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Convergence, multipurpose apertures, will cause disruption

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Abstract. The article explores the concept of convergence, which has become a key factor in the transformation of technologies in the 21st century. The author compares the impact of digital technologies to a "black hole" that absorbs analogies of the past, replacing phone books, encyclopedias, maps and individual gadgets with one universal device - a smartphone. Convergence affects not only civilian areas, but also military systems, such as assault rifles and multifunctional combat platforms, which combine the characteristics of different devices. Particular attention is paid to universal information platforms that combine the functions of processing, transmitting and analyzing data through digital interfaces. An innovative development is the universal multifunctional aperture (AIMA).

The economic feasibility and strategic effectiveness of convergence in creating compact, cheaper and accessible systems are emphasized. The prospects for reducing the cost of such technologies and their expansion within the framework of the "robot revolution" are described.

The author argues that AIMA can reduce costs and risks for humans, providing new opportunities for warfare in which autonomous systems perform essential tasks, maintaining human safety and reducing dependence on expensive traditional technologies.

Keywords: convergence, multifunctional equipment (AIMA), electromagnetic spectrum, digitalization, artificial intelligence.

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Introduction

Like a black hole

Transformation from analogue technologies to digital technology in 1980´s and 1990´s was a small revolution, as digital technology allowed to store information reliably, to transmit it over long distances and to process it in a device called processor. The processor can execute different tasks in parallel or in sequence, which makes digital equipment true multirole gadgets. Like a black hole, they have swallowed most of the things we had around some 20 years ago. There are no more phone books, sales catalogues, dictionaries, encyclopaedias, printed maps etc. In addition, many gadgets have disappeared: cameras, video cameras, voice recorders, media players, compasses, navigation devices, type writers. Even books, records and board game have been fused into a gadget called smart phone. This fusion is called convergence.

The fantastic feature of convergence is that it allows you to carry almost all the gadgets from your office, or home with you wherever you go. In addition, you can carry all the books that have ever been written, every movie, song, map and so on. With it, you can listen, read, speak and write

in any language. You know every place where you go and get never lost. It is no wonder you carry this piece of wonder everywhere you go without paying much attention to the facts that this mixture of plastics and metal is actually impossible to use when walking, or in sunshine. It is lousy typewriter, midget movie theatre and has limited optics, poor acoustics and short endurance. A typewriter, camera or paper map might be better in each different use case. However, as the smart phone is with you all the time and can do the job, it is the gadget, that is used, despite all the performance shortfalls it has.

Results

Convergence in military systems

Convergence takes place also in military domain. The assault rifle is a good example. It is a compromise between several different hand weapons, replacing them all in many instances. On one hand, it has shorter range than bolt-action rifle, slower rate of fire than a machine pistol, less hitting power than a machine gun and it is heavier and clumsier than a revolver of a pistol. On the other hand, being more powerful than a pistol, lighter than a rifle and a machine gun, it is very convenient compromise, and has therefore become the standard tool of trade for all armed forces. Assault rifles, multi-role fighter planes and may surface combatants are good examples of convergence and compromise.

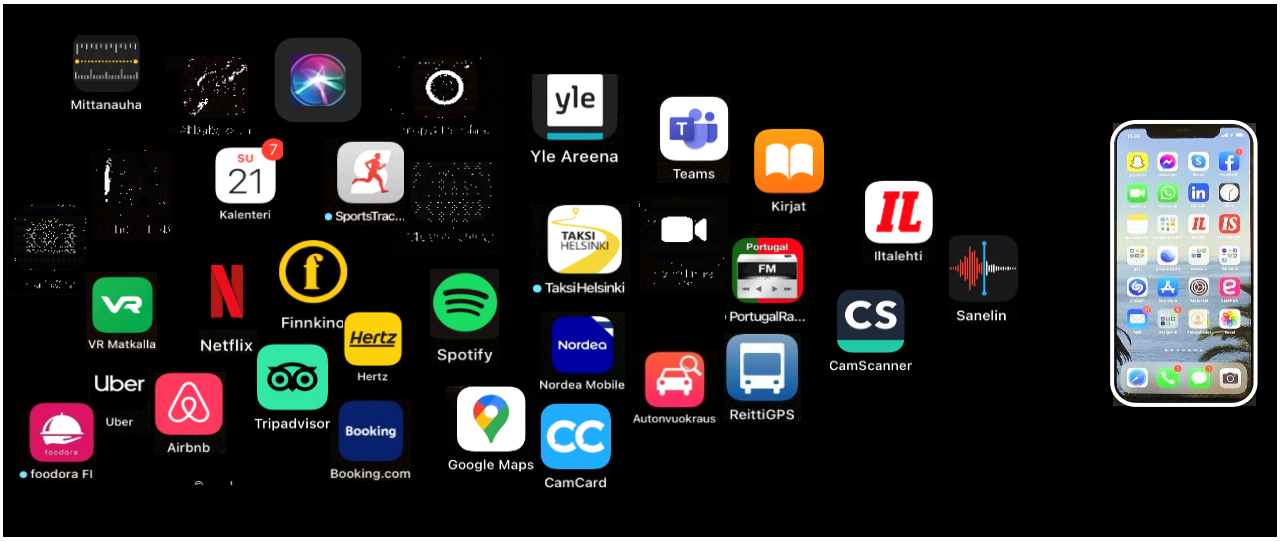


Figure 1.

Source: Image Jyri Kosola

Convergence has strongest potential in information systems. Information processing has already been converted into universal platforms, like PC: s, laptops, tablets and smart phones. Today, a lot of effort is directed at developing universal interfaces between the real world and the virtual world, where the information processing takes place. Engineers love to use sophisticated words. Therefore, this interface is called aperture.

Aperture collects incident electromagnetic radiation in the form of radio or radar waves, infrared, visible light or ultraviolet and transforms it to electric current, which is digitized in an Analogue-to-Digital Converter (ADC). As a result, the radio transmission or visual sighting is turned into binary digits, i.e. zeros and ones. These digits are stored in digital memory circuits and processed in microprocessors. Processing is based on algorithms in the program. Functions, tasks and even roles of the system can be changed by ordering the processor to execute different algorithms.

In the ideal case, the aperture is reciprocal, i.e. it both receives and transmits energy from and to electromagnetic spectrum. Transmitting is opposite process to receiving, requiring Digital-to-Analogue Converters (DAC).

Convergence in radio frequency domain

Radio and radar equipment were also involved in the digitalization wave of 1990s. Due to the limitations of digital microelectronics at those days, I was not possible to design and build digital radio or radar. Therefore, these systems have three segments: base band (BB), where signal processing takes place and radio frequency (RF) segment, where the radio signal is lead from the circuits into free space. Between baseband and RF, there is intermediary frequency (IF) segment, where the base band signal is mixed with higher frequencies to produce the desired RF frequency. Most current software-defined radios (SDR) have digital BB, but analogue IF and RF. They are called software-defined, as software is used in initializing IF and RF circuits and processing received signals once they are transferred to base band frequency. Software-based baseband and software-defined RF do not allow full software control of received or transmitted signals.

In the early 2000s, speeds and bandwidths of ADCs, DACs, memories, data buses and processors allowed direct conversion of first HF and then VHF signals. As electronic components evolve, gradually higher frequencies can be directly converted between RF and BB. That will lead to a true software radio, which can act simultaneously in different modes and roles.

Discussions

Multi-purpose RF aperture

Universal aperture working in radio and radar frequencies can receive and transmit many kinds of cooperative signals, among them communications, broadcasts, positioning, navigation and timing. It can also detect and exploit unintentional or non-cooperative emissions, like enemy communication signals and radar pulses. Similarly, the aperture can emit energy for cooperative or non-cooperative, offensive, purpose.

Dynamic use of constrained, congested and contested electromagnetic spectrum requires systems to adapt to changing conditions in the EM spectrum. This requires the universal aperture to learn the normal background, to detect anomalies and to recognize friendly and hostile operators and operations in the EM spectrum. A combination of model-based and data driven AI with comprehensive learning data set will be needed to facilitate the required speed and autonomy the spectral operations require.

Ideally, universal artificial intelligence-based multi-function aperture (AIMA) can provide:

- Multiple point-to-point connections in mesh-like ad hoc forming network for command and control, targeting and fire control;
- Point-to-multipoint broadcast service for situational awareness, tracking friendly forces and identification of friendly forces;
- Radio detection and sensing of moving and stationary objects;
- Platform position and navigation aids, altitude, threat warning, obstacle sense-and-avoid;
- General time reference;
- Detection, location, classification and identification of emitting friendly, neutral and hostile units and platforms;
- Disrupting and deceiving enemy communications, sensors and remote-controlled systems.

The aperture would provide functionalities so far related with digital datalinks, combat net radios, terminal attack controllers, artillery fire controllers, ground and air surveillance radars, counter rocket, artillery and mortar radars, fire control radars, counter-UAV and C-IED sensors and jammers, tactical ESM and jamming systems, satellite and radio navigation, Blue Force Trackers,

IFF transponders and self-protection systems, among others. Of course, AIMA cannot replace ground surveillance radars, tactical EW systems, C-UAV assets etc. on a vis-à-vis basis. However, in most cases this does not matter. The question is "would you like to have limited, but at short distances adequate capability in your vehicle or foxhole, or superb capability either unavailable at this moment or available at distances rendering it ineffective at your location?"

Especially land environment, with short line-of-sight distances and strong signal attenuation and distortion at beyond line-of-sight ranges, favours short-range solutions. For example, if the distance between terrestrial jammer and its target is reduced from 8 km to 800 metres, the required jamming power drops 10.000 fold. If the jammer is installed on small UGS capable of sneaking close to enemy location, its 10 W jammer could be ten times more effective than 10 kW tactical EW jamming system. Installed in drones with Line-of-Sight to the target, AIMA would need even less power to blind the enemy radars, or to disrupt its communications.

Quantity is quality

As the example on jammer application shows, AIMA does not have to be as capable as the legacy systems. Even with somewhat moderate performance due to design compromises, AIMA will be much more effective due to

- Availability in time and space; always with you to provide C3ISTAR, navigation and non-kinetic engagement capabilities at squad level;
- Greater numbers and density leading to shorter distances to detect and jam hostile radios and to communicate with friendly forces;
- More numerous fleet and cheaper unit cost allows risk taking, as asset are expendable;
- Better situational awareness, command & control on the move and expendable robotic assets allow tightening operational tempo and speeding OODA loop.

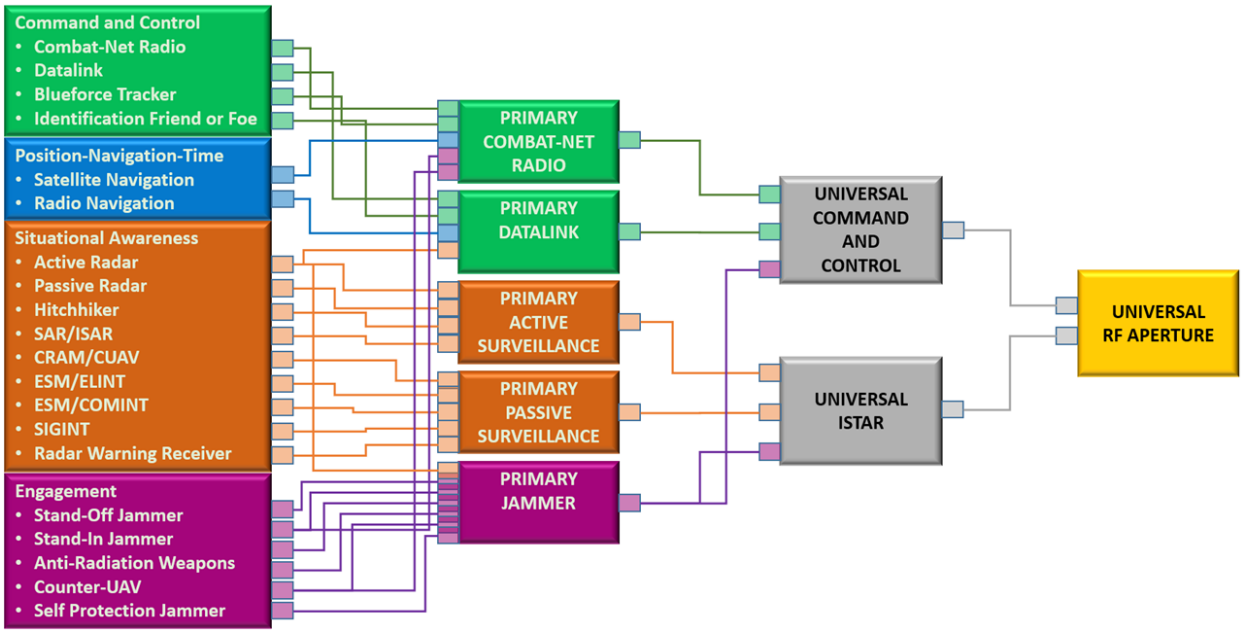


Figure 2.

Source: Image Anders Furu

Still emergent, not yet disruptive

As research on true software radios proceeds, emergent use cases will be innovated. Simulations have already shown not only emerging possibilities, but also some unforeseen challenges in installing and practical exploitation of the "big promise" of convergence. Amid

technical matters to be solved, one key issue is the cost-effectiveness in different platforms. AIMA and similar apertures contain state-of-the art electronics, like super-fast ADCs and DACs, active electronically scanned antennae (AESA) and extremely demanding signal processing. This will make the first developed gadgets expensive. We don't know how expensive, but they certainly won't be expendable. Therefore, AIMA will see first operational use in manned platforms and larger drones. But, as time passes, cost of electronics will come down. At some point the price for AIMA SoCs (System-on-Chip) will allow cost effective use on wide range of different autonomous systems. That will be part of robotic revolution.

AIMA in action, might render legacy systems obsolete

Let us imagine how AIMA could revolutionize warfare in one of many missions it can perform; suppression of enemy air defences (SEAD). This mission requires detection and location of enemy air defence radars, missile launchers and command centres, who try to hide and avoid being detected. The enemy will maintain EMCON until engaged. Therefore, SEAD mission requires a swarm of drones to enter the hostile airspace. As drones can either engage the defenders directly, or cue other weapon systems, the enemy is forced to activate its air defence system when the drones enter their airspace. ESM algorithm in AIMA will detect signals from surveillance and tracking radars and datalink radio signals between command post and missile launchers. Another algorithm classifies the target as certain type of enemy ground-based air defence (GBAD) system. Using AIMA communication algorithm, drones share their location, heading and target bearings. This allows another algorithm to calculate the positions of enemy assets belonging to the targeted GBAD system.

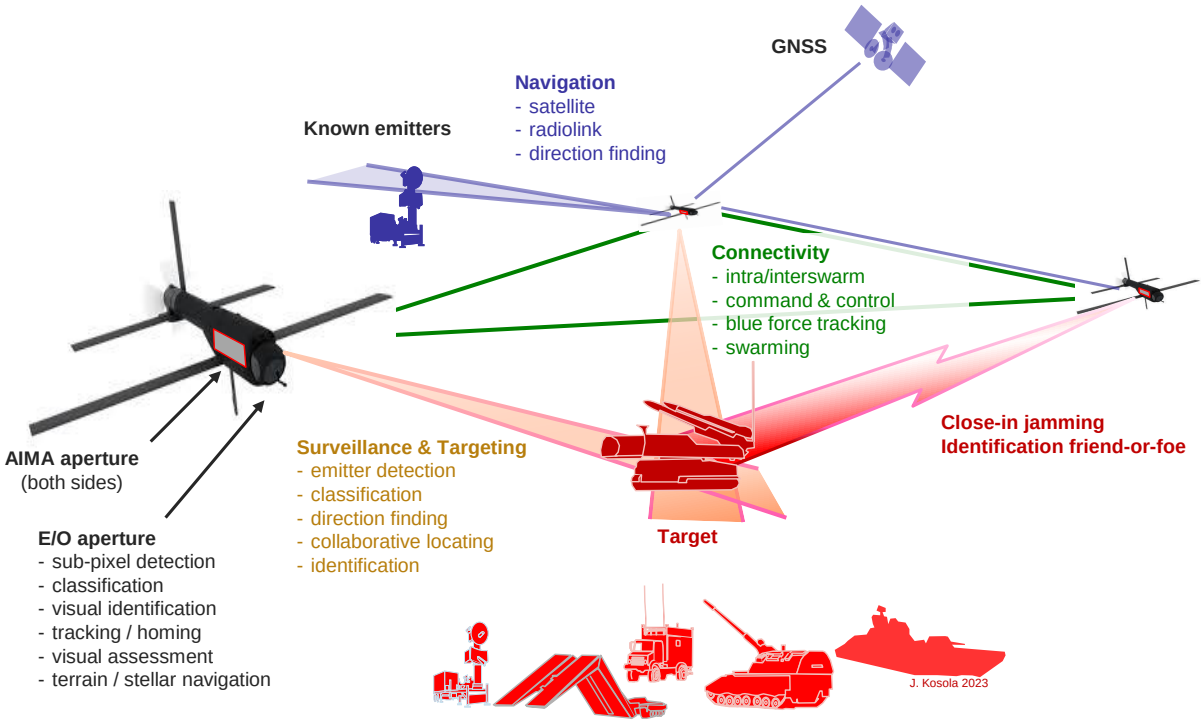


Figure 3.

After establishing clear situational picture, the drones start to prepare for attack. Based on collaborative swarm intelligence, one drone takes leader role. It allocates roles to other drones comprising the swarm, dividing it into hunters, killers and supporters. The hunters are to track targets, get a visual confirmation of the target and perform battle damage assessment after

engagement. Killers are to perform orchestrated attack on critical point in the target. The optimal attack tactics and terminal geometry depends on target type, its self-protection systems, terrain, weather etc., and must be negotiated and agreed on between swarm members. In some cases, the swarm leader does not allocate killers, but assign fire control mission and pair one drone as a sensor to a standoff shooter.

Conclusion

Supporter drones can be tasked to establish jamming-proof communications network to guarantee coordination in the swarm and to provide long-distance connectivity for the human leaders to observe, supervise, control and command the swarm. In the highly unlikely case, the enemy jamming disrupts swarm's connections; some of the drones can be tasked to use AIMA to home on jamming source, and to eliminate it. Some supporting drones might be tasked to assist in navigation. They would use both their radio frequency AIMA aperture and electro-optical aperture to correct the drifting of position in inertial navigation system (INS) and to detect spoofing attempts. A fool-proof navigation should comprise of inertial navigation supported by AIMA (Galileo, GPS, Glonass, Beijou GNSS, proportional radio navigation and direction finding of known emitters) and the electro-optical aperture (geo-referencing, stellar navigation). If AIMA is equipped with SAR algorithms, also SAR image can be used to aid fixing the INS error.

Why AIMA? Why converged aperture? The same functionalities could be created by combining legacy systems and writing few lines of software. But, due to size, weight, cost and power consumption, it would be unfeasible to install a separate datalink, ESM receiver, jammer, broadcast radio, satellite receiver and IFF transponder. AIMA also helps us to break the vicious spiral of cost escalation, that is caused by our desire for longer standoff distances. It is understandable that to keep humans safe, we need to keep distance to the enemy. But with unmanned assets with AIMAs capacity to see, hear, collaborate and engage, we could close in with the machines and keep humans at safe distance. Shorter ranges would mean lower costs for the machines, whereas safe distances would lead to lower costs also for the manned elements.

Therefore we need solutions like AIMA.

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Конвергенція, багатофункціональні апертури призведуть до підриву

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Анотація. Стаття досліджує концепцію конвергенції, яка стала ключовим фактором трансформації технологій у двадцять першому столітті. Автор порівнює вплив цифрових технологій з "чорною дірою", яка поглинає аналогії минулого, замінюючи телефонні книги, енциклопедії, карти та окремі гаджети одним універсальним пристроєм — смартфоном. Конвергенція впливає не лише на цивільні сфери, а й на військові системи, такі як штурмові гвинтівки та багатофункціональні бойові платформи, що поєднують характеристики різних пристроїв**.** Особлива увага приділяється універсальним інформаційним платформам, які поєднують функції обробки, передачі та аналізу даних через цифрові інтерфейси. Інноваційною розробкою є універсальна багатофункціональна апертура (або багатофункціональна апертура на основі штучного інтелекту, БАОШІ).

Підкреслюється економічна доцільність та стратегічна ефективність конвергенції у створенні компактних, дешевших та доступніших систем. Описуються перспективи зниження вартості таких технологій та їхнього розширення в рамках "революції роботобудування".

Автор стверджує, що БАОШІ може знизити витрати та ризики для людей, забезпечуючи нові можливості для ведення війни, в якій автономні системи виконують важливі завдання, зберігаючи безпеку людини та зменшуючи залежність від дорогих традиційних технологій.

Ключові слова: конвергенція, багатофункціональне обладнання (БАОШІ), електромагнітний спектр, цифровізація, штучний інтелект.