How Slide Rules Won a War

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Abstract

This article is a supplement to a report previously published in the *Journal of the Oughtred Society* (JOS) [1] that gave technical details about a two-dimensional programmable slide rule system. The system was developed and fabricated in the China, Burma, India (CBI) and the Pacific combat theaters in World War II. This article develops the thesis that these and other slide rules used by the 20th Air Force (AF) were responsible for our victory over Japan.

Slide Rules

A history of the slide rule has been given in the Tenth Anniversary Issue of JOS [2]. In brief, Napier's discovery of logarithms in 1610 enabled the determination of the product of two numbers by adding their logarithms and taking the anti-logarithm of the result. In effect to obtain the product z = xy, one calculates log z = log x + log y and takes the antilog of the sum. In 1620, using Napier's work, Gunter made a scale in which numbers from unity were positioned at distances proportional to their logarithms. He then used two dividers graphically to add the logarithm of the two numbers and read the product on the same scale. In 1630, William Oughtred used two Gunter type scales in a sliding arrangement to mechanically add logarithms to obtain their product. The same system could be used for division by subtracting the logarithm of the two numbers. Many other inventors, including such giants as Isaac Newton and James Watt, generalized Oughtred's device to multiply or divide functions of numbers using scales with distances proportioned by the logarithm of these functions to obtain F(x)G(y)=H. During this same period, a number of general-purpose engineering slide rules were developed and fabricated by companies such as Keuffel and Esser, Dietzgen, Hemmi, Astro-werke, and others. They served as the principal computers used in science, engineering and business for three and one-half centuries until they were displaced in the 1970s by transistor-based electronic computers. The 20th AF slide rules retained some characteristics of the Gunter and Oughtred systems and a number of subsequent slide rule systems but, as we shall see, can be characterized as two-dimensional and programmable.

Background

On December 7, 1941, when the Japanese attacked Pearl Harbor, I was pursuing my PhD in Physics at Cal Tech measuring a fundamental natural constant [3]. By June 1942, I was engaged in the development of a gunnery scoring system based upon the acoustic shock wave of supersonic bullets [4-7]. After a year with this Firing Error Indicator project, I joined the Army Air Force (AAF) Gunnery Training and Research Center near Fort Myers, Florida to implement this gunnery scoring system. When the Center was moved to Laredo, Texas, my Pasadena draft board sent me an induction notice and I was inducted at Fort Sam Houston in San Antonio. A letter from the Secretary of War assigned me as an Operation Analyst-Gunnery Expert to the 20th Air Force (AF) headquarters at the Pentagon, in Washington DC. Operation Analysts then were advisors assigned to combat theaters headquarters (Hdq) at the request of commanding generals to solve unanticipated technical combat problems.

After detailed technical briefings on the B-29's remote-controlled gunnery system at Wright Field, Ohio and Eglin Field, Florida I flew by Air Transport Command (ATC) to the 20th Bomber Command (BC) Hdq. in Kharagpur, India. My assignment was to assess the combat performance of General Electric's remote control gunnery system in the initial combat operations, in particular to investigate the causes of unanticipated B-29 combat losses to Japanese fighters and to develop ways of minimizing them.

Soon afterward, I flew over the Himalayas (the Hump) in a B-29, with General Curtis LeMay as the command pilot, to a forward base in the Ch'eng-tu valley of China. There I interviewed gunnery officers, intelligence officers, and B-29 crew members who had witnessed B-29s being shot down, in order to collect data on these encounters. After six weeks of organizing and digesting such data and a second trip over the Hump, I completed my report. My conclusion was opposite to that of a massive combat simulation study carried out back in the US indicating that the B-29 would be most vulnerable to rear attacks. My analysis showed that we had shot down seventy fighters for each B-29 lost in rear attacks whereas we shot down only three fighters for each B-29 lost in frontal attacks. The gunnery and intelligence officers endorsed my analysis, and LeMay modified our formations to bring greater firepower to bear against frontal attacks. With this change, some minor technical modifications and a simplification of the ranging technique against frontal attacks, the 20th BC gunnery problem was soon contained.

The Ship Length Slide Rule

In January 1945, Lt. Benjamin Tator, Naval Liaison Officer in Kunming, China, came to 20th BC Hdq. in Kharagpur, India with a complaint about the sloppy ship identifications made by B-29 crews on their over-water flights. To improve identifications I suggested that the B-29 gun sight system could be used to measure the length (L) of

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an observed ship. When used with a Japanese ship chart that gave the lengths of their various classes of ships, this length measurement should greatly sharpen identification. My solid geometry analysis showed that the ship length could be calculated using the height (H) of the aircraft, the target dial setting (X) needed to span the ship in the retro-flector gun sight, the angle of depression (D) of the ship from the aircraft's horizon and the aspect angle (A) of the ship. I allowed for H by providing a paste-on scale for adjusting the range handle on the gun sight. The depression angle D was measured with a protractor mounted on the gun sight yoke. The aspect angle A was estimated by considering the ship to be the hour hand of a watch. The length of the ship could then be determined by a formula L = G (D, A) X, where G is a non-separable trigonometric function of the two observables D and A. To deal with this two dimensionality, I used an extra-wide central slider and plotted two families of graphs so that the intersection of the D and A curves gave the factor G on a log scale that could be added to the log of X to give L. This slide rule is shown as the small upper central one in Figure 1. It is set for $D = 25°$, A=2 O'clock and X= 49 ft giving L about 860 ft., representing the Yamato, the biggest battleship ever built (the rest of Figure 1 will be described later).

Major Harry Allen, commanding officer of Flight C, a B-29 group of the First Photo Reconnaissance unit based in Ch'eng-tu, China heard of this work and invited me to equip and train his unit and to test the method in some special missions. With the help of the 948th Engineering Topographical Co. at 20th BC headquarters in Kharagpur, we fabricated a number of these slide rules, the special scales to set in the altitude on the range dial, and the paper protractors for the gun-sight yoke to measure the depression angle. We tested this system in a B-29 mission over the Bay of Bengal and confirmed that our measured ship lengths agreed with visual and radio identifications.

After approval by 20th AF headquarters in the Pentagon to accept Major Allen's invitation, I again flew over the Hump to the Flight C base. I instructed their gunners on the use of the slide rules and the installation of the range dials and yoke protractors. On March 11, 1945, I joined the crew of Captain Alvin Coe on a special reconnaissance mission intended to provide many ship sighting opportunities. After an uneventful flight over occupied China we began photographing the southeastern coast of Honshu on Japan's Inland Sea. Quite unexpectedly, as we were flying at 28,000 feet over Hiroshima Bay and nearby Kure Anchorage, we sighted two major assemblies of the Japanese fleet whose whereabouts had eluded our forces since the Battle of Leyte Gulf five months earlier. More than 70 warships were at anchor for lack of oil. The gunners and I used my slide rules to measure ship lengths. With the aid of a Japanese ship chart, we identified the 860-foot-long battleship Yamato and a number of other major ships. We continued northeastward along the Honshu coast of the Inland Sea and after about an hour turned and headed southwestward along the Inland Sea coast of Shikoku. This path took us again in sight of the Japanese fleet. There we encountered a head wind (later known as a jet stream) that slowed our ground speed to about 60 mph and our modified B-29 (F-13) bucked wildly in the turbulent air. As the pilot and copilot were busy struggling with a turbocharger problem, the flight engineer estimated that we had consumed so much fuel flying against the headwind that we couldn't make it back to Ch'eng-tu. Captain Coe could head for Vladivostok, the nearest allied airfield, but dismissed that. While he knew that the Soviets would have returned the crew, they had previously kept three B-29s that landed there in distress. We could also head for the island of Iwo Jima, 800 miles to the southeast. The historic battle of Iwo Jima was still under way but one airfield was in US hands. The next nearest option was an enclave in China controlled by Mao Tse-tung's Communist forces. They gave good "walkout" protection to US crews that bailed out in regions they controlled. However, since the plane belonged to another crew, Coe opted to try for a more distant base in an area still under the control of Chiang Kai-shek's Nationalist forces. Somehow, with empty tanks and a wing and a prayer, we managed a skin-of-our-teeth landing at the 14th AF fighter field in Xian. After waiting a few days to collect enough fuel, we flew from Xian to Ch'eng-tu. A day later I flew by Air Transport Command over the Hump back to Kharagpur.

Twentieth BC operations were terminated early in 1945 because of severe logistic problems related to carrying bombs and gasoline over the Hump to assemble supplies for missions from our Ch'eng-tu region bases. An analysis by members of our Operation Analysis unit, and the 20th BC statistical section with Major Robert McNamara, had earlier concluded that the military benefits of 20th BC operations were not worth the military costs. The bombing units had already transferred to the Mariannas, although 1st Photo and some of headquarters staff remained in China and India until the end of March. Our 20th BC Operation Analysis (OA) unit was packing to go back to the states for reassignment, but I was reassigned directly to 21st BC Hdq. on Guam. After flying by ATC via Australia and the Philippines, I reported to the 21st BC OA unit that had been established a few months earlier on Guam.

The Slide Rules of the 21st BC

Before taking on a new OA problem, I requested permission to study operational problems of the 21st BC. Their missions involved long over-water flights and short penetrations over Japan. These contrasted with the typical 20th BC mission that involved long flights over occupied China to military centers controlled by Japan and sometimes short flights over Japan. During this trip I flew to Saipan, where I could watch mission takeoff and landings of the 73rd Bomb Wing and those of the 313th Bomb Wing on Tinian (from a distance). While on Saipan, I visited my boyhood friend Lieutenant Lawrence Mayer, who was lead navigator of the 497th Bomb Group. Larry had navigated his aircraft damaged in the Nagoya fire raid to an emergency landing on Iwo Jima with two engines out on one side and had been awarded the Distinguished Flying Cross. Coincidentally this mission took place the same day as our mission over Hiroshima. But for Captain Coe's decision to head back to China, two boyhood buddies might have met on March 12 at the Iwo Jima air field while the battle was still raging.

Larry gave me the perspective of combat crews who were nearing the end of their 25-mission tours. When these crews were first ordered to drop fire bombs and fly in below 10,000 feet, they thought it would be a suicide mission. By the beginning of April, however, they were gratified that the fire raids had found the soft underbelly of Japan. To help me understand operational problems, Larry tried to arrange for me to go on their next mission but, without higher clearances, the pilot, Captain Delker, overruled it. In talking with my friend and his fellow crew members, I learned that almost all phases of the Pacific B-29 operations required highly specialized technical calculations. Apart from the navigators' and load balance slide rules, these calculations were mostly carried out with standard slide rules together with compilations of data in tabular or graphical forms. The diversity of technical problems identified in these conversations suggested a need to find a system that could handle many types of calculations. Building upon the two dimensionality of my ship length slide rule, I conceived of a versatile and easily fabricated computing system that was a generalization of earlier slide rule developments going back to Gunter and Oughtred. It consisted of: 1) a wide aluminum frame (mostly 4 inches wide and 16 inches long) with bent edges that served as slider guides; 2) a computing chart specialized to the particular technical problem; 3) a transparent plastic sheet for protecting and holding the computing chart in place; 4) a glazed transparent plastic slider with a vertical hairline (usually 4 inch by 10 inch, not shown in the figure) that is guided in longitudinal relative motion with respect to the computing chart; and 5) a sharp pencil (with an eraser) to write on the slider. The width of the system facilitated dealing with problems that involved non-separable functions, i.e., F(x,y) by using linear vertical scales and logarithmic horizontal scales. In effect, my generalization of the Gunter-Oughtred system could handle problems such as F(x,y)G(z,w) = H. In addition one could go from one problem to another simply by changing the computing chart. In effect, it was a programmable computing system.

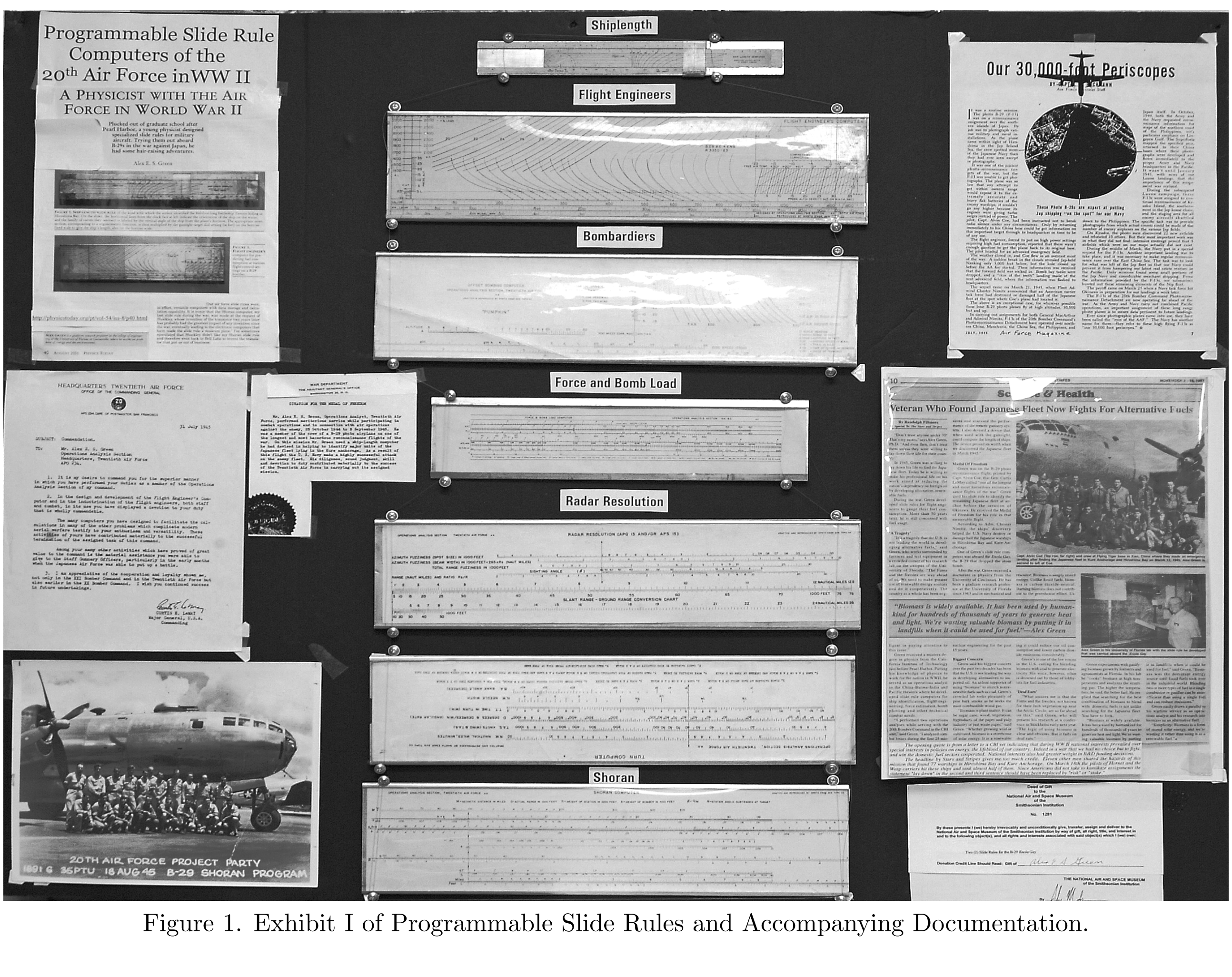

Figure 1. Exhibit I of Programmable Slide Rules and Accompanying Documentation.

When I returned from Saipan to Guam, word had spread that I could design special slide rules, and soon afterwards I received many requests for special-purpose slide rules. I set up an efficient paperwork-free slide rule design and production service. My fee to the requesting officer for a special-purpose slide rule was two bottles of their liquor allowance. I passed these along to enlisted members of the 949th Topographical Company who did not have a liquor allowance. Most of them had been drafted or otherwise selected for special skills, and being somewhat older than the average soldier, appreciated "spiritual" comfort. My slide rule design and production operation received a *defacto* priority second only to the 21st BC mission maps.

Brief descriptions of these slide rules are as follows: To meet the developing demand I needed a large supply of aluminum holders, and General LeMay suggested that I arrange to have them fabricated in Hawaii. However, to avoid paperwork delays, I used a few bottles of Old Granddad to get them fabricated at the aircraft sheet metal shop on Harmon Field during the craftsmen's non-busy hours. By May they had plenty of free time since combat damage to returning bombers was minimal by this time, and I suspect the general looked the other way.

To give an example of our operational efficiency, I will mention the case of a colonel from the 73rd Bomb Wing on Saipan who came in one day. He described the problem of carrying out the last-minute calculations on a bomb run when the intended target was obscured by clouds or a smoke screen but an offset point was visible. We quickly worked up a design that incorporated the known formula for the false bombsight settings and set our production system in motion. The next morning we had a prototype "program" for insertion into our universal aluminum holder. We took off for Rota, an island in the Marianas still held by the Japanese. We aimed at one end of their airfield's runway, and, as intended, the bombs precisely hit the other end. When we returned to Guam we began mass production of scales for all bomb types and for all bombardiers [1, 4-7].

During May, June, and July 1945, we produced about thirty varieties of slide rule charts (programs) for use on various combat problems [1]. Below the Ship Length slide rule in Figure 1 are six examples of these two-dimensional programmable slide rules (the glazed sliders with hairlines are not shown).

Flight Engineer's Computer

This computer was used by staff to estimate the fuel consumed in a planned combat mission and by combat flight engineers to calculate their actual fuel consumption. The charts incorporated data obtained in an extensive test program, conducted in the Marianas in March 1945 with an instrumented aircraft. They were available in a two-inch-thick Operational Engineering Data Book. The Flight Engineer's Computer was designed with one side for fuel consumption calculations using logarithmic scales and two-dimensional logarithmic graphs, and the other side using linear scales and contour graphs to indicate optimum flight control settings. The two-sided slide rule stored all the flight engineering information in the data book. The flight engineer used the computing side to calculate fuel consumption for actual flight control settings. He summed these numbers and made sure that the fuel consumed from base to target and back did not exceed the original supply of fuel.

The Offset Bombing Computer

This computer simplified last minute offset bombing calculations needed when the primary target was obscured by a smoke screen or a cloud but an offset aiming point was visible. Seven charts were produced each with ballistic characteristics of bombs used by the 20th AF, including the Pumpkin. This was the five-ton chemical explosive bomb of the 509th group who also dropped the nuclear bombs. Unbeknownst to me at that time, this computer could also be used for nuclear bombs, since minor differences in ballistic characteristics were inconsequential as compared to their radius of destruction.

Bomb Plot Computer

This computer was used by wing and staff photo-interpreters for plotting bomb strike patterns. Instead of bomb strike photographs that typically would take 40 seconds of straight and level flight, it used photographs of the bombs a few seconds after release in relationship to the ground.

Force and Bomb Load Compute

This computer mechanized the theory and procedures for determining the most efficient combination of bombs and aircraft to accomplish a desired mission goal. It was used by 21st BC Operation Analyst Virgil Proctor to calculate the multiple missions that were carried out every day after May 1945 when all major targets (other than those saved for our nuclear bombs) had already been destroyed.

Radar Resolution Computer

This computer was designed to determine the resolution of the APQ 13 and/or APS 15 radar systems under various conditions and to calculate ground range (R) from slant range (Rs).

Turn Computer

This computer calculated the time and the wind displacement in a turn.

Shoran Computer

This computer was designed to calculate atmospheric corrections to the geodetic calculations for the SHORAN Bombing System. This system was intended to enable the entire B-29 fleet to give close support to the planned invasion of Japan. This SHORAN slide rule design problem was posed to me early in July 1945 by Dr William Shockley (Nobel Laureate 1956, whose discovery of the transistor eventually made slide rules obsolete). As a result of my design of this slide rule, I was assigned to carry out the operational SHORAN calculations for Operation Olympic planned for November, 1945 (date unbeknown to us then).

I was to go in with a submarine carrying the master transmission station to a point about 100 miles from the Kyushu beachhead and to use a small hand-cranked digital calculator to do the geodetic calculations and my SHORAN slide rule to make weather corrections. Our calculations would determine the precise release point for each wing's SHORAN-equipped bomber. Hundreds of other bombers would then make their drops by using their regular bomb sight on the SHORAN-determined impact points.

Figure 1 is a part of one panel of a Slide Rule Exhibit that I have assembled for the annual Collectors Day event at our Florida Museum of Natural History here where I live in Gainesville, Florida. The other parts of this panel are: a letter of commendation from General LeMay dated July 31, 1945 [1]; my 1947 Medal of Freedom citation; the one-page article in *Air Force Magazine* dated July 1945 that describes our reconnaissance mission over Hiroshima and the impact of our Japanese fleet sighting; an article in a November 1997 *Stars and Stripes* journal, written by Randolph Fillmore, based upon an interview with me. It has the headline "Veteran who found the Japanese Fleet now fights for alternative fuels". (In recent years, my research has focused on use of biomass, a CO2-neutral domestic fuel that is largely wasted in landfills.) This page has the picture showing Coe and his crew at Xian after the landing on March 12,1945 [1]; a picture of our SHORAN project team when we returned to Guam from Manila on August 18, 1945, three days after hostilities ceased; the front page of a *Physics Today* article with the headline "A Physicist with the Air Force in World War II" [6] and a copy of my Deed of Gift to the National Air and Space Museum of the Smithsonian Institution of copies of the two slide rules used by the Enola Gay.

As a member of the Oughtred Society I should note that, besides the display shown in Figure 1, the other components of my Collectors Day exhibit include a 9-foot K&E instructor's slide rule, a 4-foot Post instructor's slide rule, my collection of precision engineering slide rules, my collection of industrial specialty slide rules, two books on slide rules [7, 8], proceedings of slide collector meetings in the Netherlands, Germany, and Switzerland, and several issues of *Journal of the Oughtred Society* including the Tenth Anniversary issue.

Impacts of 20th AF Slide Rules

My ship length slide rule, developed at the 20th BC in Kharagpur, India, was involved in some historic events of the Pacific war. I was unaware of the consequences of our discovery of the Japanese fleet until an article appeared in the July 1945 Air Force Magazine identifying our flight as "one of the juiciest photo-reconnaissance flights of the war" [9]. The article noted that the sequel to our flight came on March 21 when Fleet Admiral Nimitz announced that a carrier task force had destroyed or damaged half the Japanese fleet where we had located it. Our sighting also triggered the early initiation of an aerial mining campaign that had been planned for more than a year [10]. On March 27 and March 30, the 313th Bomb Wing of the 21st BC based on Tinian launched Operation Starvation by mining the Shimonoseki Strait, then the most important shipping channel in the Japanese Empire. Shortly thereafter mines were laid at the approaches to Hiroshima, Kure Anchorage and many other harbors and straits. These mines brought Japanese shipping and naval operations to a virtual halt [10-16].

Our sighting helped the Navy task forces that hit Okinawa on March 25 to initiate the Okinawa campaign. Landing operations began on April 2. On April 7, the Yamato, a light cruiser named the Yahagi, and eight Japanese destroyers that had survived our naval assault on the Hiroshima and Kure anchorages, made a dash through the Bunge Suido east to the Philippine Sea. Given only a one-way supply of oil, they were sent on a suicide mission to destroy our Okinawa troop ships. However, a B-29 reconnaissance plane spotted them and a US submarine tracked them as they sailed along the coast of Kyushu. Finally, naval aircraft of the Hornet and the Wasp sank the Yamato, the Yahagi, and four of the destroyers in the last major naval engagement of World War II, effectively bringing an end to the Imperial Japanese Navy [11-16]. With these victories, the highly effective B-29 fire raids that began on March 9 and the surrender of Iwo Jima on March 25, the tide of our war with Japan turned dramatically in our favor in March and April 1945.

After the above victories, Emperor Hirohito and Premier Suzuki realized that surrender was inevitable [11, 15]. Unfortunately they primarily used the Soviets to explore surrender terms. In February 1945, at Yalta, Roosevelt and Churchill reached a secret agreement with Stalin for the Soviets to join us in the war with Japan after the German surrender. President Roosevelt has been castigated for the Yalta agreements. However, in February 1945, he was faced with the heavy losses in landings on Japanese occupied islands as well as the high costs and ineffectiveness of B-29 operations to that point of time. Thus he followed his military advisors' recommendation to seek Soviet help in the war with Japan after Germany surrendered. Two months later when the Emperor and Premier of Japan recognized the necessity of ending the war and pursued their peace overtures through the Soviets, Stalin did not inform Roosevelt or Churchill. Essentially the last four months of our war with Japan were mostly a matter of establishing terms of surrender. In these negotiations, the Emperor, who has been generally portrayed as a benign bystander to the actions of Japan's military, has also been seen as a shrewd and skillful manipulator [15].

When I left the 20th BC in Kharagpur in mid-March, it was clear that the 20th BC bombardment campaign had accomplished very little, apart from overcoming some B-29 operational problems. By May it became clear that the 21st BC on Guam was successfully destroying the war capabilities of the Japanese homeland, the assigned mission of the 20th AF. I particularly remember one of the 949th mission map-makers asking me why the fire bombing targeted smaller cities when we had not taken out some of the larger cities. Knowing the high priority of my slide rule work, he thought I participated in mission assignments. After the war it became clear that these larger cities were saved for the nuclear bombs (Bombs).

Controversy On the End of the War with Japan

Japan

In 1946, a team of industrial experts carried out the US Strategic Bombing Survey (USSBS) [11]. They reached the conclusion that "a concentration of air attacks exclusively on railroads and urban areas, at least from March 1945 on, would in all probability have led to an earlier surrender". This would mainly be due to mass starvation for lack of means to transport food from farming areas to the population centers.

Since the close of WW II, an emotional controversy has existed over our first and thus far the only use of nuclear bombs. Academic historians and veterans have confronted each other over whether these horrifying weapons were needed to end the war with Japan [16-21]. The planned 50th Anniversary display at the Smithsonian Air and Space Museum, "The Last Act, The Atomic Bomb and the End of World War II," that was to include the Enola Gay along with "anti-nuke" exhibits greatly enhanced this controversy.

The "anti-nuke" view has been given the name "Revisionism" and the debate continues to this day [20, 21]. One group says that the Bombs were dropped to save a million American lives that would have been lost in the invasion of Japan. Another group says they were dropped as an act of racism against the Japanese.

What actually could have ended the war (more rational positions) include:

A) The war could have been ended earlier if we used the best conventional weapon strategy;

B) Softening the demand for "unconditional surrender" would have ended the war earlier;

C) The Soviets' entry on August 9 would have ended the war without the Bomb;

D) One Bomb would have been enough;

E) The two Bombs and the threat of the third were needed to end the war;

F) A demonstration of the Bomb would have ended the war.

What in the Total U.S. Effort Won the War?

Who or what won the war with Japan has also been debated in many articles, books, and TV programs. Some alternatives apart from the Bombs include:

1) USA's industrial might that produced our weapons and supplies;

2) McArthur's island invasion campaign;

3) The Navy's destruction of the Japanese fleet;

4) The cutting off of Japan's oil supply;

5) The March and April fire bomb raids;

6) The aerial mining of Japanese ports and waterways;

7) The post-April systematic destruction of Japanese war production centers;

8) Ultra, and Magic, that broke the Japanese code;

9) Photo-reconnaissance work that informed us of targets and of bombing results;

10) Slide rules that facilitated several of the above.

As an Operation Analyst and slide rule designer for the 20th AF, both of which require quantitative assessments, my view of the main factors that ended the war with Japan are as follows:

The tactical fire bombing raid on Japanese-occupied Hankow on December 18, 1944, and the devastation wrought by fire bombs on Dresden on February 14, 1945, had impressed General LeMay. Compared with the poor destructive efficiencies of high-altitude bombing, he estimated a large impact of fire raids on Japan's predominantly wooden and paper buildings. Imitating brutal tactical operations first used by the Japanese and the Germans, LeMay altered the high-altitude bombing design strategy of the B-29 and used low-altitude fire bombing tactics.

By mid-June, after completing 17 intense incendiary missions against primary target cities (Tokyo, Osaka, Nagoya, Kobe, Yokohama and Kawasaki) the 21st BC had destroyed 106 square miles of Japan's major military production centers. From mid-June through August 5, in 14 multiply targeted night bombing missions, we destroyed an additional 61 square miles. They were in 56 secondary cities selected for their war industries, transportation facilities, congestion and inflammability and adaptability to radar bombing. The median populations of the secondary cities decreased from about 200,000 to 60,000, illustrating the rapid exhaustion of major targets. Beginning in July, the 20th AF dropped leaflets to warn Japanese civilians to leave the towns to be destroyed the next evening. Shortly afterward a 20th AF order gave top target priority to Japanese railroads. This was about to be implemented when the nuclear bombs were dropped.

On August 6, the Hiroshima (Little Boy, Uranium bomb) and on August 9, the Nagasaki (Fat Boy, Plutonium bomb) destroyed an additional six square miles, about half due to fire. While the energy released by each Bomb, as measured by Cal Tech's acoustic device, was equivalent to 20,000 tons of TNT, a rating of about 2500 tons "incendiary equivalent" would more realistically quantify their military impact. Thus the two Bombs had a relatively minor military impact as compared to the total 161,000 tons of bombs US forces dropped on the Japanese homeland (147,000 tons by B-29's). However, the psychological impact, particularly in providing a face-saving exit for Japanese leaders, was much greater.

By August 1945, the 20th AF B-29 bomber fleet consisted of over 1,000 planes in the Marianas and its aircraft and bomb supply rate was building up rapidly. The

Eighth Air Force, under General James Doolittle on Okinawa, only 400 miles from southern Japan, was building up more rapidly drawing from the massive B-17 and B-24 fleets from the European theater that had dropped 1,360,000 tons on the German homeland. The US Navy, with the greatest battle fleet in history, was bombarding all coastal areas of Japan with negligible opposition. On August 9 the Soviet Union, by agreement at Yalta, began its invasion of Japanese-occupied Manchuria and Korea with massive forces.

The invasion of Kyushu, called Operation Olympic, was planned for November 1. In considering whether this invasion would be needed, one must project the probable impact of the destructive capabilities of the four aforementioned conventional forces (20th AF in Marianas, Eighth Air Force in Okinawa, the US Navy, and the Soviets) after allowing for their build-ups during the rest of August, September, and October.

A quick "back of an envelope" calculation or actual slide rule calculation indicates that Japan would have been reduced to a wasteland, and starvation would be rampant by the time Operation Olympic was to begin. While the above conclusion might appear to support the Revisionists, I mainly stress the importance of using quantitative analysis and keeping emotions or biases out of assessments. When one applies numbers to the questions: What brought the surrender? and Who or what won the war?, it becomes clear that the surrender of Japan could have been achieved without the planned November invasion. However, Truman's decision to drop the Bombs probably shortened the war by at least a month and spared millions of Japanese from starvation. It undoubtedly saved a substantial number of American lives that would have been lost during the remaining military operations.

Dropping of the Bomb also limited Stalin's involvement in Japan's future, for which the Japanese should be thankful. Truman also did the Japanese another good turn by prohibiting post-war Japan from rebuilding its military industrial complex. As a result, Japan made a remarkable "defense conversion" to consumer products [22] and quickly became the world's second strongest economic power (possibly to be surpassed by China in a few decades). Our country, preoccupied with the Cold War with the Soviets, lost much of its competitive edge in consumer products and is now burdened with a tremendous national debt.

Edward Teller and the BOMB

In 1995, the Admiral Nimitz Symposium at the 50th Anniversary of the dropping of the Bomb was nationally televised. Edward Teller, developer of the Hydrogen-bomb, stated that, in retrospect, he would not have advised dropping the Bomb. Instead he would have demonstrated its power by exploding it at 30,000 feet over Tokyo to convince Japanese leaders that we had a weapon that could destroy them (see F above). Major Sweeney, pilot of Bock's Car, that dropped the Nagasaki bomb was on the panel but didn't raise any questions. I wrote to Dr. Teller questioning the possibility of a B-29 surviving the launch of a Bomb at 30,000 feet. His answer quickly came in the form of a request "I should be deeply indebted to you if you could let me know what method you would have chosen ...".

Since my slide rules had most of the relevant flight characteristics of the B-29 and also of the Pumpkin, the 509th group's simulated Bomb, I undertook Dr. Teller's challenge. I carried out a series of calculations that led me to suggest that "Instead of a 30 k (k = 1000 ft) explosion altitude directly over Tokyo, I would use a 30 k slant range from the nearest shore point of Tokyo Bay but to explode at a 10 k altitude. At this altitude the explosion would be seen outdoors yet the harm to population should be no greater than your proposed 30 k explosion directly above Tokyo." My calculations indicated that if a reasonably-sized parachute were used with the Bomb in its descent from 30k to 10k, the Enola Gay could get even farther away from the explosion point than it did. I didn't hear from Dr. Teller for a month (he had had a minor stroke), but when I did on October 30, 1995, his letter said, "I find your discussion really significant. I hope on future occasions to quote your specific suggestions." He concluded, "Please accept my repeated thanks."

Summary and Conclusion

In the last 60 years innumerable articles, books, radio and TV programs have speculated on who and what won the war with Japan and what triggered the final surrender. Many of these reflect emotionalism engendered by the psychological impact of nuclear bombs. Very few are mindful of quantitative facts.

Not only do these speculations not use quantitative facts, in some cases, the location of the decimal place in figures cited to justify conclusions may be in error. Engineering slide rules give a numerical result, but not the location of the decimal place. This requires a mental or "back of the envelope" calculation that promotes intuitive understanding. One might question the conclusions of those whose training did not include the use of engineering slide rules.

When I originally considered writing an article with the title "How Slide Rules Won a War" I planned, with tongue in cheek, to focus entirely on my 20th AF programmable two-dimensional slide rules. However, in developing the slide rule thesis, it became clear that the title could have a much broader base. Most of the leaders and technical persons involved in the war with Japan were trained in the use of slide rules (LeMay had a BS in Civil Engineering). Thus leaders of the "greatest generation" developed an intuitive sense of orders of magnitude and an understanding of the relative importance of the factors influencing the result of proposed solution options. Apart from the earliest baby boomers, most members of postwar generations work by qualitative thinking or by pushing the buttons on calculators. They often do not really know the meaning of the numbers nor have feelings for orders of magnitude, significant figures, and major factors.

During the Japanese campaign, I was the only Operations Analyst with substantial service in the 20th and 21st Bomber Commands. To my knowledge I was also the only slide rule designer, and possibly the only one with a quantitative operational assignment (SHORAN calculator) preparing for the invasion of Kyushu. From these quantitative perspectives, when I assess the aforementioned ten Alternatives to the Bomb as winning the war, I must conclude that all of them played a role. When I examine the above mentioned A-F candidates for the final blow in getting Japan to surrender on August 15, I find some truth in all of them. Accordingly, I believe the time has come to end this divisive controversy between academics and veterans.

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