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AIRCREW SHIELDING TO FAST NEUTRONS FROM NUCLEAR DETONATIONS.(U)
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Directorate of Aircraft Maintenance

Aircraft Engineering Division

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Engineering Report S-115

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AIRCREW SHIELDING TO FAST NEUTRONS FROM NUCLEAR DETONATIONS

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Program Element 11898

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Nuclear Survivability/Vulnerability, Nuclear Hardness, Nuclear Radiation, Aircraft, Lifecycle Survivability, Aircrew Survivability, Fast Neutron Shielding, Neutron Fluence.

Future technological advances by enemy nations could compromise the effectiveness of our nuclear hardened manned systems. This study addresses the feasibility of incorporating fast neutron shields into the systems. Such shielding would enhance systems survivability and be very compatible with the use of advanced ECM and bomber defense systems such as missiles, LASERs, and particle beam weapons. It is shown that shielding providing mission completion capability for human aircrews (hence to manned systems) is technically feasible, cost effective, and relatively lightweight. Therefore it is argued that weight and space provisions (at the very least) of such shielding be incorporated into the design of new manned systems.

ABSTRACT

Future technological advances by enemy nations could compromise the effectiveness of our nuclear hardened manned systems. This study addresses the feasibility of incorporating fast neutron shields into the systems. Such shielding would enhance systems survivability and be very compatible with the use of advanced ECM and bomber defense systems such as missiles, LASERs, and particle beam weapons. It is shown that shielding providing mission completion capability for human aircrews (hence to *manned systems*) is technically feasible, cost effective, and relatively lightweight. Therefore it is argued that weight and space provisions (at the very least) of such shielding be incorporated into the design of new manned systems.

INTRODUCTION

Manned military aircraft intended for employment in strategic and/or tactical nuclear warfare could be subjected to environments generated by the detonations of nuclear weapons.* For such systems to provide credible deterrence and combat effectiveness if deterrence fails, they must be capable of surviving exposure to nuclear environments without loss of mission completion capability.

A companion study** addressed the nuclear radiation criteria needed for optimal lifecycle effectiveness. That study considered scenario/threat, technological capability, aircrew susceptibility, and advanced system defenses.

A key factor in the effort was the use of the aircrew "mission kill" radiation dose as a keystone. This "mission kill" dose corresponds to the absorbed radiation dose resulting in 90% of the aircrews being unable to function. The rationale for such a reference point was that the system should retain mission completion capability up to point where even the most resistant human aircrews succomb.

The supporting rationale for the selected nuclear radiation criteria are sound and the numerous factors considered in the analysis dovetail amazingly well. Probably for the first time common nuclear radiation criteria can be strongly defended. However, in the event enemy capabilities improve and we are forced to develop and incorporate advanced ECM and active bomber defenses compatible with the lethal volumes corresponding to the optimal nuclear radiation criteria, a significant percentage of the manned aeronautical systems could be subjected to criteria or near-criteria levels of prompt radiation. In other words, the enemy could gain the future capability to detect and attack our manned aircraft with low-yield nuclear weapons ("neutron bombs") on air to air, or surface to air missiles. In response, our aircraft would use newly installed ECM to "trick" the missiles into detonation outside the bombers' lethal volume, or its active defense (bomber defense missiles, LASERs, etc.) to destroy the missiles outside the lethal volume. Therefore the probability of exposure to criteria, or near criteria radiation could increase drastically, resulting also in increased probability of mission-kill of the manned system fleet.

To regain acceptable system survivability we must either increase the lethal volume (reducing incident radiation on the system), reduce the enemy's capability to detect, track, and attack, and/or "protect" the aircrew by chemical means and/or attenuating the incident radiation. The first option depends upon enhancing the ECM and/or the lethal defensive systems capabilities. Whether or not this is possible is debatable. I suspect that physical constraints may pose serious problems in this approach. The second option would entail increased use of "stealth" technology to decrease the

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*For aeronautical systems, such environment include blast, thermal, nuclear radiation (neutron fluence, gamma dose rate, and gamma dose), and electromagnetic pulse.

**R. Patrick, "Optimal Nuclear Radiation Criteria for Aeronautical Systems", Report S-110, HQ SAC/LGME, Offutt AFB, Ne, May 1981.

probability of detection. However, such effort may be countered by future enemy technological advances. The third option appears highly viable either alone or in combination with one or both of the previous options.

This study addresses the third option in some detail and argues that aircrew shielding should be incorporated in the initial design of new manned systems. At the very least, weight and volume allowances should be made to support possible future inclusion of such shields.

Discussion

The study footnoted previously was concerned with the development of nuclear radiation criteria. Therefore it used the aircrew mission kill radiation dose accumulation as a standard of comparison. It was argued that as long as there are aircrews capable of meaningful performance, the system must be operational. The criteria based upon this requirement were also highly compatible with the state of the art in hardening technology, they provided definitive keep out ranges/lethal volumes, and they were compatible with a minimum life cycle hardness cost philosophy. Therefore there was little need to address the much more thornier problem of aircrew mission completion dose.

In this study we are more concerned with future advances, both our own and the enemy's. Suppose that a few years after we deploy our new manned systems, the enemy improves his capability to detect, track and attack our systems with nuclear-tipped missiles. We respond by incorporating advanced ECM an/or lethal defenses (LASERs, bomber defense missiles, etc.) to increase the survivability of our systems by causing premature detonation and/or destruction of the missiles outside the keep out ranges defined by the system nuclear radiation criteria (which were incorporated into the system acquisition program).

At this point, the probability that a given system (and its crew) would be subjected to near-criteria levels of prompt radiation increases dramatically from the almost-zero value at the time the system was initially deployed to some unknown, but large, level. To regain an acceptable probability of survival we must either increase the keep out ranges of our active ECM/lethal defenses (a formidable task at best), decrease the enemy's ability to detect us (which he could be countered via other advances in technology) or increase the crew survivability.

There are basically two ways we could increase the crew's ability to function after system exposure to radiation, (1) use of chemicals to ameliorate the effects of radiation and (2) the use of radiation shields to attenuate radiation incident upon the system thus reducing the dose actucally accumulated by the crew.

The USAF School of Aerospace Medicine at Brooks AFB, Texas is devoting some effort to the development of a "wartime" pill, which would lessen the symptoms of radiation sickness with minimum side effects. Some success has been made in the area of reducing emetic behavior in test animals by using combinations of standard anti-emetic drugs. For dogs subjected to gamma radiation, the ED$_{50}$ (effective dose causing emesis in 50% of the subjects) of the non treated subjects was about 250 rads (tissue). However the ED$_{50}$ of the dogs administered the combination drug in normal dosages increased to 550 rads (tissue), a more than two increase in the susceptibility threshold.* Such results are highly promising and the follow-on efforts should be stressed much more by using commands and higher headquarters. Otherwise valuable research could be postponed, delayed and/or terminated in favor of projects with more short-term emphasis.

The second crew "hardening" technique is the incorporation of radiation shields into the system to provide protection to the aircrew. However before addressing specific shielding details, we must now turn to that problem noted previously i.e., aircrew mission completion dose levels. Only if we bound the aircrew mission completion radiation levels can we hope to develop shielding that provides adequate protection without imposing unacceptable weight penalties. (Recall that each pound of weight requires several pounds of fuel to carry it, and every pound of weight cuts down the payload). The only operationally acceptable recourse is to use only the absolute minimum shielding required for mission completion.

Major problems in defining a generic mission completion dose are variability in human response to radiation, performance capability variability with dose, type of radiation, time after exposure, workload after exposure, and numerous other factors. Therefore, in general, a mission completion dose must be estimated in terms of the effective dose at which 50% of the population are affected, ED$_{50}$, for a specific operational situation. Such estimates generally are just that ---- estimates. However for the specific case of a manned bomber on a 10-hour strategic mission an experimental research project has been accomplished and the dose used in the experiment should closely correspond to the mission completion dose for the specific operational parameters on which the experiment was based.

In that experiment,** heavy emphasis was placed upon duplicating (as much as possible) mission duration, crew workload, dose accumulation, and many other operational factors of an actual mission. Rhesus monkeys were trained to fly a platform with a joy stick and respond to an array of colored lights (Figure 1) in an attempt to simulate pilot tasks. The workload was varied to match pilot workloads during various mission phases and radiation exposures were planned to approximate the time in the mission they may occur and the level they may attain (see Figure 2).

After the monkeys were highly proficient on both tasks (as evidenced by stable performance (i.e. they were on the "flat" part of the learning curve), they were subjected to the radiation dose accumulation of Figure 2 while performing tasks for the 10-hour mission. Their performance was monitored via data links and a video system. Therefore objective and subjective evaluations of their performance and physical condition could be made. All the subjects were exercised the following day to simulate a post attack mission. Four of the six subjects were exercised on alternate days for seven days post exposure.***

Figures 3 and 4 reflect my subjective opinion on how capable they were to perform effectively. Note that these results are based upon the requirement

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*Personal communication with Dr. D Farrer, USAFSAM/RZW, Brooks AFB, Texas.

**R. Patrick, et al, "Nuclear Survivability/Vulnerability of Aircrews: An Experimental Approach", SAM-TR-81-1, USAF School of Aerospace Medicine, Brooks AFB, Texas, January 1981.

***Results of the seven day post exposure may be obtained from the author.

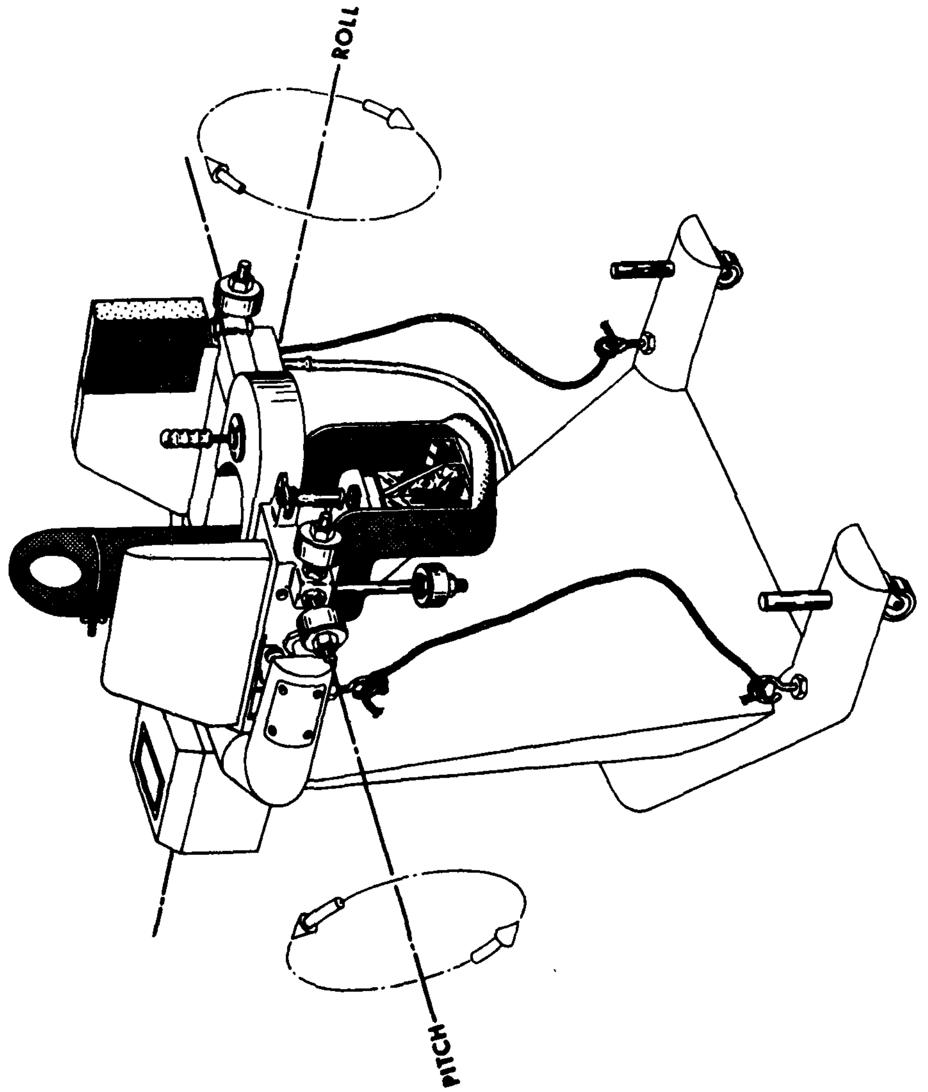


Figure 1. Primate Equilibrium Platform (PEP) with the Multiple Alternative Reaction Task (MART).

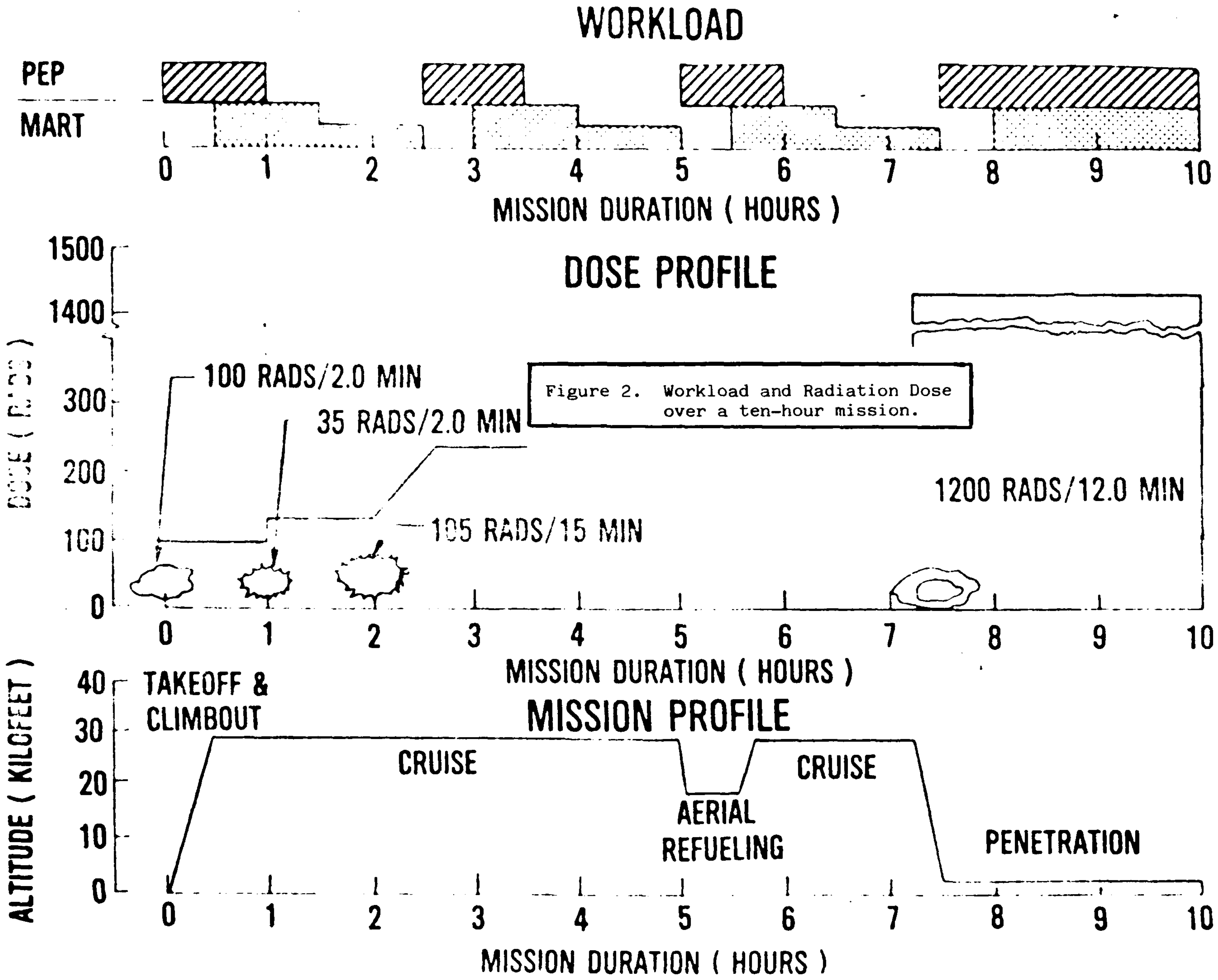


Figure 2. Workload and Radiation Dose over a ten-hour mission.

Figure 3

SUMMARY OF MISSION IMPACTS

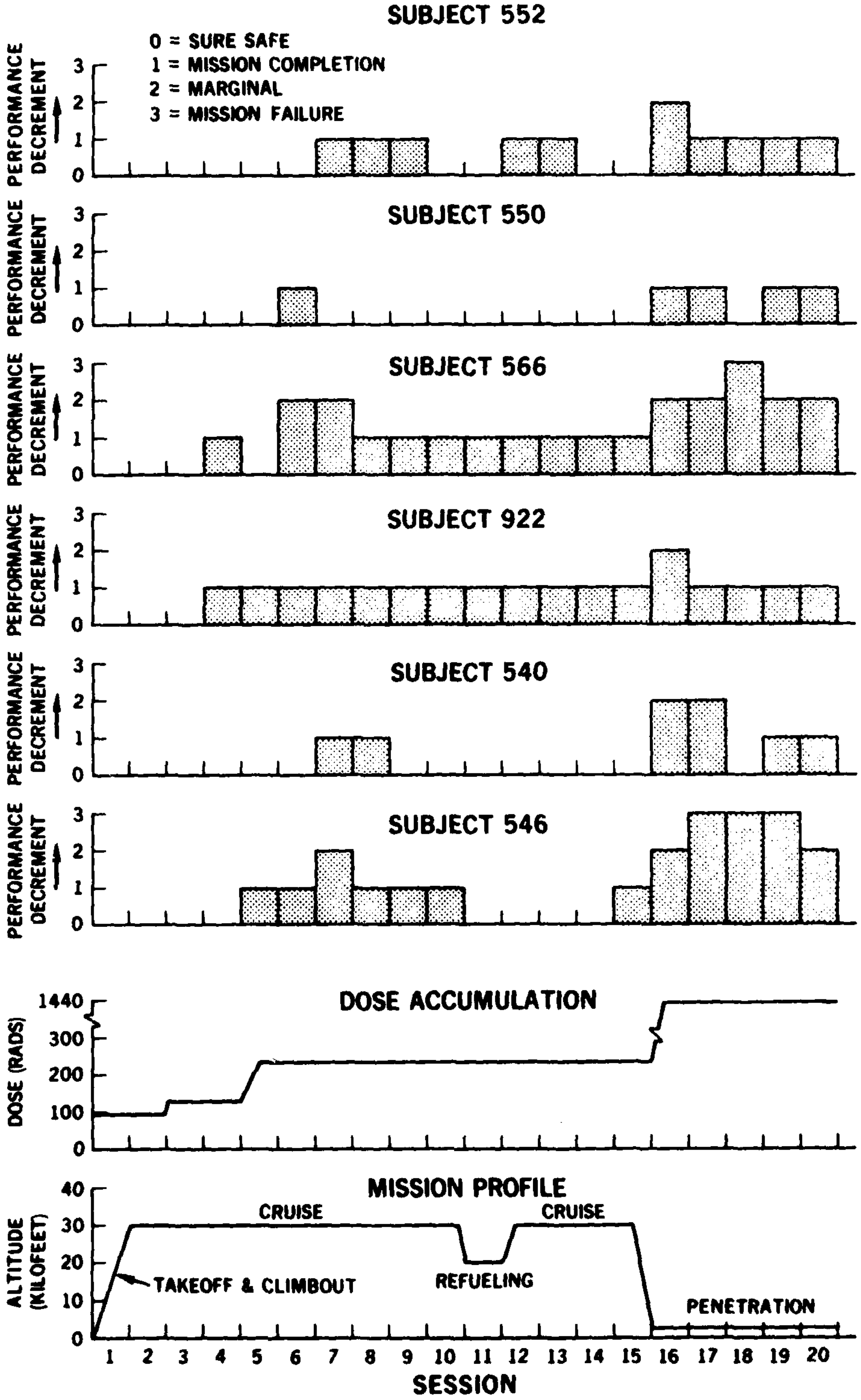
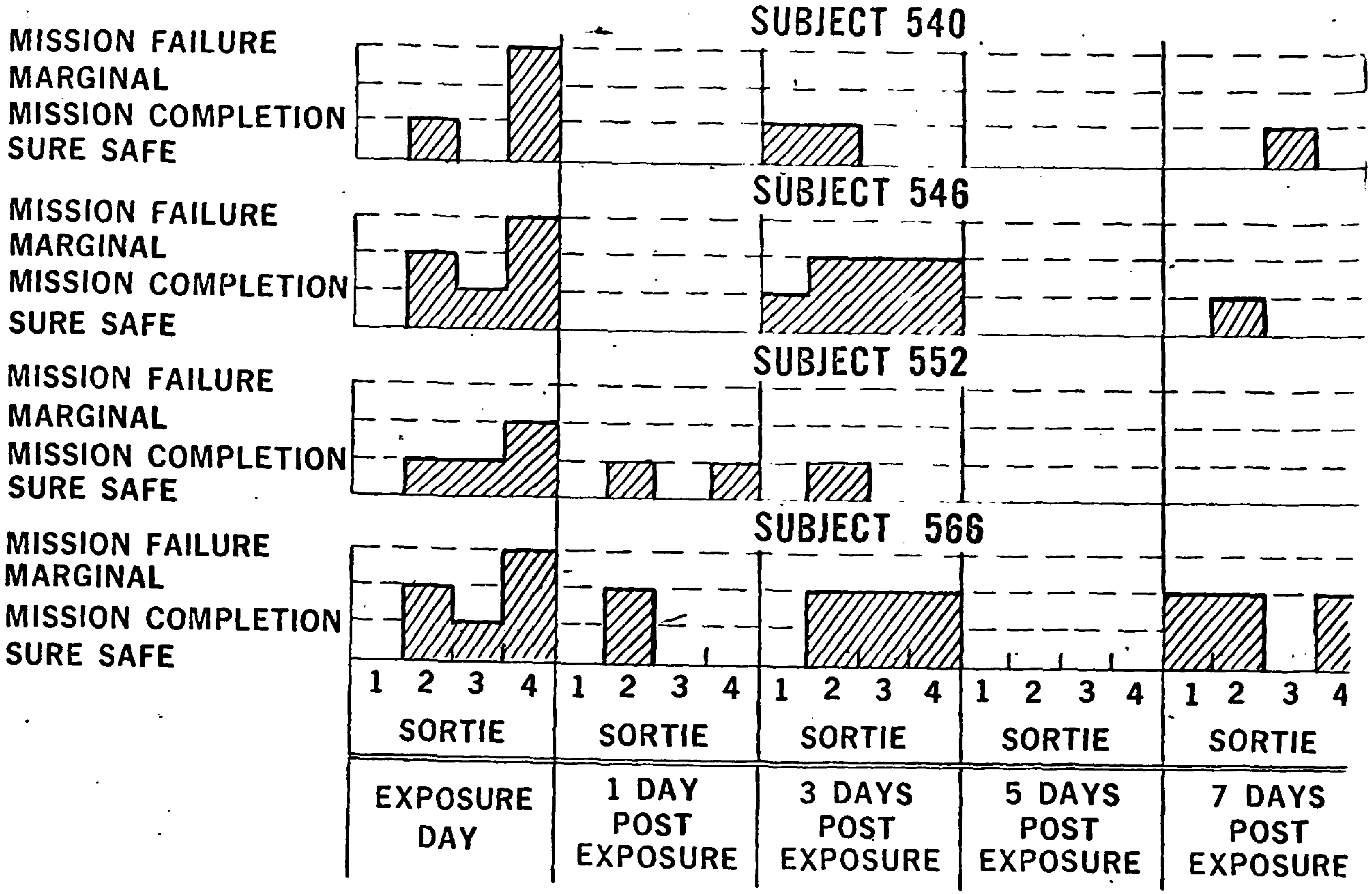


Figure 4

ESTIMATED MISSION IMPACT



the subjects "hand fly" the "aircraft". For this requirement, during penetration, 2 of 6 subjects "crashed and burned", and 3 of 6 were affected. Only 1 of 6 was relatively unimpaired. However note that by the end of the mission all had recovered and were responsive. All subjects performed rather well in the post-exposure runs.

The above results suggest that the 1440 rads dose accumulation could pose problems to aircrews required to perform continously during the mission. If we assume that 1 of 3 crew members would completely lose performance capability for an hour or so, but if we have two crew members, either of whom could take over, then our system mission kill occurs only if both are incapacited, i.e. 1 of 9 chance for mission kill.

On the other hand, if the system were computer controlled (e.g, the B-1) and the system were hardened to survive such exposure, then the system mission kill probability would approach zero. The system could fly itself and "drop bombs" for the hour or so while its crew was incapacitated (with some degrade in CEP). After the period of incapacitation the crew should recover sufficiently to finish the mission and bring the aircraft safely to a recovery base.

It is then claimed that a dose of 1440 rads (tissue) constitutes a mission completion dose for systems of interest here and that sufficient shielding must be added to reduce the total dose expected over the mission to a maximum of 1440 rads (tissue).

If we now return to the criteria study, we find that about 1000 rads (tissue) were attributed to gammas and 4000 rads (tissue) to fast neutrons. Gammas can be effectively attenuated only by dense, high Z material (such as lead), therefore extensive gamma shielding for a flying system (where weight is critical) is not practical. However fast neutrons are attenuated by hydrogen-rich, low Z materials such as water, fuel, and polyethylene. If we could provide a factor of ten attenuation of the fast neutrons, then aircrew mission compeltion capability should be compatible with system hardware mission completion capability when the system is subjected to criteria radiation exposure.

The question now is, "Is it technically feasibile, and cost-effective to incorporate neutron shields with the needed attenuation?" A briefing presented by Lt Col Lauritson of the Air Force Weapons Laboratory strongly suggests that such shielding is indeed practical. It appears that just a few inches of polyethylene impregnated with boron (to attenuate hydrogen capture gammas) would provide the needed attenuation. Of course the shield should be integrated into the cockpit structure, seats, instrument panels, glare shields, etc. Consideration must also be given to probability of detonation within any solid angle and insure that the high threat angles are treated. Flip-up shields may be a viable option during high threat mission phases for angles where permanent shields are not feasible. Such flip-up shields may either be used by both crew members simultaneously, or alternately to allow for at least one protected crew member.

In the design of the shield, attention should also be paid to the susceptibilities of the various parts of the body. For example, the limbs (arms and legs) could probably be exposed to many thousands of rads (tissue) and not result in any appreciable performance degradation. The head and brain also are relatively hardy. The most sensitive part of the body appears to be the trunk, particularly the gastro intestinal tract. Hundreds of rads in this area results in classical radiation sickness symptoms, which could impair performance.

A "first cut" shield was discussed in the AFWL briefing. Such a shield was composed of several inches of strategically located impregnated polyethylene. A factor of 15 attenuation to fast neutrons and a factor of 2 attenuation to gammas was the estimated protective factor. The additional weight per crew member was estimated to be 150 pounds. Such a shield would provide the needed increase in system survivability at little cost in weight.

RECOMMENDATION

The results presented in this brief study strongly suggest that new advanced manned systems could be made more survivable in the face of future enemy advances in technology by the incorporation of fast neutron shields into the cockpit design. The addition of such shields should be excellent investment strategy since they could provide dramatic increase in future survivability for relatively little cost. Therefore, it is recommended that new manned systems incorporate, at a very minimum, weight and volume provisions for such shields.

It is also recommended that the USAF School of Aerospace Medicine be strongly supported in their effort to develop a "wartime pill" to further enhance new survivability.

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