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GROUND-BASED AIR DEFENSE SYSTEMS NEW CHALLENGES AND PERSPECTIVE

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Abstract

While the aeroplane itself was taking its first 'baby' steps into mankind's history, some visionary officers, like Giulio Douhet or William 'Billy' Mitchell, were outlining the future baselines of air power and how it could be used to change the outcome of future conflicts. After those early days and almost in every conflict, the proper use of air power became crucial for the successful conduct of military operations. One has only to examine the psychological impact of all of the air raids that took place in the conflicts after 1914. In all of the above military operations, one key aspect remains the same throughout the years. The GBAD systems are trying to target only the aircraft. Nothing or little has been done to target the weapons themselves. During the WWI and II, the GBAD forces (mainly improvised guns in the early days and later on AAA artillery with some primitive fire and control procedures) spent thousands of rounds with virtually no effect. Whereas during the modern day conflicts the GBAD forces proved to be more competent, there are various examples (like Operation Mole Cricket 19) were they failed to fulfil their assigned mission. Today only some naval systems, like Skyguard, RAM (RIM-116A) or Phalanx are designed from scratch with the ability to track, target, engage and assess the results, on the weapons released against the ship. In the near future, the GBAD forces will come up against even greater challenges. Stealth and VLO characteristics are the rules and not the exception in modern 5th/6th generation fighters, while the relevant technologies are not limited to a handful of nations or companies, the armament is turning into smaller and more capable guided munitions, the advances in computer technology and electronics provide the airplanes and the operators with a unique situation awareness, combined with advanced electronic warfare and cyber operations capabilities. The advances in computer technology and artificial intelligence are giving a huge potential to the future dominance of the air, to unmanned systems that could take decisions upon certain actions. Combined with the fact that their production and operational exploitation is easier than that of a manned system (smaller size, less equipment, no pilot, etc.), in the future the GBAD forces will have to deal with a condensed air environment. While the air power is taking huge steps into the future, the GBAD forces are still duelling with the same doctrines, principles and systems. Still, there is no significant change regarding radar technology (i.e. the Passive Coherent Locator that has a huge potential against stealth targets, has no operational use regarding targeting or guidance) that could deal with the complete circle of search - detection - acquisition - targeting - guidance. On the other hand, GBAD forces are still "drawing circles onto a map". In this paper, we shall examine the need and potential of a radical change in doctrines and principles. We shall research whether transferring the focus of GBAD forces to the weapons instead of their carriers, could solve many of the problems and challenges. Furthermore, we shall examine the potential uses and dangers regarding space and cyberspace together with potential methods against drones. One

should always keep in mind that the primary objective of the GBAD forces is "*the elimination of the effects of the air power as there are projected against ground assets"*. With that in mind we can provide a guideline to the GBAD forces of the future.

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1. Introduction

On December 17, 1903, near the Kill Devil Hills, two visionary brothers, Orville and Wilbur Wright[1] managed something extraordinary. To create a heavier than the air machine[2] which could actually perform controlled flight. While the Wright brothers could not foresee the military perspective of their design soon became clear the potentials of the aeroplane on the battlefield. In the years to come, the aeroplane managed to go higher and faster and to make our world a little bit smaller. The evolution of the aeroplane is only compared to that of modern-day computers. Since the creation of that early and fragile machines from wood, cotton and strings, those up in the air wanted to through something to those down in the earth and vice versa. This created a race which affects and exploits almost every scientific field, whether it is chemistry, aerodynamics or microprocessors. Today's modern battlefields are dominated by the use of "flying machines", like military aircraft, helicopters and recently drones. In order to suppress the effects of this force, the Ground-Based Air Defense (GBAD) forces where created. In the history of warfare, GBAD saw successes and defeats, but today's air forces seem to "winning the game". Modern and future battlefield are going to stretch the capabilities of GBADs if they stay in the present form. Certain steps should be followed in order, not only, remedy the advances of air forces but also create an environment that will not be favourable to them. When discussing the challenges of the GBAD forces you can't ignore the importance of the air force. These two terms are linked together and in order to successfully create the framework of the GBAD's future, we have to closely examine the influence of the air force in GBAD's operations.

2. The Creation of the Ground-Based Air Defenses

While some people believe that the potentials of the aeroplane were quickly seen, even from the early years of its discovery, it is true – like every great invention – that only a couple of visionary officers show its true potential. First was an Italian General, Giulio Douhet[3], who wrote in 1909, and published in book form in 1921, "The Command of the

[1] Orville (* August 19, 1871 - † January 30, 1948) and Wilbur (* April 16, 1867 - † May 30, 1912) were American aviators, engineers and inventors which managed to invent, design and build the first heavier-than-the-air flying machine (aka Flyer I) with which managed to make the first control flight with a fixed wing airplane.

[2] Here should be made clear that the Wright brothers were not the first to create "flying machines". Various attempts precede their efforts, but this attempts were based in "balloons" and there weren't controlled.

[3] General Giulio Douhet (* May 30, 1869 - † February 15,, 1930), was an Italian military officer and air power visionary and theorist. Most famous about his book "The Command of the Air"

Air"[4]. It should be stated that when Douhet wrote his book the aeroplane was taking its first baby steps. As any breakthrough in mankind's history, Douhet's suggestions were either ignored or mocked at, and the aeroplane was not adequately used during the First World War, until the final years of the conflict. Even so, the aeroplane showed its potential by attacking targets in the air, in the ground and on the surface, together with its ability to reach cities, industrial complexes and civilian areas. Another visionary officer that quickly understood the abilities of an air force was General William "Billy" Mitchell[5], who took every effort in order to create a robust and capable air force, within the US Army. These abilities were the reason behind the creation of the Ground-Based Air Defenses or GBAD.

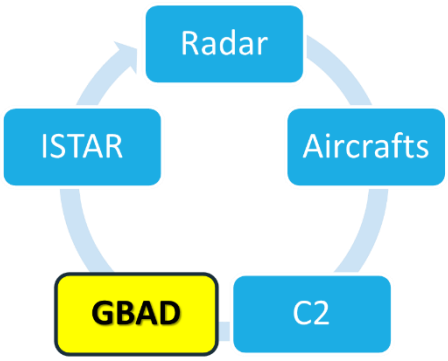
According to Douhet

"…the main purpose of the air power during the war should be the denial of use of all air force means by the enemy, by attacking to those in the air, in the ground and in the production centres. A holder of such air power could roam freely over the battlefield, interrupting the enemy supply and support lines…"

The above quote gives – in a couple of lines – the framework in which modern air forces are operating and in the same time gives the boundaries and key elements of GBAD operation. While there is no αντιστοιχος definition for the GBAD, the following definition proves adequate for the purpose of this paper.

"All defensive measures designed to destroy attacking enemy aircraft or missiles in the Earth's envelope of atmosphere, or to nullify or reduce the effectiveness of such attack[6]. Also called AD. It is divided into "Active", meaning attacking enemy's air force means and "Passive" air defence which includes all those measures necessary in order air defence means to avoid detection, targeting and destruction."

It should be stated that the GBAD forces are one link in the whole "air defence" environment. In general, the key mission of the air defence is to deny or mitigate the results or the effects – if you prefer – of the air power projected in the ground forces. These may include the destruction of the opponent's air force in the ground, the destruction of key infrastructure sites, like electrical power plants, bridges, key industrial installations and of course military elements. The following picture illustrates the complete "Air Defense" environment



3. Historical Background

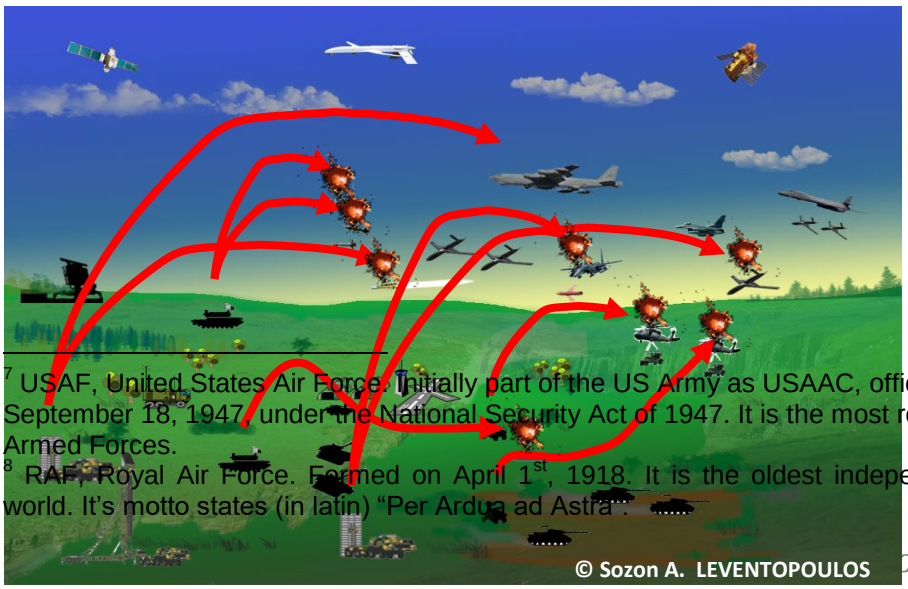
As mentioned earlier the first attempts to create a GBAD force where observed almost simultaneously with the appearance of aeroplanes on the battlefields. Since no one

[4] Original title: Il dominio dell'aria, first published in book in 1921, under the auspices of the Ministry of War.
[5] General William "Billy" Lendrum Mitchell (* December 29, 1879 - † February 19, 1936), was a US Army General and aviation pioneer. His efforts led to the creation of modern's day USAF.
[6] According to Dictionary of Military and Associated Terms, US Department of Defense.

had foreseen the effects and the threat that aeroplane posed in the conduct of ground operations, the first attempts were rather spontaneous and improvised. The situation was slightly better in big cities (like London) and in industrial areas. When the 1st World War ended many of the lessons learned were quickly forgotten, just to be remembered a few years later. The allied forces with the USAF[7] in leading position and closely followed by the Royal Air Force[8] have completely embraced Douhet's doctrine and took the necessary steps to implement it. While there is a huge debate about whether "carpet" and "strategic" bombing where actually effective or even ethical the truth is that contributed towards the end of the war. Additionally showed the boundaries and in many cases the failure of the GBAD forces in protecting and denying the use of the air by the enemy. The following table is indicative and shows the sorties and losses (estimated and from all causes) of the Luftwaffe during the "Battle of Britain".

Date	Sorties (Day)	Losses	Sorties (Night)	Losses
October 1940	**2300**	**79**	**5900**	**23**
November 1940	**925**	**65**	**6125**	**48**
December 1940	**650**	**24**	**3450**	**44**
January 1941	**675**	**7**	**2050**	**22**
Date	**Sorties (Day)**	**Losses**	**Sorties (Night)**	**Losses**
February 1941	**500**	**9**	**1450**	**18**
March 1941	**800**	**8**	**4275**	**46**
April 1941	**800**	**9**	**5250**	**58**
May 1941	**200**	**3**	**3800**	**55**

It is indicative that on 14 October 1940 the British GBAD forces fired 8326 rounds and **hit only 2 bombers from a force of 380** (maybe by lack?) and the in the raid during the 13N/14 November 1940, from a force of more than 140 German bombers **only one was shot down**. On the other side of the world, the Japanese Imperial Air Force and GBAD forces could not stop the devastation of Japanese cities and industrial complex and ultimately the use of 2 nuclear weapons in Hiroshima and



[7] USAF, United States Air Force. Initially part of the US Army as USAAC, officially founded on September 18, 1947, under the National Security Act of 1947. It is the most recent branch of US Armed Forces.

[8] RAF, Royal Air Force. Formed on April 1st, 1918. It is the oldest independent air force in the world. It's motto states (in latin) "Per Ardua ad Astra".

Nagasaki, which – pretty much – ended the war. In the years that followed 2nd World War the GBAD forces were created rather additional headaches to staff officers, than actual problems. A few examples are the Operation Mole Cricket 19, in which the Syrian GBAD complex in Beqaa Valley was actually annihilated by the combined use of RPVs, Electronic Warfare and air force, the Operation Desert Storm, which managed to cripple a well-designed air defense environment, where STEALTH aircrafts and attack helicopters[9] were used in SEAD/DEAD[10] missions and finally Operation Allied Force (Kosovo War) in which the air force actually won the war, even though the results on the ground were not as expected[11] and the first STEALTH aircraft was shot down[12] by a – legacy – GBAD system. The key element and common factor regarding the failure of GBAD forces should be looked for in the implementation, the doctrine and the framework that GBAD forces were used until today. Of course, it should be stated that during the past years GBAD forces managed to get ahead. In that view a number of various systems and capabilities where added in order to make the creation of "Anti-Access/ Area Denial" environments possible. The following picture illustrates such an environment. Today this is not the case since air forces moved forward in many levels in order to overcome and defeat it.

4. The Enemy

As mentioned earlier, the analysis of GBAD forces passes through and requires the analysis of the adversary, in our case the air force. Today we can categorize the threat that air forces pose into the following – major – categories:

- ✓ Air Breathing Targets (ABT)
- ✓ Ballistic Missiles (BMs)
- ✓ Unmanned Aerial Systems (UAS)
- ✓ High Precision Weapons
- ✓ Space
- ✓ Rocket – Artillery – Mortars (RAM)
- ✓ Cyber Space

4.1 Air Breathing Targets (ABT)

The "classical" aeroplanes and helicopters fall in this category. While we haven't seen major breakthroughs in aerodynamics or propulsion; yes we have supercruise and hyper agility, but we lack an innovation in flying dynamics or engines[13]. On the other

[9] See: Operation "Eager Anvil"
[10] SEAD: Suppression of Enemy Air Defense and DEAD: Destruction of Enemy Air Defense.
[11] It is reported but not proven yet that more than 80% of the AGM-88 HARM missiles that were fired, actually missed due to innovating measures taken by the Serbian forces.
[12] On March 27, 1999 at 20:15 (local) the 3rd Battalion of the 250th Air Def. Missile Brigade of the Yugoslavian Army equipped with legacy S-125 Neva AD System, under the command of Col. Dani, fired a salvo of 2 missiles against F-177A Nighthawk (s/n 82-0806, call sign "Vega 31") which hit and destroyed the aircraft in the first and only incident of shooting down a STEALTH aircraft.
[13] It is interested that the first airplane – Flyer I – used the whole wing in order to maneuver, by συστρέφοντάς την!! This simple and highly effective design is still far from mass production and implementation into modern and future aircrafts, despite the efforts and research by various agencies.

hand, modern fighters exploit a number of technological advances in order to upgrade their abilities and effectiveness. The main concept behind modern 5th and 6th generation fighters is Very Low Observability, which includes STEALTH technology, reduction of IR and visible footprint and the reduction of E-M broadcasts, like radar, radio and IFF. Fighters with STEALTH features (like the F-22A Raptor or the F-35 JSF, and many more) are possible today due to the extensive use of computers[14]. While there are many design concepts and every company is approaching the problem in the different way the key element remains the same. **Future aircraft would be much more difficult to detect, target and engage**. Advances in optronics create the background in order to introduce new systems with advanced capabilities, like the EO-DAS of the F-35, while the onboard radars have new and advanced features. While the effectiveness of the new AESA onboard radars against small RCS targets is unknown (at least for the public), are still a great tool, with future potential uses like electronic warfare, data transfer, etc. Finally the advances in computers and processing power made possible the fusion of data coming from various sources, thus creating an unprecedented situational awareness to the pilot. Concluding, future aircraft would be much more difficult to detect and engage and at the same time would have more and advanced fighting capabilities.

4.2 Ballistic Missiles (BMs)

The proliferation of the technology behind ballistic missiles to various legitimate and non-legitimate users is creating another threat vector to the GBAD forces. Ballistic missiles can be simple or complex designs packed with advanced capabilities, like the SS-NX-32 Bulava, which incorporates multiple Re-entry Vehicles (or RVs) together with decoys and EW capabilities. While Bulava seems a major threat, the truth is that small tactical ballistic missiles possess a more challenging one, which GBAD forces should take into serious account. Tactical ballistic missiles have limited range and are not equipped with EW and multiple RVs are easy to put into mass production and very difficult in finding the launching sites. If equipped with "dirty" payload, they can create havoc, if launched against a highly populated area.

[14] STEALTH features and aerodynamics are two opposite features. The first STEALTH fighter, the F-117A Nighthawk had limited manoeurability and – despite the F- (fighter) – its abilities in air combat were nonexistent. On the other hand Northrop Grumman with the aid of IBM create the framework (both software and hardware) in order to create a smooth surface and an excellent STEALTH bomber, the B-2A Spirit.

4.3 Unmanned Aerial Systems

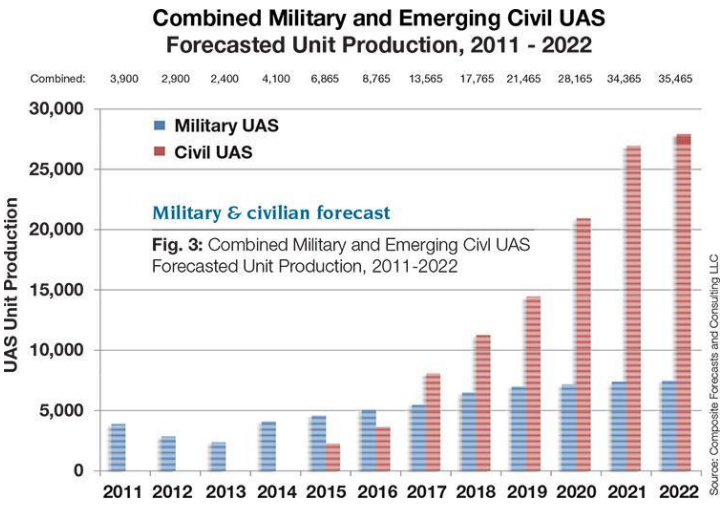


Fig. 3: Combined Military and Emerging Civil UAS Forecasted Unit Production, 2011-2022

While the common term is UAVs – Unmanned Aerial Vehicles or Drones[15], in this paper the term Unmanned Aerial Systems (UASs) is considered better because can include everything. From mini-UAVs to High Altitude Long Endurance (HALE) ones. Today in the US alone every year 10000 UAVs of all kinds are produced. Furthermore, the relevant technology is available to everyone and even someone with limited knowledge of computers and aerodynamics can create one. The key advantages that these systems have, are the reduced design, test and line-production costs which in return means that these systems can be produced in large numbers. Because these, unmanned systems, can be used in "high risk" operations, like SEAD/DEAD missions. In the near feature, the unmanned systems will be equipped with solar panels[16] in an effort to have – virtually – unlimited endurance together with their exploitation in new roles, like communications relay, which will have a reduced cost compare to the satellite equivalent. Furthermore, unmanned systems can be used in order to condense air defences and exhaust their payload[17]. **The future belongs to unmanned systems. Legacy manned aircraft will provide the role of "mother ship" to a variable number of unmanned combat systems.**

[15] The term *Drone* actually means the male of the honeybee and other bees. It is stingless and makes no honey.
[16] https://techcrunch.com/2017/01/11/google-titan/
[17] An early example of such an idea can be examined in Operation "Mole Cricket 19"

4.4 High Precision Weapons

During the early days of air warfare, the aeroplanes were forced to drop tons of bombs, just to hit a single target in a method known as "carpet bombing". While this maybe seemed sufficient during WW1 and WW2 and the early days of the Vietnam War, soon became clear that this was not the case. Using lots of "dump" munitions requires a large number of aircraft and crews (so high-risk missions) without the assurance regarding the outcome. As a result, high precision weapons were created and introduced in an effort to mitigate the risk and higher the efficiency of the missions. It is indicative that during Operation Desert Storm smart munitions and cruise missiles were less than 25% of the overall munitions dropped. This was reversed in Operation "Iraqi Freedom" was guided munitions of all types were 68% of the total weapons used. Today's high precision weapons and cruise missiles come with a number of advanced capabilities. In the early days of war in Vietnam, guidance was achieved with the help of another platform (aircraft or troops on the ground) using TV optical tracker or laser ones. This method was not perfect due to the vulnerability of TV and laser to weather and battlefield situations like smoke, fog, dust, etc. Modern weapons come with terrain following capabilities, GPS/INS navigation systems which give high precision (the GPS) and resilience to inference (the INS), advanced IR trackers and lethal warheads. The following picture depicting a TOMAHAWK cruise missile hitting a mockup of S-300 radar vehicle is indicative of the capabilities of modern high precision weapons. Finally, we should have in mind that tomorrow's weapons will have high-speed capabilities (i.e with the aid of scramjet/ramjet) and advanced optronics. The first example of these – new era – weapons is the BrahMos **ramjet supersonic cruise missile**.

4.5 Space

Space is the 4th dimension in the future (and current) battlefields. While a number of international treaties try to maintain a peaceful status regarding space, the truth is that space is exploited for military purposes. Today an increasing number of Nations have satellites with military missions whether it be military communications, navigation (the GPS constellation), surveillance (like HELIOS or DSP satellites) and more. Today's trend in space exploitation is the "cube sats", which consist of standard modules and frames. This type of satellite can be tailored to specific needs, launch quickly and cheap (compared to other satellites) and provide competitive results. In a large-scale warfare now one can predict if nations will not use space as the 4th battlefield dimension. Already the X-37B has the potential to be used as a weapon platform globally with – virtually – no countermeasure. So the friendly forces will be obliged to safeguard their assets in outer space and at the same time deny the use of that space from the enemy.

4.6 Rockets – Artillery – Mortars (or RAM)

The counter or C-RAM is playing a crucial role in modern-day warfare since the use of such systems is easy and can be done by rogue players with – virtually – no experience or need for extensive military infrastructure. Furthermore, the use of these systems is not limited to troops on the ground but can be extended and into civilian targets. The key aspects of this threat is that is cheap can be employed in large amounts (i.e. a single RM-70 rocket launcher can deliver 40 rockets in a matter of seconds) while the limited RCS and the flying time make them a difficult target to engage.

4.7 Cyber Space[18]

It is the newest addition to the 5th dimension of the future battlefields. Already the Georgian – Russian conflict of 2008 shed a glimpse of future hybrid military operations. The cyberspace and especially cybersecurity are taking higher and higher importance when designing military operations. Because cyber security is a huge subject and not part of the current presentation we can limit it to the following key points:

- ✓ We can never have a completely secure system.
- ✓ Human factor will always be the weakest link in the chain of security.
- ✓ Everyone is a target.

Cyberwarfare can "target" and civilian assets (i.e power grid) prior to or during conventional military operations. Cyberwarfare can also act as a "soft kill" alternative. While the casualties will be minimum (and that is an estimation) the consequences will be similar to that of a nuclear warfare. Current and future systems will have inherited (like the F-35 JSF) cyber warfare capabilities.

5. The Answer

5.1 Future Challenges

Based on the above-mentioned analysis we can define the future challenges of tomorrow's GBAD forces. These are:

- ➢ **Detection of targets will stretch the ability of current radars**
- ➢ **Unmanned systems will condense the future battlefield in a big number of roles**
- ➢ **Ballistic Missiles will remain a key component of the future threats**

[18] For more information, please refer to "Cyber Warfare – Affecting Land, Sea, Air and Space Operations", by Sozon A. LEVENTOPOULOS and Nikolaos BENIAS which can be found at the following site http://www.scienpress.com/journal_focus.asp?main_id=58&Sub_id=IV&Issue=186959

- **RAM will require considerable efforts to counter**
- **Munitions will enhance their targeting capabilities, range and lethality**
- **Space will be actively involved as the 4th dimension of the future battlefield**
- **Military operations in cyberspace (together with electronic warfare) will require a considerable amount of efforts and manpower in future conflicts**

5.2 The Proposal

Based on the above key factors, together with lessons learned from past conflict, we can outline the basic framework and the proposal regarding the future form of GBAD.

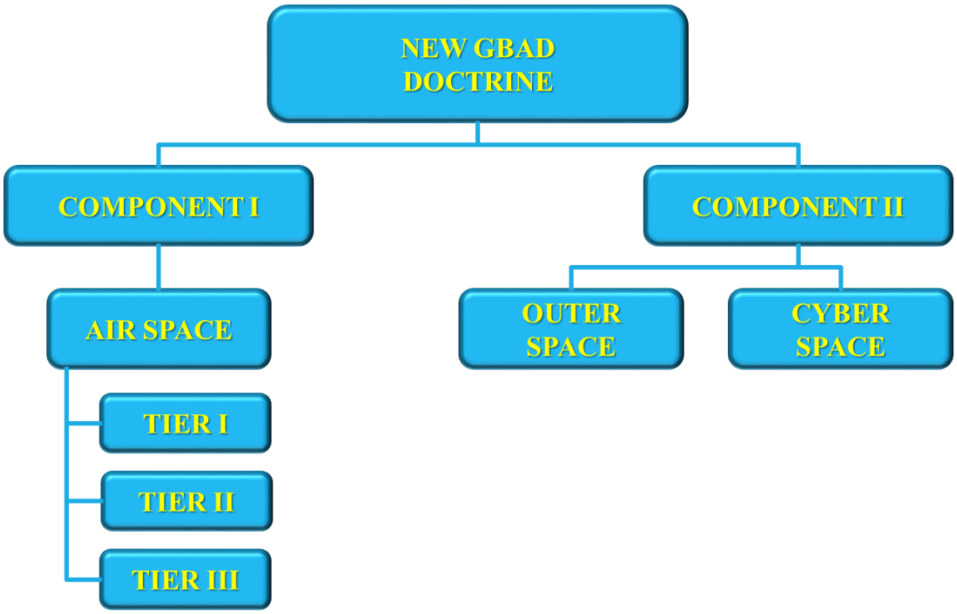
"The GBAD forces of the future should transfer their efforts from targeting and enabling the carriers to the detection, acquisition, targeting and engagement of the weapons/munitions, together with enhanced capabilities to operate and fight into the 4th (space) and 5th (cyberspace) dimension of the future battlefields."

This proposal is based on and supported by a number of key factors which – namely – are:

- **Detection, acquisition and tracking of targets is easier than that of the aircraft, even if the targets will have improved STEALTH characteristics**
- **Engagement of these targets requires fewer efforts**
- **Modern ground-based X-Band AESA radars can still operate successfully without any significant modifications**
- **Targets can be engaged in terminal ranges where their ability to manoeuvre is limited**

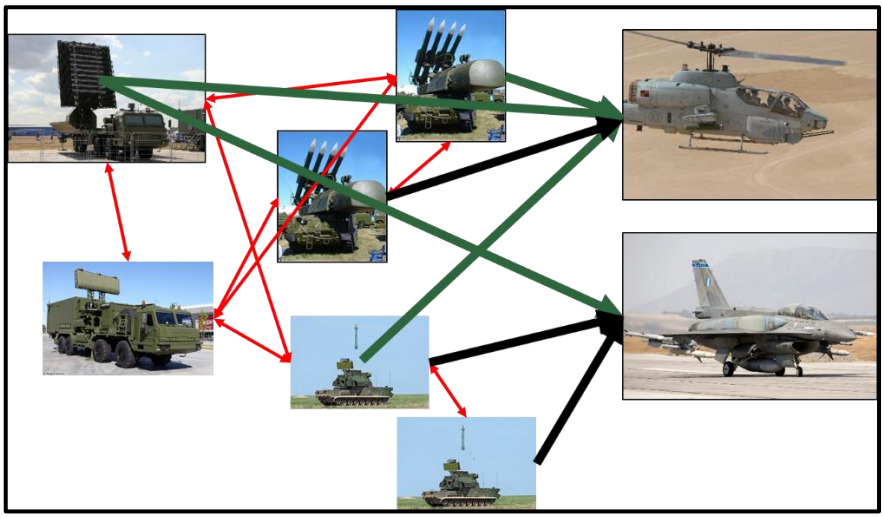
5.3 The Details

Moving forward this proposal is divided into two components. The first one is dividing the airspace into three tiers. The lower one, the middle one and the high tier.

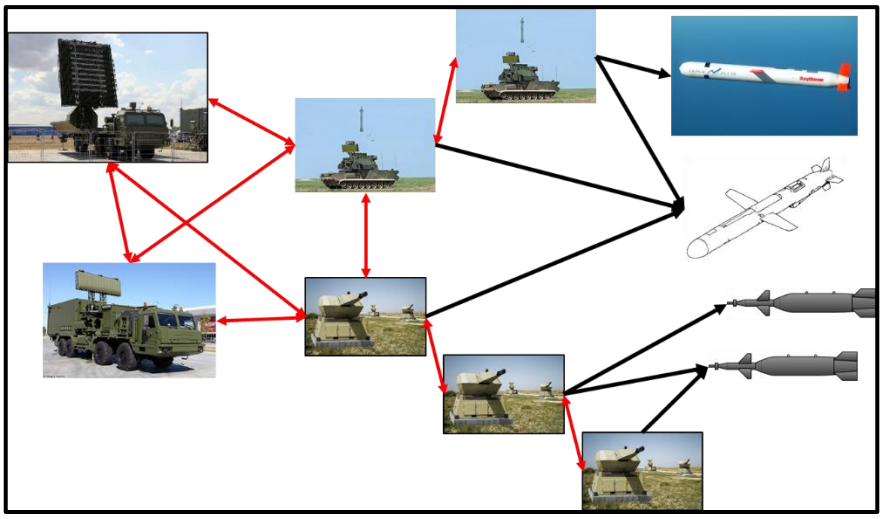


5.3.1 Tier I – The Low Tier

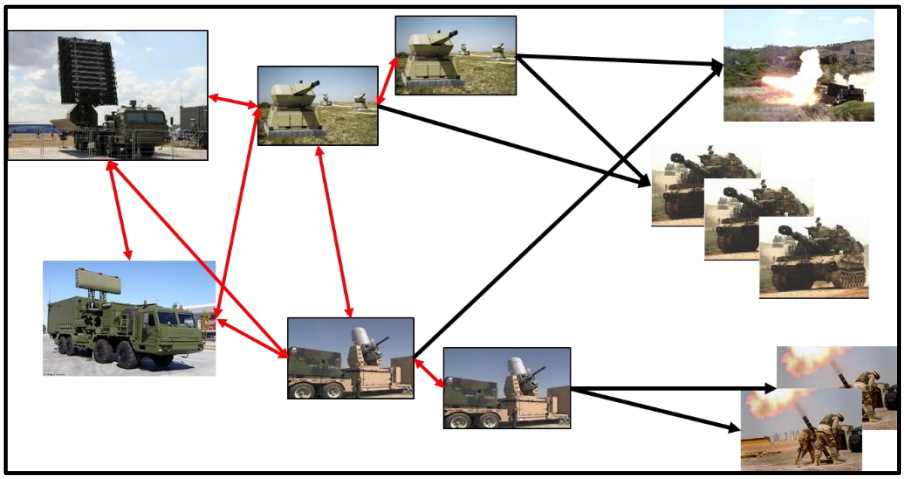
In the lower tier cruise missiles, RAM, small drones and conventional aircraft and helicopters are expected to operate. In this tier, the primary goal of the GBAD forces will be two-fold. Firstly to engage the munitions regardless the launching carrier. This can be achieved by X band radars and either hit-to-kill missiles or AAA guns equipped with a form of programmable munitions (like AHEAD). Secondly to counter both unmanned systems and RAM. The latter can be achieved again with the use of AAA. The CIWS tailored in such a way that can accurately track and engage this threat can be a valuable solution, taking also into account the high rate of fire. Additionally, the use of X band radars for both detection and tracking but also as a microwave weapon against drones can be the answer. For example, a new generation of counter-artillery radars (a modern version of TPQ series) with the ability to detect, track, engage aerial targets but also plot the launching sites can be a great solution. A graphical example of Tier I is illustrated in the following pictures



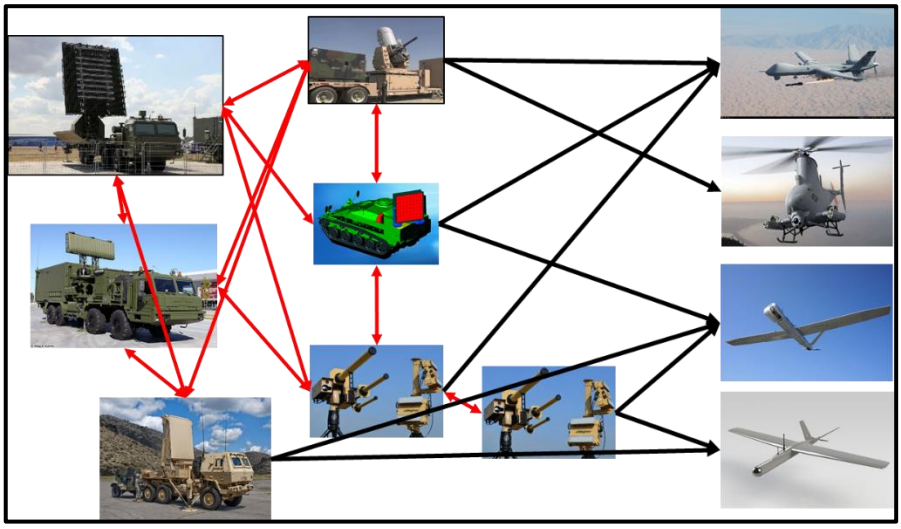
Confronting threats from legacy aircraft and attack helicopters.



Dealing with high precision weapons with the use of terminal defences.



Confronting RAM with the use of terminal defences.



Confronting Unmanned Aerial Systems. It should be noted here that high power weapons based on microwave waves may be the solution when operating in a dense environment. **The use of modern fire finding location systems may be the answer for**

both locating and eliminating UASs.

5.3.2 Tier II – The Middle Tier

In the middle tier, STEALTH aircraft and MALE UAVs are expected to operate. This is the most challenging tier since we have to change or enhance the performance of modern day radars. One solution could be the creation of a new generation of VHF radars combined with L and X band components. As expected the VHF radars have an excellent performance against STEALTH targets but their resolution cell cannot provide the necessary data for tracking and it is the part where X (or equivalent) radars are coming in. Other technologies include Over the Horizon - OTH radars, bi or multi-static radars, Passive Coherent Locators or even ESM systems that can track targets based on their electromagnetic emissions (like radar, data-links, etc.) can be employed. Every proposed solution have its advantages and disadvantages and true performance data are not available for public information! Additionally, a part of TBM targets will operate in this tier. Detection and engagement of this systems are easy even with the current technology. A future component could be the integration of laser systems. Because the power supply needs for these systems to operate, is easily available in ground installations (can be easily connected to the current power grid) implementation of laser weapons or even rail-gun can be rather easy. One element that should be improved is that of the reloading. Future lasers or rail-guns should be able to quickly "recharge" in order to successfully counter combined attacks. One good starting point is the magnetic catapults in the newly build aircraft carriers. If they can launch a multi-ton aircraft into the air and be able to support intense air operations surely can launch a small round repeatedly and at high speeds. The following table illustrates a number of systems together with advantages and disadvantages.

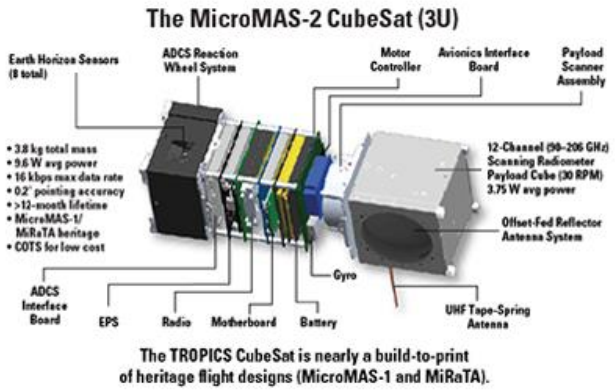
System	Pros	Cons
Over The Horizon Radar	Over the Horizon Anti – STEALTH Both air and naval targets Doppler capable	Large Installations (=target) Performance depends on weather and conditions in the ionosphere No tracking ability
Multi-Static Radar	Anti-STEALTH Based on Doppler Can track Redundancy	Very difficult processing algorithms Complex
Passive Coherent Locators	Anti-STEALTH Low cost (COTS) Redundancy The source does not radiate	Good only where there is a signal Requires computer processing power Signal Processing can be challenging

5.3.3 Tier III – The High Tier

Finally, the high tier is where TBMs and HALE unmanned systems are expected to operate. Current systems like THAAD or S-400/500 are designed to confront such threats and can successfully operate in the near future. Again laser and especially onboard aircraft systems can be implemented in an effort to confront these threats in the early stages of their flight. Laser weapons can also be implemented against HALE unmanned systems. **Here it should be highly stated that systems in all of the three tiers should be incorporated into a single network, a living organism if you like, where every bit of information will be processed and presented accordingly**.

5.3.4 Component II – Outer Space

Regarding space the problem is twofold. Firstly we should protect our assets against the enemy attacks and secondly deny the use of these assets from the enemy. While attacking is rather simply – but probably highly illegal – defending it is virtually impossible. Today is rather simple for internet users to track satellites, even the top-secret ones. Surely a dedicated enemy can achieve more. One proposed solution is the use of cube-sats. Cube-sats are cheap, can be tailored made to answer certain needs (i.e. communications or early warning), can be launched with various methods and even concealed under an irrelevant mission of a civilian satellite and are difficult to track and engage due to their size.



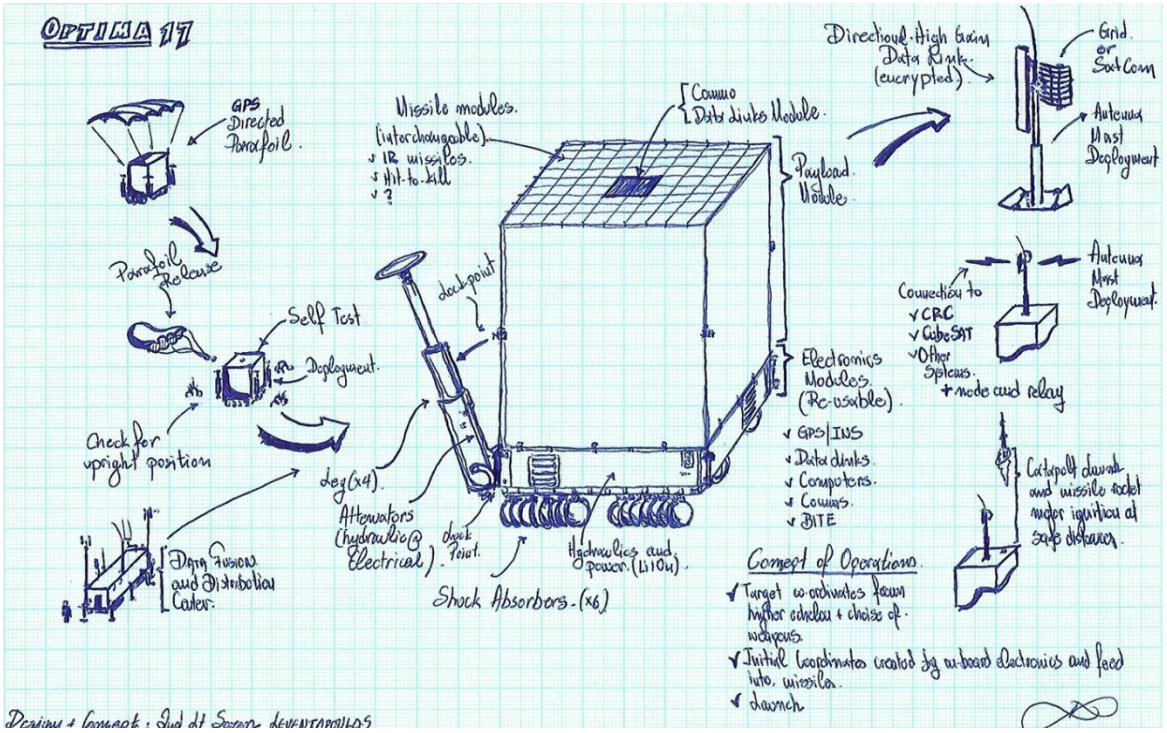
The TROPICS CubeSat is nearly a build-to-print of heritage flight designs (MicroMAS-1 and MiRaTA).

5.3.5 Component II – Cyber Space

Regarding cyberspace, the problem is too big to analyze in the current presentation. Briefly, the GBAD units should be able to attack and defend. Attacking should not be limited into networks and ISTAR installations but also against weapon systems. For example, various reports claim that the ALIS program of the F-35 is rather vulnerable against cyber-attacks. One key aspect that should be taken into curious account is the human factor and future GBAD forces should be ready to eliminate or at least mitigate the impact of the human factor in cyber operations. It should be stated that cyber warfare is far more complex than presented in the current paper. For more information and a detailed analysis regarding cyber warfare, its challenges and key components please refer to footnote 17.

5.3.6 A New System?

The following picture illustrates a new AD system proposal (early stage) which can be deployed in a matter of seconds, will be fully automatic and unmanned with advanced (based in a form of AI) features and capabilities.



6. Epilogue

For years GBAD forces were drawing circles in the map. If the circles were "looking nice" and overlapping then everyone considered "job done". Of course air force could always penetrate these circles because the latter never understood the challenges posed by the air force. Today is time to move forward from circles and **start thinking "out of the box"**. One solution could be the vertical division as described above. Furthermore, GBAD should move their centre of gravity from carriers (the aircraft) to the payload (the weapons); the Serbian Air Defense managed to shoot down an F-117 STEALTH fighter, but ultimately lost the war. Advances in processing power, microelectronics and networks can give the necessary boost for GBAD units and systems. Finally, we should always remember that **UNITY=STRENGTH** and in GBAD example **unity means interconnection**. *It is time for GBAD forces to move ahead!*

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