W76-1 Radar

David Kestly (2662): In Recognition of Sustained Excellence in the design of Radar Digital Signal Processors for the Navy's Trident warhead W76-1 and W-88 Radars.
http://www.sandia.gov/news/corp/awards/doe-awards/doeawards.html (2003)

David Kestly had responsibility for the design of the W76-1 LEP AFS Radar Digital Signal Processor (DSP). He was responsible for the architecture of the design and conceptual design of the DSP. He was the primary logic design implementer for the Permafrost-1 ASIC Radar DSP design developed in CY2003 and in previous years.
http://www.sandia.gov/LabNews/LN07-23-04/labnews07-23-04.pdf

"Dick Binnie developed an optical delay line system to test the new Arming, Fuzing System for the W76-1 (MC4700), a production tester with radar simulation was required. It converts the RF signal to an optical signal, processes it for the proper delay, and then converts it back to a useable RF signal."
http://www.honeywell.com/sites/servlet/com.merx.npoint.servlets.AttachmentServlet?annid=A7D7D1007-AABA-D01E-6850-E20D70977E91 (Connections Winter 2006)

"when the need was identified for packaged RF power amplifier transistors to support the W76 radar transmitter, this team developed processes to meet the need for small size, low cost, high-power capability, and high reliability." KCP selected to produce these
http://www.honeywell.com/sites/servlet/com.merx.npoint.servlets.AttachmentServlet?annid=A9DCD085C-B0D7-DC6B-E753-4EED176DD533

ALEGRA used for design and performance of the W76-1 radar fuze — Apr 2001
http://www.sandia.gov/LabNews/LN04-20-01/labnews04-20-01.pdf

Milestone:
"Three-dimensional electromagnetic response of the radar fusing for radar front end and height of burst. Response (ie induced pin-level voltages at the AF) of the weapon system to a range of high-frequency STS electromagnetic environments. Validated wire, slot, cable and connector models will be used" (not explicitly W76 but probably from context) 2001
http://www.sandia.gov/NNSA/ASC/pdfs/prog_plan_fy01.pdf

Permafrost IC

"The second-generation (PA2) Permafrost digital weapon controller for the W76-1 has been designed, fabricated and tested. Sandia's Microelectronics Development Laboratory fabricates PA2 in its CMOS7 radiation-hardened technology. Additional functionality in the newer version adds 44 per cent more logic gates while retaining a very demanding low leakage current requirement. The added complexity and demanding specs were countered by applying lessons learned and technology improvements to achieve unprecendented MDL yield on a chip of this complexity" 2005
Sandia Labs Accomplishments 2005
http://www.sandia.gov/LabNews/labs-accomplish/2005/lab_accomplish_2005.pdf

Prototype Testing — Sandia manufactured a British ASIC IC using the CMOS7r SOI generation prior to completing the design of the Permafrost ASIC Controller chip for the W76-1. SEU cross section

measurements at the Brookhaven National Lab (BNL) found that these ICs had a low charge deposition (LET) threshold to SEUs (i.e., light ions such as Cl could cause upsets), but BNL could not pinpoint the cause of this radiation softness. These parts were then brought to our REM system at SNL, and SEU-Images quickly revealed that ion strikes to the "off" drains of latches (flip flops consisting of two coupled SRAMs) used to transfer data on to and off of the ASIC were the cause of these upsets. The DAVINCI code was used to model three alternative designs of these latches, and a test chip utilizing these alternatives was manufactured in the MDL and tested on the REM system. SEU-Images confirmed that eliminating two resistors from the design of these latches corrected the problem. It was this new latch design that was incorporated into the Permafrost Controller, resulting in "first pass success" of the manufacture of this important radhard IC.
http://www.sandia.gov/pcnsc/research/nnsa-missions.html — date?

(CMOS7 developed by Sandia around 2000)

+1 Xyce team qualifiying W76-1 AFS to radiation environments – constructing circuit models of the Driver and Logic Assembly boards within the AFS including the Permafrost 2 (PA2) ASIC that uses Sandia's radiation hard CMOS7 process.
http://micro.sandia.gov/documents/G1430EMS%20Caps4.pdf

"MESA is the only supplier of the Permafrost digital controller that is the brains of the W76-1 warhead life extension"
http://www.sandia.gov/mission/ste/capabilities/cap_cover.pdf

MESA makes silicon chips for W76-1
http://www.sandia.gov/LabNews/070831.html

W76-0 radar:

A thorough analysis of the signal processing of the MC2823 radar fuze was presented in 1976 by Thompson based on certain assumptions concerning circuit components.^Subsequent experience has shown that the 0/1 quantizer, the latch, and the effective RF-gate-pulse and transmitter-pulse widths do not exactly meet those assumptions with a resultant change of the effectiveness (or weighting) of a point target at a given range in producing a fire output.^A new weighting function, based on laboratory measurements, is derived for use in future analysis.^It is also demonstrated herein that this change of the weighting function has negligible effect on the performance analysis provided an equating of the calculated to the measured loop sensitivity is done in order to determine the effective receiver noise.^Since this equating has always been done in calculating operational performance of the MC2823 radar fuze, earlier analytical results using Thompson`s weighting function can be accepted with confidence.^In order for the fuze to operate as a fixed-height indicator on an ascending vehicle, certain additional processing will be required to prevent an early indication of the desired height with a resultant change in sensitivity.^Weighting functions for this application are calculated and presented; they indicate that such a change would have little effect on sensitivity
(Signal-processing analysis of the MC2823 radar fuze: an addendum re weighting of point targets by position in range cell with an altimeter application)

A detailed analysis of the signal processing of the MC2823 radar fuze was published by Thompson in 1976 which enabled the computation of dud probability versus signal-to-noise ratio where the noise was receiver noise. An addendum to Thompson's work was published by Williams in 1978 that modified the weighting function used by Thompson. The analysis presented herein extends the work of Thompson to include the effects of clutter (the non-signal portion of the echo from a terrain) using the new weighting function. This extension enables computation of dud probability versus signal-to-total-noise ratio where total noise is the sum of the receiver-noise power and the clutter power.
(Signal-processing analysis of the MC2823 radar fuze: an addendum concerning clutter effects)

MC2823. Radar. W76, Customer preferred fuzing option, solid state electronics, corrosion concerns, complex technology.
http://smaplab.ri.uah.edu/Smaptest/Conferences/Ice/cieslak.pdf

W76-1 AFS

"The Arming and Fuzing System engineering team has been able to integrate radar, flight computer, and diagnostics in a single compact assembly. "
"The electrical interface between the Arming and Fuzing Subsystem and the missile was successfully demonstrated. Fuzing hardware to measure radar performance was delivered on schedule for FY04 flight testing."
http://www.sandia.gov/LabNews/LN03-19-04/LA2004/Accomp_2004.pdf

AFS flew on FCET 35. Integrates AFS into AF&F "and accurately fuzes in a flight environment". FCET 35 was the first flight test of the Permafrost ASIC.
The Concurrent Design & Manufacturing program completed development and qualification of 38 custom made high reliability components for the W76-1. 25 newly developed, 13 previously designed for use in other weapon systems. During FY06 CDM completed the qualification evaluation for 17 components, by end of year all 38 qualified for use in W76-1.
http://www.sandia.gov/LabNews/labs-accomplish/2007/lab_accomplish_2007.pdf

W76-1 Timer

MC4081 clock circuit and foam
http://prod.sandia.gov/techlib/access-control.cgi/2001/012490p.pdf

Removable encapsulants for the W76 upgrade : MC4081-2 clocks encapsulated with removable epoxy syntactic foam. (title of Sandia Report)
http://techlibpac.sandia.gov:8101/ipac20/ipac.jsp?session=12H6M4P384816.761&menu=search&aspect=basic_search&npp=10&ipp=20&spp=20&profile=pac&ri=1&source=%7E%21horizon&index=.PG&term=mc4081&aspect=basic_search&x=11&y=13#focus

Simulation of W76-1 AF&F components – "the electrical subsystems that will be simulated in the STS environment are the Main Logic Board, Timer (FPGA) and Radar ... We have to achieve this goal by May 2002 in order to meet our DP customer's phase 6.3 flight test deadline"
- High Performance Electrical Modeling and Simulation Software Normal Environment (HPEMSS) Verification and Validation plan
http://prod.sandia.gov/techlib/access-control.cgi/2002/020253.pdf

FPGA – Field Programmable Gate Array ? – IT hardware

Sandia, partnering with NASA Goddard, has developed a radiation-hardened Field-Programmable Gate Array (FPGA). Because of their ability to implement digital circuits by programming, FPGAs have become one of the most popular implementation platforms for digital circuits. This rad-hard FPGA was designed for nuclear weapon applications in harsh radiation environments by Digital Microelectronics Dept. 1735 of the Microsystems Science & Technology Center (1700 and fabricated in Sandia's Microelectronics Development Laboratory. The part has 30,000 usable gates, and is compatible with commercial Atmel 6010 non-radiation-hardened FPGAs.
http://www.sandia.gov/LabNews/LN03-07-03/LA2003/la03/nuclear_story.htm

W76-1 Stronglinks and Launch accelerometer

MC4710 Intent Stronglink for W76-1
MC4711 Trajectory Stronglink for W76-1
MC4713 Launch Accelerometer for W76-1 – the first W76-1 mechanism to be submitted to QAIP with a complete, nonconditional QER.
(Connections, Kansas City Plant, Honeywell, Spring 2008)

"Tim is responsible for product, process and project leads for an inertial switch on the W76-1"
.. Matt is employed as a product / process engineer on the W76 launch accelerometer".
http://www.honeywell.com/sites/servlet/com.merx.npoint.servlets.DocumentServlet?docid=D6D47DD80-F290-1DFF-A249-18252D8640D7

"launch accelerometers – electrical switches activated by acceleration that help ensure the safety of nuclear weapons"
Supplied to KCP in the unlatched position, but had to be tested in the latched position, ie after experiencing g forces
(NNSA monthly news September 2009)

Outline of sequence, probably Mk5, in weigandpeta chart shows "launch accelerometer closes" just after launch.

W76-0 and W78 stronglinks/launch accelerometer

MC2854 ESD- Accel (fluid) W76, Safety critical, hermetic seals & fluid aging concerns
MC2897 ESD – Decel (escapement) W76, Safety critical, springs & lubricants concerns
http://smaplab.ri.uah.edu/Smaptest/Conferences/Ice/cieslak.pdf

"There are several silicone seals of concern to the W76, used on connectors for the MC3347 isolator, the MC2912 AF&F and the CF2253 Load. The isolator seals are exposed to air whereas the other seals are in inert environments (no oxygen). We received seals from the MC2912 to evaluate. Three came from the MC3034 ... and three from the MC3024 connector." "As an example, silicone o-rings exposed for 20 years under inert conditions in the **MC2854 Inertial Switch** ...". Differences between prediction and actual ageing of seals so need more samples.
http://prod.sandia.gov/techlib/access-control.cgi/2007/076781.pdf

"The MC3160 Inertial Switch is designed to provide accident, handling, and fire safety by maintaining the W78 warhead arming circuits in an open-circuit condition until the component experiences a

proper threshold acceleration followed by a sufficient velocity change. ..... The MC3160 is a modification of the MC2854 ... Much of the test data, analyses and established capabilities were compiled in testing the MC2854 and are applicable to the MC3160".
http://prod.sandia.gov/techlib/access-control.cgi/1978/780413.pdf

W76-0 Reentry G-Switch

"MC2913, the reentry g-switch used in the Mk 4 AF and F"
http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=5617330

MEMS Reentry sensor development

We have successfully demonstrated a novel MEMS-based acceleration switch that can sense the unique environments associated with weapon re-entry. The Silicon Reentry Sensor (SiReS) is fabricated using Deep Reactive Ion Etching (DRIE) and Silicon-on-Insulator (SOI) processes developed at Sandia. More than 20 prototype units have been successfully fabricated, packaged, and tested. The project represents a spiral development effort that, if successful, could result in the first Sandia-designed MEMS device introduced into the enduring stockpile
http://www.sandia.gov/LabNews/LN03-19-04/LA2004/la04/nuclear_story.htm - 2004

W76-1 Battery

With regard to technology advances, during 2006, Sandia National Laboratories' Power Sources Group 2520 progressed on a new thermal battery for the W76-1 Lifetime Extension Program. The battery utilizes a new chemical material - an advanced cobalt disulfide cathode material. Combining this with a low melting point electrolyte allows the battery design to meet tightly controlled and even multiple voltage requirements over an extended period.

http://www.researchandmarkets.com/reports/480629/world_thermal_battery_markets.htm

Seventh Biennial Tri-Laboratory May 2007
Cobalt Disulfide as a Cathode in a Long-Life Thermal Battery Steven Showalter

MC4708 thermal battery for W76-1

With regard to technology advances, during 2006, Sandia National Laboratories' Power Sources Group 2520 progressed on a new thermal battery for the W76-1 Lifetime Extension Program. The battery utilizes a new chemical material - an advanced cobalt disulfide cathode material. Combining this with a low melting point electrolyte allows the battery design to meet tightly controlled and even multiple voltage requirements over an extended period.

'Going forward, manufacturers must remain technologically competitive to differentiate themselves from the competition,' says the analyst. 'In addition to employing lean production manufacturing operations, they must also be aware of the emerging applications for this battery chemistry, including new missiles or other product developments.'

http://www.researchandmarkets.com/reports/480629

This is the html version of the file http://www.sandia.gov/pstg/fact-sheets/MC4708-one-page-2500.
SAND 2002-4054P

The MC4708 Thermal Battery Assembly

The **MC4708** thermal **battery** assembly is a new component for the W76-1 LEP AF&F. This is the first new thermal **battery** developed for a DOE application in over 10 years. It is also one of the most challenging, with requirements for an hour of activated life, four voltage sections, large pulse loads at the end of life, and very tight volume and weight constraints. In fact, this one **battery** must do the same job as two thermal batteries in the W88 AF&F. The smiling **MC4708** PRT from the Power Sources Technology Group is pictured, along with an outside and inside view of a thermal **battery**.

This challenging design project is making excellent progress. Through extensive materials studies, the specifications for the **battery** constituents have been established with more than 50 batteries built and tested so far to evaluate the many design options. Batteries can now be built that meet the existing requirements, and a prototype design is nearly ready to be established. This represents a major achievement for the PRT and signals that the **battery** is on track to meet FPU requirements

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Contact

Paul C. Butler, (505) 844-7874, pcbutle@sandia.gov, Sandia National Laboratories, P.O. Box 5800, MS-0614,Albuquerque, New Mexico 87185-0614

Project for MC4606 Battery Header W76/W88 start date 120598 end date 300999 to Sandia $34k FY98
http://www.osti.gov/rdprojects/details.jsp?query_id=P/SNL--7786

Non-volatile radiation hardened memory

Just as general computing capability has rapidly increased, so Sandia's development of radiation hardened non-volatile has accelerated from 1 kb SRAM in 1978 to 250 kb SRAM by 1996

http://www.osti.gov/bridge/servlets/purl/642714-4ocUvd/webviewable/642714.pdf

Contact Fuze

Reclaiming 30 year old impact fuzes from W76-0 AF&F and converting them to W76-1 impact fuzes. "This involved harvesting W76-0 impact fuzes while maintaining interface compatibility, verifying functional performance following stockpile exposures, physically modifying the hardware to meet the W76-1 configuration, and providing the refurbished units met functional performance requirements". (photos)
http://www.sandia.gov/LabNews/labs-accomplish/2007/lab_accomplish_2007.pdf

MK-4 Noses with MC2984 Contact Fuzes (U)" Sandia National Laboratories, NM,. Secret, October 15,1975.

High Velocity Explosively Driven Flyer Plate Impact Test on **a** MK-4 Nose. with a MC2984 Contact Fuze (U), CNSI, Sandia National Laboratories, NM, SAND75-. 0157, September 1975

Re Small ICBM proposal:
"An unresolved fuzing issue is the need for a proximity fuze as an alternative for terrain and re-entry conditions where the contact fuze may not be suitable. In October 1989 the Air Force directed the Peacekeeper program office to develop a reliable proximity fuze and the Small ICBM program office

to retain the ability to use that fuze. Department of Energy officials advised us that a reliable proximity fuze is needed for both the Peacekeeper and the Small ICBM missiles. The feasibility of a modification to the current fuze that provides improved reliability has been demonstrated by the Peacekeeper program office. Further development of this modification has, however, been suspended awaiting funds from SAC. SAC officials stated that they are still assessing the need for a reliable proximity fuze"
http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA245542&Location=U2&doc=GetTRDoc.pdf

History of W76-1 development

W76-1 system-level performance requirements:
Military Characteristics based on W76-0/Mk4
Stockpile to Target Sequence based on W76-0/Mk4 and W88/Mk5
Interface Control Drawings based on W88/Mk5 (D5 missile)
Weapon Specifications based on W88/Mk5
(Sandia W76-1 Performance requirements)

- W76
- Areas of Emphasis –
"Fuze modification evaluation to enable W76 to take advantage of higher accuracy of D5 missile"
"W76 Arming, Fuzing and Firing (AF&F) replacement project"
"Dual revalidation".
- Issues and activities -
"AF&F approaching stated end of design life. Actual occurrence of age-related defects in unpredictable. Study under way to implement capability of W88/Mk5 AF&F into W76/Mk4 volume"
- Timeline -
SWPP - Replacement W76 AF&F - Advanced Development 1996 – 2002;
Development flight tests 1 (2001), 2 (2002)
(Stockpile Stewardship and Management Plan: First Annual Update, October 1997)

"W76 replacement AF&F" project start date 010797 end date 30092005
"The SWPP Project was created to support the reconstitution of the DOE capability to design, develop, certify and produce radiation hardened strategic war reserve re-entry systems and subsystems. Under that umbrella the SWPP Advanced AF&F Project was created."
DOE Science accelerator

4 RBs including the first fully functioning AF&F and new JTA delivered to the Navy for flight testing in FY05
http://www.sandia.gov/LabNews/labs-accomplish/2005/lab_accomplish_2005.pdf

NWC approved W76 refurb and Phase 6.2/2a in 1998 – completed in 15 months.
NWC granted conditional approval to begin 6.3 activities in March 2000 and final approval in December 2000.
http://www.lanl.gov/history/hbombon/pdf/Job%20Number%201,%20Stockpile%20Stewardship.pdf

START 1 Life Extension Options for W76

	Labs FSED		Plants FPU		Pantex refurbishment	
	Begin	End	Begin	End	Begin	End
New AF&F w/ CAP-like features	2003	2006				
New Follow-on AF&F	2007	2011	2011	2021	2012	2022

CAP possibly Corrective Action Plan

W76 0- "A new AF&F is being developed under SWPP. The first design iteration will be complete in 2006, and the second iteration in 2011. The 2011 date is consistent with the 2012 date selected for CNE"
(Los Alamos ADAPT & SWPP report 1997)

SWPP

Dec 1995 draft MOU:
DOE SWPP responsibility – "Provide component, subsystems, and systems alternative design options including the Advanced Fuzing and Firing System".

2nd meeting of Design Integration Subgroup of SWPP agenda for 25 March 1996 included a presentation on quantifying the advantages of "using proposed advanced technologies for advanced AF&F systems by Sandia" by Kaman.

DISG meeting on 18 Sept 1996 Action items incl "prepare qualitative description of advantages for advanced Arming, Fuzing and Firing systems".
SWPP Program Realization Team (PRT) set up Jan 1998, purpose of initial meeting:
.. identify SubPRTs, proposed Sub PRTs – "advanced AF&F, Pit Reuse Option and New Pit Option"

SLBM Warhead Protection Program (SWPP) Goals -
... "Minimise changes to the functional interface of the Mk4 to allow for Mk5 functionality and Mk5 nuclear safety implementations""
.. "Minimise changes to operational capability"
.. "Maintain the existing V-Gamma map"
http://portal.unesco.org/en/files/5813/10312388001SCIENCEFORPEACE8light.pdf/SCIENCEFORPEACE8light.pdf

SWPP timeline:

1990 LLNL proposed pit reuse option for Mk5
1994 Phase 2 study peer reviewed by 3 labs
Feb 1995 draft Green book – Phase 2 feasibility study completed for Navy – which became SWPP the following year
29 May 1995 Labs briefed military in Omaha on warhead candidates, became SWPP|
June 1995 first SWPP meeting
Nov 1995 SWPP plans approved by NW council standing & safety committee
Labs work integrated with targeting considerations, specifically near-ground-burst capability
At first project meeting STRATCOM homework – compare effectiveness of proximity and RUPL

options for Mk4 application (c 1995 ?)
"According to the March 1999 version of Energy's stockpile stewardship master plan, the new modular fuzing system will allow the "incorporation of Mk5 fuzing functionality (including radar-updated path length fuzing, and radar-proximity fuzing) as an option for a replacement of the much smaller Mk4 AF&F."
(G Mello that old designing fever, BAS Jan/Feb 2000)

Proposed use of Mk4A AF&F on RRW

RRW POG Kick Off Meeting 11 May 2005 –

".. stated that the starting point for the Navy is the Mk5 aeroshell with a Mk4A Arming, Fuzing & Firing (AF&F) system. He mentioned that there is a significant inventory of Mk5 aeroshells. He made it very clear that there will be no changes to the Mk5/D5 missile interface and that the Mk4A AF&F will be used as is"
" .. presented the Mk4A AF&F requirements for RRW. ... .. provided some guidance to SNL to say that they are tasked to identify how to use the Mk4A AF&F." (P3)
Ground Rules - RRW – "Mk4A fuze (SLBM) / ____ (ICBM)"

Appendix F Mk4A fuze and AF&F requirements –
Approach –
"Look at possibility of using Mk4A AF&F in Mk5 RB
- Discern compatibility issues
  - What can be used
  - What may require changes" (P2)

"Mk4A AF&F fits in Mk5 AF&F envelope" (p5)
Page 9 has diagram probably of Mk4A AF&F
Diagram for Mk4 RBA shows "AS3DX quartz antenna window (qty 2)" near aft of RB
2nd diagram shows "antenna window (qty 2)" as circle near aft of RB
USAF Mk12A RB AF&F includes FBIA accelerometer as a separate identifiable unit.

RRW 2nd POG mtg minutes /6/05 –
"The baseline is the Navy system is the Mk5 aeroshell with the Mk4A Arming Fuzing and Firing (AF&F)." (p1)
Old Action Item - "Determine Mk4A AF&F radar performance in Mk5 shell. SNL/NM will provide proposed ECD no later than 16 May 2005 (Completed)" ECD: 30 Jun 05 STATUS: OPEN (p6)

MK5

MC3812 Mk5 radar –

The MC3812 is the smallest fuzing radar that Sandia Labs. has placed into production to date. The radar weighs less than 1.5 pounds and its volume is approximately 21.5 cubic inches. A single radar housing integrates all subassembly mounting arrangements and provides the mechanical integrity needed to survive severe physical environments imposed on the system. The housing, designed to

dissipate high thermal operating loads, also electromagnetically isolates sensitive radar subcircuits from one another. The design makes extensive use of thin film technology for rf circuitry and for the logic circuitry utilizes a multilayer Polyimide-Quartz printed wiring board that permits direct surface mounting of ceramic devices.
http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=5818086

MC3813 Force Balance Integrating Accelerometer-

Instrumented a centrifuge with a Helium Neon laser optics system which assisted in the dynamic calibration of MC 3813 force balance integrating accelerometers at a force of 125 g's
http://www.osti.gov/bridge/servlets/purl/105001-AWySqv/webviewable/105001.pdf

Mk5:
MC3817 Launch accelerometer
MC3813 FBIA
MC3816 RTB
MC3814 Wireless fireset
MC3811 programmer
MC3812 Radar
MC3815 LLTB
(Sandia W76-1 Qualification and design)

MK5 Arming, Fuzing, and Firing Set Assembly. Arming, fuzing, and firing assemblies are assembled. This assembly incorporates a radar, a programmer, an accelerometer, a decelerometer, thermal batteries, a fire set, a contact fuze, and a force balance integrating accelerometer.
http://www.complextransformationspeis.com/eis0236/vol2/Apa1-2.htm
(- ie 2 accelerometers)

MC3815 Thermal Battery (LLTB) -Long Life Thermal Battery ?
MC3816 Thermal Battery (RTB)
MC3827 Clock for Mk5

Mk5 RV - ... All solid-state radar provides airburst and proximity fuzing (the first RV with this feature) .....The Mk-5 RV is basically identical to the Mk-21 used with the W87
(nuclear weapons archive) http://www.freewebs.com/nuclearUSA/

Mk21 RV / W87 ICBM warhead

Primary fuze is inertial (i.e. dead reckoning using guidance information)
Secondary dual mode S-band radar fuze (4 antennas) for airburst and surface/proximity fuzing
Fuzing options: High altitude airburst, Medium altitude airburst, Low altitude airburst, Surface/proximity burst, Surface/contact burst
http://nuclearweaponarchive.org/Usa/Weapons/W87.html

W87 has more fuzing options than W78

The MX uses a "solid state radar fuze" which is one of a number of features not in earlier ICBM.
http://209.85.229.132/search?q=cache:Pyy-MxAc928J:www.cbo.gov/doc.cfm%3Findex%3D6181%26type%3D1+fuze+mk21+minuteman&cd=21&hl=en&ct=clnk&gl=uk

Cable assembly -- "It is part of the Solid State Radar Assy, which is a major subcomponent of the MK21 Re-Entry Vehicle Arming and Fusing Assy."
https://www.fedbizopps.info/archive/2003/07-July/26-Jul-2003/FBO-00381931.htm

MK21 Solid State Radar Program
http://www.fbodaily.com/archive/2005/07-July/31-Jul-2005/FBO-00857942.htm

The RF Conductor between Video Processor and Low Pass Filter is part of the Solid State Radar Assy, which is a major subcomponent of the MK21
http://www.fbodaily.com/archive/2004/01-January/09-Jan-2004/FBO-00499782.htm

The Mk21 Solid State Radar Assembly "transmits and receives RF signals to/from the antennas and this data is used to determine the RV position during re-entry. This communication is critical to weapon system accuracy". – Lockheed Martin contract
https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=18a83f9ce76c1fcef90458f0f271a227&_cview=0&cck=1&au=&ck=

W78 / Mk12

MC3043 AF&F
MC3160 Launch accelerometer / inertial switch
MC4523 Thermal Battery for W78 JTA with MC4523 sealed cap
MC2969 stronglink used in W78 also in B61, W80 and W84
FBIA ~ dizajn i Mk/3A

Small ICBM

"at the levels of target hardness used in defining the target damage requirements in 1986, better missile accuracy than the design specification or better height-of-burst accuracy will be required to achieve the target damage requirement ... The Small ICBM program office is considering a warhead fuze modification ... that could achieve a more exact height-of-burst detonation."
http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA245542&Location=U2&doc=GetTRDoc.pdf

Research into future AF&Fs

FY2010 budget Navy R&D:

Advanced technology for Mk5 AF&F
FY2009 -"complete the down selection of new path length sensor technology"

Related item for Joint Warhead Fuze Sustainment in FY2010
includes "down select Mk5 Life Extension Program Designs".

UK involves along with USN and USAF in both 2009 and 2010.
http://www.finance.hq.navy.mil/FMB/10pres/RDTEN_BA7_book.pdf

CRS report on RRW July 2009:

The W76-1 LEP that is currently underway is an excellent program in terms of technology, schedule, and cost. I believe it meets the Navy's needs. While the LEP makes many changes and some upgrades to components of the original W76-0, it made no changes that put the

warhead's basic design at risk. For example, the W76-1 LEP POG wanted the W76-1 to remain as close to the original design as possible for the nuclear explosive package, as small differences in that package may have major effects on weapon performance. In cases where we did not fully understand the original manufacturing process for a material or component, we replicated the original process as exactly as possible. For that reason, we went to considerable effort to restore the process to manufacture "Fogbank," a material used in the W76-0, for the W76-1. We also included changes that increase margins in order to compensate for problems or uncertainties that component changes or age-related degradation might introduce. **One such change was an improved system to supply boost gas to the weapon.**

I am confident that the W76-1 will extend the life of the W76. The W76-0 was first deployed in 1978. Since the W76-1 is very close to the W76-0, data on W76-0 aging are directly relevant to gauging the service life of the W76-1. Observations on deterioration, or lack thereof, in W76-0 components increase confidence in an extended life for the W76-1. The W76-0 has aged well, and we have learned some lessons from its aging process that we have applied to the W76-1. Also, **the modified boost gas transfer system supports an extended life.**

The W76-1 POG opted for the W76-1 LEP in lieu of the WR-1 RRW for several reasons. The ability to produce a reasonable number of pits by the time they were needed was in question. If we had waited until 2020 to have the first WR-1, the W76-1 would have been out of production for many years and there would have been a risk if WR-1 had failed. Also, the Navy need for the safety and surety options was not as compelling as other services. When SLBM warheads are in Navy custody they are under heavy guard by Marines and other security personnel at bases, or out at sea.

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Information provided by Dr. Barry Hannah, SES, Branch Head, Reentry Systems, Strategic Systems Program, U.S. Navy, personal interview with the author, February 17, 2009.

The W88 is housed in a MK5 aeroshell. Because of the MK5 size, it was also the aeroshell for the proposed RRW. In the not too distant future, a W88 LEP will have to be performed and the AF&F will require replacement. The future AF&F for the MK5 aeroshell is the same AF&F regardless of the NEP [nuclear explosive package] (W88 LEP'd or an RRW). 124

(124 Personal communication, March 7, 2008.)

The FY 08 RRW funding is currently on hold, so no work has been performed to date but, SSP has been directed by the Office of Secretary of Defense (OSD) to use the FY 08 and FY 09 RRW funding to support Mk5A life extension efforts. Once the FY 08 funds are released and the FY 09 funds are appropriated, SSP will use the RRW funds for risk reduction analysis and preliminary development of a follow-on Arming, Fusing and Firing (AF&F) subsystem for all weapons associated with the Mk5 aeroshell deployed on the TRIDENT II (D5) Fleet Ballistic Missile System. Specific Mk5A AF&F efforts directed by the Office of Secretary of Defense (OSD) supports a number of tasks needed to address early technology for the life extension program for the MK5/W88 nuclear weapon system. Below is a list of some of the major areas of technology to be pursued:

define new safety architectures for the AF&F

design of high density high power radar

Non-volatile radiation hardened memory
Radiation hardened application Specific Integrated Circuits (ASICs)
High density thermal battery development
Radiation hardened Wide band analog electronics
Low noise radar receivers utilizing commercial parts
Fuze modeling and test analysis
In support of this effort, the above technologies will be synthesized into bench top systems for test purposes.125
(125 Information provided by Strategic Systems Program, U.S. Navy, March 18, 2008. The Mk5A is an upgrade to the Mk5.)

(FY2009 budget) Noting that this request was for an AF&F system (described under "Congressional Action on the FY2008 RRW Request," above), the committee eliminated funds for RRW and authorized $13.3 million for research into integrated AF&F systems. 142
(U.S. Congress. House. Committee on Armed Services. Duncan Hunter National Defense Authorization Act for Fiscal Year 2009. H.Rept. 110-652, on H.R. 5658. 110th Congress, 2nd Session, 2008, pp. 201-202.)

http://docs.google.com/gview?a=v&q=cache:iSxlVG3i8C0J:ftp.fas.org/sgp/crs/nuke/RL32929.pdf+%22w76-1%22+%22military+characteristics%22&hl=en&gl=uk&pid=bl&srcid=ADGEESjzywSFftVhLvMb4vuJlXxj35Zgvheavgbd7pqN2vBw3PqVWiAm8CenEUKIilCT-tesoq68n5JySHXEJs0rg7oNKoOCOYoLzy6wMMmnKmAi1xi6Cyu0DSnOZ6bVMevwYrOzBC3Z&sig=AFQjCNEhKWImbuKIlUb4ynDD9_AAC_4BrA

"The RRW project officers meet at Livermore. This group is now termed the WR1/Mk5A Project Officers Group, or POG"
LLNL magazine Newline, 4 January 2008

W76 Neutron generator

General Electric Neutron Devices (GEND) needed explosive timers from Mound to support their War Reserve (WR) commitments on the W76 and W78 programs. Rather than build timers from raw materials, Mound developed a process that would reclaim units returned from the field. One of the key elements in the process is the machine that disassembles timers from neutron generator assemblies. This automated machine performs the disassembly process in less than five minutes and, because no damage occurs to either part, assets are available for rework, which is less costly and time-consuming than building new parts. [April 1992]
http://www.osti.gov/energycitations/product.biblio.jsp?query_id=1&page=0&osti_id=5410814

MC4380 and MC4380A NG for W76
MC4705 is voltage bar for MC 4380 NG)

Project for MC4378 Timer/Driver W76 start date 290695 end date 300999 allocated $1.7 m in FY98 to Sandia
http://www.osti.gov/rdprojects/details.jsp?query_id=P/SNL--0474
(MC4378 is timer for MC4380 NG)

Other W76-1 components

MC4701 Arming Fuzing Subsystem for W76-1
MC4702 Firing Set for W76-1
(Connections, Kansas City Plant, Honeywell, Spring 2008)

MC4709 Terminal protection device for W76 -1 20 MC4709 fabricated and tested to determine if the surface mount version can become the baseline.
http://www.governmentattic.org/docs/NNSA_PerfEval_KansasCityPlant_2005.pdf

W76-1 2X ?? KCP collaborated in development and deployment
http://www.governmentattic.org/docs/NNSA_PerfEval_KansasCityPlant_2005.pdf

Misc

MC3831 Dual Stronglink

MC3820 Actuator, re MC3714 Thermal battery for W82
MC4300 Neutron Tube
MC4600 Neutron Generator (replacement for earlier NG on W76)

HERT

Enhanced Fidelity Instrumentation Body (EFI-B) Data obtained on the FCET 32 and FCET 35 Flight Tests through **High Explosive Radio Telemetry** (HERT

Upgrading Trident to Mk4A

"We can chart the capability of our weapon system against targets and see what accuracy has done for us. The demonstrated capability of the D5 is excellent. Our capability for Mk4, however, is not very impressive by today's standards, largely because the Mk4 was never given a fuze that made it capable of placing the burst at the right height to hold other than urban industrial targets at risk. With the accuracy of the D5 and Mk4, just by changing the fuze in the Mk4 reentry body, you get a significant improvement. Why is this important ? Because in the START II regime, of course, the ICBM hard target killers are going out of the inventory and that cuts back our ability to hold hard targets at risk. The Air Force has some plans for how to upgrade their ICBM force to restore that capability. We can do that with the Mk4 reentry body for 10 cents on the dollar in terms of investment because of the accuracy of the system and we have made this option available to the strategic CINC"

Rear Admiral P Nanos, Director of Strategic Systems Programs, US Navy, "Strategic Systems Upgrade" in the Submarine Review April 1997.

A 1997 review of the Stockpile Stewardship listed key areas of development for W76 including:

"Fuze modification evaluation to enable W76 to take advantage of higher accuracy of D5 missile.
"W76 Arming, Fuzing and Firing (AF&F) replacement project.
"Study underway to implement capability of W88/Mk5 AF&F into W76/Mk4 volume"[1]

"According to the March 1999 version of Energy's stockpile stewardship master plan, the new modular fuzing system will allow the "incorporation of Mk5 fuzing functionality (including radar-updated path length fuzing, and radar-proximity fuzing) as an option for a replacement of the much smaller Mk4 AF&F." [2]

"The plan claims that the current arming, firing, and fuzing system of the W76/Mk4 is approaching the end of its design life, and that the occurrence of age-related defects is "unpredictable." But the fuze modification will enable the W76 to "take advantage of the higher accuracy of D5 missile.""

"The labs' Submarine Warhead Protection Program work is not only to be directed toward practical, certifiable weapons, but from the beginning it was integrated with military targeting considerations--specifically near-ground-burst capability. At the first project meeting, Strategic Command's homework, due at the next meeting, was to "Determine user sensitivity to Mk4 and Mk5 yield and accuracy with overall mission effectiveness," and to "Compare systems effectiveness of prox [proximity fuzing] and RUPL [radar-updated path length fuzing] options for Mk4 application."[3]

Trident warheads options study (1994)

In January 1994 a joint DoD/DOE study into future options for Trident warheads was published. It has since been released in a heavily-redacted unclassified form. The title is "Joint DoD/DoE Trident

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[1] Stockpile Stewardship and Management Plan: First Annual Update, DOE, October 1997, obtained under FOIA by Hans Kristensen.
[2] Greg Mello That Old Designing Fever, Bulletin of Atomic Scientists, Jan/Feb 2000 quoting DOE, Stockpile Stewardship and Management Plan: Third Annual Update, March 1999, p. 5-14.
http://www.staynehoff.net/w88-follow-on-dontlike.htm
[3] Greg Mello That Old Designing Fever, Bulletin of Atomic Scientists, Jan/Feb 2000

Mk4/Mk5 Reentry Body Alternate Warhead Phase 2 Feasibility Study Report". The options were considered in two categories – Mk4A options that would fit in the Mk4 Reentry Body (RB) and Mk5A options that would fit in the larger Mk5 RB. Two Los Alamos options and three Lawrence Livermore options were proposed for Mk4A. For each of the Lawrence Livermore options there were two sub-options. One sub-option used the current Arming Fuzing and Firing (AF&F) system, while the second had a new AF&F. There were nine Los Alamos and six Lawrence Livermore options for the Mk5A. Three of the Lawrence Livermore options included two or three sub-options. The report describes some technical issues related to these options and compares their relative effectiveness.

Limitations of Mk4 AF&F

The report says that the Height of Burst (HOB) settings on the current Mk4 RB limit its capability and that they should be changed:

"Effectiveness studies show significant value to new Mk4A height of burst options for capability against harder targets" (pdf p28)

"Both design teams recommend modified AF&Fs to minimise system reliability impacts and to maximise overall nuclear safety" (p4-1)

"The analyses show significant value to new height of burst options, compared to the current fixed Mk4 height of burst options".[4]

"The fuze settings in the existing AF&F are not optimal and changing these settings would improve the effectiveness of any of these candidates."[5]

"The SPETWG [Systems Performance and Effectiveness Technical Working Group] assumed that the HOBs of a Mk4A would be changed from those of the W76/Mk4."[6]

"The new AF&F is based on the radar technology from the W88. The Mk5 radar operates at different frequencies than the Mk4 antennas are designed for. Whether it would be better for the new radar to operate at the Mk4 frequency (compatible with the Mk4 RB RF system) or operate at the Mk5 frequencies (compatible with the Mk5 radar, but not compatible with the Mk4 antenna cavity) has not yet been evaluated. ... The performance of the modified system would not be as precise as the Mk5, but could be better than the Mk4."[7]

Survey of Weapon Development and Technology 1998

In February 1998 Sandia National Laboratory published a 650 page review of nuclear weapons developments. Much of the original report was classified Secret. However it has been released in a redacted form. One section of the report looks at the options for fuzing systems for nuclear weapons and refers particularly to the systems used on Mk4 and Mk5 RBs and the options for Mk4A.

[4] Alternate Warhead Study p 4-8
[5] Alternate Warhead Study p 7-43
[6] Alternate Warhead Study p 9-10
[7] Alternate Warhead Study p 7-45f

The current Mk4 AF&F has 3 sub-systems:

- Airburst Radar with 3 range options – this is the prime system
- G-started timer – a clock initiated by G-force of the missile trajectory – this can serve as a prime system or as a backup
- Contact fuze – this is a backup

In comparison the Mk5 AF&F has 6 sub-systems:

- Airburst Radar with 5 range options
- Proximity Radar
- Timer – for high airburst
- Path Length – also described as inertial airburst
- Radar-Updated Path Length
- Contact fuze – this is a backup

The Mk5 AF&F has an accelerometer which measures changes in the RB velocity throughout its flight. It can detect deviations from the caused by weather and other factors. The Path Length system uses this accelerometer to correct the actual position on the trajectory against the projected position from the timer. The Radar-Updated Path Lenght (RUPL) further corrects this using fixes from the radar. RUPL is the prime fuzing system on the Mk5.

There is a contact fuze on the Mk4 RB. Its main role is as a backup system - a fall-back in case the prime airburst fuzing systems do not function as intended, rather than a dependable way of producing a surface burst detonation.

There are problems with the reliability of contact fuzes. One of their disadvantages is "Dependability concerns (system reliability)"[8]. The report includes the following table:

Contact fuzing degree of difficulty[9]

	Component	System
Design	Easy	Easy
Validate	Fairly easy	Very difficult

This suggests that while it is possible to validate that the contact fuze will function in experimental trials, it is very difficult to prove that a system relying on a contact fuze would function reliably in real situations where an RB could encounter something other than a firm flat even surface. The report includes a series of diagrams of various types of forest from different angles, followed by a graph of "conditional probabilities of tree impacts on the Reentry Vehicle Surface".[10] Impacting on slanted or uneven studies is a further problem. Studies into this were conducted as part of the development of the Mk4A AF&F.

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[8] Survey of Weapon Developments p 508
[9] Survey of Weapon Developments p 509
[10] Survey of Weapon Developments p 536-539

These system concerns cannot be addressed by modifying the contact fuze. Such alterations would have "little, if any, additional protection against impact irregularities". [11]

The way to have "dependable surface fuzing" and "ensure detonation prior to collision" is to use a proximity radar.[12] This provides "adequate survivability for all impact scenarios". The detonation of a warhead with a proximity radar produces a ground burst detonation which has very similar effects to one initiated by a contact fuze.

The report includes a page titled "Contact vs Proximity – Ground shock environments". This says "Proximity fuzing consistently results in minimal degradation in ground shock environments when compared to contact".[13] Alongside this are two graphs for Peak Vertical Stress Contour and Peak Stress Attenuation on Axis for weapons detonated by a proximity fuze, contact fuze and at various depths below the surface. An earlier report into the effect of Earth Penetrator Nuclear Weapons includes several very similar graphs.[14] These two reports show that there is very little difference between the effect of a weapon detonated by a contact fuze and by a proximity fuze. In these graphs it is assumed that a proximity fuze will detonate the warhead 6 metres above the surface.

The Mk4 does not have a proximity fuze, but the Mk5 does. The Survey of Weapon Developments includes a page which lists "Fuzing options for replacement Mk4 AF&F".[15] One item is "dependable surface fuzing" with an arrow indicating that the plan is to use technology used on the Mk5. Both this wording and the reference to Mk5 suggest that the proposal, at least as an option, was to introduce a proximity fuze into the Mk4A AF&F.

A second item on this list, also linked to Mk5, is "new fuzing option for Mk4". This could refer to a further additional feature such as a Radar Updated Path Length fuze.

The new modular fuzing system for Mk4A will allow the "incorporation of Mk5 fuzing functionality (including radar-updated path length fuzing, and radar-proximity fuzing) as an option for a replacement of the much smaller Mk4 AF&F."[16] This will enable the W76 to "take advantage of the higher accuracy of the D5 missile".[17] The new modular AF&F would be compatible with the W88 and with new Navy warheads under development. (Old Designing Fever)

At the first SWPP project meeting STRATCOM was, for the next meeting, to "Determine user sensitivity to Mk4 and Mk5 yield and accuracy with overall mission effectiveness" and to "compare systems effectiveness of prox and RUPL options for Mk4 application" (Old Designing Fever)

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[11] Survey of Weapon Developments p540
[12] Survey of Weapon Developments p 490
[13] Survey of Weapon Developments p 510
[14] Ground Shock from Earth Penetrator Weapons, SAND88-1497, Sandia Report, November 1988
[15] Survey of Weapon Developments p565
[16] Stockpile Stewardship and Management Plan: Third Annual Update, March 1999, p 5-14, quoted in That old designing fever, Greg Mello, Bulletin of Atomic Scientists, Jan/Feb 2000
[17] Stockpile Stewardship and Management Plan: Third Annual Update, March 1999, p 5-14

Trident warheads options study (1994)

Measures of Effectiveness for Mk4/Mk4A

The report gives some indication of the criteria used to determine the effectiveness of Trident warheads:

A section with the heading "SSPK [Single Shot Kill Probability] against 27P0 Target on C4" says:

"When the W76/Mk4 was developed, the weapon system CEP was such that this type of target was considered difficult to successfully attack. With the improvements in CEP experienced by the C4 missile, this target is no longer the challenge it once was. Nevertheless the SPETWG considered it to be an important MOE [Measure of Effectiveness] for this system, and used it in their analysis".[18]

27P0 is the VNTK for a surfaced submarine.

"The SPETWG calculated the average SSPK across the total set of potential Mk4 targets softer than VNTK 46L8. This represents a set of targets likely to be eligible for the Mk4A"[19]

"The SPETWG calculated the fraction of potential Mk4 targets that are softer than 46L8 ... This MOE provides a concise measurement of how much of the target base is held at risk".[20]

46L8 is the VNTK for an SS-11 silo.

"The effectiveness of these overall strike plans in attacking that subset of the target base identified as Other Military installations was calculated. The SPETWG believes that Other Military would be an important target set for Mk4A weapons. .... This figure of effectiveness varied monotonically with warhead yield over a span of 12 per cent".[21] → Other Mil excludes SS-11

The subsets considered in the studies were Strategic Military, Other Military, National Leadership and War-Supporting Industry.[22]

"Figure 9-28 compares the effectiveness of Mk4A candidates on a C4 missile for targets up to 1,000 psi and shows the hardness distribution of targets in the 1992 NTB (Russia Only)"[23]

The following figures were redacted from the report and only the titles are visible:

"Mk4A SSPK for a 27P0 target on C4"[24]
"Mk4A SSPK for 46L8 target on D5"[25]
"Mk4A average SSPK"[26]
"Mk4A damage to other military targets"[27]

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[18] Alternate Warhead Study p 9-14
[19] Alternate Warhead Study p 9-16
[20] Alternate Warhead Study p9-17
[21] Alternate Warhead Study p 9-22
[22] Alternate Warhead Study p 9-28
[23] Alternate Warhead Study p 9-43
[24] Alternate Warhead Study p 9-15
[25] Alternate Warhead Study p 9-16
[26] Alternate Warhead Study p 9-16
[27] Alternate Warhead Study p 9-22

"Effectiveness of Mk4A candidates on C4 versus target hardness" (figure 9-28)[28]
"Effectiveness of Mk4A candidates on C4 versus 27P0 targets"[29]
"Effectiveness of Mk4A candidates on D5 versus target hardness"[30]
"Effectiveness of Mk4A candidates on D5 versus 46L8 targets"[31]

Measures of Effectiveness for Mk5/Mk5A

A section describing a MOE for Mk5 is headed "SSPK against 52L7" and says:

"When the W88/Mk5 was developed, this was the assessed VNTK of the hardest Soviet silos. Although those SS-18 silos have since been assessed to be much harder than 7000 psi, the SPETWG considers 52L7 to be a significant figure of effectiveness for this system because of the history of its use. The [redacted] was used, and the results varied monotonically with yield, with a swing of 40 per cent between the highest and lowest yields."[32]

The next section has the heading "SSPK against 64L9" and says:

"The SPETWG calculated the SSPK of the Mk5A candidates against a 64L9 target, which represents the current assessment of the hardest Russian SS-18 silos. [redacted] Because the ability to destroy this target was a major reason for developing the D5/W88 weapon system, the SPETWG considered this to be the most important single MOE for Mk5A effectiveness."[33]

"The SPETWG calculated the average SSPK across the total set of potential Mk5A targets harder than VNTK 46L8. This represents a set of targets likely to be eligible for Mk5A."[34]

"The SPETWG calculated the fraction of Mk5A targets that are harder than 46L8 and where [redacted]. This MOE is one estimate of how much of the Mk5A target base is held at risk."[35]

"The SPETWG thought that Strategic Military would be an important target set for Mk5A weapons. ... Due to the large variation in the yields of the various candidates there was a 30 per cent swing in the values that are shown .."[36]

The following figures were redacted from the report and only the titles are visible:

"Mk5A SSPK against 52L7 target"[37]
"Mk5A SSPK against 64L9 target"[38]
"Mk5A average SSPK"[39]

If MoE varies by 40 % for 52L7 then it will vary by more than 40% for 64L9
→ So if the average MOE varies is 30% then a significant part of SOrdys military Ops must be less than 52L7 – but allowed to use INS

[28] Alternate Warhead Study p 9-45
[29] Alternate Warhead Study p 9-46
[30] Alternate Warhead Study p 9-48
[31] Alternate Warhead Study p 9-49
[32] Alternate Warhead Study p 9-24
[33] Alternate Warhead Study p 9-24
[34] Alternate Warhead Study p 9-24
[35] Alternate Warhead Study p9-26
[36] Alternate Warhead Study p 9-30
[37] Alternate Warhead Studyp 9-24
[38] Alternate Warhead Study p 9-25
[39] Alternate Warhead Study p 9-25

"Mk5A damage to Strategic Military targets"[40]
"Effectiveness of Mk5A candidates on D5 versus target hardness"[41]
"Effectiveness of Mk5A candidates on D5 versus 52L7 targets"[42]
"Effectiveness of Mk5A candidates on D5 versus 64L9 targets"[43]

Differences between Mk4 and Mk5 AF&F

The report also reveals some of the differences between the AF&F in the Mk4 and the Mk5 RBs:

The Mk5/D5 system uses an Intent Word system. This is a unique signal which must be transmitted before the warhead can be armed. The Mk4/C4 system does not have this capability.[44] On the D5 the Intent Word is sent in flight from the missile to the RBs.[45]

In order to adapt the Mk4A RB to take the unique Intent Word signal the In-Flight Disconnect cables, which link the RB to the warhead bus, must be changed from 11 pins to 14 pins.[46]

"The new AF&F will use technology similar to that in the Mk5 MC3719 AF&F. The ESSG programmer in the new AF&F will use technology similar to that used in the W88 programmer (MC3811)".[47]

"The new AF&F will function much like the Mk5 AF&F, and therefore require power during the entire flight of the RB. Two batteries are required; a low voltage-long life battery, and a short term negative-voltage battery."[48]

The battery to power the ESSG would use cobalt disulfide technology.[49]

Weapon Systems Requirement Analysis

As part of the development of a new AF&F for the Mk4A systems engineers at Sandia National Laboratory developed a computer programme to assess what effect possible improvements in the fuzing system on the Mk4A would have on the overall effectiveness of the whole US nuclear stockpile in various scenarios. The study was published in 1999 as "Weapon System Requirements Analysis Employing a Hybrid of Analytic Technologies". The main body of the report is unclassified, however several annexes are classified.

The fuzing modifications are not described. Other sources show that the proposed modifications to the AF&F would improve the Height of Burst options. The report uses as the key criteria the Effective Circular Error Probable (Effective CEP). It does not give actual Effective CEP figures but illustrates them on a scale of 1 to 2.5 against a norm. The highest figure (2.5) may represent the current Effective CEP of the Mk4 RB.

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[40] Alternate Warhead Study p 9-31
[41] Alternate Warhead Study p 9-51
[42] Alternate Warhead Study p 9-52
[43] Alternate Warhead Study p 9-53
[44] Alternate Warhead Study p 7-21
[45] Alternate Warhead Study p 10-24
[46] Alternate Warhead Study p 7-24
[47] Alternate Warhead Study p 7-29 MC3719 is the AF&F in the W87; the W88 uses MC3810
[48] Alternate Warhead Study p 7-29
[49] Alternate Warhead Study p 7-34

The following tables show the results of the study.

1999/START II Stockpile vs Russia

Normalised Effective CEP	Percent of all Targets	Percent of W76 targets
1.0	11	19
1.8	4	7
2.13	2	3
2.23	1	2
2.5	40	69
All W76	58	

Projected START III Stockpile vs Russia

Normalised Effective CEP	Percent of all Targets	Percent of W76 targets
1.0	6	15
1.03	3	8
1.79	4	10
2.18	2	5
2.5	24	61
All W76	39	

Comparison of percentage of W76 Targets

Normalised Effective CEP	Percentage of max CEP	START II	START III
1.0 – 1.03	40 – 41 %	19	23
1.79 – 1.8	72 %	7	10
2.13 – 2.23	85 – 89 %	5	5
2.5	100 %	69	61
		100 %	100 %

Strategic Response Force

Four scenarios: two former Soviet satellites, North Korea and China.

Normalised Effective CEP	Percent of Targets
1.0	4
2.5	96