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Military aeronautical charts in the past and today

Abstract. The history of the development of military aeronautical charts began immediately before the First World War. The first charts created at that time did not differ much from topographic maps. Air planes were fairly slow back then and had a small range of action, which meant that the charts were developed at the scale of 1:200,000. When speed of aircraft increased, it soon turned out that this scale was too large. Therefore, many countries began to create charts with smaller scales: 1:300,000 and 1:500,000. *The International Map of the World 1:1,000,000* (IMW) was frequently used for continental flights prior to the outbreak of the Second World War, while 1:3,500,000 and 1:5,000,000 maps were commonly used for intercontinental flights.

The Second World War brought a breakthrough in the field of aeronautical chart development, especially after 7 December 1941, when the USA entered into the war. The Americans created more than 6000 map sheets and published more than 100 million copies, which covered all continents. In their cartographic endeavours, they were aided foremost by the Brits.

On the other hand, the Third Reich had more than 1,500 officers and about 15,000 soldiers and civil servants involved in the development of maps and other geographic publications during the Second World War. What is more, the Reich employed local cartographers and made use of local source materials in all the countries it occupied. The Germans introduced one new element to the aeronautical charts – the printed reference grid which made it easier to command its air force.

The experience gained during the Second World War and local conflicts was for the United States an impulse to undertake work on the standardization of the development of aeronautical charts. Initially, standardization work concerned only aeronautical charts issued by the US, but after the establishment of NATO, standardization began to be applied to all countries entering the Alliance. The currently binding NATO STANAGs (Standardization Agreements) distinguish between operational charts and special low-flight charts. The charts are developed in the WGS-84 coordinate system, where the WGS-84 ellipsoid of rotation is the reference surface. The cylindrical transverse Mercator projection was used for the scale of 1:250,000, while the conformal conic projection was used for other scales.

The first aeronautical charts issued at the beginning of the 20th century contained only a dozen or so special symbols concerning charts' navigational content, whereas currently the number of symbols and abbreviations found on such charts exceeds one hundred. The updating documents are published every 28 days in order to ensure that aeronautical charts remain up-to-date between releases of their subsequent editions. It concerns foremost aerial obstacles and air traffic zones.

The aeronautical charts published by NATO have scales between 1:50,000 and 1:500,000 and the printed Military Grid Reference System (MGRS), while the aeronautical charts at scales between 1:250,000 and 1:2,000,000 contain the World Geographic Reference System (GEOREF).

Nowadays, modern military air planes are characterised by their exceptional combat capabilities in terms of speed, range and manoeuvrability. Aside from aircraft, contemporary armed forces make increasingly frequent use of aerial robots, drones and unmanned cruise missiles. This is why, there has been a noticeable increase, especially in NATO, in the amount of work devoted to the standardization and development of aeronautical charts, as well as deepening of knowledge of navigation and aeronautical information.

Keywords: military aeronautical charts, special military aeronautical charts, operational military aeronautical charts, JOG-Air, TPC, LFC-Europe, TFC(L)

1. Introduction

The history of development of aeronautical charts is merely one-hundred-years-old. Despite this, the development of such charts has been extremely dynamic, and dependant on the development of aviation, which happened mainly during the First World War. At the beginning of the war, many commanders still showed some reluctance to use aircraft on the battlefield[1], but their attitudes quickly changed. Aviation has revolutionised modern warfare. Air planes were used not only to conduct reconnaissance of the enemy's forces and terrain, and directing artillery faire and liaison, but also to conduct independent air combat and bombard industrial buildings and enemy's forces.

Initially, pilots made flights in clear weather and used topographic maps. The visibility of the area and possibility of comparing it with the map were the most important factors taken into consideration. Only few regulations applied to air forces, and pilots could fly virtually everywhere, without any restrictions[2]. The planes flew mostly along road routes, railways, rivers and distinctive natural objects. The first aeronautical charts were published in 1911 in France and Belgium. They were 1:200,000 charts which did not differ much from the topographic maps. The adoption of such a large scale was related to the fact that the radius of action of the planes was fairly small at that point (about 200 km) and their speed of flight was also low (100–200 km/h) (S. Czarnecki 1933).

2. The First World War

During the First World War and after its end, individual countries tended to endeavour to develop aeronautical charts according to their own concepts (between 1911 and 1929, France used 1:200,000 charts, Germany developed 1:200,000 charts in 1915–1919, in Great Britain, aeronautical charts were created using the scale of 1:253,000 in the early 1920s, while in Norway, the scale of 1:250,000 was the norm). Because of these inconsistencies, Commission internationale de navigation aérienne (CINA), which was established on 13 October 1919 during the Paris Peace Conference, instructed its member states to develop for their territories *Carte normale aeronautique internationale*[3] at the scale of 1:200,000. When speed of the planes increased, it soon tuned out that this scale was too large. Consequently, many countries began to create maps with smaller scales: 1:300,000 (Germany, Italy), 1:400,000 (Greece), 1:500,000 (USA, France, Poland), and 1:633,600 (Great Britain).

At that time, the US and Canada introduced an original concept – the so-called strip maps – maps of air routes between airports at the scale of 1:500,000 (*Air Navigation Strip Maps*), with a width of 10 inches and a varying length which depended on the distance between airports (fig. 1). The diagrams of runways at the airports were shown on the margins of these maps. The map of airports of Africa (at the scale of 1:5,000,000) and the map of North African landing sites (at the scale of 1:2,000,000), both created by the French Army Geographical Service (*Service géographique de l'armée*), were equally interesting.

3. The interwar period

In the interwar period, especially in the 1930s, there was a very rapid development of military aviation. Air planes became better equipped and armed, their speed, radius of action and operational altitude increased, and the first jet plane was flown in that period. Military theories[4] were developed which assumed that the air force would overtake other types of armed forces and dominate future battlefields

[1] In 1911, Ferdinand Foch, a French marshal, stated that: "Air planes are interesting toys, but of no military value." The scepticism towards the use of aircraft in military operations is demonstrated by the number of aircraft owned by the most important states taking part in the First World War at the beginning of 1914. France had 141 planes, United Kingdom – 113, Russia – 145 and Germany and Austria-Hungary – 268. However, a very rapid development of aviation and mass production of air planes began soon after the outbreak of the war. Over 180,000 planes were produced in total during the First World War.

[2] The first regulations on military aviation activities were developed by a group of lawyers from Hague. They were issued on 19 February 1923 as the *Hague Rules of Air Warfare*.

[3] About 100 sheets of this map had been published up to 1933, mainly for the area of France, Germany and the Czechoslovakia.

[4] General Giulio Douhet, an Italian military theoretician, assumed even that the up-coming war would be mostly air combat.

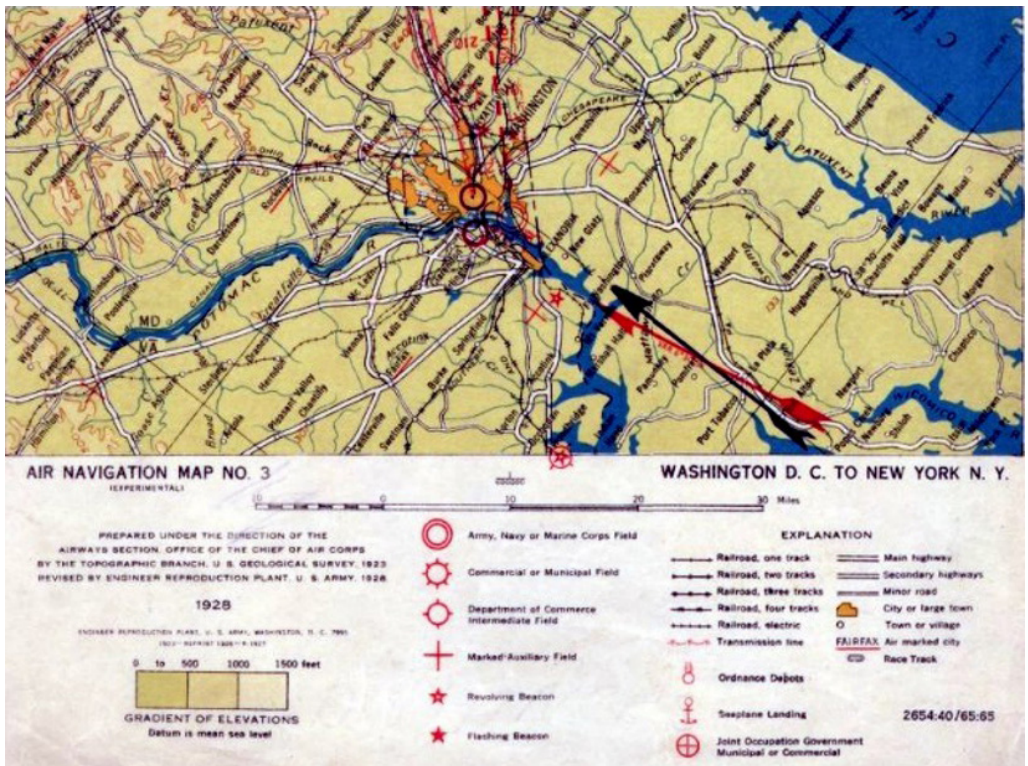

Fig. 1. An example of an American strip aeronautical chart at the scale of 1:500,000 from 1928, depicting the air route between Washington and New York

(G. Douhet 2013). The US, USSR, Great Britain, Germany and Japan were leaders in the production of military planes. Before and during the Second World War, the USA alone produced over 300,000 military air planes. This development of aviation and ideas of its potential use in the future were translated into the growth of the need for aeronautical charts and new navigational information on maps.

In 1932, the CINA made a resolution in which it recommended using the international aeronautical chart 1:1,000,000 *Carte normale aeronautique internationale* as the basis for continental flights (S. Czarnecki 1937). This was linked to the fact that at that time many countries developed the *International Map of the World 1:1,000,000* which was used for many years as an aeronautical chart, and at the same time served as a base for issuing other aeronautical charts. There was fairly little of special (aeronautical) content on these early aeronautical charts. The number of symbols usually did not exceed 20 and was limited to the presentation of airports, airstrips, restricted areas, lighthouses and magnetic data (fig. 2). The topographic content included roads, railways and waters, as well as the highest elevations, while the settlements were generalised (S. Czarnecki 1927).

In the 1930s, there were also many aeronautical charts for intercontinental flights: *Carte de base* and *Cartes des routiers aeronautiques* 1:10,000,000 charts developed by France, *Carte generale* 1:3,700,000 chart developed by England, France, Poland and Japan, and a 1:2,300,000 chart created by England, France, Poland and Czechoslovakia. In the interwar period, atlases of airports were also very popular. They contained detailed information about

the airport infrastructure. In Poland, such atlas was issued by the Ministry of Communications in 1933 and contained data on 28 civilian airports. The description was accompanied by parts of maps at scales of 1:100,000 and 1:200,000, as well as a general 1:1,000,000 map.

In Poland, the Wojskowy Instytut Geograficzny (Military Geographical Institute – MGI) published two aeronautical charts: Regular Aeronautical Chart (*Normalna Mapa Lotnicza*) at the scale of 1:1,000,000 (two sheets were published – for Warsaw and Kraków – before September 1939), as well as the 1:500,000 Map of Poland and the Neighbouring Countries (*Mapa Polski i Krajów Ościennych)*[5] (aeronautical edition). The second of these maps was created by printing special content (aeronautical and magnetic) and by including more details concerning the surface waters, roads, railways and forests on the basic Map of Poland and the Neighbouring Countries (R. Miahczyłowicz-Wolski 1937). The first sheet of this chart was published at the beginning of 1937, and 7 sheets had been published by September 1939 (out of 17 sheets covering Poland). Additionally, MGI issued two more sheets outside the country (Vienna, Copenhagen), as provisional editions, meant to be used only by the Polish Armed Forces. The magnetism-related data presented

[5] During the Second World War, a map with the same name but a different scale (1:1,000,000) and a changed sheet division was published by MGI in Edinburgh (it was printed by the Bartholomew publishing house)

Fig. 2. Examples of special symbols used on a pre-Second-World-War Polish aeronautical charts at the scales of 1:500,000 (top) and 1:1,000,000

Fig. 3. Part of an aeronautical chart at the scale of 1:500,000 from the territory of Poland

on the chart, that is, data on magnetic declination and anomalies, were provided by the Magnetic Observatory in Świder. The charts were printed on special paper (rag paper) which was very resistant to bending. Figure 3 shows the part of this map (sheet N-34-IV Warszawa-Wschód, 1938) along with the legend of basic topographic symbols.

Due to the lack of aeronautical charts covering the whole country, in the interwar period, pilots of the LOT Polish Airlines and military airmen relied mainly on the 1:300,000 operational map of Poland.

Between the First and Second World War, there was no distinction between civilian and military aeronautical charts (the only special military aeronautical chart was published by Germany, with the scale of 1:1,000,000). As a rule, they were developed by military geographical services, although commercial companies were often hired as subcontractors. During this period, charts from private com-

panies were used along official aeronautical charts. In the United States, Elrey Borge Jeppesen, an American pilot, began to develop and publish so-called *Jeppesen charts*. During the Second World War, his company[6] was one of the enterprises which were officially responsible for supplying the US armed forces with aeronautical charts. In Poland, the Lviv publishers Książnica-Atlas developed and published a 1:1,000,000 aeronautical chart which covered not only the territory of Poland, but also part of the USSR, reaching Moscow.

4. The Second World War

4.1. The Allies

Even before the outbreak of the Second World War, Germany, France, Great Britain, the USA and the USSR modified a large number of sheets of the *International Map of the World 1:1,000,000*[7] to create the aeronautical chart version. Each of these countries had their own designs for the development of these charts, different sheet formats and different descriptions of the marginal data; in some cases several charts were published for the same area.

At the beginning of the war, the US Air Force defined relevant assumptions and began publishing the *World Planning Chart* at the scale of 1:5,000,000. 41 sheets of this chart were published by the end of 1941. After the US's accession to war (7 December 1941), the requirements for aeronautical charts have gained special significance; therefore, on 1 May 1942, the Ministry of War presented detailed rules for publication of maps, including aeronautical charts, meant to be used for war-related purposes. The Aeronautical Chart Service, an entity created within the US Air Force, was charged with the preparation of guidelines for the publication, reproduction, purchase and distribution of aeronautical charts. It cooperated with several civilian cartographic agencies, developing aeronautical charts on the basis of agreements with the Air Force. In 1942, Americans printed 8,154,800 sheets of aeronautical charts. Additionally, 1,196,000 charts were purchased from various cartographic agencies. The development of charts for the area of Japan and China constituted a particularly demanding challenge, as it was necessary to transliterate local names into Latin alphabet, for which about 90 translators were employed. It is enough to mention that 72 sheets of a 1:500,000 chart were developed for the area of Japan in 1942 alone.

On 12 May 1942, the United States and the United Kingdom defined their respective areas of geographical responsibility when it comes to the development of maps, including aeronautical charts, for military purposes. The United States undertook to develop maps for North and South America, Australia and New Zealand, Pacific Islands, Dutch East India, Japan, Iceland, Greenland, and Bermuda. The British Geographical Section General Staff (GSGS) assumed responsibility for the remaining areas (mainly Europe) (fig. 4). It was also agreed that both countries would share the developed maps with each other[8]. On 10 March 1943, it was further decided that the US would develop the necessary maps for the areas of Korea, Mongolia, Manchuria, parts of the USSR and China (north of 32° N and east of 108° E). The US agreed also to accept responsibility for the preparation of several aeronautical charts for parts of Western Europe.

Until 1943, in the USA, the printing of aeronautical charts was conducted by the following two institutions: the Army Map Service and the United States Coast and Geodetic Survey. What is more, in June 1943, the Aeronautical Chart Service launched an aeronautical chart reproduction plant in St. Louis, Missouri, which by June 1946 printed about 50 million sheets of charts. Particularly significant challenges were connected with the preparation of aeronautical charts used by the Anglo-American air forces for the bombing of facilities located at the deep rears of the German army, including carpet bombing on military facilities and German cities (Berlin, Hamburg, Dresden (fig. 5), Cologne, Bremen, Lübeck, Hamm and Essen) and carrying out long reconnaissance missions, as well as landing of the allied forces in

[6] Nowadays, Jeppesen A Boeing Company is a global leader in the field of creation of aeronautical charts and navigation systems, not only for civil aviation, but also for the military sectors of many countries.

[7] About 400 sheets of this map were developed at the end of 1930s.

[8] In the course of development of maps for the area of Africa and Asia, Americans used mainly British maps published after the First World War.

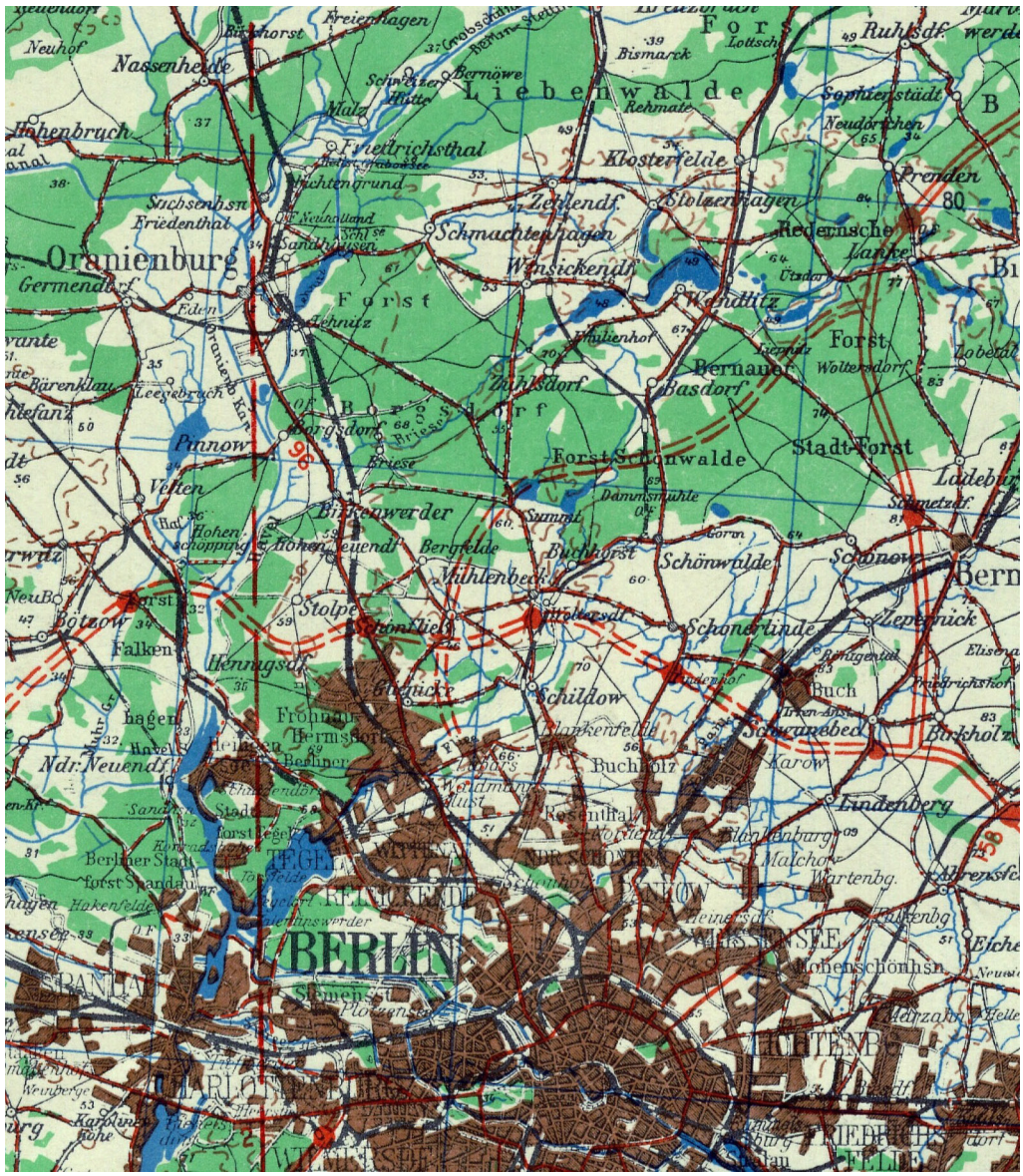

Fig. 4. Part of a British chart from 1943 (published by GSGS) at the scale of 1:250,000 (air and ground editions), N-53-Berlin sheet

1944 in Normandy. Pilots needed charts for long-distance flights, and at the same time charts showing terrain details (bridges, viaducts, transport nodes, arms factories, refineries), therefore, image maps were prepared to supplement the traditional charts, and pilots discussed their flights beforehand, using terrain mock-ups and aerial photographs (G. Douhet 2013).

The first models of charts such as *Operational Navigation Chart* (ONC), *Tactical Pilotage Chart* (TPC) and *Joint Operations Graphic-Air*

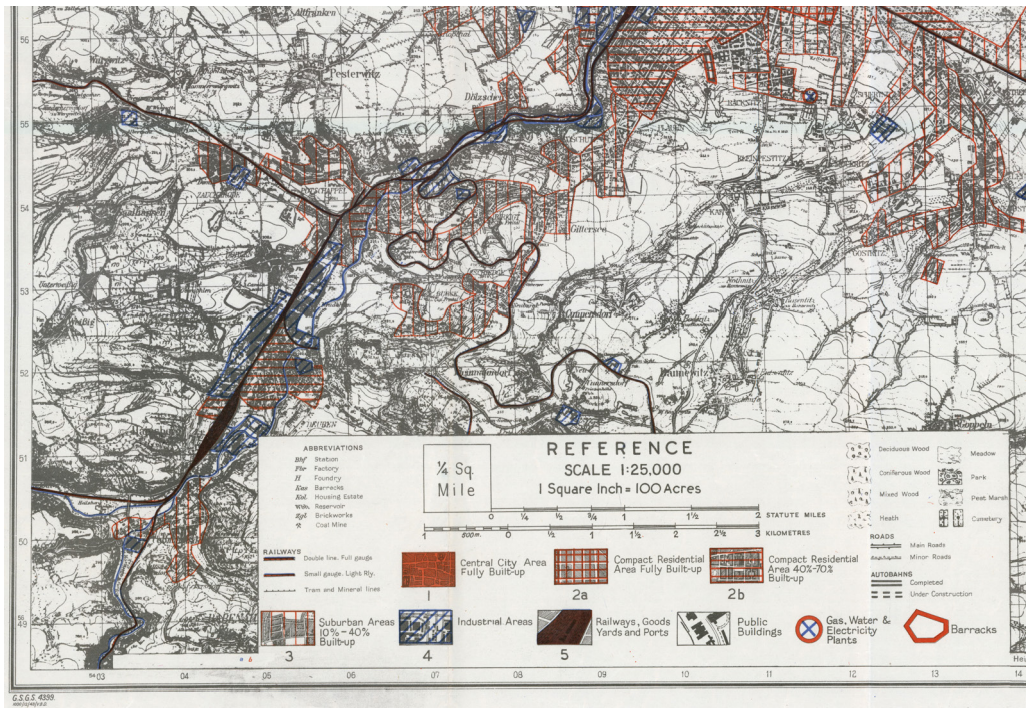

Fig. 5. Part of a British chart of Dresden at the scale of 1:25,000 (published by GSGS), intended to be used by pilots for bombing the city; developed on the basis of a German chart (*Messtischblatt*)

(JOG-A), which remain popular today, were developed and created at that time. In 1944, IMW maps in their aeronautical versions were assigned a series number: 1301. At the end of 1944, 81 officers and 1,100 civilians were employed in the Aeronautical Chart Service for the development of aeronautical charts. In total, about 5,000 people worked in various cartographic agencies during the war, which made it possible to develop over 6,000 chart sheets in 100 million copies.

During the war, the Americans and the British produced and used the charts listed below which, at smaller scales, covered the whole world, and at the scale of 1:250,000 and larger, only those areas which were important for the war effort:

• *World Planning Chart* 1:5,000,000, a chart used to plan routes and manage tactical traffic;

• *World Outline Chart* 1:5,000,000, a chart used for general planning and operational activities;

• *Long Range Navigation Chart* 1:3,000,000, a chart used in dead reckoning and celestial navigation;

• *World Aeronautical Chart*, 1:1,000,000 and 1:500,000 versions, a chart which was intended to be used mainly for pilotage and radio navigation on designated routes, as well as for dead reckoning and celestial navigation (fig. 6);

• *Western Hemisphere Chart* 1:1,000,000, a chart for pilotage;

• *Approach Chart*,1:250,000, a chart used to facilitate orientation in congested areas and areas of particular strategic importance;

• *Target Chart*, 1:180,000, a chart used for bombing targets;

• *Flight Chart*, 1:1,000,000, a chart intended mainly for pilotage and radionavigation on already established air routes, but also in dead reckoning and celestial navigation.

Maps printed on silk (*Cloth Escape Chart* or *Cloth Chart)* became a popular part of pilots' equipment in the armies of the United States

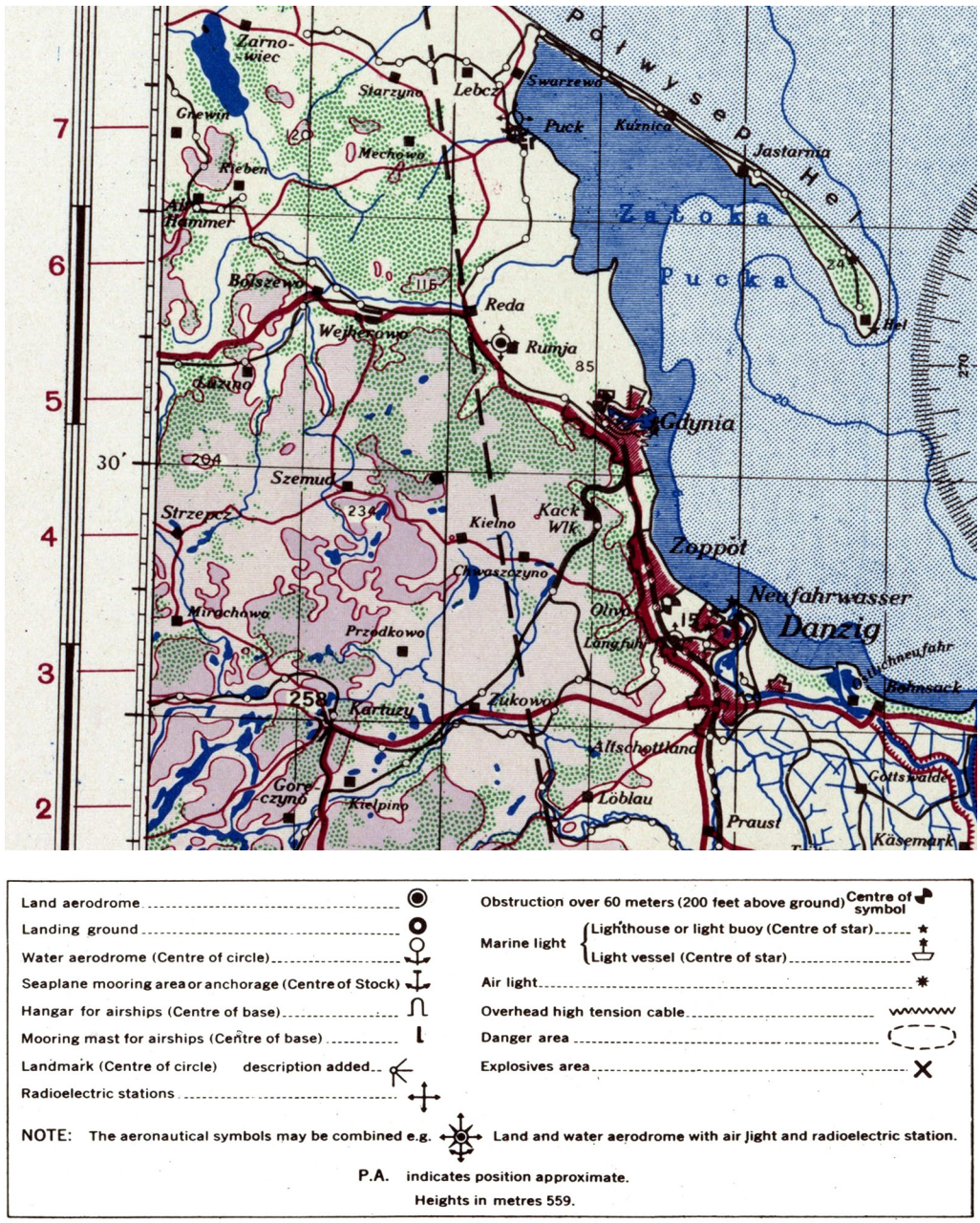

Fig. 6. Part of an aeronautical chart at the scale of 1:500,000, sheet Danzig N.E. 54/18, developed by the GSGS, printed by the Army Map Service

and Great Britain. 3.5 million of such maps were printed in total, at the scales from 1:100,000 to 1:1,000,000, and most of them were aeronautical charts. They were meant to help crews of air planes which were shot down over occupied territories with planning their return to their

home countries[9]. Most of these charts were printed by John Waddington, a company specialising in the production of games and playing cards. Similar charts (so-called Evasion Charts) were used by American soldiers during the Korean War in 1950–1953 and in Vietnam in 1968, and the British Army (GSGS) supplied them to the soldiers taking part in missions in Bosnia and Herzegovina in 1991–1995, and later in Afghanistan.

At the end of the Second World War, the *Convention on International Civil Aviation* (also known as the Chicago Convention), announced in Chicago on 7 December 1944, established the International Civil Aviation Organization (ICAO) and thus brought about a breakthrough in the standardization of aeronautical charts. In accordance with Article 37 of the Convention, the Council of ICAO adopts the *Standards and Recommended Practices* (SARPs) in the field of international civil aviation, which are issued in the form of annexes to the Convention. At the moment, there are altogether 19 annexes, and Annex no. 4 concerns aeronautical charts[10]. The agreements included in this annex, especially those which concerned the navigational content, are taken into account in the development of military aeronautical charts.

It is worth noting that at the end of the war and after its end, until 1955, the Americans and the British continued publishing the new edition of the *International Map of the World* 1:1,000,000, with the series number 1301, which later (from 1960) was replaced by the *Operational Navigation Chart*[11]. In 1992, it was used as a basis for development of the *Digital Chart of the World*.

During the Second World War, Russians used mainly aeronautical charts at the scale of 1:1,000,000 and land topographic maps.

4.2. Germany

The total war which the Third Reich planned to wage for the control of all of Europe, Asia and certain parts of Africa, necessitated earlier preparation of many types of maps and military-geographical descriptions for these areas. In the Third Reich, the development of maps and taking of geodetic measurements was the responsibility of the Reich Office for Land Survey (Reichsamt für Landesaufnahme). The geographical service was not established in individual branches of Wehrmacht's armed forces (Heer [army], Luftwaffe [air force], and Kriegsmarine [navy]) until October 1936. The most-developed geographical service was the one established in the land forces – Abteilung für Kriegskarten und Vermessungswesen. During the war, Reichsamt für Landesaufnahme dealt with the development and printing of maps of the Third Reich and the areas which had been annexed to the Reich, while Abteilung für Kriegskarten und Vermessungswesen printed maps used by the German army on the areas where they conducted their war effort[12]. Branches of this service were organized in all of the occupied countries, local cartographers were employed and the acquired printing potential was used by the Germans. Generalstab of Air Force, Section 7 (Oberkommando der Luftwaffe, Abteilung 7) was responsible for developing the necessary assumptions and providing navigation data for the publication of aeronautical charts, which it did in cooperation with Abteilung für Kriegskarten und Vermessungswesen and Abwehr.

Before the outbreak of the war, the Germans started the development of their own world map – *Weltkarte* (*Fliegerausgabe*) and *Deutsche Heereskarte* – at the scale of 1:1,000,000, on the basis of IMW (fig. 7). They covered the whole of Europe, part of Asia and North Africa[13]. Their copies were printed throughout the war. Some of the sheets did not have any aeronautical information, outside of the airports, except for the reference grid. In areas where Germany

[9] Some of these maps were smuggled together with food packets and games to German prisoner-of-war camps where allied prisoners were kept. They were meant to aid the prisoners in planning their escapes from the camps.

[10] Poland submitted the ratification documents on 4 April 1947, but due to the political situation, it did not begin to participate in the work of ICAO until 1957. The ratification of the Convention took place on 20 November 1958. The Soviet Union adopted the Convention on 16 April 1948.

[11] The projection of the IMW was changed to the Lambert conformal conic projection, and the relief was presented in contours measured in English feet. In 1981, the Defence Mapping Agency issued detailed instructions on the development of this map: http://earth-info.nga.mil/publications/specs/printed/89102/89102.pdf

[12] The Third Reich had 1,500 officers and about 15,000 soldiers and civil servants involved in the development of maps and other geographic publications during the Second World War. Generally, between 1935 and the end of the war, Germany issued over a milliard sheets of maps, much more than the Russians and Americans.

[13] The German had developed more than 100 sheets of this map by 1940.

Fig. 7. Part of a German aeronautical chart at the scale of 1:1,000,000 (*Weltkarte*), published in 1943, sheet: Moskau N-37

did not have any IMW sheets, they used maps with different scales, in versions which they reduced to the 1:1,000,000 scale. The characteristic element of this map is the fact that the reference grid is printed in red and that the highest elevations of the terrain are marked.

Another chart published by the Germans was *Deutsche Weltkarte* 1:500,000, which was also known as *Deutsche Fliegerkarte*, and which was developed for Europe, Africa and Asia Minor. The sheets presenting most areas of Europe were known as *Vogels Karte von Mitteleuropa*, with Vogel being the name of the well-known German cartographer, Carl Vogel, the author of 1:500,000 charts. They were highly rated not only by pilots, but also by general military commanders. For territories of North-West Africa, charts of this series were developed after 1940 by French cartographers with the framework of forced labour performed for the Germans. Most sheets of this chart were developed and printed by Justus Perthes, a German publishing house in Gotha (which had existed since 1785). This publishing house, just as the majority of similar printers, had been militarised in 1936 and from them one had been involved in the development of maps for warfare purposes. Charts of this series continued to be published until 1945, and some sheets were reissued several times. For the territory of Poland, Germans very often used the Polish 1:500,000 as the basis for their charts. They even used the same symbols to indicate aeronautical content. Still, the part of the chart shown below (fig. 8) differs from the Polish aeronautical chart of 1938 both in its

cartographic elements and the symbols concerning aeronautical contents, and moreover, it contains a printed reference grid.

The regulation of 18 April 1940, issued by the Minister of Aviation and the commander of the Luftwaffe, was of great importance in the development of aeronautical charts. It introduced unified principles of map use in aviation and created an obligation to present the Luftwaffenmeldenetz (Lw.M.N) reference grid on all maps.

During the war, the armed forces of the Reich very often used 1:300,000 maps. They were called *Übersichtskarte von Mitteleuropa*. Many of the sheets included also such references as *Sonderausgabe* or *Deutsche Heereskarte*[14]. The aeronautical version included a *Fliegerkarte* sign printed in red and a reference grid. Some sheets included also a reference grid for fighters (Jägermeldenetz). It was published by Oberkommando der Luftwaffe (Abteilung 7). This chart played an important role during the flights to Stalingrad when it was besieged by the German Sixth Army.

The Germans printed also aeronautical charts at the scale of 1:100,000 which were focused foremost on areas around certain cities in Great Britain, including London and Manchester (fig. 9). They were designed for night flights and printed using special reflective paints. The bombing targets and areas of prisoner-of-war camps in which German prisoners were detained were shown on the maps.

Military and geographical descriptions[15] intended for German air forces, which supplemented the content of aeronautical charts, making it easier to fly over areas with little in terms of navigational details, were also very useful.

5. After the Second World War

The role of the nuclear power as a deterrent grew rapidly after the end of the Second World War. It was treated as the basic tool of preventing the enemy from engaging in aggressive actions. Air force was seen as having particular significance in this doctrine, especially strategic bombers. At the same time, aviation engaged in a deep strategic reconnaissance covering thousands of kilometres, which required the use of aeronautical charts for intercontinental flights. What is more, the wars conducted in Vietnam, Cambodia and Laos in the mid-1960s and early 1970s, in which helicopters were commonly used, forced the development of detailed aeronautical charts. A 1:250,000 map titled *Joint Operations Graphic* (JOG) was created by the USA for the use in these countries. Two versions of *Joint Operations Graphic* were developed – one meant to be used by land forces (*Ground*) and one intended for aircraft (*Air*) – in order to ensure that both of these army branches had a uniform foundation for any combined operations of land and air forces. Both contained identical data, with the aeronautical version enriched with information facilitating air navigation. In the "ground" version, the heights were presented in meters, while in the "air" version, they were given in feet. In addition to *Joint Operations Graphic*, charts at the scale of 1:50,000 were also developed for helicopters.

During the Cold War, the Americans and the British expanded their aeronautical charts at the scale of 1:250,000 to the Eastern Europe (including Poland)[16], to the areas up to the Smolensk Meridian. At that point, they were not yet referred to as *JOGs*, although the layout of the map, its cartographic symbols and legends were the same as the ones used for *JOGs*. They were bilingual charts (in English and German) with the new N501 series number. In 1982, the Americans issued maps at the scale of 1:250,000 for the area of Afghanistan. In their "ground" and "air" versions, they are called *Combined Joint Operations.*

5.1. Aeronautical charts in the Warsaw Pact countries

In the first years after the Second World War, Russians used maps and charts developed during the war, which were mainly using

[14] The special edition included also areas outside the Third Reich.

[15] For example, in 1941, the Luftwaffe published a several-hundred-page-long study on the USSR (*Luftgeographische Beschreibung Europäisches Rußland*, Berlin 1941) containing detailed information on the conditions of the geographical environment, road and rail infrastructure, all enriched by aerial photographs, as well as maps and plans of larger cities.

[16] http://m.loadmap.net/en/catalog/c3089/s250000

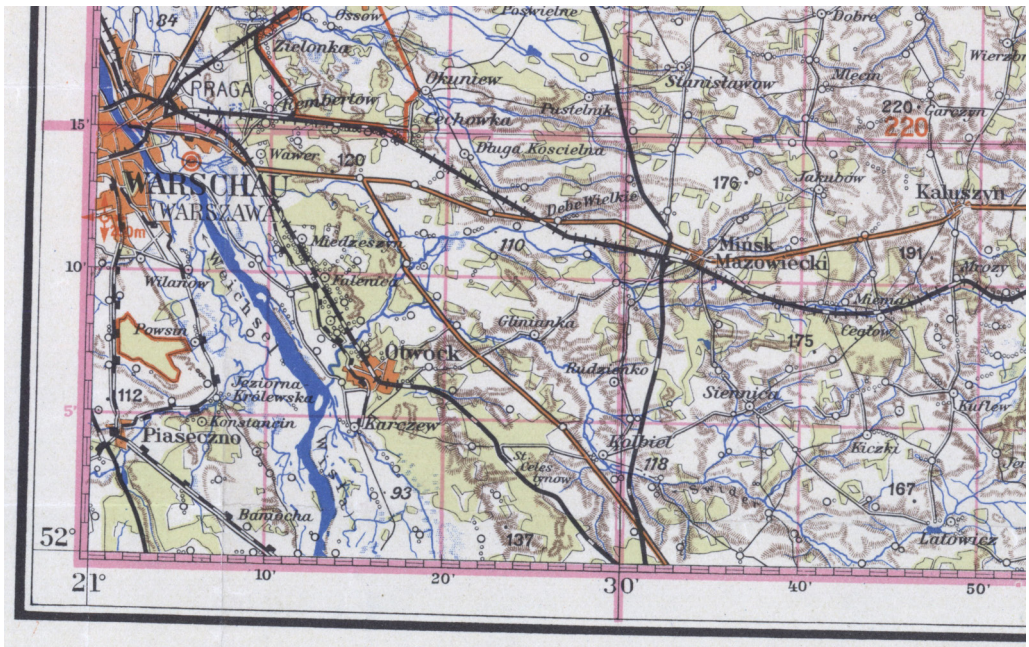

Fig. 8. Part of the German *Vogels Karte von Mitteleuropa (Fliegekarte),* 1:500,000, N-34-SO sheet, Warschau-Ost, published in May 1939

the scale of 1:1,000,000. In 1949, the USSR began publishing aeronautical charts for civil aviation in accordance with the ICAO convention, at the scales of 1:1,000,000, 1:500,000 and 1:250,000. These charts were also used by military pilots. Aside from this, in the 1970s and 1980s, Russians created new aeronautical charts for the territory of the Western Europe (for all Eastern bloc countries) – *Aeronavigatsionnaya Karta*, with the scales of 1:1,000,000

Fig. 9. Part of a German 1:100,000 map (Manchester), published in 1941 and meant to be used for bombing the city

and 1:500,000 (fig. 10). They contained information about airports, including data on the length and surface of their runways.

In Poland, the first post-WWII aeronautical chart was published in 1947 and it was developed on the basis of the *Map of Poland*[17] created by MGI at the scale of 1:500,000 (fig. 11). The aeronautical content was not limited only to airports but also urbanised regions and characteristic elevations of the terrain. In 1970s, this map, after some updating, was published as the 1:500,000 *Aeronautical Chart of Poland*. In later years, the Topographic Service of the Polish Armed Forces published aeronautical charts at the scales of 1:1,000,000 and 1:500,000 for the territory of Northern Europe (Western Theatre of War Operations) which had been

[17] This chart was developed on the basis of the pre-war 1:500,000 *Map of Poland and the Neighbouring Countries*; the layout of sheets was changes, due to the changes in Poland's territory.

developed on the basis of Soviet materials. Charts of the same scales were published for the territory of Poland, with only some changes in the nomenclature and some additional data on the current aeronautical situation.

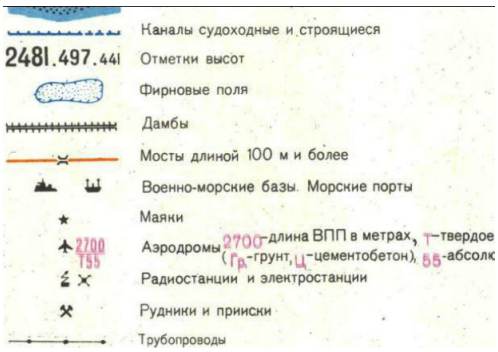

Fig. 10. Symbols of a Soviet aeronautical chart at the scale of 1:500,000, published for the Western Theatre of War Operations

5.2. Aeronautical charts in the countries of the North Atlantic Alliance

5.2.1. Standardization of the aeronautical charts in the NATO

The experience gained during the Second World War and local conflicts was for the United States an impulse to undertake work on the standardization of the development of aeronautical charts. Detailed technical specifications for the 1:250,000 *Joint Operations Graphics* (JOG) maps were published in November 1976, and the new specification MIL-J-89100 (DMA) was released in February 1995. The instructions for the development of the 1:1,000,000 *Operational Navigation Charts* (ONC) chart and the 1:500,000 *Tactical Pilotage Charts* (TPC) charts were published in January 1981. In January 1995, both these instructions were converted into technical specifications (MIL).

NATO in its standardization documents sets out the basic requirements that should be met by military aeronautical charts used in joint operations of the Alliance. This standardization applies to such elements as reference systems, projections, scope of aeronautical information, maximum dimensions, chart symbols, scales, marginal data, designation and evaluation of aeronautical charts. As in the case of other standard maps, in the production of aeronautical charts, NATO member countries follow the instructions arising from the so-called Standardization Agreements (STANAG)[18]. Some countries apply STANAGs directly, and some implement them on the national level in the form of their own regulations. In Poland, STANAGs are used as a basis for creation of Defence Standards. Only two STANAGs – STANAG 3600 (2000) and STANAG 7164 (2018) – reference directly the specification of specific aeronautical charts, respectively: American MIL-J-89100 for JOG-Air and British GSGS 5903 for LFC-Europe map series.

Essentially, military aeronautical charts meeting the requirements of the North Atlantic Alliance are divided into operational aeronautical charts and special aeronautical charts (E. Sobczyński, J. Pietruszka 2004) (table 1). According to STANAG 3677 (2000), standard scales of military aeronautical charts are as follows: 1:250,000, 1:500,000, 1:1,000,000 and 1:2,000,000. Some documents of the Alliance allow also the use of maps at the scales of 1:50,000 and 1:5,000,000.

Military aeronautical charts (both operational and special) are developed using the WGS-84 reference system, where the WGS-84 ellipsoid of rotation is the reference surface. The cylindrical Transverse Mercator projection was used for the scale of 1:250,000, while Lambert conformal conic projection was used for other scales.

The content of aeronautical charts consists of aeronautical information depicted on the basis of a topographical map, usually highly generalised. The criteria for the selection of content and conventional symbols on all charts are unified by detailed specifications. Lengths and altitudes are given in feet on all the charts.

[18] STANAG – **Stan**dardization **Ag**reement. Older STANAGs (especially those developed in the last century) consist of two parts: the so-called Cover containing formal details of the international agreement and the standardization section (*Standard*) which presents the technical details of the standard. The STANAGs which are nowadays developed in the field of geospatial information consist only of the "Cover" part which contains a reference to the relevant standardization document. Such documents can be already existing product technical instructions or new documents, so-called Allied Geographic Publications.

Table 1. Classification of standard military aeronautical charts

Scale	Chart name	Classification	Military destination
1:250,000	Joint Operations Graphic – Air (JOG-Air)	operational	operational and strategic
1:500,000	Tactical Pilotage Chart (TPC)		
1:500,000	Tactical Pilotage Chart (Maritime) (TPC-M)		
1:1,000,000	Operational Navigation Chart (ONC)		
1:1,000,000	Jet Navigation Chart (JNC)		
1:5,000,000	Global Navigation and Planning Chart (GNC)		
1:500,000	Low Flying Chart (LFC)	special (low flying)	operational and tactical
1:250,000	Transit Flying Chart – Low Level (TFC-L)		
1:250,000	Helicopter Flying Chart (HFC)		
1:50,000	Topograficzna Mapa Lotnicza (TML-Air)	others	tactical

All military aeronautical charts (except for GNC) have military reference systems. The MGRS reference system[19] can be found on the charts at scales from 1:50,000 to 1:500,000, and the GEOREF[20] reference system is used on the charts developed at scales from 1:250,000 to 1:2,000,000.

5.2.2. Military operational aeronautical charts

Military aeronautical charts include:

• *Joint Operations Graphic – Air,* series 1501 AIR, 1:250,000 (fig. 12),

• *Tactical Pilotage Chart*, series TPC, 1:500,000 (fig. 13),

• *Tactical Pilotage Chart (Maritime),* series TPC-M, 1:500,000,

• *Operational Navigational Chart*, series ONC, 1:1,000,000 (fig. 14),

• *Jet Navigational Chart,* series JNC, 1:2,000,000 (fig. 15).

Global Navigation and Planning Chart at the scale of 1:5,000,000 (*GNC* series) published by NGA constitutes an extension of the standard scale of operational aeronautical charts.

Operational aeronautical charts are meant to be used by air forces for planning flights and visual navigation, with the help, if necessary, of radio navigation aids. These charts can also be used by all types of troops when interacting with the Air Force.

The topographic base of operational aeronautical charts includes the general image of the Earth with identified objects and land forms which can be used by pilots for navigation purposes. The relief is depicted in a way that allows to determine foremost the minimum safe flight altitude. Hypsometric tints and spot heights were introduced to better depict differences in altitudes, and the illustrative character of the relief was increased through shading. Waters are shown with detail appropriate to the scale of a given map. Localities, roads and railway lines are presented in such detail, so that they could serve as navigation landmarks.

The aeronautical content of the map is printed in dark blue, which differentiates it from the topographic content. According to STANAG 3412 (2015), the aeronautical content consists

[19] MGRS – Military Grid Reference System – a military reference system based on a UTM (UPS) grid system.

[20] GEOREF – World Geographic Reference System – a military reference system based on a geographic system of latitude and longitude.

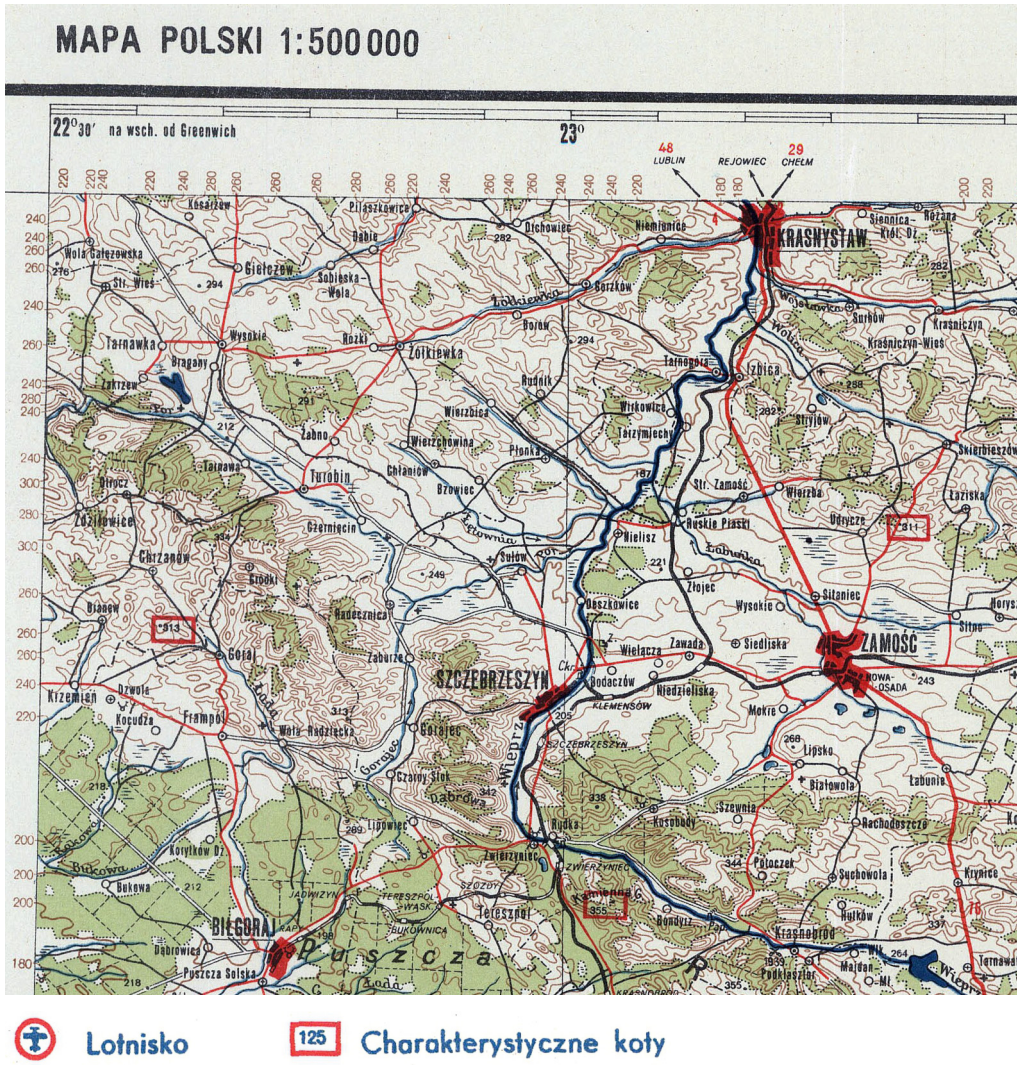

Fig. 11. Part of an aeronautical chart at the scale of 1:500,000, published by the Military Geographical Institute, Przemyśl sheet

of: airports, radio navigational aids, VFR landmarks, vertical obstructions, descriptions of Maximum Elevation Figures (MEF)[21] and magnetic data.

All marginal information is presented in English.

5.2.3. Special military aeronautical charts

Special military aeronautical charts are published only at two scales:

- *Transit Flying Chart (Low Level)*, series TFC(L), 1:250 000 (fig. 16),
- *Helicopter Flying Chart*, series HFC, 1:250,000,

[21] MEF – Maximum Elevation Figure – the number entered in each quadrangle designated by the lines of the geographical grid of the aeronautical charts, specifying the height – in thousands and hundreds of feet above the average sea level – of the highest natural or artificial object in a given quadrangle.

Fig. 12. *Joint Operations Graphic*, 1:250,000 – 1501 AIR series

Fig. 13. *Tactical Pilotage Chart*, 1:500,000 – TPC series

Fig. 14. *Operational Navigational Chart*, 1:1,000,000 – ONC series

Fig. 15. *Jet Navigational Chart*, 1:2,000,000 – JNC series

• *Low Flying Chart*, series LFC-Europe, 1:500,000 (fig. 17).

Special aeronautical charts depict information intended for planning flight routes and air navigation for military aircraft at low altitudes during peacetime. Due to their content and purpose, they are referred to as the low-flight charts. During the war and in areas for which TFC(L), HFC and LFC-Europe maps are not issued, the military uses operational charts at appropriate scales (1501-AIR and TPC).

In contrast to the military operational aeronautical charts that have almost global reach, low-flight charts are mainly developed for the territories of individual NATO countries.

The topographic base of Polish special aeronautical charts is different from the base of operational charts by its expanded topographic content and colour scheme, which make it easier to get the sense of direction quickly. A good example of differences between such maps is the different way of visualizing towns and cities. On the low-flight charts, despite their small scales, a significant part of small settlements (villages) is represented by an areal symbol, and on the transit flying charts (TFC(L)), the symbol is filled with intense yellow colour.

Aeronautical information, significantly more rich than in the case of operational charts, is presented in various colours. Controlled areas, airports and navigational aids, are marked in dark blue, low flying information is depicted in purple, night low flying routes are presented in green, and pipeline inspection routes are marked in orange, whereas restricted areas, areas to be avoided and vertical obstructions are presented in red. The fact that the colours used to depict topographic content of both maps were made to be less vibrant contributes to making the informative conventional symbols easier to read.

The big amount of details included on LFCs and high level of variability of aeronautical information pose a number of problems for countries producing low-flight charts. The lack of regularly updated official databases of vertical obstructions is one of the most important issues. STANAG 7164 (2018) requires all obstacles with a height of 200 feet or more (61 m) to be depicted on low-flight charts. The regulations of most countries impose obligations to maintain databases of vertical obstructions with relative heights of 100 meters or more (D. Ovodas, A. Česnulevičius 2011).

In accordance with STANAG 7164 (2018), special aeronautical charts are published at least once a year on dates compliant with the AIRAC-4[22] or/and AIRAC-10 cycle. The Military Geospatial-Intelligence Directorate (Szefostwo Rozpoznania Geoprzestrzennego, SRGeo)[23] publishes once a year 25 sheets of the chart of the TFCL(L) series for the territory of Poland, and five sheets of the chart of the LFC-Europe series in the AIRAC-4 cycle.

In order to make sure that the aeronautical information included on the special aeronautical charts is kept constantly up-to-date, a document updating both series of maps is published within the AIRAC cycle (every 28 days) between the successive editions of said maps. Since 2013, the German Air Operations Command, Polish Military Geospatial-Intelligence Directory and the Dutch Defence Geographic Agency have been publishing such updating document known as the Aeronautical Chart Amendment Document (ACHAD). Military users of special aeronautical charts are required to introduce the amendments contained in ACHAD to the latest edition of the relevant chart prior to planning their flights and their implementation.

5.2.4. Other military aeronautical charts

What is more, Military Geospatial-Intelligence Directory develops the *Tactical Aeronautical Chart* (Taktyczna mapa lotnicza) at the scale of 1:50,000 (M755-AIR series), which meets the NATO requirements (fig. 18), as well as a range of maps compliant with the ICAO standard.

The *Tactical Aeronautical Chart* is meant to provide detailed information about location and directions in the area where air combat is to be held, under conditions of visual navigation (VFR), at low altitudes. The chart is used for targeting and performing SAR tasks. The chart's sheet division is aligned with the centrally located military airfield, as well as its associated

[22] AIRAC – Aeronautical Information Regulation and Control. Common global dates on which aeronautical information enters into force.

[23] SRGeo was created in 2017, as a replacement of the Military Geography Directorate (Szefostwo Geografii Wojskowej).

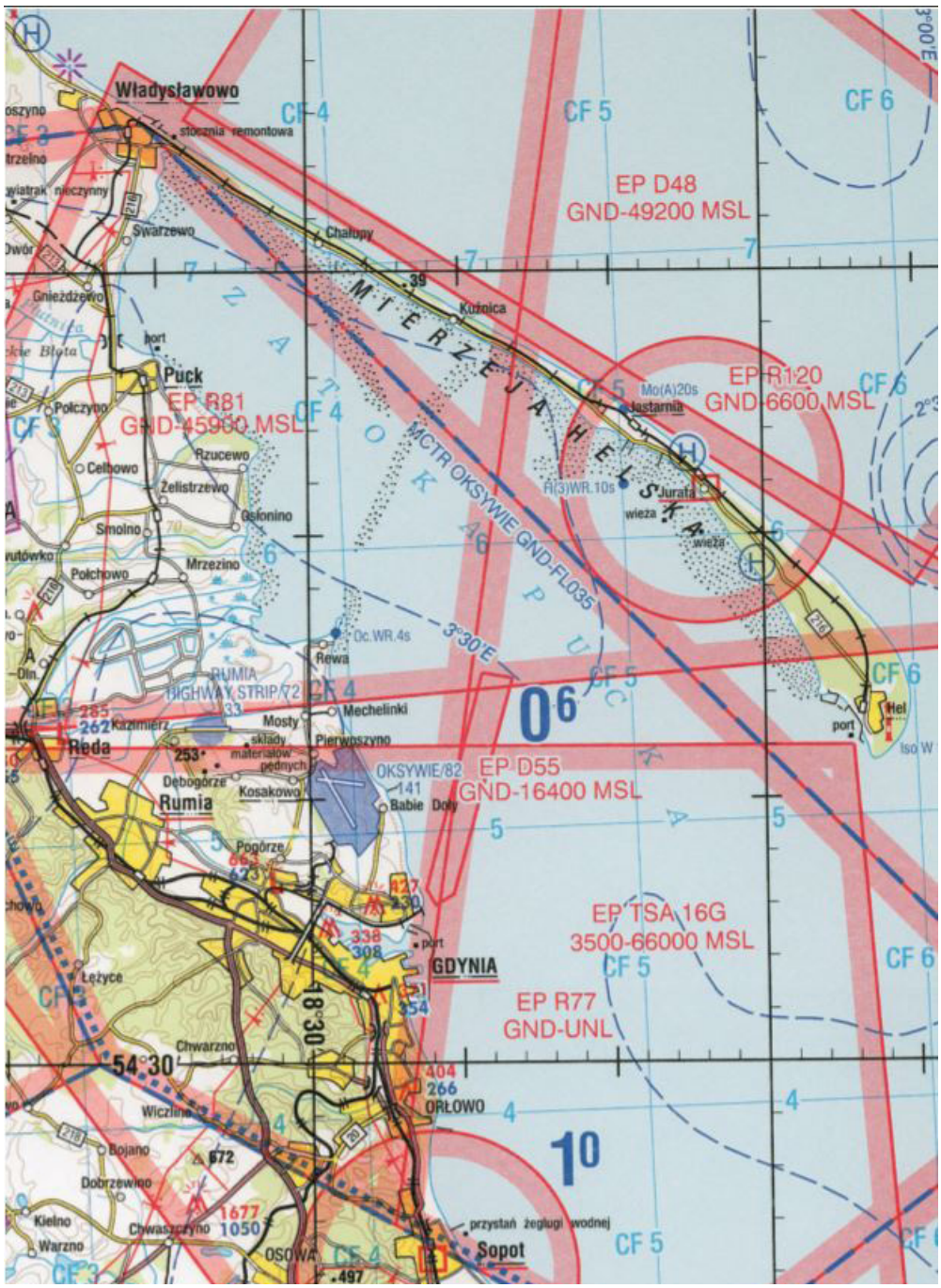

Fig. 16. *Transit Flying Chart (Low Level)*, 1:250,000 – TFC(L) series

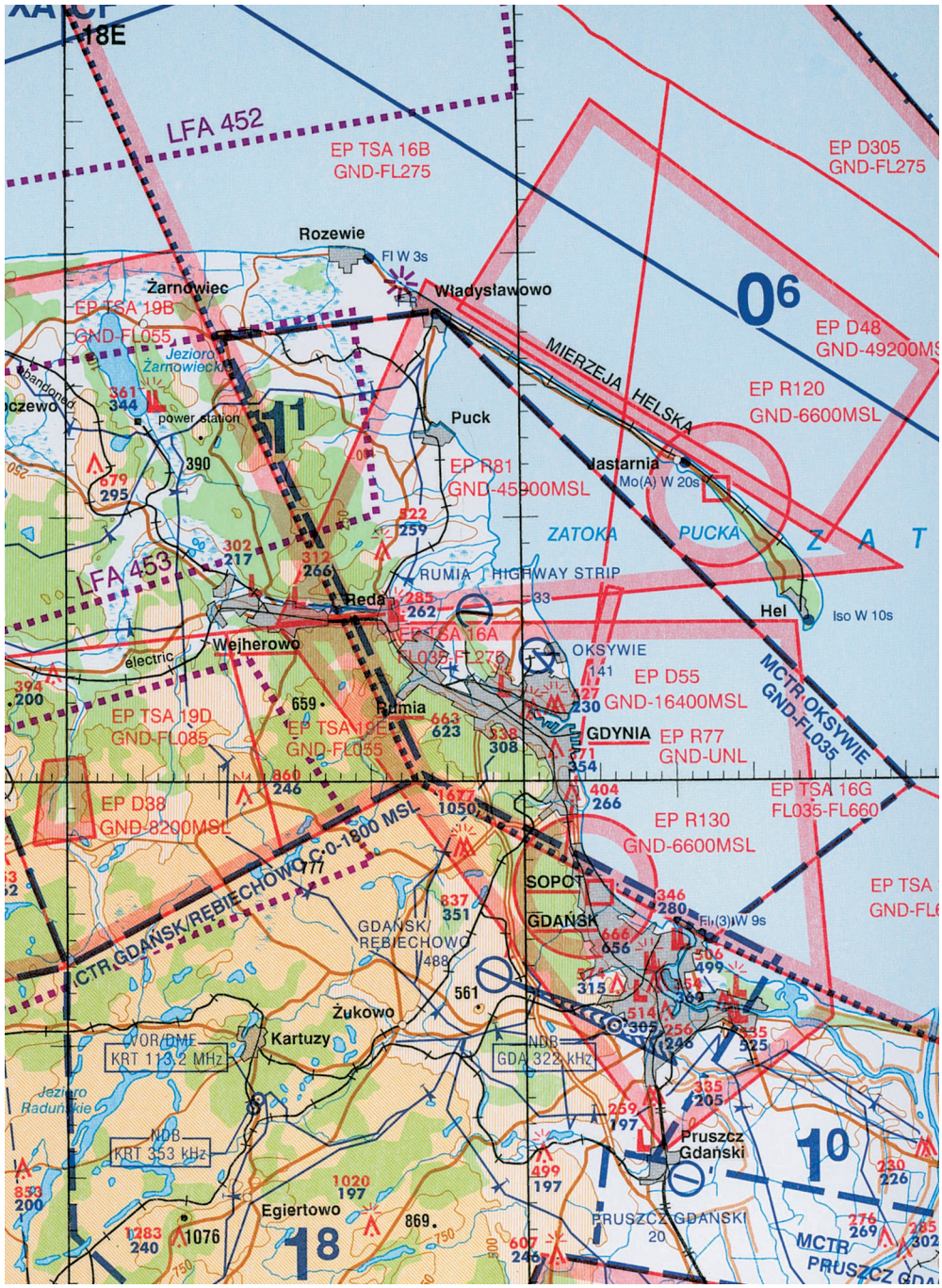

Fig. 17. *Low Flying Chart*, 1:500,000 – LFC-Europe series

zones and air spaces. The topographic base is the military topographic map series M755 which has been developed on the basis of VMap L2+. On this chart, information on altitudes is given both in meters (relief) and in feet (elements of aeronautical information).

Charts developed as attachments to AIP Poland and its military version – MIL AIP Poland – meet the requirements of the civil standard of the ICAO. They are:

• *Aerodrome Obstacle Chart – ICAO Type A,* 1:15,000 or 1:20,000,

• *Aerodrome Chart – ICAO,* 1:10,000 or 1:20,000.

The Military Geospatial-Intelligence Directory develops the above-mentioned charts in cooperation with the Military Air Traffic Service Office of the Polish Armed Forces and the Polish Air Navigation Services Agency, only for military airports.

6. Conclusions

The development of military aeronautical charts goes hand-in-hand with the development of military aviation. Wars, local conflicts and military missions forced the development of new types of charts and the introduction of new methods of presenting terrain and navigational data.

Nowadays, military aviation represents one of the basic components of the armed forces all over the world, and its role in combined operations is crucial. Aviation is also the source of the latest military technologies. Modern military air planes are characterised by their exceptional combat capabilities in terms of speed, range and manoeuvrability. Aside from the air planes, contemporary army increasingly frequently makes use of aerial robots, drones and unmanned cruise missiles. That is why in recent

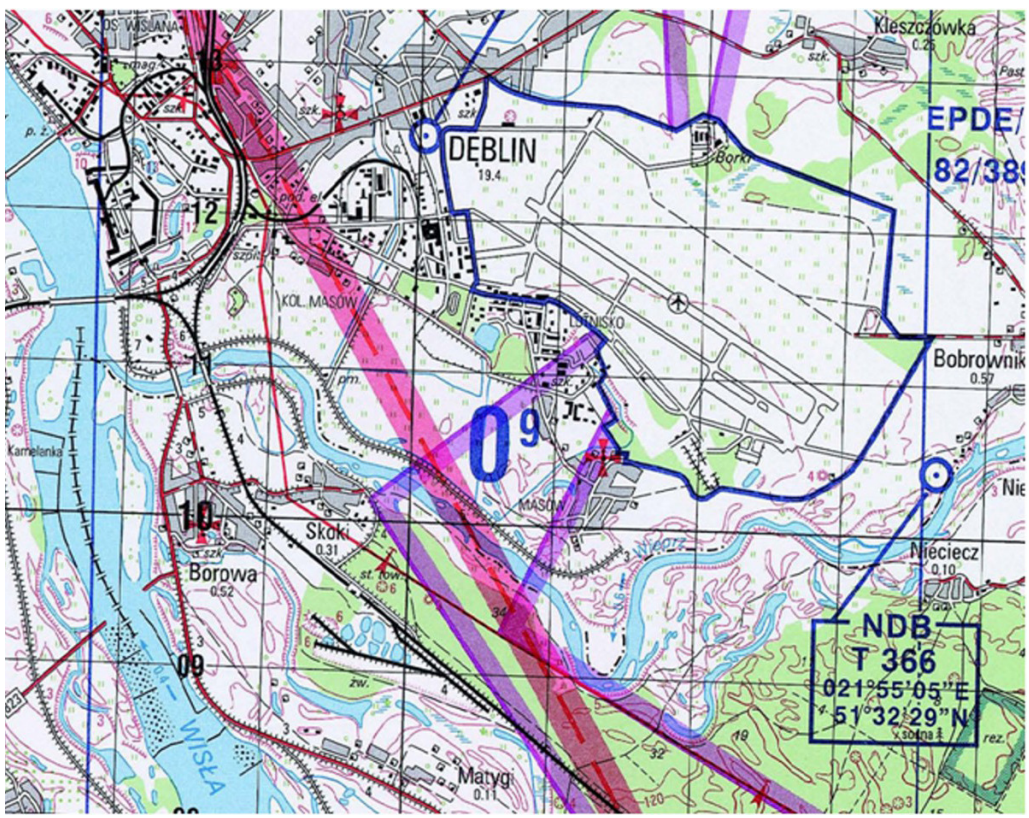

Fig. 18. *Tactical Aeronautical Chart*, 1:50,000 – M755-AIR series

years, especially in NATO, the work on the development of new aeronautical charts and the expansion of aeronautical information on charts have only intensified. The first aeronautical charts published at the beginning of the 20th century included only a dozen or so special symbols concerning the navigational contents, and nowadays their number exceeds one hundred. Further changes concern in particular the development of low-flight charts with new methods of presenting land relief, settlements, and vertical obstructions, minimum safe altitudes for flying, as well as air corridors and special zones.

Literature

Czarnecki S., 1927, *Międzynarodowa Mapa Świata 1:1 000 000*. „Wiadomości Służby Geograficznej" z. 1, pp. 37–51.

Czarnecki S., 1933, *Mapy lotnicze*. „Wiadomości Służby Geograficznej" z. 4, pp. 352–361.

Czarnecki S., 1937, *Pierwsze polskie mapy lotnicze 1:500 000 i 1:1 000 000*. „Wiadomości Służby Geograficznej" z. 2, pp. 225–235.

Douhet G., 2013, *Panowanie w powietrzu*, Warszawa: Tetragon.

Miahczyłowicz-Wolski R., 1937, *Pierwsze arkusze „Mapy Polski i Krajów Ościennych" 1:500 000*. „Wiadomości Służby Geograficznej" z. 1, p. 114.

Ovodas D., Česnulevičius A., 2011, *Baza danych wojskowych map lotniczych w krajach bałtyckich*. „Polski Przegl. Kartogr." T. 43, nr 4, pp. 369–376.

Sobczyński E., Pietruszka J., 2004, *Mapy lotnicze (Przewodnik)*. Sygn. Szt. Gen. 1559/2004. Warszawa: Sztab Generalny WP.

STANAG 3412. Aeronautical Information on Aeronautical Charts, 2015. Brussels: NATO Standardization Office.

STANAG 3600. Topographical Land Maps and Aeronautical Charts 1:250 000 for Joint Operations, 2000. Brussels: NATO Standardization Office.

STANAG 3677. Standard Scales for Land Maps and Aeronautical Charts, 2000. Brussels: NATO Standardization Office.

STANAG 7164. Special Aeronautical Charts (SAC), 2018. Brussels: NATO Standardization Office.

Internet sources

http://polski.mapywig.org/news.php – Archiwum Wojskowego Instytutu Geograficznego.

https://www.faa.gov/air_traffic/flight_info/aeronav/productcatalog/ifrcharts/ – IFR Charts.

http://www.escape-maps.com/escape_maps/history_of_wwii_british_cloth_escape_maps.htm – History of WWII British Cloth Escape Maps.

https://www.faa.gov/aircraft/ – Federal Aviation Administration.

http://maps.mapywig.org/m/m_documents/PL/ATLAS_LOTNISK_POLSKICH_1933_CBW.pdf

http://m.loadmap.net/en/catalog/c3089/s250000