DTIC/FDAC

(2)

WL/NTA-TP-89-001

EMP IN THE STEALTH ERA

PROPOSED ACTIVITIES TO PREPARE FOR TESTING ADVANCED/STEALTH WEAPONS SYSTEMS

Maj Harold T. Bishop
Capt James A. Lee
2dLt Thomas W. Hall
Ms Christine Stapp

AUGUST 1989

Approved for public release; distribution unlimited.

Aircraft and Missile Division
Nuclear Technology Office
WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base, New Mexico 87117-6008

WL/NTA-TP-89-001

EMP IN THE STEALTH ERA

PROPOSED ACTIVITIES TO PREPARE FOR TESTING ADVANCED/STEALTH WEAPONS SYSTEMS

Maj Harold T. Bishop
Capt James A. Lee
2dLt Thomas W. Hall
Ms Christine Stapp

AUGUST 1989

Aircraft and Missile Division
Nuclear Technology Office
WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base, New Mexico 87117-6008

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
Distribution A: Approved for public release; distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
WL/NTA-TP-89-001

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
Weapons Laboratory

6b. OFFICE SYMBOL (If applicable)
WL/NTAA

7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS (City, State, and ZIP Code)
Air Force Systems Command
Kirtland AFB, NM 87117-6008

7b. ADDRESS (City, State, and ZIP Code)

8a. NAME OF FUNDING / SPONSORING ORGANIZATION

8b. OFFICE SYMBOL (If applicable)

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS (City, State, and ZIP Code)

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
64711F	3763	01	167

11. TITLE (Include Security Classification)
EMP in the Stealth Era: Proposed Activities to Prepare for Testing Advanced/Stealth Weapons Systems

12. PERSONAL AUTHOR(S)
H. T. Bishop

13a. TYPE OF REPORT
Final Technical Publication

13b. TIME COVERED
FROM Aug 89 TO Sep 89

14. DATE OF REPORT (Year, Month, Day)
August 1989

15. PAGE COUNT
24

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Stealth Hardness; Testing; Electromagnetic Pulse; Trestle; B-2; Norms

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The B-2 brings new challenges for Electromagnetic Pulse (EMP) Testing. This paper discusses the unique characteristics of the B-2 and develops a time line of activities that need to be completed by the Weapons Laboratory before EMP testing of the B-2 begins.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL
Harold T. Bishop

22b. TELEPHONE (Include Area Code)
(505) 844-9908

22c. OFFICE SYMBOL
WL/NTAA

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

ABSTRACT

The B-2 brings new challenges for Electromagnetic Pulse (EMP) Testing. This paper discusses the unique characteristics of the B-2 and develops a time line of activities that need to be completed by the Weapons Laboratory before EMP testing of the B-2 begins.

CONTENTS

CONTENTS (CONCLUDED)

TABLE

EMP IN THE STEALTH ERA

1.0 INTRODUCTION

The relentless advances of technology continually force related advances in operational tactics, testing concepts and maintenance tools and techniques. The B-2, F-117, and the Advanced Cruise Missile embody most of the progress made to date in stealth airframes. While stealth designs offer potential enemies major problems for their air defense systems, they also present significant challenges for those involved in testing and maintaining the stealthy designs. This paper briefly presents a background on the B-2 and its associated technologies and ends with a discussion on how the Weapons Laboratory is getting ready to electromagnetic pulse (EMP) test an aircraft like the B-2.

2.0 MISSION

The B-2 is designed as a manned penetrating bomber that will be able to get to the target well into the 21st century. Its ability to escape a first strike and penetrate the defenses gives it a significant deterrent value. Its ability to remain undetected makes it a threat to the enemies second strike resources as it can search out and destroy mobile missiles and other targets that may escape our return missile strike.

Missions involving tactical surprise would also be ideal for the B-2. When the US conducted a raid on Libya from England in 1986, more than 100 combat and support aircraft had to be coordinated. The same mission could have been achieved using three or four B-2 bombers with one or two tankers launched from stateside. This would have reduced the risk of aircraft and human loss while increasing the tactical surprise ("General Randolph" 16).

2.1 EFFECTIVENESS

The B-2 is an effective retaliatory weapon due to its stealth design, which greatly reduces its size on radar. The radar cross section (RCS) is defined as the measure of a target's apparent size on radar. The B-2 has an estimated RCS of 5.4 square feet, which would appear to be a medium-sized bird compared to the RCS of the B-52 bomber equal to 1100 square feet. Radar detection is proportional to the fourth root of the RCS, so a small RCS gives the B-2 a distinct advantage (Sweetman, "Stealth" 1217).

It can accomplish its mission by delivering up to 50,000 pounds of either nuclear or conventional weapons. The stealth design is kept by carrying the weapons inside the aircraft on rotary launchers. Because of its smooth, aerodynamic exterior, the B-2 is very fuel efficient and has a range of up to 10,000 miles. Operating at high or low altitudes the B-2 can enter an offensive area, search out its target, complete its mission, and return to base.

The B-2 is a subsonic aircraft and does not have afterburners. By flying at high altitudes, fuel is conserved and the B-2 can achieve an unrefueled range of 6,000 to 7,500 nautical miles. By refueling in-flight, the stealth bomber has a range of 10,000 miles. (Rhodes 44).

The stealth bomber has a gross take-off weight of over 350,000 pounds. Effectiveness of the B-2 is increased by its ability to land or take off on conventional runways. It has a landing gear track of 40 feet and can operate on the same run-way as the 727 (Stringer 23).

3.0 DESIGN

The B-2 is a "flash from the past," incorporating a flying wing design which was first conceived by John Northrop in the 1920's. It is approximately the same size as the YB-49 built in the late 1940's. The B-2 has a wing span of 172 feet, a length of 69 feet, and has a maximum height of 17 feet. Four F118-GE-100s engines developed by General Electric are being used. These are non-afterburning derivatives of the F110 and can deliver 19,000 pounds of thrust apiece. The engines are mounted on top of the wings where they are harder to detect from the ground (Rhodes 44).

3.1 STEALTH

The "stealthiness" of an object is determined by its ability to avoid detection by radar, infrared, acoustic and electronic emissions. A stealth aircraft which is not detected, avoids being attacked or jammed.

3.1.1 STRUCTURE

Stealth is achieved by avoiding sharp edges and vertical surfaces which reflect radar. Also, reflective metals are replaced with composites, ceramics, and radar absorbing material (RAM). The purpose is to either absorb or refract as much radar as possible.

There has been much speculation as to what type of materials are being used for the RAM. The two main types of RAM are dielectric (non-conductive) and magnetic. Some possibilities are:

1. Carbon fiber material
2. Fiber-reinforced graphite
3. Glass fibers
4. Combinations of the above

Ceramics tend to have brittle properties, but are useful because they can withstand high temperatures and could be used in the engines. Composite materials are increasingly replacing steel and aluminum because of their strong mechanical properties and reduced weights. Aside from the engines, wing box, and landing gear, the B-2 is composed of non-metallic materials (F.C.P. 42). The engines and other large metal pieces are probably shielded from electromagnetic energy with v-shaped or honeycomb RAM which would trap and absorb incoming radar (Darrow 67).

3.1.2 INFRARED

Evading infrared (heat seeking) sensors is another problem faced by the stealth bomber. Therefore, it is necessary to cool the engine's exhaust. This also helps to eliminate contrails and protect the B-2 from being visually spotted from the ground. Eliminating the contrails may be accomplished by shielding the inlets, using a fuel additive, or by placing a baffled exhaust system on the rear of the aircraft. A baffle system would mix the cold air with the exhaust. This would also help to reduce detectable engine noise (Rhodes 45).

3.1.3 COMPOSITE SKINS

Keeping the surface of the B-2 smooth is necessary to avoid radar reflection. The seams connecting composite to metal are especially worrisome. These spots are coated with a special paint to smooth out any discontinuities (Darrow 68). Flexible skins are being developed to cover the gaps created by any moving parts such as flaperons (a combination of flaps and ailerons) or elevons (a combination of elevators and ailerons). "Smart" skins are also being developed which would have avionics embedded in the structure of the aircraft. This would replace antennas and black boxes ("Westinghouse" 284).

3.1.4 EMISSIONS

Electromagnetic emissions from the B-2 may be reduced using the following systems:

1. Astro-inertial system
2. Fiber-optic control lines
3. Laser communications
4. Fly-by-wire system

The astro-inertial system would navigate the B-2 using the stars. Fiber-optic control lines could be used instead of wiring that can "leak" electronic noise. Fiber-optic cables also help to protect the B-2 from the effects caused by a nuclear electromagnetic pulse (Goldberg 32).

Laser communications are being developed for use in high-speed data transmissions (up to 100 megabits of data per minute). Because lasers use finely focused beams, they can be used without being detected. A modern fly-by-wire (or rather, "fly-by-computer") stabilization and feedback control system is necessary to control the maneuverability of the inherently unstable flying wing design. Possible fiber-optic control linkages or "fly-by-light" may be part of the B-2 design (Rhodes 45).

4.0 COST

The latest B-2 budget estimates a total program cost of $70.2 billion for 132 aircraft. That breaks down into approximately $532 million per aircraft. The funding is spread out over at least 8 years, the exact beginning and ending years unknown. The projected peak in cost will occur in 1993 at $8.4 billion and the majority of the project should be finished by 1996, delivering a total of 127 airplanes. Five out of the original 6 developmental aircraft would be updated after tests are completed for operational use, increasing the total to 132 (Bond 20).

5.0 TESTING

Testing of the B-2 has included years of simulation testing as well as 24,000 hours of wind tunnel testing. Avionics systems have been tested for 44,000 hours and flight control systems have undergone 9,000 hours of testing. Flight crews have logged over 6,000 hours on the B-2 simulator, and 16,000 hours of engineering development testing have taken place. Structural tests have been completed including testing of the engines, escape system, fuel system, landing gear, and auxiliary power system (Rhodes 45).

Low speed taxi tests (up to 103.5 mph) occurred Monday, 10 July 1989. The initial test flight (lasting 1 hour and 53 minutes) occurred a week later on 17 July 1989. Radar signature enhancers are being used to track the B-2 on radar during the test flights (Air Force News 10). A concurrent testing program will be used. This involves continued testing of the aircraft while it is produced and deployed at the same time.

In order to accomplish its primary mission, the B-2 advanced technology bomber must be able to survive the electromagnetic pulse threat from a nuclear war. The B-2 may be built to the old Air Force EMP specification that was levied on the B-1B. If the new DoD 2169A standard is on the B-2, it will require EMP hardening up to 1 GHz and require some improvements in NTA's facility and sensor capability. Initial contact with the B-2 System Program Office (SPO) indicates a test of the B-2 at Kirtland AFB is likely in the 1992 timeframe.

6.0 GETTING READY FOR THE B-2

The "fighter pilot types" feel they can outrun EMP thus little testing of the hardness of the F-117 is expected. The missile community seems to go to DNA to use their ARES EMP facility. This leaves the B-2 as the stealth program that is coming our way. It will require the development of hardness maintenance/hardness surveillance (HM/HS) techniques as well as verification testing of the aircraft.

6.1 FREE FIELD TESTING

Our goal for the B-2 test is to determine specification compliance through free field electromagnetic pulse (EMP) testing and direct drive of the electronic equipment. A secondary goal is to develop HM/HS procedures, test techniques, and a data base for use by Oklahoma City Air Logistics Center (OC-ALC).

6.1.1 EMP ENVIRONMENT

Despite the new technology that may be incorporated in the B-2, the basic EMP environment is unchanged. The environment is set by the characteristics of a nuclear blast and is defined by DOD Std 2169. Thus, the EMP facilities will not require modification for the B-2 test except for those changes which bring the facility output closer to the 2169 specification. In other words, the B-2 does not require a different Trestle/VPD/HPD output just because it is a composite airframe.

6.1.2 COMPOSITE SKINS

One area where the B-2 could be significantly different from previous aircraft is the conductivity of the composite material in the aircraft skin. If it is nonconductive, the skin will not provide the normal barrier to EMP effects that a conductive skin does. This means the aircraft designers will have to have placed the EMP protection at the bay or box level. Our job is to measure the effect at the box level to insure there is adequate protection. Therefore, the skin conductivity does not really matter to the testers.

If the skin is conductive, then the B-2 will probably not be much different from the B-1B in EMP protection. Most state-of-the-art composites contain graphite and are conductive and potentially have polarized or directional conductivity. There are also techniques for sandwiching metal mesh inside the composite to provide conductivity. Also, the B-2 has to meet a lightning specification which imposes much higher currents on the aircraft than EMP does. To handle the lightning currents, conductive skins are almost certainly required. For these reasons, there is a high probability the skins are conductive. Again, conductive vs nonconductive mattered a lot to the people designing the EMP protection, but that is past and NTA was left out of that effort. For testing of the B-2, it really doesn't matter very much except that any directional conductivity of the skin will have to be considered in selecting aircraft test orientations.

6.1.3 FIBER OPTICS VS STANDARD ELECTRICAL SYSTEM

A second issue is whether the aircraft has fiber optics or standard electrical system. If it has fiber optics, the fiber optic cables will be immune to EMP effects. The electronic boxes associated with the fiber optic cables will need to have voltage/current measurements taken. No significant research effort would be required to test these boxes. Northrup would supply the design details and suggested access points for test measurements.

Most likely the B-2 uses a multiplexed wire electrical system similar to the B-1B. If so, the only real issue is gaining access to the hundreds of line replaceable units (LRUs) and cables to take test measurements. This is a coordinated effort between NTA who knows the measurements needed and the instrumentation available, and the contractor who understands the aircraft design. It usually takes about 18 months for the team to work out the details of the test.

6.2 DIRECT DRIVE TESTING

The above paragraphs have addressed free field testing of the B-2. A second and very important part of the test is direct drive testing of the LRUs. Depending on how the B-2 EMP specification is written, there will probably be a requirement to direct drive each box with a given waveform/current/voltage. If possible, NTA would like to drive the boxes with a composite waveform that insures the resonant frequencies are hit. The real issue is access. Everything will be tightly packed into bays on the aircraft. Getting the necessary wires and probes into the LRUs is always a challenge. Each aircraft also has a different wiring design. This means we have to work with Northrup to identify ways and places to inject the necessary current onto the wire at the LRU. Again, this is no different from the things the B-1B team went through to get ready for that test.

The test probes and data collection system used on the B-1B worked but can definitely be improved. There are problems with the 6880 digitizers such as "clock spikes" and non-stationarity that need to be addressed. These problems complicate any type of noise filtering and norms calculations.

The B-1B had problems with the current noise filtering procedures. Automated processing must be established which does not require user intervention. Thus, there will be some refinement in procedures, improvements in software, and possible probe improvements prior to the B-2 test. These changes have no major impact on the test effort but may help reduce the time required for certain operations or make probe placement easier if the probes get smaller. The 18-month test planning effort works out the details of the direct drive testing. There is no need for a major effort to change data systems, probes, or test techniques based on new technology expected in the B-2.

6.3 HARDNESS MAINTENANCE/HARDNESS SURVEILLANCE

One of NTA's PMD responsibilities for the B-2 test is to develop HM/HS test procedures, techniques and a data base for the aircraft. Present planning is to use the ellipticus antenna for continuous wave (CW) testing. The ellipticus is an improvement on the hardness surveillance illuminator (HSI) used during the B-1B test and presently operational at OC-ALC. Although currently in the design stage, ellipticus will be checked out with EMPTAC prior to the B-2 test and may be in operational use at OC-ALC. If ellipticus doesn't prove to be a desirable CW tester, the HSI would be used on the B-2. Obviously, the development and checkout of the ellipticus would have to be completed well before the B-2 test. Barring major funding cuts, this will easily be accomplished.

A final area of testing and test technique development is aperture testing of equipment access and crew entry doors and windows. The shape of the doors and access for installing sense wires inside the bay are the issues, since the composite skin doesn't impact the test. Since some of our contractor personnel have already participated in aperture tests on the B-2, we will be able to draw on their expertise.

6.4 PLANNING AHEAD

Although there are not any major research efforts necessary to get ready for the B-2, there are areas where NTA can work to insure a better, smoother test. We should work with Northrup and the SPO to arrange for some aperture testing and LRU direct drive testing at the contractor facility. There is never enough time when we get the aircraft here at Kirtland AFB. Also, early testing would flush out problems gaining access to LRUs and injecting current on the cables.

NTA should also refine the norms, especially the derivative norm to reduce data collection/manipulation needs. Along with this, much time is spent rerunning tests to get usable data in areas where there is very little EMP effect. In other words, the data is only slightly above the noise. When this occurs, the area should be flagged for later and the testing should move on quickly to higher priority areas. If there is time, the low readings can be repeated later. There is also a need for a study of ways to improve the noise reduction techniques to allow the maximum signal to noise ratio on test points of interest.

Connectors/breakout boxes always seem to be a long pole for every test. An attempt should be made to identify these early. Testing at the contractor's facility would help this issue. At NTA there always seems to be a frantic effort to locate enough probes for a test. Early attention to buying and checking out the necessary probes will help. NTA will have to work with Northrup to insure sensors can be attached to the B-2 skin for skin current measurements. The composite skin may require some extra attention in this area.

7.0 COSTS

Attachment one is an attempt to predict when various aspects of the stealth/B-2 effort will need to take place. The schedule is based on the assumption that the B-2 will be at Kirtland AFB for a major B-2 specification verification test in the summer of 1992. The milestones that need to be accomplished are listed below with a rough estimate of their cost and where the funds would come from. Shown below are the funds that would come to the Weapons Laboratory. Obviously, a lot more money goes to the involved contractors from the SPO.

Milestone	Amount	Funds From
Test Planning Team	---	
Test Concept Document	100K	B-2 SPO
Test Planning Meetings	10K	3763
Ellipticus Build/Field Map	300K	3763
EMPTAC Under Ellipticus	100K	3763
Modify NORMS	50K	3763
Modify Data Procedures	50K	3763
SPEHS/Square Wave (B-1)	20K	3763
Cable Tester On B-2	20K	3763
Aperture Tester On B-2	20K	3763
SPEHS/Square Wave On B-2	30k	3763
Probe Composite Compatibility	30K	B-2 SPO
Connector Break Out Boxes	400K	B-2 SPO
Buy/Calibrate Probes	125K	B-2 SPO

8.0 SUMMARY

In summary, the B-2 doesn't require modification of the Trestle/VPD/HPD facilities, except for upgrades to approach DoD Std 2169A requirements. There are no technical breakthroughs needed by NTA in order to do the B-2 test. NTA will need to identify a team to develop the test procedures and get ready for the actual test. This team will work with NTA contractors and the B-2 contractors and the SPO to work the thousands of issues related to connectors, breakout boxes, probes, access points, and data collection/processing/analysis. The key challenge is access into the program and SPO support so NTA has meaningful involvement. The early application of HM/HS testers on the B-2 at Palmdale or Edwards AFB is essential and NTA needs to push for this as strongly as possible.

TABLE 1. MILESTONE CHART.

PROGRAM SCHEDULE		SYSTEM NO. (PROJ)		SUBSYSTEM																TYPE												AS OF AUGUST 1989											
LINE	PROGRAM MILESTONES	PRIOR SCHED		FISCAL YEAR 19 90												FISCAL YEAR 19 91												FY 1992				FY 19				FY 19				COMPL DATE	
		MO	YR	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	1	2	3	4	1	2	3	4	1	2	3	4	QTR	FY
1	Test Planning Team			Δ				Δ																																	
2	Test Concept Document								Δ						Δ																										
3	Test Planning Meetings																		Δ											Δ											
4																																									
5	Ellipticus build/map			Δ			Δ																																		
6	EMPTAC under Ellipticus							Δ			Δ																														
7																																									
8	Modify norms						Δ					Δ																													
9	Modify data procedures						Δ							Δ																											
10																																									
11	SPEHS/Sq Wave B-1											Δ			Δ																										
12	Cable Tester on B-2															Δ		Δ																							
13	Aperture Tester on B-2															Δ		Δ																							
14	SPEHS/SQ Wave on B-2																		Δ			Δ																			
15																																									
16	Probe/Composite comp																				Δ			Δ																	
17	Connectors/Breakout Bx																						Δ				Δ														
18	Buy/Calibrate Probes																						Δ						Δ												
19																																									

TABLE 1. (Continued). Comments Related To Milestone Chart.

1. Identify test planning team. WL first. Add SPO/Northrup/Boeing/AFOTEC When possible.

2. Test concept document.
Our involvement unknown at this time. Should try for B-1B type involvement.

3. Test planning meetings.
These go on forever and work all the issues related to the B-2 test. Try to co-chair these with SPO.

5. Ellipticus build/map.
Complete the design, field map and increase power if required.

6. EMPTAC under Ellipticus.
Gain experience with Ellipticus and get ready for B-2 test.

8. Modify norms.
Change or more clearly define derivative norm. Do any other improvements/simplifications suggested by B-1B test.

9. Modify data collection/processing/analysis techniques.
Identify 6880 solutions. Identify viable noise reduction techniques. Examine how the first two items affect norm calculations. Much time is spent getting usable data in areas where the date is near the noise floor. Decide ahead of time to drop those points when they occur. They can be redone if there is time available. Concentrate on the areas of interest.

11. SPEHS/square wave on the B-1B.
If these testers work for B-1B, we will want to get some data with them on the B-2. Therefore, we should try to get some experience with them when the B-1B returns or at the depot at OC-ALC.

TABLE 1. (Concluded). Coments Related To Milestone Chart.

12. Cable tester on B-2.

If at all possible, we should take the cable shield tester to Palmdale or Edwards AFB and get some experience with the B-2 before it comes to Kirtland AFB. This should be a high priority effort.

13. Aperture tester on B-2.

Same as cable tester.

14. SPEHS/square wave/composite waveform direct drive on B-2.

Same as cable tester.

16. Probe/composite compatibility

Insure skin current probes etc. can be attached and grounded with composite skin.

17. Connector/breakout box identification.

A major issue for test planning meetings. Essential to get in orders for connectors early since they are usually scarce and late.

18. Buy/calibrate probes.

Identify any new probes and determine numbers and types of probes/sensors needed (including backups) and start early to procure.

REFERENCES

1. Air Force News Service. "B-2 Undergoes Two Tests Leading to First Flight." Focus [Kirtland AFB, NM] 14 July 1989: 10.

2. Bond, David F. "Latest B-2 Cost Data Spur Mounting Hill Opposition." Aviation Week & Space Technology 3 July 1989: 20.

3. Darrow, Barbara. "Some Nagging Doubts About Stealth." Design NEWS, 24 April 1989: 66-69.

4. F.C.P. "Strategic Bomber Spreads It's Wings." Defense Electronics January. 1989: 42.

5. "General Randolph Refutes B-2 Complaints." Air Force Systems Command Leading Edge, June 1989: 16-17.

6. Goldberg, Jay H. "The Technology of Stealth." Technology Review May/June 1989: 32-40.

7. Rhodes, Jeffrey P. "On Stealthy Wings." Air Force Magazine February 1989: 43-46.

8. Stringer, Jerry "New Facts About The New Bomber" Air Force Systems Command Leading Edge, July 1989: 22-23.

9. Sweetman, B. "Stealth." Interavia November. 1985: 1217-1219. Sweetman, B. "Stealth in Service." Interavia January. 1987: 39-40.

10. "Westinghouse Developing 'Smart Skin' Technology." Aviation Week & Space Technology, 12 June 1989: 284.

DISTRIBUTION

AUL/LSE, Maxwell AFB, Alabama
DTIC/FDAC, Alexandria, Virginia
WL/SUL/HO, KAFB, New Mexico
AFELM Rand Corp, Santa Monica, California
AFCSA/SAMI, Washington, D.C.
Official Record Copy
WL/NTAA/Maj Harold T. Bishop