THE FIRST ATOMIC BOMB MISSION: TRINITY B–29 OPERATIONS THREE WEEKS BEFORE HIROSHIMA

Darrell F. Dvorak

(Overleaf) The Silverplate first drop-test B–29 aircraft, at Muroc Army Air Field, February 1944. *(Photo courtesy of Keith Shields.)*

On July 16, 1945, the world changed forever, but the moment was witnessed by little more than 400 observers. Before dawn at a remote desert test site in New Mexico, history's first atomic bomb was exploded, culminating a top secret project codenamed Trinity. It was 50 percent more powerful than the bomb that soon would be dropped on Hiroshima and almost equal to the one dropped on Nagasaki a few days later. As events unfolded, Trinity's success meant an end to World War II without an Allied invasion of Japan, saving untold numbers of lives. But even though this epic event has been the subject of many scholarly works for more than sixty years, one important chapter of the Trinity story is still incomplete. It is the account of the fewer than two dozen men who witnessed the blast aloft in two B–29 bombers, exposed to uncertain and potentially deadly risks.

THIS PAPER …IDENTIFIES THE AIRMEN WHO CREWED THOSE TRINITY FLIGHTS, WHY THEY WERE SELECTED, AND HOW THEY PREPARED FOR THEIR MISSION

This paper identifies those intrepid flyers, why they were aboard, and what they saw. Most importantly, for the first time it identifies the airmen who crewed those Trinity flights, why they were selected, and how they prepared for their mission. Based on newly available personal military records, overlooked primary sources, and prior scholarship, this paper extends the important, but still unfinished, story of the U.S. 216th Army Air Forces Base Unit (Special) and its leading role in creating the atomic bombs that decisively ended World War II.[1] This is particularly significant because *no* 216th records for the critical year 1945 have yet been found by this author in any of the principal national archives. Most distressing, the Air Force Historical Research Agency, primary repository of Air Force historical documents, has no records of the 216th's finest hours. In 2013, the Agency wrote to an independent researcher, *"For some reason, the histories for the 216thAAF BU goes* [sic] *to September 1944 then does* [sic] *not pick up again until January 1946."*[2] One result is that official AAF manifests for the Trinity flights are missing and the author has had to reconstruct them.

The Manhattan Project

Many talented people helped create the first atomic bombs, but arguably the two most important were U.S. Army General Leslie R. Groves, head of the atomic bomb project (codenamed Manhattan Engineer District), and J. Robert Oppenheimer, scientific director of Los Alamos Laboratory (LAL), where breakthrough science and engineering transformed atomic theory into reality.[3] Oppenheimer's role began in mid-1942, a few months before Groves chose him to lead LAL. Six months later, the site for the laboratory had been chosen, construction was underway, and LAL personnel began to move in:

Jun 42 Oppenheimer appointed Scientific Director of the Development of Substitute Materials Project, forerunner of Manhattan.
Sep 42 Groves assumes command of Manhattan.
Oct 42 Groves decides to centralize atomic bomb research at a single location and selects Oppenheimer to lead it.
Nov 42 LAL site chosen in New Mexico.
Apr 43 Initial research staffs move to LAL.

Manhattan's goal was to produce several atomic bombs in order to credibly threaten the Axis powers with repeated atomic attacks as necessary to force their surrender. Later events validated that goal, but achieving it depended on solving the most profound unknowns of nuclear science.

Manhattan's Scientific Challenge

At the risk of oversimplifying, the immense power of an atomic bomb is the result of massive amounts of energy released when a particular material achieves *critical mass*, which triggers the nucleus of an atom to split apart—*fission*—releasing energy that creates an instantaneous, self-sustaining *chain reaction* of splitting nuclei within all the other atoms in the material, thereby releasing even more energy and creating an unprecedented blast. Researchers had determined that the most promising materials to produce that result were the elements Uranium-235 (U-235) and Plutonium-239 (Pu-239), but as potential weapons, the two elements had almost mirror-image advantages and disadvantages.

U-235 was difficult to produce in pure enough quantities, but could be readily incorporated into a simple "gun" bomb design wherein one sub-critical mass was "shot" into another sub-critical mass to achieve critical mass. But U-235's production difficulties meant there would only be enough for a single bomb (codenamed Little Boy). In contrast, Pu-239 was easier and cheaper to produce in purer quantities, thus requiring lesser amounts for a weapon. But in a dramatic mid-1944 development, LAL researchers confirmed that, if Pu-239 were used in the simple gun design (codenamed Thin Man), it would spontaneously begin fissioning and expire in a fizzle.

Thus, to produce several atomic bombs, LAL researchers had only one path forward: use Pu-239, but pursue development of a theoretical explosive concept known as "implosion." Implosion required uniformly compressing a plutonium sphere into a critical mass by surrounding it with explosives triggered by a complicated ignition system. Not only had this never been done before, but there were no small-scale, experimental methods that could prove that such a bomb design would work or, if so, how

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The crew of the Silverplate first drop test B–29 aircraft, at Muroc Army Air Field, February 1944. Top row: Shields, Wilkinson, Dike, Storemen, Roark, Semple. Middle row: Bender, Coles, Merrill, unknown. Front: Rochlitz. *(Photo courtesy of Keith Shields.)*

powerful it might be. It was evident to LAL researchers that eventually they would have to undertake a live field test of any new plutonium bomb implosion design.

Manhattan's Ordnance Challenge

While creation of the first atomic bombs was a triumph of outstanding science it was equally a triumph of outstanding engineering, especially the project's *ordnance* engineering, the conversion of theoretical science into practical and effective weapons. Research determined that the sizes, shapes, weights, and technologies of the uranium and plutonium bombs would be radically different from each other and unlike any other aerial bombs ever made. LAL's historian later observed, "A new field of engineering was being explored," one in which success would come from the work of "…physicists, chemists, and electrical and mechanical engineers…all of which contribute to the field and none of which dominate it."[4] But the historian failed to also credit the central role of the U.S. Army Air Forces (AAF): two events in June 1943 were the start of what became a twenty-seven-month period of ordnance research, development and testing shared between LAL and the AAF to *weaponize* LAL's work.

THERE IS NO ONE MORE RESPONSIBLE FOR GETTING THIS BOMB OUT OF THE LABORATORY AND INTO SOME FORM USEFUL FOR COMBAT OPERATIONS THAN CAPTAIN PARSONS

One event was Groves's selection of Navy Captain William S. "Deak" Parsons to lead LAL's ordnance program. Considered to be one of the military's best ordnance engineers, Parsons not only organized and led LAL's Ordnance Division, but in August 1944 he became Oppenheimer's Associate Director of LAL, and in March 1945 he was appointed Officer-in-Charge of Project Alberta to prepare for combat use of the bombs from a new air base on Tinian island in the South Pacific. Upon Parsons's death less than ten years later, his former LAL deputy eulogized, "There is no one more responsible for getting this bomb out of the laboratory and into some form useful for combat operations than Captain Parsons, by his plain genius in the ordnance business."[5]

The other June event was the AAF's selection of the B–29 Superfortress bomber to support the ordnance tests and fly the later atomic bombing missions. Aside from LAL's internal development and testing of certain bomb components, principal ordnance work centered on dropping evolving inert bomb designs from B–29s at the very high altitudes (30,000-plus feet) expected for the bombing attacks. As the bomb designs evolved, so too did the B–29 configuration, ultimately requiring a twenty-month period of plane modifications, codenamed Silverplate, to marry the planes to the final bombs. By the end of the war, sixty-five Silverplate B–29s had been delivered to the AAF, eighteen of which were used in the ordnance testing program.[6]

These two events initiated the first phase of the ordnance program, which had decidedly mixed results over its first fifteen months:

Jun 43 LAL Ordnance & Engineering Division organized under Parsons; AAF selects the B–29 to carry the atomic bombs.

Aug 43 Using a Grumman TBF Avenger, first drop tests of prototype scale model bomb at Dahlgren Naval Proving Ground, California; results are dismal.

Nov 43 Silverplate prototype delivered to AAF's flight test center at Wright Field (now Wright-Patterson Air Force Base), Ohio; dedicated test crew assigned.

Feb 44 First drop tests of full-scale bomb models begin at Muroc Army Air Field (now Edwards AFB), California.

Mar 44 LAL begins planning plutonium bomb field test, codenamed Trinity; Silverplate prototype damaged; drop tests suspended pending repairs.

Jun 44 Second drop test series conducted at Muroc.

Jul 44 LAL cancels Thin Man work; assigns top priority to implosion bomb, codenamed Fat Man.

Aug 44 LAL reorganizes to support Fat Man priority. Decisions made to expand drop test program and base it at Wendover Army Air Field, Utah, operated by the 216th AAF Base Unit (Special).

The B–29 test crew assigned in November 1943 included Major Clyde S. "Stan" Shields as plane commander and Lieutenant David Semple as bombardier. They would lead the ordnance test program through to its end in early August 1945. Considering Manhattan's supreme importance, their election undoubtedly was a testament to their aerial skills, but their value to the project over the next twenty months would go well beyond flying the B–29s.

Oppenheimer in March 1944, began planning a field test of the plutonium "Fat Man" bomb, recognizing that: "The many questions about a practical [implosion] bomb … could only be answered by an

Fat Man sphere atop Trinity tower July, 1945. *(Photo courtesy of the author.)*

actual experiment with full instrumentation."[7] Sixteen months later, those many questions would receive unexpectedly spectacular answers.

Reorganizing Ordnance Work

Beginning late 1944, reorganizations of LAL and the 216th spurred progress in preparing for the Trinity test and improving results of the ordnance test program:

PARSONS'S BROADER ROLE WAS RECOGNITION BY OPPENHEIMER AND GROVES THAT HE WAS INDISPENSIBLE TO MANHATTAN'S SUCCESS

Aug 44 Parsons role expanded to include "…all aspects of the work having to do with ordnance, assembly, delivery, and engineering.[8]

Sep 44 Trinity test site chosen at Alomogordo Bombing Range in New Mexico. 509th Composite Group begins organizing at Wendover.[9]

Oct 44 Three new Silverplate models assigned to 216th. Col. Clifford J. Heflin chosen to become 216th commanding officer. Oppenheimer approves initial plans for Trinity test.

Nov 44 Shields assigned to 216th. Four new Silverplate models assigned to 216th.

Dec 44 Navy Capt. Frederick L. Ashworth assigned to lead LAL ordnance work with the 216th. Trinity site base camp housing completed.

Jan 45 Decision to organize 216th Special Ordnance Detachment. Heflin assumes command of the 216th.

Feb 45 LAL finalizes Fat Man design. 216th Flight Test Section organized under Shields's command. Drop tests resume. Five new Silverplate B–29s assigned to FTS. Shields begins daily diary of FTS work.

Mar 45 LAL organizes Project Trinity under Kenneth T. Bainbridge. LAL Cowpuncher Committee formed to "ride herd" on all implosion work.

Parsons's broader role was recognition by Oppenheimer and Groves that he was indispensible to Manhattan's success. But his additional duties necessitated bringing aboard Ashworth, another ordnance expert, to handle the increasing pace of drop tests with the 216th. Reflecting Groves's sharp attention to Manhattan's details, especially choosing the right people, he likely chose both Ashworth and Heflin.[10]

The 216th underwent a major reorganization in order to handle its ordnance responsibilities, which were far beyond the typical airfield operations duties of an AAF base unit. Two entirely new units were organized: a Flight Test Section (FTS) commanded by Shields that was responsible for the drop tests, support of LAL ordnance field tests, and advising on Silverplate modifications; and a Special Ordnance Detachment (SOD), soon to be commanded by Captain Henry Roerkohl, that was responsible for building the evolving drop test bomb models with LAL and creating new Silverplate bomb loading/unloading equipment.[11] The 216th's reorganization was timely because LAL researchers in February 1945 completed the complex design of implosion technology, which helped determine the overall size (11 ft. long, 5 ft. wide), shape ("pineapple") and weight (10,200 lbs.) of the drop test models and final bombs. Fat Man models quickly came to dominate the 216th's ordnance work.

Also in February, Shields began keeping a classified "Daily Diary" that recorded FTS activities for the next six months, ending only a few days before the August 6, 1945 Hiroshima bombing mission. Shields's diary appears to have only been shared with very top LAL officials and Wendover officers and, although declassified in 1973, it only became fully public in January, 2013. It is now an essential reference to understand how the first atomic bombs were created.[12]

Ordnance Testing

The ordnance testing programs for Little Boy and Fat Man had several goals: produce designs whose ballistics properties ensured that they would follow predictable paths when dropped from 30,000-plus feet[13]; perfect the bombs' internal technologies (e.g., firing circuits, proximity fuzes) to ensure that they would properly detonate at predetermined heights; utilize the bombs' improving ballistics coefficients to prepare bombing tables for the bombing missions[14]; marry the bombs to the Silverplate B–29s to ensure failure-proof loading, unloading, carrying, monitoring, releasing and dropping both bomb designs; and assess the bombs' air speed and time of fall to help determine how the mission aircraft would escape the blasts.[15]

Ashworth later commented, "The engineers to conduct the test work and I would fly from Kirtland [Army Air] Field in Albuquerque to Wendover each week for the next five months... Late Friday, after that week's work was finished, we would fly back to Kirtland to prepare for the next set of test work the following week."[16] Shields's diary suggests the variety of issues that engaged LAL visitors at Wendover:

Feb 20-25 Francis Birch (Leader, Gun) observes Little Boy drop tests, including as B–29 passenger.

Mar 1 Shields and Donald Mastick (Ashworth assistant) discuss expansion of FTS, Los Alamos matters and drop test schedule.

Mar 6 Shields checks "modification of the [B–29] front pressure door to take [Edward] Doll's (Deputy Leader, Fuze Development) radar installation."

Mar 7 Shields receives Mastick memo recommending improvements in drop-test procedures; discuss next drop-test phase

Mar 18 Shields, Mastick and Robert Brode (Leader, Fuze Development) witness mishandled loading of Little Boy unit; also discuss ordnance training for 216th.

Mar 21 Shields expresses "consternation" about visit from Roger Warner (Deputy Leader, High Explosives).

Mar 22 Semple and Mastick spend most of the day investigating premature release of Little Boy due to improperly connected B–29 electric circuit.

Mar 25 Sheldon Dike (B–29 modifications) arrives from Omaha B–29 modification center with photos and blueprints of new fuel injection engines and synchronized propellers that will enable bombing from 35,000 feet.

Mar 27 Ashworth, George Kistiakowski (Leader, Explosives Division) and Cmdr. Norris Bradbury (Leader, Implosion) observe high explosive (HE) bomb drop.

Mar 30 Aboard B–29, Kistiakowsky observes poor Fat Man HE drop.

Apr 22 Shields conversation with Ashworth and Dike regarding transfer of personnel to FTS armament section.

Apr 24 Meeting of Heflin, Shields, Semple, Tibbets, Parsons, Ashworth, Norman Ramsey (Leader, Delivery) and Mastick regarding several matters.[17]

Apr 25 Parsons and Ramsey observe test drop from 32,000 feet and "seemed very pleased" with the results. Semple promoted to Captain.

Apr 26-30 Flying a C-47, FTS conducts three fuze tests for Brode using maneuver nicknamed "Dipsy Doodle."

NO TECHNOLOGY EXISTED FOR SUCH MEASUREMENTS ON THE SCALE EXPECTED FROM THE ATOMIC BLASTS… [SO] [OPPENHEIMER] ASKED… ALVAREZ TO DEVISE A WAY TO MEASURE THE ENERGY OUTPUT OF THE BOMBS, WHEN THEY WENT OFF OVER JAPAN

As drop testing progressed, another ordnance assignment loomed for FTS, this one unprecedented: "Because only a limited number of measurements could be taken at Trinity, the ones to be selected became a critical topic of discussion [at Los Alamos]…Data were needed on both the performance and the effects of the weapon. Especially important were shocks, both the air blast, which would determine the height of their combat burst, and ground shock… *The most important Trinity measurements were concerned with the bomb's destructive power. Since the principal goal was to achieve the maximum blast wave energy from the least* [nuclear] *material, the laboratory placed the greatest emphasis on measuring the energy in the blast wave* [emphasis added]."[18]

But no technology existed for such measurements on the scale expected from the atomic blasts. So

[Oppenheimer] asked [LAL physicist Luis] Alvarez to devise a way to measure the energy output of the bombs, when they went off over Japan. Alvarez asked if he could have his own B–29 bomber, as part of the bombing mission, to make those measurements, and Oppie said he could probably arrange that…. In talking to [LAL] theorists, they told [Alvarez] that the energy of [the bombs' blast] could be figured from the shape and duration of the shock wave, even if the wave were recorded at 30,000 feet above the [bomb's detonation altitude]. [19]

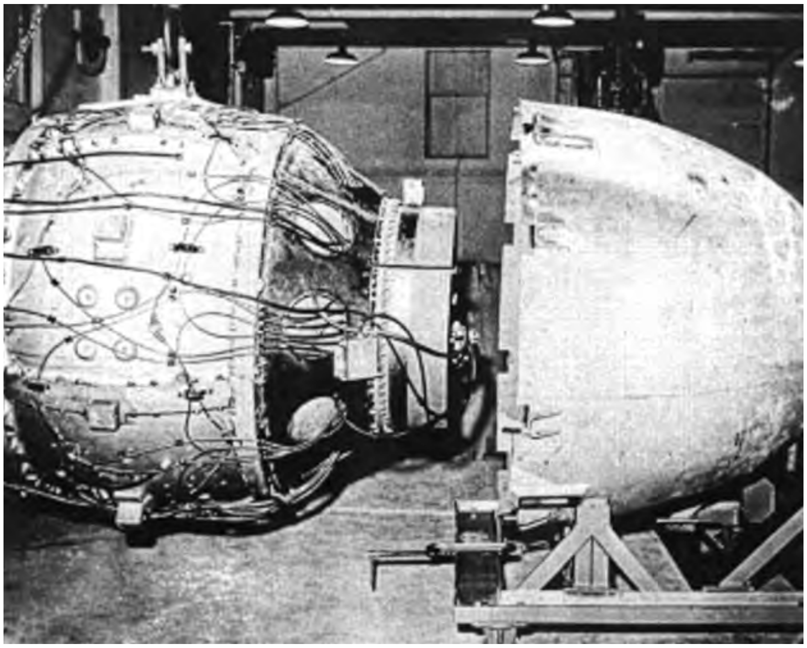
Alvarez later explained, "I would need a microphone calibrated so that its signal would increase as the blast wave hit it and decrease… as the wave passed by."[20] He assembled a small team of LAL scientists and technicians, who soon discovered that a related technology had been developed by a young university researcher who was signed on as a consultant to their project. Their final system utilized a microphone equipped with an FM transmitter and antenna packaged inside a three-foot long aluminum cylinder attached to a parachute. The cylinder would be dropped from a Silverplate B–29 over the blast to gather pressure wave data, and immediately telemeter that data to an FM receiver in the plane, that would record the wave on film. As a redundancy precaution, three cylinders would be dropped simultaneously.

In addition to measuring the blast's energy, the Fat Man test afforded Alvarez and his team the opportunity to conduct several other measurements. The blast would produce a growing radioactive "cloud" that they would measure for its size, shape, course, and gamma radiation intensity, the latter "by direct reading at a distance" and "by dropping film through cloud at intervals."[21] They would also film the event using a high speed camera that produced a slow motion recording. Another intended measurement was of "airborne products" that were to be trapped in special filters on the Silverplates.[22] And the AAF "wanted to know what the blast effects would be like on a plane 30,000 feet up and some miles away, simulating a bomb drop and scramble from the target area" but it is not clear if there were instruments to measure this.[23]

Meanwhile, Trinity project leader Bainbridge decided that it was essential to trial-run the Fat Man test with an all-hands-on-deck exercise nicknamed the "100-ton" test that took place May 7, 1945 at the Trinity site. Alvarez intended to test his blast measurement system during this trial run, but that depended on Oppenheimer getting him a B–29.

Trinity's 100-Ton Test

"The breadth and intensity of the preparations…necessary for the [Fat Man] test cannot be overemphasized. The task was one of establishing under extreme secrecy and great pressure a complex scientific laboratory on a barren desert."[24] Thus did



Fat Man sphere being assembled into nose ellipse of Nagasaki bomb. *(Photo courtesy of the author.)*

LAL's historian also frame the stakes for the 100-ton test: it was the only comprehensive field test of all those "preparations" for the Fat Man test coming two months later, including administrative procedures, equipment, instruments, etc. Despite its name, the trial run used 108 tons of high explosives, an amount that introduced uncertain risks because "very little experimental work had ever been done on blast effects above a few tons…" The explosives were set atop a twenty-foot tower at the Trinity site, because "appropriate scale factors" indicated that height would calibrate to the "100 foot height expected for the 4000 to 5000 tons [of TNT yield] expected…" in the coming Fat Man test.[25] The explosives were seeded with small amounts of radioactive product to simulate fallout that could be expected in the later Fat Man test. Shields piloted the B–29 for Alvarez that Oppenheimer had promised.

ALVAREZ AND … PARSONS, … PLOTTED ITS INTRICATE OPERATION: HOW THE PLANE WOULD APPROACH THE TOWER SECONDS BEFORE DETONATION, DROP ITS INSTRUMENTS TO MEASURE THE SPEED AND PRESSURE OF THE BLAST, THEN SWERVE AWAY IN TIME TO AVOID THE SPIRALING FIREBALL

According to Shields's diary, on May 5 he and Semple flew a B–29 to Kirtland *"…to conduct tests for Bernie Waldman* [Co-Leader with Alvarez of Airborne Observations]. *Four (4) flights were made. Two (2) during daylight hours on the 5th of May and 6th of May. Two blast tubes on chutes were dropped on the 6th. Meeting was held with people concerned and details for runs, timing, signals, etc. were worked out. Take-off was made at 0300, 6 May 1945 for practice mission. Results were satisfactory. Live run was made on 7 May. Drop was made and unit fired about 0445. Results were very satisfactory and everyone seemed pleased. Shock wave on aircraft was barely noticeable at 15,000 feet above terrain. At firing, aircraft was 26 seconds beyond target, or about 2¾ miles away from directly overhead. The glow was beautiful… returned to Wendover Field on 7 May at 1400."*[26]

LAL's historian reported, "The [100-ton] test was successful as a trial run, and was used chiefly for suggesting methods for improving procedures for the final test… The high percentage of successful measurements in [the later Fat Man test] may be attributed in large measure to the experience gained from [the 100-ton test]."[27] Trinity project leader Bainbridge wrote: "Three condenser gauges for measuring blast pressure were dropped over the target from a height 15000 ft above ground by the observation plane. One radio receiver in the plane was known to be out of order because of a fire, and one recording instrument failed. The other gave an excellent pressure-time record. The three parachutes had to be dropped in salvo instead of successively, as planned, because of failure in the bomb-release mechanism…The test appears to have been successful as a trial run. In the [Fat Man] test, it is to be hoped that a larger proportion of the measurements will be successful, but even if this were not the case sufficient data would be provided to answer a considerable proportion of the necessary questions."[28] Despite the success of the trial run, Bainbridge decided that two more weeks were needed "…to engage in the final tune-up and rehearsals, including a few with B–29 planes..."[29]

Shields had had a busy May. In addition to the 100-ton test and the ongoing drop tests, on May 14 he assumed command of the men and cargo planes of a section of a transport squadron that did not deploy to Tinian.[30] Yet June and July would be even busier for the 216th's airmen.

FTS Preparations for Trinity's Fat Man Test

Shields's Diary reveals that one month after the 100-ton test he and Semple began the first of several days planning and rehearsing for the Fat Man test:

Jun 7-8 Shields and Semple attend "various conferences" at LAL regarding "phases of coming [Fat Man] test work."

Jun 18 Shields and Semple depart for three days of rehearsals at LAL; flew blast gauge test but "chute failed."

Jun 27 Shields pilots rehearsal flight: "… four (4) blast gauges were dropped…all releases functioned normally. All chutes fell well and radar data on the rate of descent was gained."

One later account described the rehearsals in more detail: "The B–29 flew over Trinity daily, buzzing the shot tower in preparation for the test. Led by Luis Alvarez and Deac [sic] Parsons, the bomber group plotted its intricate operation: how the plane would approach the tower seconds before detonation, drop its instruments to measure the speed and pressure of the blast, then swerve away in time to avoid the spiraling fireball."[31] The "swerve" maneuver presumably was the vitally important "155 degree right turn" designed by Alvarez.[32]

Despite all its preparations for the Fat Man test, in June FTS nevertheless set a new record with five Little Boy and seventeen Fat Man drop tests.

Meanwhile, a date had to be set for the Fat Man test. It would be determined by the Trinity team's progress and by the weather conditions expected to prevail during the test. Summer is "monsoon" sea-

Flight test crew of Major Clyde "Stan" Shields, Sept. 20, 1945. *(Photo courtesy of Keith Shields.)*

son in New Mexico, and rain and lightning would pose several problems: rain would drive radioactive residue to the ground in dangerous concentrations around the Trinity site rather than dissipating over broader areas; rain might obscure observations of the test; lightning would threaten the electric circuits of the bomb and test instruments; and severe downdrafts, turbulence and lightning would threaten the aircraft. At the end of June, Jack M. Hubbard, LAL's weather forecast expert, told Groves and Oppenheimer that over the next few weeks the fairest periods for the test would be July 12-14 and July 18-21.

TRUMAN WANTED THE LATEST INFORMATION ON MANHATTAN'S PROGRESS, SO GROVES AND OPPENHEIMER CHOSE JULY 16 FOR THE FAT MAN TEST

But the new U.S. President Harry Truman was scheduled to begin a conference in Potsdam, Germany, on July 17, with British Prime Minister Winston Churchill and Soviet Communist Party General Secretary Joseph Stalin, to discuss wartime and post-war issues. In preparation, Truman wanted the latest information on Manhattan's progress, so Groves and Oppenheimer chose July 16 for the Fat Man test. Set between Hubbard's forecast of the best weather periods, their choice would cause problems.

On July 10, Shields, FTS Captain William Hartshorn, and their crews departed in two Silverplates for several days of "detached service" at Kirtland, beginning with four more days of Fat Man rehearsals. But ominously, as reported by Bainbridge, "The [July 11] afternoon rehearsals had to be changed to morning rehearsals because the daily afternoon thunderstorms interfered with the flight of the B–29 planes cooperating in the test and also produced electrical interference and pickup on lines. The second rehearsal was held the late morning of July 12, and the third the late morning of July 13, with the final rehearsal held at 11:59 the evening of the 14th."[33]

As the Fat Man field test approached, the great uncertainty as to how powerful it would be prompted some LAL scientists to wager on predictions ranging from zero to 45,000 tons of TNT. And LAL final calculations before the test predicted that the yield "…would lie between 5,000 and 13,000 tons of TNT."[34] All the predictions and calculations were wrong.

216th B–29 Crews For Trinity's Fat Man Test

Shields's papers include a handwritten, undated note recalling some of those aboard the planes for the Fat Man test. Most significant, the note reveals nine 216th airmen were aboard the two planes and, because Shields presumably knew his FTS airmen quite well, his list arguably is complete and accurate:[35]

Plane 1

A/C	Maj. Clyde S. Shields
Pilot	Capt. Richard R. Mann
Bombardier	Capt. David Semple
Unknown	Cpl. Ervin R. Rochlitz
Unknown	T/Sgt. Robert L. Blinn

Plane 2

A/C	Capt. Wm. F. Hartshorn
Pilot	1st Lt. David W. O'Harra
Bombardier	Capt. Robert C. Von Graffen
Observer	Col. Clifford J. Heflin[36]

Of all FTS crews, the aircraft commanders and bombardiers shown above were the most experienced. They had flown the most drop tests, and the flight procedures for the later drop tests, the 100-ton test, the Fat Man test (and the Hiroshima and Nagasaki missions) were similar. FTS final records show that Shields flew 110 drop tests, Hartshorn 64, Semple 116, and Von Graffen 52.[37]

LAL Observers Aboard the Trinity B–29s

It is surprising that, despite all that has been written about Trinity, relatively few accounts mention the LAL observers aboard the planes. Evidence assembled by the author indicates that at least nine LAL observers were aboard the two planes:

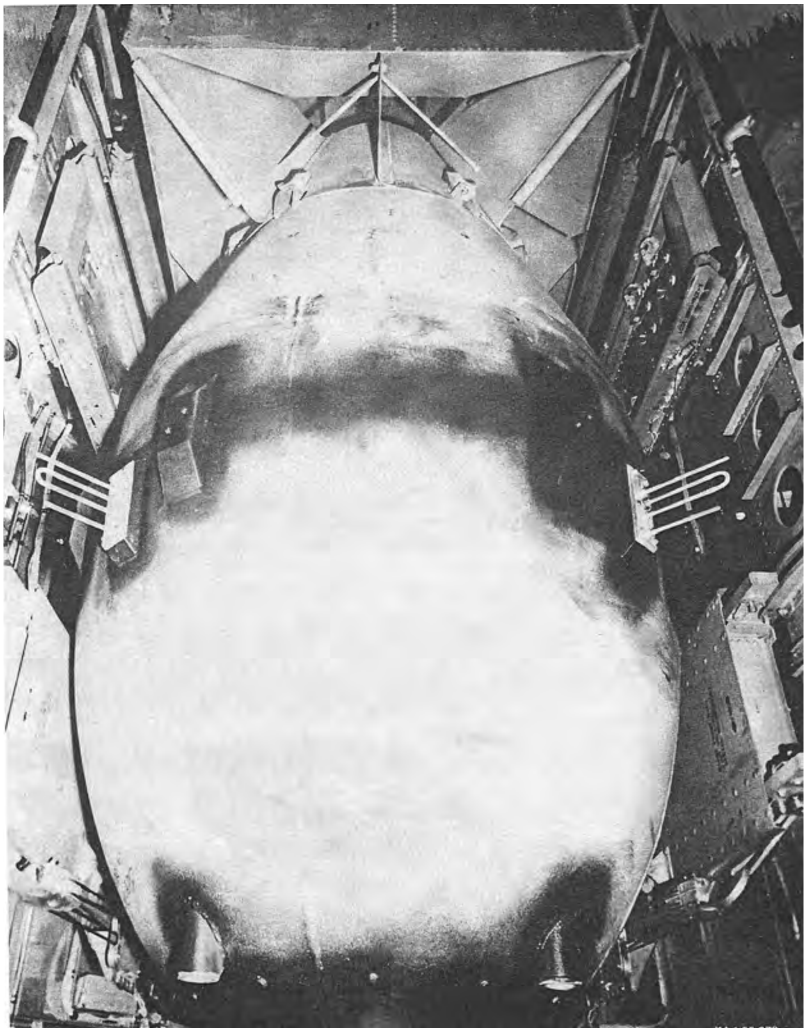
Plane 1

Capt. Wm. S. Parsons	LAL Associate Director; Leader, Ordnance Division
Luis W. Alvarez	Co-Leader, Airborne Observations
Bernard Waldman	Co-Leader, Airborne Observations
Lawrence H. Johnston	Alvarez assistant, Energy Yield Measurement
Wolfgang K.H. Panofsky	Consultant, Energy Yield Measurement
Two technicians[38]	Unknown responsibilities

Plane 2

Glenn A. Fowler	Aircraft Positioning
Wm. G. Penney	Consultant, Blast & Shock

One credible source for those aboard Plane 1 is a 2006 lecture that Johnston gave at Los Alamos in which he listed all seven men shown above.[39]



Fat Man test unit loaded in a 216th Silverplate B–29. *(Photo courtesy of the author.)*

Similarly, in his 1987 autobiography, Alvarez listed the same men (except for the technicians), but mistakenly also included Harold M. Agnew,[40] who in a 1992 interview said that at the time of the Fat Man test he was already at Tinian.[41] Parsons, Alvarez, Waldman and Johnston would all later be aboard one of the three Hiroshima mission planes. Johnston was also aboard a Nagasaki mission plane, thereby earning the distinction of being the only person who witnessed history's first three atomic bomb explosions.

HUBBARD ASSURED GROVES THAT THE WEATHER WOULD BEGIN TO CLEAR… GROVES REPLIED, YOU'D BETTER BE RIGHT OR I WILL HANG YOU

Regarding the identities of the technicians aboard Plane 1, most likely they were two of the four technicians who were part of Alvarez's team: T/5 Russell L. Ahlbrand, T/5 Walter Goodman, T/3 Emil C. Karas, and T/2 J. Wieboldt.[42] Goodman later joined Johnston aboard one of the Nagasaki planes, so he would have been likely to aboard Trinity Plane 1. If so, was among the very few men who observed two of the first three atomic bomb explosions.

Regarding LAL observers aboard Plane 2, the author has not located any sources as definitive and reinforcing as those of Johnston and Alvarez for Plane 1. Nevertheless, Glenn Fowler, a young radar specialist on Ramsey's team, was definitely aboard one of the planes with the task of positioning the two B–29s during their three-hour mission using "Identification Friend or Foe" (IFF) radar.[43]

In contrast to Fowler, the evidence that William George Penney was aboard Plane 2 is somewhat ambiguous, yet convincing to this author. First, Penney was serving as a consultant on the damage effects of the bombs, so he had a direct interest in the Fat Man blast measurement. Also, Penney was head of a group of nineteen British scientists working at LAL, and in a 1992 book about those scientists, Penney is said to have been "scheduled to be aboard" one of the planes. But author Szasz wrote that Penney didn't make the flight because, when the Trinity blast occurred, the planes were still grounded by the weather, and Penney was waiting in the officers' mess at Kirtland.[44] In a vague endnote, Szasz seems to attribute this account to a statement Penney may have made in 1988. Since there is no doubt that, although temporarily grounded by bad weather, the planes did indeed take off well before the blast, Szasz either misunderstood Penney or Penney, alone among at least nine LAL observers, was left behind.

There are other reasons to believe that Penney was aboard. Most persuasive to this author is that Shields's note lists one civilian aboard Plane 2, a "Pennington G. Britian," which the author believes is a mistaken recollection of Penney's name and an abbreviated and misspelled reference to Great Britain. Shields doesn't mention Penney in his Diary, which may indicate that they did not know each other at all or very well, which would explain why Shields did not accurately remember Penney's name and made the Great Britain notation to better identify him. Also suggestive is that Penney, as with four of Plane 1's LAL observers, later was important enough to earn a seat aboard a Nagasaki mission plane. Nevertheless, although Penney is mentioned in other sources as an "observer" at Trinity, the author has not yet found a source that definitively documents whether he was observing from the ground or from a B–29.

Silverplate models could carry up to twelve or thirteen men, (respectively, the totals aboard the Hiroshima and Nagasaki strike planes). Because Plane 2 presumably had room for up to five more passengers, one suspects that there could have been more LAL observers, but the author has only located vague references about a few others who may have been aboard.[45]

Trinity's Fat Man Test

The July 16 test was scheduled to be triggered at 4 a.m., but "at 2:30 a.m. the whole test site was being racked by thirty-mile-an-hour winds and severe thunderstorms."[46] Hubbard assured Groves that the weather would begin to clear between 5-6 a.m., to which the always blunt-speaking Groves replied, "You'd better be right or I will hang you."[47] By 4:45 a.m. the storm began to moderate so the decision was made to trigger the bomb at 5:30 a.m.

The extra 90 minute wait could not have been comfortable for the 400 observers scattered at five desert locations, most with little shelter from the storms. Probably the most uncomfortable was a young scientist huddled inside a flimsy, corrugated tin shack atop the 100-foot tower, who had been babysitting the Fat Man sphere most of the night.[48] In contrast, 95 miles away at Kirtland, the airmen and their LAL passengers were waiting in the officers' mess for the final decision. The commander of Kirtland objected to them taking off in the still stormy weather, but he was overridden. Those aboard likely hoped that they soon would receive a fair payback for all their work, but they were about to be shortchanged.

Although the storm was moderating, it didn't clear enough to allow the pilots to make their planned runs over the bomb. In a report to Secretary of War Henry L. Stimson, Groves wrote, "Because of bad weather, our two B–29 observation airplanes were unable to take off as scheduled from Kirtland…and when they finally did get off, they found it impossible to get over the target because of the heavy clouds and the thunder storms."[49] But also, Oppenheimer suddenly had doubts:

… Oppenheimer called Alvarez at the last minute. He had cold feet about how big the explosion might be… He ordered us to be at least 20 miles away from the bomb when it exploded. Alvarez was very angry about this because it would make our measurements much weaker than would be expected. But we had no choice especially when we cooled down and realized that Oppie might know something we did not.[50]

OPPENHEIMER SUDDENLY HAD DOUBTS… HE ORDERED US TO BE AT LEAST 20 MILES AWAY… SEVERAL ACCOUNTS OF THIS EPISODE ATTRIBUTE THE FAILURE OF THE PLANES TO FLY DIRECTLY OVER THE BOMB TO EITHER THE WEATHER OR OPPENHEIMER

Other accounts say that Alvarez briefly argued his case, but in any event, the scientists had suddenly become little more than spectators. Several accounts of this episode attribute the failure of the planes to fly directly over the bomb to either the weather or Oppenheimer, but the two explanations are not mutually exclusive, so actually both were factors.

Six days later, Shields submitted to Ramsey a "Report of 'T' Test Aircraft Operations," which may have been the only report from any of the airmen in the two planes.[51] As a military report, it was likely to be relatively thorough and dispassionate, and it has been cited in at least one other account of the test. The author has not yet located a copy, but a sense of what occurred in the air can be gleaned from other reports and records.

In 2005, crediting several sources including Shields's report, one historian wrote,

Five miles above the desert, two B–29 observation planes flew in widening circles, the men on board straining to catch a glimpse of the searchlight at Ground Zero far below. At the height they were flying, there was still an overcast, and it was almost impossible to see anything… A strange blue fire [St. Elmo's fire] appeared to burn around the two planes, streaming over the wings and past the windows, leaving a luminous wake in the sky.[52]

In his 1987 autobiography, Alvarez recalled, "We tuned in the Trinity control room on our radios, circled in the stormy night twenty-five miles from the tower, and followed the progress of the countdown. As it came to its final moments, the pilot banked and headed toward the tower." Alvarez also quoted from a report he filed shortly after the test: "I was kneeling between the pilot [Shields] and copilot [Mann] in B–29 No. 384 and observed the explosion through the pilot's window on the left side of the plane. We were about 20 to 25 miles from the site and the cloud cover between us and the ground was approximately [70%]. About 30 seconds before the object was detonated the clouds obscured our vision of the point so that we did not see the initial stages of the ball of fire…In about 8 minutes the top of the cloud was at approximately 40,000 feet as close as I could estimate from our altitude of 24,000 feet and this seemed to be the maximum altitude attained by the cloud. I did not feel the shock wave hit the plane but the pilot felt the reaction on the rudder through the rudder pedals. Some of the other passengers in the plane noted a rather small shock at the time but it was not apparent to me."[53]

In 2005, Johnston related: 'We took off before dawn on July 16 and flew around listening to the countdown coming from the main bunker at Alamogordo. I started the recording system. We opened the bomb bay doors and at count zero dropped our parachute gauges. There was a flash as the bomb went off and we prepared for the shock wave to reach our microphones… The flash was pretty bright, even at twenty miles. The white light lit the ceiling of our plane, faded to orange and disappeared… We circled around the rising mushroom cloud awed by the magnitude of the effects that we were seeing that we had caused."[54] In his 2006 Los Alamos lecture, Johnston said, "Getting back to us guys in the B–29, I have been asked many times in interviews, what were my immediate thoughts when we saw the bomb go off? No problem remembering. I burst out 'Praise the Lord, my detonators worked!'… If the bomb had fizzled, we each would have had dark thoughts that maybe it was his fault."[55]

In a short newspaper article published on the fifth anniversary of the test, Hartshorn is quoted as saying, "We didn't know exactly what to expect, but we didn't have to be told that huge mushroom cloud boiling up was what we had been waiting for… We had been told about the expected size of the explosion and a little about the radioactive cloud that was expected, but you can understand the suspense."[56]

Shields's and Heflin's flight records are now available and, although they were in separate planes, their logs for the Fat Man test are almost identical. Shields recorded 3:10 of total flight time and Heflin recorded 3:00. Since a regular B–29 had a top speed of 358 mph, the 190 mile round trip between Kirtland and the Trinity site could take as little as thirty-two minutes, and a Silverplate stripped of 7,200 lbs. of turrets and armor plate presumably could do it faster.[57] This suggests that the planes could have been around the Trinity site and following the cloud for as long as 2 ½ hours. Also, of their total flight time, Shields recorded 2:10 at night and Heflin recorded 2:00. This further suggests that, of their total observation time, as much as 1:45

Major Clyde "Stan" Shields wearing his Legion of Merit Award. *(Photo courtesy of Keith Shields.)*

was at night when visibility would have been limited except for the light generated by the explosion.

In sum, although the planes were too far away to get accurate readings of the blast, its yield clearly was immense and far beyond what had been expected, undoubtedly reassuring everyone involved, including the AAF. A 1985 Los Alamos study estimated that the Fat Man test yielded almost 21,000 tons of TNT compared to Hiroshima's 14,000 tons and Nagasaki's 21,000 tons.[58]

ALTHOUGH THE PLANES WERE TOO FAR AWAY TO GET ACCURATE READINGS OF THE BLAST, ITS YIELD CLEARLY WAS IMMENSE AND FAR BEYOND WHAT HAD BEEN EXPECTED

Manhattan's Sprint to the Finish

Two days later, Shields sent a memo to Ramsey complaining that the test was "a good example" of LAL personnel's "inability to understand aircraft operations and their apparent disinterest."[59] His Diary doesn't further describe the matter, but the comment is perhaps evidence of the cumulative pressures he faced that July:

FTS conducted a peak 32 drop tests, 12 of Little Boy and 20 of Fat Man, essentially completing the program except for a couple of Fat Man tests in early August.

On July 27, in three B–29s, Hartshorn's crew and two from the 509th began a critical mission to carry Fat Man bomb assemblies from Kirtland to Tinian.

In late July, another FTS crew began a mission to carry "Bernie Waldman's stuff," consisting of all the equipment needed to record the Hiroshima and Nagasaki bombings.

The transport unit that Shields took over in May, "…carried 127,000 lbs. of freight and 356 passengers in a 30-day period," most of which probably occurred in June-July.

On July 23 Shields summarized his frustrations in very personal terms:

The demands of the Project… as far as aircraft and test crews are concerned, has (sic) *grown to amazing proportions. It is impossible for us to send a crew overseas* [to Tinian]*, have two (2) crews at* [Inyokern, California drop test range]*, furnish crews to* [Kirtland] *for Waldmans* [sic] *stuff and still continue to perform efficiently here* [at Wendover] *without crews to fly them or maintain them. Aircraft present something of a problem also. They are not like a car—you just can't step on the starter and go charging off into the "wild blue yonder" without taking into consideration a few other small items such as weather, availability of units,* [work load] *compliance, tech inspections, 50 and 100 hr. routine inspections, plus normal fatality rate on complicated flying machines. However, we shall endeavor to meet the requirements of the Project to the best of our ability, but please reserve us a padded cell or two—we can use them… On the 23rd of July Major Shields is going fishing for four (4) days and confidentially he doesn't care if the joint burns down while he's gone… Also, four (4) of the 1st pilots in the organization are expecting sons or daughters in the near future (including Major Shields) which also is not conducive to peace of mind.* [60]

At the end of August, Shields sent a memo to Oppenheimer that was a brief account of FTS's accomplishments and its "boundless" admiration for LAL's accomplishments. But surprisingly, he also said,

Probably the thing that stands out more in our minds than anything else was the disappointment of being rejected as a team to drop the first Atomic Bomb. Capt. Parsons had given his word, when the tests were first started and we had proven the practicability of the weapon, that if it worked we would drop it.[61]

Presumably, Shields was referring to February 1944, well before Groves and AAF Commanding General Henry H. "Hap" Arnold worked out plans for creating the 509th Composite Group. But Shields's frustrations and disappointments would have multiplied if had known that *all* of the 216th's accomplishments in 1945 would be long buried, and by an official order no less.

Groves anticipated the unprecedented public clamor for more information after Japan was bombed, so he had commissioned physicist Henry DeWolf Smyth to prepare an official, unclassified report, "Atomic Energy for Military Purposes." Released three days after Nagasaki, it would long serve as a guide to what could and could not be publicly revealed. Unfortunately for the 216th, the report said nothing about Manhattan's ordnance program. As related by his biographer, Parsons opposed releasing ordnance information because of its direct military usefulness, but Oppenheimer "found Smyth's treatment of Parsons's Ordnance Division 'critically misleading' and, in his review of a draft of the [Smyth] report, pointed out that, '[The Ordnance Division] had, and still has, the all-important and difficult job of making a weapon of this thing, of fuzing and designing it in such a way that it can be used in combat and can be effective. I take it that you won't be saying much about this aspect of the work but you should certainly know that it is a very large set of problems and will increasingly be so.' To overcome Oppenheimer's objections, Smyth took the easy way out: he deleted everything dealing with the weaponization of the bomb—'for reasons of security.'"[62] Perhaps this decision also swept away the 216th's records into a top secret vault where they may remain, unexamined, to this day.

Aftermath

The two months following the end of the war saw many changes at LAL and Wendover, including the exodus of key personnel (e.g., Oppenheimer) returning to their pre-war occupations. Because of overcrowding, LAL moved field testing to Oxnard Field (later Sandia Base), near Albuquerque, and because of the inconvenient distance between LAL and Wendover, AAF ordnance testing moved to Kirtland.

THEIRS IS A STORY OF A DIFFICULT AND DANGEROUS JOB PERFORMED IN THE CLOUDLESS VASTNESS ABOVE 30,000'

On September 21, 1945, new LAL Director Norris Bradbury convened a small conference at Wright Field to discuss future AAF aircraft that might be able to carry future atomic bombs: medium bombers B–45, B–46, B–47, B–48 and heavy bomber B–36. Heflin and Semple represented the 216th and, along with three Los Alamos personnel, opined that none of the aircraft in development would be suitable for carrying atom bombs because of limited speed, range, and/or load-carrying capacity. Among Bradbury's later recommendations to Groves was to form a "semi-permanent committee" composed of two representatives each from Wright, Manhattan, and the AAF to "channel development problems that arise and to make recommendations thereon."[63] Heflin was proposed as one of the AAF reps, but the AAF had other plans for him.

On September 28, 1945, Shields wrote a memo to "Whom It May Concern" that documented an impressive list of major accomplishments in the ordnance testing program 1943-1945. In addition to the drop tests, he listed bomb design modifications, Silverplate modifications, flight operations procedures, pioneering high altitude bombing, and training the 509th's bombing crews.[64] (Curiously, an important improvement in Fat Man's tail design is a matter of some confusion because of mysterious changes in original sources.[65])

Information about the post-war military careers of the 216th airmen aboard the Trinity flights is available for only three of them: Shields, Semple and Heflin:

Shields returned to civilian life in October, and in November he received the Legion of Merit, the AAF's fourth-highest award. He rejoined the AAF in February 1946 and was assigned to Kirtland to pilot atomic bomb tests in Operation Crossroads until April 1947, when he became chief of flight testing at Victorville Field, California, 1947-1948. Shields died in 1977 at age 59.

When ordnance testing moved to Kirtland, Semple went with it. On March 7, 1946, filling in for another bombardier, "after dropping a Fat Man practice bomb, [Semple's B–29] disintegrated for unknown reasons and spun into the ground from about 32,000 feet. All ten men on board died… [Semple] was scheduled to be the bombardier on one of the crews being considered for the honor of dropping the atomic bomb on Test Able of Operation Crossroads."[66] He was 43 years old and had served more than 20 years, having first joined as an enlisted airman. The crew later assigned to Crossroads re-named their B–29 "Dave's Dream" in Semple's honor. Among his awards were the Silver Star, Legion of Merit, Distinguished Flying Cross, Air Medal, and Presidential Unit Citation. His military records were recently donated to the WWII Museum in New Orleans.

Heflin was relieved as Wendover Commanding Officer on October 22 and eleven days later became CO of Roswell Army Air Field, New Mexico, to which the 509th returned from Tinian and where its bombing unit was soon incorporated into the new Strategic Air Command. Heflin retired in 1968, after more than 30 years of exemplary service and was awarded the Distinguished Service Medal, in part for his role in Manhattan. His highly-decorated military career is summarized in a 2012 paper (see endnote 1) that first partially lifted the curtain concealing the 216th's leading role in developing the atomic bombs. He died in 1980 at age sixty-four.

In sharp contrast to the unknown 216th airmen, post-war biographical information about the seven LAL men aboard the Trinity flights is widely available. But worth mentioning here, Alvarez returned to teaching and research at the University of California at Berkeley, was awarded the 1968 Nobel Prize in Physics, and in his 1987 autobiography wrote: "My last weeks at Los Alamos were not happy. Many of my friends felt responsible for killing Japanese civilians, and it upset them terribly. I could muster very little sympathy for their point of view…I have difficulty seeing why so many people see nuclear weapons as mankind's greatest threat. Not one of them has been used since World War II, and without question they have prevented World War III…"[67]

In his Trinity scrapbook, Shields penned his thoughts about the project that dominated his life for three years:

Toward this end we worked. This scrap book is about a small group of Army Air Forces personnel who ate, slept, and dreamed of the day when this would happen. Theirs is a story of a difficult and dangerous job performed in the cloudless vastness above 30,000'. Nowhere will you find mention of these pilots, bombardiers or enlisted men that made its use possible, but they know and are satisfied with a job "well done." ■

NOTES

1. Darrell F. Dvorak, "The Other Atomic Bomb Commander: Col. Cliff Heflin and His 'Special' 216th AAF Base Unit." *Air Power History*, Winter 2012 Vol. 59 No. 4, pp. 14-27.
2. Scott W. Muselin from Cathy Cox, AFHRA Archivist, Aug. 14, 2012, Air Force Historical Research Agency, Maxwell AFB, Alabama. Copy in author's possession courtesy of Muselin.
3. For the period from its founding through the end of WWII, Los Alamos was officially known as Los Alamos Laboratory but code-named "Project Y" and often referred to as simply "Y" or "Project". After the war, it was renamed Los Alamos Scientific Laboratory and still later, Los Alamos National Laboratory, as it is known today.
4. David Hawkins, "Manhattan District History: Project Y: The Los Alamos Project: Vol 1. Inception Until August 1945." Los Alamos Scientific Laboratory, Los Alamos. (1946, 1947) p. 22.
5. Adm. Frederick L. Ashworth, quoted by Roger Meade, "Backward Glance," Nuclear Weapons Journal, Issue 1, 2010, Los Alamos National Laboratory, Los Alamos, 2010, p. 35.
6. Richard H. Campbell, *The Silverplate Bombers: A History and Registry of the Enola Gay and Other B–29s Configured to Carry Atomic Bombs*. (Jefferson, N.C.: McFarland & Company, 2005). pp. 159-60.
7. Hawkins, p. 266
8. *Ibid.*, p. 174
9. The 509th, commanded by Col. Paul W. Tibbets, flew the atomic bombing missions.
10. Regarding Ashworth, see Admiral Frederick L. Ashworth, *Frederick L. Ashworth: United States Navy: An Autobiography.* (Walla Walla, Wash.: Northwest Library Bindery, 2001.) pp. 157, 171: "[Groves] always insisted on having a spare for everything… I became the spare for Parsons." Regarding Heflin, see Dvorak, pp. 17-19.
11. Dvorak, pp. 19-21.
12. Major Clyde S. Shields, "Daily Diary For Flight Test Section." 216th Army Air Forces Base Unit, Headquarters Wendover Field, Wendover, Utah. February 2, 1945 – August 2, 1945. The diary is organized chronologically, not by page numbers. For an account of SOD's daily work, see James Les Rowe, *Project W-47.* (Livermore, Calif.: JA A RO Publishing, 1978).
13. "The number and complexities that must be taken into account [to accurately drop an unguided bomb] are daunting. The aircraft's speed over the ground, its horizontal distance to the aiming point at the instant of release, and its vertical distance from the target or altitude must be determined with small margins of error. The instant-to-instant yawing, pitching and rolling motions inherent in the flight of an airplane… impart their own accelerations to the bomb at the instant of release from the airplane and contribute to errors that are magnified many times during the bomb's fall to the target. The wind speeds and directions beneath the bomb bay and all the way to the ground also significantly affect the bomb's trajectory… A bomb's fall is retarded by air resistance, which depends on the air density, a function of its temperature, humidity of the air, atmospheric pressure, and speed of the falling bomb. Finally, there are the ballistics characteristics specific to the bomb itself: size, weight, shape, fin type, even the surface roughness of the casing." Stewart Halsey Ross, *Strategic Bombing in World War II: The Myths and the Facts*. (Jefferson, NC: McFarland & Company, 2003) pp. 123-124.
14. The bombing tables were matrices of factors for operating the mechanical computer of the B–29's Norden bombsight.
15. The maneuver to ensure the planes escaped from the atomic bombs' blasts has been memorialized as the "155 degree turn to the right," and the FTS deserves some credit for being among the first to practice it. According to one historian, the maneuver "… was designed by Luis Alvarez to place the Enola Gay as far away as possible from the burst during the bomb's drop to its detonation altitude of 1,750 feet above [Hiroshima]…" Lillian Hoddeson, et al, *Critical Assembly: A Technical History of Los Alamos During the Oppenheimer Years, 1943-1945*. (Cambridge: University Press, 2004.) p. 392. In addition to being a physicist, Alvarez was a rated pilot, so he certainly would have been capable of designing the maneuver. Tibbets sometimes has been credited for it, but in his autobiography he wrote: "The scientists had told me that the minimum distance at which we could expect to survive would be 8 miles…Calculations convinced me that the most effective maneuver would be a sharp turn of 155 degrees…" Paul W. Tibbets, Clair Stebbins and Harry Franken, *Mission: Hiroshima*. (Briarcliff Manor, N.Y.: Stein and Day, 1985.) p. 170.
16. Robert and Emilia Krauss, eds., *The 509th Remembered: A History of the 509th Composite Group as Told by the Veterans Themselves, 509th Anniversary Reunion, Wichita, Kansas, October 7-10, 2004* (Buchanan, MI: 509th Press, 2005.) p. 16. At a distance of about 50 miles, Kirtland was the closest Army Air Field to Los Alamos.
17. As suggested by these excerpts, Donald Mastick was a frequent visitor. Years later, he recalled, "I'll always remember one round-trip [drop test] when the plane threw a collector ring on one port engine. Stan [Shields] killed the engine and feathered out, grumbling. Then about 100 miles out of Wendover, another port engine went out. With a characteristic remark, Shields killed all remaining engines and settled down to dead-stick that heavy plane to a landing at Wendover… I was in the bombardier seat and during the last mile it seemed we were cutting off sagebrush. That was my most memorable experience at Wendover." Krauss, p.133
18. Hoddeson, pp. 351, 358-59.
19. Lawrence Johnston, "Adventures at Wartime Los Alamos." Lecture at Los Alamos National Laboratory, Los Alamos. (August 9, 2006) pp. 25-26.
20. Luis W. Alvarez, *Alvarez: Adventures of a Physicist*. (New York: Basic Books, 1987.) pp. 138-40.
21. Kenneth T. Bainbridge, ed. "Trinity." Los Alamos Scientific Laboratory, Los Alamos. (May 1976) p. 35.
22. Hawkins, p. 280.
23. Kenneth T. Bainbridge, "'All In Our Time': A Foul and Awesome Display." *Bulletin of the Atomic Scientists*, Educational Foundation for Nuclear Science, Chicago. (May 1975 Vol. XXXI No. 5) pp. 45-46.
24. "Men who worked in well-equipped laboratories became familiar with field work." Hawkins, p. 271.
25. Hawkins, p. 270.

26. Shields Diary, May 8.
27. Hawkins, p. 271.
28. Bainbridge "Trinity," pp. 11-12.
29. Bainbridge "All In Our Time," pp. 41-42.
30. Dvorak, pp. 21-22 describes this added responsibility in more detail.
31. Lansing Lamont, *Day of Trinity: The Dramatic Story of the Los Alamos Atomic Explosion, and the Men Who, in July 1945, Opened the Nuclear Age.* (Kingsport Tenn.: Kingsport Press, 1965.) p. 157.
32. See endnote 16. Alvarez was a rated pilot, but may have been modest about his pilot skills: "Once, the pilot of a B–29 gave me the controls, and I put the plane into a well-coordinated 360-degree turn banked at 70 degrees, maintaining altitude to within forty feet. The pilot complimented me on my performance and asked casually if I knew the wings came off at eighty degrees." Alvarez, p. 268
33. Bainbridge "Trinity," p. 28.
34. Hawkins, p. 202.
35. Aside from Shields's papers, the author has located only one source published before 2012 that identified any of the 216th airmen aboard, and it only named Shields: Stephen Walker, *Shockwave: Countdown to Hiroshima*. (New York: HarperCollins, 2005.) p. 325. Walker credits a report by Shields, "Report of T Test Aircraft Operations" dated July 22, 1945.
36. Dvorak, p. 22, erroneously credits Heflin as pilot of Plane 2 based on his flight record for July 16, 1945. At the time, rated pilots on flying status who were on the flight order for a flight could log time in a heavy bomber as "First Pilot."
37. Clyde S. Shields, Memo: Test Section Personnel and Missions Flown, Headquarters Wendover Field, Flight Test Section, Wendover, Utah, Sept. 19, 1945. p. 1. Copy in author's possession, courtesy of Keith Shields.
38. According to Johnston, p. 28, these men were members of LAL's Special Engineering Detachment (nicknamed "SEDs"), an Army unit composed of enlisted, technically-skilled personnel that at its peak numbered 1,800 men.
39. Johnston, p. 28.
40. Alvarez, p.141: "Larry [Johnston], Harold [Agnew], and Bernie [Waldman] were aboard, and Pief [Panofsky] was our guest." Agnew at the time was a relatively junior scientist, but became Director of Los Alamos, 1970-1979.
41. Harold M. Agnew, Transcript, Voices of the Manhattan Project, The Los Alamos Historical Society, Los Alamos, November 20, 1992. http://manhattanprojectvoices.org/oral-histories/harold-agnews-interview
42. Bainbridge "Trinity," p. 23.
43. Interview, Glenn A. Fowler, May 17, 1983, SNL Archives; reprinted in *Sandia Lab News*, Sandia National Laboratories, Albuquerque, Jun. 12, 1983, p. 5.
44. Ferenc Morton Szasz, *British Scientists and the Manhattan Project: The Los Alamos Years*. (St. Martin's Press, New York, 1992.) p. 63.
45. One possibility is mentioned in a July 10, 1945 report by Louis H. Hempelmann, Jr., Director of LAL's Medical unit, concerning plans to track radiation from the Trinity blast: "It seems certain that two airplanes will follow the cloud. One airplane crew has instructions to follow the cloud for as much as 8 hours (Waldman's crew). The meteorologists expect to fly near the cloud but not for a time long enough to be useful to the [radiation monitoring equipment]." L.H. Hempelmann, "Preparation and Operational Plan of Medical Group (TR7) For Nuclear Explosion 16 July 1945." Los Alamos Scientific Laboratory, Los Alamos, June 13, 1947. Copy in author's possession. This seems to suggest that Plane 2 had meteorologists aboard, but it may simply be awkward phrasing. Also, Lamont, p. 187, writes, "Another medic would ride the B–29 observing the [Fat Man] test…," but offers no further details.
46. Kai Bird and Martin J. Sherwin, *American Prometheus: The Triumph and Tragedy of J. Robert Oppenheimer*. (New York: Alfred A. Knopf, 2005.) p. 307.
47. Richard Rhodes, *The Making of the Atomic Bomb*. (New York: Simon & Shuster, 1988.) p.665.
48. The young man was Donald F. Hornig, who later had a storied career in academia and advising President Lyndon Johnson. Douglas Martin, "Donald Hornig, Last to See First A-Bomb, Dies at 92." The New York Times, New York. (January 26, 2013)
49. General Leslie R. Groves, "Gen Groves' Memorandum Describing First Nuclear Test in New Mexico." *Public Broadcasting Service: American Experience: Truman: July 18, 1945.* www.pbs.org/wgbh/ amex/truman/psources/ps_memorandum.html
50. Krauss, p. 110.
51. Shields Diary, July 22.
52. Walker, p. 61.
53. Alvarez, p. 141.
54. Krauss, p. 110.
55. Johnston, p. 30.
56. Associated Press, San Antonio Express, "Five Years Ago: First Atom Bomb Blast Recalled on Anniversary," July 16, 1950. Copy in author's possession courtesy of Keith Shields.
57. Campbell, p.1.
58. John Malik, "The Yields of the Hiroshima and Nagasaki Nuclear Explosions." Los Alamos National Laboratory, Los Alamos, September 1985, pp. 1, 17.
59. Shields Diary, July 18.
60. In a notable series of coincidences, Shields had been stationed at Bellows Field, Hawaii, when Pearl Harbor was bombed December 7, 1941; his daughter was born on August 14, 1945, the day Japan agreed to surrender; and his great-grandson was born on Pearl Harbor Day, December 7, 2007.
61. Robert S. Norris Papers, Hoover Institution Archives, Stanford, CA. Shields memo to Oppenheimer: "Subject: Final Diary – Flight Test Section, "Kingman" dated August 30, 1944.
62. Al Christman, *Target Hiroshima: Deak Parsons and the Creation of the Atomic Bomb*. (Annapolid, Md.: Naval Institute Press, 1998.) pp. 205-6. Ironically, Parsons's crucial role in Manhattan was mostly unknown until Christman's biography was published. Similarly, Hawkins's official history of LAL was written in 1946-47 but not declassified until 1961.
63. Norris E. Bradbury, Memo to General Leslie R. Groves, September 28, 1945. Archives, Los Alamos National Laboratory, Los Alamos. www.lanl.gov/history/postwar/ postwarworld.shtml
64. Major Clyde S. Shields, "Memo: To Whom It May Concern: Test Section Record," September 28, 1945. Copy in author's possession courtesy of Keith Shields.
65. There are factual conflicts between, as well as unexplained changes to, original sources regarding whether Ramsey or Semple should be credited with fundamental modification of the tail of the Fat Man drop test model, which dramatically improved the ballistics of Fat Man.
66. Campbell, pp. 187-188.
67. Alvarez, pp. 147, 152.