Silent Trackers

The Spectre of Passive Surveillance in the Information Age

A spectre is haunting the Information Age – the spectre of passive surveillance. In recent years passive surveillance systems have evolved to such an extent that they are set to overtake radar as the preferred means of target tracking. To be susceptible to passive surveillance a platform must emit. In the West, the level of pulsed communication between inter-linked weapon systems has increased markedly, particularly since the advent of Information Warfare in the early 1990s, rendering individual platforms more susceptible to detection and targeting by passive means. Such is the digital dependency of modern warfare that if a platform does not emit, then it is unlikely that it can perform a useful role.

The major feature of passive surveillance is that it is a 'silent' process. There are no signal emissions from a truly passive system. Nor are passive sensors susceptible to electronic jamming. A jammer simply provides a stronger signal-of-opportunity which a passive detector can readily exploit. One effective counter-measure to passive surveillance would be to locate the passive sensors using imagery and then physically destroy them. However, the compact antenna and electronic systems used in modern passive systems allow them to be blended into their surroundings, whether natural or urban.

Passive surveillance systems normally use low power compared with conventional radar and the compactness of the antennas and electronic sub-systems is such that they could also be mounted in small, pilotless platforms. As a result there are potentially significant cost advantages compared with a radar-based surveillance system.

The current proliferation of passive surveillance systems in increasingly dense electromagnetic environments represents a significant military challenge. Although passive surveillance is a threat to any military platform, this article emphasizes its operational significance from the standpoint of air power. Some of the unrecorded history of passive surveillance is described for the first time, with particular emphasis on the remarkable contributions of the Czechs.

NATO'S COLD WAR DILEMMAS

The current proliferation of passive surveillance systems in increasingly dense electromagnetic environments represents a significant military challenge

Passive surveillance played a pivotal role for Soviet air power during the Cold War, providing a means for tracking NATO aircraft that was wholly independent of radar. Soviet investment in passive surveillance for tracking purposes greatly exceeded Western levels and the surveillance systems they developed far outpaced Western equipment. Only in the late 1990s has NATO begun to consider the procurement of passive surveillance equipment for tracking purposes on a comparable footing with active sensors.

Had the Cold War broken out at any stage through the 1980s into active air engagements over the Central European plain, it is arguable that unexpectedly high Allied losses would have been incurred and could have resulted in military disaster for the West. There are many factors to consider and this is likely to become a controversial issue in years to come. Western planning assumptions concerning the prospective air battle in Central Europe failed to take adequate account of the passive surveillance threat.

The failure lay not in a lack of awareness of passive surveillance as such. There *was* ample awareness, for example, of Soviet Signals intelligence (SIGINT) activity, and selective emission control (EMCON) was an integral part of NATO operating procedures. Yet at some stage a platform must emit in order to play a useful role and EMCON can only do so much when the navigation aids of an aircraft have to emit continuously in order to complete the mission (the Tornado GR1 is an example of an aircraft designed around the radar threat. Its terrain-following radar would allow it to penetrate Soviet radar at low level, but passive tracking would have negated this capability).

The failure lay in insufficient appreciation in the West of the specific Soviet ability to generate an air picture using tracking and the utility of this information during the engagement, when radar, communications and other aircraft emissions become unavoidable. Whatever the claims and counter claims of what was known about the passive threat during the 1980s, the simple fact remains that one side possessed a passive tracking capability and the other didn't. Moreover, that advantage was one-sided tactically as well as technically. The NATO view was radar-centric and its operational planning was orientated to a threat perceived as the mirror image of its own sensor mix, not against the actual threat which existed.

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A parallel can be drawn from military history. By the summer of 1940 German intelligence had become aware of the British Chain Home raid reporting system. By then, the Germans had independently developed excellent radars.[1] Yet the Luftwaffe held an all too restricted view on the role and utility of radar in general [2] and of Chain Home in particular. Their High Command lacked, at that critical juncture, sufficient recognition of the primacy of role of Chain Home in tracking the threat and the vital early warning this provided to RAF fighter squadrons.[3] Consequently, with little, the "few" did much; their limited assets concentrated just when and where they were needed. During the Battle of Britain, German attacks against Chain Home were ineffective and half-hearted, with only Ventnor RDF station on the Isle of Wight briefly put out of action in the one concerted attack against the RDF network on 12 August 1940.[4] It was not just that the Chain Home towers were difficult targets; simple intelligence analysis would have been sufficient to identify the critical receiver and operator nodes in the immediate vicinity of the towers which the Luftwaffe possessed the means to destroy. Rather, it was a matter of the cultural addiction of the German high command to outdated concepts which misconceived enemy tactics and capabilities as the mirror image of its own. A more intelligent strategy based on systematic targeting of the enemy's 'eyes and ears' could have produced a different result in 1940.

During the Battle of Britain, German attacks against Chain Home were ineffective and half-hearted…

In the Battle of Britain, the Germans had no effective radar counter-measures and their defeat was a setback that led ultimately to their downfall. After the experiences of 1940 the Germans changed their views on the utility of radar and engaged in an earnest war of radar counter-measures with the British from which the military science of Electronic Warfare was to emerge. NATO's failure to respond

Typical Chain Home (CH) radar station

in the 1980s to the threat posed by passive surveillance compares with the Luftwaffe's shortcomings in 1940 because in neither case was there sufficient emphasis on counter-measures. Awareness of the passive threat during the 1980s would have triggered a contest of passive counter-measures, although this never emerged during the Cold War and Western cultural habituation to radar resulted in a hidden and one-sided advantage. Mercifully, there was no Battle of Central Europe yet concerns for the future mean that it remains vital to analyse this historical background and the capabilities of the passive surveillance equipment in question.

In the early 1960s, NATO formally committed itself to a policy of defence as far forward in Western Germany as was militarily feasible. Defence in-depth was not a politically desirable option and unwise from a military standpoint since loss of the thin band of West German territory, with its concentrations of industry, manpower and lines of communication, might put NATO at an irretrievable disadvantage. The policy shift from 'trip-wire' to forward defence was marked by new emphasis within NATO on what might be achieved with its all too limited conventional forces. NATO's strategic planners wrestled with the intractable dilemmas inherent in the policy of forward defence and by the early 1980s many had concluded that military logic ultimately dictated that the best form of defence lay in the adoption of pre-emptive tactics. A notable exponent of this viewpoint was the distinguished American scholar, Samuel Huntington, who argued that NATO's defensive strategy almost guaranteed defeat and that the only way to defend West Germany was to contemplate retaliatory offensive attacks against Soviet weak points.[5] This new thinking had its echoes in a significant re-shaping of US Army and Air Force doctrine as both services sought to revamp the defensive mind-set of the nuclear era and replace it with a readiness to use conventional forces in the exploitation of depth, initiative, mobility and the synergies of joint offensive action. Airland Battle was the main doctrinal product of these efforts and in 1982 it was incorporated into the US Army Manual, FM 100-5.[6]

Canted antennas on this FuG 220 reduced interference

After the experiences of 1940 the Germans changed their views on the utility of radar and engaged in an earnest war of radar counter-measures with the British from which the military science of Electronic Warfare was to emerge

Shifts in the US doctrinal paradigm undoubtedly influenced SACEUR and his staff at SHAPE in their re-evaluation of NATO doctrine aimed at improving NATO's conventional force posture. Although great emphasis was placed on the force multiplication potential of then emerging technologies, such as precision-guided munitions, the influences of Airland Battle were evident in the NATO's concept of Follow-on Forces Attack (FOFA), which was promulgated by NATO's Defence Planning Committee in 1984. Deep attack into the enemy's hinterland by both ground and air

The electronic battle, particularly in the early phases of the air campaign, was vital to the achievement of surprise

forces was envisaged in the FOFA concept, in which the element of tactical surprise was crucial. The electronic battle, particularly in the early phases of the air campaign, was vital to the achievement of surprise. Equally important was the ability to identify well-dispersed friendly and enemy units engaging one another in fluid tactical environments. The major aim of the electronic battle was denial of early warning by Soviet radars – the supposed 'eyes and ears' of the enemy. However, the pivotal role of passive surveillance for the Warsaw Pact and the inherent advantages of passive surveillance in distinguishing between friendly aircraft and hostiles, were barely recognised by NATO's military planners.

This failure was not confined to NATO but was, and remains, deeply embedded within Western military and military-academic culture. For example, in an assessment of NATO air power in Central Europe, the distinguished military author, Alfred Price, while recognizing NATO's weakness in identification friend-or-foe (IFF), shows scant regard for Soviet electronic capabilities:

> *'…although the provision of reliable identification for aircraft is a high priority NATO requirement …the problem is likely to haunt air commanders well into the 1990s. The only consolation is that the Warsaw Pact air forces face a similar problem, made worse by the fact that they have many more aircraft and their electronic systems are less advanced than their Western counterparts'.*[7]

SOVIET SECRET EYE

What was so special about the Soviet passive surveillance network was its ability to fuse information received from many sites…

In passive systems, a clear distinction needs to be made between the ability merely to detect an emission by passive means, for electronic intelligence or SIGINT purposes, and an ability to track the movements of an aircraft or other platform using only the radio-frequency emissions from its radar, communication or navigation equipment. Electronic intelligence capabilities were nothing exceptional and were widely available in both the East and West. What was so special about the Soviet passive surveillance network was its ability to fuse information received from many sites, in order to provide autonomous tracking capabilities that were comparable with or better than radar.

The principal advantage bestowed on the Soviets by passive surveillance was continuity of air situation coverage, even during periods of sustained and intensive electronic jamming of their air defence radars. NATO planners assumed that electronic suppression of Soviet radars would sufficiently diminish Soviet awareness of the air situation during the early and critical phases of air battle that it would permit that deep NATO interdiction and strike against Soviet airfields and territory with sustainable or tolerable allied losses. Yet when the Soviet passive surveillance capability is weighed in the overall balance of forces, the reverse scenario is more plausible.

In the opening phases of air battle, the major thrust of NATO effort would have involved electronic jamming to suppress the early warning and fire control radars of surface-to-air missile sites. Suppress these systems, so the argument ran,[8] and you create windows of opportunity in which to execute surprise attack against Soviet weak points. Yet NATO's airborne jammers would have provided massively enhanced radio illumination (in the sense of self-illumination of individual platforms) of the air space over Central Europe and so actually have assisted Soviet exploitation of passive means.

The Soviets, on the other hand, could have flooded Western air defence radars with electronic noise confident in the knowledge that this would have minimal effect on their own ability to visualize the air battle passively. Furthermore, while NATO air forces had no effective covert means for distinguishing between friend and foe, the Soviet passive surveillance network provided a built-in and covert IFF capability. It is a surprising yet proven and highly effective feature of passive surveillance that when signals analysis is applied to the detected emission, both target track and track identity can be displayed. NATO's air order of battle would have been constantly and literally 'in-picture' on Soviet display screens and available for distribution to all major centres of Soviet air command and control. In today's parlance, information advantage would have rested squarely with the Warsaw Pact and greatly aided Soviet efforts to carry out a campaign of deep attack and strike within Western air space.

Ramona was capable of generating multiple tracks on enemy aircraft based only on their radar emissions and provided fast and accurate identification of the target through near instantaneous analysis of the target's radar electronic signature

RAMONA

NATO's planning assumptions were probably reasonable up to 1981. After 1981, NATO's military planners ignored Ramona, a fully automatic air surveillance system that formed the backbone of the Soviet passive surveillance network throughout the 1980s. Ramona was capable of generating multiple tracks on enemy aircraft based only on their radar emissions and provided fast and accurate identification of the target through near instantaneous analysis of the target's radar electronic signature. This was a major advantage for the Soviet side because in Western systems the IFF function had to be derived from separate primary and secondary radars that were non-covert and could be exploited for passive tracking by an opponent.

The Ramona fully-automatic passive air surveillance system. Throughout the 1980s, it formed the backbone of the Soviet passive surveillance network

Ramona was developed in the 1970s for use within the Warsaw Pact by the Czech Military Technical Research Institute at Brno and produced by the Czech company, TESLA (TEchnika SLaboproudA which roughly translates as 'Low Voltage Technology'), with the involvement of some other companies. Although not the first such system produced by TESLA, Ramona's capabilities as a fully automatic 'silent tracker' put it very much in a class of its own. Ramona introduced into air defence an automated aircraft tracking capability that was sustainable in hostile electromagnetic environments. East or West, there was no other system quite like it.

The first Ramona was exported to the Soviet Union in 1981 and was followed by many more. With more than 20 Ramona systems deployed across the European theatre by the early 1980s, Soviet coverage of the air battle in Central Europe was comprehensive. The tracking provided by Ramona was effective up to the radio horizon (about 450 kilometres), well beyond that of most conventional radars, and at least as accurate. This allowed the deployment of Ramona in depth, far behind the forward edge of the land battle. Early warning of NATO air missions would have been available to Soviet air commanders, enabling air defence units to be put into readiness states in advance of any NATO incursion. With ample early warning, the allocation and cueing of surface-to-air missile batteries would in most cases have occurred before NATO jets crossed the forward edge of battle. If hot war had broken out, Western combat aircraft of all types would have encountered unexpected speed and efficiency in Soviet air defences. On board radar warnings received would probably have been short, if anything was detected at all. Western SIGINT collectors would also probably have encountered an unexpectedly low level of early warning radar activity in general, interspersed by floods of electronic noise jamming.

In short, NATO would have been hit forcibly by that most devastating weapon – technological surprise – leaving its air command and control network dislocated and confused. How did such potentially devastating circumstances arise?

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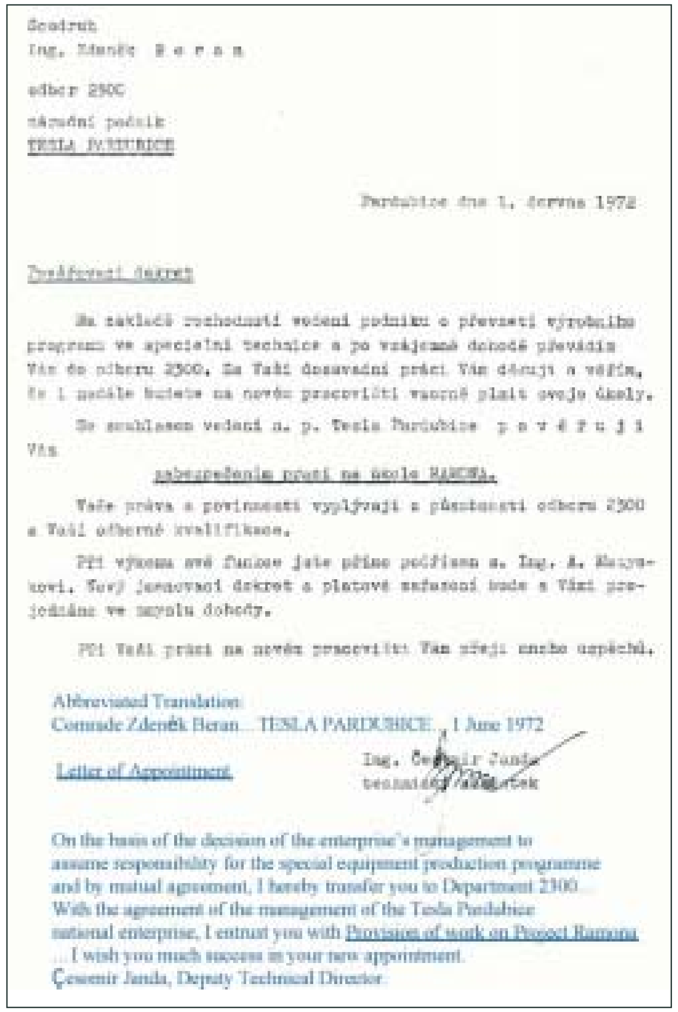
Each country of the Warsaw Pact tended to have its own specialisation to serve the wider needs of the alliance. For the Czechs, it was passive surveillance. They pioneered passive surveillance and to this day remain undoubted world leaders in the technique. It is indeed fortunate that the Cold War ended when it did, for a still more deadly successor system called Tamara was developed by the Czechs in the second half of the 1980s. This is the first occasion this once highly classified and historic material has been seen in the West. It was passed to the author during detailed discussions on the history of passive surveillance with many of the Czech scientists and technologists originally involved in the development of Ramona. (The author acknowledges and warmly thanks Zdenek Beran for providing this important historical material. Mr Beran has been a pioneer of passive surveillance since 1952 and was one of the leading players in the development of both Ramona and its successor system Tamara).

These pioneering achievements are part of a larger, longer and fascinating story, as yet untold in the West (the author is writing a book on the history of radiolocation in Czechoslovakia). It is a story of extraordinary persistence by the Czechs over several decades, initially in the face of Russian rejection.


Soudruh
Ing. Zdeněk B e r a n
odbor 2300
národní podnik
TESLA PARDUBICE

Pardubice dne 1. června 1972

Převáděcí dekret

Na základě rozhodnutí vedení podniku o převzetí výrobního programu ve speciální technice a po vzájemné dohodě převádím Vás do odboru 2300. Za Vaši dosavadní práci Vám děkuji a věřím, že i nadále budete na novém pracovišti vzorně plnit svoje úkoly.

Se souhlasem vedení n. p. Tesla Pardubice p o v ě ř u j i Vás

zabezpečením prací na akci RAMONA.

Vaše práva a povinnosti vyplývají z působnosti odboru 2300 a Vaší odborné kvalifikace.

Při výkonu své funkce jste přímo podřízen s. Ing. A. Maryškovi. Nový zařazovací dekret a platové zařazení bude s Vámi projednáno ve smyslu dohody.

Při Vaší práci na novém pracovišti Vám přeji mnoho úspěchů.

Ing. Čestmír Janda
technický náměstek

Abbreviated Translation
Comrade Zdeněk Beran ... TESLA PARDUBICE ... 1 June 1972

Letter of Appointment

On the basis of the decision of the enterprise's management to assume responsibility for the special equipment production programme and by mutual agreement, I hereby transfer you to Department 2300 ... With the agreement of the management of the Tesla Pardubice national enterprise, I entrust you with Provision of work on Project Ramona ... I wish you much success in your new appointment.
Čestmír Janda, Deputy Technical Director

Letter of authorization for the production of Ramona

The story of aircraft tracking using passive surveillance begins in the 1950s at UVR (Institute for Radio Technological Research), Opočinek, a research and development institute involved in civil and military projects, located in the district of Pardubice in the East Bohemian region of former Czechoslovakia. UVR Opočinek specialized in radio-location, more commonly known today as radar. The initial intellectual stimulus which led the Czechs to investigate passive surveillance was provided by a gifted young scientist called Vlastimil Pech. Many talented and hard working individuals have contributed over the years to the research, development and production of passive systems in Czechoslovakia. Without Pech's initial vision and drive in the late 1950s, it is doubtful that such research would ever have begun.

Pech joined UVR Opočinek in 1951, shortly after its creation from the research elements of nearby TESLA Pardubice, a large state concern which manufactured a wide variety of radio and electronic equipment. Although notionally separated, TESLA and UVR continued to work very closely and effectively as a single organization. TESLA/UVR policy was to take only the best graduates and deliberate reliance was placed on the creative energy of youth. This approach rings falsely with the Western image of the former Eastern bloc as plodding and lacking innovative skills: this was far from the case at TESLA/UVR. There was even a practice of brainstorming in the 1950s and ample freedom of expression was granted for this purpose. This was, of course, an intellectual freedom of the technical variety, not to be confused with political freedom of expression.

Pech worked in a section that looked at future technologies and he was involved in many innovative projects at TESLA/UVR. In 1958, misfortune struck when he fell victim of a political purge and was summarily dismissed. Despite the easy intellectual atmosphere at TESLA/UVR, such arbitrary treatment – and far worse – was not uncommon in the Czechoslovakia of that era. Mercifully for Pech, the purge proved to be of a temporary nature and such was his evident value to the Czechs that he was soon allowed to work at another TESLA plant at Lanskroun, which specialized in electronic component technology. Here, once again, he was given ample freedom to express his technical ideas and was even on one occasion allowed to visit the United Kingdom. It is likely that by 1959 Pech had already begun to ponder the problem of the long range detection of airborne radars and at TESLA Lanskroun he persuaded influential figures in the Czech military to look seriously at his ideas for passive tracking.

Conventional ground-based radar suffers several critical disadvantages. Chief amongst these is that it relies for target detection on extremely faint radio echo returns from the target aircraft and this signal weakness leaves the radar receiver vulnerable to

What was new was the elegant mathematical treatment employed by Pech that made the construction of a tracking system a practical proposition using a network of time-delay circuitry

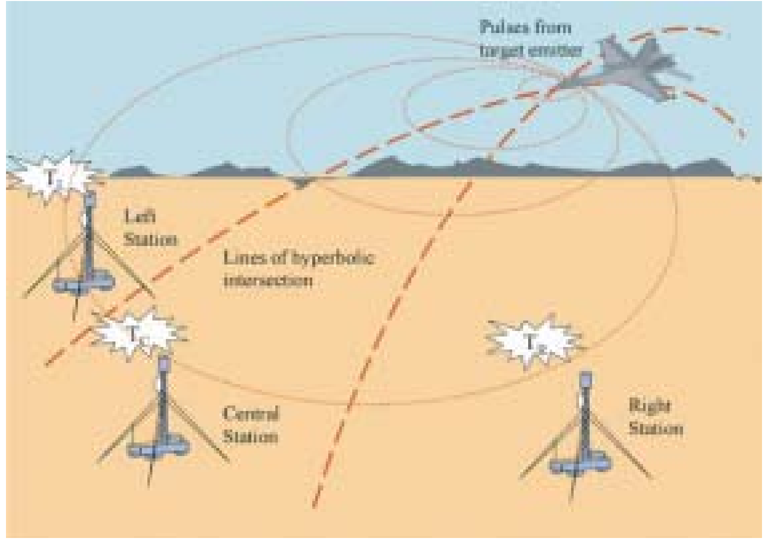
jamming and limits the maximum range of detection. Why not, Pech reasoned, exploit the signal energy emitted by the aircraft's own radar system? Since such emissions were increasingly prevalent, Pech realized that the pulsed emissions from aircraft radars were highly vulnerable to passive detection and would be ideal for tracking purposes because the available signal energy is incomparably greater than the radar 'skin echo'. Moreover, any attempt at jamming ground-based radars would simply generate an even stronger signal that could itself be used to locate the jamming source.

The Czech military were so impressed by Pech's ideas that they took them back to the Military Technical Research Institute at Brno, a research centre of the Czechoslovak Army. Pech himself soon followed and it is at Brno that the first serious efforts to develop a practical passive surveillance system began in 1960. His concept was based on near-simultaneous measurements at different ground locations of the time of arrival of pulses emitted by a target aircraft radar for, if three or more ground stations are available to detect a signal from a common source, the tiny differences in time of arrival between each of them can be used to calculate the target position in two or even three dimensions.

The time-difference-of-arrival (TDOA) technique was not new, even at that time, and it had previously been used both in the East and the West [9] in diverse direction-finding applications. What was new was the elegant mathematical treatment employed by Pech that made the construction of a tracking system a practical proposition using a network of time-delay circuitry. A TDOA system dedicated to the aircraft tracking function was also a major departure that went well beyond the angle-of-arrival information obtained in standard direction finding, to the provision of highly accurate aircraft tracks displayed in real-time. However, the significance of this achievement has been unrecognized in the West even to the present day.

The crucial feature of Pech's novel mathematical treatment, which he successfully patented and termed the 'Chronometric-Hyperbolic Principle', was that it related time and position directly, with no intermediate angle calculation, greatly simplifying and speeding up the computational process needed to establish an emitter's position. If a set of three or more detectors can be arranged to intercept and correlate the time of arrival of individual pulses, then the location of the target can be determined with a precision that depends mainly on the accuracy of the timing measurement. Pech's mathematics are then applied directly to the timing measurements to generate hyperbolic curves (comprising planes not lines of intersection), such that the target lies at the point of their intersection.

Pech's ideas were also presented to the Russians who studied them with considerable interest. They performed their own assessments but at first concluded that the method



Chronometric-hyperbolic principle

could not be made to work. Undeterred, the Czechs persisted and after three years of effort developed a practical prototype TDOA system christened the PRP-1 Kopáč, which was ready for operational service with the Czechoslovak air defence forces in 1963. Kopáč was the world's first passive TDOA surveillance system dedicated to aircraft tracking.

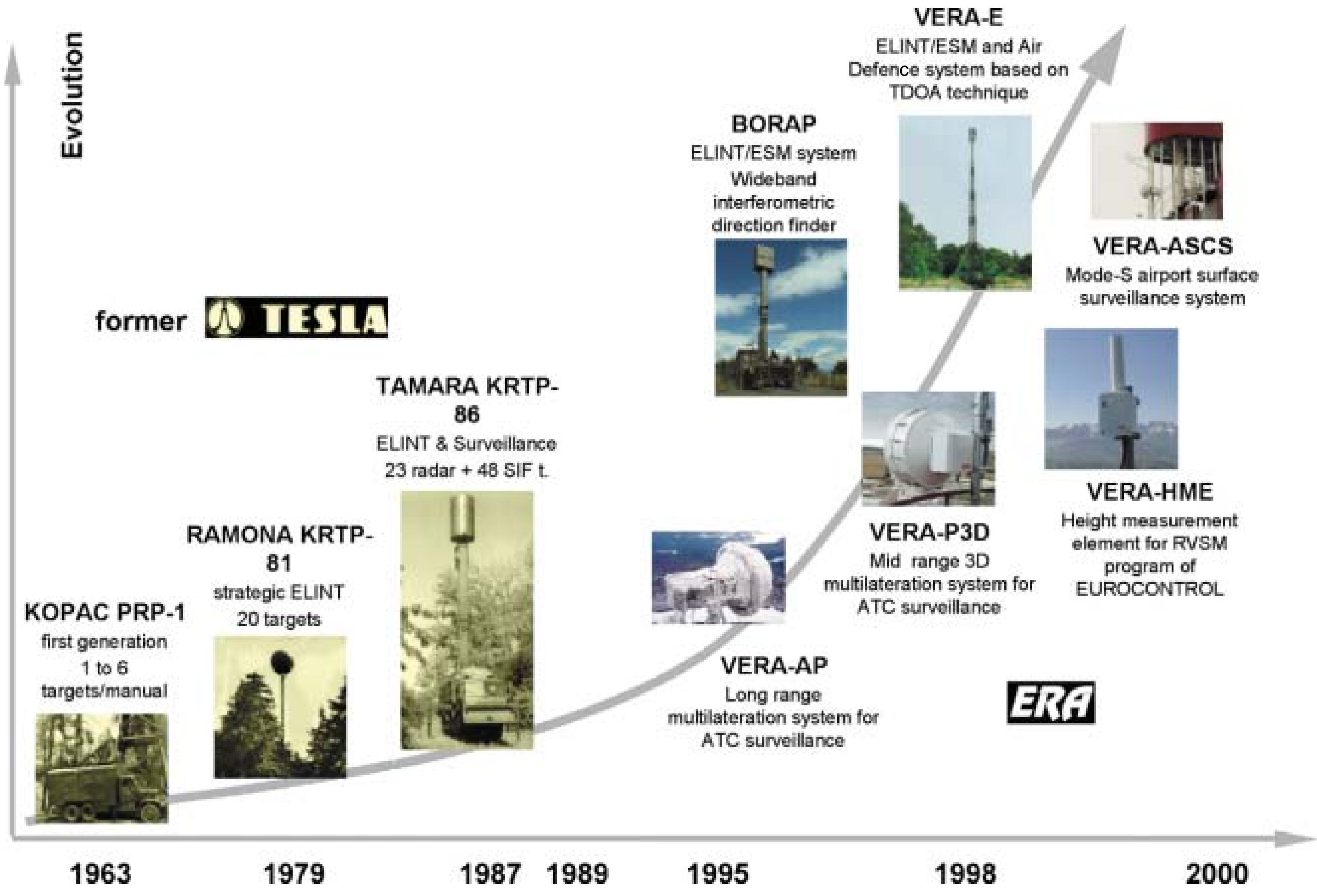
Tamara was a significant improvement on Ramona, providing not only full mobility but a still greater capacity for target tracking

The technologies available for PRP-1 Kopáč in the early 1960s were far from ideal and the capabilities of that system were severely limited by the need for manual intervention in the tracking process. Nevertheless, the operational utility of the long range and early warning of NATO incursion provided by Kopáč was quickly recognized within the Warsaw Pact and in 1972 massive funding was authorized by the Soviet Union for the development of a more advanced and fully automated successor system – Ramona. The first prototype of Ramona was ready for deployment in 1978 and more than 20 systems were later exported to Russia. A small number of additional units were also exported outside the Soviet block. Ramona was highly successful and gave reliable service in the Soviet passive surveillance network throughout the 1980s. However, Ramona was a static system which the Russians considered would be increasingly vulnerable to precision attack, should NATO be alerted to its significance. To rectify this weakness a mobile successor system called Tamara was developed during the 1980s and the first production unit was completed in 1986. Tamara was a significant improvement on Ramona, providing not only full mobility but a still greater capacity for target tracking. In particular, it extended the target set so that aircraft communications and navigation equipment could be detected, including TACAN (TACtical Air Navigation equipment), DME (Distance Measuring Equipment) and even the all important NATO JTIDS (Joint Tactical Information Distribution System) communication link.

An order for around 20 Tamara systems had been delivered to Russia by 1990. However, with the collapse of the Warsaw Pact all development funding was frozen, leaving TESLA with several unsold systems and the collapse of its entire market. These events had a devastating effect on the company. The Czech government decided to privatize TESLA and in 1994 a sale was organized in which Thompson CSF put in a bid for the radar segment of the company. However Thompson lost out to a bid led by a former Czech general, Mr Barak, who promised to keep the company intact. The newly privatized company was called HTT (High Technology Transfer) TESLA. During the 1990s it made heroic attempts to survive: the unpalatable truth was that no market could ever match the scale of that once provided by the Soviet Union. The inevitable collapse of HTT TESLA commenced in 1997 on the sale of the company to an asset stripper, with final declaration of bankruptcy in 1999.

TESLA encountered difficulties across a broad front. The United States was irritated by marketing strategies that included discussions with states hostile to Western interests, while the management style of the new owners alienated much of the TESLA workforce whose support was so sorely needed. For many in the company the writing was on the wall by 1994 and far-sighted and talented employees decided to leave HTT TESLA and set up their own companies. Altogether 46 new companies were spawned from HTT TESLA during the 1990s. The most important of these in the story of Czech passive surveillance was undoubtedly ERA, which was founded in 1994.

Today, ERA is a successful and thriving company of about 150 employees. It manufactures a wide range of civil and military passive surveillance equipment, including airport and runway surveillance equipment in use by Eurocontrol and several major airports in the EU. The main military product of ERA is the VERA-E system, which is a powerful though compact passive surveillance capability that uses state-of-the-art Western electronics. VERA-E is the true successor to Tamara. The export of VERA-E and other military equipment is strictly controlled by the Czechs in full compliance with their newly found responsibilities within NATO.



Evolution of Czech passive surveillance systems

GROWING MENACE OF PASSIVE SURVEILLANCE

With the demise of the Soviet bloc and the Western re-alignment of the Czechs, Russia and the Ukraine turned, throughout the 1990s, to indigenous production of passive surveillance equipment. During the Cold War they had witnessed for themselves the power of passive surveillance and set high priority on the development of new passive systems, despite an appalling shortage of military funds. Russia developed the VEGA/Orion series equipment for passive surveillance and Ukraine followed suit with Kolchuga. Both VEGA/Orion and Kolchuga are currently available for export.

The technology and range of application of passive surveillance has not stood still through the 1990s in the countries of the former Eastern bloc

The technology and range of application of passive surveillance has not stood still through the 1990s in the countries of the former Eastern bloc. These newer systems deliver potent air and surface surveillance capabilities. Novel extensions to passive surveillance will undoubtedly generate new capabilities for use in both land and naval warfare. Nor will the applications of passive surveillance remain purely defensive as digital linkages are extended between sensor and shooter. Yet, in the West, the operational utility of passive surveillance continues to be almost wholly neglected. The reasons for this neglect are manifold, but certainly at least part of the explanation lies in long standing and hard-to-break cultural habits within the EW community. It is a habit which pervades both military and academic establishments as well as their publications. For example, a recent and otherwise outstanding textbook [10] on EW fails to make any mention of tracking using passive surveillance. If Western EW experts show such scant awareness of the problem, what more can be expected of the operational community? This failure to wake up to the dangers posed by passive surveillance increases the danger the West faces and, if it persists, sooner or later Western air forces will be badly exposed in future conflict. OPERATION ALLIED FORCE was an early warning of trouble ahead.

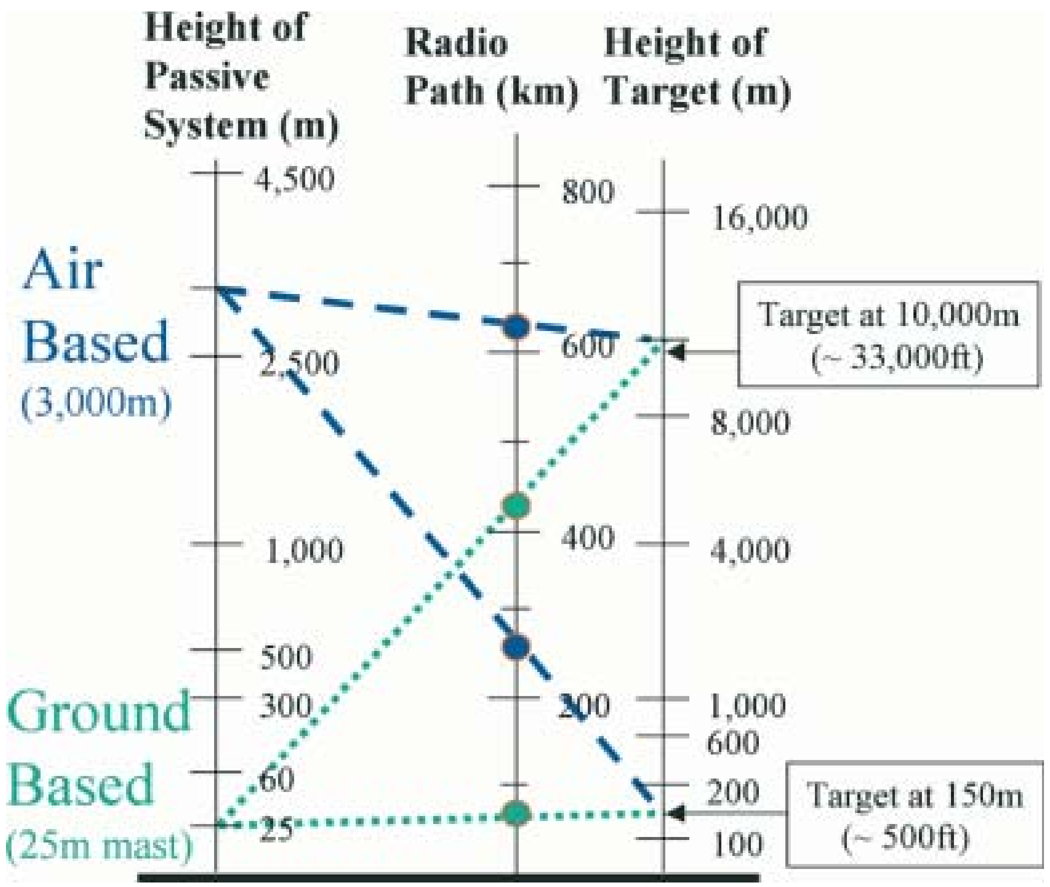
In OPERATION ALLIED FORCE an unprecedented conflict between NATO and a minor military power took place. Despite the availability of precision long-range weaponry, NATO failed to destroy the most important targets within the Federal Republic of Yugoslavia's integrated air defence system, which were mobile or 'time-critical'. There was precision weaponry but insufficient precision knowledge delivered in near real-time, that would have enabled NATO to suppress Serbian air defences with the speed and effectiveness it would have wished. The Federal Republic of Yugoslavia was ultimately defeated by NATO. This had more to do with the sheer tonnage of ordnance directed at her fixed infrastructure than damage inflicted on her mobile air defence assets, which survived largely unscathed.

In the heady aftermath of The Gulf War, instant analysts of the day christened it 'The First Information War'. This was always an absurdity, even though it was taken seriously and led in subsequent years to a rush to embrace concepts of 'information based warfare' that were criticized by this author.[11] In the somewhat more sobering aftermath of OPERATION ALLIED FORCE, 'The First Lack of Information War' is a more fitting epithet given the panoply of information systems and sensors brought to bear against this little country. As NATO struggled to find the positional information it so badly needed, the Serbs, on the other hand, using limited means, were remarkably adept at interpreting what NATO was doing. With little they knew much, greatly aided by NATO's massive electronic footprint, while NATO, with much, in crucial areas, knew little of what they really needed to know – the precise location of the enemy at any given time.

OPERATION ALLIED FORCE is evidence that something is not right with the information revolution; it has already gone sour and has itself introduced dangers stemming from the massive and wholly avoidable flood of military digital messaging that today pervades the electromagnetic ether. The panoply of information systems procured since the Gulf War has had precisely the opposite effect to that intended and left their users at best confused and at worst blind in the moments of most acute need. The misuse of information and its associated technology has locked the military command element into cumbersome, technology-driven processes that are inflexible and unresponsive in fluid tactical environments. Because worse circumstances than OPERATIONAL ALLIED FORCE are both conceivable and foreseeable, pre-emptive action against the menace of passive surveillance is essential, not least because the technologies of passive surveillance will not stand still.

THE NEXT GENERATION

The current generation of passive surveillance equipment, whether Czech, Russian or Ukrainian, suffers from one crucial limitation: all equipment is ground based



A nomogram shows the extension of passive surveillance coverage for ground and airborne targets using an air-based passive platform flying at 3,000 metres. Low level targets are detected to a range of 250 kilometres and high level targets are detected out to 640 kilometres. The nomogram shows that coverage for the ground based platform is much more limited, and assumes a smooth and spherical '4/3 earth', to allow for the effects of atmospheric refraction. As the height of the surveillance platform increases, the area of ground that can be surveyed expands dramatically. Even at the limited and easily achievable height of 3,000 metres, an area coverage of 40,000 square kilometres is feasible.

The current generation of passive surveillance equipment, whether Czech, Russian or Ukrainian, suffers from one crucial limitation: all equipment is ground based. Just as surveillance radars reached a stage in the 1970s where an airborne early warning (AEW) capability became feasible in order to extend the range of coverage of both air and surface targets, so passive surveillance technology has now reached a stage where it too can and will go airborne. The most important advantage of an airborne passive surveillance system is that the radio horizon of ground and airborne targets is greatly extended.

In a ground-based system the area of terrain that can be surveyed is very small. In practice, irregular or mountainous terrain will complicate the assessment. As a general rule, the radio horizon greatly restricts the operational utility of a ground-based system.

Surface systems are highly vulnerable to passive surveillance because there are few maritime or land-based operational platforms that can operate effectively without emitting at least some form of communication. Most vulnerable of all are the many tactical systems that are deployed at short notice and forced to rely on communication by open broadcast. An important advantage over imaging methods is that surface survey by a passive surveillance system can be executed at short notice and it takes minimal time to complete; there is no need to be within imaging range of the target. In contrast, the competition for scarce imaging resources, whether satellite or overflights, is generally fierce and the delays before a result is obtained can be too great for the detection of time-critical targets, such as early warning radars and surface-to-air missile batteries, which may relocate in a matter of hours.

We can now see that an airborne passive surveillance capability would also have significant advantages in the detection of airborne targets. Airborne targets below the radio horizon normally escape detection. This limitation is solved in the airborne passive system because of the rapid expansion of the radio horizon with increasing platform height. A detection range of 630 kilometres is feasible against airborne targets flying at 10,000 metres. With platforms flying at high level, still greater detection ranges are possible – beyond 800 kilometres – greater than is achievable using a radar AEW system. This promises to open the way to air defence surveillance on a continental scale using a small number of passive systems. For large countries, such as Australia, air surveillance coverage of the whole country has long been a goal but one that was never achievable using conventional radar.

CLOSING REMARKS

In today's digitized battlespace, passive surveillance for real-time target tracking is set to play a much more significant role than it did during the Cold War. In the West, the rush to fill every available data-link with information – the essential along with the unfiltered trivial – has created avoidable vulnerabilities. As kilobytes grow into megabytes and now into gigabytes, the mass of data pulses surging through the electromagnetic ether presents a free gift to any opponent who wishes not only to detect allied platforms, but continually to track and identify them in real-time.

The alert must be vigorously sounded, for whatever is done in the West, passive surveillance is fast becoming the preferred surveillance system of choice in many non-Western states

New initiatives, if quickly and actively pursued, can reverse current disadvantages and keep the West ahead of its potential opponents. The alert must be vigorously sounded, for whatever is done in the West, passive surveillance is fast becoming the preferred surveillance system of choice in many non-Western states. The Information Age has everywhere loudly advertised its presence, not only in the military presses but also in the electromagnetic ether. Against the Serbs, NATO just about coped; against tougher and larger opposition it could be a very different story.

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