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In Consideration of Nighttime Precision Bombing by the U.S. during World War II: Its Historical Significance and Future Tasks

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This article focuses on the nighttime precision bombing campaign using a latest radar conducted by the United States Army Air Forces at the end of World War II. Previous studies have paid little attention to this campaign, which lasted from late June 1945 until the end of the war. This article shows that it has historical significance in that the mobilization of science, technology, and industry made possible certain tactics that were previously considered unfeasible. This campaign also suggests that the state of science, technology, and industrial policies determined the way the war was fought. This paper presents the future tasks whose completion is necessary to illuminate the overall picture of the campaign. First, it is necessary to clarify how the scientific, technological, and industrial bases that enabled these tactics were put in place and, second, to elucidate why oil-related facilities were selected as targets for nighttime precision bombing operations. By answering these questions, we will be able to offer a full perspective of nighttime precision bombing operations with the radar and, by extension, understand the characteristics of how the American military fought the war.

Introduction

This article discusses the strategic bombing campaign against Japan conducted by the United States Army Air Forces (USAAF) in the final months of World War II. Particularly, it focuses on the nighttime precision bombings of petroleum facilities beginning in late June 1945, summarizes these operations and results, examines their strategic impacts and historical implications, and clarifies future tasks that should be accomplished.

To offer an early conclusion, the operations against petroleum facilities had little influence on the consequences of the war. Therefore, previous studies have only referenced them briefly, if ever, and they failed to examine their historical significance[1]. Although the official history of the 315th Bombardment Wing details the personnel, training, and

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[1] Craven and Cate [1983b:1955]; United States Air Force [1953]; Werrell [1996]; Crane [2016]. The latest study of the history of the U.S. precision attacks and strategies does not refer to this campaign at all. Rogers [2023].

missions of the unit (information on which this article depends heavily), this study does not detail any industrial, scientific, or technological bases that could elucidate their operations, and it fails to identify their historical implications[2].

However, these operations did have historical implications in that they demonstrated the importance of science and technology, as operations previously considered unfeasible were made possible with the newly developed radar. In addition, to perform the operation required not only technological developments but also a certain amount of equipment to be produced, that is, industrial mobilization. As historian Paul Kennedy suggests, the feasibility of certain tactics or operations depends on scientific and technological efforts, and identifying them is important, despite tending to be underestimated[3]. Indeed, the performance and success of the nighttime precision bombing depended on many factors. That is, exaggeratedly, to paint a complete picture of these operations reveals how the US fought the war.

Concerning the American way of war, especially strategic bombing during World War II, most previous studies focus on the transition from precision tactics to indiscriminate ones. Quoting Paul Fussell's literature, Eiko Ikui points out that the US military placed value on accuracy in the early stages of the war, but in the latter phase, accuracy and precision was not considered important and the way of fighting changed to one that prioritized efficiency and consumed large amount of munitions[4]. Some authors accuse the US military of performing strategic, especially indiscriminate bombing as immoral act[5]. For them, the US and the Great Britain (also Germany and Japan) violated international laws stipulating that any military had not to target innocent civilians. By reflecting the strategic bombing campaign during World War II from this perspective, however, such authors dismiss the US' efforts to pursue a precision attack as a way of more economical and humanitarian tactics. After World War II, the US military have continued to do so. As James Patton Rogers suggests, analyzing the American pursuit of precision "reveals rare insights into the intellectual history, evolution, and character of American warfare[6]." Therefore, this article sheds light into the American way of war by examining previously overlooked operations during World War II.

1. Summary of the Strategic Bombing of the Japanese Homeland

To place in a context the nighttime precision bombing during the last stage of World War II, this chapter summarizes the strategic bombing campaign against Japan. First, what is a "strategic bombing"? Attacking an enemy from the air is generally defined as two methods. One is "tactical," to support a fighting on the front line, and it involves targeting enemy forces themself, as well as the roads, railroads, and bridges used to transport personnel and supply. Although roads, railroads, and bridges are the targets of "strategic bombings," the aim of a tactical attack is to support ground forces.

The second method is strategic, aiming to diminish the enemy's war-fighting ability. In modern wars, especially in total wars, which are fought with all the strength of a nation,

2 Swann [1986].
3 Kennedy [2013].
4 Ikui [2018: 2006] pp. 168-179. See also Schaffer [1985].
5 See Grayling [2006] and Arai [2008].
6 Rogers [2023] p. 2. As mentioned above, however, Rogers does not refer the nighttime precision bombing campaign with a radar during World War II.

continuation of the war requires industrial productivity to supply munitions and labor forces to support the productive capability. Therefore, the desirable targets for strategic bombings are as follows: military arsenals, powerhouses, fuel factories, cities, and civilians. Bombing cities also has the purpose of demoralizing the civilian population to raise war weariness among them, leading to a quick end to the war.

Furthermore, strategic bombing consists of two methods: precision bombing and area bombing, where the former aims for the targets mentioned above accurately and with minimum bombers, bombs, and sacrifices of enemy civilian. As detailed later (3-1), the USAAF preferred this method of bombing from an economic and humanitarian perspective, but it is technically difficult to pinpoint a target with bombs from the air. Meanwhile, area bombings target objectives and the surrounding neighborhood, destroying them certainly. This means area bombings produce greater civilian losses and they are indeed applied to destroy a city itself and kill its civilians as a demoralization tactic.

In both European and Pacific theaters, because the Allies could attack the German and Japanese homelands only by bombing from the air, strategic bombing garnered high hope from the war's onset. It was reflected by the fact that while the US produced about 300,000 aircrafts during the war, it weighed long-range bombers, such as B-17s, B-24s, and B-29s used primarily for strategic bombing[7]. Among these, B-29s were the latest and most long-range, so they were most appropriate for attacking Japan proper. The Twentieth Air Force (20th AF) was responsible for bombing Japan, and all heavy bombers received by the 20th AF were B-29s. During the war, approximately 3,700 B-29s were produced, and over 1,000 among them were delivered to the 20th AF[8].

As such, the 20th AF was organized to perform strategic bombing against Japan. The war against Japan had many theaters, including China-Burma, the Pacific, the Far East, and Alaska, and Air Forces were deployed to each. This meant that each Air Force was subject to the policies of the commanding general of each theater. In contrast, the 20th AF was solely responsible for the Joint Chiefs of Staff, the top military decision maker, and they could then engage in the bombing of Japan, regardless the policy of each theater. Further, the 20th AF had two bomber commands (BC), the 20th and 21st, the former of which placed its headquarters at Kharagpur, India, and conducted a bombing campaign against Japan, East Asia, and Southeast Asia as a whole from forward bases, such as Chengdu, China. In addition, the 21st BC, based on the Mariana Islands, which were conquered in July and August 1944, carried out a bombing campaign against the Japanese homeland. As chief portions of the 20th BC were incorporated into the 21st BC later, this article examines mainly the actions of the 21st BC.

The 21st BC consisted of five bombardment wings (BW): the 73rd, 313th, 314th, 58th, and 315th Wings, in order of deployment to Marianas. Each BW comprised four bombardment groups (BG), and each BG was authorized to have 45 B-29s, totaling a maximum BW force of 180 B-29s. However, each BW or BG began operating before their force was complete, and the build-up of each force advanced gradually[9].

The commander of the 21st BC was Haywood Hansell, Jr., who was an enthusiastic advocate of "precision" bombing[10]. Because the Japanese aircraft industry was set as the

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[7] Approximately 35,000 long-range bombers were produced during the war. The total airframe weight of long-range bombers was 35% of that of all aircrafts built by the war's end. Craven and Cate [1983c:1955] pp. 352–353.

[8] Muelen [1995]; Office of Statistical Control [1945] p. 179.

[9] Craven and Cate [1983b] p. 522.

[10] Haun [2019] p. 220.

primary target at the headquarters of the 20th AF, the 21st BC engaged primarily in precision bombing against the installations relating to the aircraft industry in the first phase of the campaign. On November 24, 1944, 21st BC ushered its first operation with 111 B-29s against the Nakajima Aircraft Musashi plant. This operation, however, could not produce a significant result, so the Musashi plant was attacked repeatedly. Three days later, the 21st BC targeted Musashi plant again, but no airplane could drop bombs on the primary objective. Due to heavy clouds, the units could not conduct visual, that is precision, bombing, so they dropped their bombs on an urban area set as the secondary target of the mission. Many similar cases were seen. For example, the original target of the Ginza air raid on January 27, 1945, was the Musashi plant. These facts represent the reality of "precision" bombing campaigns[11].

The 21st BC changed its policy clearly in late February 1945, and in January 1945, Hansell was replaced by Curtis LeMay as head of the 21st BC. The headquarters at Washington hoped that LeMay would make a difference through massive incendiary attacks on large cities, instead improving "precision" bombing. However, LeMay did not begin the area bombing operation using incendiaries immediately upon his arrival as the commander. While he "tested" the incendiary bombing against cities twice, he waited for the number of B-29s necessary to conduct such an operation to be deployed and readied. On February 25, his "test" had achieved success with 229 B-29s, so he decided to conduct a full-scale operation against Tokyo[12]. Thus, 325 B-29s took off from Mariana Islands toward Tokyo on the night of March 9, dropping their bombs at midnight from a low altitude (about 9,000 ft), and their bodies were made lighter by removing their arms so they could carry more incendiaries. The extent of the damage caused by this operation has been well documented.

Beginning with the Tokyo air raid, the 21st BC conducted successive operations against urban areas of large Japanese cities: Nagoya, Osaka, Kobe, and again Nagoya. However, the 21st BC involved not only the incendiary campaign, but also some additional operations. First, the Command engaged in a "tactical" bombing of the Kyushu airfields as a part of the Okinawa campaign, which began in April 1945 and continued to the middle of May[13]. Second, the 313th BW assumed the mining campaign on Japan Sea, Inland Sea, and more from late March, and it was continued until the war was over. The official history of the USAAF during the World War II, *The Army Air Forces in World War II* (hereafter, *AAF in WW II*), described that the mining campaign had achieved meaningful results[14].

Concerning the incendiary bombings of large cities, the 21st BC targeted the Nagoya urban area on March 18 and Kawasaki and Tokyo on April 15. After an interval of about a month, the 21st BC resumed the campaign with raids against Nagoya on May 14 and 17. A month after that, the incendiary campaign against "large" cities ended with attacks on Osaka and Amagasaki, flying 511 superforts[15]. Since then, the 21st BC aimed at middle or smaller cities populated from 31,350 (Tsuruga) to 323,200 (Fukuoka) with incendiaries until the war ended[16]. While attacks against large cities were conducted by almost all forces available to the Command (300–500 B-29s), middle or smaller cities were bombed by one bombardment wing (100–180 B-29s). Until the war ended, over 60 cities had been burned out.

11 Koyama [2018] pp. 29–30.
12 Fujita [2021].
13 Craven and Cate [1983b] pp. 627–635.
14 Craven and Cate [1983b] pp. 662–674.
15 Craven and Cate [1983b] pp. 608–627, 635–644.
16 Craven and Cate [1983b] pp. 653–658, 674–675.

Despite LeMay's policy change, precision bombing of war industries, such as aircraft plants, was not abandoned, and this kind of operation was conducted repeatedly over several months. For example, the 21st BC engaged in precision bombing operations against the Musashi plant and Tokyo Army arsenal on August 8, Ogikubo plant of Nakajima and Tokyo Army arsenal again on August 10, and Hikari Navy arsenal (Yamaguchi) and Osaka Army arsenal on August 14. LeMay modified the operational method, such as lowering bombing altitude and using far heavier bombs to achieve far more meaningful results than Hansell's operations[17].

As stated above, 21st BC involved many kinds of bombing operation since LeMay had assumed the role of commander. This was possible because personnel and aircrafts were deployed one after the other to the Mariana Islands, and readied to begin these missions. The 313th BW, a second unit that arrived at Marianas, began its operation on February 4, 1945. In addition, the 314th BW joined the "test" incendiary attack against Tokyo on February 25, leading to the air raid on March 9 conducted by three BWs. Nighttime precision bombings with a newly developed radar against oil facilities by the 315th BW were carried out in the context of building forces and diversifying operations. The next chapter describes in detail all the operations of the 315th BW based on *AAF in WWII*, *A Unit History of 315 Bomb Wing: 1944-1946*, and the documents of the United States Strategic Bombing Survey (USSBS)[18].

2. Missions of the 315th Bombardment Wing

The 315th BW, activated on July 17, 1944, was deployed incrementally from March to April 1945, having received B-29Bs, a variant of the B-29 dedicated to nighttime operations and equipped with a new radar device, the AN/APQ-7, to carry out nighttime precision bombings of oil facilities. The BW consisted of four bombardment groups, the 16th, 501st, 331st, and 502nd, in order of deployment at Marianas. The 16th and 501st BGs conducted their first operations on June 26 and the 331st and 502nd on July 19. It took about a year from the activation of the BW to the beginning of actual operations, indicating that engaging required various preparations, including the deployment of B-29s, the construction of bases, and training. These issues will be discussed in another paper.

Table 1 shows all missions by the 315th BW, that is, 15 missions aimed at 9 targets. Total sorties were about 1,200 and total weight of bombs dropped was 9,084 tons. Bomb weight per one aircraft was relatively heavy due to using B-29Bs, which were deprived of most arming to conduct nighttime bombings. Their first mission targeted Utsube River Oil Refinery (Second Navy Fuel Arsenal, Yokkaichi, Mie), with 35 bombers of the 16th and 502nd BGs and dropping 223 tons. The damage of this mission on its own was unclear, but combined with the damages of mission number 209 on June 17, which attacked Yokkaichi city, issuing collateral damage to this oil refinery, and mission number 218 on June 22, which aimed it for a secondary target, the 315th BW's first mission destroyed 34% of the roof area and rendered 1.6% of the oil capacity (33,870/2,073,080 barrels) unavailable. This target was bombed on July 9 again, and because of all these missions, half the roof area was destroyed and 4% of the oil capacity was rendered unavailable (according to

17 Craven and Cate [1983b] pp. 646–653.

18 The USSBS documents used in this article are mainly Damage Assessment Reports. All have been collected by the National Diet Library, Japan. Its Digital Collection is made almost entirely available (https://dl.ndl.go.jp/collections/A00018).

Table 1. All Missions by the 315th Bombardment Wing

Date of Mission (Mission Number)	Primary Target	Sorties	Number of B-29s which dropped bombs against primary target	Weight of Bombs Dropped (tons)
June 26（232）	Utsube River Oil Refinery (Yokkaichi)	35	33	223
June 29（238）	Nippon Sekiyu Oil Refinery (Kudamatsu)	36	32	209
July 2（245）	Maruzen Oil Refinery (Shimotsu)	40	39	297
July 6（255）	Same as above	60	59	442
July 9（261）	Same as number 232	64	61	469
July 12（267）	Kawasaki Petroleum Center	62	55	452
July 15（270）	Same as number 238	71	61	494
July 19（281）	Nippon Oil Refinery (Amagasaki)	86	85	702
July 22（283）	Ube Coal Liquefaction Co.	82	74	637
July 25（291）	Mitsubishi Oil Refinery and Hayama Petroleum Company (Kawasaki)	85	77	668
July 28（303）	Shimotsu Oil Refinery	84	78	658
August 1（310）	Same as number 267	130	121	1,025
August 5（315）	Same as number 283	113	108	938
August 9（322）	Same as number 281	109	97	918
August 14（328）	Nippon Oil Refinery (Tsuchizaki)	143	134	954

Source: Koyama [2018]. There are some cases in which the number of sorties and the weights of the bombs dropped differ from those mentioned in the text.

Damage Assessment Report 141, 41.6% of the capacity had been “removed” before the attacks, but in the reports, the amount “removed” was counted as “damage”)[19].

The second target was Nippon Sekiyu Oil Refinery (Kudamatsu, Yamaguchi), attacked on June 29 and July 15, and these missions rendered 60% of the oil capacity (349,000/58,7000 barrels) unavailable[20]. Then, on July 2 and 6, Maruzen Oil Refinery (Shimotsu, Wakayama) was attacked by the 315th BW. Like earlier missions, the first of two made a trivial difference, but the latter destroyed 79% of the roof area. Total tank damages showed that 51.5% was classified as “destroyed” and 37% as “damaged” (total tank capacity was about a million barrels)[21]. Curtis LeMay described the latter mission as the most successful radar bombing ever[22], foreshadowing the overall success of nighttime precision bombing campaigns with the most advanced radar.

[19] Damage Assessment Report, no. 141, mission 261 (July 9–10) combined with 209 (June 18), 218 (June 22), and 232 (June 26), July 17, 1945.
[20] Damage Assessment Report, no. 179, mission 270 (July 15–16), combined with 238 (June 29), August 15, 1945.
[21] Damage Assessment Report, no. 142 mission 245 (July 2) and 255 (July 6), July 21, 1945.
[22] Werrell [1996] pp. 199–200.

The next target was Kawasaki Petroleum Center, a complex of Standard Vacuum Oil Co., Nippon Oil Co., Mitsui & Co., and Rising Sun Petroleum Co., toward which 60 B-29s flew, 53 of which dropped 452 tons on the primary target. However, this attack destroyed or damaged only 6% of tank capacity (total 1,334,000 barrels) [23]. On July 19, the operation against Nippon Oil Refinery (Amagasaki) produced "excellent results," according to a mission resume[24], and the Amagasaki plant was bombed again on August 9, with the Damage Assessment Report (no. 191) recording the total damage of these missions at about 70% of the original total oil capacity (1,175,400/1,496,700 barrels) [25].

Ube Coal Liquefaction Co., "the largest synthetic oil producer in the Japanese inner zone outside Manchuria," was the next target of 80 airborne aircraft, 90% of which dropped 620 tons on the primary target[26]. Although the results of this mission itself are unclear, the strike attack report of this operation noted that "excellent results are indicated by scope photos[27]." On August 5, the 315th BW carried out a second raid against Ube plant that resulted in "100% of refinery units and 80% of the stores and workshops damaged or destroyed[28]." According to the Damage Assessment Report (no. 175), the combined results of the 315th BW's missions (54.5%) with previous removal (45.5%), the plant became completely inoperative[29].

On July 25, the 315th BW attacked Kawasaki, an operation to which two additional bomber groups joined. Many targets were bombed, including Mitsubishi Oil Refinery and Hayama Petroleum Company, toward which 83 B-29s flew, 75 of which dropped 650 tons on the primary targets[30]. In addition, on August 1, Kawasaki Petroleum Center was bombed again with 1,017 tons by 120 B-29s (of 128 airborne). According to the damage assessment reports, the combined results of these missions are as follows: 537,400 barrels, 38% of Mitsubishi's original capacity (1,404,400 barrels) was damaged or destroyed; 334,000 barrels of 761,600 barrels at Hayama plant was rendered unavailable; and half of Kawasaki Petroleum Center's tank capacity, all combined with the damage by the mission in mid-July[31]. Between bombings of Kawasaki, on July 28, the 315th BW attacked Shimotsu Oil Refinery (different from Maruzen Oil Refinery) and damaged and destroyed 75% of the total capacity (927,300/1,246,000 barrels)[32].

The last target of the 315th BW was Nippon Oil Refinery, located in Tsuchizaki, Akita prefecture. This mission was the "longest and largest raid of the war" by 315th[33], considered generally successful, as 70% of the original capacity was destroyed and damaged, and "[t]he buildings of the refinery were 98% affected, 87% destroyed and 11%

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23 Damage Assessment Report, no. 157, mission 267 (July 12–13), August 3, 1945.

24 Mission Resume for mission 251 (July 19–20). The damage assessment report for this mission recorded the damage of the attack as 39% of tank capacity (587,300/1,496700 barrels). The history of the 315th BW, however, notes, "Post-mission photo-reconnaissance showed the wing mission on Amagasaki had mixed results." Swann [1986] p. 102.

25 Damage Assessment Report, no. 191, mission 322 (August 9–10), August 21, 1945.

26 Target Information Sheet, Ube Coal Liquefaction Company, July 20, 1945.

27 Strike Attack Report, no. 130, mission 283 (July 22–23), July 27, 1945.

28 Mission Resume for mission 251 (August 5–6). This attack also damaged or destroyed half of the Ube Iron Works Co.

29 Damage Assessment Report, no. 175, missions 270 (July 15–16), 283 (July 22–23), and 315 (August 5–6), August 14, 1945.

30 Mission Resume for mission 291 (July 25–26), August 3, 1945.

31 Damage Assessment Report, no. 173, missions 291 (July 25–26) and 310 (August 1–2), August 10, 1945; Damage Assessment Report, no. 184, mission 310, August 18, 1945.

32 Damage Assessment Report, no. 172, mission 303 (July 28–29), August 12, 1945.

33 Swann [1986] p. 113.

gutted and seriously damaged[34]." On the same day, when the Japanese government decided to surrender, the 20th AF carried out full-fledged attacks on various targets with over 800 B-29s. The commanding general of the USAAF, Henry Arnold, hoped "as big a finale a possible" against Tokyo; he planned to call on the Eighth Air Force, a part of which had been transferred to Okinawa from Europe[35]. However, his subordinate, Carl Spaatz, argued that Tokyo was not appropriate for such an operation and proposed to attack various targets, which Arnold accepted[36]. As such, the 315th BW completed their mission as usual.

Concerning the achievement of 315th BW, *AAF in WW II* concluded:

> On the whole, the experiment was markedly successful. The formations were able to attack the primary target on every mission, and while the results varied they were generally good… USSBS statisticians calculated that 315th Wing bombardiers had achieved an accuracy rate of 13.5 per cent, as compared with 5.4 per cent achieved, under more difficult tactical conditions, with the Eagle [AN/APQ-7] radar in Europe[37].

Moreover, as with the accuracy of the campaign with the AN/APQ-7, military historian Kenneth P. Werrell states, "Eagle demonstrated accuracy approximating that of visual bombing, and on occasion exceeding it[38]." The accuracy of the 315th BW's missions depended on many factors, so it should not be attributed only to the performance of the EAGLE radar[39]. However, LeMay was overly impressed by the achievement of the unit, so he planned to change the targets of the 315th from oil to nitrogen plants and bridges and to install the EAGLE radar in the B-29s of the other wings[40].

3. Some issues of nighttime precision bombing

In this chapter, the author describes three issues of nighttime precision bombing, the first of which is the USAAF's strategic bombing doctrine. Second, it is important to identify how this kind of campaign was made possible and, third, why oil-related facilities were targeted.

3-1. Strategic Bombing Doctrine of the USAAF

The purposes of strategic bombing are, as noted in Chapter 1, destruction of the enemy's war capacity by attacking directly the political and industrial core and by demoralizing the population through targeting non-combatants. Then, precision bombing and area bombing were assumed as means to accomplish these ends. Precision bombing literally means dropping bombs on a target, such as a war plant, "precisely," whereas with area bombing, bombers attack the surrounding "area" of a target. Because the method also hurts the civilian of the area attacked, it is used to target non-combatants directly.

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34 Damage Assessment Report, no. 205, mission 328 (August 14–15), September 10, 1945.
35 Maurer [1983b] p. 463.
36 Craven and Cate [1983b] p. 732.
37 Craven and Cate [1983b] p. 661.
38 Werrell [1996] p. 200.
39 The United States Strategic Bombing Survey, Oil and Chemical Division, *Oil in Japan's War*, pp. 121–123, National Diet Library Digital Collection. This report lists factors that led to differences in accuracy between the European and Pacific theaters (315th missions), including bombing altitude, opposition violence, and bomb size. In the European theater, altitude was higher, opposition was more violent, and bombs were lighter than in the Pacific.
40 Werrell [1996] p. 200.

Within the US Army, the Air Corps Tactical School (ACTS), which was originally established as the Air Service Tactical School in 1920, studied the doctrine of strategic bombing. This group was called the "Bomber Mafia," one of whom was Haywood Hansell. They established precision bombing as their doctrine, as well as put forth the "Industrial Web Theory," which assumes that the various parts of a modern city are connected to and interact with each other complicatedly like a "web." Therefore, they considered the destruction of one important part of a city enough to spread the effect throughout, and they thought it was technically possible to bomb precisely thanks to the new availability of B-17, the then-newest long-range bomber, and the Norden bombsight by the middle of the 1930s[41].

Moreover, the international law and the moral of a bombing from the air was took into consideration. In an interwar period, although any treaty that prohibits the bombing of civilian was not realized, major powers discussed whether or not it was justified, resulting in Hague Rules of Air Warfare (1923) that stipulates that "Aerial bombardment for the purpose of terrorizing the civilian population, of destroying or damaging private property not of military character, or of injuring non-combatants is prohibited[42]." As Arai Shin'ichi suggests, this Rules functioned as the guides for air warfare of many states[43]. In particular, the US government disliked the bombing of civilian from moral perspective. Henry L. Stimson, then-secretary of state, strongly condemned Japan for bombing of urban arears of Chinchow and Shanghai during the Manchurian Incident, and the President Frankin D. Roosevelt, in 1939, demanded the belligerent nations not to "undertake the bombardment from the air of civilian populations of unfortified cities…[44]" Against this backdrop, the ACTS developed precision bombing doctrine[45].

In a sense, World War II was a spectacular testing site for demonstrating that the strategic bombing doctrine of the USAAF would work well. Then, both in Europe and the Asia-Pacific theater, it became apparent that the doctrine was only theoretical and ideal. Although the USAAF engaged strategic bombing operations with the Royal Air Force (RAF) in Europe, US precision bombing, that is, daytime visual bombing from a high altitude, was not only safe but also precise. The RAF, which was involved in strategic bombing against Nazi Germany from an earlier stage of the war, had already changed the policy from precision to nighttime area bombing using a radar[46]. The USAAF, however, was adamant that its original method was superior. However, in the daytime, bombers were susceptible to enemy intercepts, and from a high altitude, crews could not drop bombs on targets precisely. Although the USAAF continued precision bombing only officially, it launched de facto area bombing with an attack against Münster in October 1943—this resulted in the Dresden bombing in February 1945[47].

Daytime visual bombing from a high altitude, which had not worked in Europe, was applied in the war against Japan for certain reasons. First, the headquarters in Washington set the Japanese aircraft industry as one of the primary targets. Second, the commander of

41 Biddle [2002]; Crane [2016] pp. 14–30; Morris [2017] pp. 112–197.
42 Henke [1993] p. 17.
43 Arai [2008] pp. 73–79.
44 Nakazawa [2014] pp. 81–96; Bennett [2019] p. 22.
45 In addition, economic constraints within the Army Air Corps made precision bombing doctrine desirable. Biddle [2002] p. 183; Crane [2016] pp. 21–22.
46 Schaffer [1985] p. 35; Webster and Frankland [2006: 1961] pp. 381–417.
47 A military historian Ronald Schaffer detailed that the USAAF's bombing policy had changed from precision to area bombing in the European theater. He pointed out that moral consideration had little impact on the process. Although the USAAF conducted de-facto area bombing, it did not carry out nighttime bombing in Europe. Schaffer [1985].

the 21st BC was Haywood Hansell, who had been one of the Bomber Mafia and was an adherent of the doctrine. Third, B-29s were not deployed in the field enough to carry out area bombings successfully against a city on a broad scale[48]. In any case, as mentioned above, Hansell could not garner an achievement with precision bombing and so was replaced by LeMay as the commander. While he engaged in an area bombing campaign with incendiaries, LeMay continued precision bombing missions to bring successful results gradually. Even he, however, could not succeed with nighttime precision bombings[49].

By placing in this context nighttime precision bombing with a radar by the 315th BW, its historical significance becomes clear. That is, it can be said that a series of missions by the BW is the best example that the latest technologies overcame various difficulties involved in daytime visual (precision) bombing. These missions had a minor impact on the result of the war because they were carried out in the final stage of the conflict, and they were aimed at oil-related facilities, which had not been considered essential targets, as will be detailed later[50]. However, this example demonstrates that science and technology are crucial factors in modern war in that they can make possible operations previously viewed as impossible. If the war had not ended in August 1945, the USAAF might have returned to its doctrine and produced results with minimum civilian losses. In other words, if nighttime precision bombing had been feasible earlier, the USAAF would not have changed its policy to area bombing with incendiaries. In this sense, this case shows that science and technology have a considerable impact on methods of conducting a war. It will be discussed how the success of the missions by the 315th BW influenced the US's later methods of engaging in war[51].

3-2. What made nighttime precision bombing possible

In the previous section, the author notes that science and technology had overcome the obstacles involved in daytime visual bombing, a process that can be summarized as follows: the Radiation Laboratory established at the Massachusetts Institute of Technology succeeded in developing the AN/APQ-7 (EAGLE) radar, which had a higher resolution than the existing radar system, the AN/APQ-13; Western Electric received an order for the mass production of the EAGLE; it was decided that the B-29B, a variant of the B-29 for nighttime operations, would be equipped with the EAGLE; Bell Aircraft was asked to produce all B-29Bs, and 653 B-29s were manufactured by September 1945, 311 of which were B-29Bs[52]. This meant that nighttime precision bombing could be achieved by mobilizing not only science and technology but also the industrial capabilities that could mass-produce these radars and the bombers equipped with them. Although it is important that scientific, technological, and industrial bases could influence the way a war is fought, this aspect will be examined in other articles. Here, this paper summarizes the facts

48 Fujita [2021].

49 Craven and Cate [1983b] pp. 546–576, 646–653; United States Air Force [1953] pp. 169–172. A historian John W. Dower said that the news of repeated bombings against cities and massive destruction and Japanese victims numbed the sensibilities of public and media. For example, on May 30, 1945, the *New York Times* reported the 6 bombings on Tokyo caused the deaths of a million, or perhaps 2 million of Japanese. Dower points out that despite the highly exaggerated numbers, neither the quality paper which reported it nor the American public who read it had any doubts. Dower [2010] pp. 183–184.

50 A USSBS's report concluded that "[t]he contribution of the bombing offensive against oil to the Japanese defeat was therefore negligible. The war had already been won by the blockade." USSBS, *Oil in Japan's War*. p. 65.

51 In the Korean War, the U.S. Air Force tried nighttime operations, including precision bombing with short range navigation (SHORAN) radar. USAF [1953] pp. 197–211.

52 The number of B-29Bs produced by Bell was determined from the following websites, Aircraft Serial Number Search (http://users.rcn.com/jeremy.k/serialSearch.html) and USASC-USAAS-USAAC-USAAF-USAF Military Aircraft Serial Numbers--1908 to Present (https://www.joebaugher.com/usaf_serials/usafserials.html).

concerning the development of the radar and the production of B-29Bs.

To begin with the development of EAGLE, recommended by Vannevar Bush, who was then-president of the Carnegie Institution in Washington, D.C., President Roosevelt established the National Defense Research Committee (NDRC) in June 1940 and the Office of Scientific Research and Development (OSRD) in June 1941 to mobilize scientists and engineers in preparation for war. The role of both institutions was not research and development, instead enabling studies by personnel and research institutions for certain research and issuing contracts for such[53]. The OSRD's funding amounted to half a billion dollars by the end of the war[54]. It was the NDRC that recommended the establishment of a laboratory to research primarily microwaves, that is, radar, at the Massachusetts Institute of Technology (MIT), eventually becoming the Radiation Laboratory (Rad Lab). In sum, the OSRD funded 114 million dollars to MIT, which was made the biggest contractor of the OSRD[55].

EAGLE was developed at Rad Lab, after which flight experiments were successfully completed in May 1944. Western Electric initially received an order for 612 EAGLEs, but it eventually took on the responsibility to produce 1,660. This, however, did not proceed smoothly. The idea of a higher-resolution radar with high-frequency microwaves had been embraced as early as November 1941, meaning it took about 2 and a half years to complete the flight experiments. One reason for such a long time needed was that because the feasibility of the EAGLE was considered questionable within Rad Lab, it was not necessarily highly prioritized. Although MIT and Rad Lab were abundant funding, economic and human resources were naturally so limited that Rad Lab had to set priorities based on the importance and feasibility of each development. The relatively low priority of EAGLE inevitably led to the delay of the research and development of the equipment and the achievement of more precise bombing operations[56]. To make clearer the picture of nighttime precision radar bombing, it is necessary to place in this context the overall policy and direction of Rad Lab or the OSRD, but this point will be examined in other articles.

Concerning the production of B-29B, as previously noted, it was B-29B, a variant of the B-29, that was equipped with an EAGLE, and Bell undertook the production of them all. Originally, it was Boeing that developed and manufactured B-29s, so why did Bell sign a contract to produce them? As it happened, not only B-29s, but also many goods saw their production charged to companies under license contracts other than those that developed them. In the case of B-29s, Boeing produced them at the Wichita second plant in Kansas and the Renton factory in Washington. In addition, government-owned factories were constructed at Omaha, Nebraska, and Marietta, Georgia, where Glen L. Martin Company would operate the former and Bell the latter. It was called government-owned, contractor-operated (GOCO) when private companies operated plants funded federally[57]. Thus, the production of B-29s and B-29Bs had to be placed in the context of U.S. industrial mobilization.

Since the author has few primary documents to clarify why Bell was charged to produce

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53 Stewart [1948] pp. 7–51.

54 Larry Owens notes that the OSRD issued almost 2,300 contracts with 321 industrial institutions and 142 academic and other non-profit institutions. Owens [1994] pp. 526, 565–576.

55 Owens [1994] p. 565.

56 Brown [1999] 192–193; Office of Scientific Research and Development, National Defense Research Committee, Division 14, *Radar: Summary Report and Harp Project*, vol. 1 of Summary Technical Report of Division 14, NDRC, pp. 75–77 (Downloaded from the Library of Congress, https://www.loc.gov/item/2015490937/ [Last access, March 15, 2024]).

57 For GOCO, see Wilson [2016] pp. 62–83.

B-29Bs, this paper describes how Bell came to produce B-29Bs and the pace at which they were manufactured. In January 1940, the U.S. Army Air Corps envisaged a Very Heavy Bomber (VHB) having a higher performance than the existing Heavy Bombers, such as the B-17 (Boeing) and B-24 (Consolidated Aircraft Corporation). The USAAF signed a contract with Boeing for prototype aircrafts in September, but concerned with the speed of completion, the USAAF reached agreement with the company for the construction of the Wichita second plant in June 1941 before prototype flying, and in July, it ordered 1,050 B-29s. Martin and Bell was also asked to build the B-29s[58]. In December 1941, the construction of a new factory at Marietta was planned, and then in May 1942, it was decided formally that Bell would operate the plant. Due to the delay in the completion of the new plant and the lack of manpower, it was as late as November 1943 when Bell produced their first B-29[59]; eventually, the Marietta plant would deliver 205 B-29s by the end of 1944, all of which were ordinary B-29s.

As late as around October 1944, the USAAF considered the production of B-29Bs and B-29Bs equipped with EAGLE[60], and in November, it was decided to organize a unit of EAGLE-equipped B-29Bs. Then, in December, the 315th BW was notified that the special unit would be their own[61], and the first B-29Bs by Bell–Marietta were delivered to the 315th BW in February or March 1945[62]. Further, the 16th BG, one unit of the 315th BW, received an almost authorized force (45 B-29s) by May, and on June 26, the 315th BW began its first mission. Therefore, it was impossible for the 315th BW, dedicated to nighttime radar precision bombing, to be ready begin start their operations without the effort of Bell in mass-producing B-29Bs, totaling over 300. However, questions remain: why was Bell asked to manufacture B-29Bs, what challenges did Bell face with the change in specifications, and what was the position on B-29B production in the overall B-29 production plan? These are future issues.

3-3. Why were oil-related facilities targeted?

That nighttime radar precision bombing became possible with technological and industrial bases is a completely different issue from the fact that oil-related facilities were targeted for operations. In this section, the author explains the reasons for the latter.

The Army Air Corps had adopted precision bombing as its strategic bombing doctrine, based on which the USAAF identified power plants and oil facilities as important targets in the European theater. However, the USAAF did not consider oil plants essential to the bombing campaign in the war against Japan. Thus, in November 1943, a report of the Committee of Operation Analysts (COA)[63] listed merchant shipping, steel production, the antifriction bearings industry, urban industrial areas, aircraft plants, and the electronics industry as strategic targets to be prioritized. The following October, another report of the committee set the aircraft industry, urban industrial areas, and shipping ("by all available means, including mining") in order of priority[64], but neither mentioned oil-related facilities.

58 Craven and Cate [1983b] pp. 6–7.
59 Muelen [1995] p. 54.
60 Lauris Norstad to Curtis LeMay, October 5, 1944, 20th Air Force-Official File (2), Pentagon Series, Project Subseries, Box 27, Lauris Norstad Papers, 1930–1987, National Diet Library, Japan.
61 Swann [1986] p. 27.
62 Swann [1986] p. 40; Mann [2004] p. 30.
63 COA was created by the directive of Henry Arnold in late 1942 to discuss and recommend bombing target and analyze "the rate of progressive deterioration that should be anticipated in the German war effort as a result of the increasing air operations." Craven and Cate [1983a:1949] pp. 349, 353–354.
64 Craven and Cate [1983b] p. 552.

This is because a blockade or attack on oil tankers directly was more efficient than bombing inland oil plants, at least concerning the Japanese oil industry. In fact, Japanese oil production capacity was already reduced by these operations by the time the 21st BC undertook its operations. Nevertheless, oil-related plants were attacked from June 1945, but why? To answer this question, *AAF in WWII* explains:

> By April, however, AAF intelligence had come to the opinion that the petroleum industry in Japan was in so critical a state that the destruction of facilities and stores would react immediately upon the tactical situation. Consequently, LeMay and Lt. Gen. Barney M. Giles, who came to Guam as the deputy commander of the Twentieth Air Force, eventually decided that during its combat-testing period the 315th Wing would devote its efforts exclusively to oil targets. This decision had the enthusiastic indorsement of Gen. Carl Spaatz, slated to command all B-29's under USASTAF [U.S. Army Strategic Air Force], who had been an ardent advocate of the oil campaign in the ETO [European Theater of Operations] [65].

The argument that the destruction of oil plants had become "critical" is unsound because they were bombed sporadically by then, and the Japanese oil production capacity further worsened due to other operations, such as blockades and mining around the Japanese waters[66]. Two reasons can be offered for why oil facilities emerged as the target of nighttime precision bombing with EAGLE.

First, there remained few targets that the 21st BC could attack, as the top-priority target, the aircraft industry, was near utter destruction due to the ongoing efforts of precision bombing under LeMay's command. For example, because of missions toward the Mitsubishi Heavy Industry Nagoya Engine factory and Musashi plant of Nakajima on April 7, as well as Musashi again on April 12, the Musashi plant's operations came to a halt[67]. Then, on July 24, the final precision bombing of aircraft factories was carried out when 625 B-29s destroyed seven targets. LeMay had modified his tactics, such as using 2,000-pound bombs and lowering the bombing altitude to ensure a precise result. Thus, missions against the aircraft industry by the newly arrived 315th BW would have a negligible effect.

Besides, by June 1945, the targets of nighttime area bombing shifted from larger cities to middle and smaller cities, and it was decided at the end of 1944 that B-29Bs equipped with the EAGLE would be deployed to the 315th BW. In contrast to precision bombing, area bombing did not necessitate precision attack, and this is because area bombing could be carried out in nighttime with an existing radar. Therefore, it must be nonsense that an EAGLE-equipped unit would carry out such missions. Over 60 Japanese cities were leveled by area bombing campaigns, despite a study of new targets in June 1945 listed only 25 cities. In retrospect, the destruction of over 60 cities can be judged excessive. The incremental build-up of the 21st BC led to the excessiveness. Sorties of the 21st BC per month had risen steadily, along with the number of B-29s deployed to Marianas (Figure 1). If the 315th BW had joined the campaign against middle or smaller cities, only some less significant cities would have been added to the list of cities destroyed. In sum, it would have been unnecessary for the 315th BW to attack existing targets with other units.

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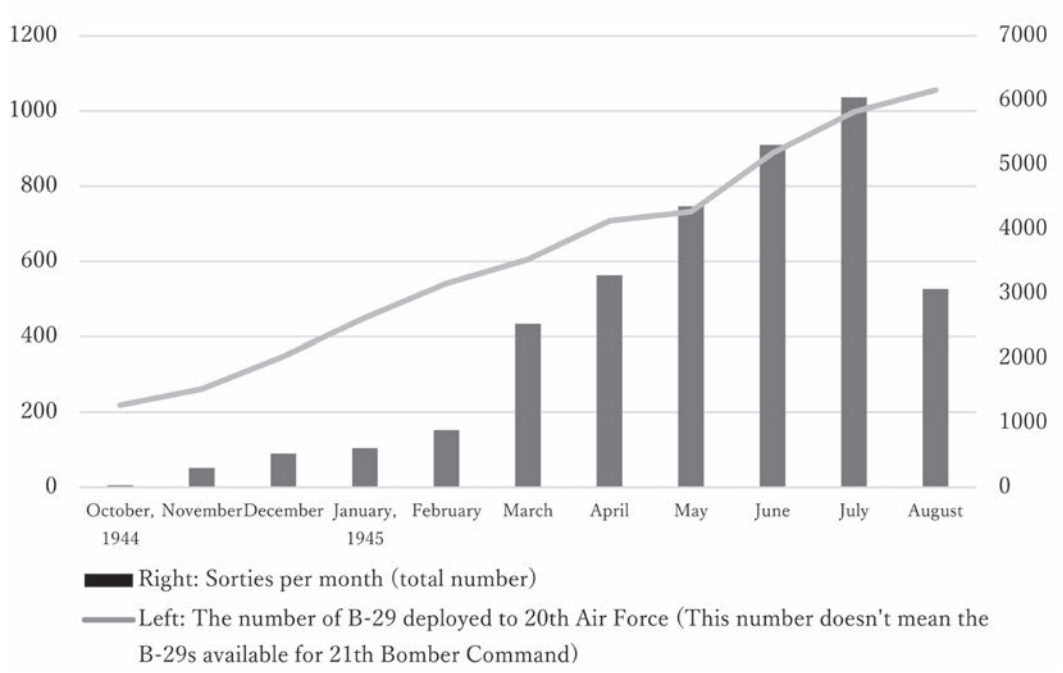
65 Craven and Cate [1983b] p. 660.
66 USSBS, *Oil in Japan's War*, pp. 45-66.
67 Craven and Cate [1983b] pp. 647–648.

Figure 1. Sorties per Month and B-29s Deployed to 20th AF



Source: Koyama [2018] and the Office of Statistical Control [1945].

Therefore, another target system for the 315th BW was needed, but oil plants showed little reason to be attacked. Nevertheless, they were chosen as targets for the unit because they were considered best for the "test" of the newly developed radar set, which is the second reason oil plants were selected. Furthering this point, an official history of the 315th notes, "Japan's oil refineries provided ideal test targets because they were relatively undamaged, well-defined, and located near the coastline," so bombardiers could easily identify their targets with EAGLE[68]. Werrell suggests that if the war had not ended in August, the 315th BW, which completed the test successfully, would have conducted missions to more significant inland targets, including bridges[69]. Indeed, the USAAF set railroads and stations as primary targets in the final days of the war, and on August 14, the last day of the war, the 21st BC bombed the Marifu railroad yards (Iwakuni station) in Yamaguchi with 115 B-29s, a mission that implies a gradual shift in priority from urban areas to transportation systems.

There were other cases in which modern technologies or embraced tactics were "tested" in battlefields. For example, the firebombing against Tokyo on February 25, 1945, was carried out as test of area bombing with incendiaries, and the success of this test led to the March 9–10 air raid. (Other tests were conducted on Nagoya on January 3 and Kobe on February 4, but they were judged as failures.) More explicit instances include the atomic bombings. Where and how the atomic bombs would be used was discussed from April 1945. Further, it was decided in an earlier phase that the bombs would be used against cities of a certain size. When desirable cities were selected, the condition was that any

[68] Swann [1986] p. 123; Werrell [1996] p. 199.
[69] Werrell [1996] p. 199; Swann [1986] p. 122.

target city should face minor damage from strategic bombing by the time of the atomic bombings, so the suffering from the nuclear attacks could be examined. Because this would be impossible if target cities were leveled, strategic bombing missions were prohibited against cities listed for the A-bomb, including Kyoto, Hiroshima, and Kokura. These facts suggest that Hiroshima and Nagasaki were not the most important strategic targets for destruction as early as possible, which was the case with petroleum facilities.

Conclusion

This article summarizes the nighttime precision bombing campaign using the new radar by the 315th BW, which demonstrates its historical significance and suggests the challenges to painting a clearer overall picture. Although this campaign had a negligible impact on the consequences of World War II, it is of great historical significance in that the industrial, scientific, and technological mobilization enabled the realization of missions previously considered impossible. The way of engaging in war itself depended on the wartime mobilization of industry, science, and technology, and importantly, the timing of the missions and their feasibility depended on the priorities in research and development and the pace of weapons and equipment production. If the USAAF had achieved precision bombing earlier, would it have carried out an area bombing campaign on such a scale?

To clarify the overall picture of the nighttime precision bombing campaign with radar, the following problems must be addressed. The first is how industrial, scientific, and technological bases were established to make possible such a campaign. Rad Lab at MIT developed EAGLE, so the history of its development should be clarified by placing it in the context in which the Rad Lab was set up and the overall research trends at the time. In addition, Bell assumed the production of B-29Bs equipped with EAGLE, so it must be explained how and why the AAF contracted with Bell. In doing so, the contract should be placed in the overall picture of the development and production of B-29s. Second, it must be understood in detail why petroleum facilities were chosen as the targets of EAGLE missions. As already mentioned, the choice of oil facilities strongly implies that the missions had an experimental aspect, which seems to reflect how the U.S. military engaged in war. Therefore, it can be said that a clearer understanding of the precision bombing campaign with EAGLE would shed light on how the war was fought by the U.S. military.

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