and explosive effects on human tissues, and the effects of hyperbaric oxygen treatment of soft tissue injuries. This includes simulation techniques for training the battlefield and other casualties' treatments.

A10.13 – Human Health Physics

Research into the application of dosimetry techniques to assess the nature and scale of radiation effects on military personnel. Also includes work to understand the use of epidemic modelling including use of man as a detector.

A10.14 – Human Performance Monitoring Techniques

Research into techniques to sense and monitor the performance of personnel. Includes physiological sensing and monitoring.

A10.15 – Human Factors in Manufacturing

Research into techniques that enhance human capabilities within the industrial workplace, both in the design shop and on the factory floor. Also includes "time-and-motion" studies in the context of human control over manufacturing processes.

A10.16 – Human Machine Teaming

Research includes the definition of a novel design and interaction principles for managing automated/autonomous aircraft functions and cooperating with System-of-Systems teammates, including adaptive interfaces can be defined as man-machine teaming (MMT). This theme addresses the definition of a new paradigm of human-machine teaming in future collaborative and connected air warfare. New generation military aircraft participating in collaborative air combat will require a human system interface that enhances the awareness of the tactical situation and allows an ergonomic cooperation between crews and machines for a safe flight and high performance in cooperation with both manned and unmanned assets. This will cover human-machine/human-human/machine-machine Teaming (HUM-T).

A10.17 – Cockpit Automation

Full description planned for the next update cycle.

A11 – Mechanical, Thermal & Fluid-Related Technologies & Devices

A11.01 – Mechanical/Hydraulic Technologies & Devices

Research in mechanical and hydraulic technologies and their application in a wide range of devices used in land, sea or air systems. Also includes understanding, modelling and evaluation of devices such as bearings, seals, clutches, actuators, pumps, etc

A11.02 – Lubrication Technology

Research to aid the evaluation and analysis of lubricants and lubricating systems used in defence equipment under demanding conditions. Also includes work to understand problems relating to lubrication faults and failures and associated hazards. Research to improve capability to specify, conduct approval and quality assessments, and monitor performance of lubrication products and systems throughout service life. Also includes new lubrication systems technologies. Also takes account of future requirements from environmental protection for lubricants will be taken into account.

A11.03 – Thermal & Thermodynamic Technologies & Devices

Research in thermal and thermodynamic technologies and their application in a wide range of devices used in land, sea and air systems. Also includes understanding, modelling and evaluation of thermodynamic cycles, heat exchangers, thermal de-icing devices, etc. Also includes work on heat transfer by conduction, convection and radiation. Also includes work into combustion processes typical of gas turbines and conventional internal combustion engines.

A11.04 – Fluid Mechanics - Phenomenological and Experimental

Research to identify and understand phenomena in aerodynamics, gas dynamics and hydrodynamics, e.g. vortex behaviour, flow separations, unsteady flows including cavitation, all other types of flows. Also covers work in experimental facilities - wind tunnels; shock tubes; water tanks; etc. Also includes work to understand the nature of facility testing, including wall interference corrections, support interference corrections, non-intrusive measurements, balance design and calibration, pressure measurements. Also includes work to support the testing of all types of fixed wing and rotorcraft components such as intakes, afterbodies, propellors, helicopter rotors, isolated weapons, weapon carriage and release, wing/body configurations, dynamic derivative, scale effect, and transition fixing. Compliments CFD research in A11.05 – Fluid Dynamics Techniques.

A11.05 – Fluid Dynamics Techniques

Research to understand computational fluid dynamics, and to aid the evaluation and analysis of hydrodynamic (aerodynamic respectively) performance of all types of marine (aerial respectively) platforms. Also the evaluation and analysis of supercomputer outputs, fluid dynamic and numerical mathematics in turbulence modelling, transition prediction, viscous flow, solution algorithms (including high power computing – HPC), grid generation, CFD/CAD interfaces, GUI and data interpretation/presentation. Also includes fluid dynamics for air vehicles (fixed wings and rotorcraft) and the use of models to predict loads, signature, novel rotor and fixed wing technology and advanced configurations, and the aerodynamic effects of icing on rotors and fixed wings. Also includes high resolution CFD techniques (LES/DES) for the flow modelling for the acoustics.

A11.06 – Flow Control Technologies

Research to improve aerodynamic performance of systems through a local mechanical or fluidic action. Targeted systems include wings, control surfaces, rotating components (rotors, fans, compressors…). The research covers development, integration and test (numerical, wind tunnel and flight) of sensors, actuators and control techniques.

A11.07 – Aeroacoustics Techniques

Research to establish the acoustic signature of all type of vehicles (land, sea, air) in all types of environments. Includes noise source identification/characterisation, propagation and perceived noise as well as noise reduction technologies development, through numerical and experimental means. Also includes specific numerical developments in CAA (Computational Aero Acoustics).

Chapter B. System-related Technologies

Chapter B. Table of Contents

B01 – Lethality & Platform Protection

B01.01 – Warheads

Research to understand, model, evaluate and analyse all types of warhead designs employing chemical energy (CE) and electromagnetic energy (EM) in the context of armour/anti-armour interactions, weapon/target interactions, attack of hard/buried targets and underwater weapon applications, including the behaviour of the debris cloud and any unwanted effect. Also includes work on insensitive munition designs. Also includes work to support quality assurance of all types of warhead components. Also includes research relating to fuzing, as a device to activate the warhead, such as microwave fuzes and all types of fuze systems and arming systems. Also includes research on solid state devices for safety and arming purposes, "smart" functionality, and application of electrical, optical and other novel methods of initiation of propellants and charges. Also includes the environmental effect study and resistance of warhead against vibrations, shock, extreme temperatures, EMC and EMC exposures.

B01.02 – Penetrators

Research to understand, model, evaluate and analyse all types of penetrator designs employing kinetic energy (KE) in the context of armour/anti-armour and hard/buried target interactions. Also includes relationship between microstructure and performance.

B01.03 – IED Detection and Defeat Techniques

Full description planned for the next update cycle.

B01.04 – Battle Damage Reduction Techniques

Research to understand and reduce the vulnerability of military platform structures and installations to all types of penetrative and blast or shock wave effects. Also includes performance degradation and operational analysis.

B01.05 – Explosive Ordnance Disposal

Research to support the evaluation and analysis of land-based countermine technology. Also includes work to understand all forms of EO and related devices requiring disposal, including underwater EOD. Also includes research on disposal systems for energetic materials and other munition materials in accordance with environmental legislation requirements.

B01.06 – Mine Detection and Clearance

Research to evaluate and analyse counter-mine technologies covering mechanical, magnetic, RF detection and manual, remote controlled and autonomous neutralisation systems and platforms. Also includes work on diver signatures, diver communication, mine hunting and avoidance sonars, sweeping, UUV systems and MCM reconnaissance and disposal systems. Also includes research on landmine detection, neutralisation and route marking systems. Also includes work on advanced handheld landmine detection systems. Also includes work to use Artificial Intelligence (AI) supported systems for the image processing and pattern recognition.

B01.07 – Armour systems

Research to model, evaluate and analyse all types of armour systems, such as hard armour for vehicles, soft armour for personnel and SAPI plates. in the context of armour/anti-armour and hard/buried

target interactions and behaviour of the debris cloud (including UXO removal). Also includes work on heavy armours and electric armours, including materials behaviour studies under extreme stress/strain rate conditions. Also includes mine and improvised explosive device (IED) effects simulation work and protective measures modelling. Also includes understanding anti-torpedo hardkill devices for ships and submarines.

B01.08 – Defensive Aids Suite Systems

Research to understand and improve the performance of all elements in DAS systems, including identification, recognition and semi or fully automatic countermeasures. Research on the related sensor data and AI algorithms including networking and the potential use of UAVs and advanced pyrotechnic countermeasures. Also includes work on platforms integration and compatibility with other systems to ensure that any conflicts between the DAS system and the platform's signature control techniques are minimised. Also includes DAS/CDAS aspects of weapon/target interactions.

B01.09 – Other Platform Protection Measures

Research to understand and improve techniques and procedures to protect sea systems platforms from threat weapons such as torpedoes such as work on netting techniques. Also includes research to analyse and develop extensive sensor equipment and threat detection systems for active counter measures. Also includes analysis of actions for recovering (through reconfiguration, repair and replacement) lost fighting, sailing or floating capability against a range of threats. Also includes research on platform protection measures not mentioned specifically elsewhere in these notes. Also includes smart countermeasures against torpedoes.

B01.10 – Combat Management Systems

Research into systems able to support decision making processes in operations through the integration of all weapons, sensors and data generated. They include specific consoles and actuators to display tactical data and to activate firing systems.

B01.11 – C4ISR

Research to evaluate and analyse rapid and accurate decision-making and proactive decision support tools for C2/CS/ISR in Big Data environments, for manned and unmanned aerial, land-based, surface (ships, boats, UAV, USV) and underwater vehicles (submarines, UUV). Includes also multi sensor, high speed data fusion engines.

B02 – Propulsion and Powerplants

B02.01 – Gas Turbines

Research to evaluate and analyse compressor and turbine component characteristics, power and heat management aspects/heat exchangers, combustor technologies, aero engine emissions, noise prediction and reduction, aero engine controls and system simulation plus auxiliary systems. Also includes system integration aspects such as intakes, nozzles and ducting concerning diverse platforms and related structural design aspects. Also includes variable cycle engine/variable engine component technologies. Also includes improved testing techniques to determine engine performance parameters and component/engine part characteristics. Also includes work to improve the resistance of gas turbines to effects such as erosion, wear, foreign/domestic object damage and environmental effects, corrosion in particular. Also includes supply chain aspects at technology level. Further research

activities could focus on the usage of Gas turbines as power generators for electric or hybrid propulsion systems and their optimization towards the use of synthetic fuels. Scaling effects (smaller size but higher quantity) could also be considered.

B02.02 – Reciprocating and Rotary IC Engines

Research to understand integration aspects, as well as improving efficiency, of IC engines for platform and weapons systems. Also includes research on engines to give a high performance irrespective of fuel type. Also includes research on reducing vibration and/or noise generation in these engines (acoustic/hydroacoustic signature). Research on operation with alternative fuels like synthetic fuels and hydrogen. Research on transferability of developments from civil applications with special consideration of military fuels in regard of special measures for exhaust compliance in civil applications. Research on requirements for engines combined with electrified powertrains.

B02.03 – Rocket Engines and Ramjets

Research to understand solid and liquid fuel ramjets, ramrockets and rockets. For example, combustion systems, ramburner aerodynamics and reaction kinetics, throttle control systems, air intakes, nozzles including nozzleless boost systems, design of rocket and ramjet missile cases and associated internal insulation systems. Also includes relevant predictive modelling studies. Includes research on chemical propulsion on-board satellites.

B02.04 – Gun and Launch Tube Propulsion

Research to understand all aspects of gun tube designs using chemical propellants (all calibres). Also includes work on relevant weapon system integration applications and associated structural design issues. Also includes work on electrothermal gun system designs. Also includes research into non-chemically-driven launcher tube systems (but not electrically driven tube systems).

B02.05 – Electrical Propulsion - Rotary & Linear

Research to understand electric propulsion systems including their integration into submarines, surface ships, underwater weapons, UUVs, and manned and unmanned land vehicles. Also includes work on relevant platform or weapons system integration aspects and associated structural design issues, as well as power provision, storage and distribution systems. Also includes work on electromagnetic launch systems/gun designs and their integration into land and sea platforms, such as power supplies and power management systems. Also includes associated predictive modelling and simulation on all of the above aspects.

B02.06 – Transmissions and Powertrains

Research to understand rotorcraft and propeller engine transmissions and their role in the overall power train. Also includes research to understand ship/submarine gearboxes and powertrains in the context of their acoustic impact. Also covers work on the improvement of wheeled and tracked vehicle transmissions and powertrains, including life and reliability aspects. Research to manage the transition from conventional powertrains to electrified powertrains, including all different hybrid and electrified powertrain architectures and integration aspects. Also includes research on dedicated hybrid transmissions and related power management systems, including external power charging systems and power storage systems in military environment research on safety, reliability, maintainability. Research on potentials to increase agility and fuel efficiency. Research on interoperability of transmission and powertrain systems on different vehicles.

B02.07 – Electromagnetic Launch

Includes research into railguns, single-/multistage coilguns, armaturer, sliding contacts, rail erosion, Lorentz force, power supply, pulse-forming-networks (PFN), homopolar generators, magnetic permeability.

B02.08 – Ion Thrusters

Research to understand ion thruster designs to improve performance and operating life. Includes research on ion thrusters integration on-board satellites.

B02.09 – Nuclear Propulsion

Research to provide advice on the engineering aspects of non-nuclear elements in nuclear propulsion systems.

B02.10 – Air Propellers and Rotors

Research to understand propeller and lifting rotor design in the context of performance, integrity and life aspects, and interactions with the local operating environment included radiated noise effects. Also includes work to understand rotor interactions with the local operating environment. Also includes work to minimise rotor icing effects.

B02.11 – Advanced Propulsors and Propellers

Research to understand and analyse propulsors/propellers configurations (design, materials) for low signatures and high efficiency. Also additive layer manufacturing for propellers.

B02.12 – Final Drive - Wheels and Tracks

Research to understand wheel and track interactions with the local operating environment, to improve traction and safety, and to maximise integrity and life. Research on impact of electrified powertrains in military environment and on interaction between vehicle and terrain.

B02.13 – Alternative Propulsion Systems

Alternative fuels as part of the energy source mix can increase energy efficiency and reduce reliance on fossil fuels which in turn reduces vulnerability to cost and operational risks (including to logistics from moving fuel supply convoys across hostile environments) while enhancing mission endurance from increased manoeuvrability / freedom of action over extended periods of time. Such concepts are relevant across the maritime, land and air operating domains and address alternative fuels (biofuels, synthetic fuels, synthetic gas, hydrogen, oxygen, gas) impacts on engines for military uses: performance in severe conditions, acoustic discretion, logistics issues, lifetime, bacterial and microbial development issues, and cost-benefit as well as engine and propulsion performance according to fuel type and blend.

B02.14 – Fission and Fusion

Full description planned for the next update cycle.

B02.15 – Thrust Vectoring

Includes research into all related factors to manoeuvring, command and controls and integration in aerial platform.

B02.16 – Variable Cycle Engine

Full description planned for the next update cycle.

B02.17 – Hybrid Propulsion

Full description planned for the next update cycle.

B02.18 – Supersonic Propulsion

Full description planned for the next update cycle.

B02.19 – Hypersonic Propulsion

Full description planned for the next update cycle.

B02.20 – Scramjet

Includes research into scramjets and PDE.

B02.21 – Green Naval Power Generation and Propulsion

Research includes low signature energy converters, agile high-energy distribution technologies, adaptive energy management and control systems, energy efficiency of hybrid system configurations, system safety in harsh operational environments (e.g. H2 storage and handling, battery-safety), model-based system architectures on the basis of (Sub-)System models and Simulations, safety and security aspects of hydrogen based (including PtX, e-fuels, drop-in fuels) energy supply and propulsion systems, functional and non-functional requirements for stationary/mobile supply infrastructures (land and sea based), non-technical aspects of defossilization and decarbonization.

B03 – Design Technologies for Platforms and Weapons

B03.01 – Aerodynamic Designs

Research to understand, evaluate, analyse and exploit aerodynamic designs, both steady and unsteady, using CFD code application in conjunction with experimental data as appropriate, on fluid dynamic problems, relating to aircraft and engines, stealthy weapon designs, part aircraft configurations such as intakes, afterbodies, weapons, weapon carriage and release systems, and high lift systems. Also includes associated predictive modelling and assessments based on wind tunnel testing. Includes work on applied aerodynamics; prediction and measurement techniques, development/validation/application of semi-empirical codes. Modelling stores carriage loads and release trajectories, drag prediction. Also includes work to exploit
experimental and theoretical aerodynamics data generated in research activities in A11.04 – Fluid Mechanics - Phenomenological and Experimental and A11.05 – Fluid Dynamics Techniques. Also includes research on relevant parts of aeroelastic and aerothermodynamics disciplines.

B03.02 – Hydrodynamic Designs

Research to understand impact of hull form and integration of stealth technology on the hydrodynamic, hydroacoustic, hydrodynamic/hydroacoustic coupling effects, signature-management, sea-keeping and handling of all types of marine platforms and marine structures. This includes the hydrodynamic and hydroacoustic aspects of all naval weapons systems, such as the effects of flow noise on torpedo homing systems or an integrated signature management system. Also includes work to understand and exploit wake effects.

B03.03 – Structural Design

Research to understand, evaluate and analyse structural design for all platforms and weapons systems, and for battlefield bridging. Includes the structural aspects of integration with aerodynamic, thermal, ballistic (in term of protection) and stealth design. Also includes the use of new design approaches and materials (such as composites, additive manufacturing, etc.) to protect ground vehicles through innovative armour. Also includes predictive modelling and simulation, and dynamics and acoustic measurement, and associated test activities. Also includes work to understand and prevent transmission of noise through structures in military equipment. Also includes research on relevant parts of the aeroelastic discipline.

B03.04 – Mechanical Designs

Research to understand, evaluate and analyse mechanical engineering design for all platforms and weapons and their sub-systems. Also includes associated test activities, and predictive modelling. Also includes work to improve aircraft launch and recovery systems in conditions of low visibility and at restricted austere sites or on ships. Also includes research on relevant parts of the thermomechanics and hydromechanics discipline. Includes research on structural health monitoring.

B03.05 – Low Observability and Stealth Designs

Research on analysis of threat stealth design and threat sensor technology leading to improvements in own reduced signature stealth designs for all platform and weapon applications. Also includes associated predictive modelling and work on specialised testing facilities to improve stealth design aspects, and research into problems of co-ordinating the management of all signatures. Research to understand hull vibration in ships and submarines arising from machinery and fluid flow effects, and work to relate the results to signature characteristics is also part of this topic. Focus particularly on vibration and noise transmission from hydraulic circuits is done from the maritime perspective. Focus on reduced radar signature by any means (e.g. reduce their radar cross-section, skin transparent to the radar or capable of absorbing the radar waves) is done from the aerial systems perspective.

B03.06 – Ballistic Designs

Research to understand the integration of ballistic design and related design drivers into platform and weapon systems. Includes work on internal and external ballistics of projectile behaviour and gun and launcher system designs. Also includes new or disruptive approaches, modular-based integration, and European standards for ballistic weapons in land, air and naval platforms.

B03.07 – Thermal/Cryogenic/Power Management Designs

Research to understand, evaluate and analyse thermal/cryogenic/power management design factors, and improve their integration in all platforms and weapon systems. Also includes research on relevant

parts of the thermomechanics and aerothermodynamic disciplines. Also includes associated test activities and predictive modelling and simulation and standardization approaches.

B03.08 – Electrical/Electronic Designs

Research to understand, evaluate and analyse electrical/electronic design factors, and improve their integration in all platforms and weapons systems. Also includes associated test activities and predictive modelling. Research on the digitization and increasing interconnection of weapon systems and their sub-systems, taking into account redundancy aspects as well as condition monitoring and status reporting. Also includes research on all dedicated electrified components, like servomotor, electromechanical actuator, inverter technology and power management systems related to the electrical and electrified weapon systems (generic part is covered by A05 – Electronic, Electrical & Electromechanical Device Technology). Research on safety, reliability and maintainability of electrical and electrified weapon systems.

B03.09 – Optical Designs

Research to understand, evaluate and analyse optical design factors, and improve their integration in all platforms and weapon systems. Also includes associated test activities and predictive modelling.

B03.10 – Acoustic Designs

Research to understand, evaluate and analyse acoustic design factors, and improve their integration in all platforms and weapons systems. Also includes associated test activities and predictive modelling.

B03.11 – Environmental Protection Designs

Research and development of designs aimed at reducing the effects of icing on the performance of military equipment. Also includes work on designs to combat the effects of thermal extremes on military equipment. Also includes work to develop improved designs for the protection for all types of engines from the effects of sand ingestion.

B03.12 – Multidisciplinary Designs

Research to provide best compromises taking into account several disciplines/targets.

B03.13 – Supersonic and Hypersonic Designs

Full description planned for the next update cycle.

B04 – Electronic Warfare and Directed Energy Technologies

B04.01 – Directed Energy Technologies (DET) - RF

Research to understand RF DE systems and their effects on silicon microelectronic components, circuits and sub-assemblies. Also includes integration aspects of DE into weapon systems. Also includes work on non-destructive RF DE systems and their integration in the context of anti-ship missile defence systems.

B04.02 – Directed Energy Technologies (DET) - Lasers

Research to understand integration of laser DE systems into weapon and counter measure systems and platforms. Also includes work to exploit high power laser technology.

B04.03 – Directed Energy Technologies (DET) - Other

Research to understand other types of DE, for example, particle beam technology, and their integration into weapon systems and platforms.

B04.04 – Electronic Countermeasure (ECM) - RF

Research to evaluate and analyse techniques such as generic and specific countermeasure waveforms to be integrated into ECM systems employed to protect platforms. Includes work on comms.ECM and non-comms ECM. Also includes work to understand tactical comms.ECM, long range surveillance and tactical battlefield ECM systems. Also includes novel microwave filter and MMIC design aspects of ECM systems, and power amplifiers for jammers. Also includes work to understand effects of RF on microelectronic component survivability. Includes research into micro- and milli-metre wave ECM techniques.

B04.05 – IR/Visible/UV

Research to evaluate and analyse techniques including generic and specific waveforms to be integrated into Electro-Optical Countermeasure (EOCM) systems. Also includes work on comms. EOCM, and non-comms. EOCM. Also includes work exploiting laser technology, stealth materials, novel negative luminescent device technologies and E-O sensors in the context of ECM systems. Also includes work to understand sensor design and signature measurement related to EOCM.

B04.06 – Electronic Countermeasure (ECM) - Acoustic

Research to evaluate and analyse design of countermeasures to acoustic homing torpedoes and their launch platforms. Also includes work to understand acoustic ECM systems integration and the associated man-machine interface requirements.

B04.07 – Electronic Countermeasure (ECM) - Magnetic and Electrical

Research to evaluate and analyse the design and performance of magnetic and electrical CMs to incoming torpedoes and their fuzes. Also includes work to understand the M&E threat to spacecraft systems. Also includes research to understand the integration of ECM systems into combat systems.

B04.08 – Electronic Support Measurement (ESM) - Communications

Research to evaluate and analyse communications ESM techniques and technology. Also includes work to specify ESM systems capabilities/performance and to integrate ESM with weapon systems and for tactical employment. Also includes work to understand Information warfare technology, long range and tactical battlefield communications and counter comms.technology. Also includes evaluations and analyses of geolocation of interferors and unauthorised users. Also includes research to apply HTS technology to ESM-Comms.systems.

B04.09 – Electronic Support Measurement (ESM) - Non-Communications

Research to understand techniques for the high probability of intercept of RF signals, their rapid identification, and for integration of ESM systems into weapon and combat systems. Also includes radiographic mapping of electromagnetic sources from satellite observations. Also includes research to apply HTS technology to ESM-non-Comms.systems.

B04.10 – Electronic Protective measures (EPM) - RF

Research to evaluate and analyse RF EPM and integration of EPM systems with weapon systems. Also includes work to analyse spread spectrum techniques applied to comms.signals at SHF and EHF. Also includes work to understand hardening of comms. assets and to set standards for advanced adaptive EPM for HF comms. Includes research at micro- and millimetre wave frequencies for EPM purposes.

B04.11 – Electro Optical Protective Measures (EOPM) - IR/Visible/UV

Research to evaluate and analyse image processing algorithms for navigation and targeting sensors employed by threat systems. Also includes understanding EOPM across visible, IR and FIR, for eyes, imagers and magnifying optics. Also includes work on the integration aspects related to weapon systems, and on sensor design issues.

B04.12 – Electronic Protective measures (EPM) - Acoustic

Research to evaluate and analyse mine avoidance sonars employed in submarines and surface ships. Also includes work related to acoustic EPM systems integration at the man-machine interface.

B04.13 – Electronic Protective measures (EPM) - Magnetic and Electrical

Research to understand and reduce the effects of magnetic and electrical stray fields and hazards on all types of military equipment.

B05 – Signature Control and Signature Reduction

B05.01 – Radar Signatures

This technology covers all used radar frequencies. Research to evaluate, model, analyse and manipulate platform radar signatures and integration of radar signature control into weapon systems. Also includes work relating threat radar sensor technology and the environment to own platform signatures. Also includes work on active stealth measures (in the context of radar signatures).

B05.02 – Laser Signatures

Research to evaluate model, analyse and manipulate platform laser signatures and integration of laser signature control into weapon systems. Also includes work to understand threat laser sensor technology, low observable materials technology and operating environment signatures.

B05.03 – Thermal / IR Signatures

Research to evaluate, model, analyse and manipulate platform IR signatures and integration of signature control into weapon systems. Also includes work to understand the effects of pigments and other materials on signature control. Also includes issues relating to stealthy missile launch detection (plumes), threat IR sensor technology, and operating environment signatures. Also includes work to

understand thermal signature control in the context of gas turbines, reciprocating/rotary engines, and rockets and ramjets.

B05.04 – Visible/UV Signatures

Research to understand, model and manipulate platform UV/Visible signatures and integration of signature control with weapon systems. Also includes work to understand threat UV/Vis sensor technology, missile detection filters and operating environment signatures. Also includes research to understand the behaviour of coatings and micro-structured surfaces that minimise laser retro-reflections.

B05.05 – Acoustic Signatures

Research to evaluate, model, analyse and manipulate underwater acoustic signatures of all types of marine craft, and torpedo decoys. Also includes work to detect and classify targets, mine threat analysis, and to optimise processing techniques. Also includes work to understand acoustic echo characteristics of target ships and submarines to be employed in own sonar, torpedo and fuzing systems. Also includes work to develop and improve measurement techniques for underwater signatures, both active and passive. Also includes work to understand acoustic signature detection of helicopters including modelling to predict rotor noise and its propagation through the environment. Also includes work on land-based systems acoustic signatures, particularly on the application of passive and active acoustic signature control to land equipment. Also includes work to understand laser generated acoustic waves. Also includes work to understand acoustic signature control in the context of gas turbines, and reciprocating/rotary engines.

B05.06 – Electrical and Electrochemical Signatures

Research to understand mine threat to maritime vessels and also to understand and model mechanisms by which electrical signatures of naval platforms may be reduced or manipulated. Also includes work to understand electrical signatures for TEMPEST testing, evaluation and certification. Also includes research to understand and model mechanisms by which electrical and electrochemical signatures of contaminated areas can be traced and monitored.

B05.07 – Magnetic Signatures

Research to evaluate, model and analyse mine threat for maritime vessels and to understand mechanisms for reducing or manipulating magnetic signatures of naval platforms. Also includes work to understand the interaction between torpedo fuzes, targets and countermeasures in the undersea environment. Also includes work to understand measurement of the magnetic signature content of equipment and components fitted in mine hunting/mine countermeasure vessels. Also includes work on magnetic signature ranging and reduction. Also includes work to evaluate and analyse display technology for operation in environments with magnetic fields. Includes smart systems to manipulate or compensate magnetic signature for equipment and structures on board (enhanced degaussing technologies).

B06 – Sensor Systems

B06.01 – RF Sensors/Antennas - Active

This technology covers all used radar frequencies. Research to evaluate and analyse detectability of air targets, surface targets using active radar. Also includes work to evaluate and analyse DSP, system

modelling, detectors, antennas, system design, active array technology and advanced processing for multifunction radar. Also includes work to understand space-based comms. antennas and radar for surveillance. Research to evaluate and analyse returns from air targets, surface targets and sensor performance. Also includes work to evaluate and analyse system design, system modelling, integrated sensor suites, conformal antennas, SAR (Synthetic Aperture Radar), MTI (Moving Target Indication), maritime rec., advanced phased arrays, and obstruction avoidance sensors. Also includes work to understand calibration and metrology advice. Also includes work to enable effective integration of radomes. Also includes meta-material based low profile radiated panels, Tx & Rx in same module, small antennas and high datalinks OTM and UCAB for remotely piloted aircraft providing surveillance.

B06.02 – RF Sensors/Antennas - Passive

This technology covers all used radiometric frequencies. Research to evaluate and analyse detectability of air targets, surface targets using passive radiometric sensors. Also includes work to understand antenna calibration. Research to evaluate and analyse returns from air targets, surface targets and sensor performance. Also includes work on systems aspects, temperature sensitivity and resolution, and passive radar sensors. Also includes work to exploit MMIC design and device packaging technology for a low cost passive radar imager.

B06.03 – Imaging Radars

Research on imaging radars (Synthetic Aperture Radars - SAR), either space-based or land-based, focus on the selection of the appropriate frequency, antenna design, signal processing and image quality.

B06.04 – IR Sensors - Active

Research to evaluate and analyse integrated sensor suites incorporating targeting, navigation, and terrain and obstruction avoidance sensors. Also includes work to understand optics, system modelling, detectors, lasers and system design. Also includes work to understand vision systems for AFVs and WASAD, and to understand intelligent surveillance. Also includes work to understand laser detection of mines in very shallow water/surf zone, underwater target detection and laser weapon fuzing. Also includes work to understand laser rangefinders, vibration sensors, laser sources, and CLARA.

B06.05 – IR Sensors - Passive

Research to evaluate and analyse integrated sensor suites incorporating targeting, navigation, terrain and obstruction avoidance IR sensors. Also includes work to understand optics, system modelling, IR detectors, lasers and system design. Also includes work to understand vision systems for AFVs and WASAD, and intelligent surveillance systems. Also includes work to understand IR detection of buoyant mines on the sea surface, and IR detection of land mines. Also includes work to understand space-based IR surveillance. Also includes work to understand smart IR sensors. Also includes work to understand "obsolescence management" of IR sensor systems, including interpretation of national standards. Also includes work to evaluate and analyse advanced IR detector designs for improved identification and Counterstealth. Also includes work to understand COTS sensor technology in the context of defence equipment. Also includes work to enable effective integration of IR domes.

B06.06 – Visible/UV Wave Sensors

Research to understand integrated sensor suites incorporating UV/Visible sensors for targeting, and other applications. Also includes work to analyse optics, system modelling, UV/Vis detectors, UV/Vis lasers and system design. Also includes research to exploit organic semiconductors for application in photon detection and image intensifiers, also to analyse the performance of UV-sensitive missile

launch detectors. Also includes work to maintain awareness of visual sensors for space-based surveillance.

B06.07 – Acoustic Sensors - Active

Research to understand airborne ASW systems and maintain technical specifications for active and sonic processors. Also includes work to understand HF acoustics and propagation and support analysis of MCM, mine avoidance and MCM reconnaissance systems. Also includes work to evaluate and analyse design and integration of towed bodies for LF active sonar and the application to underwater homing and acoustic countermeasures. Also includes work to understand active sonar transducers, arrays, and associated signal/data processing and display systems. Also includes work to enable effective integration of sonar domes.

B06.08 – Acoustic Sensors - Passive

Research to understand airborne ASW systems and specifications for passive sonobuoys and service sonic processors. Also includes work to understand acoustics and propagation for land and airborne vehicle detection and location of artillery and rockets. Also includes work to understand HF acoustics for passive mine detection. Also includes evaluations and analyses of underwater weapon passive sensors in the presence of high levels of flow noise. Also includes the design of towed arrays in terms of handling and reliability, sonar performance, and other passive sonar systems and passive sonar array types. Also includes work to exploit ferroelectric liquid crystal polymers for application in compact, sensitive, directional sonar elements. Also includes work to exploit novel silicon acoustic sensors and integrated sensors for passive sonar systems. Also includes work to enable effective integration of sonar domes.

B06.09 – Non-Acoustic Sensors - Underwater

Research to evaluate and analyse non-acoustic sensors for mine detection in very shallow water/surf zone and for MCM reconnaissance. Also includes work to understand non-acoustic sensor technology for application to underwater weapon homing and fuzing, and as a nonacoustic UW sensor to complement acoustic sensors. Also includes work to understand behaviour of non-acoustic sensors in the military oceanographic environment. Also includes wake detection systems and biodetection (biologics) techniques for underwater non-acoustic detection systems.

B06.10 – Electrical & Electrochemical Sensors

Research to understand and develop underwater electric potential (UEP) sensor technology. Also includes research to understand and develop electric and electrochemical sensors for the determination of pre-defined contaminants.

B06.11 – Magnetic Sensors

Research to understand integration of novel magnetic material with silicon circuitry to provide smart micro-magnetic sensors. Also includes work to understand magnetic sensor application to weapon systems and to fuzing systems in all weapons (except underwater) and in land mine detection systems.

B06.12 – CB Sensor Systems

Research to support and maintain expertise in CB sensor systems which monitor the level of the hazard, identify the agent and identify exposure retrospectively. Also includes work to apply genetic engineering and amplification, antibody/antigen interactions, gene probes, 3D printed modular point-

of-care or lab-on-a-chip structures, biosensor and printed biosensors transduction to CB detection systems.

B06.13 – Explosive Detection Sensors

Research to understand application of EDS to very shallow water/surf zone mine detection and to land mine detection. Also includes work to enhance detection system performance for explosives.

B06.14 – Microsensor Systems for Active Control of Structures

Research to understand silicon microsystems technology for sensors and transducers and use of fibre probes using frequency selective RAM. Also includes work to exploit smart/functional material technology to control the shape of intelligent structures, including sound damping applications. Includes structural applications of micro-electronic and mechanical systems (MEMS) technology to active structures.

B06.15 – Motion Sensor systems

Research into new approaches to gyroscopic control systems and other inertial sensors for platforms and weapons, particularly those based on solid-state devices. Also includes associated work on the relevant signal processing element of motion sensor systems. Also includes work on techniques to measure structural vibration.

B06.16 – Environmental Monitoring Systems

Research to support the design of systems to monitor atmosphere quality in submarines and crew spaces in other military platforms and installations. Also includes work to determine and analyse noise levels in crew spaces.

B06.17 – Multispectral/Hyperspectral Imaging (VIS/IR/UV)

Research to evaluate and analyse multi-spectral and hyperspectral imaging sensors in all wavebands (VIS/IR/UV). Also includes work to understand optics, system modelling, hyperspectral detectors, lasers and system design. Also includes work to understand and process spectral image cubes to DRI of camouflaged target. Also includes work to understand counter measure systems. Also includes work to understand space based hyperspectral surveillance systems. Also includes work to understand smart hyperspectral sensors. Also includes work to evaluate and analyse advanced hyperspectral detector designs Also includes work to understand COTS and SWAP-C sensor technology in the context of defence equipment. Also includes work to enable effective integration of hyperspectral systems.

B06.18 – Nanosensors

Research to understand and develop nanosensors for monitoring physical and chemical phenomena in hard-to-reach regions, detecting biochemicals in cellular organs, measuring nanoscopic particles in industry and the environment. This topic complements the research done at topic A05.15 – BioMEMS / Bio Sensors.

B07 – Guidance and Control systems for Weapons and Platforms

B07.01 – Navigation systems

Research to understand integration and application of navigation systems to missile seekers, AFV fire control systems, and MCM and reconnaissance systems. Also includes work to apply silicon microsystems technology for micro-accelerometers and micro-gyros, including embedded control and signal processing electronics. Also includes work to understand "obsolescence management" and technology insertion in the context of navigation systems. Also includes research to evaluate and analyse autonomous sensing of global maritime and littoral environments for manned / unmanned marine vehicles and vessels. Also includes autonomy obstacle avoidance architectures.

B07.02 – Weapon Guidance and Control systems

Research to evaluate and analyse use of guidance and control technology to remote guidance techniques for underwater weapons, and to integrated precision attack techniques, MLRS and other ballistic systems. Also includes work to understand the application of silicon microsystems technology to precision G&C systems employed in missiles. Also includes work to understand "obsolescence management" and technology insertion in the context of G&C systems. Seekers/Homers (both above and underwater) - Research to evaluate and analyse seeker/homer systems used in both air-launched and underwater weapon systems and attack platforms. Also includes work to exploit advanced focal plane arrays and related image processing and data fusion techniques. Also includes work to evaluate and analyse seeker guidance system tests using dynamic infra-red scene projectors. Also includes work to understand small RF phased arrays and multispectral (radar & IR) sensors in the seeker context. Also includes research to exploit acoustic sensor technology for precision homing systems.

B07.03 – Platform Guidance and Control systems

Research to evaluate and analyse G&C systems, including avionics and vetronics (vehicle and electronics), in the context of platforms, AFV fire control systems, autonomous vehicles, and in relation to integrated precision attack techniques. Also includes work to exploit HFI technology for control systems in crew spaces/cockpits. Also includes work on multivariable, discrete, nonlinear control design methods and relevant image processing and data fusion technology. Also includes work to understand attitude and orbit control systems employed in satellites.

B07.04 – Dynamic Positioning

Research activities in computer-controlled systems to automatically maintain a vessels position and heading using propellers and thrusters.

B07.05 – Display systems

Research to understand characteristics of displays and to apply novel display science to military display systems, to provide operational support to humans and to minimize the human error, used in or for helmet systems, missile seekers, AFV fire control systems, torpedo track information displays, and related display information on target/environmental conditions. Also includes work on displays in the context of "obsolescence management" and technology insertion, haptic screens and devices to promote and respond touch sensations remotely (reply to touch and provide tactile sensations by varying the friction between the user’s finger and the screen). Work on digital mirrors allowing to perform instant interaction through a physical digital twin is also included.

B08 – Simulators, Trainers and Synthetic Environments

B08.01 – Skills Training systems

Research to understand skills training, and application of synthetic environments to skills training systems for all service environments. Also includes application of hardware-in-the-loop and PC-based systems to skills trainers.

B08.02 – Tactical/Crew Training systems

Research to understand synthetic theatre of war (STOW) and the application of synthetic environments, including virtual reality techniques in simulators to reflect the critical cues provided by the real platform. Also includes application of hardware-in-the-loop and PC-based systems to tactical/crew trainers. Also includes research on applications that use Learning Management System (LMS) technologies and their evolutions on mobile systems and Cloud architectures. Also includes research areas related to the use of AI, BD and ML technologies in individual and group training systems. Also includes research on the use of MSaaS and TaaS architectures for distributed training.

B08.03 – Command & Staff Training Systems

Research to understand command level training systems, STOW and the use of speech for interactive training. Also includes work to understand the application of synthetic environments to command level training systems and computer assisted staff training systems. Also includes application of hardware-in-the-loop and PC-based systems to command and staff trainers. Also includes research and training support applications for decision making of military personnel (commanders and staff) using AI, ML and BDAA technologies.

B08.04 – Virtual Reality and Augmented Reality

Research to evaluate and analyse virtual crew stations as a tool for procurement and training. Also includes work to understand integration of 3-D imaging and display technology in the fields of remote telepresence/remote (MRO) support, and cognitive aspects of operator performance. Also includes the overlaying of digital information onto the physical world (augmented reality - AR). Also includes unambiguous representation of the environment feature data can be achieved when 3D models in the virtual world match real-world ones, in particular extracting information from internet available data. Also includes work to assess the physiological impact imposed by man, the task, and the environment. Also includes the multimodal integration and multisensory inputs connected to direct visualization. Also includes work to understand techniques for measuring performance in VR & AR environments. Also includes work to understand the nature of physiological and psychological interactions between humans and VR & AR, and the value of VR & AR in design and training systems. Also includes the influence of visual, proprioceptive, and vestibular information on self-motion perception and the related problem mitigation (motion/cyber-sickness). Also includes research on the evaluation of Human Factors integration.

B08.05 – Synthetic Environments - Synthetic Force Generation

Research to understand synthetic environments for such purposes as; training, OA, procurement, requirements capture process, platform and weapons systems, sensor systems and relevant countermeasure systems. Also includes work to understand the use of stimulators and simulators, system performance, design, testing, validation, acceptance and use, and environments. Also includes

work to understand the nature of physiological and psychological interactions between humans and SEs. Also includes work to assess the value of SEs in design, selection and training activities. It also includes research for the design and development of synthetic force components with cognitive abilities deriving from the use of Machine Learning and Deep Learning algorithms.

B08.06 – Synthetic Environments - Natural Environment Generation

Research to understand SEs for natural environment generation. Includes work to facilitate the rapid generation of geotypical terrain and feature/cultural data. Includes work to understand Variable Representation in support to simulation systems. Also includes research on the application of models to generate internal wave wake for the prediction of surface wave modulations.

B08.07 – Synthetic Environments - Management systems

Research to include the management of databases covering terrain, environment, dynamic models, and other relevant databases. Also work on the configuration management and maintenance of models and software for SEs. Also includes work to exploit HLA, languages and AI for SEs.

B09 – Integrated Systems Technology

B09.01 – Systems Engineering and Integrated Systems Design

Research to understand systems engineering aspects of future weapon systems designs, including system architecture (architecture models), integrated and platform systems, systems integration processes, requirement engineering and management. First, this includes EW systems integration, Sensor integration, work to evaluate and analyse combat systems, software system designs, display technology, system architectures, flight trials techniques, work to understand multiple vehicle installations, thermal management of platform and weapon systems. Second, this includes work to understand definition and integration of user requirements into specifications for manned systems including Human Factors Integration, MANPRINT procedures and design standards for the procurement of future manned systems. Third, this includes work to integrate disparate information systems, computer systems and communications systems and improve systems performance analysis at the systems level.

B09.02 – Interoperability Standards

Research to evaluate and analyse UKAD airborne early warning systems, including combat identification and operating environment. Also includes work to interpret national and international standards for all technologies in a defence context. Also includes work to understand weapon system interoperability issues, including interoperability of small arms ammunition. Also includes work to understand standards for cable and connectors, including specification writing. For CIS: Research to understand communications methods and networks, including network management techniques, to support end-to-end connectivity via the integration of terrestrial bearers with HF and Satcom systems. Also includes work to evaluate non-proprietary system concepts and open standard solutions for military applications, civil networks and relevant testing methods. Also includes work to understand system interoperability across the digitized battle space, particularly for comms. systems, protocols, software and COTS issues. Also includes work to enhance and adopt simulation interoperability standards (DIS, HLA, …) for demonstrators, test beds and training systems.

B09.03 – Radiation Hardening

Research to understand integrated system design, particularly weapon system vulnerabilities against EMP. Also includes work to evaluate and analyse integrated hardening, reconfiguration and electronic monitoring techniques. Also includes work to understand protection against space radiation, and radiation hardening of ICs (see also B09.10 – Electromagnetic Compatibility).

B09.04 – Robotics and Automated/Autonomous systems in Operational Systems

Research to understand automated and autonomous systems for remote operations and engineering systems. Research to evaluate the potential for multi-robot systems (MRS) in military domains to provide cost savings by automating, protect operators and enable new missions. Also includes intensive analysis and characterisation of possible applications, operation environments and interoperability and evaluation of future advances for MRS which must be taken into consideration for oncoming system design and implementation. Also includes work to understand applications of various technologies to remotely controlled sea, land, air and space equipment. Also include research on the integration of robotic and automated/autonomous systems into legacy and future vehicles (air, sea, land and space domains), as well as embedded computing, internal data network, communications, sensor fusion (cameras, LiDAR, Radar, etc.) and data exploitation even by teaming with manned vehicles. Research on autonomous navigation, obstacle avoidance and manned-unmanned swarming. Also includes research on open architectures to optimize interoperability between systems with autonomous functions (SAF) employing a concept of modularity. Also includes work on standardization and certification. Also includes research into on-orbit satellite servicing which refers to actions performed in orbit, such as refuelling or repairing satellites, deploy or assemble large structures from separate parts, capture, hold and manipulate objects using robotic systems. This Space application will benefit from the decreasing cost of commercial launches, thus offerings a large business potential for on-orbit servicing. Research on this topic should be done in close connection with B08.04 - Virtual Reality. Looking at unmanned vehicles, all operations and actions should be transmitted bi-directional, with the aim of improved control of autonomous systems and better understanding of the shared decision-making process.

B09.05 – Manned and Unmanned Teaming

Research to understand the framework of cooperation between manned and unmanned systems (manned-unmanned teaming). Research to understand natural modes of interaction, dynamically changing levels of autonomy, prediction of behaviours of large numbers of unmanned systems, task allocation/assignment, planning, coordination and control for heterogeneous systems. From the aerials system perspective, manned-unmanned-teaming is expected to increase the mission efficiency of future airborne systems in many ways. Equipped with sensors, the swarm of unmanned systems can provide situational awareness to a mission group commander located a safe distance away aboard the manned aircraft.

B09.06 – Reliability and Maintainability of Systems

Research to understand probabilistic structural analysis on reliability of aerial, ground and naval systems This includes work to monitor and predict all types of platform reliability and durability issues. Furthermore, this includes work to understand configuration control and identifying alternative components, the reliability of PC boards within systems under systems conditions, cost-effectiveness, fitness for purpose and environmental impact of military packaging.

B09.07 – Health Monitoring systems

Research to understand integrated systems for health monitoring of all engineering systems. Research on big data techniques and artificial intelligence/machine learning (AI/ML) for health monitoring and maintenance forecasting. Also includes work to evaluate and analyse electronic monitoring techniques.

B09.08 – Safety systems

Research to understand all engineering systems characteristics and unsafe system testing procedures, based on physical or electronic interfaces, particularly of weapon systems. Also includes work to evaluate and analyse reliable fire detection (early stages particularly), and chemical products released during overheating/early stages using robust sensors (i.e. nanosensors, biosensors and others) providing unambiguous indications.

B09.09 – System Repair Technologies

Research to understand the consequences of repair schemes and procedures on system performance and system durability. Also includes work on logistic standardisation and on the modelling and simulation for the evaluation of logistic performances. Includes research on design for robotic repair architectures adapted to orbital spacecraft.

B09.10 – Electromagnetic Compatibility

Research to understand EMC issues in integrated system design, particularly in weapon system. Includes research into experimental methods to quantify electromagnetic phenomena in military systems including material property measurement, and antenna measurement. Includes work to identify and overcome electromagnetic hazards, and improved designs to allow equipment to function in the presence of lightning strikes and to survive nuclear electromagnetic pulses (NEMP). Also includes research to understand the consequences of lightning strikes and nuclear electromagnetic pulses on all defence equipment. Also includes associated predictive modelling and simulation both for emission and susceptibility. Also includes work to evaluate and analyse EMC interference and failure. Also includes holistic innovative approaches to redefine classic EMC specification methods for vehicle-integrated devices (e.g., power electronics), with a particular focus on increasingly electrified vehicles (including hybrid systems) and the need to minimize device weight and volume. Also includes the research on EMC design of vehicle systems and other ground systems especially in system environments with higher voltage levels (see also A05.08 – Other Electrical Power Systems & Devices and B03.08 – Electrical/Electronic Designs).

B09.11 – In-Service Data Capture systems

Research to improve techniques for the capture and analysis of in-service operational data including cloud and secure access technologies. Also includes research for the acquisition of data from heterogeneous operating systems and their real-time processing carried out thanks to BDAA and AI algorithms.

B09.12 – Integrated System Testing and Evaluation

Research to develop improved cost-effective whole-system tests and evaluation methods. Also includes work to use M&S technologies to support whole-system tests.

B09.13 – Middleware systems

Research to ensure that the most appropriate forms of middleware are fully exploited in data warehousing activities and message-oriented applications relevant to defence applications.

B09.14 – Co-operative Systems Technologies

Research to understand new cooperative engagement capabilities that allows combat systems to share unfiltered sensor measurements data associated with tracks with rapid timing and precision to enable the battlegroup units to operate as one. Also includes research on critical technologies like MMIC, integrated circuit technologies, new generation of microprocessors, etc. Also include cooperating systems. Also includes to research on capabilities for collecting, processing, storing, disseminating, and managing information on demand to war fighters, policy makers, and support personnel. Also includes social media based co-operative environment

B10 – Communications and CIS-related Technologies

B10.01 – Communications Systems - Below Microwave Frequencies

Research to understand the requirements for, and design of architectures for tactical communications systems below microwave frequencies. Also includes work to evaluate and analyse design of systems working at frequencies from ELF through HF to SHF and EHF. Also includes work to understand operations, environment and the transmission media. Also includes work to understand the vulnerability of systems at the RF modulation, coding and protocol level. Also understand systems management issues in the context of threat and countermeasures. Also includes work to understand the requirements for tactical and trunk management systems and the interaction at network and systems level. Also includes work to evaluate and analyse EHF for satellite payloads and ground stations. Also includes research to understand and optimise long haul communications systems in the context of SATCOM and STRATCOM.

B10.02 – Communications Systems - Micro and Millimetre Wave

Research to understand low-cost phased array technology for communications links. Also includes work to design architectures for tactical and strategic communications systems including antenna subsystems. Also includes work to understand supporting generic technology like MMICs and solid-state microwave sources in the context of communication system design. Also includes work to evaluate and analyse designs for high power microwave tubes for transmitter systems. Also includes work relevant to SATCOM.

B10.03 – Optical Wireless Communications - IR/Visible/UV

Research to evaluate and analyse miniature laser device technology in the context of understanding novel optical communications systems. Research on wireless IR communications refers to the use of free-space propagation of light waves in the near infrared band as a transmission medium for communication. Research on transmission / communications systems used for short-medium-long range communications including IR laser systems. Also includes research on optical vortex beams like an optical communication.

B10.03.01 – IR/Visible/UV

Full description planned for the next update cycle.

B10.03.02 – RF Submilimetric

Full description planned for the next update cycle.

B10.04 – Communications Systems - Acoustic

Research to understand acoustic communications system design for UUV to submarine communications, and for off-platform sensors, also for multi-static operations design, underwater navigation design, and for speech and signal intelligibility system design. Also includes work on communications systems for interacting with man in airborne systems.

B10.05 – Mission Type - Consequence Management

The Consequence Management (CM) mission type consists of activities to maintain or restore essential services and to manage and mitigate problems resulting from disasters and catastrophes, including natural, man-made, or terrorist incidents. Chemical, biological, radiological, nuclear, and high yield explosives (CBRNE) CM activities are specifically conducted to alleviate the effects of deliberate and inadvertent releases of CBRNE which have the potential to cause high casualties and large levels of destruction.

B10.06 – Communications & CIS Security Systems

Research to understand system vulnerabilities, INFOSEC, information warfare techniques and security systems refers to processes and methodologies involved with keeping information confidential, available and assuring its integrity. Research to understand the general principles of systemic intervention, disruption and infection in highly interconnected systems of systems. Also includes novel concepts, tools and mechanisms for containment (avoid spreading of attacks) and to assist the affected entities with eradication. Also includes work to model degraded systems and to gain an understanding of security policy and architectures. Also includes work to evaluate and analyse COMSEC.

B10.07 – Command & Information Systems Integration

Research to evaluate and analyse combat management systems C2, surveillance and satcoms systems, and intelligence systems and their integration at all levels. Also includes work to study CIS concepts development, prototyping and CIS systems definition. Also includes work to exploit data fusion, speech and special systems CIS. Also includes work to understand efficiency, vulnerability and survivability of communications networks. Also includes work to understand open systems, JCSI architecture and test bed processes, information management and infosec. Also includes work to evaluate and analyse distributed systems. Also includes research to improve modelling capabilities in the context of communications systems.

B10.08 – Distributed Networks

Research to understand and evaluate automated network technologies. Includes wireless sensor networks. Also includes networks of many tiny microelectromechanical systems (smart dust). Also includes virtualization management systems and deployment that provides novel solutions. Also includes cognitive radio networks capable of identifying spectrum opportunity in their environment based on emerging technologies (Nano radio, LED radio). Also includes improving co-ordination in ad hoc networks by means of research and development novel algorithms. Also includes specknet architecture (networking protocols) and speckled computing as an enabler technology

B10.09 – Non-Cooperative Target Recognition

Research to exploit novel technologies for thermal imaging systems and secure communication systems. Also includes work to understand combat ID systems (IFF), and radar systems for Non-Cooperative Target Recognition (NCTR) systems, and for NATO identification systems.

B10.10 – Intelligent Technologies for Complex Systems

Research to understand the emergent behaviour, self-organization, and cooperation among complex systems. Research to understand, identify, and predict the behaviour of complex systems, especially as systems grow in size, inter-connection between components, the number of component attributes and their distribution. Also includes complex learning systems in terms of non-functional requirements, like scalability, flexibility, security, availability, integration and interoperability of different systems.

B10.11 – Geographic Information Systems

Research to develop expertise in geographic information systems, particularly using digital map processing facilities. Also work to optimise the use of imaging satellites data in GIS.

B10.12 – Optimisation, Planning & Decision Support Systems

Research to support a Battlespace Spectrum Management System. Includes work to aid the tactical decision-making process to contribute to improved survivability and operational effectiveness using approaches which derive "measures of effectiveness". Also work to demonstrate that decision support systems can be used to formulate Staff Targets/Requirements. Also work to investigate the provision of a global optimisation for service to all users across the JBD environment. Also includes work to develop and improve mission support systems. It also includes research and development of new applications and procedures that integrate technologies such as AI, ML and the use of BDAAs in support processes for decision making. Also includes research and development of new applications and network architectures based on MSaaS, TaaS, cloud and virtualized environments that allow the training of military personnel in a more pervasive and effective way. The development of these research areas can be applied to the training phases, to the operations planning phase and also to the debriefing and rehearsal phases. Also includes research and development on support systems for the management of the operational phase of planned missions.

B10.13 – Infrastructure to Support Information Management & Dissemination

Research to aid the validation of the UCS concept using the Integrated CIS Infrastructure Demonstrator. Also work to integrate BISA with CIBIS and UCS concept research. Also includes work to get existing information sources to appropriate users taking advantage of advanced dissemination management systems. Also includes work to model the behaviour of complex network-based systems.

B10.14 – Network Management Systems

Research to improve the understanding of network management requirements and techniques, including data links to all potential users.

B10.15 – Air Traffic Management Systems

Research to gain knowledge of airspace management issues applicable to all defence air platforms including UAVs. Also includes work to improve air traffic control and management systems and concepts. This topic includes the ATM's main pillars, namely: Air traffic Services (ATS); Air Traffic Flow

Management (ATFM) and Airspace Management (ASM). Military integration into civil airspace, cooperative ATM and UTM are also considered in this domain.

B10.16 – Communication Systems - CBRN Applications

The Chemical, Biological, Radiological and Nuclear (CBRN) Applications enable users to collect, process, present and distribute information that supports the major functions of CBRN Defence operations. CBRN Defence is the set of military activities that are conducted by forces to protect the NATO populations, territory or forces against attacks with CBRN weapons or agents, and to minimize the effects of these attacks. CBRN Applications provide decisions makers with accurately display of the CBRN environment in order to execute a comprehensive threat and risk analysis, which include information on own forces' CBRN capabilities and information on hostile capabilities and threats, allowing the creation of CBRN estimates and the CBRN annex to the operational plan.

B10.17 – Communication Systems - Casualty Rate Estimation Services

The Casualty Rate Estimation Services provide functionality to estimate casualty rates based on various scenarios (e.g. conventional, CBRN). These services will evaluate risk probabilities as well as provide confidence levels for these estimates.

B10.18 – Space Traffic Management

Research on Space Traffic Management (STM) aims to enable safe, scalable, routine, high-tempo space for all users in outer space. It prevents the collision risk with other platforms including nanosatellites and orbital debris. STM systems could be organized to provide the following functions: Traffic Management and Concepts (safety analysis, procedures), Architecture and Infrastructures (scalable integration in space), Range Tracking, Surveillance (deconfliction, debris tracking), Characterization (characterization of space objects) and Integrated modelling, Simulation and Testing.

B11 – Personnel Protection Systems

B11.01 – Physical Protection systems - Threat

Research to understand the issues involved in the design, selection and evaluation of specialist clothing and equipment to protect individuals and groups operating in military threat situations. Also includes work to understand human protection and survival systems in environmental extremes including radiological, thermal, and sensory threat conditions. Also includes work to understand Electro-Optical Protection Measures (EOPM) for bare eyes. Also includes work on body armour systems and related behind-armour protective clothing systems. Also includes work to achieve lighter and modular ballistic protections. Also includes work on human and physical resources protection against directed-energy weapons (DEW). Also includes work on concealment and threat deception technologies, including smart, adaptive (meta) materials for stealth coatings, adaptive camouflage and signature reduction. Also includes research into, and development of designs aimed to integrate the ballistic protection in the vehicle chassis and weapon system hull. Also includes work to understand protection for Mine Countermeasure (MCM) diving, safety and support systems and decompression tables.

B11.02 – Physical Protection systems - Environment

Research to understand the short- and long-term effects of exposure to high altitude and other extreme environments on human physiology in applications like aircrew escape systems, diving systems, and submarine escape systems. Also includes work to understand maintenance of physical

and visual performance with effective communication in high ambient noise environments. Also includes work to design, select and evaluate specialist clothing and individual equipment, and investigations of the degradation in individual and collective performance when exposed simultaneously to diverse agents/contaminants. Also includes work on on-board oxygen generating systems, breathing regulator technology, anti-G systems, air conditioning for humans and equipment, and internal noise control for habitability purposes.

B11.03 – CBR & N Protection systems - Physical

Research to understand the construction, performance and utilisation of individual and collective protection equipment (IPE & COLPRO), decontamination systems and contamination management, and chemical hardening processes. Also includes work to exploit surface chemistry technology and airflow cleaning and management systems. Also includes work to optimise the handling of supertoxic chemicals. Also includes work to understand the Human Factors Integration (HFI) issues associated with the design, selection and evaluation of NBC protective systems. Also includes work to understand integration of COLPRO systems onto land vehicles. Also includes work to exploit auto decontamination systems requiring no filter cartridge replacement and self-cleaning, reusable NBC clothing. Also includes work to understand how to integrate sensors in the garments for early contamination detection. Also includes work to investigate the potential of electrospun nanofibers particularly regarding filtration, sensor integration and energy storage. Also includes work to evaluate and analyse the statutory requirements regarding ionising radiation environments.

B11.04 – CBR & N Countermeasures - Medical

Research to understand the identification, efficacy, licensing and military acceptability of NBC medical countermeasures. Also includes work to analyse effectiveness of pre-treatments (drugs and vaccines) and therapy (drugs and procedures) for all materials that comprise the CB threat spectrum. Also includes work on anti-emetic drugs used to combat deleterious effects of radiation. Also includes work which exploits biotechnology, pharmacology, toxicology and pathology for the protection of military personnel from CB threats. Work on drugs based on genetically modified organisms (such as recombinant DNA (rDNA) or DNA molecules derived from different sources) with many applications, ranging from pharmaceutical, regenerative medicine, human performance enhancement and treating certain complex medical conditions is also included.

B11.05 – Protection Systems – Architecture

Research to understand the requirements and the design of open architectures for modular, integrated personal protection systems (MIPPS). Also includes work to integrate threat and environment protections into MIPPS. Also includes work to investigate the potential of new technologies (e.g. electrospun nanofibers) to integrate filtration, sensors and energy storage into MIPPS. without handicapping comfort and customizing the protection requirement of the different body areas, adapting it to the mission's risk level and to the vital body organs. Also includes work to understand how to integrate MIPPS with other systems (e.g. soldier systems). Also includes work to define common requirements for testing and validating MIPPS. Also includes work to define mathematical modelling and digital twins of the MIPPS to predict the possible expected risks under different scenarios.

Chapter C. System-level Technologies

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C01 – Integrated Platforms

C01.01 – Undersea Platforms

Research to investigate conceptual designs of modularity for underwater platforms related to improved operational and navigational performance in response to future threats. These aspects will be related to hydrodynamic and structural properties, functionality, stealth, manoeuvrability, autonomy, resistance to impacts, leaks and fire. Evaluation of deep-sea threats and environmental conditions and their impact on design and modularity. Also includes investigations requiring autonomous AI based mission execution capabilities and communications.

C01.02 – Fighting Land Vehicles

Research and technologies for weaponized military vehicles used for combat operations, considering the following categories: mobility (wheeled, tracked, other), power system and management (electric battery, fuel cell, internal combustion engine using fossil fuels, internal combustion engine using regenerative fuels, such as hydrogen and e-fuels, hybrid drive system by combination of internal combustion engine and electrified components), weapon system (direct fire, lethal/non-lethal, indirect fire), survivability (active protection, passive protection), architecture (digital, analogic), automation (manned, optionally unmanned, optionally manned, unmanned), driver assistance systems and interoperability.

C01.03 – Logistic, Command and Surveillance Land Vehicles

Research and technologies for vehicles providing logistic, command and reconnaissance support to the fighting units, having regard to their reduced protection and firepower compared to the to the combat vehicles.

C01.04 – Combat Fixed Wing Aircraft

Full description planned for the next update cycle.

C01.05 – Tactical and Strategic Fixed Wing Transport Aircraft

Full description planned for the next update cycle.

C01.06 – Surveillance Fixed Wing Aircraft

Full description planned for the next update cycle.

C01.07 – Training Fixed Wing Aircraft

Full description planned for the next update cycle.

C01.08 – Remote Carrier Aircraft

Full description planned for the next update cycle.

C01.09 – Helicopters/Rotorcraft

Full description planned for the next update cycle.

C01.10 – Unmanned Vehicles

Research and technologies for UxVs (Unmanned Air/Ground/Surface/Underwater Vehicles), varying in size and shape, including those operated remotely (via satellite, radio, or line-of-sight) by a human operator, those highly automated and those controlled by an autopilot, as well as manned vehicles that can optionally be operated unmanned and vehicles that are designed as purely unmanned systems to autonomously perform tasks. Research of technologies, sensors, payloads, command and control systems, propulsion, positioning and on-board power generation/control, navigation and communications systems associated with UxVs. Also research activities to convert existing military vehicles (land, sea and air) into unmanned platforms so that they can be operated remotely or autonomously . Research on drive-by-wire capabilities. Research on unmanned vehicles applied to a specific domain, such as:

C01.10.01 – Unmanned Land Vehicles

Research and technologies for all kind of UGV applications, such as mule systems, logistic transport vehicles, command and control vehicles, infantry fighting vehicles, armoured personnel carriers, main battle tanks and other fully autonomous ground systems.

C01.10.02 – Unmanned Maritime Vehicles

Research on all aspects of unmanned surface and underwater vehicles either remotely operated or with differing levels of autonomy. Also includes research on launch and recovery systems.

C01.10.03 – Unmanned Air Vehicles

Research on all aspects of unmanned air systems and vehicles (fix and rotary wings) either remotely operated or with differing levels of autonomy. Research on launch and recovery systems is not included in this topic but in the taxonomy item C01.08 – Remote Carrier Aircraft.

C01.11 – High-Altitude Platform Systems

Research to develop high-flying aircraft or airships, which will operate from altitudes of 17 to 24 km benefiting from favourable atmospheric conditions in the stratosphere. HAPS include lighter-than-air and heavier-than-air systems (UAVs) with high autonomy and persistence. The main use is as a communications station, having been recognised by the ITU as a separate category of radio station and has assigned the 2, 31/28, and 47/48 GHz frequency ranges for its operation. Compared to LEO/GEO satellites, HAPS perform better in terms of latency and dispersion losses, as well as quick deployment. In military use, in addition to communications stations, HAPS have applications in ISR, with a higher resolution capability.

C01.12 – Lighter-Than-Air Platforms

Research includes lighter-than-air manned and unmanned platforms (blimps, balloons, airplanes) that operate in the atmosphere at high altitudes benefiting from favourable atmospheric conditions in the stratosphere for extended periods of time in order to provide services conventionally provided by an artificial satellite orbiting in space. Proposed applications include border security, maritime traffic monitoring, anti-piracy operations, disaster response, agricultural observation, atmospheric observation, weather monitoring, communications relay, oceanographic research, Earth imaging and telecommunications.

C01.13 – Communications Satellites

Communication satellites can belong to 3 main categories: Geostationary satellites (GEO), Low Earth Orbit satellites (LEO) including multiple satellites constellation configurations, Highly Elliptical Orbits satellites (HEO) to better serve the polar regions. Typical research areas related to communication satellites concern communication payload design, on-board signal processing, active antennas design, on-board reconfiguration, etc.

C01.14 – Reconnaissance/Observation and Navigation Satellites

Research on reconnaissance/observation satellites include at least three classes of satellites: Low Earth orbiting satellites operating in the optical domain (visible and IR), Low Earth orbiting satellites carrying a synthetic aperture radar (SAR), Satellites operating in the geostationary orbit (observation and early warning). Typical research areas concern optical instrument design, SAR design, on-board signal processing, on board storage memory, very high data rate transmission to ground stations, etc.

C01.15 – Navigation and Other Satellites

Navigation satellites such as GPS or Galileo are in fact positioning and time-synchronization satellites. They operate in the Medium Earth Orbits (MEO) around 20 000 km altitude on a series of inclined orbital planes. Research concerning these satellites mostly concern the on-board atomic clocks and signal generation to reduce the sensitivity to jamming or spoofing. Other satellites that relate to navigation are those that pickup AIS signal from sea vessels and relay them to ground stations. They are mostly micro-, nanosatellites, CubeSats and or other minisatellites operating in LEO. Other satellites of interest to defence are electronic intelligence satellites that pick up and analyse signals from ground-based radars and other transmitters.

C01.16 – Space Launchers

Space launchers can be categorized according to their payload capacity:

- Large launchers which can put several tons (typically 5 to 6 tons) on a GEO Transfer orbit (e.g. Ariane 5 and Ariane 64, Atlas V);
- Medium sized launchers such as the Soyuz and Ariane 62 which can launch 2 to 4 tons in the GEO Transfer orbit;
- Small launchers which do not aim to the GEO satellites market but rather focus on Low Earth Orbiting satellites, which include medium-size spacecraft (typically 500 Kg (as well as sets of microsatellites and nanosatellites. Many such launchers are available today such as Vega in Europe, Rocketlab in the US, Electron in Japan and many more are being developed by a series of small start-up industries.

Typical research associated with space Launchers focus on advanced propulsion system, guidance systems, launcher recovery design and associated systems, lightweight dispenser systems, etc.
New space launchers could be composed of a part of reusable components (e.g. SpaceX Falcon 9 launcher).

C01.17 – Fighting Sea Surface Platforms

Research to evaluate and analyse the design of fighting sea surface platforms from different aspects, namely operational capabilities, survivability, operability, maintainability, and interaction with the marine environment.

C01.18 – Logistic and Support Sea Surface Platforms

Research to investigate the impact of the development of primary energy sources in the civilian sector (e.g. hydrogen, methanol, synthetic fuels) on availability, standardisation of infrastructure/systems and their costs in military use. Develop conceptual approaches for the preparation of a common situation picture across all logistics concepts within the EU and for all military sections.

C01.19 – Amphibious Operations Platforms and Systems

Research into systems able to support operations launched from the sea by an amphibious force to conduct landing force operations within the littorals. Landing Platform Dock (LPD), Landing Helicopter Dock (LHD).

C01.20 – Stores and Weapons Release/Discharge Systems

Research to understand, evaluate and analyse the factors involved in release/discharge of stores and weapons from land, sea and air platforms. Includes model and full-scale experiments and predictive modelling.

C01.21 – Space Debris Management and Deorbiting Systems

Research on technologies for deorbiting satellites aims at designing various systems that can help speed up a spacecraft descent into the Earth's atmosphere where it will burn up after its mission is over. This reduces the chance that it will be involved in a collision and frees up the useful orbit for another satellite. A rapid reliable deorbiting of satellites with critical military payloads after their end-of-life is a specific requirement. Another class of deorbiting technologies regards specifically the orbital debris, with the objective to reduce their number and dangerousness for the active satellites.

C01.22 – Onboard Aircraft Take-Off and Landing Systems

Research on EMALS (Electromagnetic Aircraft Launching System), UAV launching systems and landing system and onboard aircraft landing systems. Also includes research on helicopter operation and landing systems and (VTOL) Vertical Take-Off and Landing onboard operations.

C01.23 – Launch and Recovery of Vehicles at Sea

Research to study and improve L&R in adverse conditions of manned/unmanned marine vehicles from naval platforms, implementation of tools for the prediction of ship motions suitable for real time decision support systems. Also includes tools for the integration of stability actuator into design and (autonomous) launch and recovery system design.

C02 – Weapons and Effectors

C02.01 – Mines - Land

Full description planned for the next update cycle.

C02.02 – Missiles - Anti Air

Full description planned for the next update cycle.

C02.03 – Missiles - Anti Surface (Sea)

Full description planned for the next update cycle.

C02.04 – Gun Systems - Platform Mounted

Full description planned for the next update cycle.

C02.05 – Gun Systems - Hand Held

Full description planned for the next update cycle.

C02.06 – Directed Energy Weapons

Research to develop and implement directed energy weapons into air, land, and naval platforms. Includes research on microwave guns, High Energy Laser (HEL) weapons and Electromagnetic Pulse (EMP) weapons. Research on directed energy weapon systems to understand new capabilities and limitations.

C02.07 – Non-Lethal Weapons

Full description planned for the next update cycle.

C02.08 – Weapons Systems Security

Research on advanced weapon systems & security. Also includes weapons storage and security system including electronic controls and vaults. Also includes research on new standards, adequacy of physical protection in storage. Also includes analyses asset value, potential threats and vulnerabilities, and proposes countermeasures to mitigate risk of unauthorized access, sabotage and theft. Also includes potential countermeasures and recommendations to mitigate risks.

C02.09 – Mines - Sea

Research to understand self-contained explosive devices placed in water to damage or destroy surface ships, submarines and maritime infrastructure including port access. Research includes mine types, damage caused by mines, countermeasures and mind laying tools and systems.

C02.10 – Missiles - Anti Ground (Land)

Full description planned for the next update cycle.

C02.11 – Torpedoes

Research to understand underwater weapons that are fired above or below the water surface, are self-propelled and self-guided, and are equipped with an explosive warhead that detonates either on contact with or near the target (anti surface, anti submarine warfare). Major research areas include power sources, propulsion, guidance systems, warhead, hydrodynamics, handling devices, and launch systems. Conventional torpedoes. Torpedo guiding systems. Hypercavitating torpedoes. Searching torpedoes. Torpedo storage systems. Torpedo Launching systems.

C02.12 – Hypersonic Missiles

Research into Hypersonic cruise missiles, Advanced Hypersonic Weapons (AHW) and Hypersonic glide vehicles (HGV).

C02.13 – Hypersonic Projectile

Full description planned for the next update cycle.

C02.14 – Counter UxV Systems

Full description planned for the next update cycle.

C02.15 – Counter Hypervelocity Systems

Full description planned for the next update cycle.

C02.16 – Space-Based Weapons

Full description planned for the next update cycle.

C02.17 – Electromagnetic Railguns

Full description planned for the next update cycle.

Chapter D. Supplementary Technology Areas

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D01 – Operating Environment Technology

D01.01 – Oceanography

Research to understand military oceanography and develop expertise in water column and seafloor and ocean bed imaging. Also includes work to understand the underwater environment in terms of its effect on underwater weapon homing algorithms. Also includes research to understand HF acoustics propagation for applications like MCM sonars.

D01.02 – Terrain Science

Research to understand terrain for representation in models and synthetic environments. Work to develop expertise in digital map processing facilities. Also includes work to understand land mapping from space imagery.

D01.03 – Meteorology

Research to understand representation of weather systems in models and synthetic environments to preview the potential impact of the meteorology conditions in the spread of an agents or contaminants. Also includes work to understand ocean-atmosphere coupling for underwater propagation modelling, and effect of meteorological conditions on long range radar propagation at sea. Also includes work to sense remote air movements using optical techniques. Also includes research to analyse and develop fully coupled (ocean-atmosphere-wave-ice) global, regional and local models and prediction tools for operational planning.

D01.04 – Upper Atmosphere & Space Environment

Research to understand ionospheric and exo-atmospherics space environment and its effects on military spacecraft. Includes work to measure and model space radiation and to assess the orbital debris population and its characteristics. Also includes research to understand effect of ionospheric environment on EHF satcomms, sensors for BMD, HF and space-based radar and precision time systems like GPS.

D01.05 – Acoustic Propagation in Air & Water

Research to develop mathematic models and relevant simulators aiming at describing the behaviour of sound waveforms in air and underwater taking into account all potential variables, such as the effects of reverberations, reflections, changes in the speed of the sound source and changes in the peculiar characteristics of the element into which the propagation is taking place.

D01.06 – Electromagnetic Propagation in Air & Water

Research to develop mathematic models and relevant simulators aiming at describing the behaviour of electromagnetic waveforms in air and underwater taking into account all potential contingency variables, such as the effects of reverberations, reflections, effects of meteorological variations on long-range transmissions and changes in the peculiar characteristics of the element into which the propagation is taking place.

D01.07 – Optical propagation in Air and Water

Research to understand and model propagation of optical waves in air and/or in water to take into account its effect on optical system performance and image modelling and imaging systems.

D02 – Manufacturing Processes, Design Tools and Techniques

D02.01 – Design for Improved Reliability & Maintainability

Research to understand interface requirements and applicability of data employed in system engineering to the industrial process. Also includes work to understand reliability modelling of land vehicles and equipment, satcom systems, and aircraft and helicopter structures and systems where dynamic characteristics under vibration conditions is important. Also includes work to understand open systems, high integrity systems and device reliability design concepts. Also includes work to evaluate, analyse and produce Asics, interconnects and packaging for cryptographic ICs.

D02.02 – Cost Engineering

Research to understand the integration of structural, aerodynamic, signature and control techniques for cost optimisation at the design stage. Also includes work on structural design and materials requirements in the context of cost reductions. Also includes work on cost modelling and analysis for land vehicles, equipment, and for space surveillance and satcom systems. Also includes work to understand minimisation of cost in instances where there are technology obsolescence implications. Also includes design for improved affordability.

D02.03 – Concurrent Engineering and Reduced Design Cycle

Research to understand the implications of configuration control at all levels from IC board to platform. Also includes work to understand concurrent engineering design tools

D02.04 – Advanced Prototyping

Research to understand device prototyping and of rapid prototyping tools for software developments. Also includes work to understand the implications of a virtual manufacturing approach. Also includes rapid prototyping in an air system context.

D02.05 – Techniques and Systems for Production Manufacturing

Research to understand, analyse and evaluate techniques and systems for production manufacturing of defence equipment. Examples include, flexible assembly,
robotics/automation, IT systems, "just-in-time" provision of components and subsystems, reduced emissions manufacture, etc. Includes work to minimise systems installation problems during the later stages of assembly. Examples include use of robotics, modular systems, multiplexing, improved interfaces/connectors, operator support tools for installation and remedial functions, and visualisation tools.

D02.06 – Project Management and Control

Research to understand, analyse and evaluate improved project management and control techniques and associated factors. Also includes human resource management, cultural issues, IT applications to communication and programme control, error budget management, etc.

D02.07 – Manufacturing Process Simulation

Research into all aspects of the manufacturing process that are amenable to advanced simulation techniques in order to identify potential problem areas and cost-effective remedial solutions. Also includes relevant aspects of material behaviour modelling.

D02.08 – Lean Manufacturing

Research to evaluate techniques which minimise delays in component supply and insertion into the manufacturing and assembly processes.

D02.09 – Process Control Technology

Research on methods of real time process control applied to manufacture of all defence products. Examples are cure monitoring of composites, weld process monitoring, and on-line tolerance measurement and control. Also includes relevant aspects of material behaviour modelling.

D02.10 – Environmentally Friendly Factory Processes

Research to understand and aid implementation of environmentally friendly (EF) materials and processes wherever possible in the manufacturing cycle, so that adverse human effects caused by chemical effluent sources or noise transmission are minimised. Also includes work to meet the requirements of the Montreal Protocol and other international agreements in the context of EF factory processes and product behaviour.

D02.11 – Knowledge-based Engineering

Research to maximise the effective use of existing data and know-how contained in libraries of past experience.

D02.12 – Digital Twin

A digital twin is a virtual representation of a system and spans its lifecycle. It is updated from real time data and uses simulation and machine learning to assist in decision making. Research in digital twin can lead to increases in efficiency and productivity.

D02.13 – Bio-Inspired Systems

Research activities that focus on the design, development and understanding of systems that mimic the behaviours or processes of biological entities (i.e. during the diverse CBRN mitigation actions). Also includes work on bio-inspired sensors and networks, biochips and biosensors able to diagnose cheaply and rapidly diseases, physiological states and genetic features of organisms. Research activities in the development of nanorobots (nanobots) and bio-nanobots in the health promotion, and to the use of molecular knowledge to maintain and improve health at a molecular scale should be considered Research activities in biorobotics to develop artificial limbs (i.e. robotic arms/legs and or “robotic mules”) and exoskeletons to augment limb functions (i.e. reinforce their mobility and/or increase their strength) is also included

D02.14 – Multi-Disciplinary Design and Analysis Framework

Full description planned for the next update cycle.

D02.15 – Requirement Definition Studies

Full description planned for the next update cycle.

D03 – Defence analysis

D03.01 – Policy, Force Development and Balance of Investment Studies

Full description planned for the next update cycle.

D03.02 – Combined Operational Effectiveness and Investment Appraisals

Full description planned for the next update cycle.

D03.03 – Platform and System Concept Studies

Research to understand the Concept of Use (CONUSE) and Concept of Employment (CONEMP) of platform and system, including weapon systems. Also includes work for Concept Development & Experimentation (CD&E) using Modelling & Simulation (M&S).

D03.04 – Scenario Generation

Research on generation, modelling and simulation of possible scenarios for evaluations and forecasting on symmetric, asymmetric and hybrid operations and related training, also through wargaming. Also include work on Artificial Intelligence (AI) applied to scenario generation. Also includes research to define the tools and languages to describe a scenario for CONUSE, CONEMP, demonstration, OA, test and training. Also includes description of components of military scenarios that can be shared across a variety of Modelling & Simulation systems. Also includes development of tools and threat models.

D03.05 – Tactical Development and Support to Operations and Training

Full description planned for the next update cycle.

D03.06 – Other Effectiveness and Performance Studies

Full description planned for the next update cycle.

D03.07 – Military Doctrine Analysis

It includes the research sectors that deal with the analysis of the doctrines adopted by the various countries (for example in supporting Decision Making), their comparison and the search for solutions and applications that improve their effectiveness, efficiency and application in operational theatres. Also includes research aimed at integrating, in applications and procedures based on military doctrines, state-of-the-art solutions that use innovative technologies such as AI, ML and BDAA. It includes research for advanced training of military doctrine, using applications and architectures based on, for example, LMS, MSaaS, and TaaS.

D03.08 – Wargaming and Combat Simulation

Research on modelling and simulation of wargaming for the training and evaluation of techniques, tactics and procedures, analysis on the wargaming effects on the combat capability development. Also include work on the definition and standardisation of training methodologies. Research on Artificial Intelligence for the simulation of virtual dynamically changeable environments.

D04 – Installations and Facilities

D04.01 – Ground Stations

Full description planned for the next update cycle.

D04.02 – Fortifications / Defences

Full description planned for the next update cycle.

D04.03 – Battlefield Engineering

Full description planned for the next update cycle.

D04.04 – T&E Facilities

Full description planned for the next update cycle.

D04.05 – Site Decontamination

Tactics, techniques, and procedures (TTP) for planning and executing decontamination operations in a CBRN environment.

D04.06 – Maintenance and Repair Facilities and Organizations (MRO)

Full description planned for the next update cycle.

D05 – Personnel Equipment, Processes and Health Aspects

D05.01 – Equipped Personnel

Technologies that make military actions easier and more connected, providing tactical awareness, allowing soldiers to see beyond their personal sight using GPS, smartphones, tablets, and even helmet-mounted screens. Further relevant advances in technology that produced better and lighter body armour, exoskeletons, better weapon optics and imaging devices, and a host of other specialized protective and offensive gear.

D05.02 – Recruitment, Selection and Allocation

Full description planned for the next update cycle.

D05.03 – Training and Education

Full description planned for the next update cycle.

D05.04 – Health and Well-being

Health and well-being are important aspects for quality of life. The self-reported EQ5D questionnaire determines health-related quality of life (HRQoL) and may be used to assess well-being and treatment effects. This topic includes nutrition, training, prevention of stress-related disorders, and staff work-life balance. Research on psychophysical state monitoring system inbuilt in uniform and integrated

with C4I systems. Analysis of medical parameters controllable on battlefield with low error probability decision making process for soldier state evaluation.

D06 – Defence Functions and Policy Support

D06.01 – Access to Critical Raw Materials outside EU

Full description planned for the next update cycle.

D06.02 – International Security

Full description planned for the next update cycle.

D06.03 – Ethics - Rules of Engagement

Full description planned for the next update cycle.

D06.04 – Equipment Disposal and Circular Economy

Full description planned for the next update cycle.

D06.05 – Non-Proliferation

Research on preventing the spread of CBRN weapons and their technology, promoting cooperation in the peaceful uses of nuclear energy and CBRN knowledge, and to further the goal of achieving CBRN disarmament and general disarmament.

D06.06 – Hazard Assessment

Includes studies on detecting, identifying, assessing, previewing, controlling, monitoring and eliminating all of the potential hazards on human, equipment, property or environment.

D06.07 – Logistics, Integrated Life-Cycle Support

Full description planned for the next update cycle.

D06.08 – Counter Stealth

Full description planned for the next update cycle.

D07 – Battlespace Information

D07.01 – Information Infrastructure

Full description planned for the next update cycle.

D07.02 – Information Warfare

Full description planned for the next update cycle.

D07.03 – Command & Control

Full description planned for the next update cycle.

D07.04 – Digitization of the Battlespace

Full description planned for the next update cycle.

D07.05 – Intelligence, Surveillance, Target Acquisition & Reconnaissance (ISTAR)

ISTAR stands for information, surveillance, target acquisition, and reconnaissance, which is a practice that links several battlefield functions together to assist a combat force in employing its sensors and managing the information they gather. ISTAR is the process of integrating the intelligence process with surveillance, target acquisition and reconnaissance tasks to improve a commander's situational awareness and consequently their decision making. The inclusion of the "I" is important as it recognizes the importance of taking the information from all the sensors and processing it into useful knowledge.

D07.06 – Military Intelligence and Industry Intelligence

Military intelligence is a military discipline that uses information collection and analysis approaches to provide guidance, share good practices on CBRN security and direction to commanders in support of their decisions. This is achieved by providing an assessment of data from a range of sources, directed towards the commanders' mission requirements, or responding to questions as part of operational or campaign planning, or the development of an Early Warning System for CBRN risks[1]. Areas of study may include the operational environment, hostile, friendly and neutral forces, the civilian population in an area of combat operations, and other broader areas of interest, supported by advanced modelling techniques from artificial intelligence, machine learning and big data analytics. Intelligence activities are conducted at all levels, from tactical to strategic, in peacetime, the period of transition to war, and during a war itself.

D08 – Business Process

D08.01 – Requirements Capture

Full description planned for the next update cycle.

D08.02 – Concepts and Product Definition

Full description planned for the next update cycle.

D08.03 – Product Supportability

Full description planned for the next update cycle.

[1] CBRN Glossary. European Commission, Directorate-General Home Affairs. Source: https://ec.europa.eu/home-affairs/sites/default/files/what-we-do/policies/crisis-and-terrorism/securing-dangerous-material/docs/cbrn_glossary_en.pdf

D08.04 – Whole-life Cycle Improvement

Full description planned for the next update cycle.

D08.05 – Business Process Simulation

Full description planned for the next update cycle.

D08.06 – Benchmarking and Best Practice

Full description planned for the next update cycle.

D08.07 – Lean Enterprise Models

Full description planned for the next update cycle.

D08.08 – R&T Management

Includes research, analysis, design, modelling and evaluation studies of research and technology management. Also includes studies on technology roadmapping, technology monitoring, technology foresight, technology inventory and technology portfolio.

D08.09 – Design in the Extended Enterprise

Full description planned for the next update cycle.

D08.10 – Procurement and Contracting Processes

Full description planned for the next update cycle.

Chapter E. Specialized Technology Taxonomies

Chapter E. Table of Contents

E01 – Artificial Intelligence

E01.01 – Algorithms and Strategies for Decision Making

E01.01.01 – Symbolic, Logic-based and Knowledge-based

Approach based in expression of concepts and processes by sets of symbols according to a limited set of logically defined rules and the use of background knowledge and constraints to define the search space. By the combination of different symbols following certain rules, complex ideas are formed and reasoning is possible.

E01.01.01.01 – Logic Programming

Learning hypothesis comprising a set of rules, given background knowledge and constraints for the search space and based on formal logic. Examples of classical tools are Prolog, Lisp and Foil.

E01.01.01.01.01 – Inductive Logic Programming

Finds hypothesis from a set of positive and negative examples with the ability to provide declarative background knowledge to the learning engine.

E01.01.01.01.02 – Deductive Logic Programming

Starting out with a general hypothesis, the possibilities to reach a specific and logical conclusion are analysed. A theory is held and predictions of its results are made, going from the general to the specific observations. The inference engine is directed by data.

E01.01.01.01.03 – Abductive Logic Programming

Through an incomplete set of observations and using the best information available, it provides the likeliest possible explanation based on making and testing hypotheses. It often entails making an educated guess after observing a phenomenon for which there is no clear explanation.

E01.01.01.01.04 – Probabilistic or Statistical Logic Programming

Automatic reasoning that takes into account uncertainty and chance.

E01.01.01.01.05 – Defeasible Logic Programming (DeLP)

It represents information in the form of weak declarative rules and a defeasible argumentation inference mechanism for warranting the entailed conclusion. Argumentation formalism is used for deciding between contradictory goals where queries are supported by arguments that could be defeated by other arguments.

E01.01.01.01.06 – Other Logic Programming

E01.01.01.02 - Expert Systems

Systems based on knowledge and expertise providing reasoning capabilities for a specific area represented by ontologies, rules and information databases. The core components of expert systems are the knowledge base and the reasoning engine. They were the first operative form of AI algorithms.

E01.01.01.02.01 – Rule Based Reasoning (RBR)

The expert knowledge of the system is expressed manually by human experts in the form of simple logical tests that establish a set of rules often implying causality. Learning often done by re-weighting of rules via reinforcement learning.

E01.01.01.02.02 – Case Based Reasoning (CBR)

Problems are solved by finding solutions from similar cases experienced in the past. CBR allows for sustained learning, since experiences from new cases are registered when new problems are solved, being added to the knowledge database. Learning often done by re-weighting of features and the adaptation heuristics as well as identifying case utility via reinforcement learning.

E01.01.01.02.03 – Fuzzy Expert Systems

Collection of membership functions and rules that are used to reason about data allowing a better management of the uncertainty in comparison with Boolean logic and oriented towards numerical processing.

E01.01.01.02.04 – Multilingual Knowledge Base

The knowledge base used by the expert system supports different languages.

E01.01.01.02.05 – Knowledge Graphs

Type of knowledge base to enhance search engine's results with information gathered from a variety of sources connected by different relationships. Represents a collection of interlinked descriptions of entities like real-world objects, events, situations or abstract concepts. In some contexts, the term knowledge graph is used to refer to any knowledge base represented as a graph.

E01.01.01.02.06 – Other Expert Systems

E01.01.02 - Connectionist - Artificial Neural Networks (ANN)

ANN are interconnected assemblies of simple processing elements, units or nodes whose functionality is loosely based on the animal neuron. The processing ability of the network is stored in the inter-unit connection strengths, or weights, obtained by a process of adaptation to, or learning from, a set of training patterns.

E01.01.02.01 – Hebbian Nets

Neural networks providing unsupervised learning based in the concept that two connected neurons activated simultaneously strengthen their connection, facilitating their activation in the future.

E01.01.02.02 – McCulloch-Pitts Neuron and Perceptron

Algorithms for supervised learning of binary classifiers based on a linear predictor function combining a set of weights with the feature vector.

E01.01.02.03 – Adaline and Madaline

The adaptive linear neuron (or element) is an early single linear unit artificial neural network based on the McCulloch–Pitts neuron. It consists on weight, bias and summation function and it is trained by the delta rule. Madaline is an extension to multiple layers.

E01.01.02.04 – Hetero-Associative Nets – Memories

Single-layer networks in which the weights are determined to store a set of pattern associations.

E01.01.02.05 – Auto-Associative Nets – Memories: Hopfield Nets

Single layer of processing elements where each unit is connected to every other unit other than itself and compute its output recursively in time until the system becomes stable.

E01.01.02.06 – Competition-Based Nets: Kohonen Nets

Also called Self-organizing maps. These networks are based in competition for activation across the layers. The network evolves via competitive dynamics and self-organize by unsupervised learning.

E01.01.02.07 – Boltzmann Machines

Networks of symmetrically connected, neuron-like units that make stochastic decisions about whether to be on or off. One subclass is restricted Boltzmann machine (RBM) that can be seen as a stacked DBM as it has several layers of hidden units.

E01.01.02.08 – Autoencoders (AE)

Unsupervised ANN that learns how to efficiently compress and encode data. They are capable of reconstructing as close as possible the original input from the reduced encoded model. They are used for dimensionality reduction and information retrieval.

E01.01.02.09 – Deep Neural Networks (DNN)

DNN or Deep Learning Architectures (DLA). Multilayer neural networks addressing complicated notions by breaking it down into simplified characteristics through multiple layers. Computes hierarchical features or representations of the observational data, where the higher-level features or factors are defined from lower-level ones.

E01.01.02.09.01 – Deep Autoencoders (DAE)

Algorithms whose output target is the data input itself, often trained previously with DBN or using distorted training data to regularize the learning. There should be more than one hidden layer to be considered as deep.

E01.01.02.09.02 – Deep Boltzmann Machines (DBM)

The deep Boltzmann machine (DBM) is a special BM where the hidden units are organized in a deep layered manner, only adjacent layers are connected, and there are no visible-visible or hidden-hidden connections within the same layer.

E01.01.02.09.03 – Deep Convolutional Neural Networks (DCNN)

Also named as CNN (without the prefix) or convnets, the architecture consists of three types of layers, namely convolutional, pooling, and fully connected. Oriented to process data that have a grid-like topology like images but as well to several others including text.

E01.01.02.09.04 – Deep Recurrent Neural Networks (DRNN)

They can keep memory on past states of the network thanks to a feedback capability. They provide memory to neurons allowing to capture information about what have been calculated so far.

E01.01.02.09.05 – Deep Belief Networks (DBN)

Probabilistic generative models composed of multiple layers of stochastic, hidden variables. The top two layers have undirected, symmetric connections between them. The lower layers receive top-down, directed connections from the layer above.

E01.01.02.10 – Graph-Based Neural Networks

Neural networks that operate directly on arbitrarily structured graphs and which do not have an underlying Euclidean or grid-like structure, represented by graphs and manifolds or surfaces and not showing typical properties as global parameterization, common system of coordinates, vector space structure or shift-invariance.

E01.01.02.10.01 – Graph Attention Networks

Neural network architectures that operate on graph-structured data, leveraging masked self-attentional layers to address the shortcomings of prior methods based on graph convolutions or their approximations.

E01.01.02.10.02 – Graph Auto-encoder

This model makes use of latent variables and is capable of learning interpretable latent representations for undirected graphs.

E01.01.02.10.03 – Graph Generative Networks

Neural networks capable of generating graphs.

E01.01.02.10.04 – Spatial-Temporal Graph Convolutional Networks

Spatial-temporal graph convolutional networks (ST-GCN) move beyond the limitations of previous methods by automatically learning both the spatial and temporal patterns from data.

E01.01.02.10.05 – Geometric Deep Learning

Umbrella term for emerging techniques attempting to generalize (structured) deep neural models to non-Euclidean domains such as graphs and manifolds.

E01.01.02.11 – Generative Adversarial Networks (GAN)

Framework for estimating generative models via an adversarial process simultaneously training two models: a generative model G that captures the data distribution, and a discriminative model D that estimates the probability that a sample came from the training data rather than G. The training procedure for G is to maximize the probability of D making a mistake.

E01.01.02.12 – Other Neural Networks

E01.01.03 – Decision Trees, Probabilistic, and Meta-Heuristics Search Algorithms

These algorithms take a problem as input and return a solution from the search space which is the set of all possible solutions.

E01.01.03.01 – Decision Trees

Non-parametric supervised learning methods used for classification or regression suffering normally from bias (for simple trees) and variance (for complex trees). Use of graphical representations of the possible options that can be selected in the resolution of a problem or a case, where internal nodes represent actions, arcs represent outcomes of an action, and leaves represent final outcomes. Construction of an optimal decision tree is an NP-complete problem and metaheuristics are normally used to solve them.

E01.01.03.01.01 – Classification or Binary Tree – Discrete

It builds classification models in the form of a tree structure by breaking down a dataset into smaller and smaller subsets by learning a series of explicit if-then rules on feature values that results in

predicting a target value. A classification tree consists of the decision nodes with two or more branches and the leaf node which represents a classification as final node of any branch.

E01.01.03.01.02 – Regression Trees – Continuous

Performs regression function where the predicted outcome is a real number, performing a regression function.

E01.01.03.01.03 – Random Decision Trees

Decision trees formed by stochastic processes.

E01.01.03.01.04 – Random Forests

Machine learning algorithm that operates by constructing a multitude of decision trees at training time and providing as output the class that is the mode of the classes (classification) or mean prediction (regression) of the individual trees.

E01.01.03.01.05 – Bagged Decision Trees

Consists of trees trained independently on data that is bootstrapped from the input data, bag being bootstrap aggregation, used to reduce the variance of a decision tree. They create several subsets of data from training sample chosen randomly with replacement.

E01.01.03.01.06 – Boosted Decision Trees

Create a strong learner by iteratively adding “weak” learners and adjusting the weight of each weak learner to focus on misclassified examples. Creates a collection of predictors learning sequentially with early learners fitting simple models to the data and then analysing data for errors. Fit consecutive trees (random sample) and at every step, the goal is to solve for net error from the prior tree.

E01.01.03.01.07 – Behaviour Trees

Directed acyclic graphs (DAGs) formed by hierarchically organizing behaviour sub-trees consisting of nodes. Visiting a node, respectively the sub-tree it roots, means running it according to its semantics. Execution of a node or a sub behaviour tree result in an aggregated return state. The first time they are evaluated or reset, they start from the root, parent nodes act like selectors, and each child is evaluated from left to right. The child nodes are ordered based on their priority.

E01.01.03.01.08 – Other Decision Trees

E01.01.03.02 – Probabilistic Methods

Methods based on statistics and randomness rather than deterministic analytics.

E01.01.03.02.01 – Monte Carlo

Probabilistic method of analysis based on repeated random sampling to solve problems that might be deterministic in principle. Monte Carlo simulation produces distributions of possible outcome values.

E01.01.03.02.02 – Fuzzy Logic

Approach to computing based on "degrees of truth" rather than Boolean logic (true or false-1 or 0) in order to better deal with uncertainty.

E01.01.03.02.03 – Markov Processes

Probabilistic process where the future depends only on the present and not on the past and used to model changes in probability distribution over time. Through Markov chains, the probability of a variable for any time in the future can be determined.

E01.01.03.02.04 – Kalman Filters

Algorithms using multiple sequential measurements to produce estimates of unknown variables by calculating each timeframe a joint probability distribution over them.

E01.01.03.02.05 – State Machines

Mathematical model defined by a list of states, its initial state, and the conditions for each transition from one state to another in response to defined external inputs.

E01.01.03.02.06 – Bayesian Networks

Or: 'Belief Networks', describes systems by a directed acyclic graph, specifying relationships (arcs) of conditional dependence between its variables (nodes). A model is created by the graph, together with a joint probability distribution for the variables that can be used to make the inferences. Probability estimates are encoded for a large number of different competing hypotheses, with respective belief probabilities updated as new information becomes available.

E01.01.03.02.06.01 – Pure Bayesian

Application of Bayes' theorem by direct estimation of the parameters of the conditional distribution from the training sample by maximizing the conditional likelihood.

E01.01.03.02.06.02 – Naive Bayesian

Application of Bayes' theorem assuming that the value of a particular feature is independent of the value of any other feature.

E01.01.03.02.06.03 – Semi-Naive Bayesian

Algorithms that seek to retain the numerous strengths of naive Bayesian while reducing error by alleviating the attribute interdependence estimation problem.

E01.01.03.02.07 – Classifiers.

Process of predicting the class of the data points given

E01.01.03.02.07.01 – Logistic Regression

Analyses data to explain the relationship between one dependent binary variable and one or more nominal, ordinal, interval or ratio-level independent variables. Estimates the probability of an occurrence of an event based on one or more inputs.

E01.01.03.02.07.02 – K-Nearest Neighbour (kNN)

Simple, supervised machine learning algorithm that can be used to solve both classification and regression problems. KNN captures the idea of similarity (sometimes called distance, proximity, or closeness) calculating the distance between points on a graph.

E01.01.03.02.07.03 – Support Vector Machine (SVM)

Support vectors are the data points that lie closest to the decision surface (or hyperplane). SVMs maximize the margin around the separating hyperplane.

E01.01.03.02.07.04 – Discriminant Analysis

Statistical analysis using a discriminant function to assign data to one of two or more groups.

E01.01.03.02.08 – Other Probabilistic Methods

E01.01.03.03 – Metaheuristics

Higher-level procedures or generalized heuristics aimed to generate or choose a heuristic providing a sufficiently good solution to an optimization or search problem when there is incomplete, defective information, limited computation or time capacity. Heuristic is any approach to problem solving or self-discovery that employs a practical method, not guaranteed as optimal or perfect but sufficient to reach an immediate goal.

E01.01.03.03.01. – Evolutive

Algorithms inspired in biological evolution.

E01.01.03.03.01.01 – Genetic Algorithms (GA)

Mimic genetic evolution mechanisms to better adapt decisions to new problems and new data. At each step selects individuals at random from the current population to be parents and uses them to produce the children for the next generation. Over successive generations, the population "evolves" toward an optimal solution. The evolution comes from external factors.

E01.01.03.03.01.02 – Differential Evolution (DE)

Optimizes a problem by iteratively trying to improve a population of candidate solutions with regard to a given measure of quality by combining existing ones and keeping the best. The evolution comes from internal and external factors.

E01.01.03.03.02 – Artificial Immune Systems (AIS)

Algorithms mimicking biological immunology that apply immune principles, functions and models to problem solving.

E01.01.03.03.03 – Swarm Intelligence

Algorithms that resolve problems based in the collective behaviour of decentralized, self-organized systems.

E01.01.03.03.03.01 – Particle Swarm Optimization (PSO)

Population-based optimization technique based on a cooperative searching strategy particularly devised to prevent the particles from being trapped into the local optimal solutions and locating the global optimal solution efficiently.

E01.01.03.03.03.02 – Artificial Bee Colony (ABC)

ABC provides a population-based search procedure in which individuals called foods positions are modified by the artificial bees with time and the bee's aim is to discover the places of food sources with high nectar amount and finally the one with the highest nectar.

E01.01.03.03.03.03 – Whale Optimization Algorithm (WOA)

This algorithm includes three operators to simulate the search for prey, encircling prey, and bubble-net foraging behaviour of humpback whales. It mimics the social behaviour of humpback whales.

E01.01.03.03.03.04 – Firefly Algorithm (FA)
Inspired by the flashing behaviour of fireflies and the phenomenon of bioluminescent communication, the algorithm is used to optimize the machining parameters (feed rate, depth of cut, and spindle speed).

E01.01.03.03.04 – Physics Based
Algorithms that solve problems imitating laws of physics.

E01.01.03.03.04.01 – Harmony Search Algorithm
It tries to mimic the improvisation process of musicians in finding a pleasing harmony.

E01.01.03.03.04.02 – Electromagnetic Modelling Optimization (EMO)
Optimization algorithm based in the principles of electromagnetism.

E01.01.03.03.04.03 – Simulated Annealing (SA)
Probabilistic technique for approximating the global optimum of a given function. The simulation of annealing can be used to find an approximation of a global minimum for a function with a large number of variables.

E01.01.03.03.04.04 – Photosynthetic Algorithms (PA)
Utilizes the dark reaction rules governing the transfer of carbon molecules from one substance into another in the Calvin–Benson cycle and photorespiration.

E01.01.03.03.05 – Enzyme Algorithms (EA)
Algorithm based on the fundamental mechanism of enzyme reactions.

E01.01.03.03.06 – Multimodal Optimization
Algorithms that optimize an objective function with at least two global optimizers.

E01.01.03.03.07 - Pathfinding Algorithms
Algorithms that identify the optimal or good enough path meeting some criteria (distance, cost, speed, etc.) between two points.

E01.01.03.03.08 – Agent-Based Modelling and Simulation
Simulation of computational models invoking the dynamic actions, reactions and intercommunication protocols among agents in a shared environment, in order to enhance the analysis of systems' behaviour and to assess strategies for its functioning in the descriptive or predictive modes.

E01.01.03.03.09 – Other Metaheuristics

E01.02 – Functions Provided by AI Algorithms

E01.02.01 – Human Language Technologies (HLT)

The processing of human language by a computer program. It does not refer to computer languages. HLT tasks include text translation, sentiment analysis and speech recognition and generation.

E01.02.01.01 – Text Analytics
The process of drawing meaning out of written communication.

E01.02.01.01.01 – Vector Space Mode (VSM)
Algebraic model for representing text documents (and any objects, in general) as vectors of identifiers, such as, for example, index terms.

E01.02.01.01.02 – Latent Semantic Analysis (LSA)
Latent Semantic Analysis (LSA) is a theory and method for extracting and representing the contextual usage meaning of words by statistical computations applied to a large corpus of text.

E01.02.01.01.03 – Lexical Databases
A lexical database contains nouns, verbs, adjectives and adverbs grouped into sets of cognitive synonyms (synsets), each expressing a distinct concept. Synsets are interlinked by means of conceptual-semantic and lexical relations. A wide known example is Wordnet.

E01.02.01.02 – Term Extraction
Term extraction or terminology extraction is an automatic method of analysing text in order to identify phrases which fulfil the criteria for terms.

E01.02.01.02.01 – Tokenizing and Stop-Word Removal
In natural language processing, useless words in data are referred to as stop words. Tokenizing is the process of removing all the stop words in a string, and thereafter selecting all the words in that string that may pertain to the topic or subject matter.

E01.02.01.02.02 – Part of Speech (POS) Tagging
Process of marking up a word in a corpus to a corresponding part of a speech tag, based on its context and definition.

E01.02.01.02.03 – Stemming and Lemmatization
Converting tokens into morphological stems by reducing inflectional forms and sometimes derivationally related forms of a word to a common base form.

E01.02.01.03 – Term Weighing
Procedure that takes place during the text indexing process in order to assess the value of each term to the document. It is the assignment of numerical values to terms that represent their importance in a document in order to improve retrieval effectiveness.

E01.02.01.03.01 – Raw
The weight of a term is computed as the number of times that the term occurs in the text.

E01.02.01.03.02 – Binary
Assigns a weight of 0 in case the term does not occur and 1 vice versa.

E01.02.01.03.03 – Term Frequency (TF)
Assigns a weight proportional to the frequency of the term occurrences in the given text fragments.

E01.02.01.03.04 – Inverse Document Frequency (IDF)
Assigns a weight depending on the number of given texts that include the term rated to the total number of texts.

E01.02.01.03.05 – TF – IDF

Computes the weight as the multiplication of TF and IDF with the aim of achieving the benefits from both.

E01.02.01.04 – Similarity Metric

Ways to compute the distance of two vectors.

E01.02.01.05 – Sentiment Analysis

Identification, extraction, analysis and categorization of affective state or opinion from text, social media activity, audio, video or biometric sensors information.

E01.02.01.06 – Geotagging

The process of creation of geospatial metadata by adding geographical identification metadata to different sets of data existing in very different formats.

E01.02.01.07 – Document Categorization

Automatically categorizing documents into pre-defined topic hierarchies or taxonomies.

E01.02.01.07.01 – Machine Learning Categorization

Categorization models are automatically created from training data representing each category.

E01.02.01.07.02 – Topic Tagging Categorization

Uses a variety of different concept tagging rules and it is most suitable when the target categories can be defined using a combination of relatively unambiguous terms and phrases. Concepts can be defined in several different ways.

E01.02.01.07.03 – Semantic Extraction Categorization

Categorize documents in target categories based in semantic entities or events.

E01.02.01.08 – Speech Production

Relates to the processes responsible for the production of speech sounds and possible processes for fluent speech with respective models.

E01.02.01.09 – Speech Recognition

Speech recognition is the ability of a machine or program to identify words and phrases in spoken language and convert them to a machine-readable format.

E01.02.01.10 – Other HLT Functions

E01.02.02 – Computer Vision

Interdisciplinary field dealing with the way in which computers see and understand digital images and videos, spanning all tasks performed by biological vision systems, including sensing visual stimulus, understanding what is being seen, and extracting complex information into a form that can be used in other processes

E01.02.02.01 – Image Acquisition

Process of obtaining images.

E01.02.02.02 – Image Pre-Processing

Operations aiming to improve the image provided by the sensor by suppressing distortions or enhancing its features to facilitate the following steps of processing.

E01.02.02.03 – Feature Extraction

Process of dimensionality reduction by which an initial set of raw image data is reduced to more manageable information sets for processing.

E01.02.02.04 – Detection – Segmentation

Division or partition the image into various parts called segments in order to make use of the most important segments for processing the image.

E01.02.02.05 – High-Level Processing

Related to image and video understanding, it studies how to reconstruct, interpret and understand images based in the properties of the structures present in the scene.

E01.02.03 – Situational Awareness

Situational awareness or situation awareness (SA) is the perception of environmental elements and events with respect to time or space, the comprehension of their meaning, and the projection of their future status.

E01.02.03.01 – Detection

Process performed in order to know if a particular object or condition is present by comparing the acquired data against a threshold.

E01.02.03.02 – Classification

Systematic arrangement in groups or categories according to established criteria.

E01.02.03.03 – Pattern Recognition

Classification of data based on knowledge already gained or on statistical information extracted from patterns and/or their representation.

E01.02.03.04 – Clustering

The task of grouping a set of objects in such a way that objects in the same group are more similar to each other than to those in other groups or clusters.

E01.02.03.05 – Identification

Establish the absolute sameness with one of a number of possible individual members of a class of known elements.

E01.02.03.06 – Data Fusion

The process of combining data from multiple sources to improve the information and inferences achieved by using a single data source.

E01.02.04 – Navigation

Support of AI algorithms to navigation related functions.

E01.02.04.01 – Pathfinding or Path Planning

Consists in finding the shortest route between two points.

E01.02.04.02 – Search and Optimization

A search algorithm is the step-by-step procedure used to locate specific data among a collection of data. Optimization is the procedure which is executed iteratively by comparing various solutions until an optimum or a satisfactory solution is found.

E01.02.04.03 – Fault Detection, Identification and Recovery (FDIR)

The fast detection and identification of faults enables the choice of an appropriate recovery strategy, potentially mitigating the consequences of an out-of-control vehicle and recovering performance.

E01.02.04.04 – Task Allocation

Process of ensuring that tasks to be done have been assigned to a team or resource, and the workload has been distributed properly to balance the load among them.

E01.02.05 – Analytics

Application of statistics, computer programming and operations research in order to quantify and gain insight to the meanings of data. Especially useful in areas recording huge amounts of data or information.

E01.02.05.01 – Identity Analytics

Process of ascribing a user identifier (ID) to a human being or to another computer or network component.

E01.02.05.02 – Predictive Analytics

Describes a range of analytical and statistical techniques used for developing models that may be used to predict future events or behaviours.

E01.02.05.03 – Behavioural Analytics

Subset of business analytics focusing on finding out how and why people behave the way they do when using digital technologies applications.

E01.02.05.04 – Big Data Analytics

Strategy of analysing large volumes of data. This big data is gathered from a wide variety of sources, including social networks, videos, digital images, sensors, and sales transaction records. The aim in analysing all this data is to uncover patterns and connections that might otherwise be invisible, and that might provide valuable insights about the users who created it.

E01.02.05.05 – Serious Gaming

Games designed for industries like defence, engineering, health care or security with several purposes other than entertainment like training, analysis or support to decision making.

E01.02.05.06 – Regression

Function consisting in fitting a curve to a set of data.

E01.02.05.06.01 – Linear Regression

Linear regression is the problem of fitting a linear function to a set of input-output pairs given a set of training examples, in which the input and output features are numeric.

E01.02.05.06.02 – Nonlinear Regression
Nonlinear regression models are those that are not linear in the parameters they use. An example is the Levenberg-Marquardt nonlinear least squares algorithm.

E01.02.05.06.03 – Gaussian Process Regression Model
Gaussian process regression (GPR) is a nonparametric, Bayesian approach to regression included in the area of machine learning. the Bayesian approach infers a probability distribution over all possible values.

E01.02.05.06.04 – SVM Regression
Support vectors are the data points that lie closest to the decision surface (or hyperplane). SVMs maximize the margin around the separating hyperplane.

E01.02.05.06.05 – Generalized Linear Model
Generalized linear models (GLM) extend the concept of the well understood linear regression model. A generalized linear model introduces a link function around the linear combination of the explanatory variables. That way also non-normal and discrete distributions of Y can be fitted within this model class.

E01.02.05.06.06 – Regression Tree
Work basically the same way as classification trees with the large difference that the target feature values can now take on an infinite number of continuously scaled values.

E01.02.06 – Other Functions Provided by AI

E01.03 – Features, Characteristics and Related Concepts

E01.03.01 – Perception, Conditioning and Data Format

E01.03.01.01 – Text data
Data in written form.

E01.03.01.02 – Voice data
Data in the form of sound produced by human speech.

E01.03.01.03 – Image data
Data in graphic representation.

E01.03.01.04 – Sensor Raw data
Data from sensors provided without further processing.

E01.03.01.05 – Data Conditioning and Cleaning
Work to be done to ensure the quality of the data as it is directly related to the quality of the results of the analysis. Also referred as data curation.

E01.03.01.06 – Data Compression – Dimensionality Reduction
Techniques to reduce the data dimension. They can be lossless, recovering exactly the data compressed, or lossy with some loss of accuracy. The use of principal component analysis (PCA) is very extended as a linear dimensionality reduction technique for extracting information from a high-

dimensional space by projecting it into a lower-dimensional sub-space. But there are other techniques like linear discriminant analysis (LDA), non-negative matrix factorization or even the autoencoder.

E01.03.01.07 – Data Structure

Differentiates the data based in its structure.

E01.03.01.07.01 – Unstructured Data

Unpredictable structure where the content lacks metadata and cannot readily be indexed or mapped onto standard database fields. Examples are e-mails, instant messages, images, videos, satellite imagery, documents or social media posting.

E01.03.01.07.02 – Semi-Structured Data

Semi-structured data is information that does not reside in a rational database but that has some organizational properties that make it easier to analyse.

E01.03.01.07.03 – Structured – Data bases

Data whose elements are addressable for effective analysis. It has been organised into a formatted repository that is typically a database.

E01.03.01.08 – Other Format or Data Conditioning

E01.03.02 – Machine Learning (ML)

Refers to the ability of algorithms to learn from data by modelling the systems that produce those data without being explicitly programmed to do so. These models identify and extract patterns, acquiring their own knowledge and are inferred from data and predict the outcome of new inputs.

E01.03.02.01 – Supervised Learning (SL)

Models are created by training with labelled or annotated data. During training, the output associated with every input is known and the system learns these associations.

E01.03.02.02 – Semi-Supervised Learning (SSL)

A portion of the training data is not labelled or annotated.

E01.03.02.03 – Unsupervised Learning (UL)

Data sets are not labelled. They are sorted according to similarities or differences allowing to cluster the data in similar groups.

E01.03.02.04 – Reinforcement Learning (RL)

Type of learning through data sets not labelled. After data processing, the system improves its outcome through feedback.

E01.03.02.05 – Deep Reinforcement Learning (DRL)

Learning technique using only the input, reward and terminal signals together with the set of possible actions in a similar way as humans do.

E01.03.02.06 – Multiagent Learning and Planning

The objective is to learn action models for multi-agent planning systems from a set of input plan directives. For multi-agent planning, each agent requires an action model as input that takes into account the possible prerequisites and outcomes, as well as interactions with other agents.

E01.03.02.07 – Transfer Learning (TL)

Train high-performance learners with data obtained from different domains. This goes against the assumption of traditional machine learning methodologies where training data and testing data are taken from the same domain, such that the input feature space and data distribution characteristics are the same.

E01.03.02.08 – Deep Learning (DL)

Machine learning models applied to ANN with multiple layers of nonlinear processing units. Deep learning is a subset of machine learning done mainly by CNN or RNN but as well with other ANN like A02.09.01. DAE as autoencoders with more than one hidden layer.

E01.03.02.09 – Adversarial Learning (AL)

It aims at enabling the safe adoption of machine learning techniques in adversarial settings. Tries to improve the system security that may be compromised by exploiting specific vulnerabilities of learning algorithms through a careful manipulation of the input data.

E01.03.02.10 – Other Learning Strategies

E01.03.03 – Computing Infrastructure - HW Implementation

The AI algorithms can be implemented in different hardware and with certain specific settings that condition their performance.

E01.03.03.01 – Real Time Technologies

A real-time system has been described as one which "controls an environment by receiving data, processing them, and returning the results sufficiently quickly to affect the environment at that time". Depending on the deadline time after a triggering event by which a response has to be completed there are different categories.

E01.03.03.01.01 – Hard Real-Time Systems

An overrun in response time leads to potential loss of life and/or big financial damage. Many of these systems are considered to be safety critical.

E01.03.03.01.02 – Soft Real-Time Systems

Deadline overruns are tolerable, but not desired with no catastrophic consequences.

E01.03.03.01.03 – Firm Real-Time Systems

The computation is obsolete if the job is not finished on time.

E01.03.03.01.04 – Weakly Hard Real-Time

Systems where only a percentage of deadlines have to be met.

E01.03.03.02 – Non-Real Time Technologies

No deadlines of time in their computation.

E01.03.03.03 – Cloud Computing

The on-demand availability of computer system resources, especially data storage and computing power, without direct active management by the user. The term is generally used to describe data centres available to many users over the Internet.

E01.03.03.04 – Edge Computing

Systems that process data very close to where they were created, at the edge of the network. The advantage is that it reduces the amount of information to be transmitted over the network, reducing network traffic and related costs.

E01.03.03.05 – Fog Computing

Decentralized computing structure where resources, including the data and applications, get placed in logical locations between the data source and the cloud, also known as 'fogging' and 'fog networking'. Pushes intelligence down to the local area network level of network architecture, processing data in a fog node or IoT gateway.

E01.03.03.06 – Data Warehouses

Central repository of information that can be analysed to make better informed decisions. Data flows to a data warehouse from transactional systems, relational databases and other sources. Decision makers gain access to data through business intelligence (BI) tools and other analytical applications.

E01.03.03.07 – Data Lakes

Holds data in an unstructured way and there is no hierarchy or organization among the individual pieces of data. It holds raw data or only slightly processed or analysed.

E01.03.03.08 – Big Data Technologies

Different kind of technologies supporting the big data concept like those included in the Hadoop Ecosystem, Apache Spark, R, NoSQL Databases, etc.

E01.03.03.09 – Distributed Processing

Distributed data processing is a computer networking method in which multiple computers across different locations share computer processing capability. Distributed data processing considerably lowers the cost of data sharing and networking across an organization by comprising several minicomputers with a significant lower cost.

E01.03.03.10 – System on Chip (SoC)

An integrated circuit (IC) integrating multiple components of a system on a single chip.

E01.03.03.11 – Health and Usage Monitoring Systems (HUMS)

Electronic units equipped with sensors monitoring the ageing-effects on materials. Provide the health status of materials and how their properties change over time.

E01.03.03.12 – Neuromorphic Computing

Emulation of the neural structure of the human brain matching its flexibility and the ability to learn efficiently from unstructured stimuli.

E01.03.03.13 – Other Processing

E01.03.04 – Man to Machine Interaction

Interdisciplinary field covering many aspects of science and technology focused on a human and a machine in conjunction. The final goal is the development of an intuitive, natural and multimodal way of interaction between the operator and machines.

E01.03.04.01 – Planning and Decision Support for Human Machine Teams

Specificities of the organization and structure of teams between humans and machines supported by AI.

E01.03.04.02 – Trustable and Explainable AI

The adoption of AI techniques by humans generally requires an understanding of its functions and reliability in its actions.

E01.03.04.03 – Human Agent Negotiation

Analysis and design of automated agents that proficiently negotiate with humans considering different environments and constraints.

E01.03.04.04 – Human Machine Interface (HMI)

Refers to the exchange of information between users and devices. Typically, information is displayed in graphic format through the graphical user interface or GUI but several developments exist to produce new means of connexion between humans and machines.

E01.03.04.05 – Other Man to Machine Interaction

E01.03.05 – Machine to Machine (M2M)

Describes any technology that enables networked devices to exchange information and perform actions without the assistance of humans. AI facilitates the communication between systems, allowing them to make their own autonomous choices.

E01.03.06 – Distributed AI (DAI)

Subfield of AI dealing with interactions of intelligent agents. DAI attempts to develop intelligent agents that make decisions allowing them to achieve specific goals in a world populated by other intelligent agents with their own specific goals.

E01.03.07 – Embodied Intelligence

Analysis, design and understanding of the behaviour of intelligent agents considering the interaction between the agent and the environment, taking into account the limitations caused by the specific characteristics of the agent.

E01.03.08 – AI Ethics

Domain covering the ethical quality of an AI prediction, the outcomes it produces in the end and the impact on humans of the application of AI to the defence domain.

E01.03.09 – Modelling and Simulation (M&S)

Through the modelling of systems and behaviours, and their execution through simulations, it is possible to provide data for the machine learning (ML) training process. In order to make ML work properly, models with the adequate quality are requested. Additionally, ML provides models of the systems by training with the data produced by those systems.

E01.03.10 – Other Features, Characteristics and Related Concepts

Annex i. Main changes from v1 (2008) to v2 (2021).

New taxonomy items included in v2 (2021)

The following items have been included in the OSRA Defence Technology Taxonomy v2.0. For more details refer to the specific chapters.

- *1D & 2D Materials*
- *Access to Critical Raw Materials outside EU*
- *Adhesive Joints*
- *Aeroacoustics Techniques*
- *Alternative Propulsion Systems*
- *Amphibious Operations Platforms and Systems*
- *Bio-Inspired Systems*
- *BioMEMS / Bio Sensors*
- *Bolted Joints*
- *Brazing/Soldering*
- *C4ISR*
- *Casualty Rate Estimation Services*
- *CBRN and nanotechnology developments*
- *CBRN Applications*
- *Characterization of Energetic Materials*
- *Chromic/Tunable Materials*
- *Cockpit Automation*
- *Cognitive Systems Computing*
- *Combat Management Systems*
- *Co-operative Systems Technologies*
- *Corrosion resistant*
- *Counter Hypervelocity Systems*
- *Counter UxV Systems*
- *Cyber Defence*
- *Digital Twin*
- *Distributed Networks*
- *Electromagnetic Launch*
- *Electromagnetic Railguns*
- *Energetic Materials Production Technique*
- *Energy Efficient Technologies*
- *Energy Storage*
- *Ethics – Rules of Engagement*
- *Explosive Joining*
- *Fission and Fusion*
- *Flow Control Technologies*
- *Green Naval Power Generation and Propulsion*
- *High Power Computing*
- *Human Machine Teaming*
- *Hybrid Propulsion*
- *Hypersonic Missiles*
- *Hypersonic Projectile*
- *Hypersonic Propulsion*
- *IED Detection and Defeat Techniques*
- *Ignition Techniques*
- *Intelligent Technologies for Complex Systems*
- *IR/Visible/UV*
- *Launch and Recovery of Vehicles at Sea*
- *Maintenance and Repair Facilities and Organizations*
- *Manned and Unmanned Teaming*
- *Medical Research and MedTech*
- *Metamaterials and Metasurfaces*
- *Mission Type - Consequence Management*
- *Multicore Systems*
- *Multi-Disciplinary Design and Analysis Framework*
- *Multidisciplinary Designs*
- *Multispectral/Hyperspectral Imaging (VIS/IR/UV)*
- *Nanosensors*
- *Neuroscience*
- *Non-Conventional Fuels Novel Energetic Materials*
- *On Board High Energy Storage and Distribution System*
- *Onboard Aircraft Take-Off and Landing Systems*
- *Optical propagation in Air and Water*
- *Painting*

- *Protection Systems – Architecture*
- *Quantum Computing Technologies*
- *Quantum Optics*
- *RF Submilimetric*
- *Scramjet*
- *Space Debris Management and Deorbiting Systems*
- *Space Traffic Management*
- *Space-Based Weapons*
- *Supersonic Propulsion*
- *Sustainable and Synthetic Fuels*
- *Synthetic Biology Technologies*
- *Telemedicine*
- *Textiles and Woven Materials*
- *Thermal barrier*
- *Thrust Vectoring*
- *Unmanned Air Vehicles*
- *Unmanned Land Vehicles*
- *Unmanned Maritime Vehicles*
- *Variable Cycle Engine*
- *Weapons Systems Security*
- *Wear Resistant Surface Protection Technologies*
- *Welding*

Taxonomy items in v1 (2008) with relevant changes

The following items, already included in the OSRA Defence Technology Taxonomy v1.0 (2008), have been notably updated in the v2.0 (2021). For more details refer to the specific chapters.

- *Acoustic Power Sources & Devices*
- *Acoustic Propagation in Air & Water*
- *Advanced Propulsors and Propellers*
- *Air Traffic Management Systems*
- *Architectures*
- *Communications & CIS Security Systems*
- *Communications Satellites*
- *Conventional Fuels*
- *Corrosion and Wear Control Technology*
- *COTS and OSS Assessment*
- *Device Packaging*
- *Display Materials & Devices*
- *Dynamic Positioning*
- *Electric Machines and Actuators*
- *Electrical/Electronic Designs*
- *Electrochemical Energy Conversion Fuel Cells*
- *Electrochemical Energy Storage - Batteries*
- *Electromagnetic Compatibility*
- *Electromagnetic Propagation in Air & Water*
- *Encryption / Crypto Technologies*
- *Equipped Personnel*
- *Explosives*
- *Explosives Detection Techniques*
- *Fighting Land Vehicles*
- *Fighting Sea Surface Platforms*
- *Gas Turbines*
- *Hazard Assessment*
- *Health and Well-being*
- *High-Altitude Platform Systems*
- *III-V Compounds*
- *Image/Pattern Processing Technology*
- *Information & Data Fusion Technology*
- *IR/Visible/UV*
- *IR/Visible/UV Detector Materials & Devices ISTAR (= Intelligence, Surveillance, Target Acquisition & Reconnaissance)*
- *Laser Signatures*
- *Lasers -all Types*
- *Lighter-Than-Air Platforms*
- *Logistic and Support Sea Surface Platforms*
- *Logistic, Command and Surveillance Land Vehicles*
- *Low Observability and Stealth Designs*
- *Medical sciences and capabilities*
- *Military Doctrine Analysis*
- *Military Intelligence and Industry Intelligence*
- *Mines - Sea*
- *Molecular Biology* Technologies
- *Navigation and Other Satellites*
- *Non-Laser Devices*
- *Non-Proliferation*
- *Optical Designs*
- *Optical Signal Processing Technology*
- *Optical Wireless Communications - IR/Visible/UV*
- *Optimisation, Planning & Decision Support Systems*
- *Other Electrical Power Systems & Devices*
- *Other Platform Protection Measures*
- *Physical Protection systems - Threat*
- *Plasma Techniques*
- *Platform and System Concept Studies*
- *Pyrotechnics*
- *R&T Management*
- *Reciprocating and Rotary IC Engines*
- *Reconnaissance/observation and Navigation Satellites*
- *RF Power Sources & Devices*
- *Robotics and Automated/Autonomous systems in Operational Systems*
- *Robotics in Medicine*

- *Scenario Generation*
- *Software Engineering*
- *Space Launchers*
- *Tactical/Crew Training systems*
- *Torpedoes*
- *Transmissions and Powertrains*
- *Transparent Materials*
- *Undersea Platforms*
- *Unmanned Vehicles*
- *Wargaming and* Combat Simulation

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