TOWARDS AFFORDABLE WEAPONS

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The following propositions need no documentation. They are universally accepted:

- the cost of Information Technology & Communication equipment per unit of performance continues to decline (as suggested by Grosch's Law: "the cost of computing systems increases as the square root of the computational power of the systems")

- the proportion of costs attributable to Information Technology & Communication equipment in the total cost of weapon systems continues to increase.

Therefore, other things being equal as Anglo-Saxon partial equilibrium economists like to say, the unit cost of weapon systems should have declined greatly, and should continue to decline.

Yet, notoriously, weapons have not become cheaper but more expensive, and that is true of each and every category of weapons, whether combat aircraft, warships, armored fighting vehicles, air-defense radars, or any other such.

Evidently, other things are not equal. The most obvious cause of increasing unit costs is the decline in the production rates of weapon systems, which generates negative economies to scale. That decline has been drastic, and so are the industrial consequences.

Weapon systems were once mass-produced. As in all forms of manufacturing, that made it possible to produce equipment of increasing performance at declining unit costs, by investing in dedicated production equipment and infrastructures, automated machinery and specialized tooling, up to the extent justified by the economies obtained, and allowed by available technologies.

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Unit costs were thus reduced by replacing labor with capital equipment. During the Second World War, even when monetary savings as such were not always the highest priority, the efficiency of highly capitalized mass production was still highly valued, because it increased the supply of weapon systems. Besides, even if budgets were not limited, the supply of highly skilled labor always was, and that is what highly capitalized plants replaced. Moreover, when labor is replaced by machines the homogeneity of the output increases—and that usually means that the quality increases.

Now also available but underutilized technologies would allow further savings of labor, even to the point of robotic production But because so few weapon systems are produced, investments in more automated machinery cannot be economical in many cases.

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In stark contrast to civilian industry, in which customized and flexible, IT-controlled or robotic production equipment has been added to classic mass-production lines, as exemplified by automobile plants for example, many weapon systems are actually hand-made to a large extent, with a profligate use of costly skilled and highly skilled labor equipped more with power tools and static jigs rather than automated machinery.

That in turn generates additional costs because humans are less reliable than machines, and the greater the manual content of production, the greater is the potential for manufacturing errors that require repairs or replacement and cause disruptive delays

But then of course a production capacity of 200,000 per year is more or less a minimum for an automobile plant, while in the realm of defense production not even small arms are produced in such numbers, let alone anything as elaborate as a car.

1.

It is worth looking at specific examples to comprehend the magnitudes involved when comparing past and present production rates and economies-to-scale.

Consider the production runs of the famous fighters of WWII versus today's best-selling jet fighters: *Messerschmitt Bf 109*: 30,000 +; *Focke-Wulf FW 190*: 20,000+; *Supermarine Spitfire*: 33,198; *Yak-9*: 16,700; *Mitsubishi Zero*: 10,936 – and the late-comer North American *P-51 Mustang*: 15,586. These production runs lasted 6-7 years or less, with annual production rates ranging from 1,500 to 3000 per year, i.e. 4 to 8 per day on average.

By contrast, a total of 4,300 *F-16*s have been produced in 28 years (1978-2006) = 153/year, i.e. 0.4/day on average. That number is low, yet still much higher than in the case of the *F-18*, the other contemporary US fighter, let alone the *Eurofighter*, the *Sukhoi 27-30* series, or the *Rafale*.

2.

The 0.4 per day cumulative *F-16* production rate, moreover greatly overstates the economies to scale that actually obtainable, because 28 years is a long time and many modifications and upgrades were introduced to overcome obsolescence; each of which imposed its own learning curve and temporary loss of production efficiency. The difference between the Block 1 *F-16*s of 1978 (IOC 1979) and the current Block 50/52 is so great that they are scarcely the same aircraft – they certainly have much less commonality that the first and last versions of the *Spitfire* or *Messerschmitt Bf 109*.

For the same reason, even the most successful fighters of the Cold War that were produced in greater numbers did not achieve much greater economies to scale: the 9,860 *Sabre F-86*s were assembled in three different countries in several variants, while the *MiG-21*s that entered service with some fifty air forces was produced in several variants over some twenty-five years, not counting aircraft still now being re-manufactured. Thus *Mig-21* production rates and the resulting industrial efficiencies were not much better than those of the 2,578 *Starfighter F-104*s or the 5,195 *Phantom II F-4*s produced between 1958 and 1979, though still much better than those of all other fighter aircraft, including the Dassault *Mirage* series, successful though it was commercially (531 *Mirage V*s, *523 Mirage IIIE*s), though those numbers too remain a wonder for Dassault whose *Rafale* has been in production for some ten years without reaching the hundred mark.

3.

Nor are fighter aircraft the worst category from the viewpoint of diminished production rates and the resulting inefficiencies – in fact they are one of the better categories. Remaining with aircraft, we note that in WWII even bombers were produced in numbers exceeding 10,000: Boeing *B-17 Flying Fortress*: 12,726; *Consolidated B-24 Liberator* 18,188; *Junkers JU88*: 15,000+; *Wellington*: 11,461; and the ground-attack *Ilyushin Il-2 Sturmovik* (a much smaller machine): 31,163. Again that translates in peak production rates of 3-4 per day. Those numbers can be compared to the production rates of contemporary bombers such as the *B-2* or the *Tu-160* running at 3-5 *per year*, not per day.

4.

Armored fighting vehicles have undergone much the same decline in production rates. Even the Germans, whose tank production was afflicted by wrongheaded industrial policies which did more damage than Allied bombing, managed to turn out 8,544 *PzKpw IV*s from 1937 to 1945, a miserable performance as compared to the bigger and better *Sherman M4*, of which 21,231 were produced in the calendar year 1943 alone, or the superior Soviet *T-34*, of which 34,780 were produced from 1940 till 1944.

Because of the centrality of the "inter-German border" as the central front of the Cold War and the resulting focus on continental warfare and therefore armored warfare, tank production figures remained high after 1945, though again not production rates, except during the Korean War years of accelerated rearmament. Thus some 12,000 US *M48*s were built from 1952 to 1959, followed by more than 15,000 *M60*s though over twenty years, so that production rates declined from 1700 to 750 per year. Because of its very extended production run (1951-1981) the *T-54/T-55* series did not achieve economies to scale proportionate to its total production of some 65,000 in all variants – more than any tank, or tank series for that matter – and nor does the *T-80* now, although 20,000 have been produced – since 1983 however.

But those are of course huge numbers as compared to recent tank production. There have been total production runs as small as 400 (Italy's *Ariete*) and not even annual production rates in the low tens are considered extravagantly inefficient.

5.

In the case of warships, production rates were necessarily low even at the height of WWII, with few exceptions such as US *Fletcher-class* (175 commissioned, 1942-44) and *Gearing class* destroyers (98 commissioned, 1944-1946). Since then warships worldwide have been acquired in very small numbers, with few exceptions such as the USN's *Spruance DD 963*-class (30 commissioned 1973-1979) the *Arleigh Burke* class (27 since 1989) and still in production in an upgraded version. As for the Soviet Union, it mass produced diesel-electric submarines in the 1950s turning out 256 W-class (NATO designation) boats in nine different shipyards, and much later 40 *Krivak* class frigates were built; otherwise the USSR followed the US in producing fewer and fewer warships, with shipbuilding processes and methods necessarily much less efficient than those of competitive civilian yards.

6.

So the explanation seems simple, and the remedy seems impossible. If the unit cost of weapon systems continues to increase because too few are produced to be produced efficiently, then there would be no other solution than to produce many of them. But that is an obvious impossibility – not even the US could pay for 15,586 *F-35 Joint Strike Fighters*, infinitely more elaborate aircraft than the *P-51 Mustang* ever was, nor could the USAF begin to absorb them, while the US Army could not make much use of 20,000 of 21,231 *M1A2* tanks whose cost would be much higher than the *Sherman* even if built in like numbers, because of its much more elaborate armor and systems.

7.

This reminds us that the unit costs of weapon systems have continued to increase not just because fewer and fewer are acquired, but also because of their increasing complexity and advancement.

8.

From the perspective of the bigger armed forces, the ones that would acquire weapons and systems in greater numbers if they could afford them, a vicious circle has long been at work:

- weapons are expensive, so few are acquired
- weapons are few, so they require superior performance
- that requires macro- and micro-innovations that are costly
- that makes weapons even more expensive, so that fewer are acquired...

And so it has continued from the 1950s till the present, in a downward spiral – except that the time needed to bring innovations into production makes the spiral worse, because weapons that will not be fielded for many years ahead must promise even higher performance, which increases costs, further reducing acquisition numbers...

Traditional platforms and classic weapons as cost-drivers and performance-degraders

1.

There have been many wars and upheavals since 1945 as well as much scientific and technological advancement. But there has been nothing as revolutionary as a prolonged world war that fully engaged the energies of the leading countries, overthrowing all that is outdated and opening the way for macro-innovations.

That is why the platform and weapon configurations that emerged from the Second World War have remained so resistant to change, in spite of all the new possibilities opened by technological advancements since 1945.

Now these traditional configurations that date back sixty years or more have become severe obstacles to military advancement, and they compound the ill consequences of the procurement paradox to deny a more Affordable Defense.

2.

That happens because instead of shaping new platform and weapon configurations to fit them, today's IT, communications, sensor and guidance technologies must fit into the nooks and crannies of 1945-pattern platforms. It is very costly to fit everything where it does not really belong.

Moreover, those platforms retain their 1945 character as autonomously operating units – even though in war they would always operate in groups anyway, not by themselves.

3.

For example, the procurement paradox dictates that airborne radars, including the latest AESA (Active Electronically Scanned Arrays) must be altogether more expensive – say 100 times as expensive pound for pound – as even the most advanced and elaborate of high-definition television sets. But what makes them a 1,000 more expensive is the need to miniaturize and package AESA technology to fit into the nose-cones of fighter aircraft, whose function is actually aerodynamic, and which were never meant to house, power, refrigerate and secure equipment as elaborate as an AESA set.

4.

Given the combat value of highly powered AESA sets, which can not only detect, acquire and track multiple targets but also attack electronic circuitry with focused beams, combat aircraft should be designed around them, and not the other way around.

More effectively, it is task forces of dissimilar combat aircraft that should be designed around them, some with AESA sets, others with a greater weapons load, others equipped for defense suppression and so on.

Instead, in the *F-18* and *F-15* aircraft that have them, it is one AESA set per aircraft nose-cone just as it was with mechanically-scanned radars when those aircraft were originally designed more than thirty years ago (the *F-15A* first flew in 1972 and the *YF-17* in 1974), and indeed much before then,

5.

The same is true of most other new technologies and of most platforms. Instead of providing suitable and economical forms into which the new content can easily be accommodated, the new must be miniaturized and contorted so that it can fit into old forms, greatly increasing costs while reducing effectiveness.

For all the talk of heady advancement and breakthrough, the 1945 platforms have proven to be amazingly persistent, evidently because 1945 force-structures have not been modernized either.

6. Item: combat aircraft

There were no dedicated fighter aircraft in 1914 but only varied biplanes and triplanes, none of them armed. In the crucible of war, there was drastic innovation.

31 years later in 1945, the jet-propelled monoplane fighter and fighter-bomber (*Messerschmitt 262*) was already flying.

61 years later in 2006, instead of drastic changes to accommodate the IT revolution, networked communications, sensor relays etc., the 1945 configuration has not changed at all.

All the current fighters in service and those on offer, the *F-15, F-16, F-18, F-22, F-35 JSF*, the *Eurofighter, Rafale, MiG 29, Su-27/30* still perpetuate the *Me 262* configuration, with their one or two aircrew, their own sensors for self-sufficient operation in both air-to-air and air-to-ground missions.

7.

They also perpetuate a 1945 conception of air power, in which the fighter pilot is an airborne knight with all his weapons on his flying horse, ready to battle against the enemy on his own, unless there is a second crewman to play the loyal companion in self-sufficient combat. From that the homogeneity principle follows, whereby the aircraft are all equipped in the same way without any task-force optimization, even though fighter aircraft are most unlikely to be sent into action on their own.

8. Item: battle tanks

There were no armored fighting vehicles in 1914 but only wheeled trucks and tractors, none of them armed.

31 years later in 1945, the heavily armored Main Battle Tank manned by 4-5 crew and with the main armament a high-velocity long-barreled gun in a freely rotating turret (*T-34, Sherman, Panther*, *Tiger*) was already operating.

61 years later in 2006, instead of drastic platform innovation to respond to the proliferation of light armor-piercing weapons on the one hand, and of surface-to-surface missiles on the other, today's *MBT*s, the *M1*, *T-80*, *Leopard, AMX-50* etc. can all still be confused with a *Panzerkampfwagen VI Sd.Kfz 182* ("*King Tiger*") of 1944.

Nor is the similarity superficial, because today's tanks still rely on a high-velocity gun as their main armament, as if guided missiles had never been invented, and because the performance improvements they embody are indeed incremental – not revolutionary as they were between the tanks of 1918 and those of 1945.

Instead of altogether greater striking power, today's tanks are burdened with more and more active and passive defenses against anti-tank missiles that cost 1% as much as they do, if that.

9. Item: aircraft carriers

There were no aircraft carriers in 1914 but only seaplane tenders (or rather one, *HMS Hermes*).

31 years later in 1945, the large-deck aircraft carrier with below-deck hangar space, only a small island on top, hydraulic catapults for launching and arrestor cables for recovery had already become the capital ship of the age, valued for its ability to bring air power to bear without aircraft range limits, at a time when they were severe and unrelieved by aerial refueling.

61 years later, the very same 1945 platform configuration remains unchanged by all the subsequent improvements large and small, from steam catapults and angled decks to nuclear propulsion.

Manned aircraft can now have global range and so can missiles so that sea-basing is no longer a prerequisite as it once was.

On the other hand, the advent of guided weapons has both made large aircraft carriers perilously concentrated targets, and also allows strike aircraft manned and unmanned, land-based or sea based to be more effective while delivering smaller tonnages of ordnance.

10.

The fighter aircraft, main battle tank and aircraft carriers are of central importance for their respective arms, so much so that the renewal of those specific platforms with ever more perfected new versions of the very same classic forms, greatly preoccupies service organizations and service chiefs.

There are of course other 1945 and post-1945 traditional platforms and weapons that are resistant to change in ways that increase costs and degrade effectiveness, including the classic medium field artillery, over-the-beach amphibious vessels and vehicles and the attack helicopter.

All are valuable – but only as specialized equipment, because these days much can be done with guided mortar bombs and flexible air power, and because large-scale opposed amphibious landings in the 1944 style and assaults by massed attack helicopters cannot possibly succeed in modern conditions against armed enemies. Both are simply too vulnerable to contemporary weapons, even if not especially well handled. (In the 1991 Iraq war the Marine landing was canceled because of a handful of modern mines, while in the 2003 Iraq war the US Army's *AH-64*s failed against Iraqi armored forces of low quality, suffering much damage while inflicting little. Large metal objects that fly slowly just cannot coexist with anti-aircraft weapons, even not very good ones that jet fighters need not fear greatly

Macro-innovation for a more affordable defense

1.

It follows that the key to a more affordable defense on the equipment side is to break the stranglehold of traditional platforms and weapons, so as to achieve macro-innovation with new configurations, instead of resisting obsolescence with micro-innovations. They can only improve old configurations incrementally – yet at great cost because of the procurement paradox and its downward cost/numbers spiral.

2.

Therefore the international ("cross-country") experiences of particular interest are those that introduce new platform and weapon configurations, and – as important if not more so – new combinations of both.

3.

Instead of the 1945 model of maximum homogeneity in platforms and weapons, (mass armies, air forces and navies needed mass-produced equipment), current circumstances and today's technology favors heterogeneity and mixed task forces.

4.

For example, there are now many kinds of sensors, and sensor data can be securely communicated up and down the chain of command, as well as distributed in real time to different platforms.

Therefore, not all platforms need all their own sensors. The individual platforms of an air squadron, tank battalion or missile-boat flotilla can have dissimilar sensor suits, either to reduce costs, or to increase total sensor performance, or some combination of both.

Two actual examples of new platforms are examined in what follows by way of conclusion, neither of them futuristic fantasies, because both actually exist in various forms, though both platform concepts are still grossly underutilized.

Conclusion

New Platforms I: unmanned aerial vehicles.

UAVs are not new at all – many were operating in the 1950s and drones were flying long before then. Moreover, the simplest function of UAVs, to fly over the enemy to observe "the other side of the hill" is a requirement so elemental that in the past supposedly conservative armies rushed into service anything that could fly, from hot-air balloons as of the eighteenth century to biplanes as of 1911 (The Italian war against Ottoman Turkey).

Likewise, by June 1982 the Israeli army incorporated observation RPV as they were then known into the 162nd division that fought in Lebanon, and the results of that experience was widely shared, in the first instance with the US.

Yet the integration of UAVs within each relevant echelon *as organic equipment* has only just started. This is due more to diffused institutional resistance to all non-classic platforms, than to the opposition of pilot-dominated forces to pilotless aircraft.

The result in any case is that even in the richly equipped US Army and US Marine Corps along with other leading ground forces around the world, UAVs are still only available for some echelons and not others, some formations and not others, and more as experimental machines than standard issue equipment.

2.

Institutional resistance can be documented. For example, the *IAI/TRW Hunter* UAV program was canceled in 1996 because US Army evaluators found many and severe defects: range was inadequate, the data link was unsatisfactory, the *Hunter* was too big to fit into the designated transport aircraft, the software was unstable and the engines too were unacceptable. After considering or purporting to consider an absurdly expensive US $2 billion dollar (!) program to remedy those defects–it would have increased cost of by US$38 million (!). For each one of 52 Hunters, the planned acquisition was canceled.

So far it seems a straightforward case of not buying defective equipment.

But as it happens the initial batch of unimproved *Hunters* that was supposedly crippled by many and severe defects remained in hand, and this is what has been done with them till now:

– In the spring of 1999, eight surviving *Hunters*, redesignated "*RQ-5A*," were sent to Albania to support operation *Allied Force*, the NATO air campaign against Serbia

In 281 (!) sorties the *Hunters* provided real-time video to senior officers on the spot and through satellite links, to both US and Europe headquarters (NATO commander US General Wesley Clark valued that flow of Intelligence so highly that he would contact the *Hunter* team directly).

During *Allied Force*, *Hunters* detected targets such as air-defense radars, artillery and missile launchers, staying on station during attacks for immediate damage assessments that reduced re-strike needs. The *Hunters* were flown very low unlike manned aircraft (kept above 15,000 feet by order): two were damaged and repaired, one flew into a mountain, and five were lost in action, apparently shot down.

In 2002, the *Hunters* were used again in experiments, to drop "*Brilliant Antiarmor Munitions* (BATs)," that have an acoustic/infrared seeker. A test drop of four BATs in early October 2002 scored three direct hits on tank targets. Later a *Hunter* also performed drops of the BAT derivative "*Viper Strike*" fitted with a laser seeker: nine drops resulted in seven hits.

In 2003, the US Army used *Hunters* in the invasion of Iraq and the subsequent occupation

By mid-2004, *Hunters* had flown 30,000 flight hours, and 14 more were purchased.

3.

Evidently, the 1996 cancellation was due to unnecessary or exaggerated requirements, exactly as in the case of previous US Army attempts to acquire UAVs or RPVs as they were then known, and specifically the Lockheed Aquila program.

This is simply another and more insidious form of institutional resistance to new platform configurations.

4.

Instead of simply refusing to consider them, new platform configurations, in this case UAVs, can be *de-natured* by requiring performance and reliability characteristics appropriate to manned platforms. Following that path leads to UAVs that are as costly as manned platforms or more so, but of course still lacking in manned performance. The program can then be canceled.

The UAV configuration is inherently suited for:

- small aircraft – down to hand-launched size or much larger, but still too small to hold a human in the cockpit, variously fitted out for observation, relay, very light strike, etc.

- long endurance – which would require living facilities aboard a manned aircraft

- ultra-long range. as well as long endurance, for the same reason

Equally, UAVs are *not* suited for the delivery of fighter-bomber payloads, except in a one-way/one-time missile configuration, simply because an aircraft that carries a large payload and has enough acceleration and enough reliability to return can also contain a crew, and cannot have a cost advantage once UAV-specific control costs are added.

5.

It is possible that UAVs have finally overcome institutional barriers in the more advanced armed forces around the world (e.g. the USAF has just issued the requirement that its *F-35 JSF*s should be produced in an unmanned version as well, the institutional barriers to UAVs).

But that will become certain when the next necessary step is taken: the deployment of UAVs in groups, as squadrons, fleets etc., so that they can operate synergistically as manned platforms now do.

When that happens a new level of maturity in using UAVs will have been reached, and a new requirement will then emerge: automatic or almost automatic operation.

Once UAVs cease to be rarities and experiments, once they are deployed as broadly as they should be, it will be found that they consume excessive numbers of pilot-rated personnel, unless largely automated as they indeed can be, from initial check-out, loading and take off to landing.

New Platforms II: the *Versatile Combat Aircraft*

6.

Multi-role fighters became all the rage in the 1960s after the abandonment of the interceptor/interdiction distinction, and lately Dassault bravely markets its *Rafale* fighter as "omni-role" (although it does not make tea).

There is no doubt that under whatever name, it was an advance in the 1960s to abandon increasingly obsolete distinctions between interceptors and other fighters and fighter-bombers (and interdiction aircraft), which were only prolonged into the 1960s because there were still distinct "interceptor" commands (PVO Strany in the USSR, the USAF Air Defense Command etc.) which shared the proclivity of the US Marine Corps to have their very own aircraft, not flown by other commands or services.

7.

Now the time has come for another advance, to transfer:

- specialized sensor
- hub communications
- command and control; and, also
- stand-off weapon delivery functions,

from:

fighters, fighter-bombers, and all other relatively small, tightly-packed aircraft with one/two crew, wherein all of the above must be squeezed into very restricted and fragmented spaces at great cost, and with little flexibility to modify, upgrade or replace,

to:

the relatively large Versatile Combat Aircraft – no smaller than a long-range executive jet but more often larger – whose main cabin can accommodate a good number of equipment racks as well as operating personnel, and which has most or all of the following attributes:

- a fuselage fitted with connectors for dorsal, lateral and belly antennae

- one or more internal bays from which sensors and free-fall weapons can be dropped

- wings with "smart" hard points for sensor pods and launched or dropped weapons

- and aerial refueling provisions, in and out.

8.

No such aircraft can be cheap, and in larger and more complete versions based on such aircraft as the *777-200* or *A-340-5* or yet larger *747*s or *A-380*s, the *Versatile Combat Aircraft* would be very expensive indeed.

9.

Yet VCAs would still be very *economical,* that is to say very cost-effective, for countries that do have expansive operational requirements over considerable distances.

For such countries, VCAs could save vast amounts of money as compared to the variety of different platforms that they would replace, while providing unconventional looking but certainly greater capabilities. They, moreover, would be far more easily and cheaply kept up to date with upgrades, modifications and new modules than the capabilities of the present tightly-packed platforms.

10.

VCAs would achieve cost-effectiveness in three distinct ways:

Versatility:

the same aircraft, not merely the same type of aircraft, could be fitted out as needed by loading specific equipment in the racks, the boarding of the appropriate operating personnel of the relevant branch(s), command(s) and service(s), and by the uploading of the mission-specific expendable sensors and weapons in the bay or at the hard points, so as to serve for each separate function, including:

- maritime surveillance and classification and surface strike

- anti-submarine detection, location and attack;

- airborne early warning and BVR interception with long-range air-to-air missiles
- airborne command, control and tactical direction of air, ground or naval forces
- detection and classification of surface targets with Synthetic Aperture Radar (low AA-threat) – attack of detected surface targets in low AA-threat environments
- as above, with added sensor capabilities against low-contrast targets via controlled UAVs
- as above, in higher threat AA environments, by means of ECM and kinetic suppression
- transport, including parachute drop from bays
- airborne refueling, in and out.
- ELINT and ESM

And such other missions as a low-acceleration, low maneuverability, non-stealthy aircraft of long range and longer endurance can perform.

Force-wide flexibility:

because the same aircraft, not merely the same type of aircraft would perform functions now fragmented among different platforms, each of which offers its own non-fungible capabilities that cannot be merged in order to be surged, as with VCA capabilities.

The importance of this attribute also depends on the variety of missions that are now performed, or need to be performed.

Commonalities combined with Synergies

Synergies are advantages derived from diversities that are themselves costly, but with the VCA they can be obtained in full while at the same time having the cost savings of commonality.

A large operator may want to have two different VCAs or even three of different sizes, but within each group would of course enjoy the acquisition, operation, maintenance, and upgrade savings of having the same engines, the same cockpit, the same flight-crew training, the same replacement parts. At the same time, different VCAs of the single class acquired or two or three, would be fitted as needed for the mission, so that identical aircraft would carry out different missions synergistically with their different operating crews, equipment, and ordnance.

11. The non-issue of vulnerability

As noted, the VCA is not wholly new, there are precedents such as *AWACS*, *J-STAR*, *PHALCON* and others. Many have been used operationally, not always in low threat environments. Operating as they do at high altitude (they can send down UAVs to probe below them) at cruising speeds in the Mach 0.8 range, they are inherently hard to intercept, are easily escorted, and can be equipped to carry formidable defenses for penetration missions.