This paper was cleared by ASC99-0651 on 2 April 1999.

Status of display systems in B-52H *

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ABSTRACT

Display technologies for the B-52 were selected some 40 years ago have become unsupportable. Electromechanical and old cathode ray tube technologies, including an exotic six-gun 13 in. tube, have become unsupportable due to the vanishing vendor syndrome. Thus, it is necessary to insert new technologies which will be available for the next 40 years to maintain the capability heretofore provided by those now out of favor with the commercial sector. With this paper we begin a look at the status of displays in the B-52H, which will remain in inventory until 2046 according to current plans. From a component electronics technology perspective, such as displays, the B-52H provides several 10-year life cycle cost (LCC) planning cycles to consider multiple upgrades. Three Productivity, Reliability, Availability, and Maintainability (PRAM) projects are reviewed to replace 1950s CRTs in several sizes: 3, 9, and 13 in. A different display technology has been selected in each case. Additional display upgrades in may be anticipated and are discussed.

Keywords: display, interface, standard, digital, civil, military, commercial, avionics, instrument, gages, dial, indicator, monitor, meter, panel

1. INTRODUCTION

The Air Force has several fleets of aircraft that have been in inventory for several decades that will remain in inventory for several more decades. The the attrition rate for the current bomber fleet comprised the B-52H Stratofortress, B-1B Lancer, and B-2A Spirit are projected by the Air Force to fall below the minimum level of 170 total bombers by 2037.[1] Planning for a replacement bomber might start in 2013. Meanwhile, the Air Force plans to spend $3.5B over the next ten years upgrading the current bomber fleets. The Air Force says the B-52H must last another 40 years. The B-52H fleet now flying was built in the early 1960s using 1950s electronics technology.[2,3] Several of the antiquated display technologies are no longer available. Thus, continued operation requires in investment of non-recurring engineering to insert newer, available display technology. There is silver lining: newer technologies pay their way on to the aircraft in the form of (a) lower purchase price and, especially, (b) significantly lower O&M cost over each 10 years of operation as a result of the greater reliability of the newer technology.

The B-52H is an interesting case study in the maintenance of aging aircraft via a continual electronics update program. In recent years several electronic displays have come to be of particular concern to the Air Force Air Combat Command, including three different sizes of monochrome cathode ray tubes (CRT) designed some 40 years ago with 50 year-old technology. Funded efforts exist for each of these three displays under the Air Force Productivity, Reliability, Availability, and Maintainability (PRAM) program. Lessons learned from these three projects can be applied to both other displays in the B-52 and other aging DoD weapon systems.

Commercial-off-the-shelf (COTS) electronics are being adapted as frequently as possible in military avionics applications where low volume production is the rule. The physical displays may range from custom-grade to ruggedized consumer-grade, but packaging must make the display compatible with the operational environment, which includes not only all the normal combat aircraft military "-ilities" but the complex electronics environment into which the newly re-

* Publication Citation: D.G. Hopper, F.M. Meyer, and K.E. Wodke, "Status of display systems in B-52H," in ***Cockpit Displays VI: Displays for Defense Applications***, Darrel G. Hopper, Editor, Proc. SPIE 3690, 83-92 (1999).

designed electronics box must be placed. The form-fit-function (F3) requirement is a special challenge in combat vehicles. If necessary, a mil-custom military display may affordable if it would last 10 years in operation.

2. CREW STATION

Displays at each crew station in the B-52H are described at a general level to establish the nature of the currently fielded technology and to establish a baseline of the display capability which must be maintained in all crew stations. All displays include electromechanical, cathode ray tube (CRT), flat panel, even paper on the knee or clipboard. Quantities are one (1) unless stated otherwise. The Gunner's Station is not described as the position is unmanned.[4],[5],[6]

2.1. Pilots' Station (two seats total)

The pilot and co-pilot bring maps, fuel curve papers, and weight and balance papers on board the aircraft that are specific to the aircraft and mission. These paper displays are held on a clipboard on the left side of the pilot's crew station.

2.1.1. Pilot's Instrument Panel (Pilot/Copilot). There are 49 types of controls and indicators on the Pilot's Instrument Panel. There are a total of 121 items, consisting of status lights (incandescent bulbs with fixed label legends), displays (information can change), and switches/controls (can also contain some status lights). Of the 121 total, there are 16 status lights, 85 displays, and 20 switch/controls.

2.1.2. Pilot's Side Panel. There are 18 types of controls and indicators on the pilot's side panel there are a total of 23 items as follows: 3 status lights, 7 displays, and 13 switches/controls.

2.1.3. Pilot's Overhead Panel. There are 12 types of controls and indicators on the pilot's overhead panel. there are a total of 12 items as follows: 1 status light, 1 display, and 10 switches/controls.

2.1.4. Copilot's Side Panel. There are 26 types of controls and indicators on the co-pilot's side panel. . there are a total of 29 items as follows: 3 status lights, 8 displays, and 18 switches/controls.

2.1.5. Aisle Stand. There are 23 types of controls and indicators on the aisle stand. there are a total of 30 items as follows: 1 status light, no displays, and 29 switches/controls.

2.2. Radar Navigators' Station (Typical)

There are 44 types of controls and indicators at the Radar Navigator's Station. This is broken down into 44 items as follows: 9 status lights, 6 displays, and 29 switches/controls.

2.3. Navigators' Station (Typical)

There are 49 types of controls and indicators at the Navigator's Station. This is broken down into 50 items: 5 status lights, 16 displays, and 29 switches/controls.

2.4. EW Officer's Station (Typical)

There are 34 types of controls and indicators at the Electronic Warfare Officer's Station. This is broken down into 35 items: 2 status lights, 15 displays, and 18 switches/controls.

2.5 Display Types

Display types vary widely and are listed as follows:

2.5.1. A liquid-filled "Whiskey" compass

2.5.2. Electro-mechanical meter movement

2.5.3. Spring-wound (mechanical)

2.5.4. Pitch and roll attitudes are displayed in the standard manner with the pitch scale located on the attitude sphere and the bank pointer and imprinted bank scale located on the lower half of the instrument.

2.5.5. Cathode Ray Tube Electro-Optical Viewing System (EVS) Monitor

2.5.6. Stationary dial by a rotating pointer. A rotating subdial is also provided

2.5.7. Digital display

2.5.8. Indicator has a diagram marked with a miniature runway and a scale calibrated from 0° to 20° both right and left. Two movable pointers, mounted one above the other, indicate the degree of turn. The lower pointer, a simple needle, indicates the forward gear, and the upper pointer, in the form of a miniature aircraft, indicates the rear gear.

2.5.9. A calibrated compass card, located on the upper portion of the instrument, is read against a lubber line fixed on the instrument mask. The mask has a cutout in the lower portion which shows reciprocal heading. A spring-loaded push-to-set type synchronizing knob is located on the lower left portion of the indicator and is used to realign or calibrate the dial to known references.

2.5.10. Thumbwheel channel indicator switches

2.5.11. Channel indicator window

2.5.12. A liquid crystal display module

2.5.13. Four-digit LED Readout

2.5.14. Programmable keyboard consists of 20 programmable software keys with switch legends and functions. The PKB keys will accommodate two sizes of type, graphic images, and bit mapped displays

2.5.15. Pressure Gage that displays system pressure in inches of mercury

2.5.16. 6-gun oscilloscope display**.** The counter is a subtractive type counter

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3. TECHNOLOGY INSERTION PROGRAMS

3.1. Funded display replacement programs

There have been/are three Productivity, Reliability, Affordability, Maintainability (PRAM), or Improved Item Replacement Program (IIRP), programs for displays in the B-52H to replace monochrome green CRT's dating from the 1950s and 1960s. These three displays and their purposes are summarized in Table I. The B-52H is illustrated in Figure 1. Photographs of the current pilot and navigator instrument panels, including the 3-in. and 9-in. displays, are provide in Figures 2 and 3, respectively.

Table I. Three displays of current concern in B-52H. *

Display		**Technology**		**MTBF (flight hours)**		**Manufacturing Price (current technology)**	
		Current	**Replacement**	**Current vs. Needed**		**Previous Vendor**	**Current Vendor**
Number	**Purpose**	**Green CRT**	**PRAM Candidate**				
IP-1310	RWR: ALR-46 ALR-59 ALR-69	3-inch circular 1-gun	TFEL	2400	5,000		$5,200
ASQ-151 ASQ-157 (175?)	LLTV FLIR Radar Navigation	9-inch rectangular 4:3 aspect 1-gun	POD/DMD or TFEL or AMLCD	50 to 150	5,000		$26,000
IP-1168	EW Receiver System: ALR-20A	13-inch rectangular 3:4 aspect 6-gun	CRT 1-gun	100	5,000	$8,000	$40,000

* The IP-1310 goes into several other fleets, including F-16, as well. The ASQ-151/157 goes into the B-1B as well.


B-52H

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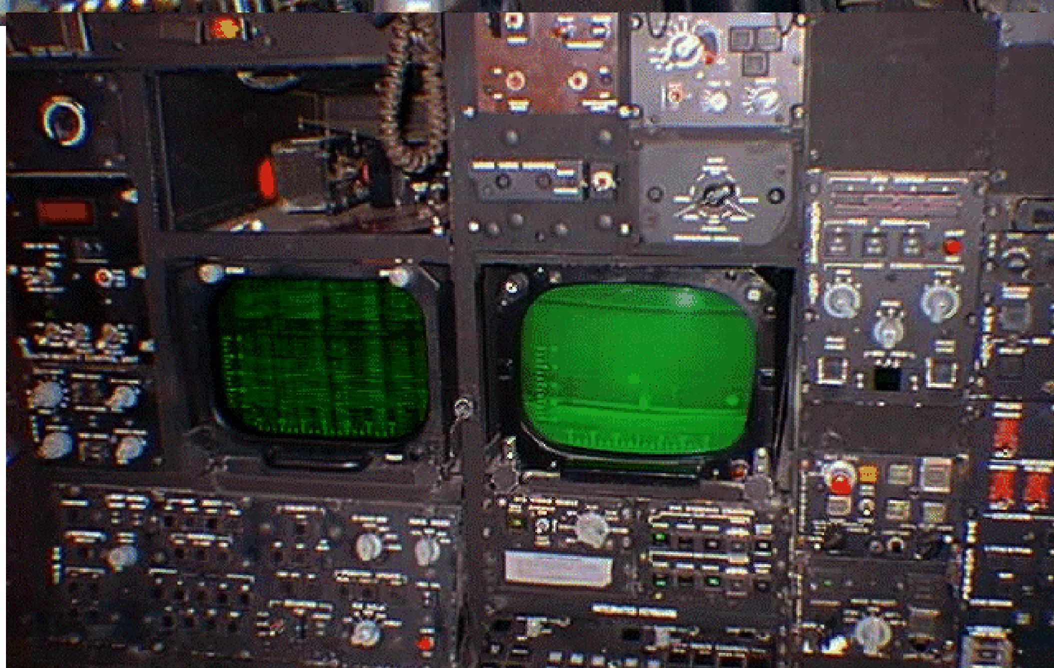

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Figure 3. Photograph of IP-1310 3-inch monochrome CRT for ALR-46/59/69 Radar Warning Receivers (RWR).

3.2. Three-inch circular azimuth indicator for ALR-46 (B-52, F-16, A-10, etc.)

An AFRL-managed DARPA-funded low voltate Thin Film Electroluminescent (TFEL) program created a technology base which has been incorporated by Planar in its direct view displays and selected for use as the FLIR display in the M1A2 Abrams tank system enhancement program and for use in upgrading the RWR in several Air Force air fleets. AFRL is now, HECV consulting in the manaagement of the follow-on SOCOM-managed DARPA funded program to develop produces based on TFEL technology. Georgia Technology Research Institute (GTRI) is under contract to provide technology updates to the ALR-46 system for the Warner-Robins Air Logistics Center under funding from the ASC PRAM Office to investigate a method to replace the CRT in the ALR-46 Radar Warning Receive with a 3 x 3 inch TFEL display.[7] The IP-1310 is the single highest failure item in the RWR and only an 18 month supply of the 3" CRTs was available as of Aug 98. GTRI received the work from WR-ALC in 1995 to research a replacement for the ALR-46 /IP-1310 CRT. The ID-2554 program needs more funding, as of Aug 98 to complete testing and engineering drawings. The ID-2554 is to be integrated into the F-16, F-15, B-52., and B-1 RWRs.

3.3. Nine-inch 4:3 rectangular format MFD/EVS (common to B-52H and B-1B)

In an attempt to evaluate CRT display replacement possibilities, Battelle Memorial Institute attempted to demonstrate AC gas plasma, EL, and AMLCD displays in a B-52.[8] The reliability of the 9" monochrome CRT had been 50-100 hours with a repair and replace cost of $26,000 per removal. After this demonstration, ACC was not pleased with the maturity of any of the three flat panel technologies and after searching for alternatives came across the Polyplanar Optic Display (POD) concept at Brookhaven National Laboratory (BNL). ACC then proceeded to investigate ways to fund further research and develop the POD concept into a flight instrument. In 1995 the Productivity Reliability, Availability, and Maintainability (PRAM) office agreed to fund the POD development based on the request from ACC and have the program managed by AFRL. The PRAM office invested $2.7M from Jan 95 to Jan 98 just as BNL had completed the final prototype and demonstration of the POD to ACC.[9,10]

Battelle took over of the management of the BNL facility from Associated Universities, Inc. This change was felt to be a good arrangement for the POD project since Battelle was experienced both with the instrument requirements and the advanced display technology research. For example, Battelle considered fabrication of acceptable POD screens using a unique optical fabrication facility developed at the Battelle Pacific Northwest Lab, which is also managed for DoE by Battelle.

Triton Labs, Inc. has purchased license rights to the manufacture of POD screens. The POD has been demonstrated. Pending further funding opportunities, manufacturing developments, refinements, and requirements need to be addressed.

Potential future work with alternative technology (TFEL, AMLCD) are warrented to develop an acceptable replacement.

3.4. Thirteen-inch six-gun monochrome green ALR-20 EW (unique to B-52)

The AFRL Aerospace Displays Program was requested to consult on reliability issues with the ALR-20A CRT beginning about 1994. A three phase program of assistance was developed: (1) help WR-ALC increase the yield on the current CRT to get working units to the field; (2) consult on an ASC PRAM project involving OO-ALC and Boeing to develop a technology insertion program to replace the six-gun CRT with a modern, manufacturable design based on a one-gun CRT; (3) re-develop the entire ALR-20 system including a yet more modern, digital flat panel display technology to leverage commercial trends to flat panel displays.

The initial concern of AFRL was the 1950s technology six-gun CRT still currently being used and manufactured by a sixth generation contractor (Hughes) who had not inherited the expertise used in decades past to successfully make this unique CRT. Hughes Lexington had been under contract from 1992 to 1997 for 123 units. The CRTs delivered during this time had a MTBF of 50-100 hours at a cost of $8000 each. Hughes Lexington became Lexel in 1997. The last contract with Lexel was for 43 units starting Nov 1997 to Oct 98 (1 year @ Approx 4 per month) at a cost 5 times the original contract cost (Hughes had been achieving a yield of one good CRT per 5 manufactured.) Various things had been tried during the program to improve the quality control: the cleanliness of the Hughes Lexington assembly process was reviewed, the compatibility of various new materials that had been used in the assembly process was discussed, the cathodes were analyzed by the materials lab (AFRL/MLSA) and found to have excessive nickel on the surface this was ultimately determined to be a concern for the cathode binder material, and the electron guns (i.e. mica replaced with other man made materials).

Since the reliability of the CRTs was not improving the availability of the CRT had not improved, WR-ALC contracted Condor Systems, Inc. to develop a signal processing solution to the 6–gun CRT problem using a single gun CRT. Again, the PRAM office funded the program through OO-ALC to develop the replacement solution. WR-ALC is managing the technical portion of the contract through Boeing AC to be sure the new display is compatible with what is currently in the aircraft.

AFRL/HECV, exercising its "best buyer" mission obligation as a service laboratory, has consulted at program reviews to ensure the Air Force program managers were supported by Lab display knowledge in making their decisions.

A 1999 Congressional plus-up has enabled AFRL/SNZ to begin a total re-design of entire ALR-20 EW system. This redesign may use flat panel displays.

4. POTENTIAL FUTURE INSERTION EFFORTS

A comparison of the description of the current B-52 crew stations in Section 2 above with the three ASC PRAM projects in Section 3 makes it clear that there is a large opportunity space over the next decade to consider affordability upgrades via display technology insertion. The current Form-Fit-Function programs may be augmented with modification programs in which sections of instrument panels, such as those for engines status, are combined into one large flat panel display. Other air fleets of aging aircraft (C-141B, C-130E) are undergoing complete cockpit upgrades.

Newly proven avionics display technologies include AMLCD (for color or monochromatic, narrow or wide field of view) and TFEL (only monochrome green, only wide field of view) are available cockpit panel display technology insertion efforts. [11],[12],[13],[14] Other, as yet unproven, technologies (such as FED, AMOLED,VRD) may become available in a few years.

The savings opportunity is established in Table II, which shows the return-on-investment (ROI) for replacing the 9 inch CRT in the B-52H fleet with a modern flat panel display technology is 13:1 .

Table II. Return on investment analysis for technology update of 9-in. CRT in B-52H with new, flat panel display.

B-52H RETURN ON INVESTMENT FOR POLYPLANAR OPTIC DISPLAY (ASQ-151/175 replacement)							
						PROJECT DATA	
Cost of Logistics Item or Repair and Replace Action(RRA) = ($)						$26,000	
Number of Platforms						97	
Operational Hours / Fleet / Yr)						25,565	
Units / Platform						7	
Mean time Between Failures (MTBF)= (Hrs)						100	
Maintenance Support Interval = (Yrs)						10	
Project Cost = Non Recurring Engineering(NRE) Cost						$2,000,000	
New Technology Cost						$50,000	
Total Required Units = Units/Platform * Number of Platforms							679
Total Required Unit Hours = Units/Platform * Operational Hours/Fleet/Yr* Maint Support Int							1789550
		7	25,565		10		
Total Units Required Over Platform Lifetime = Total Required Unit Hours / MTBF							17895.5
			1789550		100		
Platform Support Cost = Total Units Required Over Platform Lifetime * Unit Cost							$465,283,000.00
			17895.5		$26,000		
Return on Investment (ROI)							
Cost of Old Technology = Platform Support Cost							$465,283,000.00
Implementation Cost = Units/Platform * Number of Platforms * Unit (New) Cost							$33,950,000.00
	7		97		$50,000		
Gross Savings = Cost of Old Technology - New Technology Cost							$431,333,000.00
		$465,283,000		$33,950,000			
Useful Life Savings (ULS)= Gross Savings - Project Cost							$463,283,000.00
		$431,333,000		$2,000,000			ROI
ROI= Useful Life Savings / (Project Cost + Implementation Cost)							13
	$463,283,000		$35,950,000				

5. DISCUSSION

Common sense requires that an acquisition person trying to achieve the best value and performance look at what has been used in current, legacy aircraft because it is likely that many airframes will be in service for quite some time more. The B-52H will be in service until about 2046, for example. Near-term upgrades must be achieved using conservative (i.e. proven in other DoD weapon systems requiring similar combat performance) avionics display technology, such as CRT, LED, color and monochrome AMLCD, and monochrome TFEL. Mid-term upgrades might use other newly arriving technologies as well, such as DMD. Far-term applications will have new options, including improved versions of those technologies already mentioned and, perhaps, color TFEL, FED, AMOLED, and solid state laser-based displays.

Commercial industry must be leveraged to the maximal extent possible. Commercial trends may be “mined” for aerospace display applications. However, military integrators must demonstrate an ability to package any display selected to achieve the performance required in the B-52H, or other, operational combat crew station environment. This military requirement must be met not by mil-standards dictating details of engineering design, but rather via the setting of tough performance specifications (reference Mar 98 report to Congress by SECDEF Cohen).

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