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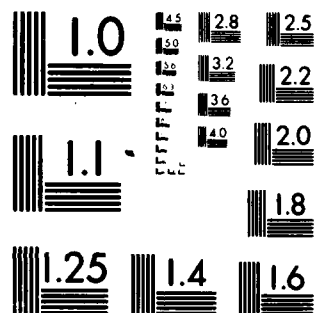
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ON-BOARD AIRCRAFT DAMAGE ASSESSMENT

Boeing Aerospace Company
P.O. Box 3999
Seattle, Washington 98124

1 September 1978

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SUMMARY

If strategic aircraft were damaged in a nuclear encounter it would be vital for the crew to have an accurate assessment of the remaining capability of their weapon system. This study investigated the potential system and component damage categories and evaluated the capability of existing on-board sensors to determine this damage. Current sensors are shown to be inadequate and types of sensors are proposed that could give real time on-board estimates of damage. A plan is presented to develop the hardware, software and procedures for on-board damage assessment.

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PREFACE

This work was funded by the Defense Nuclear Agency under contract DNA001-78-C-0138 as a continuing part of a study of mission completion of strategic aircraft. Capt M. Rafferty (USAF) was the Contracting Officer's Representative and we gratefully acknowledge his support and helpful comments.

The work was performed by Mr. E. N. York as Technical Leader, and Dr. S. L. Strack was the Program Manager.

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1.0 INTRODUCTION

Maximum utilization of strategic forces requires that all aircraft capable of completing their mission should continue the mission even though damaged. Aborts should not be made because of light damage. This is emphasized in the flight training and in strike planning of strategic aircraft. Present emergency wartime doctrine may be summarized as "continue if at all possible." This should result in maximum damage to the primary targets (or alternates in some cases). It may not lead to the most effective utilization of the available surviving aircraft fleet.

The importance of retaining a reserve nuclear force capable of future action is becoming recognized as a necessary part of national military requirements so it is important not to sacrifice aircraft incapable of completing their mission if they might be able to return to a recovery base.

Aircraft capable of reaching a recovery base (or their home base) but not capable of completing their assigned mission would be valuable additions to the nuclear reserve force. Erroneous crew decisions on damaged aircraft can obviously lead to decreased strike effectiveness if missions are aborted that could have been completed. Erroneous crew decisions could also lead to needless sacrifice of valuable reserve forces if hopeless missions are continued. To avoid erroneous decisions the crew needs a knowledge of performance capability not only under current flight conditions but under the expected conditions for the remainder of the mission. Flight control capability that is adequate for mid course cruise may not permit terrain following maneuvers during later mission phases. Projecting damaged mode operational capability for later mission phases will require information not necessarily available from "pilot feel" of current control response. Quantitative information on increased fuel consumption is necessary to determine whether a damaged aircraft (with increased drag) can still reach its assigned target. Quantitative information on roll rates, pitch rates, and yaw rates will be necessary to determine whether terrain following and route following maneuvers remain possible. Such quantitative information is not available at present. Increased fuel consumption can be determined when enough time has passed to permit new engine settings and

measured ground speeds to stabilize. Other aircraft performance changes can only be estimated from the "feel" of control response. Electronic equipment can usually be checked only by turning the equipment on and determining whether it appears to operate properly.

The task of making on board damage assessments is made even more difficult by normal peacetime operating procedures. Standard Operating Procedures very properly have been developed to minimize the likelihood of serious accidents. Any equipment malfunction or structural damage which could jeopardize a flight results in grounding the aircraft until the condition is rectified. In-flight damage of any significance usually results in an emergency landing at the nearest field. Crews therefore have little experience in flying damaged aircraft. Wartime experiences, plus occasional peacetime accidents, have demonstrated that many aircraft fly surprisingly well with dramatic structural damage. While this experience indicates the potential for mission completion by damaged aircraft, there is little quantitative flight test information from past damaged aircraft to provide a basis for predicting flight performance capability. And for any selected crew there is little probability their past flying experience would include aircraft damaged similar to the damage they must assess in making a decision to continue, to attempt alternate missions or to abort.

Target damage assessment will provide an unfolding list of targets destroyed and targets remaining. This information is of maximum value if new/alternate targets can be quickly attacked or if repeated attacks can be quickly directed against targets surviving prior attack. The flexibility of manned aircraft offers the potential of capitalizing on target damage assessment capabilities. But to do so within minimum time requires the changed target lists to be within reach of the existing aircraft. To determine whether new targets are within "reach" requires information on the performance capability of the aircraft. For damaged aircraft this must include quantitative assessment of the remaining capability.

Some of the capabilities of aircraft include the flexibility of the crew to react to changed conditions, the ability to recall missions after take off, and the ability to reconstitute at alternate bases. This flexibility cannot be fully utilized unless on board damage assessment permits proper crew decisions on whether mission completion is possible.

2.0 PURPOSE

The major purpose of on-board real time damage assessment is to answer the following questions:

What is the remaining capability of the aircraft?

1. What is the military potential of the ordnance/armament/payload if it can be delivered to a target?
2. What is the flight performance capability for getting to a target?
3. What is the ancillary/support equipment capability (ECM, communication, navigation) to contribute to arriving at a target?
4. What is the capability of reporting on remaining capability to permit battle capability evaluation by command organizations?

A program to assess the feasibility of real time on-board damage must address the operational implications as well as technical capability.

1. If perfect on board real time performance capability information were available, what decisions should the crew be expected to make? What decisions can be made when the information is limited?
2. What information could be derived from existing available sensors? What additional information could be derived from minor modifications to existing sensors or by inexpensive additional sensors? Will information that is reasonably achievable be adequate to permit useful crew decisions?
3. If the best possible decisions are made, is the increased effectiveness worth the additional cost and effort? Are there any possible dramatic payoffs or will potential improved effectiveness be of minor significance.

The purpose of this current task was to prepare a program plan for resolving the problems involved in on-board damage assessment. It was anticipated the plan would be developed through the following steps.

1. Identification of potential system and component damage categories.
2. Preliminary evaluation of existing on-board sensor capability.
3. Identification of categories of testing methods and procedure for flight crew use.
4. Development of the sequence of actions necessary to specify and develop hardware, software and procedures for on-board damage assessment.

3.0 DAMAGE CATEGORIES

A review was made of several previous aircraft hardness assessments (analyses) to determine whether unique problems or situations existed that were peculiar to specific aircraft or whether different aircraft had the same damage categories. It was found that differences (in terms of damage assessment) among the various aircraft examined were mainly in the number of components and how they were grouped into identified (named) subsystems. In some cases components were grouped, and examined, as pneumatic, hydraulic, electrical or mechanical and in other cases as flight control, engine control, or environmental control. The differences between aircraft appeared to be more a matter of subsystem nomenclature than actual functional differences. Strategic bombers were then selected as typical aircraft to examine and damage categories identified that would be appropriate to the nomenclature used for strategic bombers. The same or quite similar categories are expected to be applicable to other aircraft types. Table 1 lists identified damage categories.

TABLE 1. DAMAGE CATEGORIES

A. Pilot/crew injury/disability/confusion

1. Visual Impairment
 - a. Flash blindness - reduced ability to see/interpret instruments
 - b. Retinal burns - small blind spots
2. Physical injury
 - a. Thermal burns of exposed skin
 - b. Mechanical injury from violent aircraft displacements and accelerations
 - c. Lacerations, cuts if canopy spalls or fails
3. Radiation Sickness (from cloud penetration)
 - a. Nausea
 - b. Vomiting (extremely serious if wearing oxygen masks)
 - c. Weakness
 - d. Loss of coordination
4. Confusion/disorientation
 - a. Increased work load, requirement for many rapid decisions if damage occurs. Increased opportunity for errors with little time to correct them.
 - b. Increased tension, probability for errors, if mission is not progressing as planned and practiced.
 - c. Distraction by concern for friends, family members, if evidence indicates a nuclear war has started.

B. Electrical/Electronic Equipment

1. Upset or damage to primary flight instruments
2. Upset or damage to engine instruments and power control system
3. Upset or damage to navigation equipment
4. Upset or damage to communication equipment
5. Upset or damage to mission equipment
 - a. Offensive equipment
 - b. Defensive equipment

6. Upset or damage to monitoring instruments and devices
 - a. Engine performance, flight performance
 - b. Emergency systems
 - c. Damage assessment devices

C. Aircraft Structural Damage

1. Secondary Structures
 - a. Thermal blistering or roughening of painted surfaces
 - b. Denting of access panel covers, aerodynamic fairings
 - c. Denting or loss of control surfaces
 - d. Loss of skin panels
 - e. Denting or loss of flight augmentation devices - flaps, slats, spoilers, dive brakes
 - f. Damage or loss of radomes, antennas
 - g. Cracking or loss of windows, windshield, camera ports
2. Engines
 - a. Surge, stall, flameout
 - b. Nacelle damage
 - c. Engine/nacelles lost
3. Primary structure
 - a. Warping, denting of wings, empennage, fuselage
 - b. Loss of leading edges, trailing edges, wing tips
 - c. Shearing of rivets and fasteners
 - d. Buckling of ribs, frames and stiffeners
 - e. Buckling of spars
 - f. Tension failure of ribs, frames, stiffeners
 - g. Tension failure of spars

4.0 ON-BOARD SENSOR CAPABILITY

4.1 Damage Data

A preliminary evaluation was made of combat damaged aircraft reports to determine whether existing on-board sensors, visual observations by the crew, and flight control response would be suitable for real time damage assessment. The information was obtained from the Combat Data Information Center at Wright-Patterson AFB.

There were two reports of "mission completion" (one after bomb release) where there was degradation in the handling and control capability that would have been valuable to investigate farther, but the reports had minimal or no pilot debriefing, so it was not possible to determine if the pilot really knew what damage had occurred. Even the on-ground damage assessment described only the number of holes patched and not the subsystem damage which could have caused "soft" or degraded control.

Discussions with military pilots and ex-pilots revealed that pilots were not aware of any way of determining structural damage other than the limited visual examination from the cockpit. The crew of an aircraft which lost its vertical fin in severe turbulence in 1964 were not aware of the actual physical damage until a chase plane gave them details. They were, of course, very conscious of the lack of adequate flight control.

It was felt that the maintenance reporting system might provide damage assessment information but it was found the system is wired only to systems within the avionics bay and weapons system bay. It does provide permanent records (paper trace) on the performance of a number of systems but provides no information on flight performance capability of the aircraft.

4.2 Existing Sensors

The available information on sensor capability, read out/displays, and crew visual capability were examined to determine their ability to provide information related to four topics:

1. Free-field environments, such as thermal radiation, peak overpressure, neutron fluence, gamma dose and electromagnetic pulse (EMP) field strength which potentially can be measured to predict damage conditions.
2. Immediate aircraft responses, such as inside surface skin temperature, amount of wing tip deflection, strain of structural members, and accelerations which potentially can give assurance that no damage occurred or give estimates of magnitude of damage.
3. Post-encounter aircraft visual appearance and flight performance. Visual observations could determine whether control surfaces are damaged. Flight performance (control response and roll, pitch and yaw rates at specified control inputs) could determine ability to perform required maneuvers later in the mission. Changed air speed at fixed engine settings could determine increased drag and increased fuel consumption.
4. Mission Equipment/electronic equipment performance, methods of determining operational status and damaged mode capability which could determine whether mission essential electronics can still perform acceptably.

Since none of the equipment examined offered any acceptable degree of on-board damage assessment capability, the intent of ranking different existing sensors was abandoned. Instead it was found more useful to examine the capability of additional sensors or hardware to aid on-board damage assessment.

4.3 Future Sensors

1. Burst location, yield determination and prediction of damage.

If the yield, height of burst, azimuth, and distance from a nuclear burst can be measured then the damage can be predicted to some extent. A combination of an EMP sensor (high frequency dipole or loop antenna and receiver) and a thermal sensor (photocell or photomultiplier) can give very high reliability of determining that a nuclear detonation has occurred. The yield can be determined reasonably well (probably within $\pm 30\%$) by measuring the time from the first

flash of light to the first thermal minimum or to the second thermal maximum. This requires either a visual readout or a precalibrated timing circuit to determine the time from sensor activation to minimum or maximum. Azimuth to the burst location can be determined by radar returns from debris from surface bursts, or from the ionized radar shadow region (no return) from air bursts. Existing weather radars, and search radars are capable of determining azimuth to a nuclear burst providing they have the necessary azimuth coverage. A ring of photocells, each collimated to a narrow field of view, can determine the azimuth to a burst as can any wide angle optical system with an imaging readout. The optical systems developed for IR seeking or optical seeking missiles could be adapted for nuclear burst azimuth determination.

No quick reliable means for determining the distance to a nuclear detonation has been uncovered. The only highly reliable method is to obtain two azimuth readings or to measure the rate of azimuth change and to calculate the distance from geometry. This requires flight times long enough to fly a base leg adequate to obtain suitable azimuth readings plus heading changes in case the burst is nearly head on or tail on. This triangulation to obtain distance is probably of little practical use since the time required is excessive compared to the time available from burst to blast wave intercept. A combination of integrated thermal exposure, and thermally measured yield could be used to give a distance. Variation in atmospheric attenuation, clouds, or snow cover will cause errors in the distance but could be compensated for to some extent by estimates of the ambient atmospheric condition.

2. Free-Field Intensities at the Aircraft and Prediction of Damage.

Sensors are available to measure most of the free-field intensities that are of concern for aircraft damage. Peak overpressure can be measured by either mechanical, electrical, or piezoelectric sensors. Thermal flux and integrated thermal exposure can be measured by calorimeters, by photocells, or photomultipliers. Ionizing radiation can be measured by ionization chambers or by radiation sensitive crystal detectors. Gust velocity and gust angle of attack could be measured by a pitot static system and angle of attack indicators for nearly head on gusts or for overtaking gusts. Gust velocity for side on gusts or vertical gusts could be calculated from the difference in total pressure

measurements on the upstream and downstream sides of the fuselage. An array of 4 sensors located at 90 degree intervals around the fuselage would cover gusts from all directions. If the free-field environments are measured, then damage can be predicted from existing computer codes.

3. Aircraft Reponse and Prediction of Damage.

Sensors are available to measure almost all the initial aircraft response modes that are of concern for damage prediction. Abrupt changes in altitude can be measured by barometric altimeters or radar altimeters. Abrupt changes in attitude can be measured by attitude reference instruments such as directional gyros, artificial horizons, turn and bank indicators, or the inertial navigating system. Skin temperatures can be measured by thermocouples. Strain gages can measure the peak strains in selected structural members to determine fin bending loads, horizontal tail bending loads, wing and nacelle bending loads, and fuselage bending and torsion loads. Engine RPM and tail pipe temperature can determine engine response to the blast wave encounter. If sure safe values and predicted damage values are available for these measurements, then damage can be predicted reasonably well.

4. Observation of Structural/Mechanical Damage.

Visual observation and changed control response are currently the most reliable way of determining that structural damage has occurred. However evidence from in-flight accidents indicates that the visual observation field of view is extremely limited. In several accidents the crew have been unable to determine that structural damage had occurred or even knowing that damage was present they could not assess the magnitude of damage. Whenever the damage is within the crew field of view, then visual assessment of the damage is good. Methods of improving the visual field of view therefore should be very useful in assessing external structural damage. Optical periscopes which could be extended above and below the fuselage are one candidate. A movable TV camera or several fixed TV cameras is another promising candidate. Changed control response is usually an immediate and dramatic indicator of damage to the control surfaces. If flight control is adequate to regain stable flight, then response to known control forces offers a method of estimating control surface damage. At present, the actual control forces are not known and cannot be readily determined since control surfaces are moved by actuators with stick forces obtained from

synthetic constraints to provide realistic feel. Damage to internal structures such as frames, stringer, spars, ribs, or longerons cannot be assessed from external viewing and are seldom readily accessible for inside observation. Strain gages can be used to show deformation which indicates damage and strain gages can be placed anywhere desired.

Another promising technique for determining damage to internal structures is acoustic/vibration changes. Damaged structure does not generate or transmit the same vibration frequencies as sound structure. This has been used as a monitoring device and diagnostic method for detecting incipient damage to rotating machinery. For aircraft structure a buzzer or vibrator could introduce a signal which is read at the other end of a structure of interest - say a wing spar. If the structure sustains damage, the frequencies transmitted would be changed. Another indicator of damage can be obtained from drag changes which manifest themselves as changed airspeed at same engine settings, changed trim settings to retain selected attitude, and changed engine speeds and areas of fuel consumption to retain desired airspeed.

5. Observation of Avionic Damage.

Many avionic items have self-diagnostic routines to indicate malfunctions or damage. In others, damage will be obvious from erratic operation or complete shutdown. In general the assessment of damage to avionics will therefore be straightforward. It may take considerable time to check all on-board avionics but in most cases evidence of damage will be easily determined. But whether the equipment is operational or not is usually easy to determine (not necessarily rapidly).

Exceptions are offensive avionics which are not turned on and viewing devices or receivers which have no active emitters in range. Negative output from damage is difficult to separate from an absence of emitters unless self-diagnostic routines or circuits are incorporated in the design.

6. Damage to Damage Assessment Equipment.

The addition of diagnostic equipment always introduces the potential for false information when the diagnostic equipment malfunctions. For any equipment items added for on-board damage assessment design requirements must assure that the

added equipment is more rugged than the equipment to be monitored. This should not be difficult since most of the potential damage assessment equipment items are relatively simple compared to most avionics.

A combination of sensors appears to be the best way to provide on-board damage assessment as no one sensor can answer all damage assessment questions. The following items seem most useful.

1. Reliable Nuclear Burst Detection.

Because of the likelihood of closed curtain operation crew observation of a detonation is not reliable so a nuclear burst detector is necessary. Extremely high reliability and low false alarm rate can be obtained by a combination of an EMP sensor and a photocell light detector. False alarms (primarily from lightning) can be minimized by requiring simultaneous EMP and light signals with the light having a double pulse. Circuitry to achieve this is not difficult. Rough direction of the burst, perhaps by an array of photocells, is essential for prompt initiation of escape maneuvers.

2. Selected Aircraft Response Measurements.

Abrupt changes in altitude, in attitude, in indicated airspeed, and in engine operation can be determined from existing flight indicators. Addition of thermocouples to measure skin temperature rise at several locations could establish the absence (or presence) of thermal damage. Strain gages on major structural components could establish whether safe flight loads were exceeded. Power, space, and weight requirements for thermocouples and strain gages are minimal. Stored readout of peak values should not be difficult.

3. Observation of External Structural Damage.

A movable TV camera which can be extended above and below the fuselage would permit remote visual observation of the entire external surface. Lighting would be required for nighttime observation.

4. Vibration Frequency Spectrum Transmission for Internal Structural Damage.

This would require a development program and the establishment of normal background signatures but the success of vibration frequency measurements for fault detection in large rotating machinery and weld defect testing make this seem very promising.

5. Observation of Avionic Damage.

Diagnostic checkout routines or self-checking circuits would be needed for avionics not already having such features.

6. Control Response Calibration

This could be done by developing a catalog of normal response rates for standard control movements. Comparison of observed response rates with standard rates would give direct measure of control system damage.

7. Drag Increase.

This could be determined from power settings required to maintain selected airspeeds. Revised airspeed and altitude conditions for best remaining range-payload capability could be pre-calculated.

5.0 CATEGORIES OF TESTING METHODS AND PROCEDURES FOR CREW USE

In examining existing equipment and possible additional sensors/equipment for on-board damage assessment nothing was found that is significantly different in training, maintenance, or operational use from other hardware systems. The normal sequence of prototype hardware development, flight testing of equipment, development of operating procedures, crew training procedures, maintenance procedures and fleet deployment can be followed for any potential sensor/equipment items considered. Two facets of on-board damage assessment that could introduce significant differences from the normal sequence of implementing new hardware are the very large number of possible damage situations and the difficulty of making prompt correct decisions in the high stress situation following damage.

The large number of possible combinations of damage to primary structure, secondary structure, flight control surfaces and electronic/electrical systems leads to the requirements for extensive crew training. Flight simulators can be adapted to include readout/display from proposed sensors and the simulated effects of damage can be input to the simulator flying characteristics. This is not technically difficult but it would require a considerable amount of simulator time to provide aircrew proficiency for a representative number of potential damage situations. This could require additional simulators at some air bases. In actual on-board damage situations it is believed that diagnosis of damage will be more difficult than decisions after damage is known. Practice in interpreting readout/displays in flight simulators will be very valuable in diagnosing actual damage.

For purposes of on-board damage assessment one important aspect of damage is how it influences the crew's ability to make proper decisions. This is a somewhat different aspect of damage than is usually addressed in conducting a mission completion evaluation. An example of this difference can be illustrated by the failure of the intercom system in a damaged aircraft. This would not in itself prevent mission completion if the aircraft otherwise could reach the target area, find the target and release its ordnance. Absence of the intercom could however, greatly delay and complicate the process of determining what damage had

occurred and whether mission completion was possible. If the plan is to continue the mission if at all possible, then intercom loss is not serious. If the plan is to make on-board damage assessments and decisions, then intercom loss may seriously degrade the ability for prompt and correct decision making. The fact that damage may strongly interfere with damage assessment complicates the picture, and also points up the value of advanced planning, training and, if possible, flight simulation for damage assessment. Crew stress will be high in any damage situation and stress makes it difficult to properly identify and react to new situations. The fewer unexpected situations occur, the less opportunities there are for mistakes.

The categories of testing and flight procedures that appear useful for developing and implementing on-board damage assessment capability include:

1. Laboratory tests of sensors and display systems.
2. Flight testing of prototype systems
3. Crew training in flight simulators with readout/display systems.
4. Compilation of diagnostic indicators to relate readout/display information to damage.
5. Decision criteria - for each assigned mission at what degraded aircraft capability should the crew elect to:
 - a. continue the mission as planned
 - b. change flight profile but continue to prime target
 - c. change to alternate target
 - d. return to home base
 - e. direct to alternate/emergency base
 - f. bailout.
6. Flight training for a limited number of simulated damage modes.

6.0 OUTLINE OF PROPOSED FUTURE WORK FOR ON-BOARD DAMAGE ASSESSMENT

Planning for the next phase of on-board damage assessment work was completed in June 1978 and an outline for the proposed task presented to DNA. The briefing charts prepared for that presentation are given below:

ON-BOARD DAMAGE ASSESSMENT

PURPOSE

HOW DOES IT WORK

WHAT IS THE PAYOFF

WHAT IS PRESENT STATUS

WHAT ARE NEXT STEPS

PURPOSE

THE PROGRAM WILL PROVIDE THE CAPABILITY FOR A CREW TO DETERMINE THE EXTENT OF THE DAMAGE TO THEIR AIRCRAFT FROM A NUCLEAR ENCOUNTER. IN ADDITION, IT WILL GIVE THEM THE INFORMATION TO MAKE THE BEST DECISION FOR THEIR ALTERNATIVES:

CONTINUE TO PRIMARY TARGET WITH FULL CAPABILITY

CONTINUE TO PRIMARY TARGET WITH MODIFIED FLIGHT PROFILE

REVISE PLANS AND ATTACK ALTERNATE TARGET

SAVE AIRCRAFT ONLY WITH RETURN TO BASE

HOW DOES IT WORK

THE FOLLOWING HARDWARE/SOFTWARE ELEMENTS WILL BE
USED TO GIVE THE CREW NECESSARY INFORMATION

SENSORS TO VERIFY A NUCLEAR DETONATION

SENSORS TO MEASURE THE SEVERITY OF THE NUCLEAR
ENVIRONMENTS EXPERIENCED

SENSORS TO DETERMINE SURFACE DAMAGE

SENSORS TO ESTIMATE DAMAGE TO SELECTED

STRUCTURAL MEMBERS

SENSORS TO DETERMINE SYSTEM DAMAGE - ELECTRICAL,

HYDRAULIC ETC. (THESE GENERALLY ARE EXISTING INSTRUMENTS)

SOFTWARE AND PROCEDURES TO DETERMINE REMAINING

AIRCRAFT CAPABILITY

PROCEDURES FOR SELECTING BEST USE OF REMAINING
CAPABILITY

WHAT IS THE PAYOFF

MAXIMUM COVERAGE OF PRIMARY TARGETS

NO UNNECESSARY ABORTS

BEST USE OF AVAILABLE RANGE/PAYLOAD TO REACH TARGET

BETTER COVERAGE OF ALTERNATE TARGETS WHEN CAPABILITY
DOESN'T PERMIT REACHING PRIMARY TARGET

MAXIMUM RETENTION OF RESERVE FORCE BY AIRCRAFT THAT
WOULD BE LOST IN FUTILE ATTEMPT TO REACH TARGETS

WHAT IS PRESENT STATUS

1. SURVEY OF AIRCRAFT EXISTING EQUIPMENT/SENSORS SHOWS NEGLIGIBLE MECHANICAL DAMAGE ASSESSMENT CAPABILITY EXCEPT FOR FUEL FLOW AND ENGINE TEMPERATURE.
2. DISCUSSIONS WITH AIRCRAFT DAMAGE COMMUNITY INDICATES NO PREVIOUS STUDIES OR SIMILAR WORK TO DRAW UPON.
3. POTENTIAL SENSORS HAVE BEEN IDENTIFIED WITH APPLICATION TO CATEGORIES OF DAMAGE.
4. MAJOR DIFFERENCES BETWEEN STRATEGIC AIRCRAFT AND TACTICAL AIRCRAFT HAVE BEEN IDENTIFIED.

WHAT ARE NEXT STEPS

- I. PRELIMINARY DEFINITION OF POTENTIAL ON-BOARD SENSORS
 - A. BURST LOCATION SENSORS
 - B. FLIGHT PERFORMANCE SENSORS/PROCEDURES
 - C. VISUAL INSPECTION AIDS
 - D. STRUCTURAL DAMAGE SENSORS
 - E. SYSTEM AND SUBSYSTEM EQUIPMENT CHECK OUT CIRCUITS/PROCEDURES
- II. DETERMINE APPROXIMATE SENSOR CAPABILITY FOR 3 LEVELS OF SOPHISTICATION
 - A. BEST PERMISSIBLE STATE OF ART
 - B. REASONABLE ESTIMATE OF MIL SPEC CAPABLE SENSOR
 - C. SIMPLEST KNOWN SENSOR
- III. TRADE STUDY OF EFFECTIVENESS OF EACH LEVEL OF SOPHISTICATION
 - A. CAN THE CREW UTILIZE THE SENSOR OUTPUT
 - B. ARE DECISIONS IMPROVED AS SOPHISTICATION INCREASES?
- IV. DETERMINATION OF ITEMS OF COMMONALITY AND ITEMS OF DIFFERENCES AMONG STRATEGIC AIRCRAFT AND TACTICAL AIRCRAFT

7.0 CONCLUSIONS

An evaluation was made of pilot assessment of the capability of combat damaged aircraft. It was concluded that there was very little existing capability to know what structural damage had occurred. Existing instruments told the crew of fuel leaks or engine fires, but little other information was available. Damage categories corresponding to nuclear damage were considered and it was felt that the crew would have only very limited visual capability to make any on-board damage assessment.

Sensors are existing or under development to determine the range and magnitude of a nuclear burst, and damage could be calculated as inferred from the information. Damage estimating sensors, especially TV cameras, are feasible and would be very valuable for the crew. In addition to merely a knowledge of what damage had occurred, the crew must also be trained to evaluate the damage and make optimum decisions regarding the completion of their mission.

8.0 RECOMMENDATIONS

The capability to make accurate on-board aircraft damage assessments and to then plan their mission in an optimal manner is not yet available to aircraft crews. In order to provide this capability a development test and prototype flight program should be implemented. It would include the following tasks:

1. Define in more detail actual hardware that could be used for on-board sensors.
2. Evaluate sensor capability vs. cost (or sophistication) for existing and developmental sensors.
3. Make a trade study of the ability of the crew to use the damage information as a function of sensor sophistication.
4. Determine commonality and differences in requirements of strategic and tactical aircraft.
5. Proceed with an integrated analysis/test program to develop and put prototype sensors on an aircraft to evaluate their effectiveness.

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