

AD-A281 895

DOCUMENTATION PAGE

Form Approved

OMB No 0704-



This report contains information that may be exempt from public release under the Freedom of Information Act (5 U.S.C. 552). It is the policy of the Department of Defense to make available to the public information that is not exempt from public release. If you are unable to obtain this report, please contact the Information Management and Budget, Paperwork Reduction Project (0704-0188) Washington, D.C. 20503.

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED

THESIS/DISSERTATION

0

4. TITLE AND SUBTITLE

A HISTORY OF POLISH ANTI-MISSILE  
DEFENSES

5. FUNDING NUMBERS

6. AUTHOR(S)

BRAD HAYWORTH

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

AFIT Student Attending:

UNIVERSITY OF KANSAS

8. PERFORMING ORGANIZATION  
REPORT NUMBER

AFIT/CI/CIA-

94-099

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

DEPARTMENT OF THE AIR FORCE

AFIT/CI

2950 P STREET

WRIGHT-PATTERSON AFB OH 45433-7765

10. SPONSORING/MONITORING  
AGENCY REPORT NUMBER

3918 94-22803



11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for Public Release IAW 190-1  
Distribution Unlimited  
MICHAEL M. BRICKER, SMSgt, USAF  
Chief Administration

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

DTIC  
SELECTED  
JUL 21 1994  
S-B-D

DTIC QUALITY INSPECTED 1

14. SUBJECT TERMS

15. NUMBER OF PAGES

34

16. PRICE CODE

94

30

17. SECURITY CLASSIFICATION  
OF REPORT18. SECURITY CLASSIFICATION  
OF THIS PAGE19. SECURITY CLASSIFICATION  
OF ABSTRACT

20. LIMITATION OF ABS

ABSTRACT  
FOR  
"A HISTORY OF POLISH ANTI-MISSILE DEFENSES"

(1 page preface, 1 page glossary, 26 pages text,  
5 pages endnotes, 3 pages bibliography)

Capt Brad Hayworth  
US Air Force  
M.A. (Russian and East European Studies)  
University of Kansas-Lawrence  
1994

Modern Polish defensive efforts against offensive missiles began during World War II and have continued to the present. Both human and tactical factors impacted Polish anti-missile performance during World War II, during the post-war period (1945-1991), and during the most recent years (1992-1993). Human factors include morale and command relationships; tactical factors include equipment, techniques, and strategies. Poland's loss of independence affected wartime human factors. Polish aviators successfully utilized several anti-missile tactics during World War II; other Poles participated extensively in wartime anti-missile operations, too. Integration into the Soviet air defense system affected the operators of Polish anti-missile defenses in the post-war era. Soviet-designed tactical elements in Poland's post-war anti-missile defenses were potentially effective yet limited. Poles used anti-aircraft artillery, surface-to-air missiles, aircraft, radar/radio-electronic combat, naval assets, and other military and non-military means during the post-war years to counter the offensive missile threat. [Current Polish military writing contains previously unknown/little-known information about Polish air defenses during the post-war period. In particular, Polish surface-to-air missile operator training exercises are described. These exercises included training against both cruise missile and ballistic missile simulators as well as against aircraft simulators (i.e. potential missile-launching platforms). See Nastrozny article.] Polish anti-missile personnel have faced a significantly different security environment in recent years. During the most recent period, Polish air defense tactics including anti-missile tactics have become more independent and innovative.

**A HISTORY OF POLISH ANTI-MISSILE DEFENSES**

**BRAD HAYWORTH**

**REES 898/899**

**(DR. FLETCHER)**

**5 MAY 1994**

<b>Accession For</b>	
NTIS GRA&I	<input checked="" type="checkbox"/>
DIAG TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Special
A-1	

## PREFACE

References to weapons systems which are mentioned in this work will conform to North Atlantic Treaty Organization (NATO) and/or Western military terminology guidelines. For example, the Soviet surface-to-air missile (SAM) system which bears the Soviet designation "V-75 Dvina" will be referred to by its NATO designation, SA-2. Weapons systems names will appear in all capital letters (e.g. HOUND DOG, SPITFIRE, etc.), and these names should not be confused with the abbreviations and acronyms cited in the glossary on the following page.

Additionally, the Soviet strategic air defense system will be referred to as PVOS (*Protiovozduzhnoi Oborony Strany*) (Air Defense of the Nation) throughout this work to minimize confusion, even though the name of the Soviet strategic air defense system was altered during the 1970s to reflect certain administrative and doctrinal changes.

## GLOSSARY

The following abbreviations and acronyms appear in the text:

AAA (Anti-Aircraft Artillery)

ABM (Anti-Ballistic Missile)

AGL (Above Ground Level)

ALCM (Air-Launched Cruise Missile)

CCD (Camouflage, Concealment, and Deception)

D-Day (6 June 1944)

GLCM (Ground-Launched Cruise Missile)

mm (millimeter)

mph (miles per hour)

NATO (North Atlantic Treaty Organization)

PAF (Polish Air Force)

PVOS (*Protivovozdushnoi Oborony Strany*) (Air Defense of the Nation) (Russian)

RAF (Royal Air Force)

REC (Radio-Electronic Combat)

SAM (Surface-to-Air Missile)

US (United States)

USSR (Union of Soviet Socialist Republics)

V weapon (*Vergeltungswaffe*) (vengeance weapon) (German)

WLOP (*Wojska Lotnicze i Obrony Powietrznej*) (Aviation Army and Air Defense) (Polish)

WOPK (*Wojska Obrony Powietrznej Kraju*) (Army of Air Defense of the Country) (Polish)

WP (Warsaw Pact)

WTO (Warsaw Treaty Organization)

## INTRODUCTION

Offensive missiles are a significant modern political and military challenge. A successful strike by a single missile can achieve objectives as divergent as a limited show of force or a devastating attack using means of mass destruction. Offensive missiles have become an integral part of military operations, and offensive missiles affect foreign policies and international relations. For the purposes of this discussion, the modern period of offensive missile history begins during World War II, although offensive missiles have been used since ancient times.<sup>1</sup> Polish involvement in modern missile warfare began during World War II and has continued to the present. Moreover, Poles have been significantly involved in defensive actions against modern offensive missiles. A historical survey of Polish anti-missile activities can be divided into three distinct periods--the wartime period, the post-war period (1945-1991), and the recent period (1992-1993). During each period, there are identifiable human and tactical factors which affected Polish anti-missile defenses. Human factors are personal elements which impact anti-missile performance; these factors include morale and command relationships. Tactical factors are practical elements utilized by personnel engaged in anti-missile defensive actions; these factors include anti-missile techniques, strategies, and equipment/technology. Although human and tactical factors can be discussed separately, there is obviously some overlap in their consideration.

At the outset, some preliminary definitions are in order. This survey will address Polish defensive actions against cruise missiles and ballistic missiles. A cruise missile is an unpiloted, expendable, armed conveyance which, like an airplane, utilizes aerodynamic flight; cruise missiles may be air-breathing or rocket-driven; cruise missiles may fly autonomously or have their flight interrupted for guidance updates. Anti-ship cruise missiles and unguided rocket artillery are beyond the scope of this survey. Ballistic missiles are unmanned rockets which are powered during ascent to extremely high altitudes but not during descent when they are accelerated toward the earth by gravity. Many ballistic missiles can be guided during ascent, but few ballistic reentry vehicles are guided.<sup>2</sup> Germany's "vengeance weapons"

(V weapons) were early examples of modern cruise missiles (V-1) and ballistic missiles (V-2).

#### WARTIME HUMAN FACTORS

During World War II, Polish anti-missile personnel faced a number of challenges. Polish aviators would be the most visible participants in anti-missile operations, and when members of the Polish Air Force (PAF) made their way to England in late 1939, they were confronted first with a language problem. English was the language of command for the Royal Air Force (RAF) and the British air defense system. Moreover, the British doubted Polish airmanship; Polish resistance to the German invasion in September 1939 had not been highly regarded. Consequently, the British wanted to train the Poles for less prestigious flying duties.<sup>1</sup> Poles initially served as volunteer reservists in Britain's RAF. As France fell to the Germans in May-June 1940, more Polish fliers came to England. An agreement between the British and the Polish government-in-exile created an independent PAF that was loyal to the Polish administration in London but was operationally subordinate to London's RAF. Poles in RAF reserve status were reassigned to the PAF, but RAF rules still applied. Until Polish fliers were considered technically and linguistically proficient, they were commanded by British officers.<sup>2</sup> The Poles eventually overcame language and administrative difficulties, and proved their mettle during the Battle of Britain.

Polish fliers performed effectively during operations against Germany's V weapons. Polish fighter pilots in Britain destroyed a number of V-1s.<sup>3</sup> Polish fighter pilots in airborne defensive patrols over England augmented ground-based radar surveillance/tracking of V-1s with airborne visual observation. Polish aviators also contributed to anti-missile efforts through their involvement in bombing missions directed against V weapons installations.

Poles who participated in other World War II anti-missile activities often did so under difficult and unusual circumstances. The Polish military intelligence service was instrumental in breaking the German military communications encryption system; the Allies capitalized on these contribu-

tions and exploited German communications to track V weapons developments and deployments.<sup>5</sup> Data from Polish and Belgian laborers who worked at or had access to the V weapons research/development site at Peenemunde, Germany were utilized by Allied intelligence.<sup>6</sup> Reports from Polish workers in France informed the Allies about V weapons construction projects in France.<sup>7</sup> The Polish Underground passed drawings, photographs, and parts from V weapons testing activities in Poland to Allied intelligence.<sup>8</sup> Polish special operations troops who were loyal to the Polish government in Britain and were part of the Allied forces in the West highlighted V-1 launch positions in France for Allied bombers. Poles who were forced to serve in the German army carried out sabotage operations against V-1 operations in France.<sup>9</sup>

Wartime political developments would significantly impact Polish military personnel (including anti-missile air defense personnel) during the post-war period. Allied wartime negotiations at Teheran and Yalta plus the successes of the Red Army placed Poland in the Soviet sphere of influence, and Soviet leader Joseph Stalin wanted to ensure Moscow's influence in the Polish armed forces. The Polish People's Army was formed 21 July 1944 from the union of two Soviet-sponsored Polish military forces.<sup>10</sup> The presence of Soviet officers in Polish units guaranteed Polish loyalty. These Soviet officers also provided military leadership for the Poles whose leadership ranks had been decimated by the Soviet murders at Katyn and by the departure from the USSR of Polish troops (including officers) loyal to the Polish government-in-exile. Additionally, some Poles were incorporated into Red Army units. When Soviet and Soviet-directed Polish forces entered pre-war Polish territory in August 1944, their mission was not only to expel the Germans but also to co-opt the military forces of the Polish Underground.<sup>11</sup> In the closing stages of the war, the Polish military was forced to adopt a pro-Soviet orientation.

#### WARTIME TACTICAL FACTORS

Poles fighting in the West were familiar with World War II anti-missile operations. Polish fighter pilots in Britain exercised several tactics against the V-1. In the beginning, fighters were scrambled from a ground alert posture to respond to V-1 attacks, but ground alert reactions were too



slow. Continuous, around-the-clock airborne alert was therefore adopted.<sup>12</sup> Two belts of airborne fighters plus a belt of anti-aircraft artillery (AAA) and a belt of barrage balloons comprised the layered air defense system which was designed to destroy V-1s.<sup>13</sup> RAF SPITFIRE and TEMPEST propeller-driven fighters were modified structurally for maximum speed to optimize intercept possibilities. The first British jet fighter entered service in time to see action against the V-1.<sup>14</sup>

Although the V-1 flew straight and level at altitudes of 2,000-2,500' above ground level (AGL), fighter intercepts of the V-1 were challenging.<sup>15</sup> Face shots were dangerous because of rapid closure with exploding debris from destroyed targets. Rear hemisphere intercepts were difficult, because some British fighters could not overtake V-1s flying at maximum cruising speeds (up to 450 mph).<sup>16</sup> To achieve greater speeds and further enhance intercept possibilities, RAF fighters descended on V-1s from higher altitudes. Side shots were most successful. A V-1 intercept required at least 200 yards clearance to prevent pilot/aircraft fragmentation by the exploding missile warhead.<sup>17</sup> Smaller caliber machine guns with longer firing ranges were less effective against the thick-skinned V-1 (sheet steel) than shorter-range larger caliber guns; target destruction and aircraft/pilot survivability were ever a pilot's consideration.<sup>17</sup>

Survivability was also an issue when the "tipping" tactic was used. V-1s flew pre-set gyroscope-controlled courses, and these gyroscopes could be rendered useless if the missile's flight was sufficiently disrupted. RAF pilots discovered that they could disable V-1s by flying alongside the missile, placing the aircraft wing under the wing of the missile, and performing a roll maneuver. The missile would spin uncontrollably and then crash. "Tipping" sometimes damaged fighters; the steel wings of the V-1 could bend the lighter aluminum wings of SPITFIRE and TEMPEST fighters.<sup>18</sup>

Timely acquisition of incoming V-1s was essential to alert the appropriate elements of the British air defense system. Radars provided warning of ingressing V-1 missiles. Certain radars were optimized for detecting low-altitude targets; other radars were optimized for acquiring high-altitude targets. Radar sites were tied into a communications system that provided

warning and guidance to fighters and AAA sites. The Germans deployed radar jammers on the French coast and degraded not only these acquisition radars but also AAA fire control radars. However, German jammers no longer threatened the British air defense system after pre-D-Day bombing operations were conducted by Allied bomber crews including Polish crews against German positions in France.<sup>19</sup> The V-1 had a prominent visual signature. Pilots on airborne alert could visually acquire and track the "large flame with wings sprouting out of it," the missile with its "tail on fire."<sup>20</sup> This was especially noticeable at night. Acquisition, tracking, and target destruction were more difficult when the Germans altered the missiles' ingress azimuth and when the Germans saturated the air defense system with greater numbers of simultaneous V-1 launches.<sup>21</sup>

Because Allied D-Day invasion forces threatened V-1 launch areas, the Germans employed air-launched V-1s. Modified German He-111 bombers flew toward England at low altitude to avoid radar detection, climbed to high altitude, and then released their V-1 payload. The missile proceeded along course toward its target, and the bomber would return to base. Air-launched V-1s would have been even more difficult to counter if the Allies had not negated a number of actual and potential He-111 staging bases and if the Allies had not shot down so many He-111s in other aerial combat actions. Additionally, shortages of aviation fuel affected He-111 operations.<sup>22</sup> The unpredictability of missile ingress was greater for air-launched missiles than for ground-launched missiles, since there were fewer potential ground launch locations.

Denial of launch positions was an important anti-missile tactic. Allied bombing missions against fixed V-1 launch sites forced the Germans to deploy the V-1 in a semi-mobile mode. The Germans increasingly utilized camouflage, concealment, and deception (CCD) to degrade the effectiveness of Allied reconnaissance and bombing activities. Allied aircraft targeted lines of communication to hamper V-1 road mobility and transport; V weapons storage facilities and supporting industries were also struck. Aerial interdiction by Polish aviators and others complicated but did not prevent V-1 launch operations.<sup>23</sup>

The best V-1 denial tactic was territorial penetration. However, the Germans sometimes launched V weapons even in the face of rapid advances by Allied ground troops. Unless an area was completely secured, there was no assurance that another launch could not be conducted.<sup>24</sup> German efforts to build extremely secure, super-hardened V-1 launch/storage sites in France from which means of mass destruction would be delivered underscores the importance of territorial control as an anti-missile tactic.<sup>25</sup>

Defensive possibilities against the V-2 were much more limited than for the V-1. The V-2's ballistic, supersonic descent made interception by aircraft or destruction by AAA practically impossible, and there was no effective warning of an incoming V-2. Although an ascending V-2 was somewhat vulnerable, engagement was still extremely difficult.<sup>26</sup> Launch denial was a more viable tactic. However, the Germans also employed CCD and road mobility with V-2 operations. Additionally, the V-2s were sometimes launched from the middle of large population centers (e.g. The Hague) to deter bomber attacks.<sup>27</sup> Interdiction of lines of communications impeded V-2 mobile operations, but territorial penetration was the most effective way to prevent V-2 launches. German preparations in France to deploy silo-based intercontinental ballistic missiles which would carry unconventional warheads again demonstrates the necessity of controlling territory.<sup>28</sup> Polish anti-V-2 contributions included intelligence support, aerial interdiction, and attempted territorial control.<sup>29</sup>

Some World War II anti-missile operations were general military actions which were also familiar to Poles serving with the Soviets in the Eastern Theater. Specific airborne anti-missile tactics were employed only by Polish fighter pilots in the RAF, but missions like aerial interdiction and territorial control/denial were familiar to Poles fighting in both theaters.

#### POST-WAR HUMAN FACTORS

There were some noteworthy personnel changes in the Polish armed forces immediately after the war. Many Poles who had fought in the Western Theater returned home to Poland, a number of Soviet officers (not all) went back to the USSR, and peacetime military training and force structures were adopted.<sup>30</sup>

Nevertheless, Soviet control of Polish forces was still strong and increasingly evident. As Soviet-Western relations deteriorated, Moscow intervened more and more in the political and military affairs of East European states within the Soviet sphere of influence. At Moscow's behest, the Polish military undertook a systematic purge of "unreliable" Polish officers in 1947. Demotion, forced retirement, arrest, torture, and execution were unleashed against the "unreliable" officers, and morale fell dramatically as evinced by resignations, alcoholism, and suicides. In 1949, a Russian officer who had some Polish ethnic heritage was appointed Commander-in-Chief of the Polish armed forces to ensure Polish military obedience; Russians with various Polish backgrounds occupied most senior Polish military leadership positions.<sup>31</sup>

Moscow's domination of the Polish armed forces negatively affected the quality of Polish military personnel including air defense troops. Soviet-approved political indoctrination of Polish troops was institutionalized and vigorously applied. As political training became increasingly important, the academic and professional military standards of the Polish officer corps declined. Qualified Polish citizens shunned military career opportunities as officers, and required military service (for enlisted conscripts) was usually viewed with little enthusiasm.<sup>32</sup>

Post-war Polish national air defenses were reconstructed according to Soviet designs. Soviet wartime air defense experiences plus Stalin's concern about Western strategic air power led to an increased emphasis on air defense. Air Defense of the Nation (*Protivovozdushnoi Oborony Strany*) (PVOS) formed in 1948 as a separate command within the Soviet Ground Forces service, but the air defense mission was simply added to the other taskings of the various Soviet military services.<sup>33</sup> Since the Soviets viewed East Europe as part of the Soviet security system, the reliability and capability of East European air defenses were also essential. Thus, Moscow influenced the initial design, orientation, and equipping of Poland's air defenses, and Warsaw submitted Polish air defenses to Soviet oversight.<sup>34</sup> Stalin believed that the shorter-range, inaccurate offensive missiles developed during World War II and the offensive missiles developing right after the war were less threatening than

the proven capabilities of longer-range bombers which could deliver nuclear bombs. Soviet and East European air defenses at this time were built primarily around anti-bomber requirements, although the offensive missile threat was not completely ignored.<sup>35</sup> Both the Soviets and the West had cruise missile and ballistic missile development programs.

In 1954, Moscow reemphasized air defense. The *PVOS* became an independent service in 1954; centralized command and control of dedicated assets were necessary to assure adequate air defense.<sup>36</sup> Bombers were still perceived as the greatest threat, but ground-launched cruise missiles (GLCM) had become a more potent threat. Advances in jet propulsion technology allowed for cruise missiles with longer-ranges and heavier payloads (including nuclear). Soviet and American ballistic missile programs were progressing, but operational deployment of longer-range, heavier payload rockets was still tentative.

The formation of the Warsaw Treaty Organization (WTO) (also known as the Warsaw Pact [WP]) on 14 May 1955 did not change the character of the military relationship between the USSR and Eastern Europe. During Stalin's tenure, the Soviets had signed bilateral treaties of friendship and cooperation with their East European allies. The WTO did not abrogate Stalin's bilateral treaties, but supplemented these treaties by providing for additional confraternity between Eastern Europe and Moscow. Air defense including anti-missile defense was among the WTO's military considerations, and this further perpetuated Soviet involvement in East European air defense matters.<sup>37</sup>

The WTO position on air defense epitomized Soviet control over East European military forces. The WTO had no operational wartime responsibilities. The WTO prepared bloc forces during peacetime for Soviet-directed allied warfare.<sup>38</sup> Soviet wartime control of East European armed forces was evident even in the peacetime organization of air defense. East European air defenses were subordinated to Moscow's *PVOS* commander "whose 'second hat' as WP commander of Air Defense Forces [seemed] to be a formal designation only."<sup>39</sup>

Polish military morale and air defense capability were enhanced as a result of the October 1956 Polish-Soviet confrontation. After Stalin's death, suppressed national and individual aspirations were expressed in demands for

greater flexibility and autonomy from Moscow. Unlike the second stage of the 1956 Hungarian Revolution, Warsaw did not want to abrogate the Soviet-ensured security arrangement of Eastern Europe. Therefore, the Soviets agreed to certain Polish demands. With one token exception, all Soviet officers who had been appointed to senior Polish command billets were sent back to the USSR, and Soviet forces in Poland adopted a somewhat lower profile. Polish pilots and other Polish military figures imprisoned during the Stalinist period were released. Because Stalin feared an imminent and massive conventional war in Europe, a "mass production" approach to Polish pilot training had been instituted during the early 1950s.<sup>40</sup> This practice was terminated after October 1956, and Polish pilot training was subsequently rationalized. Command of the PAF passed from a senior Soviet officer to a leading Polish officer who had been instrumental in standing up to the Soviets during the October crisis.

Despite some adjustments in Polish-Soviet relations after October 1956, there was no change in the air defense union between Warsaw and Moscow. The Soviets continued to perfect air defenses in their own forces and among East European forces. In 1958, Moscow institutionalized the distinction between strategic and tactical air defenses.<sup>41</sup> Strategic air defense, the aerial defense of important political, economic, and military sites and of national aerospace borders, became the responsibility of the PVOS; tactical air defense, the aerial defense of maneuvering ground units, became the responsibility of a separate air defense branch of the Soviet Ground Forces. Soviet air defense technological achievements (particularly defensive missiles [surface-to-air missiles] [SAM]) could be more effectively deployed in mission specific roles, and the strategic/tactical air defense distinction permitted mission-specific employment of appropriate equipment. In the late 1950s, the Soviets encouraged their East European counterparts to upgrade their air defenses in view of the increasingly complex air defense environment and in view of incorporating new Soviet air defense equipment, specifically the SA-2 SAM, into national air defense systems.<sup>42</sup>

Warsaw followed Moscow's lead, and reorganized Polish national air defense forces. From 1959-1962, Poland's air defense service, Army of Air Defense of

the Country (*Wojska Obrony Powietrznej Kraju*) (*WOPK*), was established as an independent service branch similar to the *PVOS*.<sup>43</sup> *WOPK* assumed responsibility for Polish interceptor fighter aircraft which previously had been assets of the PAF and for the new SA-2s arriving from the USSR. The *WOPK* was ultimately subordinate to *PVOS*. Moreover, attempts to perform air defense at the strictly national level were found to be unworkable not only in Poland but elsewhere in Eastern Europe. The Protocol on the Establishment of a Unified Air Defense System of the Warsaw Treaty Member States which was signed 1 February 1963 only formalized the previous relationship between national air defenses and the *PVOS*.<sup>44</sup>

Soviet influence and control of the *WOPK* was extensive. Russian was the language of command. Russian-language technical manuals and instructions for the Soviet equipment used in Poland required a working knowledge of Russian or suitable Polish translations. Until the late 1960s, Polish military training manuals were direct translations of (Russian-language) Soviet manuals; even after the late 1960s, Polish training manuals contained little independent Polish military thought or doctrine.<sup>45</sup> After 1960, Poland's interceptor fighters were "fully integrated" into the Soviet air forces in Poland.<sup>46</sup> Soviet fighter units in Poland and Polish fighter units were "mixed...for operational purposes," and fighter-related communications were in Russian.<sup>47</sup> Polish interceptors also exercised frequently with East German and Czechoslovak fighter units. Polish fighter pilots and SAM operators perfected their skills at training sites in the USSR. A former commander of the *WOPK* indicated that the *WOPK* coordinated daily with other WTO members. Civilian aviation was also considered part of the air defense network. Polish corps level air traffic sections were "manned by a Russian communications unit, with two Russian officers always on duty."<sup>48</sup> Flight plans needed advance approval from the air traffic section, and could not be unilaterally changed by Polish commanders. Frequent and recurring WTO/*PVOS* air defense exercises also ensured bloc-wide operability. During the 1960s and 1970s, the integration of the Polish military including the *WOPK* into the Soviet-dominated alliance was further enhanced by new generations of bilateral treaties between Moscow and some of Moscow's East European allies and by bilateral treaties among East

European socialist states.

There were four military-related events which degraded *WOPK* morale and mission-mindedness. *WOPK* senior staff members were impressed by Israeli performance during the 1967 Six-Day War, but they were not impressed with the combat record of Soviet equipment and tactics used by the Arabs. These sentiments were significant not only because of their anti-Soviet implications but also because of anti-Semitic political currents in Poland at that time. Three senior *WOPK* officers received military demotions and then were dismissed from Poland's leading political party, because they insisted that lessons learned from the Six-Day War pointed out deficiencies in Poland's Soviet-designed air defense system. Also, the *WOPK* itself was reprimanded for a "pro-Israel stance."<sup>49</sup>

Polish participation in the 20-21 August 1968 invasion of Czechoslovakia hurt *WOPK* morale. Many Polish troops later felt angry and guilty because of their role in the invasion, and the *WOPK* was significantly involved in the pre-invasion preparations and in the invasion itself. The *WTO/PVOS* air defense exercise "Sky Shield" during July-August 1968 involved radar, SAM, and aircraft operators from East Europe and the USSR. A number of additional exercises occurred during 1968 because of the developments in Czechoslovakia, and although these exercises were not primarily air defense exercises, the *WOPK* supported these activities. During the invasion, the US and NATO noted heavy use of Polish air space. The air traffic over Poland included Soviet transport of the airborne division which landed in Prague, and the *WOPK* facilitated the transit of the Soviet transport aircraft. After the Soviets arrested Alexander Dubcek and his Presidium supporters, the Soviets transported the detainees to a military command center in Poland and from there to the USSR; the *WOPK* also expedited this air traffic.<sup>50</sup>

*WOPK* personnel were likely disheartened because of their participation in domestic crises. In December 1970, Polish troops were ordered to crush worker protests at certain Baltic ports; forty-four civilians were killed with over 1,000 wounded. Troops were sent to other sites of potential unrest, too. Polish military forces used during the December operations involved 61,000 army troops, 1,700 tanks, 1,750 armored personnel carriers, transport



aircraft, helicopters, and several naval craft.<sup>51</sup> The WOPK provided air space management and control for the aerial assets used in these actions. Some Polish troops refused to fire at their fellow citizens; there were several reports of mutinous, disorderly military conduct.<sup>52</sup>

The imposition of martial law distressed the Polish armed forces including the WOPK. After the Polish government reluctantly agreed on 31 August 1980 to allow independent trade unions (Solidarity), Soviet, Czechoslovak, and East German forces undertook extraordinary military preparations near Poland's borders.<sup>53</sup> Additionally, Polish troops were involved in several WTO-related exercises during the fall of 1980 and during 1981, and the WOPK participated directly and indirectly in these exercises.<sup>54</sup> The impasse between the Polish government and Solidarity continued, and at midnight 12/13 December 1981, martial law was declared. Regardless of the claims that martial law prevented foreign military intervention in Poland, martial law embittered Polish troops. External meddling, especially by Moscow, had been apparent to the Polish military which was scrutinized closely by the Soviets during the military exercises of the crisis period. Even though regular Polish military forces had not been tasked with the most unpleasant duties associated with martial law enforcement, many troops were unhappy that they had been mobilized against Polish citizens. Anger was directed not only at Moscow but also at Poland's governing military elite. Martial law was eventually lifted (22 July 1983), but the Polish government remained heavily militarized.

Polish military obligations during the 1980s remain unchanged, and morale dropped even further. The WOPK still functioned within the Soviet air defense network. However, long-standing economic, political, and social dissatisfaction intensified in Poland. Polish military officers had become increasingly disgruntled, especially younger officers.<sup>55</sup> Since the WOPK had a relatively high proportion of officers relative to conscripts, officer discontentment was a greater problem for the WOPK. Anti-militarism and pacifism became evident in Polish society, and this negatively affected military morale.<sup>56</sup>

Poland's first non-communist government since World War II formed in August-September 1989, but this did not immediately change Warsaw's military

relationships. Polish military commitments changed only when German-related security issues were resolved. East German political developments at the end of 1989 intimated the possibility of German reunification, and Polish and Soviet anxieties about potential territorial demands by a reunited Germany were fueled by the West German Chancellor's ambiguity on the subject. Poland's Prime Minister stated Warsaw would not alter its military relations with the USSR until the German question was sufficiently addressed, even though Poland, Czechoslovakia, and Hungary already were discussing whether the WTO ought to continue.<sup>37</sup> Subsequent Western assurances concerning German reunification satisfied Soviet and East European concerns, and the military structure of the WTO was abolished 25 February 1991. WTO dissolution included breaking up the WTO air defense system; Poland's air defense system was no longer part of the PVOS.<sup>38</sup>

Nevertheless, the political developments of August-September 1989 brought some changes to the Polish military establishment rather quickly. Reduction in the size of Polish armed forces began earlier in 1989, and there were more reductions in late 1989. In November 1989, the military's Main Political Board was abolished; indoctrination was replaced by an emphasis on national traditions and values; soldiers were banned from joining political parties. In February 1990, Warsaw announced a change in its military orientation. Poland would no longer automatically view the West as hostile, and Poland would adopt a thoroughly defensive military posture. Civilian control of the Polish Ministry of Defense was declared in January 1991. As the post-war period ended in 1991, steps were being taken to reduce the harshness of Polish military service, and the popularity of the military among Polish society was beginning to increase.<sup>39</sup>

#### POST-WAR TACTICAL FACTORS

In post-war Poland, the deployment and tactics of anti-missile systems like AAA were affected by a number of things. AAA had destroyed many V-1s during World War II, and AAA was counted on for post-war air defense, too. AAA available to Polish forces at the beginning of the post-war era consisted of 25 mm, 37 mm, 76.2 mm, and 85 mm guns which the Poles had used with the

Soviets in the Eastern European Theater. At the end of the war, Poland only possessed 358 of these Soviet-supplied guns; this was even fewer guns than Poland had at the beginning of the war (482).<sup>60</sup> However, the Poles had Soviet air defense assistance during 1944-1945, so significant numbers of AAA guns were not necessary for Polish forces.

During the late 1940s and the 1950s, AAA in Poland was deployed similar to pre-war and wartime situations. Larger caliber guns were used for point defense of key political, economic, and military installations (strategic), and smaller caliber, more transportable gun systems were designed to protect advancing ground forces (tactical). Soviet post-war deliveries of additional numbers and types of guns bolstered Polish AAA capabilities, but the range limitations of AAA guns combined with the cost and impracticality of widespread or universal gun coverage favored the use of fighters for regional aerial defense.<sup>61</sup>

Polish AAA in the early post-war years suffered from technical weaknesses. Soviet AAA fire-control radar technology was based on Western systems that the West knew how to counter. Although Soviet intelligence had acquired modern Western AAA fuzing technology, Soviet industry was unable to produce sufficient numbers of these modern fuzes.<sup>62</sup> Soviet AAA limitations became Polish AAA limitations, since Poland was supplied by Moscow. Moreover, the Soviets traditionally kept the best air defense technology for themselves.

To defend against high-altitude bombers Moscow built larger caliber systems like the KS-19 100 mm and the KS-30 130 mm guns which were capable of reaching even greater heights.<sup>63</sup> Poland received the KS-19 for very high altitude coverage and smaller caliber guns to provide for air defense at lower-medium altitudes.

Soviet SAM deliveries changed Polish AAA deployment. AAA ineffectiveness against maneuvering targets plus limited gun ranges were weaknesses which Soviet SAMs were designed to overcome. As Poland received Soviet strategic SAMs in the early 1960s like the SA-2, the mission of strategic point defense was transferred from large-caliber AAA to SAMs. Some older large guns were retired, but other large caliber AAA was allocated to the Polish Army for the role of tactical air defense of ground force assets. The transfer of Soviet

tactical SAMs to the Polish ground forces beginning in the early 1970s further restricted AAA deployment. Larger guns were increasingly phased out, and highly-mobile, quick reaction AAA systems of small-medium caliber were retained."

Although Polish AAA was increasingly deployed only in the tactical air defense role, AAA still had a noteworthy role in anti-cruise missile defense. Polish military writing acknowledged the superiority of AAA compared with SAMs against short-range/low-altitude targets; SAM performance degradation at low altitudes created aerial zones in which only AAA could provide adequate defensive coverage. In the tactical role, both SAMs and AAA were needed for comprehensive aerial defense of ground troops. The low-altitude threats normally confronting tactical air defense weapons like AAA were assumed to be aircraft, but cruise missiles were also probably in view as evinced by extensive Polish acknowledgement of AAA success against the V-1 cruise missile during World War II."

On the other hand, AAA potential against ballistic missiles was acknowledged skeptically. Polish air defenses conformed to Soviet thinking on the issue of AAA in the anti-ballistic missile (ABM) role. The Soviets believed that the best defense against ballistic missiles was anti-missile missiles; the possibility of using extremely large caliber AAA against ballistic threats was largely ruled out. The Soviets closely followed US supergun experiments conducted in the 1960s, but Soviet strategists questioned the effectiveness of superguns. According to Moscow, there were two fundamental problems with using superguns to shoot projectiles into the stratosphere to intercept incoming ballistic projectiles. Using unguided gun projectiles to engage possibly maneuverable ballistic reentry vehicles was cited as one major fallacy. Also, the air defense system which would be required to overcome possible system saturation by both real and dummy ballistic targets would be prohibitively costly and complex."

The introduction of SAMs into post-war Polish air defenses was a significant development for Polish anti-missile capability. The Soviet-built SA-2 was designed to provide strategic air defense against medium-high altitude penetrators, and this system represented the first SAM in the Polish

air defense system. SA-2 deliveries to Poland began in 1961. Poland restructured its air defense system in anticipation of SA-2 delivery, and Poland's restructured air defense system (WOPK) was organized into three air defense districts which were commanded from headquarters at Warsaw, Bydgoszcz, and Wroclaw. The boundaries of the air defense districts reflected a westward defensive orientation (i.e. against NATO). Each air defense district controlled a three-regiment SA-2 division, and these air defense assets were part of Moscow's PVOS.<sup>67</sup>

Although the SA-2 was engineered primarily as an anti-bomber system, the SA-2 had anti-missile applications. As noted earlier, Soviet air defense doctrine right after the war had emphasized defense against bombers which could carry gravity weapons. In the following years, however, some Western bombers were tested and eventually deployed as missile-launching platforms (e.g. US B-52s and the HOUND DOG air-launched cruise missile [ALCM]/air-launched semi-ballistic missile). Soviet pre-deployment testing of the SA-2 included firing exercises "even against relatively small towed targets" which could have represented missiles.<sup>68</sup> Polish SAM operator training started in 1960 at the Soviet SAM firing range in the Kazakh Republic. Initial training included live fire familiarization exercises against targets at medium-high altitude. SA-2 training complexity increased in the middle 1960s with the introduction of active and passive radio-electronic interference into exercise scenarios. Beginning in 1969, Polish SA-2 troops trained against non-maneuvering, high-speed (Mach 2), high-altitude, winged rocket-like targets; these targets were simulating aircraft and/or cruise-missiles. That same year, SA-2 practice against subsonic aircraft simulators (i.e. possible missile-launching aircraft) became more challenging with some aircraft simulators flying and maneuvering at lower altitudes (down to 2,600' AGL). Target acquisition, target designation, and command training also became more demanding.<sup>69</sup>

The SA-3 provided low-medium altitude strategic air defense and complemented the SA-2's coverage of higher altitudes. Poland began receiving the SA-3 in the late 1960s, and this system was administratively organized and deployed like the SA-2.<sup>70</sup> SA-2 and SA-3 firing sites were located close

enough together to provide all-altitude air defense of critical installations in Poland. Joint SA-2/SA-3 training for Polish SAM operators commenced in 1973; these exercises were more realistic and complex, and involved pilots and radio-electronic combat (REC) troops. At this time, automated command systems were also integrated into air defense training. Beginning in 1973, Polish SA-2 units engaged maneuvering, supersonic winged rockets at medium-high altitudes; again, the SA-2 was used to counter targets resembling cruise missiles. Aircraft simulators which flew at progressively lower altitudes (some as low as 650' AGL) and in an intense noise-jamming environment were destroyed by SA-3 operators. In 1976, SA-2 live fire training was directed against supersonic, winged rockets descending from extreme heights (72,000-92,000' AGL) in exercises apparently designed to simulate engagement of semi-ballistic/ballistic reentry vehicles. SA-3 training in 1976 emphasized air defense in an increasingly complex radio-electronic environment against aircraft penetrating and maneuvering as low as 330' AGL.<sup>71</sup>

Although Soviet tactical SAMs began entering the Polish inventory in the early 1970s, successful anti-missile employment was unlikely with these systems except for the SA-8. Tactical SAMs were supplied to Polish ground forces to counter enemy aircraft and helicopters at low-medium altitudes, and only in fortuitous situations could some of these weapons engage missiles. Moscow's tactical SAM deliveries to Poland during the 1970s and 1980s included the SA-6, SA-7, SA-8, SA-9, SA-13, SA-14, and SA-16.<sup>72</sup>

The SA-8 was developed from a Soviet naval SAM that required an anti-missile capability. The Soviet Navy's interest in fielding a low-altitude air defense system for smaller surface combatants initiated the research and development of a spatially compact, quick reacting SAM that could negate the primary aerial threats to surface ships--aircraft and anti-ship cruise missiles. The SA-N-4 became the most widely deployed radar-guided Soviet naval SAM, and the SA-N-4's land-based counterpart, the SA-8, consequently inherited these naval design criteria. The SA-8's high speed missile plus potential engagement capabilities at extremely low altitudes (down to 33' AGL) intimated some anti-cruise missile potential.<sup>73</sup>

Polish SAM operator training which included anti-missile training evolved

as the air defense threat environment changed. In the late 1970s and in the 1980s, the variety and extent of radio-electronic disturbance increased, and command and target designation scenarios also became more complex. SAM operators were given minimal or inadequate reaction time to counter their target, and multiple target engagements with little reaction time between successive targets were also written into exercise programs. In the second half of the 1980s, Polish SA-3 troops destroyed lower-altitude, low radar cross-section targets which simulated cruise missiles.<sup>74</sup>

The 1989 addition of the SA-5 to Poland's air defense arsenal enhanced anti-missile capabilities.<sup>75</sup> The Soviet-built SA-5 was designed as a medium-high altitude, long range system which employed a large, fast missile. There has been considerable discussion whether the SA-5's role is anti-aircraft or anti-missile; the SA-5 has some capability against both threats. Although SA-5 development began at the same time as US high-altitude, high-speed aircraft experiments, extensive testing of SA-5-related radars in the 1970s during ABM-related tests suggested an ABM role. Significant modification would have been necessary to make the SA-5 effective against higher-angle/higher-speed ballistic reentry vehicles, but the SA-5 appeared to have some capability against lower-angle/lower-speed ballistic or semi-ballistic threats.<sup>76</sup> Poland gained more anti-missile capability with the SA-5, since the SA-5 provided additional yet limited ABM defense and another defense against missile-carrying aircraft.

SAM training at the Soviet firing range ended in 1990. From 1960-1990, Polish operators had fired 507 missiles and destroyed 245 targets in various combat scenarios.<sup>77</sup> Although live fire training helped Polish SAM troops perfect their skills, Polish military writing had indicated that *PVOS* training materials needed more emphasis on nighttime air defense operations including SAM operations.<sup>78</sup>

Polish aviation in the post-war period developed under Soviet guidance. Moscow determined the doctrine and the equipping of Polish air forces according to Soviet security concerns; even after October 1956, Moscow was able to maintain some influence. The majority of Poland's fighters in the post-war era were supplied by the USSR or were Soviet aircraft designs built

in Poland.<sup>79</sup>

Polish post-war fighter tactics were adapted to counter missile threat developments. The Polish Air Force was furnished with jet fighters in the early 1950s. The greater speeds of jet fighters improved intercept capabilities, but the speeds of cruise missiles and missile-carrying aircraft which developed after the war also increased. When fighters which were equipped with airborne intercept radars entered Polish service, interception of cruise missiles and missile carriers became theoretically possible at longer ranges and in even more restrictive visual conditions. In the post-war years, Polish pilots trained for nighttime intercepts.<sup>80</sup> Depending on the type of aircraft, Polish fighters could use guns and/or air-to-air missiles to destroy hostile intruders. Information from the 1973 Polish SAM training exercises indicated that air defense pilots trained against the same simulated threats that confronted SAM operators, i.e. aircraft and missiles.<sup>81</sup> The same problems that had been associated with V-1 aerial intercepts applied to post-war cruise missile intercepts--early warning and tracking of targets, pilot/aircraft readiness, aspect of target intercept, and pilot/aircraft survivability. The preferred Soviet (and consequently Polish) fighter intercept profile of a missile-launching aircraft was a look-up rear-hemisphere shot at medium-high altitude, but low-altitude flight made such intercepts difficult. Western strategists had recognized the difficulty of low-altitude engagements, and for several years, low-altitude profiles were utilized by Western bombers and cruise missiles. Poland's 1990 acquisition of Soviet-built MiG-29 fighters enhanced the possibilities of destroying low-altitude targets, because the MiG-29 had improved low-altitude intercept capabilities.<sup>82</sup> As during the wartime period, the possibilities of using fighters to intercept ballistic missiles were virtually nil.

Other aviation-related anti-missile tactics which had been utilized during the war also had post-war application. Bombing/Aerial interdiction of missile-related targets and the aerial transport of special forces trained for anti-missile operations were still viable.

Although the Polish Navy was a separate service from the WOPK, the Polish Navy had significant anti-missile responsibilities during the post-war years.



The airspace over the Baltic Sea was a potential launch site and/or flight avenue for missiles or missile carriers, and using the Baltic for missile launch/ingress avoided potential diplomatic problems in the case of unauthorized missile or aircraft overflight. A July 1966 naval and air defense exercise in the Baltic that involved Soviet, East German, and Polish forces was one event which demonstrated the importance of defending Baltic aerial approaches.<sup>53</sup> Naval aviation assets deployed along the Baltic were tasked primarily with maritime-related missions, but hostile intruders flying into Poland from coastal areas could be engaged by maritime aviation assets and not just by WOPK interceptors.<sup>54</sup> Air defense weapons on Polish ships could also be used against missiles and aircraft which threatened Polish territory, although naval weapons were utilized primarily for protecting Polish naval assets. The most notable ship-based air defense weapon in the Polish Navy was the SA-N-1, the naval counterpart to the land-based SA-3. Polish SA-3 training exercises engaging not only aircraft but also missile target simulators intimated similar roles at sea. Soviet-built destroyers equipped with the SA-N-1 have served in the Polish Navy since the early 1970s.<sup>55</sup> Picket ships are vessels specially equipped with aerial search radars, and picket ships augment ground-based radar coverage. Picket ships can also control and vector land-based interceptor fighters, and the Polish naval inventory included a picket ship from 1982-1991.<sup>56</sup> Polish naval base air defenses had anti-missile responsibilities, too.<sup>57</sup>

Acquisition and tracking of missiles and missile-launching platforms was critical to successful anti-missile operations. Successful V-1 engagements had resulted from effective radar surveillance of missile ingress, and radars were also heavily utilized in the post-war period. Soviet- and Polish-built radars provided extensive radar coverage of Polish air space, especially in those regions where aerial threats were most likely to ingress. Active radar surveillance for Poland was land and sea-based. Threats like low-altitude cruise missiles and low-flying ALCM carriers were a nettlesome radar detection problem, and Polish military strategists were well aware of the low altitude threat flying over either land or sea.<sup>58</sup> Whether radar detection was degraded due to radar equipment limitations, the radar horizon, or other factors,

Polish military planning called for selectively positioned optical observation and reconnaissance posts to supplement ground-based radar coverage." Passive detection of missile-related activities could also provide warning, since some missile activities had characteristic electronic and/or infrared signatures. Polish troops assigned to REC units were tasked with passive detection of electronic emitters including missile-related emitters, and Polish SAM training in 1973 involved coordination with REC personnel against aerial targets which included missile-related threats.<sup>90</sup>

Communication was an integral part of missile warning. Since Poland's WOPK was part of the PVOS, Warsaw would be informed about missile-related threats which originated or operated outside Poland but which potentially could impact Poland. Similarly, the WOPK could inform other elements of the PVOS. Timely and accurate communications were essential in providing adequate warning, especially for high-speed cruise missiles and ballistic missiles. PVOS and national air defense integration created an enlarged, mutually-supportive air defense network, but extra layers of command in the PVOS due to the presence of both Soviet and East European personnel slowed information dissemination.<sup>91</sup> Polish military doctrine acknowledged the importance of effective communication including the importance of civil defense forces in passing threat information through non-military channels.<sup>92</sup>

Some anti-missile efforts did not involve active military means; non-military and passive military measures were also effective. Securing and sheltering important national capabilities from hostile manned and unmanned aerial attacks was a major responsibility of Polish civil defense forces.<sup>93</sup> After basic military service, all Polish conscripts became reservists, and reserve duty could include service in civil defense units.<sup>94</sup> Poland's historical traditions of resisting enemy invasions and safeguarding assets of the homeland also figured into missile attack survival. The entire nation had a part in protecting Poland's material and human resources. Military forces enhanced their survivability to missile attacks through CCD. CCD before launch complicated enemy reconnaissance and targeting/planning; subsequent CCD could degrade the accuracy or effectiveness of certain missiles. In addition, hardening, redundancy, dispersal, and mobility of potential missile targets

decreased the potential damage from any single missile, and created the requirement for multiple missile launches to achieve the same damage expectancy."

Foreign policy and arms control represented another form of post-war anti-missile defense, and the Rapacki Plan was an example of a Polish missile-related foreign policy and arms control initiative. In 1957-1958, Poland's Foreign Minister, Adam Rapacki, advocated a disarmament plan which dealt with Poland's main security concern--Germany. The plan contained a number of proposals including the establishment of a nuclear-free zone in Poland, Czechoslovakia, East Germany, and West Germany. Discussions about West Germany acquiring its own nuclear weapons troubled Warsaw, but the 1954 NATO deployment of US and British tactical nuclear weapons in West Germany gave the Rapacki Plan immediate relevance. Nuclear-capable weapons deployed in 1954 in West Germany which directly threatened Poland included aircraft-delivered munitions and US-built MATADOR tactical GLCMs. Moscow endorsed Warsaw's proposal, since the prospect of a non-nuclear West Germany also assuaged Soviet worries. The West rejected the offer, because the plan would upset the balance of power in Europe and would give the Soviets a military advantage in the region. NATO viewed its tactical nuclear forces as the necessary counterpoise to superior Soviet conventional capabilities." Nevertheless, the Rapacki Plan fully promoted Polish interests, and if the nuclear-capable forces had been withdrawn and banned from the region as set forth in the plan, Polish anti-missile air defense concerns could have been simplified.

#### RECENT HUMAN FACTORS

In some ways, the morale of Polish military personnel in 1992 and 1993 has been less problematic, but there have been difficulties nonetheless. Warsaw's complete sovereignty over the military undoubtedly has been a welcome change, especially for the air defense forces where PVOS control and integration had been so prevalent. However, economic realities have increasingly confronted the military's ability to procure equipment and train personnel including anti-missile air defense personnel. Military administrative and doctrinal changes have also been disruptive. Moreover, the size of Polish armed forces

has declined even more."

In recent years, there have been significant changes in Polish security relationships including anti-missile defenses. Shortly before the dissolution of the WTO and the PVOS, Poland's air defense system was reorganized again. The WOPK and the PAF merged into a single service, Aviation Army and Air Defense (*Wojska Lotnicze i Obrony Powietrznej*) (WLOP).<sup>99</sup> The WLOP, formerly attached to the monolithic, multinational PVOS, was now tasked with defending Polish airspace alone in the face of potentially hostile neighbors. However, Warsaw has signed military cooperation agreements with various countries in an attempt to strengthen Polish security, and Poland has been seeking NATO membership. Also, Poland has tried to cultivate good relations with neighboring states like Germany.<sup>100</sup> Polish military writing has acknowledged the resurrection of the interwar concept of a Polish, Czech, Slovak, and Hungarian "buffer zone" between two large potential aggressors (Germany and Russia).<sup>100</sup> Because the historical record of alliance-based security has sometimes been disappointing for Poland, Polish security policy will contain a measure of realism and self-reliance. Polish security will involve a dual-tracked approach--strength from alliances plus strength from autonomous development.

This security policy dualism has been evident in the air defense realm. The WLOP has not solicited the type of international integration which existed within the PVOS; Warsaw has sought to maintain and build up air defenses independently. However, Warsaw has not become completely self-sufficient, but has actively facilitated military cooperation. Hungarian air defense troops trained at Poland's Ustka SAM training range in 1993, and the Czechs intend to practice at Ustka in 1994.<sup>101</sup>

#### RECENT TACTICAL FACTORS

Dissolution of the WTO/PVOS and new international relationships terminated Poland's access to live fire SAM training opportunities in Kazakhstan beginning in 1991. Live fire exercises provided the most realistic and highest form of training in terms of simulated threats and operational stresses. Computerized training should economically fulfill some training

requirements, but complex command training requires live fire scenarios.<sup>102</sup>

Nevertheless, Polish SA-3 troops have been able to maintain their combat skills against missile threats. For a number of years, the Polish Navy deployed the SA-N-1, the shipborne version of the SA-3, on its largest surface combatant, and a naval SAM firing range was built along the Baltic at Ustka, Poland to train SA-N-1 operators. Plans for possible WLOP SA-3 training at the Ustka range were drawn up in 1991, and preliminary SA-3 live fire tests were conducted the next year. The realism and potential instructional benefits of the test firings were so great that training at Ustka became a mandatory part of Poland's SA-3 combat instructional program beginning in 1993. SA-3s at Ustka have been targeted against missile-like targets. Polish troops who operate other SAM systems will also train at Ustka after range modification.<sup>103</sup>

Recent Polish thinking on anti-missile-related tactics has been realistic yet innovative. Polish strategists have discussed the prospect of fighters performing independent airborne search and destruction of enemy aerial objects. Modern combat will probably involve the destruction or degradation of ground-based radar support for aircraft, and groups of fighters need to prepare for scenarios of airborne search and attrition of targets. Groups of airborne fighters must coordinate and position themselves to achieve maximum airborne intercept radar coverage in order to defend a particular aerial region.<sup>104</sup>

The Polish Navy still has an important anti-missile role. The loss of the Polish Navy's picket ship after 1991 has left Poland without the ability to acquire missile-related threats farther out in the Baltic. However, current Polish naval doctrine calls for airborne reconnaissance patrols by Polish naval aviation assets. Although these patrols will be established primarily for the protection of maritime assets, appropriate information regarding enemy aerial threats would be passed to the air defense system.<sup>105</sup> Polish military strategists are cognizant of the importance of precise identification and tracking of all aerial objects, military and non-military, over the sea; awareness of the military potential of certain non-military naval scenarios indicates Polish concern for all types of naval-related attacks including

missile attacks which use maritime air space.<sup>106</sup>

Polish tacticians have also recently acknowledged that training, planning, and precise execution of tasks are critical to successful operations and that technological advantage or overwhelming mass are not always required to achieve aerial combat objectives.<sup>107</sup> Because Poland's anti-missile defense arsenal does not contain only the newest, most advanced systems, these comments are particularly relevant. Older systems can be effective when operated by trained personnel; during Operation Desert Storm, the Iraqis successfully engaged some US TOMAHAWK cruise missiles with mature air defense weapons like AAA and the SA-8.<sup>108</sup> Arms control and security agreements affect military force levels, and force structure guidelines like the Conventional Forces in Europe Treaty which became effective 17 July 1992 impact Polish anti-missile capabilities (e.g. restricting the number of aircraft and military personnel).<sup>109</sup> Training, planning, and precise execution of the anti-missile mission are even more important when the size of equipment holdings and the number of military personnel are limited.

#### CONCLUSION

Polish anti-missile defenses have undergone noteworthy development. Wartime anti-missile efforts were in defense of non-Polish territory, but were ultimately related to regaining Polish independence. Despite handicaps and hardships, Poles performed capably during World War II anti-missile operations. In the post-war era, Polish anti-missile performance was degraded somewhat by unfavorable political and social factors, but Polish anti-missile defenses were designed and controlled sufficiently to meet Soviet expectations. Despite national sovereignty problems and command inefficiency within the PVOS, the PVOS extended Polish anti-missile defenses beyond Polish air space. Some PVOS equipment and strategies which were utilized by Polish anti-missile personnel were potentially effective, yet other PVOS equipment and tactics were inadequate in the anti-missile role. Polish post-war anti-missile defensive efforts included military and non-military means. In recent years, Poland's anti-missile defense system has confronted a significantly different international security environment, and Polish anti-missile training

and tactics have become more independent. Operator proficiency and tactical innovation have become increasingly important because of Poland's current economic difficulties and because of hardware and personnel constraints in Poland's air defense forces.

#### ENDNOTES

The following acronyms appear in the Endnotes Section:

**IISS:** International Institute for Strategic Studies

**ORAE:** Operational Research and Analysis Establishment

**PWLOP:** (*Przegląd Wojsk Lotniczych i Obrony Powietrznej*) Review of Aviation Army and Air Defense

**SASO/USACAC:** Soviet Army Studies Office/US Army Combined Arms Center

**WMON:** (Wydawnictwo Ministerstwa Obrony Narodowej) Publishing House of the Ministry of National Defense

**WTO:** Warsaw Treaty Organization

1. Michal Wojewodzki, *Akcja V-1, V-2 (V-1, V-2 action)* (Warsaw: PAX Publishing Institute, 1972), 513-516.

2. W. Seth Carus, *Cruise Missile Proliferation in the 1990s* (Westport, Connecticut: Praeger Publishers, 1992), 5-8.

3. Jerzy B. Cynk, *History of the Polish Air Force, 1918-1968* (London: Osprey Publishing Ltd., 1972), 164-167.

4. *Ibid.*, 193.

5. Wladyslaw Kozaczuk, *ENIGMA* (Washington, D.C.: University Publications of America, Inc., 1984), 58-60, 185-186.

6. Jozef Garlinski, *Hitler's Last Weapons: The Underground War Against the V-1 and V-2* (New York: Times Books, 1978), 50-57.

7. Wojewodzki, 232-234.

8. Kozaczuk, 191-192.

9. Garlinski, 127-133.

10. Teresa Rakowska-Harmstone, Christopher D. Jones, and Ivan Sylvain, *Warsaw Pact: The Question of Cohesion, Phase II-Volume 2, Poland, German Democratic Republic, and Romania* (ORAE Extra Mural Paper No. 33) (Ottawa: Department of National Defence) (November 1984), 42.

11. Teresa Rakowska-Harmstone and others, *Warsaw Pact: The Question of Cohesion, Phase II, Volume 1, The Greater Socialist Army: Integration and Reliability* (ORAE Extra Mural Paper No. 29) (Ottawa: Department of National Defence) (February 1984), 150-155; Rakowska-Harmstone, Jones, and Sylvain, 42-49, 53-57.

12. David Johnson, *V-1, V-2: Hitler's Vengeance on London* (New York: Stein and Day, 1982), 61-62.

13. *Ibid.*, 99.

14. *Ibid.*, 80.

15. Bernard Newman, *They Saved London* (London: Werner Laurie, 1952), 153-154; Johnson, 43.

16. Johnson, 62.

17. Newman, 154.

18. Johnson, 80, 82.

19. Cynk, 188-189, 195-196; Newman, 155.



20. Johnson, 79; Newman, 170.
21. Johnson, 97, 160.
22. Garlinski, 183; Johnson, 159; Newman 171.
23. Cynk, 188-189, 191-192; Garlinski, 170-171, 183.
24. Garlinski, 169-170.
25. Philip Henshall, *Hitler's Rocket Sites* (New York: St. Martin's Press, 1985), 209-211.
26. Author's note: The reported aerial destruction of a V-2 by machine guns from a US B-24 bomber was completely fortuitous. When a formation of Allied bombers was returning to England from a bombing mission over Germany, an ascending V-2 was visually acquired and then shot down over the Low Countries as the missile flew through the bomber formation. An unsuccessful intercept attempt of another ascending V-2 by a SPITFIRE pilot who happened to be flying near a launch area is more indicative of the chances of aerial interception of a V-2. See Johnson, 168-169.
27. Garlinski, 172.
28. Henshall, 209-211.
29. Cynk, 191-192; Garlinski, 173-175.
30. Rakowska-Harmstone, Jones, and Sylvain, 58-59.
31. Andrew A. Michta, *Red Eagle: The Army in Polish Politics, 1944-1988* (Stanford: Hoover Institution Press, 1990), 43-47.
32. Rakowska-Harmstone, Jones, and Sylvain, 63-65; Rakowska-Harmstone and others, 322.
33. Daniel Goure, "Securing the Skies of the Motherland," *Strategic Air Defense*, ed. Stephen J. Cimbala (Wilmington, Delaware: Scholarly Resources, Inc., 1989), 169-170.
34. Harold S. Orenstein, *Selected Translations from the Polish Military Press, Volume VIII* (Ft. Leavenworth: SASO/USACAC) (1 April 1991), 10; Jeffrey Simon, *Warsaw Pact: Problems of Command and Control* (Boulder: Westview Press, Inc., 1985), 2-3; Rakowska-Harmstone, Jones, and Sylvain, 64.
35. Steven J. Zaloga, *Soviet Air Defence Missiles: Design, Development, and Tactics* (Coulson, UK: Jane's Information Group Ltd., 1989), 4-5; Ronald Huiskens, *The Origin of the Strategic Cruise Missile* (New York: Praeger Publishers, 1981), 15-17.
36. Goure, 170-171.
37. A. Ross Johnson, Robert W. Dean, and Alexander Alexiev, *East European Military Establishments: The Warsaw Pact Northern Tier* (New York: Crane, Russak, and Co., Inc., 1982), 11-12; Rakowska-Harmstone and others, 49-50, 156-157; Simon, 2-4.
38. Johnson, Dean and Alexiev, 12, 15; Rakowska-Harmstone and others, 316-317; Simon, 215-217.
39. Johnson, Dean, and Alexiev, 16.
40. Cynk, 240.
41. Goure, 171.

42. Zaloga, 52-53.
43. Orenstein (1 April 1991), 10-11.
44. Rolf Berger, "The Rise and Fall of the WTO's Unified Air Defence System," *Jane's Intelligence Review* 4, no. 7 (1992):291; Zaloga, 53.
45. Rakowska-Harmstone and others, 187-188, 262; Simon, 214-215.
46. Rakowska-Harmstone, Jones, and Sylvain, 98.
47. Ibid.
48. Ibid., 99.
49. Johnson, Dean, and Alexiev, 33, 45-46.
50. Jiri Valenta, *Soviet Intervention in Czechoslovakia, 1968: Anatomy of a Decision*, rev. ed. (Baltimore: The Johns Hopkins University Press, 1991), 73, 113, 146, 150; Michta, 63-66.
51. Michta, 68.
52. Ibid., 67-69.
53. Simon, 166.
54. Ibid., 168-177.
55. Rakowska-Harmstone, Jones, and Sylvain, 79.
56. Michta, 197, 207; Rakowska-Harmstone and others, 322, 324.
57. Bruce D. Porter, *Red Armies in Crisis* (Boulder: Frederick A. Praeger, 1991), 22; *Strategic Survey 1989-1990*, ed. Sidney Bearman (London: IISS, 1990), 42.
58. *Keesing's Record of World Events* 37, no. 2 (February 1991):38026; Berger, 291.
59. Porter, 19-22.
60. Antoni Przeniczny, *Rozwoj artylerii przeciwlotniczej* (Evolution of anti-aviation artillery) (Warsaw: WMON, 1973), 128-130; Zaloga, 4-6.
61. Zaloga, 4-6.
62. Ibid., 7-8.
63. Ibid., 53.
64. *Military Balance 1967-1968* (London: IISS, 1967), 5; Zaloga, 53.
65. Przeniczny, 145-149, 181, 199-200.
66. Ibid., 180-184, 199.
67. Zbigniew Swiatnicki, "Wizja inteligentnej obrony powietrznej," (Vision of intelligent air defense), *PWLOP* 63, no. 2 (February 1991):17; Zaloga, 53, 61.
68. Zaloga, 105.
69. Jerzy Mastrosny, "Poligonowe strzelania rakietowe," (Rocket training-range firings), *PWLOP* 65, no. 7/8 (July/August 1993):80-83.

70. Zaloga, 53, 89.
71. Mastrozny, 82-84.
72. "Pointer," *Jane's Intelligence Review* 4, no. 3 (March 1992):112; *Jane's Land-Based Air Defence 1988-1989*, eds. Tony Cullen and Christopher F. Foss (Coulsdon, UK: Jane's Information Group, 1988), 90-94; Zaloga, 230, 243, 283, 304, 308.
73. Zaloga, 256-257, 272, 310.
74. Mastrozny, 82, 84-86.
75. *Jane's Land-Based Air Defence 1989-1990*, 2nd. ed., eds. Tony Cullen and Christopher F. Foss (Coulsdon, UK: Jane's Information Group, 1989), 263.
76. Zaloga, 98, 102-106, 123-124.
77. Mastrozny, 86.
78. Harold S. Orenstein, *Selected Translations from the Polish Military Press, Volume II: Artillery, Helicopters, Night Operations, Psychological Factors* (Ft. Leavenworth: SASO/USACAC) (3 September 1987), 164-165.
79. Cynk, 240-243, 247-248.
80. Orenstein (3 September 1987), 165.
81. Mastrozny, 82.
82. William Baxter, *Soviet Airland Battle Tactics* (Novato, California: Presidio Press, 1986), 151-152; *The Military Balance 1990-1991* (London: IISS, 1990), 52.
83. Simon, 220.
84. Berger, 291.
85. Zaloga, 89, 95-97.
86. *Jane's Fighting Ships 1989-1990*, 92nd. ed., ed. Richard Sharpe (Coulsdon, UK: Jane's Information Group, 1989), 443; *Jane's Fighting Ships 1991-1992*, 94nd. ed., ed. Richard Sharpe (Coulsdon, UK: Jane's Information Group, 1991), 454; *Jane's Fighting Ships 1992-1993*, 95th. ed., ed. Richard Sharpe (Coulsdon, UK: Jane's Information Group, 1992), 469-470; Milan Vego, *Soviet Naval Tactics* (Annapolis: Naval Institute Press, 1992), 330-331;
87. Harold S. Orenstein, *Selected Translations from the Polish Military Press, Volume III: Supplement* (Ft. Leavenworth: SASO/USACAC) (26 April 1988), 144.
88. Kazimierz Chmielewski, "Wykrywanie obiektow nisko lecacych," (The detecting of low-flying objects), *Przegląd Morski* 41, no. 4 (March 1988):10-13.
89. Boleslaw Chocha, *Obrona terytorium kraju* (Defense of the territory of the country) (Warsaw: WNSOW, 1974), 115-116.
90. Mastrozny, 82.
91. Berger, 291-294.
92. Chocha, 113-118, 122, 169-170.
93. Ibid., 113, 117-118, 199.

94. Rudolf Woller, *Warsaw Pact Reserve Systems: A White Paper* (Munich: Bernard and Graefe Verlag, 1978), 82-83.
95. James L. Bonomo and James A. Thomson, *The Promise of Passive Defenses* (RAND/P-7320) (Santa Monica: The RAND Corporation) (April 1987), 1.
96. Arthur B. Rachwald, *Poland Between the Superpowers: Security vs. Economic Recovery* (Boulder: Westview Press, Inc., 1983), 18-23; Homer E. Newell, *Guide to Rockets, Missiles, and Satellites*, 2nd. ed (New York: McGraw-Hill Book Company, Inc., 1961), 33, 42, 51; Huiskens, 21-24.
97. *Military Balance 1991-1992* (London: IISS, 1991), 91-92; *The Military Balance 1992-1993* (London: IISS, 1991), 80-81; *Military Balance 1993-1994* (London: IISS, 1993), 85; Włodzimierz Ogródowczyk, "Lotnictwo morskie w operacjach marynarki wojennej," (Maritime aviation in naval war operations), *PWLOP* 65, no. 6 (June 1993):13; *Nastrozny*, 87.
98. Orenstein (1 April 1991), 10.
99. Jan de Weydenthal, "Poland's Security Policy," *Radio Free Europe/Radio Liberty Research Report* 2, no. 14 (2 April 1993):31-33.
100. Marian Kopczewski, "Kierunki zmian w obronie powietrznej państw Europy środkowej po okresie transformacji," (Directions of changes in air defense of the states of Central Europe after the period of transformation), *PWLOP* 65, no. 5 (May 1993):39-44.
101. *Nastrozny*, 88.
102. *Ibid.*, 86-87.
103. *Ibid.*, 87-88.
104. Jerzy Szczygiel, "Samodzielne poszukiwanie i zwalczanie obiektów powietrznych: przeżytek czy perspektywa?" (Independent searching for and destroying of aerial objects: ancient relic or perspective?), *PWLOP* 65, no. 2 (February 1993):19-23.
105. Ogródowczyk, 12.
106. Marek Ilnicki and Andrzej Makowski, "Identyfikacja obiektów wojskowych w warunkach działań bojowych na morzu," (Identification of military objects in conditions of combat tasks at sea), *Przegląd Morski* 45, no. 10 (December 1992):3-4, 6-9.
107. Jerzy Machura, "Panowanie-przewaga w powietrzu w operacjach obronnych," (Aerial control-superiority in defensive operations), *PWLOP* 65, no. 6 (June 1993):4-7.
108. John W. R. Taylor, "Gallery of Russian Aerospace Weapons," *Air Force* 77, no. 3 (March 1994):75; Carus, 29.
109. *Military Balance 1993-1994* (London: IISS, 1993), 245, 248, 252.

## BIBLIOGRAPHY

The following acronyms appear in the Bibliography Section:

IISS: International Institute for Strategic Studies  
ORAE: Operational Research and Analysis Establishment  
PWLOP: (Przegląd Wojsk Lotniczych i Obrony Powietrznej) Review of Aviation Army and Air Defense  
SASO/USCAC: Soviet Army Studies Office/US Army Combined Arms Center  
WMON: (Wydawnictwo Ministerstwa Obrony Narodowej) Publishing House of the Ministry of National Defense  
WTO: Warsaw Treaty Organization

Baxter, William. *Soviet Airland Battle Tactics*. Novato, California: Presidio Press, 1986.

Bearman, Sidney, ed. *Strategic Survey 1989-1990*. London: IISS, 1990.

Berger, Rolf. "The Rise and Fall of the WTO's Unified Air Defence System," *Jane's Intelligence Review* 4, no. 7 (July 1992):291-294.

Bonomo, James L. and James A. Thomson. *The Promise of Passive Defenses*. (RAND/P-7320) Santa Monica: The RAND Corporation, April 1987.

Carus, W. Seth. *Cruise Missile Proliferation in the 1990s*. Westport, Connecticut: Praeger Publishers, 1992.

Chmielewski, Kazimierz. "Wykrywanie obiektów nisko lecących," (The detecting of low-flying objects), *Przegląd Morski* 41, no. 4 (April 1988):10-13.

Chocha, Bolesław. *Obrona terytorium kraju* (Defense of the territory of the country). Warsaw: WMON, 1974.

Cullen, Tony and Christopher F. Foss, eds. *Jane's Land-Based Air Defence* (Year). Coulsdon, UK: Jane's Information Group, 1988-1991.

Cynk, Jerzy. *History of the Polish Air Force, 1918-1968*. London: Osprey Publishing Ltd., 1972.

de Weydenthal, Jan. "Poland's Security Policy," *Radio Free Europe/Radio Liberty Research Report* 2, no. 14 (2 April 1993):31-33.

Garlinski, Jozef. *Hitler's Last Weapons: The Underground War Against the V-1 and V-2*. New York: Times Books, 1978.

Goure, Daniel, "Securing the Skies of the Motherland," *Strategic Air Defense*, ed. Stephen J Cimbala. (Wilmington, Delaware: Scholarly Resources, Inc., 1989), 161-202.

Henshall, Philip. *Hitler's Rocket Sites*. New York: St. Martin's Press, 1985.

Huiskens, Ronald. *The Origin of the Strategic Cruise Missile*. New York: Praeger Publishers, 1981.

Ilnicki, Marek and Andrzej Makowski, "Identyfikacja obiektów wojskowych w warunkach działań bojowych na morzu," (Identification of military objects in conditions of combat tasks at sea), *Przegląd Morski* 45, no. 10 (December 1992):3-9.

Johnson, A. Ross, Robert W. Dean, and Alexander Alexiev. *East European Military Establishments: The Warsaw Pact Northern Tier*. New York: Crane, Russak, and Co., Inc., 1982.

**Johnson, David.** V-1, V-2: Hitler's Vengeance on London. New York: Stein and Day, 1982.

*Keesing's Record of World Events* 37, No.2 (February 1991):38026.

**Kopczewski, Marian.** "Kierunki zmian w obronie powietrznej panstw Europy srodkowej po okresie transformacji," (Directions of changes in air defense of the states of Central Europe after the period of transformation), *PWLOP* 65, no. 5 (May 1993):39-44.

**Kozaczuk, Wladyslaw.** *ENIGMA*. Washington, D.C.: Publications of America, Inc., 1984.

**Machura, Jerzy.** "Panowanie-przewaga w powietrzu w operacjach obronnych," (Aerial control-superiority in defensive operations), *PWLOP* 65, no. 6 (June 1993):4-7.

**Nichta, Andrew A.** *Red Eagle: The Army in Polish Politics, 1944-1988*. Stanford: Hoover Institution Press, 1990.

*Military Balance* (Year). London: IISS, 1963-1993.

**Nastrozny, Jerzy.** "Poligonowe strzelania rakietowe," (Rocket training-range firings), *PWLOP* 65, no. 7/8 (July/August 1993):80-88.

**Newell, Homer E.** *Guide to Rockets, Missiles, and Satellites*, 2nd ed. New York: McGraw-Hill Book Company, Inc., 1961.

**Newman, Bernard.** *They Saved London*. London: Werner Laurie, 1952.

**Ogrodowczyk, Wlodimierz.** "Lotnictwo morskie w operacjach marynarki wojennej," (Maritime aviation in naval war operations), *PWLOP* 65, no. 6 (June 1993):8-13.

**Orenstein, Harold S.** *Selected Translations from the Polish Military Press, Volume II: Artillery, Tanks, Helicopters, Night Operations, Psychological Factors*. (Ft. Leavenworth: SASO/USACAC) (3 September 1987).

\_\_\_\_\_. *Selected Translations from the Polish Military Press, Volume III: Supplement*. (Ft. Leavenworth: SASO/USACAC) (26 April 1988).

\_\_\_\_\_. *Selected Translations from the Polish Military Press, Volume VIII*. (Ft. Leavenworth: SASO/USACAC) (1 April 1991).

"Pointer," *Jane's Intelligence Review* 4, no. 3 (March 1992):112.

**Porter, Bruce D.** *Red Armies in Crisis*. Boulder: Frederick A. Praeger, 1991.

**Przeniczny, Antoni.** *Rozwoj artylerii precyzyjnej (Evolution of anti-aviation artillery)*. Warsaw: WMON, 1973.

**Rachwald, Arthur B.** *Poland Between the Superpowers: Security vs. Economic Recovery*. Boulder: Westview Press, Inc., 1983.

**Rakowska-Harmstone, Teresa, Christopher D. Jones, John Jaworsky, and Ivan Sylvain.** *Warsaw Pact: The Question of Cohesion, Phase II, Volume 1, The Greater Socialist Army: Integration and Reliability*. (ORAE Extra Mural Paper No. 29) Ottawa: Department of National Defence, February 1984.

\_\_\_\_\_, **Christopher D. Jones, and Ivan Sylvain.** *Warsaw Pact: The Question of Cohesion, Phase II, Volume 2, Poland, German Democratic Republic, and Romania*. (ORAE Extra Mural Paper No. 33) Ottawa: Department of National Defence, November 1984.

Sharpe, Richard, ed. *Jane's Fighting Ships (Year)*. Coulsdon, UK: Jane's Information Group, 1989-1992.

Simon, Jeffrey. *Warsaw Pact: Problems of Command and Control*. Boulder: Westview Press Inc., 1985.

Swiatnicki, Zbigniew. "Wizja inteligentnej obrony powietrznej," (Vision of intelligent air defense), *PWLOP* 63, no. 2 (February 1991):15-21.

Szczygiel, Jerzy. "Samodzielne poszukiwanie i zwalczanie obiektow powietrznych: przezytek czy perspektywa?", (Independent searching for and destroying of aerial objects: ancient relic or perspective?), *PWLOP* 65, no. 2 (February 1993):19-23.

Taylor, W. R. John. "Gallery of Russian Aerospace Weapons," *Air Force* 77, no. 3 (March 1994):59-76.

Valenta, Jiri. *Soviet Intervention in Czechoslovakia, 1968: Anatomy of a Decision*, rev. ed. Baltimore: The John Hopkins University Press, 1991.

Vego, Milan. *Soviet Naval Tactics*. Annapolis: Naval Institute Press, 1992.

Wojewodzki, Michal. *Akcja V-1, V-2 (V-1, V-2 action)*. Warsaw: PAX Publishing Institute, 1972.

Woller, Rudolf. *Warsaw Pact Reserve Systems: A White Paper*. Munich: Bernard and Graefe Verlag, 1978.

Zaloga, Steven J. *Soviet Air Defence Missiles: Design, Development, and Tactics*. Coulsdon, UK: Jane's Information Group Ltd., 1989.