Early in 1951, a synergistic exchange of ideas between Dr. Edward Teller and Dr. Stanislaw Ulam resulted in the so-called “three concepts” of modern thermonuclear design which are applicable to both liquid- and solid-fueled thermonuclear devices:

a. Separate stages -- a physically separate fission explosive (stage) and a capsule (stage) of thermonuclear fuel, centered at separate points.

b. Radiation coupling -- channeling (ducting) of thermoradiation from the first stage to ignite the second stage.

c. Compression -- implosion of the thermonuclear fuel capsule prior to ignition to achieve maximum yield.[7]

An additional feature of the design was the so-called “sparkplug,” a fissile cylinder or hollow rod of uranium-235 or plutonium running axially through the center of the fusion fuel mass. When compressed, this “sparkplug” (which could also be boosted by being filled with a deuterium-tritium gas mixture) fissioned and generated tritium and fast neutrons in the middle of the fusion fuel. This fission reaction initiated and accelerated the fusion reaction amidst the highly compressed fusion fuel. Tritium was generated *in situ* and no external supply was required.

In terms of George Gamow's earlier analogy-by-demonstration, the Teller-Ulam configuration essentially pulverized the petrified wood (by compression), soaked the resultant dust with lighter fluid (the tritium produced amidst the fuel by the fissioning "sparkplug"), and then ignited the powder. The primary fission trigger no longer acted as the igniter for the fusion process but merely served as a catalyst to prepare the fusion fuel for ignition by the "sparkplug."

Increasing the fuel density had the same effect as adding tritium: raising density reduced heat loss, making ignition possible, while adding tritium reduced the ignition temperature, allowing for burning even with high heat loss. However, using up large amounts of tritium at the expense of many dollars and potential plutonium, i.e., dozens of fission weapons, was clearly uneconomical and impractical. After the advent of the “three concepts,” tritium was only required for fusion-boosted weapons, primaries, and “sparkplugs.”

When a tentative 50,000 lb., six-foot diameter, 20-foot long hydrogen bomb size was established in 1951, LASL advocated that the Air Force conduct drop tests using a drogue parachute to slow the falling bomb and allow the delivery aircraft more time to escape the blast. An immediate requirement was the development of a large parachute to support 50,000 lbs. dropped at release speeds in excess of 300 knots (345 MPH) at altitudes between 35,000 and 45,000 feet.

The Air Force program that assisted this effort was known as Project *Caucasian*. *Caucasian* had seven subtasks, including the modification of four B-36H aircraft as prototype bomb carriers; the modification and redesign of the B-2 bomb lift to carry a 50,000 lb. load; development of a series of drogue parachutes to decelerate and stabilize the falling bomb; and development of practice

[7]Brief of the Appellant, THE PROGRESSIVE, Inc., filed June 15, 1979, in the United States Court of Appeal for the Seventh Circuit, case no. 79-1428, pp. 19, 20.

drop shapes.[8]

1952: The First Full-Scale Test and Weapon Design Begins

The design of the first full-scale test device embodying the "three concepts" proceeded rapidly during 1951 and 1952, and by the fall of 1952, was ready for testing at Eniwetok atoll in the Marshall Islands. The test device, named the *Sausage* for its long cylindrical shape, was 80 inches in diameter and just over 20 feet long; it weighed 82 tons. Most of this weight was contained in a massive foot-thick outer steel casing which enclosed the device's primary (a TX-5 unboosted fission bomb), and a complex cryogenic liquid-fueled secondary with a tritium gas-boosted plutonium "sparkplug."

At the time of its detonation, the *Sausage* was the largest and most complex cryogenic device in the world. An irony of its design was that in order to attain the highest temperature ever achieved on earth, the deuterium in the device had to be chilled to near absolute zero, the lowest temperature on earth.

The test of the device during the Operation IVY Mike shot on November 1, 1952 was successful. Even before the test, design of the first solid-fueled hydrogen bombs -- the *Alarm Clock*, *Zombie*, *Runt*, and *Shrimp* -- had begun at LASL. These devices later became prototype weapons named TX-14, TX-15, TX-17, and TX-21, respectively.

As work proceeded on this second generation of hydrogen weapons, the Department of Defense (DOD) began studying likely delivery systems. The ConVAir B-36 *Peacemaker*, the largest bomber then in the U.S. Air Force inventory, was the most obvious delivery vehicle for the H-bomb: On June 30, 1948, a B-36 had dropped 72,000 lbs. of conventional bombs during a test flight. The B-36B could carry 86,000 lbs., including conventional high explosive bombs weighing up to 43,000 lbs. and measuring 364 inches long and 54 inches in diameter, the size of the American variants of a World War II British *Grand Slam* bomb.

Availability of the first stockpile hydrogen weapon, the TX-14 *Alarm Clock*, was assured by the end of 1953. This bomb was equipped with a 64-foot diameter drogue parachute. The Air Force instituted Project *Caucasian*, using two B-36Hs, to make aircraft and bombing equipment modifications to carry the TX-14 in the B-36. The Air Force's Strategic Air Command (SAC) authorized a "1A" priority for this program.[9]

At a conference at Wright Field in July 1952, attended by representatives of the Air Force, ConVAir, Sandia Laboratories, and LASL, an agreement was reached to "freeze" maximum bomb diameter to 62.5 inches and to limit its weight to 25 tons. This monster was to be

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[8] *The Development of Thermonuclear Weapon Delivery Techniques: Project CAUCASIAN*, pp. 2, 5, 6, 11.

[9] *A History of the Air Force Atomic Energy Program, 1943 - 1953*, Lee Bowen and Robert D. Little, et. al., 1959, Vol. IV, *The Development of Weapons*, p. 209.