ANNEX A TO
CRR16 MCR
DATED 12APR 16

LONG TERM ASPECTS

The **Long Term Aspects (LTA)** of requirements provides an outlook to the timeframe of 15 to 30 years, delineating prospective capability requirements. The primary role of the LTAs is to inform NATO and national capability development efforts by depicting the potential direction of travel and may increase the Alliance's ability to meet challenging requirements. Practically, those LTAs of requirements will be used to inform both national and NATO Science &Technology communities about future capability gaps based on the perceived Future Security Environment and foreseen technology developments, before long term decision making is made.

The LTAs were identified in concert with requirements listed in main MCR document; and aligned with CH Tier 2 levels for increased granularity. For sake of facilitating future coordination, the NATO Unclassified LTAs are annotated in this annex, per NATO Directive on the Security of Information, AC/35-D/2002-REV4, par 5.

Long Term Aspects were identified and developed in line with four drivers as defined in Reference:

a. Driver 1 - future gap with no mid-term solution.

b. Driver 2 - new strategic environment and new concepts.

c. Driver 3 - threat evolution countering extant capabilities.

d. Driver 4 - technological opportunity to enhance capabilities.

Given the decrease in certainty the further into the future that capabilities are envisaged, long-term aspects of requirements are, by necessity, qualitative in nature and have consequently been described in textual format, detailing their rationale, effectiveness, potential areas of research and the linkages to FFAO military implications.

Many LTA’s have utility across the capability areas but are owned by a single service domain. Inherently joint capability areas such as SOF and amphibious forces tend to own few LTA’s but are stakeholders in many. LTA development must therefore think beyond its own lead domain and ensure wide stakeholder engagement is maintained for both SOF & amphibious. This is particularly crucial at the requirement setting stage.

PREPARE (R)

PREPARE: FORCE PREPARATION (R.1)

1. **Distributed Training and Exercises.** Capable of advanced distributed learning, training and exercises in an interoperable environment that develops adaptability and continuous learning.

a. **Rationale.** To facilitate training in all areas, reduce cost and environmental impact and improve realism, training scenarios should continue to be enhanced by simulation and modelling (Driver 1). The future operating environment will continue to be complex with opponents that are fully cognisant of Alliance operating procedures and possible areas of weakness. Advances in technology will allow for more fidelity in the capturing of the nuances of operations within the training environment. The incorporation of tools that will learn and depict adaptive systems will broaden comprehensive education and training. Increased interoperability offers the potential of greater training realism in a networked environment (Driver 2). Distributed training delivers significant cost savings by reducing resource expenditure and lengthening system life expectancy. It has the potential to support training that is difficult or impossible today such as concepts, force structures and technologies that are not yet available. While this does not apply universally to all training activities, the result is a more flexible training environment offering more choices than the current environment (Driver 4). Fidelity needs to be maintained.

b. **Effectiveness.** The applications must consider friendly, enemy and neutral forces as well as indigenous forces/population and in so doing capture cultural and human/societal behavioural issues that will increase the fidelity of training environments. They will need to incorporate artificial intelligence systems that allow for adaptive interaction within the training environment so as to provide for continuous learning. It will require continued study and development of educational methods and pedagogy that will support training. They should operate in an environment with multi-secure levels and provide an effective implementation of a comprehensive approach to operations. They must provide coherent training across all echelons, NGO/IOs, civilian organisations and support for real-time mission planning and rehearsal. They must allow operators and joint commanders to “war game” operational scenarios before deploying forces and/or executing missions (Mission Rehearsal), and allow a critical post-mission review for training and assessment of operational capabilities giving leaders the opportunity to further develop adaptive leadership skills. Different simulation systems should be able to play in parallel, while exchanging data from distant locations, using agreed standards for data models and proper network protocols (for example virtual simulators for Air, Land and/or Sea platforms should communicate together and with constructive simulation for HQ training, while trainees are physically in their own country).

c. **Potential Areas of Research.** Self-establishing ad hoc/mesh networks, advanced and interoperable training standards, integration of training capabilities into C4ISR and weapon system, interactive multi-echelon/multi-user simulation and training, multi-level/multi-domain security, advanced training equipment (down to individual level), theoretical models that support development of learning programmes, artificial intelligence learning from simulated battles.

d. **Linkage to FFAO Military Implications.** Prepare – Training and Exercises. Leader Development, Cooperation with Security Partners.

PREPARE: CAPABILITY DEVELOPMENT (R.2)

2. **Enhanced Human Performance.** Capable of optimising the performance and endurance of personnel during operations.

a. **Rationale.** Future technology will allow the human body to be fused with technology to enhance physical and cognitive performance. Training and technological solutions may be developed to mitigate the human limitations on operations resulting from lack of sleep, high stress and high workloads. Many of these technologies will be available to both military and civilian users, including non-state actors and may present a variety of challenges to NATO forces. While some of these innovations will undoubtedly cause significant ethical debate, NATO should not discount the possibility that these technologies will manifest themselves in the operating environment and forces will therefore have to train for them. The decreasing pool from which to recruit personnel will demand different human resource management (Driver 1 and 4). A wide range of conditions may adversely affect human performance on deployed operations including sleep deprivation/mental fatigue, disease, injuries, shortages of food and water, heat and cold stress, muscle fatigue and data overload. Personnel with increased physical performance and endurance will lead to a more effective force which can sustain a higher operational tempo (Drivers 1 and 2). Stress and disease can significantly reduce the effectiveness of personnel deployed on operations. An increasing understanding of the mechanisms that support these conditions will allow the development of methodologies to reduce these underlying conditions (Driver 4). Increased human performance in terms of resistance to disease and stress (and the contributing factors to stress such as fatigue and low calorie intake, etc.) will reduce the impact of battlefield stress and endemic diseases. This will increase the effectiveness of deployed personnel and also reduce the workload of medical staff (Driver 4).

b. **Effectiveness.** The capability needs to significantly improve the performance and endurance of deployed personnel on operations in terms of increased disease resistance, enhanced human performance (the ability to lift more, move more for longer periods, etc.), mental acuity and increased stress resistance / reduction. Lines of development could include: Medical Prevention, Protection and Treatment, and Health Promotion; Physical Optimisation and Psychological Readiness, and Resilience.

c. **Potential Areas of Research.** Exo-skeletons (and measures to reduce the threatening appearance of such systems), improved vision systems (contact/sun lenses), biotechnology to prevent disease and fatigue, concentrated nutritional time release additives, preventative medicine, psychological research and training, performance enhancing measures, ergonomics, immunisation and prophylaxis biology/microbiology/molecular biology, advanced trauma care, advanced diagnostic and treatment techniques, biomedical computer modelling, macro content optimisation for performance enhancement, neuro-protective nutrients, physiological interactions of nutrition and dietary supplements and anthropometric research & projections.

d. **Linkage to FFAO Military Implications.** Prepare – Human factors.

3. **Influencing the Physical Environment.** Capable of influencing the physical environment to produce conditions that are advantageous to Alliance operations.

a. **Rationale.** The physical environment is a critical factor in all military operations. The ability to influence factors such as the weather may arise in the time horizons of this study. This capability could seek to improve conditions for Alliance forces or degrade conditions for enemy forces. It could also be used to support humanitarian and disaster relief (Driver 4). Open source material indicates that potential adversaries are conducting research and experiments in this area.

b. **Effectiveness.** This LTA is concerned with generating short term effects on the local environment not global climate change. This capability will have to be supported by exact measurements of environmental factors and the development of accurate forecasting models. Capabilities in this area should not result in widespread, long term effects on the environment which might contravene the UN Environment Modification Convention. Trans-border effects must also be considered.

c. **Potential Areas of Research.** Cloud seeding, polymer gels, lasers, ionised particles, solar radiation management and carbon dioxide removal.

d. **Linkages to FFAO Military Implications.** Engage – Joint Influence, Prepare – Comprehensive Approach to Military Operations.

PROJECT (D)

PROJECT: DEPLOYMENT / REDEPLOYMENT (D.2)

4. **Deployment and Mobility of Forces.** Capable of rapidly deploying military and civilian capabilities at strategic distances into a theatre of operations, and then moving them in theatre to enable swift crisis resolution.

a. **Rationale.** The ability to project and move capabilities from a strategic distance are fundamental to creating a deployable force and preventing the escalation of crises. While current capabilities exist to perform both strategic and tactical movements, they are expensive and not available in quantities required. Currently, the majority of capabilities for operations are deployed by sea; for strategic distances this requires significant time. Lightweight combat forces can be delivered into theatre quickly by air, but the force is not fully effective until their equipment arrives later by conventional sealift. The limited amount of strategic lift currently within the Alliance restricts the size of combat force and associated support that can be rapidly deployed (Driver 1). Faster delivery of an effective force into theatre may enable a swifter resolution of conflicts or prevent civilian casualties (Driver 4). Quicker and safer tactical redeployment within a theatre may mitigate some of the future threats as well as take the fight to the enemy, thus preventing escalation of a crisis or alleviating it earlier. Any savings from a more efficient delivery method can be reinvested in modern engagement capabilities and improving the quality of the lift to reduce material damaged in transit (Driver 4).

b. **Effectiveness.** The capability must reduce the time required to deploy an effective force at strategic distances from Alliance territory to all possible terrain environments. Forces range from heavy to light, including special operations and specialized forces in support of coalition operations (e.g. communications squadron, helicopter squadron, etc.). Automated systems that link national and NATO systems must support the Reception, Staging, and Onward Movement (RSOM) of forces. Once in theatre, rapid tactical and operational redeployment and forward movement must be achieved to ensure NATO forces retain the initiative within a crisis. Focus should be maintained on the multinational aspects of deployment and movement of forces especially in the areas of improving doctrine and identifying movement 'hubs and spokes' around the world. Alternate approaches must be faster, cheaper or provide higher quality movements capabilities than currently exist. Alternate approaches should seek to reduce the amount of capability that needs to be physically forward deployed. A reduction in the logistics footprint will improve both the cost and speed of deployment and tactical movement. Standing MOU's for transit rights may support this requirement. The ability to enter an Area of Responsibility (AOR) from all domains must be retained to ensure operational flexibility. The interchangeability of vehicles and other parts or the ability to locally manufacture them in theatre will improve deployability. This requirement includes the ability to rapidly establish bases across the AOR, including remote locations, and to rapidly repair airfields and ports. This capability must be effective against the growing range of A2AD.

c. **Potential Areas of Research.** High Speed Ships, Wing In Ground (WIG) effect technology, larger cheaper air transport methods (airships), pre-positioned

stocks[88], Decision Support Tools / modelling, Deployable Port of Debarkation (POD) / Improvement of POD, Asset / Force Tracking, Multi–Role Assets, Air-to-Air Refuelling, standardization / common fit of equipment to lift assets. Short(er) haul aircraft, convertible rotary-to-fixed wing aircraft, austere environment aircraft, total asset visibility and global positioning systems, 3D printing/additive manufacturing, robotics, material science/nanotechnology, small sensors and power systems.

d. **Linkages to FFAO Military Implications.** Project – Deployment and Redeployment, Reception and Staging, Mounting, Basing.

[88] Studies could include methodologies for most efficiently determining the positioning of stocks (e.g. afloat) in connection with NATO Global Hub and NATO Joint Sea-based Logistics Support Concepts. Innovative of methods to move prepositioned stocks (afloat) (e.g. autonomous ships, containers that are submerged on the continental shelf until required and then autonomously position themselves off the coast of the effected nation).

ENGAGE (E)

ENGAGE: JOINT MANOEUVRE (E.1)

5. **Area Access Control.** Capable of controlling access to designated unattended areas and borders, and controlling access to appropriate personnel and equipment.

a. **Rationale.** Current unattended area denial methods are indiscriminate and affect animal, human, friend, foe, civilian, and military alike. Most are effective for an indefinite period and remain a hazard long after their original purpose has become invalid. After time, locations and sizes of areas are forgotten or were poorly documented during periods of intense conflict. Even if locations are precisely known, removal is difficult even for the originator. Possible collateral damage will influence opinions of the indigenous population and will challenge any attempt to achieve joint influence. (Driver 1) Future operations will likely require the control of large areas with limited manpower to prevent individuals from entering controlled areas. (Driver 2) Potential adversaries will continue to use remote areas for training and re-supply and will use difficult terrain and environments to their advantage in order to prevent infiltration of areas under their control. (Driver 3) Advances in technology, especially in wide area detection and surveillance systems, will provide supporting components to the systems required to provide this capability. (Driver 4)

b. **Effectiveness.** This capability provides a means of controlling access to an area or border and can be employed in remote areas where manpower is limited. This capability must deny area access yet discriminate among intruders whether animal, human, friend or foe to prevent unintended injury to friendly/neutral forces and allow safe passage when required. Capability may use lethal or non-lethal means, but should be controllable and not produce long lasting environmental contamination. It must be capable of monitoring across all environments: air, sea, and land, including subterranean. NATO forces will also require the ability to create a permissive operational environment. This includes the ability to enter and operate in an area despite anti-access and areal denial methods.

c. **Potential Areas of Research.** Non-lethal mine fields, electronic fence, radiation, directed acoustic, remotely controlled mine fields, pattern/target recognition, biometrics, image analysis, seismic sensor nets, fusion of intelligence capabilities, robotics, and artificial intelligence (AI). For example, AI could provide a capability that is able to predict next hostile intrusion based on environmental data. In this case, AI could put the human “on the loop” rather than “in loop” in that the AI would determine what threats should be raised for decision on actions to be taken by humans. ‘Big data’ is a technique wherein some deeper meaning can be found by a meta-analysis of large volumes of data. It is not AI. This and other techniques would be available to AI to make assessments, and most probably in the future make some level of decisions, about what is happening in the environment.

d. **Linkages to FFAO Military Implications.** Protect – Counter Area Denial.

6. **Support Insertion and Extraction of SOF.** Capable of rapidly projecting Special Operations Forces to uncertain or contested environments with low visibility and small footprints.

a. **Rationale.** Forces deployed into theatre are susceptible to detection from multiple means. To maintain the element of surprise and minimise the force ratio to ensure a successful operation, it is important to minimise the announcement of the arrival of forces into theatre (also the ability to extract force without the enemy knowing can be beneficial e.g. in reconnaissance missions). Forces covertly inserted into theatre may be more effective (i.e. force multiplier) if complete surprise can be achieved. The emergence of asymmetric or hybrid warfare as a method to avoid the strengths of the Alliance has led to additional employment of Special Operations Forces. (Driver 1) Increasing use of small teams of Special Forces to conduct operations or provide training and support to indigenous forces will be seen in the coming decades. The ability to covertly bring these forces to bear will be a higher priority. The increasing urbanisation[89] of the world's population will require the introduction of forces into urban environments. (Driver 2) Incorporation of advanced technologies to this capability would significantly reduce the risk during deployment and extraction. (Driver 4)

b. **Effectiveness.** The capability to safely and quickly insert and extract forces (company size and larger, not only Special Forces) into the theatre of operations with a very low probability of detection from visual, aural, or any other electro-magnetic spectrum detection means (e.g. Infrared, Thermal Imaging, Radar, etc.) will significantly improve the likely hood of mission success. Delivery of supplies should be self-verified and, if required, should be neutralisable (i.e. self-destruct capability or made not unusable).

c. **Potential Areas of Research.** Electro-magnetic spectrum absorption/diffraction material, active stealth, signature reduction, low noise engines, augmented reality, precision air drop (PAD), chameleon camouflage, cloaking systems, sound damping systems, Artificial Intelligence (AI), novel guidance and power systems, lightweight materials, UAVs, autonomous delivery systems, holography, augmented visual systems, and nanotechnology to include employment for precision delivery (e.g. controllable porosity, controllable line links for increased parachute control).

d. **Linkages to FFAO Military Implications.** Engage – Joint Manoeuvre: Enhanced Manoeuvre, Rapid response.

7. **Non-Lethal Weapons[90] (NLW)/Capabilities.** Capable of incapacitating or repelling personnel with a low probability of fatality or permanent injury, and disabling equipment with minimal undesired damage or impact on the environment.

a. **Rationale.** Though identified as a critical capability, the current lack of concepts, doctrine or training on the employment of NLC continues to hamper the development of tactics, techniques and procedures, and causes restrictions in the use of currently available means (Driver 1). Across the full spectrum of missions, NATO will be confronted frequently with circumstances where it would be inappropriate to use lethal force. A layered response will be required to reduce

[89] SFA, FFAO, NATO Conceptual Study of Urbanisation.
[90] The NATO policy on NLWs [NATO Non-Lethal Weapon Policy, 27 Sept. 1999] defines NLW as follows: "Non-lethal weapons are weapons which are explicitly designed and developed to incapacitate or repel personnel, with a low probability of fatality or permanent injury; disable equipment, with minimal undesired damage or impact on the environment".

collateral damage, improve mission effectiveness and achieve joint influence through winning 'hearts and minds.' NLC would contribute to public/political expectations to provide situational de-escalation, increase flexibility and improve force protection in a wide spectrum of situations such as crowd control or critical infrastructure protection. Given the increasing likelihood of operations in urban environments with large, possibly non-belligerent populations, this capability becomes even more important (Driver 2).

b. **Effectiveness.** NLC effects must be scalable, discriminating, and controllable. They should be effective at various ranges (short to long) to ensure an efficient layered response. They should be highly reliable and precise effects. NLC will be complementary and be used in conjunction with lethal weapons to enhance the latter's effectiveness and efficiency across the full spectrum of missions. NLC should enhance the capability of NATO forces to achieve its objectives where the use of lethal force may not be necessary or desired, or could discourage, delay, prevent or respond to hostile activities.

c. **Potential Areas of Research.** Prevent or respond to hostile activities.

d. **Potential Areas of Research.** Bio-technology, drug development, bio-medical engineering, directed energy (electromagnetic or acoustic), material technology (stickies, slipperies, etc.), robotics, anaesthetics, behaviour monitoring, pattern recognition, long-range effects DNA tagging, and innovative delivery mechanisms.

e. **Linkages to FFAO Military Implications.** Engage – Joint Influence

ENGAGE: JOINT FIRES (E.2)

8. **Assured Precision Strike.** Capable of employing joint precision strikes with assurance and minimum risk of collateral damage.

a. **Rationale.** Threat systems in the future battle-space will be increasingly mobile, hard to find, and with powerful lethal efficiency. Failure to rapidly detect, identify, assess, track, and accurately attack timely critical targets, including weapons of mass destruction, will heighten the risk to NATO's military forces. (Driver 1 and 2) Unintended effects, such as collateral damage, civilian casualties and fratricide, reduce the ability of the Alliance to achieve its objectives and could seriously damage its cohesion and international standing. The increasing complexity of the battle-space foreseen in the future will heighten this concern. Growing urbanisation will increase the likelihood of urban operations driving a need for greater precision. (Driver 2) Possible adversaries are aware of Alliance restraint and are most likely to use numerous tactics to disguise targets and draw forces into committing targeting and strike errors in order to make use of these actions in the media to condemn the Alliance and strengthen popular support. Improved methods of camouflage, concealment and deception would be employed (Driver 3) Advances in supporting technologies within the overall 'kill chain' will allow significant improvements in assurance and accuracy. (Driver 4)

b. **Effectiveness.** The Alliance will require the capability to mount selective lethal or non-lethal precision strikes from the full range of delivery platforms (land, sea and air) with assurance of target discrimination to limit unintended effects in

order to deny, degrade and destroy adversary forces, facilities, and infrastructure throughout the operational area. The capability must be persistent and responsive, minimising the time between decision to strike and effects on target. It should have an ability to abort as near as possible to impact and be capable of being rendered inert, while limiting collateral damage and avoiding critical technology loss. Once correctly identified, mobile and static targets must be quickly, adequately and accurately attacked either from land, sea, air, or space. There will be a greater requirement to strike targets accurately in urban environments. Sensors and engagement systems must have significantly improved resolution, alternate navigation capability, portability and accuracy driven by improvements in underlying technologies. This capability should be resilient, have scalable weapon effects and should allow precise and timely BDA assessment. This capability must be available in electronic, navigation, communications and cyber degraded environments. It should be capable of engaging autonomous systems. It must be effective in all environments.

c. **Potential Areas of Research.** Command and information system design, decision-support tools, airspace management, image/pattern processing and data fusion techniques, advanced sensors, precision guided weapons, warhead design, scalable weapons, alternative precision navigation system, EMP, non-lethal systems, directed energy, MEMs, nanotechnology and materials, artificial intelligence, and robotics hypersonic.

d. **Linkages to FFAO Military Implications.** Engage – Joint Fires

9. **Land Engagement Capability.** Capable of engaging in land high mobility, high-tempo manoeuvre dominance operations with increased effectiveness and survivability (see LTA 33).

a. **Rationale.** Defence of Alliance territory will always necessitate the ability to seize and hold terrain using Land Engagement assets. In addition, the Alliance will likely continue to conduct expeditionary operations either at the periphery of the area of operations (AOR) or beyond AOR (BAOR). NATO operations often require rapid tactical deployment over long distances to be successful. Size, weight, range and sustainability of current armoured systems are limiting factors to rapid deployment. Once deployed, future high-tempo NATO operations require long range and agile assets against a wide variety of symmetrical and asymmetrical targets. Legacy systems lack the speed, agility and range required for rapid force projection and battlespace manoeuvrability. The growing likelihood of urban operations, given the continuing urbanisation of the world's population, will require land systems that can operate in cities. (Driver 1) Future land engagement systems must have the survivability, lethality, and range to successfully perform future NATO missions. Land engagement capability needs to evolve and advance to remain viable with flexible fighting systems against future NATO threats. (Driver 2) Possible adversaries continue to develop counter measures against land systems that have the potential to negate the Alliance ability to conduct operations in some areas. (Driver 3)

b. **Effectiveness.** Forces must be able to maintain access to any area and manoeuvre across all terrains including littoral zones to support amphibious operations, within urban environments and the arctic. The focus should be on "effectors" and their integration with information capabilities in vehicles to be used

for “land engagement”. The Human Dimension of design, focussing on accommodation and design approach, must also be emphasised in order to increase potential capabilities[91]. The future land engagement capability needs to be lighter, faster, have higher availability/reduced maintenance, have greater operational range and greater engagement effectiveness than legacy systems, and yet be no less survivable. This capability must be available in electronic, navigation, communications and cyber degraded environments. It should be capable of engaging autonomous systems. It should be able to operate in distributed, non-contiguous operations with a minimum number of personnel and logistics support. Mobility and Survivability both personnel and equipment should be highly emphasised.

c. **Potential Areas of Research.** Directed energy weapons, intelligent munitions technology, land surface effects, IR and electro-optical sight, electro thermal/electromagnetic gun systems, non-lethal scalable effectors, autonomous/semi-autonomous effects enablers, biomechanical augmentation, integration modelling, health and usage monitoring, sensor fusion, digital architecture, bandwidth compression, smart materials, renewable energy sources, high-field magnets, modular/multi-functional assets, robotics, automation and unmanned systems.

d. **Linkages to FFAO Military Implications.** Protect – Counter Area Denial.

[91] For more information on the five design parameters Effects, Survivability, Mobility, Human Dimension and Information and the most promising emerging technologies in each area, see NATO Army Armaments Group Land Capability Group Land Engagement Report on Future Technologies for Land Engagement (AC/225(LE)D(2012)0001(PFP) dated 22 October 2012.

SUSTAIN (S)

SUSTAIN: MILITARY ENGINEERING SUPPORT TO SUSTAINMENT (S.1)

10. **Sustainable Systems and Green Defence.** Capable of efficient use and management of power, energy and waste.

a. **Rationale.** The power, energy and environmental footprint required to support and sustain a deployed force places an extremely large environmental and logistic burden on operations. Distributed operations where units are required to operate across non-contiguous areas will continue to stress logistics sustainment (Driver 1). Traditional methods of transporting fuel and other resources throughout the AOR place considerable forces at risk from IED and other attacks (Driver 2). Reduction in the logistic footprint will enhance the operational resiliency and further reduce the environmental and energy footprint. Future technological advances, including additive manufacturing (3-D printing), use of alternative energy sources, unmanned delivery and evacuation systems and robotics, have the potential to revolutionise the sustainment of Allied forces in maintenance, repair, replenishment, and health services. If the 'logistics tail' is reduced through the exploitation of emerging and novel technologies, it enables a more effective and resilient combat force capable of enhancing sustainability (Driver 4).

b. **Effectiveness.** This capability should increase the sustainability / operational resilience of the deployed joint force and reduce its impact on the environment, through the efficient use and management of power, energy and waste on operations; the capability must increase the effectiveness of the force in two main areas. Firstly, it should significantly enhance the sustainability and operational resilience of the units in theatre, thus leading to savings in the logistics capabilities and materiel required to support the force. Secondly, it should significantly reduce the burden of the force on the environment and minimise any environmental remediation activities required following the conclusion of the operation. This capability should minimise logistics footprints, ensure uninterrupted logistic support, and where necessary create backup sustainment systems. The capability must encompass more efficient power and energy consumption on deployed operations, a more effective energy management system and reduction/exploitation/conversion of waste on operations. This capability is coupled to the development of more efficient individual soldier equipment. Focus should be on reducing the deployed environmental, energy and logistic footprint and improving the acquisition and equipment life-cycle processes. The capability should include the development and use of multi-sourced energy options. The success of this is dependent on the right mixture of all available energy options, especially the developments of different power sources.

c. **Potential Areas of Research.** Novel renewable energy sources, smart energy management systems, advanced water generation systems, fuel/energy efficiency, micro-grids, waste to energy systems, alternative fuel sources (solar powered transportation assets, solar energy used to run the camps), geothermal power, reduction in and/or reusable material packaging, individual soldier power systems, Systems Based Architecture, cultural and behavioural change in the military environment. Multi-sourced energy engine solutions for maritime assets (solar panels, sky sails / kites, bio-fuel, hydrogen or Maritime Diesel Oil (MDO) and Maritime Gas Oil (MGO)).

d. **Linkage to FFAO Military Implications**. Protect – Environmental and Hazard Protection, Sustain – Innovative Supply of Materiel and Services and Minimised Logistic Footprint.

11. **Increasing Battle-Space Mobility.** Capable of improving the freedom of movement (FOM) of own personnel within a theatre of operations.

a. **Rationale.** Currently, area denial technologies such as IEDs (including those delivered by the air) are challenging the mobility of the force (Driver 1). Future Allied expeditionary and urban operations will likely see increased difficulty entering and operating within a theatre of operations due to the development and proliferation of new and emerging area denial methods and the increasing likelihood of operating in complex urban terrain (Driver 2 and 3). The move toward more distributed, non-contiguous operations will continue, thus stressing the ability of units to move between outlying positions (Driver 2). This will increase the demand for military engineering capability as a key enabler (Sustain and Project) to fully support operational agility for all kind of NATO led operations (Driver 3).

b. **Effectiveness.** NATO forces will require the capability to conduct a wide range of military engineering tasks to gain and maintain freedom of movement and support force protection within the theatre from the operational to tactical level. The capability must significantly enhance the ability to enter and operate within all possible theatres of operations, gain and maintain freedom of movement and to support sustainment of all kinds of NATO operations either within Alliance territory or supporting expeditionary operations within both austere and non-austere environment. It has to enable forces to project physical presence into an area of operations and to rapidly project advance force and force liaison capabilities. It also must support military operations that are in large urban areas with complex terrain. Forces must be able to enter and operate in an area of operations despite the adversary's use of A2AD methods. Future forces also require the ability to detect, locate, exploit, and neutralise or destroy the effects of landmines, naval mines, anti-ship and anti-aircraft weapons, improvised explosive devices included conventional and improvised CBRN devices, hostile UAS, electronic warfare, and other area denial systems.

c. **Potential Areas of Research.** New self-sustainable, modular, light weight, flexible and scalable technologies / systems for mobility support e.g. enhanced route clearance sensors (such as Ground Penetrating Radar), logistic bridges and assault bridging adaptable to land and air platforms (to adopt the required Military Load Classification (MLC) for sustainment but also for Project / Engage), remote controlled ground penetrating detection and reconnaissance systems for all kind of explosives and/or hazardous materials that allow operators to search from longer distances, unmanned systems, material science/nanotechnology, RADAR/LIDAR, robotics.

d. **Linkage to FFAO Military Implications.** Sustain – Military Engineering, Protect – Counter Area Denial.

SUSTAIN: SUPPLY OF MATERIAL AND SERVICES (S.3)

12. **Increased Self-Sustainment.** Capable of increasing the self-sustainment of units deployed in the chosen theatre by an efficient exploitation of resources within the AOR.

a. **Rationale.** The quantity of equipment and materiel required to support a deployed combat force places an extremely large burden on strategic lift (Land, Air and Sea). Reduction in the requirement to deploy the forces and associated 'logistics tail' to and in theatre will place less strain on already overburdened strategic lift assets in the initial deployment and reduce the amount of re-supply required in theatre (Driver 1). If the 'logistics tail' is reduced through the exploitation of emerging and novel technologies, it enables a more effective combat force to be deployed more quickly (Driver 4).

b. **Effectiveness.** The capability must significantly enhance the self-sustainment of units in theatre through the better use of: modular and flexible logistic structures, with common stock systems and procedures, available resources, thus reducing the equipment deployed, the combat service support requirements and the sustainment requirements in theatre. The capability must encompass enhanced production of consumables and reduction/exploitation/conversion of waste. This capability is coupled to the development of more efficient personnel and equipment. Focus should be on reducing the deployed footprint and improving the acquisition and equipment life-cycle support processes. In addition, forces should be trained to conduct operations from forward areas with limited logistic support, and reduced reliance on local infrastructure.

c. **Potential Areas of Research.** Novel renewable energy sources, water from the air, water from exhaust, Health and Usage Monitoring System (HUMS), in transit visibility (ITV), asset tracking, Logs C4I, efficient weapon systems, platform efficiency, fuel / energy efficiency, reliability and maintainability, novel expedient surfacing, food and water from waste, lightweight portable UV water filtration, energy from waste, greater personnel efficiency through improving skills, reduced equipment maintenance and improved reliability, asset visibility including sense and respond Logistics, on-site manufacturing and power generation, in-theatre production and fabrication of equipment, reach back support for conducting in-theatre repairs (i.e. to manufacturer / supplier) including additive manufacturing (3-D printing), use of alternative energy sources, unmanned delivery and evacuation systems and robotics.

d. **Linkage to FFAO Military Implications.** Sustain – Innovative Supply of Materiel and Service and Minimised Logistic Footprint, Future Force Sustainment.

SUSTAIN: IN THEATRE MOVEMENT & TRANSPORTATION (S.4)

13. **Autonomous Delivery Systems.** Capable of employing unmanned systems to conduct independent cargo transportation and delivery over extensive distances.

a. **Rationale.** Supporting distributed Forces requires the movement of large amounts of materiel over long distances often in austere, high threat environments. These logistics operations have been vulnerable to enemy interdiction, often with numerous casualties (Driver 1). There is a continuing requirement to support distributed, non-contiguous operations (Driver 2). Unmanned transportation systems would limit the requirement for personnel and support facilities especially in early stages of operations and reduce risk to force in an asymmetric warfare environment (Driver 3). These systems are likely to achieve cost benefits over contracted support (Driver 4).

b. **Effectiveness.** The capability should significantly enhance the movement and transportation capability, sustainability and force protection of the forces. Reduction of required human resources for force protection and in support functions may result in allocation of the resources to critical combat functions. This capability should include transportation assets across all domains.

c. **Potential Areas of Research.** Unmanned Aerial Delivery Systems (autonomous UAVs, airships, unmanned air-to-air refuel assets, etc.), unmanned transportation helicopters, unmanned trucks (cargo, fuel and ammo), artificial intelligence, mapping, networks, directed energy, radar/LIDAR, 3D modelling.

d. **Linkages to FFAO Military Implications**. Protect – Unmanned Systems, Sustain – Innovative Supply of Materiel and Services and Minimised Logistic Footprint.

SUSTAIN: MEDICAL SUPPORT (S.4)

14. **Battlefield Medical Attention.** Capable of providing remote/immediate medical assessment and treatment to ensure that battlefield casualties receive appropriate attention within timelines.

a. **Rationale.** The early and accurate diagnosis of the need for medical attention and the fastest possible treatment is the most effective way to deal with casualties; this can currently only be achieved by placing qualified practitioners in close proximity to all forces (Driver 1). If large numbers of casualties are taken, either during a high intensity battle, from weapons of mass destruction or due to natural disasters, there is currently little or no capacity due to limited numbers of qualified medical staffs, to ensure that medical timelines or levels of clinical excellence can be guaranteed (Driver 1). Failure to treat casualties in a timely manner would have a negative effect on forces' morale, popular support and Alliance cohesion (Driver 2). Advanced technologies, especially in the area of autonomous and robotic systems, will improve critical components of the systems supporting this requirement and significantly improve the overall capability. Reach-back through innovative methods using robotics, information systems, cameras, and other devices may make delivering healthcare viable even when health care providers are not present. (Driver 4).

b. **Effectiveness.** The capability needs to be able to quickly identify the requirement for medical attention and deliver an accurate diagnosis. The capability should provide prompt remedial treatment to either cure or stabilise the patient and prepare them for evacuation (if necessary). Focus should be on immediate care to the second level of care at the medical aid station (the first location capable of performing emergency surgery). The capability will enable the effective management, movement and treatment of patients resulting from events with large scale casualties to maximise the chance of successful remedial treatment System must allow the Alliance and its participating nations to increase effectiveness and efficiency in the medical care allowing for tracking of patients, learning cycles within treatment and C2. Capabilities, systems and processes will need to include integrated assessment of the health situation, support to effective human performance, the delivery of accurate diagnosis, the provision for remedial treatment, tracking the availability of supply and medical evacuation assets, and the sharing of information with all medical stakeholders in the field. Physical, mental

health and environmental considerations need to be considered within the capability.

c. **Potential Areas of Research.** Artificial intelligence, robotics, medical unmanned systems, optics, secure and dependable communications, biometric data collection and transmission, nanotechnologies, medical decision support tools (telemedicine), development of “stasis” techniques to enable stabilisation to improve medical timelines without decrease in medical effectiveness, improved medical command and information systems, remote triage and autonomous; ambulances, diagnostics of patients, administration care and treatment.

d. **Linkage to FFAO Military Implications.** Sustain – Networked Sustainable Medical Support, Medical support in de-centralised operations & Enhanced Individual Resilience.

CONSULT, COMMAND & CONTROL (C3)

CONSULT, COMMAND & CONTROL (C3): COMMAND & CONTROL (C.2)

15. **Planning and Decision Support.** Capable of improved planning and decision support.

a. **Rationale.** Current operations have demonstrated the continuing difficulties of operational design wherein most elements within a theatre are interlinked and cascading consequences are difficult to foresee. The necessity to provide joint influence across all domains requires supporting tools that can assess the interaction of many factors and variables. (Driver 1) Future conditions will bring about increasingly complex and hybrid operations, media scrutiny, and strategic and time compression, which will increase the overall difficulty of planning and executing coherent operations. (Driver 2) New technologies will present the opportunity for significantly enhancements in planning while emerging tools will compensate for the threatening overload of available information. (Driver 4) Accelerated planning and decision support improves decision quality, shortens the decision cycle and increases information superiority over opponents who will also be making progress in this area. The required tools will allow the large quantities of data received by HQs to be processed, fused and presented in a manner that can be readily assimilated and actioned by decision makers. (Driver 4)

b. **Effectiveness.** The capability needs to be repeatable, timely, accurate, complete, adaptable and relevant to the operational context. It must enhance military decision-making within an increasingly complex operational environment using more holistic approaches that ensure proactive, innovative, coherent, systematic and integrated solutions. It must be able to assess the increasing complexity of the future battlefield through automated analyses of cascading consequences and threshold behaviour. Systems and processes need to properly integrate the human component to allow understanding, adapting to and influencing the cultural, social and medical dimensions of human behaviour to enable effective alignment of the kinetic and non-kinetic effects of operations. It must consider military-civilian interaction within an increasingly complex operational environment using refined approaches to ensure as complete coordination and collaboration as is possible. It will need to be in compliance with the principles of command as well as recognized organisational principles and applicable SOPs. It cannot increase staff workloads, but should increase staff effectiveness and potentially reduce the need for staff. It should increase co-ordination opportunities between different command levels, as well as between different HQ functional areas, and significantly improve the degree of situational awareness. It should support dynamic decision support to identify, plan, and achieve desired effects, as well as, measuring achieved effects. This capability will need to be exercised at all levels of command. The capability must support a collaborative environment and the sharing of information amongst trusted partners and be able to handle different classifications to meet mission requirements. Likewise, it must enable communications amongst all actors and accommodate timely interaction to achieve mutual objectives. The processes for which this capability is intended is not limited to operational planning, but could also be extended to resource and other planning processes. For most relevant technologies, particularly advances in cognitive science and cutting-edge information systems applications, the centre of gravity for innovation exists in

commercial (i.e. non-defence) industry and academia. This will require an extensive outreach effort.

c. **Potential Areas of Research.** Cognitive and behavioural sciences, visualization techniques, information processing and management, data combination and fusion, data filtering, processing, time stamps, artificial intelligence, modelling and simulation, and training environments, enhanced and/or advanced war gaming and 'Red Teaming'[92], organisational theory and organisational behaviour, human/machine interfaces, decision science, artificial intelligence (AI). For example, AI could use a number of techniques, like simulation, to rapidly assess courses of action, combine a large of number of streams of intelligence and assess its accuracy, rapidly assess the environment from sensors and then use the entirety of the information to make recommendations to the commander.

d. **Linkages to FFAO Military Implications.** C2 – Future Decision Making and Information Processing Tools, Partner Integration and C2.

CONSULT, COMMAND & CONTROL (C3): COMMUNICATION & INFORMATION SYSTEMS (CIS) (C.3)

16. **Beyond Line of Sight Communications.** Capable of providing beyond line-of-sight communication to allow command and control of expeditionary forces in a networked environment.

a. **Rationale.** The evolution of the global environment requires NATO forces to have the ability to deploy in any part of the world, in an austere environment and without host nation support. Among others, the ability to exert command and control over deployed forces, and, therefore, a tactical and operational BLOS communications capability that fulfils future requirements is an absolute requirement. Intra-theatre communications require frequently require BLOS communications, in particular at the operational level, with bandwidth and other requirements not provided by current systems. (Driver 1 and 2). Flexible BLOS communications capability is essential for future NATO combat forces and systems to operate and achieve effects at all ranges and within obstructed environment such as urban areas. Secure, robust, reliable, and affordable means of augmenting available capacity will help the Alliance meet future security challenges, while reducing the cost and resource requirements of current systems. (Driver 4)

b. **Effectiveness.** Future tactical and operational BLOS communications capability must be flexible, robust, secure, reliable and affordable and meet the future demands of Alliance command and control (C2) and intelligence, surveillance, and reconnaissance (ISR) at all levels. Some BLOS capabilities must be inexpensive enough for a transmitter to be considered disposable, so it can be mounted in a weapon system allowing sensor-to-shooter connectivity conforming to future standards. BLOS communications must have a Low Probability of Detection, Low Probability of Exploitation and Low Probability of Interception. It must allow

[92] Red Teaming. The practice of viewing a problem from an adversary or competitor's perspective, with the aim of enhancing decision making by either specifying the adversary's preferences or strategies or simply acting as a devil's advocate.

communication between C2 elements in NATO territory and deployed forces at great distance from NATO territory. It must simultaneously support seamless communications between widely distributed and highly mobile forces within an extensive Joint Operations Area, enhance the potential of NATO assets to effectively operate at long range, facilitate real time reach-back and enable command and control over long distances. It must facilitate 'one to one' and 'one-to-many' communications. The system must have sufficient bandwidth to allow mobile, secure, rapid and timely information flow between all levels of command. This capability must be available in electronic, navigation, communications and cyber degraded environments. It must work across all environments including the arctic.

c. **Potential Areas of Research.** Satellite communications technologies; high altitude, long endurance UAS technology (fixed wing platforms, airships); ad hoc networking technologies which exploit space-based, airborne, land-based and seaborne communications nodes as appropriate; RF and laser communications technology; software defined radio technology, Secure Communications Interoperability Protocol (SCIP), cryptology, ad hoc/mesh networks, WIFI/VIFI.

d. **Linkages to FFAO Military Implications.** C2 – Communications

PROTECT

PROTECT: DEFENCE (P.2)

17. **Active Ballistic Missile Defence.** Capable of intercepting and mitigating the threat from in-flight ballistic missiles.

a. **Rationale.** Continued proliferation of ballistic missile technology, coupled with performance improvements in ballistic missile design leading to increased missile ranges, trajectory shaping options, counter-measures capability and warhead sophistication will ensure that the threat from ballistic missile continues to be a challenge. (Driver 2 and 3) The combination of advanced ballistic missiles and chemical or nuclear warheads provides potential adversaries with powerful anti-access capabilities, and, hence, seriously threatens the Alliance, including its ability to rapidly and effectively deploy forces to regional crises areas. (Driver 2) Advances in missile technology will increase the level of difficulty of defence through the incorporation of evasive warheads, decoys and other aids. Conversely, advances sensor and warhead technology will improve the ability of the Alliance to counter these systems. (Driver 4)

b. **Effectiveness**. The Alliance requires the capability to intercept and destroy, or otherwise mitigate the threat from in-flight ballistic missiles regardless of the missile flight path. The C2 system must be interoperable with national system to enable the sharing of targeting data. The Alliance will need to address the increasing level of difficulty of defence brought about by the incorporation of evasive warheads, decoys and other aids. Proliferation of these technologies will mean that these threat systems will continue to be pervasive in future theatres of operation. Engagement of threat munitions will continue to be the pacing issue for technology and system development. Sensors and engagement systems will have significantly improved resolution, portability and accuracy driven by improvements in underlying technologies. This capability must be available in electronic, navigation, communications and cyber degraded environments.

c. **Potential Areas of Research.** Space based active and passive systems, hyper-sonics, lasers (free electron, solid state and chemical), directed energy weapons (millimetre wave), Sensor Networks, Data Fusion, Information Sharing, and Command, Control and Communications Networks (C3 Networks).

d. **Linkages to FFAO Military Implications.** Protect – Ballistic Missile Defence.

18. **Counter CBRN.** Capable of detecting, warning and neutralising the full spectrum of CBRN agents or contaminants at long range and identifying the type of agent or contaminant and the area affected.

a. **Rationale.** Most current CBRN detection is done at close range through collecting samples. This is undesirable as it is potentially harmful to human collectors and it contaminates remotely operated vehicles. A long-range detection capability is required. This would be particularly useful in cases where border crossing authority has not been granted, but there is a suspicion of the release/escape of CRBN agents (Driver 1). Advanced detection of CBRN agents will enable planning for an appropriate response (warfighting or humanitarian).

Currently, there is limited standoff capability for containerised biological/chemical agents, enhancing this ability will avoid the potential risks of sending personnel to affected areas (Drivers 1 and 4). CBRN capabilities are being sought by several potential adversaries and will continue to be highly prised by asymmetric actors (Driver 3). Advances in technology, especially in the area of nanotechnology, will allow improvements in several components of this system (Driver 4).

b. **Effectiveness.** The capability must detect, classify and quantify the full spectrum of CBRN agents, preferably at appropriate stand-off distances or prior to release. The position of the release/escape and the size of the affected area(s) need to be accurately determined and relayed to end users in a timely manner. The capability must be reliable and durable, able to withstand the effects of the agents or contamination should it come into contact with them. The sensing capability needs to be fully integrated into the wider Joint Intelligence, Surveillance and Reconnaissance (JISR) system. The capability must operate regardless of the delivery mechanism. The capability must be able to effectively conduct mass decontamination of formations, bases, airfields and ports and undertake forensic analysis of CBRN events. The capability should allow for the development of pre-crisis CBRN situational awareness on related technology and proliferation. It must provide all deployed personnel with the means to monitor personal exposure to biological hazards and contribute daily collected data for subsequent analysis and identification. Protection should be integral to all weather condition clothing and individual equipment in order to enhance survivability without increasing combat load and logistics burden or impairing individual endurance. It must possess an improved capability to effectively conduct decontamination of sensitive equipment and areas using non-aqueous and non-toxic means, mass decontamination and undertake forensic analysis of CBRN events. It should capitalize, where appropriate, on autonomous platforms to conduct surveillance, reconnaissance and exploitation, rescue and extraction, and hazard and consequence management.

c. **Potential Areas of Research.** Biotechnology, chemical agents, smart materials, AI, laser sensors, multi-hyper-spectral sensors, meteorological estimation, enzymatic technologies, and nanotechnology.

d. **Linkages to FFAO Military Implications.** Protect – Protection from WMD/E.

19. **Counter Directed Energy Weapons.** Capable of protecting Alliance forces against the use of directed energy weapons (DEW) and devices.

a. **Rationale.** Low power laser (tens of kilowatts) and directional radio frequency (wideband) devices are available today and could be employed by possible adversaries against Alliance forces. Adequate protection capabilities from these devices is lacking and will become more vital over the medium term as they are scaled up in power and scaled down in size, weight and cost. (Driver 1) Significant advances in related science and technology areas are very likely to continue resulting in an operational environment that will include a wide range DEW weapons and devices. High-power megawatt-level lasers and terawatt-level narrowband RF weapons will likely remain within the purview of states, while low and medium power weapons devices will be highly proliferated and offer significant capability to even unsophisticated adversary groups or individuals with limited

resources, thereby increasing the necessity and complexity of protecting Alliance forces from evolving DEW and devices. (Driver 3 and 4)

b. **Effectiveness.** Alliance forces will need improved sensing abilities to determine the nature of directed energy threats as well as improved protection abilities. These abilities should be effective regardless of the environment in which Alliance forces are operating (land, sea, air, space) and protective systems should not adversely affect the ability of forces to operate.

c. **Potential Areas of Research.** Materiel science, acoustics, eye protection, optics, electromagnetics, lasers, high powered microwaves, millimetre wave energy, and particle beams.

d. **Linkages to FFAO Military Implications.** Protect – Emerging Technology.

20. **Counter Improvised Explosive Devices.** Capable of countering the threat from improvised explosive devices (IED) at any point in the life cycle.

a. **Rationale.** IEDs pose a lethal hazard to all personnel – uniformed military, contractor personnel and civilians – and are tactical weapons capable of having a strategic effect. The devices are inexpensive to produce and can explode from direct contact or remote activation. IEDs can be emplaced almost anywhere in the land/sea environment, may be delivered from the air and may be borne in almost any conveyance, animal, human or mechanical. The use of IEDs to attack forces will remain a serious component of future operations and will be a widely available anti-access, area denial tool. (Drivers 1 and 2). Possible adversaries will continue to use asymmetric means to attack superior forces and peer competitors may employ IEDs as part of destabilization and hybrid campaigns. IEDs provide a cost effective means to inflict damage on enemy forces and will progress with the continued proliferation of both the technology to construct these devices and emerging tactics, techniques and procedures readily disseminated via the internet (Driver 3). The threat is evolving in parallel with progress in newly available commercial technologies. The ability to counter IEDs in a timely manner would prevent death or injury to individuals, reduce damage to vehicles, equipment, and materiel, and mitigate the strategic effects of IED use. (Driver 4). Detection of IEDs components before they are constructed or placed reduces the risk to personnel and impact on operations more than simple detection/neutralization of emplaced devices (Driver 4).

b. **Effectiveness.** The capability must allow the interception of constituent IED parts, financing and/or expertise before IEDs reach the point of construction. If this is not possible, it must prevent IED construction when base materials are co-located. The capability must permit the interception of constructed IEDs before they are positioned and the inhibition/detection of IEDs that have been positioned. It must render safe/dispose of detected IEDs and, where necessary, reduce the impact of detonated IEDs. The capability must also encompass a learning function for IED operations and develop Tactics, Techniques, and Procedures accordingly. The capability must include forensic analysis of IED events and the exploitation of information to trace events back through to their initiators. Counter IED must work in all weather conditions and across all relevant military domains (Air, Land and Sea). The monitoring must cover the whole of the theatre of operations and possible neighbouring/nearby countries possibly involved in the production process.

Foreign Disclosure regulations will continue to hinder full cooperation across nations.

c. **Potential Areas of Research.** Advanced sensors (forward-looking Ground Penetrating Radar (GPR), hyper-spectral, UWB, smell, etc.), biological sensors (sensor system), advanced electronic countermeasures, smart dust, data fusion, advanced pattern recognition, directed energy (EMP/HPM) and acoustic weapons, advanced materials for self-protection (nanotechnology, meta-materials, etc.), detection of power sources, and IM/IX (Information Management and Sharing).

d. **Linkages to FFAO Military Implications.** Protect – Counter Area Denial.

21. **Counter Low Signature Airborne Threats** Capable of detecting and successfully engaging low signature airborne targets[93].

a. **Rationale.** Small air vehicles, small unmanned air vehicles and general aviation used for hostile or illegal purposes already pose a significant detection and engagement challenge because of their low visual, IR and radar signatures. (Driver 1) Small and medium sized UAVs will continue to be commercially available at decreasing cost and will be easily modifiable into weapons systems. (Driver 3) Future air threats such as manned and unmanned combat aircraft, surveillance and reconnaissance aircraft and advanced cruise missiles will be designed with Low Observable (LO) technology in order to defeat current detection and engagement systems. (Driver 3 and 4). The developing ability to deploy swarms of vehicles could overwhelm existing systems. . Progress in passive sensors networks and big data analysis may provide benefits in stealth targets detection (Driver 3).

b. **Effectiveness.** This capability must be a day and night, clear and adverse weather capability against low radar cross section/signature targets across the joint spectrum. Targets may be manned and unmanned combat aircraft or surveillance and reconnaissance aircraft, anti-ship missiles, cruise missiles, small civil aircraft (e.g. General Aviation), or model aircraft modified or commandeered for hostile purposes. It must detect and allow engagement of low signature targets operating at low or high altitude, low or high speed, and in swarms. For practical purposes, these unmanned platforms have to be detected in a timely manner outside of a minimum range in order to protect Alliance formations, bases, airfields, and ports. It will need to counter multiple targets, operating in and seeking to exploit complex air environments e.g. heavy civilian air traffic. It will need to encompass the ability to search for and detect, identify and track targets of low signature (e.g. visual, radar, infra-red (IR)) at sufficient range to allow interception and effective engagement/counter measures before they can reach a location from which they can attack or achieve detrimental effects on their intended or potential targets. Target engagement will require the appropriate target acquisition, weapons, and associated fire control and capabilities, such that it is not adversely affected by the low signature of the target e.g. impediment to weapon fusing. The capability should disrupt the system such that it is not able to accomplish its mission. This capability must be available in electronic, navigation, communications and cyber degraded environments.

[93] This LTA address stealth but not microdrones. For coherence with foreseen developments in CRAM, countering low, small and slow targets has been integrated in LTA Countering CRAM.

c. **Potential Areas of Research.** Sensor networks, including passive sensors, advanced radars (ultra-wide band, low frequency, multi-static), multispectral passive detection systems, LIDAR, acoustic sensor, advanced data processing and fusion, network analysis and decision support tools, directed energy weapons (e.g., HPM/EMP and lasers), pattern recognition, and exploitation of EM spectrum.

d. **Linkages to FFAO Military Implications.** Protect – Unmanned Systems, Swarm Techniques, Alliance Integrated Air and Missile Defence, Protection from Ground Based Air Defence and Integrated Air Defences.

22. **Counter Sea Mines.** Capable of rapidly countering static underwater threats, including fast detection, identification and neutralization of all types of sea mines in all water bodies and at all water depths.

a. **Rationale.** Sea mines represent relatively inexpensive means of damaging and destroying ships, resulting in personnel casualties, and hampering military and commercial shipping. They can be used both for sea control and sea denial. At times, even the threat of mines will seriously hamper the ability of Alliance forces and commercial concerns to freely operate. (Driver 1) Modern sea mines are more sophisticated and can discriminate between targets and sweeps, thus, reducing the efficiency and performance of current mine countermeasures. Sea mines can be difficult to detect e.g. buried and concealed mines and if floating or drifting, their location may be unknown even to the emplacing party. Neutralization of sea mines, particularly in very shallow water, ports and harbours can result in collateral damage, e.g. to critical infrastructure. (Driver 1) Assured access to littoral areas, and in some cases inland waterways/rivers will continue to be vital to the successful transport of equipment and personnel to operational areas, and to the projection of power from the sea in support of joint operations. The capability to counter emerging sea mine threats will continue to be essential to ensure the successful conduct of future NATO joint operations. (Driver 2) The use of these types of systems against Alliance forces will continue to be attractive to possible adversaries – state and non-state – due to their ease of use, relative low cost and effectiveness. (Driver 3)

b. **Effectiveness.** The capabilities must achieve rapid effect by surface, sub-surface land or aerial means, faster detection and identification of sea mines, with higher probability of detection and lower false alarm rate against all types of sea mines, including (but not limited to) contact or influence mines, floating, moored, ground, or self-burying mines, and pressure-sensitive mines. It must allow for the conduct of covert and in-stride mine countermeasure activities. The capability must also accurately locate, classify and neutralize sea mines in a timely fashion whilst minimising collateral damage and enabling timely access to affected areas. The detection, classification and neutralization capabilities must be effective against sea mines in all waters, including under ice and in rivers, and at all water depths (including ports and harbours), and be carried out at a safe stand-off range from operational units to minimise the risk to personnel (keeping the man out of the mine field) and infrastructure.

c. **Potential Areas of Research.** Advanced sensors for both local and wide-area mine detection and identification (e.g., lasers, radar, imaging acoustics, and advanced sonar technologies to detect buried and concealed mines), sensor fusion, water space management systems, improved automation and autonomy,

advanced signal processing (e.g., target assessment and change detection), advanced decoys, mine-homing munitions, advanced (with regards to speed and coverage) unmanned and autonomous underwater/surface vehicles (AUV, USV), new weapon types (e.g., high-power acoustics), capable gun systems with advanced hit efficiency and destruction ammunition (AHEAD).

d. **Linkages to FFAO Military Implications.** Protect – Counter Area Denial, Lines of Communication, and Protection from Surface and Sub-surface Threats.

23. **Counter Rocket, Artillery and Mortar (CRAM).** Capable of defeating in-flight short and long range rocket, artillery shells and mortar rounds.

a. **Rationale.** Rocket, artillery and mortar attacks will continue to be a significant cause of casualties and strain the ability to protect Alliance bases, airfields, and ports. Current radars and other surveillance assets can help locate sources of rocket, artillery and mortar fires for counter targeting, but there is a need for mature device to counter the munitions that have been fired and are in-flight. (Driver 1) (Driver 2 and 3) A counter rocket, artillery and mortar capability, including early warning, will reduce military/civilian casualties and support successful NATO operations. Current studies on CRAM systems already consider LSS threat. (Driver 4) Increasing computing power, development of more capable, light, portable sensors and engagements systems will greatly enhance the ability of NATO forces to defeat these types of weapons systems. (Driver 4)

b. **Effectiveness.** These threat munitions have radar cross-section that will become smaller over time and may increase in velocity. Proliferation of these technologies will mean that these threat systems will continue to be well spread in future theatres of operation. Directed Energy and Millimetre Wave weapons require further development before being fielded in quantity and will require appropriate Concepts of Operation to mitigate this threat. Engagement of threat munitions will continue to be the pacing issue for technology and system development. Threat detection, track and engage so as to preclude fratricide will continue to be a significant issue for the decade to come. Sensors and engagement systems will have significantly improved resolution, portability and accuracy driven by improvements in underlying technologies.

c. **Potential Areas of Research.** Advanced radars (multi-spectral, UWB), LIDAR, rapid capable gun systems with advanced hit efficiency and destruction ammunition (AHEAD), advanced jamming, HPM/EMP anti-munitions weapons, deployable lasers, high-speed/high-precision guided anti-munitions missiles, hyper-sonics, new weapon types (e.g., electromagnetic “guns”, high-power acoustics), and directed energy systems.

d. **Linkages to FFAO Military Implications.** Protect – Defence against Rocket Artillery, Mortars and Missiles

24. **Counter Threat to Low Altitude Airborne Vehicles.** Capable of countering threats to low speed/low altitude air vehicles.

a. **Rationale.** Low speed and low altitude aircraft such as helicopters and small fixed wing aircraft will continue to be particularly vulnerable to low technology weapons such as shoulder-fired Rocket Propelled Grenades (RPGs) and man-

portable air defence systems (MANPADS). High performance aircraft are also vulnerable during take-off and landing. (Driver 1) These low technology weapons are relatively inexpensive and will continue to proliferate throughout the world, putting NATO assets at risk. (Driver 2) The ability to safely operate NATO low altitude vehicles is crucial to mission success, making it imperative to counter threats to those vehicles. (Driver 2) Possible adversaries will make use of the continued proliferation of these systems and supporting technologies to interrupt lines of communication and inflict losses on Alliance forces. (Driver 3)

b. **Effectiveness.** The capability must reduce the losses of and damage to low speed/low altitude air vehicles. It must encompass the ability to search for and detect, identify and track potential and active threats at sufficient range to allow threat engagement or avoidance before detrimental effects occur. It must locally and remotely inform as to the position, speed, heading and overall behaviour of threats and provide an accurate threat assessment. It will cover protection of all air platforms (Transport, Jet, Helicopter, UAV). It must consider IR, RF, and EO threats' sensors. It could include passive measures to reduce the effectiveness of the threat.

c. **Potential Areas of Research.** Sound damping, jamming (IR, EO), armours, materials (alloys, nanotechnology), sensors to detect threat, signature reduction (acoustics, IR). Advanced expendable (chaff, flares, optical decoys), and Directed Energy (IR, Laser, HPM)

d. **Linkages to FFAO Military Implications.** Protect – Protection from Ground-Based Air Defence and Integrated Air Defences.

25. **Counter Mobile Underwater Threats.** Capable of countering and engaging mobile underwater threats including Anti-Submarine Warfare.

a. **Rationale.** These threats are capable of denying the Alliance strategic, operational and tactical freedom of manoeuvre. The strategic deterrence provided by strategic submarines is one of the key military components of the Alliance. Together with sea based BMD, conventional strike and assured access to open seas and littoral areas, their protection rely on the ability to deny the adversary mobile underwater threats either by avoiding detection, or by neutralizing the threats (Driver 1). Many countries will continue to acquire more advanced submarines, both strategic submarines and tactical nuclear and/or enhanced diesel-electric submarines. There is as well a trend toward development of more sophisticated and lethal underwater vessels (manned and unmanned) smaller than the traditional submarine, but larger than a naval mine. These various submarines and underwater vessels have increased endurance, reduced vulnerability to detection and increased sensor and weapon ranges (Driver 3). Torpedo technology continues to evolve and improve. Torpedoes represent a serious threat to maritime operations in a range of water depths. Current capabilities for detecting and countering torpedoes, mainly focusing on soft-kill, must therefore improve and be augmented by evolving soft- and hard-kill capabilities to remain effective against emerging torpedo threats. In the future, mobile underwater threats may also be fitted with short range air defence weapons which may deny the Alliance efficient use of airborne capabilities to counter mobile underwater threats (Driver 4). The threats from combat swimmers, naval drones and even trained marine animals capable of executing offensive operations against shipping and stationary facilities,

are particularly relevant for ships (military and commercial) in ports, harbours, and anchorages. The detection and classification of such threats with sufficient warning to allow the employment of appropriate measures represents a significant challenge, particularly in the noisy and cluttered environment typically found in ports and harbours, and coastal waters in general (Driver 1 and 3).

b. **Effectiveness.** The capability must be improved to develop the ability to rapidly and reliably detect, localise, track, classify, localise, track, and neutralize or destroy all types of mobile underwater threats including those employing swarm weapons, in all environmental conditions and at increased ranges. Advances in this area are required for improved harbour protection. It must possess an improved ability to analyse and characterize the maritime environment through enhanced detailed modelling and simulation. It must result in increased sensor ranges to ensure sufficient warning for employment of appropriate measures and increased weapons ranges, including enhanced hard and soft-kill capabilities, employable by both surface and sub-surface units. It will require improved covertness/stealth and reduced signatures to lower vulnerability to mobile underwater threats. It must be effective in all open water including the arctic.

c. **Potential Areas of Research.** Enduring wide area high-precision detection and tracking, new sonar waveforms, advanced signal processing, enhanced acoustic spectrum denial capabilities, advanced seekers and warheads, integration and fusion of multiple sonar systems, low frequency sonar, high-speed hydrodynamics, chemical/acoustic counter-measures, signature reduction technologies, advanced decoys and hard-kill systems, deployable barriers in harbours, mobile and static barriers, and development of new doctrines and tactics, techniques and procedures.

d. **Linkages to FFAO Military Implications.** Protect – Protection from surface and sub-surface threats, Counter Area Denial, Lines of Communication, Swarm Techniques, Unmanned Systems.

26. **Cyberspace Superiority Capability.** Capable of achieving advantage over the opposing forces in the conduct of cyber operations at given time and in given domain (place) without prohibitive interference by the opposing forces.

a. **Rationale.** NATO must ensure sufficient access to cyberspace with resiliency of its networks and systems to assure adequate support to the mission. NATO must improve its defensive capabilities and develop the ways and means to operate in cyberspace. Based on current NATO policy, this can only be achieved by integrating NATO-member states capabilities into the broader NATO operational planning process. As with all NATO missions, without the use of national assets during operations, there is potential for failure. In addition to the tools, tactics, techniques and procedures, it is also necessary to consider the law, situational awareness and rules-of-engagement for cyber operations. Operators, planners and leaders need greater understanding of how they can fight under all conceivable circumstances. NATO's heavy reliance on computer systems and networks to store, process and transfer information is likely to increase even more in the future. However, while we can certainly monitor activities in cyberspace and react to some threats, we do not have the technology to ensure control/superiority of it (Driver 1). Cyberspace is going to be a very important part of the future battlefield. Future operations may start in cyberspace and operations and will most probably be

conducted within it during the duration of the conflict, increasing the importance of its control/superiority (Driver 2). This dependence is recognised by possible adversaries who may wish to attack the Alliance and member nation's systems and networks. Potential opponents, both state and non-state, aim to increase their cyber-attack capability, thereby threatening the Alliance's future ability to achieve Information and Decision Superiority (Driver 3). Conversely, many potential opponents will exhibit a similar reliance on computer systems and networks for various operational capabilities. Effective monitoring of such systems and networks may therefore provide a means of disrupting or neutralising such capabilities (Drivers 3 and 4).

b. **Effectiveness.** Cyberspace superiority even local or mission-specific cyberspace superiority, may provide sufficient freedom of action to create desired effects (protecting own CIS or supporting operations). Freedom of action, in turn, enables command, control, communication, computers, intelligence, surveillance and reconnaissance capabilities. The capability must allow the Alliance to protect information resident in its computer systems and networks from being obtained, manipulated, disrupted, denied, degraded or destroyed by an opponent. Cyber operations will support and must, therefore, be appropriately coordinated or integrated with other forms of offensive and defensive operations occurring in other parts of the battlefield. Cyber operations need appropriate planning and direction, which in turn requires suitable information and intelligence. The penetration and attack of opponent computer systems and networks, if deemed appropriate and authorised, often requires non-attribution, so this capability must be able to execute covert operations. Protecting Alliance information will require a triad including security tools such as firewalls and encryption technologies; internal policies and processes that detail access to and use of information technology; and security education. Social networking tools will continue to allow societies to connect and maintain contact; therefore, the capability to provide internet access to societies to which it has been denied by domestic authorities will be a useful tool for the Alliance. The Alliance should be prepared to operate despite the loss or disruption of cyber infrastructure and hardware, including loss of space assets, network servers, undersea cables, radio communications, and power generation. NATO should have the ability to track friendly and enemy activities in congested cyberspace, the ability to partner with states and corporations to prevent cyber disruption and the ability to restore cyber access to key areas rapidly once interrupted. Legacy or alternate technologies, for example celestial or map and compass navigation techniques, should be retained to provide resilience and help counter the cyber-threat. If a cyber-disruption occurs, forces should understand how systems degrade and be able to transfer vital functions to other systems automatically. Vulnerability assessment teams should aggressively search to identify network vulnerabilities and recommend remedial action. Active and passive tools must be developed within the cyber domain to identify, analyse and react to incursions that occur at electronic speeds.

c. **Potential Areas of Research.** Artificial intelligence in support of Cyber Defence and Cyberspace Superiority[94], cryptography, cloud computing, computer

[94] Ref L. 'By 2030, the use of artificial intelligence and robotics will be pervasive throughout societies. State and non-state actors working through proxies or specialised cyber forces use robotic and artificially

systems, forensics, Information Assurance Security Management Infrastructure for NATO (IASMIN), NATO Computer Incident Response Capability, and NATO Cyber Operation Capability.

d. **Linkages to FFAO Military Implications.** Protect - Security of Communications and Information Systems (CIS) including Cyber Defence. Prepare - Integrated Cyber Operations, Planning, Exercises and Training. Engage - Joint Manoeuvre (Cyber Manoeuvrability); Joint Influence (Cyber Influence and Cyberspace Engagement). Inform – Collection (threat information in cyberspace).

27. **Electro-Magnetic Spectrum Dominance.** Capable of selectively denying the use of the EM spectrum to opponents without impacting its use by the Alliance

a. **Rationale.** Future opponents will continue to exploit the EM spectrum to counter NATO forces and capabilities. EM applications such as radar surveillance, radio communications, and target designation will continue to evolve, and will directly or indirectly place NATO forces and missions at risk. The Alliance will continue to rely heavily on capabilities that use the EM Spectrum. (Driver 1) A peer competitor will bring with it sophisticated applications in the EM Spectrum for which the Alliance will need to develop counter-measures and counter-counter measures to preserve Alliance capabilities. (Driver 2) Possible adversaries continue to close the technology advantage that the Alliance has thus far enjoyed and will continue to make use of the global technology proliferation and dual-use technology to threaten Alliance operations. (Driver 3)

b. **Effectiveness.** The capability must be able to preserve the Alliance's ability to exploit the EM full spectrums while allowing for it to selectively and flexibly Disrupt, Degrade or Deny its use to opponents. It must cover all areas of EM spectrum potentially useful to adversary/NATO forces and take into account compatibility of NATO force EW with other own-force RF use (comms, detection, ECM for RCIED). It must leverage innovative technological solutions to optimise the military use of the available EM spectrum in light of the exponentially increasing requirements for data transfer, as well as avoid collateral damage to civilian spectrum users.

c. **Potential Areas of Research.** Intercept technologies, decryption, exploitation technologies, low-signature materials (including nano-technology and intelligent materials), own use of advanced and jam resistant signal waveforms, advanced high-precision EM countermeasures (including EMP and HPM), pattern recognition, advanced signal processing (e.g. AI or neural networks), low level signal recognition in jammed environment, cellular telephone technology, power generation and packaging, directed energy technologies, palletised jammer systems, stand-off jamming, digital learning jammers, and jamming techniques.

d. **Linkages to FFAO Military Implications.** Engage – Joint Manoeuvre, Joint Fires, Joint Influence.

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intelligent systems, customised software architectures, and highly sophisticated electronic warfare equipment to degrade national/NATO command and control systems.'

28. **Integrated Personnel Protection.** Capable of providing integrated personal protection from the range of threats faced in operational theatres.

a. **Rationale.** Personal protection is currently provided by a number of different means; body armour, CBRN suit that are not currently integrated. Current systems of body armour and CBRN protection are heavy, restrict movement, can lead to excessive body heat and do not provide complete protection. (Driver 1) Enemy forces will attempt to stress Alliance cohesion by inflicting casualties on Alliance forces. (Driver 3) Advances is several areas such as material science will result in lightweight, improved integrated personal protection that will increase survivability of NATO personnel from a range of threats without leading to reduced effectiveness and decreased individual endurance (Driver 4).

b. **Effectiveness.** The capability must be considerably lighter, more ergonomic, flexible and durable. It must give immediate protection against a wider range of threats than current systems. This should include improved ballistic threat protection, environmental protection, non-lethal and CBRN protection. It should reduce individual signature and provide life-signs monitoring and protection against fatigue.

c. **Potential Areas of Research.** Advanced lightweight armour, enhanced textiles, microclimate conditioning, electric armour, smart materials, CBRN protection, flame retardant materials, composite materials, ergonomics, ceramics, nanotechnology, decreased 'detectability', biotechnology, life sign monitoring and locating of personnel, exo-skeleton, and ballistic micro-fibre shelters.

d. **Linkages to FFAO Military Implications.** Prepare – Human Factors, Sustain – Networked Sustainable Medical Support, Protect – Protection from WMD/E.

29. **Space Capability Preservation.** Capable of maintaining access to space and defence of space capabilities.

a. **Rationale.** Future Alliance operations could occur anywhere around the world. This places more reliance on spaced based capabilities for communication, geo-positioning, and intelligence collection. Thus, ensuring access and functionality of these capabilities is paramount to successful NATO operations. (Driver 1) Evolutions in the strategic environment will see the Alliance undertaking deployments at strategic distance that will require space assets to provide weather observation, intelligence support and communications. (Driver 2) Recognising the reliance of the Alliance on space-based assets, possible adversaries can be expected to improve their capabilities to disrupt these systems, irrespective of international treaties. (Driver 3) Advances in technologies to protect NATO assets from electromagnetic, laser, and physical threats must be developed. (Driver 4)

b. **Effectiveness.** The Alliance requires the capability to counter opponent's space denial operations, and hence preserve a space capability/situational awareness for NATO assets, through a combination of defensive measures of space- and ground-based assets and rapid, affordable replacement of space assets. Space Situational Awareness (SSA) will be critical component of this capability. Three principal pillars must be considered: (1) critical understanding and shared awareness of NATO's equities and dependence; (2) identification and

monitoring (via SSA) of current and future risks/threats to NATO's utilisation of space; and (3) effective accommodation (of risks) and reconstitution of lost space capability. Resilience and potential abilities to substitute space with non-space capabilities (e.g. navigation) need to be addressed.

c. **Potential Areas of Research.** Smart/functional materials, space propulsion, radar absorbing materials/signature reduction technology, advanced armours, electronic counter measures, unmanned space platforms, robotics, rapid launch capability, CubeSats, power systems, use of electromagnetic field to influence space debris.

d. **Linkages to FFAO Military Implications.** Protect – Defence from Space Weapons, Security of Communications and Information Systems (CIS) including Cyber Defence.

30. **Vehicle mobility and survivability.** Capable of improving the mobility, safety and survivability of vehicles.

a. **Rationale.** In future operations, the asymmetric threat to vehicles will continue to increase and peer competitor effectors and surveillance capabilities may threaten to outstrip Alliance counter-capabilities. Therefore, enhanced vehicle survivability, either by reduced signature (i.e. not being detected / targeted) or by protection from direct or indirect threat attack, is required. (Driver 1) Continuing advances in vehicle technology and lower costs for systems, such as proximity and collision avoidance for example will make movement more effective in all conditions, providing major improvements in darkness and brown/white out conditions in degraded visual environments. (Driver 4) Vehicles with increased mobility in a range of terrain and climates will enable operations in all threat environments. Vehicles that can self-deploy, carry more, move quicker and are more robust and easily maintained will reduce the logistics tail. Some of these technologies could be extended to air vehicles. (Driver 4).

b. **Effectiveness.** The capability will need to significantly improve the mobility and survivability of vehicles used on deployed operations (including combat service support vehicles) in all environmental conditions, through superior force protection and physical security measures. Vehicles will need to be easily deployed by a range of strategic lift capabilities, have increased self-deployability in-theatre and provide improved survivability against a range of current and future threats without significantly impacting the weight or dimensions of the vehicle. In general, vehicles will be lighter, faster, have longer range and increased payloads. It should enhance the general safety of the vehicles. They must be capable of operating in all terrains, all weather, and may need to be amphibious. Their endurance must be greater and must be more sustainable and more easily maintainable i.e. less breakdowns, interoperable components/parts.

c. **Potential Areas of Research.** Smart/Advanced armours, augmented reality, active protection, acoustic signature reduction, silent fuel cell based APU, multi-spectral stealth technology, active stealth, advanced detection systems (e.g. Smell), proximity detection, semi-active suspension systems, light-weight running gear components, innovative chassis and traction concepts, hybrid drives, electric energy storage, drive train optimization, hybrid electric drive, new battery technology multi-fuel capable, hybrid vehicles, alternative propulsion fuel cells

rubber tracks, smart materials, renewable energy sources, high-field magnets, modular/multi-functional assets, robotics, automation and unmanned systems.

d. **Linkages to FFAO Military Implications.** Protect – Counter Area Denial, Emerging Technologies.

INFORM

INFORM: COLLECTION (I.1)

31. **Dismounted Soldier Situation Awareness.** Capable of enhancing the situational awareness (SA) of individual soldiers and increasing shared knowledge without imposition of additional cognitive burden.

a. **Rationale.** Situational Awareness is a key factor in the effective conduct of operations. Increased situational awareness provides a better perception of elements in the local environment and increases team cohesion leading to an increased battle tempo and a reduced risk of fratricide and collateral damage. This is accomplished through seamless transfer of information at the lowest tactical level and between soldiers of different nationalities operating at the platoon, squad or section level as well as other force elements operating in the area, but without imposing additional cognitive burden. Through data interoperability, soldiers in a coalition environment will have improved Command Execution, Target Acquisition and Situational Awareness, leading to an increased comprehension of the situation, a more accurate understanding of possible future events and more informed decisions by the soldier. However, many required technologies are not currently available. (Driver 1) The evolution of the strategic environment, with the increased focus on asymmetric, hybrid and urban warfare, increasingly requires soldiers to operate in small teams. In this environment this capability is even more important, as soldiers are required to make rapid decisions amidst very confusing situations. (Driver 2) Likely advances in miniaturisation of components and reduce power requirements will bring about a significant increase in the potential equipment that could be carried by individual soldiers. This capability could reduce the manpower required to fulfil some missions, as the increased situational awareness of the soldier will increase his ability to execute. (Driver 4)

b. **Effectiveness.** These capabilities will be operated in dynamic and austere environments. They must be scalable to the unit's organisational design. The capability needs to be lightweight, compact, robust for extreme conditions and optimized to consume a minimum of battery power. The system's display must also be clear and easy to understand. The system needs to provide information on opposition forces, friendly forces and neutral/non-combatant elements with a high enough level of accuracy and timeliness to enable targeting. The system needs enough available bandwidth to transmit and receive various formats of information (maps, schematics, imagery, data, messages, positional updates, etc.) and sufficient power to transmit in all terrains over various distances. The system must be interoperable with other situational awareness tools available to NATO using NATO standard interfaces. The system should possess tools that can automatically filter appropriate information based upon learning accomplished within the environment. The system must not limit the ability of the soldier to experience and interact with the physical environment around him/her. It must be able to operate in a navigation, communications and cyber degraded environment. The system should allow sharing of information collected by the soldier with other force elements which may include vehicles,

c. **Potential Areas of Research.** Smart/functional materials, electric power cells, integrated microsystems, human/technology interface, pattern/image processing and data fusion techniques, communications services,

augmented/mixed reality, improved batteries, distributed/ad hoc/mesh networks, BLOS communications, 3D mapping, cognitive studies.

d. **Linkages to FFAO Military Implications.** Inform – Broad mapping.

32. **ISR Collection Capability.** Capable of collecting in a timely manner the imagery, data and information on opponents/neutrals and the environment required to meet Alliance end-user requirements.

a. **Rationale.** There will continue to be a requirement for improved conversion of information into intelligence; better use of indicators and warnings; the ability to mine and analyse large amounts of unstructured data (big data); an interagency approach which builds shared awareness through intelligence exchange; and early warning systems which can anticipate social unrest and detect rapid gatherings of people (Driver 1). It is estimated that by 2040 cities will contain 65% of the world's population (Ref L and M); this will significantly increase the requirements for sensors that can collect information in urban environments (within buildings and subterranean structures). Along with urbanisation, the ISR community will find it more difficult to collect data as possible adversaries will continue to develop innovative ways to camouflage and conceal targets and deceive Alliance sensor systems. Whether that data is derived from imagery or signals, there is a need for the capability to appropriately filter out the "noise" from the target(s) (Driver 2). The combination of increasing threats, information age advancements, and fiscal constraints demands should push NATO to develop robust, integrated, resilient, and innovative ISR capabilities (Driver 3). With the speed of technology advancement, comes efficiency in performance and also smaller size. The smaller size will enable the ability to acquire smaller capabilities i.e. smaller sensor = smaller platform (aircraft/ship/tank) (Driver 4).

b. **Effectiveness.** Future Alliance ISR must support an Alliance Comprehensive Approach which involves the combined use of Alliance military, political, economic and civil powers. It must facilitate more complete Alliance Strategic Awareness. It also needs to support operations to control and exploit the air, land, sea, space, electromagnetic and cyberspace domains of the battlefield with specific focus in urban areas. It must detect and identify targets despite technological advances in stealth, camouflage, concealment and deception techniques. It must support the full range of NATO missions and provide strategic, operational and tactical end users (decision makers, planners, operators etc.) with relevant, accurate and timely products in a form that is readily assimilated. Such products need to cover the appropriate Political, Military, Economic, Social, Infrastructural, Informational (PMESII) aspects of opponents and neutrals (which may be state or non-state) and other relevant parties. The military component may feature irregular as well as regular forces and the threat they pose may be hybrid. The capability must include training and cultivating human sources of information and particular attention should be paid to threats such as terrorism, espionage, subversion, sabotage, and organised crime. Likewise, it must collect and analyse human networks to define the relationship between people at the individual, family, tribal, national and international levels. It must detect adversary information operations, especially in the early stages of development. It must detect and collect non-conventional threat activities. It must be able to obtain information on factors such as objectives, capabilities, intentions and plans from strategic, operational and tactical perspectives, as well as environmental information. The capability must be

able to schedule assets to support operations as required. Alliance ISR and its associated collection capabilities must support the creation of the various tactical and recognised pictures, and ultimately the Common Operational Picture as required by end users. Collection capabilities must be persistent, pervasive and commensurate with the Alliance's global outlook, allowing timely warning of crises. It must be capable of identifying and tracking individuals and moving targets regardless of terrain and clutter within a challenging electromagnetic environment. It must detect, classify, and identify individuals in complex 3D terrain, including urban, using biometrics and other accurate methods. It must be able to collect the growing volume and velocity of all source data from a wide variety of sources.

c. **Potential Areas of Research.** Data analytics, neuromorphic computing, cognitive modelling, flexible autonomy, develop flexible autonomy and all-source intelligence fusion and visualization technologies for enhanced analysis and planning capabilities for C2 and ISR. Field a secure, self-forming, resilient, and agile IP network using existing infrastructure and advanced data link gateways enabled high capacity global C2 and tactical data-links with mission-aware networking. Active and passive sensors, hyper-spectral sensing, unmanned air, ground and underwater vehicles, robotics, meteorological assessment, bio-technology, automated pattern, object and change recognition, Information processing and management, artificial intelligence, cognitive and behavioural sciences, visualisation and human/technology interface and modelling and simulation, see through walls/underground, energy systems for deployed sensor networks, very small sensors, renewable/rechargeable power sources.

d. **Linkages to FFAO Military Implications.** Inform – Collection, Broad Mapping.

33. **Allied Future Surveillance and Control Capability.** Capable of providing long range surveillance and Command and Control of weapons systems to take appropriate actions.

a. **Rationale.** Many of the current platforms providing both AEW(BM-C2) and ASC(P-AHM) capabilities are expected to remain in service until 2025; after that time, due to the evolution of the technology and the age of the platforms, a modernisation effort will be required to extend their lifespan until 2035. From that time, it is not expected that the existing airframes can provide a relevant capability to NATO (Driver 1). It is expected that the design and production phases of a replacement capability of this magnitude takes a time period longer than 15 years which calls for attention and action in the short term to prevent the loss of essential capabilities of NATO in approximately 2035 (Driver 1). Operational needs have extended the capabilities of the platform to include amongst others Joint Intelligence, Surveillance and Reconnaissance (JISR), air and missile defence and maritime situational awareness The AEW Capability is special in the sense that it is not only required for crisis time (Driver 2). The progressive implementation of the NATO Network Enabled Capability, with the integration of most sensors and effectors in the battlefield on a common network, with the huge amount of information they produce, will cause the existing systems to be unable to adequately fulfil their missions unless some developments are made in this area. (Driver 1) An improved C2 System for the conduct of Battle Management will be essential in the future to allow the Commander to conduct the full spectrum of operations, from the lightest to the most demanding ones, in a more effective way.

(Driver 2) Advances are likely in the development of intelligent tools that will assist user by presenting critical information in the correct format at the correct time will allow much better assimilation of the vast depth of available information. (Driver 4). Conceptual work is still ongoing.

b. **Effectiveness.** The capability must be able to integrate information from most if not all sensors and weapon control systems in the battlespace. It must be able to support the coordination of the activities of national and multinational forces and civilian actors in the theatre of operations. It must be able to contribute to and/or execute the overall Command and Control of the battlespace in a distributed environment. It must coordinate with regional Air Traffic managers to implement robust Airspace Integration approach that facilitates effective operational mission accomplishment. It must contribute to Joint ISR collection from various areas to include the littoral areas, international waters, overland friendly airspace, and overland in contingency Joint Operating Areas. It must satisfy the relevant agreed standards to enable interoperability among different national systems. It must facilitate the planning of operations in the presence of uncertainty. It must be able to process and filter information, presenting the operator only with the data relevant to the task being accomplished. It must present a Common Operational Picture of friendly, neutral and enemy forces and civilian actors present in the theatre of operations. It must facilitate more complete Alliance Strategic Awareness. This capability must be available in electronic, navigation, communications and cyber degraded environments. An ongoing ACT-led study on Allied Future Surveillance and Control Capability (AFSC), aimed at answering to this LTA will identify more precise requirements in the years to come.

c. **Potential Areas of Research.** Technologies and Systems: Data fusion techniques, advanced communications services, information processing and management, ad hoc networking, middleware, and artificial intelligence. Data analytics, all-source intelligence fusion and visualization technologies, ad hoc/mesh networks, advanced data link gateways, active and passive sensors, hyper-spectral sensing, unmanned air, ground and underwater vehicles, robotics, meteorological assessment, bio-technology, automated pattern, object and change recognition, information processing and management, artificial intelligence, cognitive and behavioural sciences, visualisation and human/technology interface and modelling and simulation, see through walls/underground, energy systems for deployed sensor networks, very small sensors, renewable/rechargeable power sources.

d. **Linkages to FFAO Military Implications.** Inform – Collect, Analysis, Broad Mapping, Sharing.

INFORM: PROCESSING (I.2)

34. **Intelligence Processing, Fusion and Exploitation.** Capable of processing, fusing and exploiting the imagery, data and information provided by Alliance ISR capabilities and generating intelligence products that can be readily assimilated by end users.

a. **Rationale.** ISR processing, fusion and exploitation is a vital military capability to confront the ever-increasing array of threats across all levels of war (strategic, operational, and tactical) ranging from non-state actors/insurgents to peer adversaries, who employ a wide range of capabilities up to and including

weapons of mass destruction across all environments (permissive, contested, and highly contested) (Driver 1). Global access to technology, worldwide connectivity, and increased access to all domains by our adversaries are closing the information superiority gap that will ultimately challenge our ability to dominate air, space, and cyberspace (Driver 2). The combination of increasing threats, information age advancements, and fiscal constraints demand and enable the development of integrated, resilient, and innovative ISR capabilities (Driver 3). To fully capitalize on these innovations will require new concepts of operations, and a new way of designing our force. Concepts of operation enabled by information-centric, interdependent, and functionally integrated organisations are the keys to future military success (Driver 4).

b. **Effectiveness.** This capability must be able to process information originating from air, land, sea, space, electromagnetic and cyberspace environments to facilitate more complete Alliance Strategic Awareness. It must provide strategic, operational and tactical end users (decision makers, planners, operators, etc.) with relevant, accurate and timely intelligence products in a form that is readily assimilated. Such products need to cover the appropriate Political, Military, Economic, Social, Infrastructural, Informational aspects of opponents and neutrals (which may be state or non-state) and other relevant parties, identifying trends and developments, assisted by regional experts to support intelligence collection, liaison, education, and training at all times. It must analyse indicators and warnings to better identify the early phases of a crisis and enable timely decision-making. The military component may feature irregular as well as regular forces and the threat they pose may be asymmetric or hybrid. It must analyse networks and evaluate potential adversarial command and control structures. It must support the creation of the various tactical and recognised pictures, and ultimately the Common Operational Picture needed by end-users. It must be capable of operating in a degraded electronic, cyber, navigation and communications environment. It must be able to process the growing volume and velocity of structured and unstructured information while analysing trends presented in the overall content of data. It must be able to provide products in the formats required by user within the necessary timelines. It must have a repository of knowledge about the operational environment that enables the conduct of collaborative planning.

c. **Potential Areas of Research.** Data analytics, cognitive modelling, all-source intelligence fusion and visualization technologies for enhanced analysis and planning capabilities, ad hoc/mesh networks, advanced data link gateways enabled high capacity global C2 and tactical data-links with mission-aware networking, 3D mapping, cognitive and behavioural sciences, visualization techniques, information processing and management, data combination and fusion, data filtering, artificial intelligence, modelling and simulation, enhanced and/or advanced war gaming and 'Red Teaming'[95], organisational theory and

[95] Red Teaming. The practice of viewing a problem from an adversary or competitor's perspective, with the aim of enhancing decision making by either specifying the adversary's preferences or strategies or simply acting as a devil's advocate.

organisational behaviour, human/machine interfaces, decision science , artificial intelligence.

d. **Linkages to FFAO Military Implications.** Inform – Analysis, Broad Mapping, Sharing.

35. **Systems Analysis and Knowledge Development.** Capable of building a holistic knowledge base from a coherent, systematic, and integrated analysis of the operational environment.

a. **Rationale.** There is a current lack of an ability to assemble and understand all aspects of the operational environment due to both an abundance of material and a lack of an ability to sort out important information from background noise. (Driver 1). The continuing accelerating complexity of the future environment driven by the increasing velocity and interdependence of information will make the development of this capability more critical. Supporting technologies will allow for more systematic development of a network of knowledge and tools that will exploit multiple information sources and use collaborative analysis, in a continuous and dynamic manner to build timely, coherent, relevant knowledge to enhance decision-making (Drivers 2 and 4).

b. **Effectiveness.** The capability will need to exploit multiple information sources to build timely, coherent, relevant knowledge and so enhance decision making. The capability will need to build a common, shared, holistic knowledge base of the operational environment and in support of this must examine holistically friendly, neutral and potential adversaries as well as the environment as a complex adaptive system, including its structures, behaviour, objectives and courses of action to accurately identify and assess strengths, vulnerabilities, and interrelationships. It must consider human factors as components of the overall system and include the cultivation and use of human sources. The goal will be to present options, in the form of specific actions that can be taken against specific nodes (political, military, economic, social, infrastructural or informational), to assist decision-makers at strategic, operational and tactical levels in focussing capabilities to achieve desired effects. The actions need to link to the resources necessary to carry out the actions and also to intended primary and cascading effects. Measures of effectiveness will be needed for each desired effect. For most relevant technologies, particularly advances in cognitive science and cutting-edge information systems applications, the centre of gravity for innovation exists in commercial (i.e. non-defence) industry and academia. This requires an extensive outreach effort.

c. **Potential Areas of Research.** Information processing and management, Artificial Intelligence (AI), human network analysis, cognitive and behavioural sciences, modelling and simulation, and human intelligence gathering methodologies, cultural models, systems analysis, human/machine interfaces , fusion of multi-format data (text, imagery, relationships), expert systems, game theory, cultural modelling, text mining analysis, semantic extraction, document summarisation and categorisation, link analysis, trend extrapolation. For example, AI could continuously monitor and assess the provenance and accuracy of all available information while building a database of connections and relationships that could be used by the AI or humans to garner insights.

d. **Linkages to FFAO Military Implications.** Inform – Analysis, Broad Mapping, Sharing.