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Nuclear Vulnerability of the U.S. M60A1 Tank in an Initial Radiation Environment: Mash Code System Analysis

J. M. Barnes
J. O. Johnson
T. J. Burns
J. D. Drischler

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Engineering Physics and Mathematics Division

NUCLEAR VULNERABILITY OF THE U. S. M60A1 TANK IN AN INITIAL RADIATION ENVIRONMENT: MASH CODE SYSTEM ANALYSIS

J. M. Barnes*
J. O. Johnson
T. J. Burns
J. D. Drischler

*Computing and Telecommunications Division

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The authors would first like to express their gratitude to the Defense Nuclear Agency for continuously supporting and patiently monitoring the development, verification, and validation of the MASH code system. The authors would like to thank D. Kaul and S. Egbert of Science Applications International Corporation for their efforts in transcribing the M60A1 geometry from written output into a computer file for use in the MASH analysis. The authors would also like to thank H. Caton of Ballistic Research Laboratory for his efforts in recovering the original VCS analyses that is used in this study. Finally, the authors would like to thank Mrs. Sue Shriner for her significant efforts in preparing this manuscript for publication.

EXECUTIVE SUMMARY

This report summarizes the results of a re-assessment of the prompt nuclear weapon radiation shielding characteristics of the U. S. M60A1 medium tank utilizing the Monte Carlo Adjoint Shielding Code system - MASH. Comparisons to the Vehicle Code System (VCS) results previously calculated and documented by Ballistic Research Laboratory (BRL) are also presented. Results of this study (along with other studies) are to be used in the recommendations to the North Atlantic Treaty Organization (NATO) Panel VII Ad Hoc Group of Shielding Experts for replacing VCS with MASH as the reference code of choice for future armored vehicle and other nuclear vulnerability calculations.

The capability to accurately assess and predict the nuclear shielding effectiveness of materials in vehicles, structures, trenches, and other configurations is of considerable interest to the Department of Defense (DoD) and the Defense Nuclear Agency (DNA). A research effort involving several institutions has worked towards providing this capability for several years, resulting in the first code system called VCS and the successor, referred to as MASH. MASH was specifically designed to calculate the neutron and gamma-ray radiation environments and shielding protection factors (the ratio by which the free-field radiation is reduced due to the presence of the vehicle or structure). MASH employs a forward discrete ordinates calculation to determine the neutron and gamma-ray flux on a coupling surface surrounding the armored vehicle or shielded structure and an adjoint Monte Carlo calculation to determine the dose importance of the surface flux. MASH then folds the flux together with the dose importance to yield the desired detector response(s).

Radiations from a nuclear weapon can be time-segmented for the purpose of shielding analyses. Initial radiations are conservatively defined as those occurring within one minute of the burst. All subsequent nuclear emissions are called residual radiations. The significant constituents of initial nuclear radiation in the free field are prompt neutrons and secondary gamma rays resulting from neutron interactions with the nuclei of the air and ground. The radiation source used in this study (and in the previous BRL study) is an unclassified 1 kt boosted fission nuclear weapon detonated at a height of 100 meters above the ground. The neutron yield is 3.102×10^{23} neutrons. The dose to shielded systems from prompt (fission) gamma radiation generated during a weapon burst is generally negligible and, therefore, was ignored in this work.

The weapon source spectrum was modeled in the discrete ordinates codes to determine the air-over-ground environment from which the flux on the coupling surface could be obtained. The air-over-ground model utilized 140 radial intervals and 175 axial intervals in a flat topographical r-z model to represent a 2500-m by 2500-m air environment. One meter of ground was included to model ground scattering. The source height was set at 100 meters above the air/ground interface at the center of the radial mesh (r=0.0). Six source/vehicle ground ranges (170, 340, 680, 1020, 1360, and 1700 meters) were chosen for obtaining the flux on the coupling surface. The radiation shielding characteristics for the "battlefield condition" vehicle configuration of the M60A1 was investigated in this study. In the "battlefield condition," the turret is oriented with the gun in the forward position with the hatches closed and with a full complement of ammunition and fuel. Four vehicle orientations relative to the weapon detonation (front facing, left side facing, right side facing, and rear facing) were investigated. Four detector locations were chosen for calculation of the dose inside the M60A1. These corresponded to the mid-head position for the commander, loader, gunner, and driver of the M60A1. The crew members were each represented by a four body description consisting of a head, torso, thighs, and legs. The Snyder-Auxier neutron tissue dose and Claiborne-Trubey gamma tissue dose response functions were utilized to obtain the dose at these locations.

The adjoint Monte Carlo calculations for the commander, loader, and gunner detector positions, generated and tracked 100,000 primary source particles sampled over the energy range of interest. The driver detector position required 200,000 primary source particles to obtain statistical convergence responses similar to the other three crew member locations. An energy dependent relative importance factor was utilized over the energy range to increase the frequency of sampling the adjoint source particle from energy groups which have a significant effect on the dose response function. The secondary particle production probability was set to unity for all regions and energy groups in the Monte Carlo calculations, and the in-group energy biasing option was switched on. Only one region dependent and energy independent set of splitting and Russian Roulette parameters was utilized in the calculations. The results of the above parameter setup allowed nominally 90 to 95 escaping particles for each 100 source particles generated. Since the adjoint leakage file is utilized to obtain the dose response at the detector location, maximizing the number of leakages per source particle (without biasing the "true" adjoint leakage spectrum) is of prime importance in obtaining adequate statistical convergence in an efficient manner. Optimizing splitting and Russian Roulette parameters on a geometry model as complicated as an armored vehicle is virtually impossible. The only reasonable alternatives for improving statistics is to increase the total number of source particles generated and tracked, or simplifying the geometry model.

The VCS and MASH neutron protection factor (NPF) results show a factor of 1.3 for the commander, 1.8 to 1.9 for the gunner, 1.6 to 1.7 for the loader, and approximately a factor of three for the driver (3.5 for VCS, and 2.8 for MASH). The decrease in the NPF as a function of crew elevation in the vehicle indicates a large fraction of the dose enters from the top of the vehicle. The gamma protection factor (GPF) results ranged from approximately 3 to 36 for the VCS calculations and 3 to 32 for the MASH calculations, depending on crew member location, vehicle orientation, and source/vehicle ground range. Neutron protection factor changes versus vehicle range relative to point of burst are negligible, whereas variation of the vehicle orientation relative to the source can have a significant effect on both the neutron and gamma protection factors.

The NPF represents the degree of protection afforded by the M60A1 tank against initial radiation. For all cases in which the in-vehicle total radiation dose (neutrons and secondary gammas) exceeds 100-cGy (distances less than or equal to 1020 meters source/vehicle ground range), the neutron dose (including vehicle secondary gamma radiation dose) to the crew members comprises greater than 90% of the total initial radiation dose. As the in-vehicle dose increases (vehicle moving closer to the source), the effective contribution from air and ground secondary gamma radiation decreases. At 170 meters ground range, the neutron dose contribution (direct neutron and vehicle secondary gamma production) in all configurations exceeds 98% of the total dose. Therefore, even though the gamma protection factors range from approximately 3 to 35, they represent protection from an insignificant portion of the total dose and are not representative of the degree of protection afforded the crew members in the M60A1 tank.

Analysis of the neutron and gamma doses and protection factors indicate excellent agreement between VCS and MASH. VCS calculated a NPF of 1.8 and a GPF of 6.9, and MASH calculated a NPF of 1.7 and a GPF of 6.5. These factors represent the M60A1 "vehicle" protection factors and are the vehicle average independent of crew position. The results from both codes systems also exhibited the same trends relative to crew member location, source/vehicle ground range, and vehicle orientation. Slight differences were seen in the neutron free field doses, and neutron and gamma doses at the driver location. The principal differences in the doses at the crew member locations were due to vehicle secondary gamma production (vehicle (n,γ)), and ground secondary gamma production (ground (n,γ)).

ABSTRACT

The capability to accurately assess and predict the effectiveness of radiation shielding materials in vehicles, structures, trenches, and other configurations is of considerable interest to the DoD and the DNA. A research effort involving several institutions has worked towards providing this capability for several years, resulting in the first code system called the Vehicle Code System (VCS) and the successor to VCS, referred to as the Monte Carlo Adjoint Shielding Code system - MASH. The purpose of this report is to present the results of a re-assessment of the prompt nuclear weapon radiation shielding characteristics of the U. S. M60A1 medium tank utilizing the MASH code system, and comparison to VCS results previously calculated and documented by BRL. Results of this comparison are to be used in the recommendations to the NATO Panel VII Ad Hoc Group of Shielding Experts for replacing VCS with MASH as the reference code of choice for future armored vehicle and other nuclear vulnerability calculations.

In general, the VCS and MASH neutron protection factor (NPF) results show a factor of 1.3 for the commander, 1.8 to 1.9 for the gunner, 1.6 to 1.7 for the loader, and approximately a factor of three for the driver (3.5 for VCS, and 2.8 for MASH). The gamma protection factor (GPF) results ranged from approximately 3 to 35 depending on crew member location, vehicle orientation, and source/vehicle ground range. Neutron protection factor changes versus vehicle range relative to point of burst are negligible, whereas variation of the vehicle orientation relative to the source can have a significant effect on both the neutron and gamma protection factors.

Analysis of the neutron and gamma doses and protection factors indicate excellent agreement between VCS and MASH. VCS calculated a NPF of 1.8 and a GPF of 6.9, and MASH calculated a NPF of 1.7 and a GPF of 6.5. These factors represent the M60A1 "vehicle" protection factors and are indicative of the vehicle average independent of position. The results from both codes systems also exhibited the same trends relative to crew member location, source/vehicle ground range, and vehicle orientation. Slight differences were seen in the neutron free field doses, and neutron and gamma doses at the driver location. The principal differences in the doses at the crew member locations were due to vehicle secondary gamma production (vehicle (n,γ)), and ground secondary gamma production (ground (n,γ)).

1.0 INTRODUCTION

1.1 Objective

This paper summarizes the results of calculations to estimate the nuclear radiation shielding characteristics of the U. S. M60A1 medium tank utilizing the new Monte Carlo Adjoint Shielding (MASH) code system.[1] The MASH results are compared with results previously calculated and documented[2] by the Ballistic Research Laboratory (BRL) using the Vehicle Code System (VCS).[3,4] Results of the comparisons are to be used in the recommendations to the NATO Panel VII Ad Hoc Group of Shielding Experts for replacing VCS with MASH as the reference code of choice for future armored vehicle nuclear vulnerability calculations.

The specific objective of the effort described in this report was to determine the protection afforded the crew members of the M60A1 medium tank against the initial radiation released from a nuclear weapon detonation. Additionally, the effects on this protection for parameters such as source-vehicle separation distance, and vehicle orientation relative to the source were investigated.

1.2 Purpose of MASH Development

An armored vehicle can provide protection against the effects of a nuclear weapon. In the case of tactical weapons, prompt radiation may be the dominant effect over a considerable area surrounding the detonation. To facilitate the calculation of radiation protection factors for a given vehicle; i.e., the ratio by which the free-field radiation is reduced due to the presence of the vehicle, VCS was developed by Oak Ridge National Laboratory (ORNL). While the title implies the code system was to be used only for vehicles, VCS could be used for other shielded structures also. For over a decade, the Department of Defense (DoD) and NATO have relied almost exclusively on VCS for calculating neutron and gamma-ray radiation fields and shielding protection factors for tactical armored vehicles, buildings, and other shielded configurations from nuclear weapon radiation.

Over the course of time, many different versions of VCS were developed by installations using the code and making modifications and/or improvements to suit their particular purpose. The result of this independent development was a proliferation of different versions of VCS, of which most were not compatible and yielded different results. The Defense Nuclear Agency (DNA) and Army Foreign Science and Technology Center (AFSTC) expressed concern over the potential for disagreement between independent analyses of the same armored vehicle. As a result, BRL, ORNL, and Science Applications International Corporation (SAIC) were tasked to identify the problems associated with the "current" version(s) of VCS, incorporate the various modifications (which would improve the code) , and create a singular referenced version of VCS.

The purpose was to establish a version of VCS which is generally acceptable to the user community, and place this version under responsible custody on the DNA computing network for use on the CRAY computer system at Los Alamos National Laboratory (LANL). This final version of VCS was renamed MASH (to mitigate confusion with the various versions of VCS) and given a version number, i.e. MASH 1.0, for referencing purposes.

MASH is currently being appraised as the "code-of-choice" to replace VCS. However, before it can be adopted, the code system must first be verified and validated through comparisons with experimental data and with previously calculated results using VCS. This effort is one of the primary objectives of the ORNL MASH Verification and Validation Subtask of the DNA Radiation Environments Program (REP).

1.3 Background

The detonation of a nuclear weapon results in the release of energy in the form of blast, thermal radiation, and nuclear radiation. Usually, for large yield air bursts, blast damage is the dominant hazard to combat vehicles. However, scenarios can be identified in which the detonation of improved nuclear weapons, i.e. lower yield (<100 kt) tactical weapons, require tactical changes by the military commander to counter an increased nuclear radiation threat. In order for a military commander to deploy his armor or defend against enemy armor, he must have knowledge of the protection afforded his crews against the nuclear weapon radiation.

1.4 Initial Radiation Environment

Radiations from a nuclear weapon can be time-segmented for the purpose of shielding analyses. Initial radiations are conservatively defined as those occurring within one minute of burst. All subsequent nuclear emissions are called residual radiations. The significant constituents of initial nuclear radiation in the free field are prompt neutrons and secondary gamma rays resulting from neutron interactions with the nuclei of the air and ground. The contribution from prompt (fission) gamma radiation generated during a weapon burst is assumed to be negligible for the purposes of this work.[5]

The radiation source used in this study (and in the previous BRL study[2]) is an unclassified 1 kt boosted fission nuclear weapon detonated at a height of 100 meters above the ground. The neutron yield is 3.102×10^{23} n/kt. The emitted neutron source spectrum is presented in Table 1, and shown graphically in Figure 1. Dose to shielded systems from prompt fission gamma rays is generally negligible and therefore was ignored.

Table 1. Neutron Energy Group Structure and Boosted Fission Weapon Neutron Source Spectrum.

Group Number	Upper Energy (eV)	Boosted Fission Weapon Source (n/kt)	Group Number	Upper Energy (eV)	Boosted Fission Weapon Source (n/kt)
1	1.9640+07[a]	0.000+00	24	8.2085+05	5.619+21
2	1.6905+07	0.000+00	25	7.4274+05	1.039+22
3	1.4918+07	0.000+00	26	6.3927+05	8.952+21
4	1.4191+07	1.189+21	27	5.5023+05	1.823+22
5	1.3840+07	6.034+21	28	3.6883+05	1.825+22
6	1.2523+07	1.417+21	29	2.4724+05	1.553+22
7	1.2214+07	2.192+21	30	1.5764+05	8.057+21
8	1.1052+07	1.362+21	31	1.1109+05	1.555+22
9	1.0000+07	1.235+21	32	5.2475+04	6.359+21
10	9.0484+06	1.400+21	33	3.4307+04	3.332+21
11	8.1873+06	2.960+21	34	2.4788+04	1.019+21
12	7.4082+06	3.922+21	35	2.1875+04	1.012+22
13	6.3763+06	7.501+21	36	1.0595+04	9.820+21
14	4.9658+06	2.473+21	37	3.3546+03	7.497+21
15	4.7237+06	6.723+21	38	1.2341+03	1.807+22
16	4.0657+06	1.077+22	39	5.8295+02	0.000+00
17	3.0119+06	2.584+22	40	2.7536+02	0.000+00
18	2.3852+06	3.262+21	41	1.0130+02	0.000+00
19	2.3069+06	2.008+22	42	2.9023+01	0.000+00
20	1.8268+06	1.690+22	43	1.0677+01	0.000+00
21	1.4227+06	1.837+22	44	3.0590+00	0.000+00
22	1.1080+06	1.009+22	45	1.1253+00	0.000+00
23	9.6164+05	9.696+21	46	4.1399-01	0.000+00
				1.0000-05	
			Total Neutron Yield (per kt) = 3.102+23		

[a]Read as 1.9640×10^7.

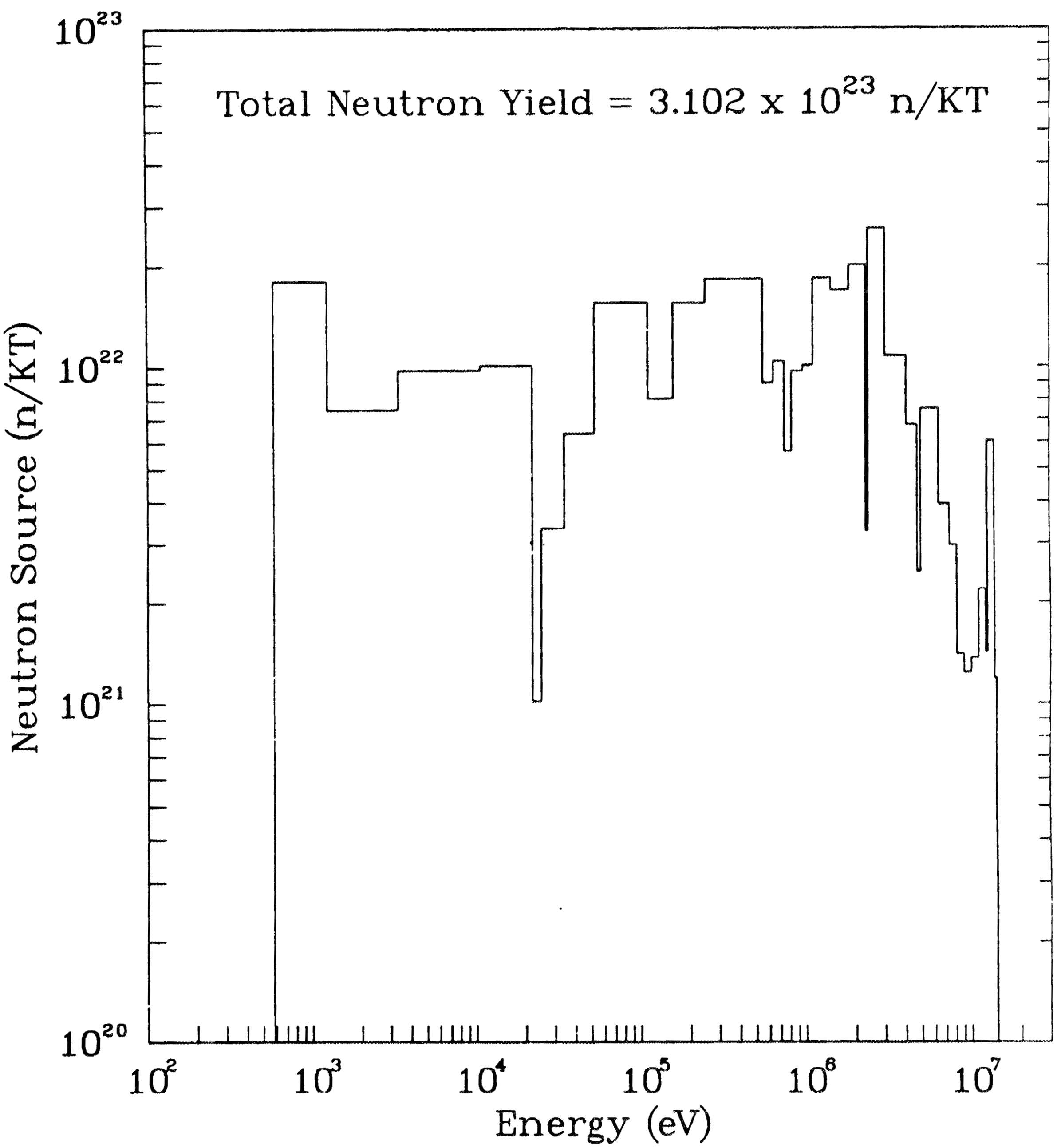

Figure 1. Boosted Fission Weapon Neutron Source Spectrum Used in the VCS and MASH U. S. M60A1 Tank Analyses.

2.0 CALCULATIONAL PROCEDURES

MASH was specifically designed to calculate the neutron and gamma-ray radiation environments and shielding protection factors of armored vehicles, structures, trenches, and other shielded configurations. The MASH calculational technique employs a GRTUNCL-DORT[6] forward discrete ordinates calculation to determine the neutron and gamma-ray flux on a coupling surface surrounding the armored vehicle or shielded structure and a MORSE[7] adjoint Monte Carlo calculation to determine the dose importance of the surface flux. MASH then utilizes the Detector Response Code (DRC)[1] to fold the flux together with the dose importance to yield the desired detector response(s).

2.1 Definition of Protection and Reduction Factors

Two quantities that are indicative of the ability of a ground combat vehicle to protect its crew members from penetrating nuclear radiation are protection factors (PFs) and reduction factors (RFs). The protection factors are more useful in the characterization of the vehicle shielding, whereas the reduction factors are more useful for comparisons with experimental data.

The total protection factor (TPF) is defined as follows:

$$TPF = D_{FF}/D_{IV} \qquad (2\text{-}1)$$

where:

D_{FF} = the free-field total dose,

and

D_{IV} = the in-vehicle total dose.

Two of the biologically important radiations from the detonation of a nuclear weapon are neutrons and subsequent secondary gamma rays.[5] A more complete shielding analysis is possible by further defining a neutron protection factor (NPF) and gamma protection factor (GPF).

The neutron protection factor (NPF) is defined as:

$$NPF = N_{FF}/(N_{IV} + G_V) \qquad (2\text{-}2)$$

where:

N_{FF} = the free-field neutron dose

N_{IV} = the in-vehicle neutron dose

and

G_V = the in-vehicle dose from gamma rays produced by neutron interactions with the vehicle (secondary gammas).

The gamma protection factors (GPF) is defined as:

$$GPF = G_{FF}/G_{AG} \tag{2-3}$$

where:

G_{FF} = the free-field dose from gamma rays produced by prompt fission and from neutron interactions with the air and ground.

and

G_{AG} = the in-vehicle dose from gamma rays produced by prompt fission and from neutron interactions with the air and ground.

The neutron protection factor limits the incident radiation field to neutrons, scattered or unscattered, and secondary gamma radiation arising from (n,γ) reactions with the vehicle. Similarly, the gamma protection factor consists of that incident radiation resulting from gamma rays produced by prompt fission and extra-vehicle (n,γ) reactions (air and ground). The prompt (fission) gamma radiation from the source sometimes can be neglected relative to the gamma radiation produced by (n,γ) reactions in the air and ground.[5]

Because detector systems are unable to discern the origin of the gamma rays (i.e. source, air secondary gamma ray, vehicle secondary gamma ray, etc.) contributing to the in-vehicle dose, it is anticipated that the calculated reduction factors will be more easily compared with experimental measurements than the protection factors.

The total reduction factor (TRF) is defined as follows:

$$TRF = D_{FF}/D_{IV} \tag{2-4}$$

where:

D_{FF} = the free-field total dose,

and

D_{IV} = the in-vehicle total dose.

It should be noted that the total protection factor (Eq. 2-1) and total reduction factor (Eq. 2-4) are equivalent.

The neutron reduction factor (NRF) is defined as:

$$NRF = N_{FF}/N_{IV} \tag{2-5}$$

where:

N_{FF} = the free-field neutron dose,

and

N_{IV} = the in-vehicle neutron dose.

The gamma reduction factor (GRF) is defined as:

$$GRF = G_{FF}/G_{IV} \tag{2-6}$$

where:

G_{FF} = the total free-field gamma dose from all sources, (i.e. prompt fission, air and ground interactions)

and

G_{IV} = the total in-vehicle gamma dose from all sources, (i.e. prompt fission, air, ground, and vehicle interactions).

DRC bins the contributions to the dose in several arrays (called detectors in the code) to allow for the calculation of protection factors. The detector response definitions used in DRC are given in Table 2, and the definitions of the parameters and protection factors used in DRC to characterize the effectiveness of the vehicle shields are given in Table 3.

Table 2. Detector Response Definitions in DRC.

Detector	Response Definition
1	Direct neutron - a neutron entering the vehicle and contributing a neutron dose.
2	Capture gamma rays from vehicle - a gamma ray resulting from a neutron entering the vehicle and contributing a secondary gamma-ray dose.
3	Capture gamma rays from ground - a gamma ray resulting from a neutron entering the ground without passing through the vehicle and generating a secondary gamma-ray dose from a ground interaction. (This dose is already included in the upward-directed gamma rays that enter the vehicle. This generally is negligible.)
4	Direct gamma rays - a gamma ray entering the vehicle and contributing a gamma-ray dose. This source of gamma rays includes both gamma rays originating from the source, and capture gamma rays from the air.
5	Total gamma-ray dose - Sum of detectors 2, 3, and 4.
6	Gamma-ray dose from gamma rays entering the vehicle (usually dominated by direct gamma rays - Sum of detectors 3 and 4.
7	Neutron and gamma-ray dose from neutrons incident on the vehicle - Sum of detectors 1 and 2.

Table 3. Definitions of Parameters and Protection Factors Used to Characterize the Effectiveness of Vehicle Shields.

Parameter	Response Definition
FFN	Free Field Neutron Response
FFG	Free Field Gamma Response
NPF	Neutron Protection Factor NPF = FFN / Det. 7
GPF	Gamma Protection Factor GPF = FFG / Det. 6
TPF	Total Protection Factor TPF = (FFN+FFG)/(Det. 7 + Det. 6)
NRF	Neutron Reduction Factor NRF = FFN / Det. 1
GRF	Gamma Reduction Factor GRF = FFG / Det. 5
TRF	Total Reduction Factor TRF = (FFN+FFG)/(Det. 1 + Det. 5)

2.2 Air-Over-Ground Environment

The boosted fission nuclear weapon spectrum (Table 1) was modeled in the GRTUNCL and DORT codes to determine the air-over-ground environment from which the flux on the coupling surface could be obtained. GRTUNCL calculates the uncollided component of the flux and DORT calculates the scalar and directional fluxes of the collided component. All three components are processed through VISTA[1] to obtain the flux on the coupling surface to be folded in DRC. The air-over-ground model for this study utilized 140 radial intervals and 175 axial intervals in a flat topographical r-z model to represent a 2500-m by 2500-m air environment. One meter of ground was included in the calculations to model ground scattering. The source height was set at 100 meters above the air/ground interface at the center of the radial mesh (r=0.0). The air-over-ground model utilized a 240 direction forward biased quadrature, a P_5 Legendre expansion of the cross sections, the reference DNA Defense Applications Broad-group Library (DABL69) 69 group (46n/23γ) cross-section library,[8] and referenced air and ground materials utilized in previous BRL calculations of armored vehicles.[2] The material compositions for the air and ground used in this analysis are given in Table 4. Utilizing these materials enables the ORNL analysts to directly compare the present air-over-ground environment results with the results previously calculated with VCS. Six source/vehicle ground ranges were chosen in VISTA for obtaining the flux on the coupling surface. These ground ranges were 170, 340, 680, 1020, 1360, and 1700 meters.

For documentation purposes, the input data streams (decks) for GIP, GRTUNCL, DORT, and VISTA are included in the appendices. This will enable future versions of MASH to be "benchmarked" to the analysis reported in this document.

2.3 Vehicle Geometry

The radiation shielding characteristics for only one vehicle configuration of the M60A1 was investigated in this study. This configuration, is referred to as the "battlefield condition." Schematic diagrams of the top, front, and side views of the M60A1 "battlefield condition" vehicle configuration are shown in Figure 2. Isometric views of the M60A1 "battlefield condition" configuration are shown in Figures 3 and 4, with Figure 4 detailing the crew locations. For the "battlefield condition," the turret is oriented with the gun in the forward position with the hatches closed and the vehicle with a full complement of ammunition and fuel. Four vehicle orientations relative to the weapon detonation were investigated. The details of the "battlefield condition" and vehicle orientations are given in Table 5.

Table 4. Composition of Materials Used in the VCS and MASH M60A1 Tank Neutron and Gamma Dose and Protection Factor Analyses.

Element	Material Composition (atoms/barn·cm)				
	Air	Ground	Steel	Personnel	Aluminum Alloy
Hydrogen		9.75-03		5.98-02	
Carbon			1.07-03	9.03-03	
Nitrogen	4.19-05[a]			1.29-03	
Oxygen	1.13-05	3.48-02		2.50-02	
Sodium					
Magnesium					3.35-04
Aluminum		4.88-03			5.73-02
Silicon		1.16-02	6.41-04		
Argon	2.51-07				
Calcium				2.25-04	
Chromium			8.76-04		
Manganese			9.75-04		1.48-04
Iron			8.06-02		
Nickel			8.08-04		
Copper					1.02-03
Molybdenum			2.25-04		
Tungsten-182					
Tungsten-183					
Tungsten-184					
Tungsten-186					
Lead					
ρ(gm/cm^3)	1.29-03*	1.70+00	7.80+00	1.00+00	2.70+00

[a]Read as 4.19×10^{-5}.
*At 0°C, sea level; not U.S. Standard Atmosphere of 15°C.

Table 4. Composition of Materials Used in the VCS and MASH M60A1 Tank Neutron and Gamma Dose and Protection Factor Analyses. (continued)

Element	Material Composition (atoms/barn·cm)				
	Fuel	Ammunition Filler	Battery	Wheels & Tracks	Glass
Hydrogen	6.03-02[a]	1.17-02	3.06-02	2.31-01	
Carbon	3.35-02	5.11-03	5.81-03	2.31-02	
Nitrogen		8.97-03			
Oxygen		1.06-02	2.64-02		2.35-02
Sodium					1.31-03
Magnesium					
Aluminum					
Silicon				2.68-04	8.79-03
Argon					
Calcium					2.18-03
Chromium				3.95-04	
Manganese				3.41-04	
Iron				3.05-02	
Nickel				3.35-04	
Copper					
Molybdenum				8.92-05	
Tungsten-182					
Tungsten-183					
Tungsten-184					
Tungsten-186					
Lead			1.05-03		2.97-03
ρ(gm/cm^3)	7.69-01	6.10-01	1.23+00	3.80+00	2.25+00

[a]Read as 6.03×10^{-2}.

Table 4. Composition of Materials Used in the VCS and MASH M60A1 Tank Neutron and Gamma Dose and Protection Factor Analyses. (continued)

	Material Composition (atoms/barn·cm)		
Element	Tungsten Carbide	Computer/ Intercom	Lead
Hydrogen			
Carbon	4.70-02[a]	6.02-03	
Nitrogen		6.62-03	
Oxygen		1.17-04	
Sodium			
Magnesium		1.49-03	
Aluminum		1.07-04	
Silicon		3.88-03	
Argon		1.81-03	
Calcium			
Chromium			
Manganese		1.25-03	
Iron			
Nickel			
Copper		5.69-06	
Molybdenum			
Tungsten-182	1.27-02		
Tungsten-183	6.88-03		
Tungsten-184	1.48-02		
Tungsten-186	1.38-02		
Lead			3.28-02
ρ(gm/cm^3)	1.56+01	6.00-01	1.14+01

[a]Read as 4.70 x 10^{-2}.

Table 5. Definitions of M60A1 "Battlefield Condition" and Orientations Relative to the Source Used in the VCS and MASH Neutron and Gamma Dose and Protection Factor Analyses.

Parameter	Definition
Battlefield Condition	
	All Hatches Closed Gun Turret Forward Fuel Tanks Full Full Ammunition Stowage
Vehicle Orientation	
RO	Rear Side Facing Source
RSO	Right Side Facing Source
FO	Front Side Facing Source
LSO	Left Side Facing Source

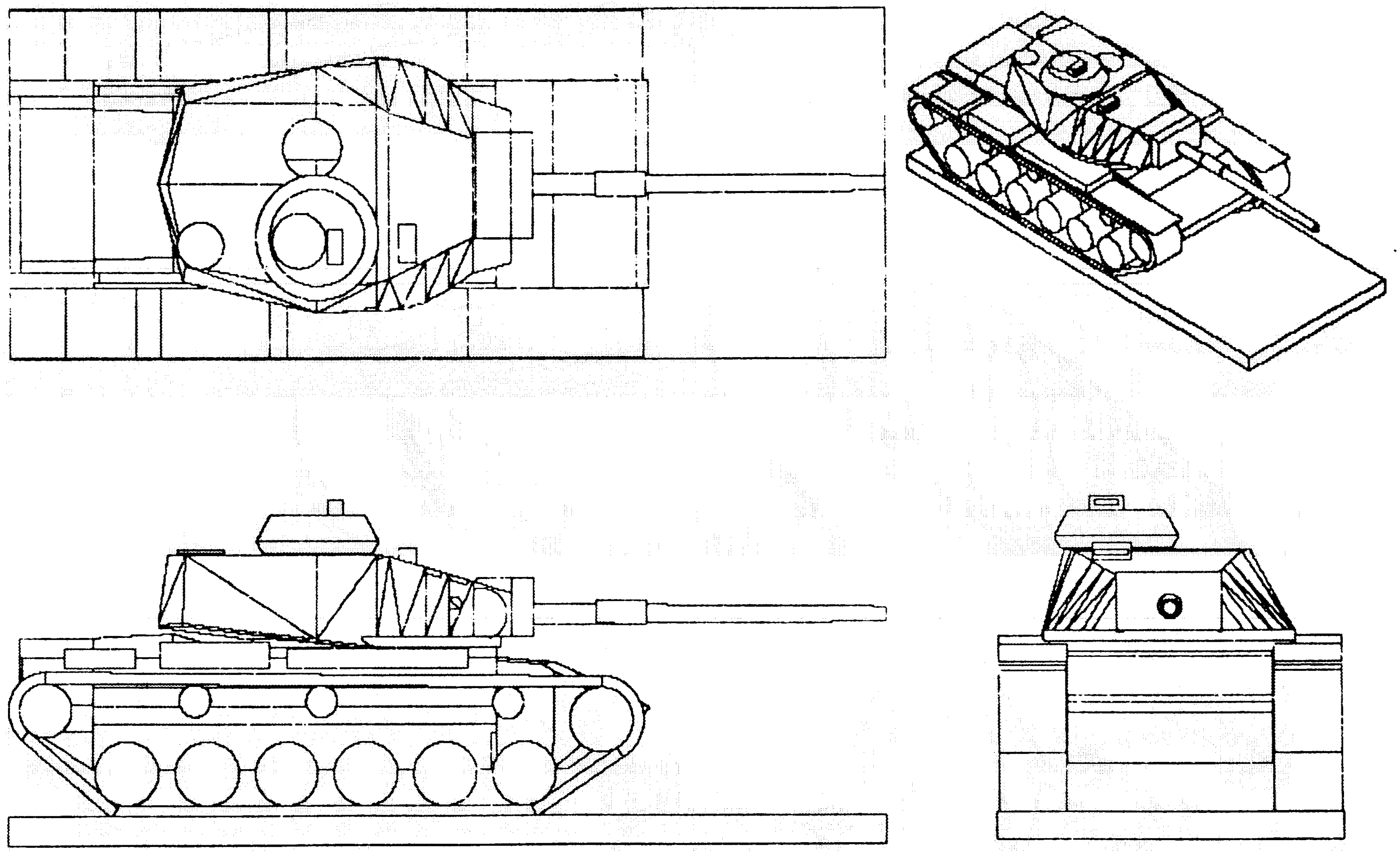

Figure 2. Schematic Top, Side, and Front Views of the U. S. M60A1 "Battlefield Condition" Vehicle Configuration.

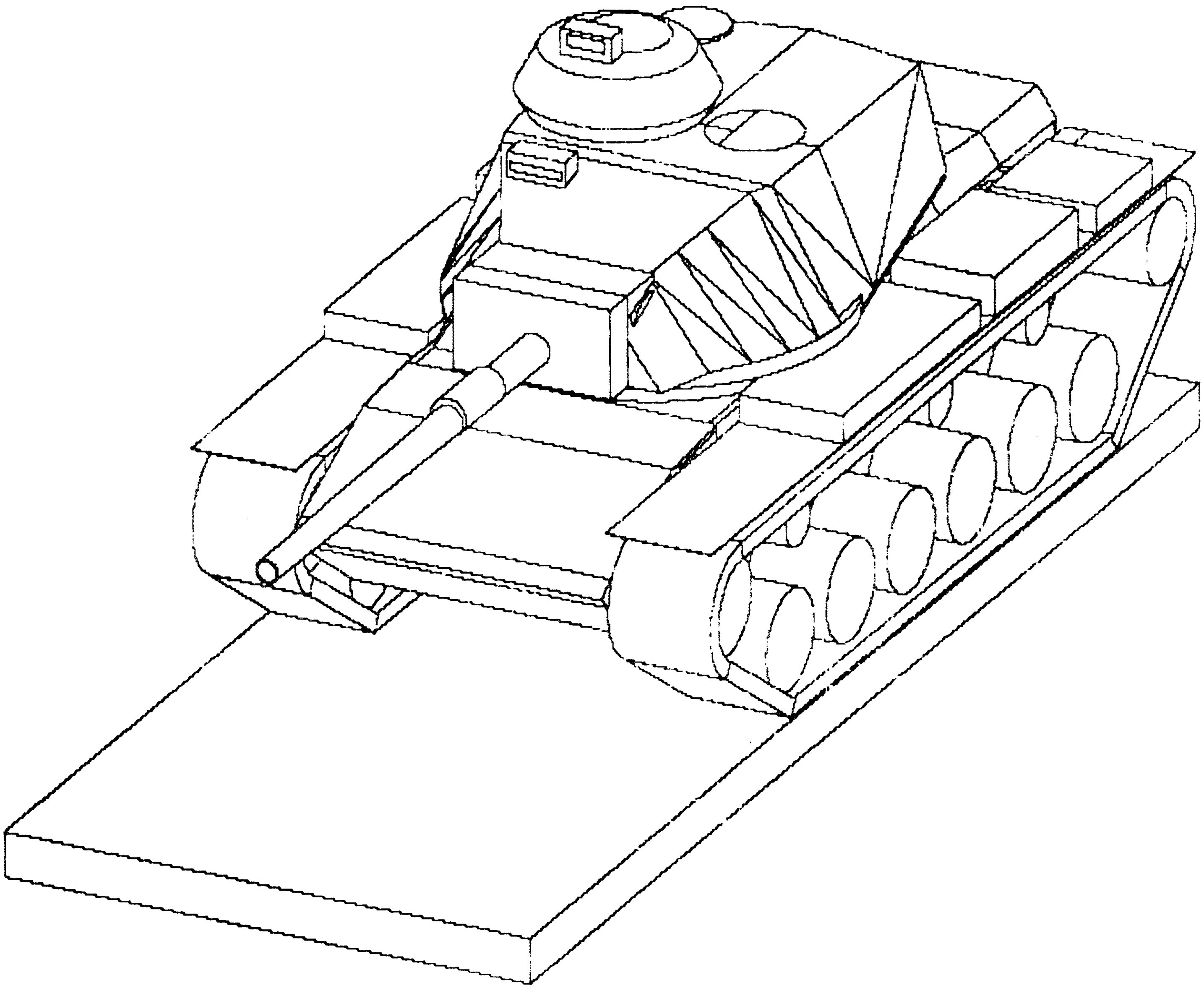

Figure 3. Isometric View of the U. S. M60A1 "Battlefield Condition" Vehicle Configuration.

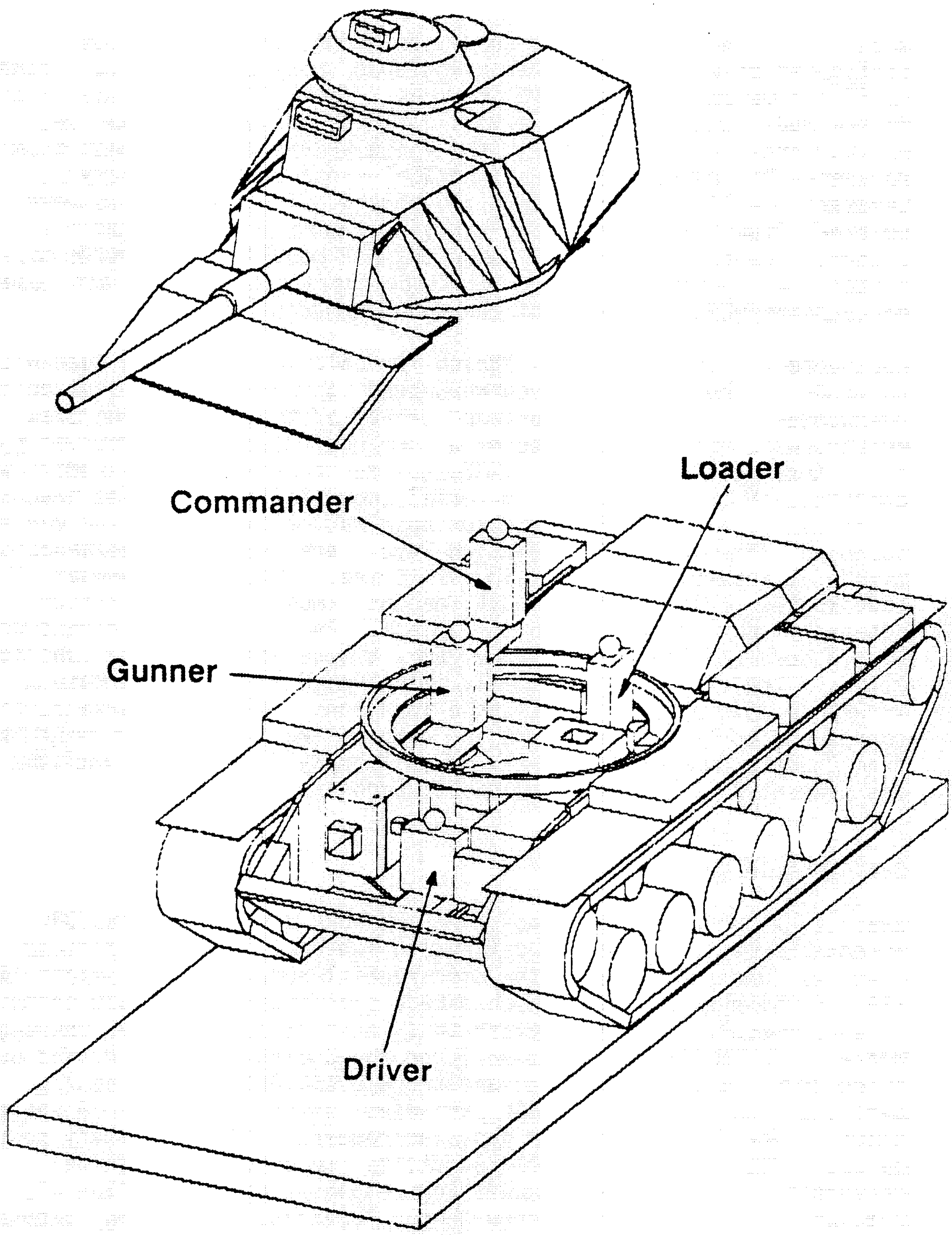

Figure 4. Isometric View of the U. S. M60A1 "Battlefield Condition" Vehicle Configuration Indicating the Crew Member Locations.

Modeling of the "battlefield condition" M60A1 armored vehicle configuration was accomplished using a 301 body combinatorial geometry (GIFT)[9,10] description with 303 regions. The GIFT geometry description of the M60A1 used in this analysis is included in the appendices. Nuclear cross sections used in the calculations were obtained from the reference DNA DABL69 69-group (46n/23γ) cross-section library[8] to generate the 13 materials shown in Table 6. These materials were obtained from the original BRL study[2] and were prepared from the elemental cross-section sets using the GIP module[1] in the MASH code system. A P_5 Legendre expansion of the cross sections was also used for the adjoint MORSE analysis of the M60A1 armored vehicle.

Four detector locations were chosen for calculation of the dose within the M60A1. These detectors corresponded to the mid-head position for the Commander, Loader, Gunner, and Driver of the M60A1. The crew members were each represented by a four body description consisting of a head, torso, thighs, and legs. Except for the head, these bodies were comprised of the "personnel" material shown in Table 4. The head was comprised of air and the radiation dose was calculated at the center of the head. The resulting radiation levels are then the dose deposited in tissue at a particular point in air for each of the crew members. The coordinates (relative to the GIFT geometry model) for these four detector locations are given in Table 7. The Snyder-Auxier neutron tissue dose and Claiborne-Trubey gamma tissue dose response functions given in Table 8, and graphically illustrated in Figure 5, were utilized in DRC to obtain the dose at these locations. These response functions correspond to the ones used in the original BRL study,[2] and originated from the old DNA DLC-31 37n-21γ group library.[11] They are included in the present analysis for comparison purposes.

2.4 Vehicle Calculation

Statistical uncertainties less than ±5% were desired for the DRC integral detector responses defined in Table 2. This would yield (require) uncertainties on the differential results to be within ±5% to ±15% in the energy ranges which make a significant contribution to the integral results. To accomplish this level of convergence, the adjoint Monte Carlo (MORSE) calculations, for the Commander, Loader, and Gunner detector positions, generated and tracked 100,000 primary source particles (100 batches of 1000 particles) sampled over the 69 energy groups. The Driver detector position required 200,000 primary source particles (200 batches of 1000 particles) to obtain statistical convergence of the integral detector responses defined in Table 2 similar to the other three crew member locations. An energy dependent relative importance factor was utilized over the 69 groups to increase the frequency of sampling the adjoint source particle from energy groups which have a significant effect on the dose response function. The secondary particle production probability (GWLO) was set to 1.0 for all regions and energy groups in the Monte Carlo calculations, and the in-group energy biasing option in MORSE was switched on. Only one region dependent and energy independent set of splitting and Russian Roulette

Table 6. Material Numbers Used in the VCS and MASH Analyses of the M60A1 "Battlefield Condition" Vehicle Configuration.

MORSE Material Number	Material Description	MORSE Material Number	Material Description
1	Air	8	Battery
2	Ground	9	Wheels and Tracks
3	Steel	10	Glass
4	Personnel	11	Tungsten Carbide
5	Aluminum Alloy	12	Computer/Intercom
6	Fuel	13	Lead
7	Ammunition Filler		

Table 7. GIFT5 Region/Body Number and Coordinate Positions of the Center of the Head for each Crew Member in the M60A1 "Battlefield Condition" Vehicle Configuration.

Detector Position	GIFT5 Region/Body Number	Coordinate Positions (in centimeters)		
		X-Coordinate	Y-Coordinate	Z-Coordinate
Commander	92	-86.800	-65.000	115.000
Gunner	96	-11.000	-60.200	55.500
Loader	100	-36.000	60.235	57.500
Driver	248	151.400	0.000	-32.860

Table 8. Snyder-Auxier Neutron and Claiborne-Trubey Gamma Tissue Kerma Response Functions Used in the VCS and MASH M60A1 Tank Analyses.

Group Number	Snyder-Auxier Neutron Tissue Dose ($cGy \cdot cm^2/n$)	Group Number	Claiborne-Trubey Gamma Tissue Dose ($cGy \cdot cm^2/\gamma$)
1	7.8500-09[a]	1	0.0000+00
2	7.7800-09	2	3.0500-09
3	7.7400-09	3	3.0500-09
4	7.7100-09	4	2.4300-09
5	7.4900-09	5	2.1200-09
6	7.2100-09	6	1.9200-09
7	6.8900-09	7	1.7100-09
8	6.4900-09	8	1.5000-09
9	6.2300-09	9	1.2700-09
10	6.1000-09	10	1.0900-09
11	5.9700-09	11	9.5900-10
12	5.8200-09	12	8.1300-10
13	5.5700-09	13	6.4100-10
14	5.3400-09	14	4.8200-10
15	5.0900-09	15	3.6000-10
16	4.5600-09	16	2.4800-10
17	4.0000-09	17	1.6400-10
18	3.8200-09	18	1.0100-10
19	3.7400-09	19	7.4400-11
20	3.5200-09	20	7.7300-11
21	3.5200-09	21	1.1700-10
22	2.9400-09	22	2.2300-10
23	2.9400-09	23	6.2600-10
24	2.9400-09		
25	2.9400-09		
26	2.9400-09		
27	1.6900-09		
28	1.6900-09		
29	1.6900-09		
30	9.7200-10		
31	7.4500-10		
32	5.8900-10		
33	5.8900-10		
34	5.1300-10		
35	4.4900-10		
36	4.2100-10		
37	4.7900-10		
38	5.2500-10		
39	5.5800-10		
40	5.5800-10		
41	5.9400-10		
42	6.1800-10		
43	6.2800-10		
44	6.2200-10		
45	6.0000-10		
46	5.1700-10		

[a]Read as 7.8500×10^{-9}.

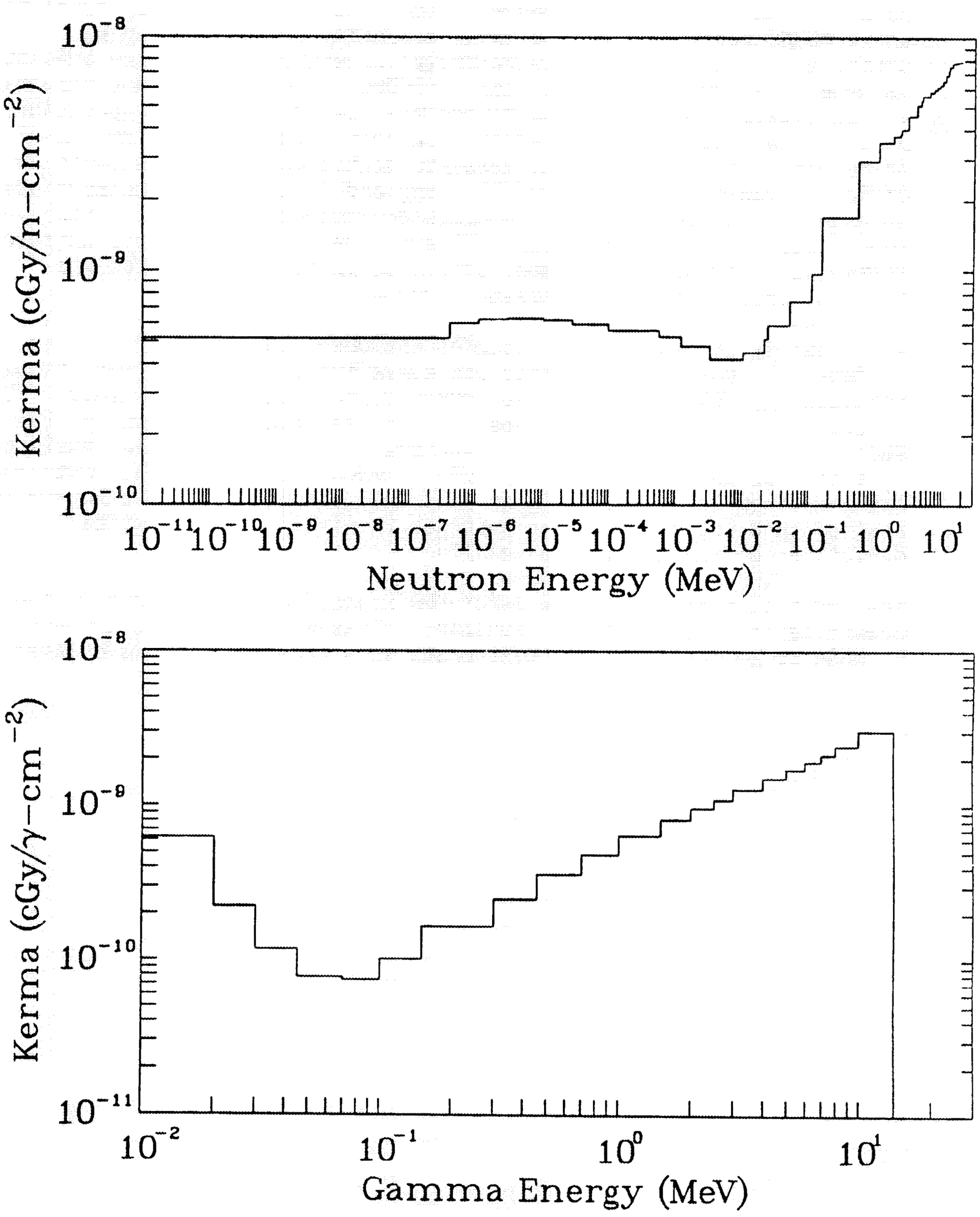

Figure 5. Snyder-Auxier Neutron and Claiborne-Trubey Gamma Tissue Kerma Response Functions Used in the VCS and MASH U. S. M60A1 Tank Analyses.

parameters was utilized in the MORSE calculations. The results of the above MORSE parameter setup allowed nominally 90 to 95 escaping particles for each 100 source particles generated. Since the adjoint leakage file from MORSE is utilized in DRC to obtain the dose response at the detector location, maximizing the number of leakages per source particle (without biasing the "true" adjoint leakage spectrum) is of prime importance in obtaining adequate statistical convergence in an efficient manner. Optimizing splitting and Russian Roulette parameters on a geometry model as complicated as an armored vehicle is virtually impossible. The only reasonable alternatives for improving statistics is to increase the total number of source particles generated and tracked, or simplifying the geometry model.

As presently configured, DRC assumes the DORT flux on the "coupling surface" is dependent on energy and elevation only, and not on azimuth. Consequently, DRC only uses the flux at a particular radius (e.g. 170 meters) in the DORT mesh and does not use the radii encompassing the M60A1. This assumption is valid for small objects at a great distance from the source. Since the size of the M60A1 is small relative to the distance from the source, it was felt this assumption was valid for this analysis and would produce an uncertainty within the statistical deviations of the calculated results.

The input data streams (decks) for MORSE and DRC are included in the appendices for documentation purposes. This will enable future versions of MASH to be "benchmarked" to the analysis reported in this document.

3.0 DISCUSSION OF RESULTS

A comparison of the VCS and MASH free-field neutron and gamma doses as a function of source/vehicle ground range is given in Table 9. The neutron and gamma radiation dose and protection factors for all crew members are presented in Tables A-1 through A-8 in Appendix A. The results are presented for all source/vehicle ground ranges and vehicle orientations for the M60A1 "battlefield condition" vehicle configuration. In each table, a ratio of the VCS to MASH protection factors is given. The protection factor data in Tables A-1 through A-8 are further represented in Tables 10 through 14. In Tables 10 and 11, comparisons of average VCS and MASH neutron and gamma protection factors as a function of source/vehicle ground range are presented for each crew member location. In Tables 12 and 13, comparisons of average VCS and MASH neutron and gamma protection factors as a function of vehicle orientation are presented for each crew member location. Finally, in Table 14, comparisons of the overall average VCS and MASH neutron and gamma protection factors (averaged over all source/vehicle ground ranges and vehicle orientations) are presented for each crew member location.

It should be noted that a protection factor is a parameter that has been defined to help characterize shielding effectiveness and is not in itself a physical quantity. The inverse of the protection factor, i.e. the transmission factor, however, is the measure of the fraction of dose attenuated by the vehicle or structure and represents a physically measurable quantity. When computing an average protection factor, the average of the transmission factors should be obtained and then inverted to obtain the average protection factor. This corresponds to the harmonic average protection factor and will more closely represent the true average protection factor of a number of vehicles randomly oriented on the battlefield. The harmonic average will always be less than or equal to the arithmetic average and therefore yield a conservative estimate. In this report, the average protection factors were calculated using the definition of the harmonic average.

3.1 Free-Field Dose

The ratio of the VCS neutron free-field dose over the MASH neutron free-field dose ($n\ FF_{VCS}/n\ FF_{MASH}$), presented in Table 9, indicates that VCS calculates approximately 5% to 20% more dose than MASH. The ratio further suggests an almost constant difference from approximately 680 meters to 1700 meters ground range. The ratio of the VCS gamma free-field dose over the MASH gamma free-field dose ($\gamma\ FF_{VCS}/\gamma\ FF_{MASH}$) also indicates VCS calculates approximately 5% to 20% more dose than MASH. However, for the gamma dose, the ratio indicates a diminishing difference (17% to 1%) from approximately 680 meters to 1700 meters ground range. Absolute justification for these differences is impossible without additional knowledge of the original VCS calculations. However, the differences suggests different quadrature

Table 9. Comparison of VCS and MASH Free-Field Neutron and Gamma Doses as a Function of Source/Vehicle Ground Range for the M60A1 "Battlefield Condition" Vehicle Configuration.

	VCS Calculation		MASH Calculation			
Range (m)	Free-Field n Dose (cGy)	Free-Field γ Dose (cGy)	Free-Field n Dose (cGy)	Free-Field γ Dose (cGy)	$\frac{n\ FF_{VCS}}{n\ FF_{MASH}}$	$\frac{\gamma\ FF_{VCS}}{\gamma\ FF_{MASH}}$
170	3.69+05[a]	2.34+04	3.56+05	2.22+04	1.04	1.05
340	6.43+04	5.21+03	5.75+04	4.63+03	1.12	1.13
680	3.31+03	4.38+02	2.79+03	3.73+02	1.19	1.17
1020	2.37+02	5.31+01	2.00+02	4.79+01	1.19	1.11
1360	2.07+01	8.64+00	1.75+01	8.17+00	1.18	1.06
1700	2.04+00	1.71+00	1.78+00	1.70+00	1.15	1.01

[a]Read as 3.69×10^5.

Table 10. Comparison of Average VCS and MASH Neutron Protection Factors as a Function of Source/Vehicle Ground Range for the M60A1 in the "Battlefield Condition" Vehicle Configuration.

Detector Position	Code System	Source/Vehicle Ground Range (in meters)					
		170	340	680	1020	1360	1700
Commander							
	VCS	1.3	1.3	1.3	1.3	1.3	1.3
	MASH	1.3	1.3	1.3	1.3	1.3	1.3
$\frac{NPF_{VCS}}{NPF_{MASH}}$		1.00	1.00	1.00	1.00	1.00	1.00
Gunner							
	VCS	1.9	2.0	1.9	1.9	1.9	1.9
	MASH	1.8	1.9	1.8	1.8	1.8	1.8
$\frac{NPF_{VCS}}{NPF_{MASH}}$		1.06	1.05	1.06	1.06	1.06	1.06
Loader							
	VCS	1.7	1.7	1.7	1.7	1.7	1.7
	MASH	1.6	1.6	1.6	1.6	1.6	1.6
$\frac{NPF_{VCS}}{NPF_{MASH}}$		1.06	1.06	1.06	1.06	1.06	1.06
Driver							
	VCS	3.3	3.5	3.5	3.5	3.5	3.5
	MASH	2.7	2.8	2.8	2.8	2.8	2.8
$\frac{NPF_{VCS}}{NPF_{MASH}}$		1.22	1.25	1.25	1.25	1.25	1.25

Table 11. Comparison of Average VCS and MASH Gamma Protection Factors as a Function of Source/Vehicle Ground Range for the M60A1 in the "Battlefield Condition" Vehicle Configuration.

Detector Position	Code System	Source/Vehicle Ground Range (in meters) 170	340	680	1020	1360	1700
Commander							
	VCS	6.2	5.2	4.2	3.7	3.4	3.2
	MASH	5.6	4.8	3.9	3.5	3.2	3.1
$\frac{GPF_{VCS}}{GPF_{MASH}}$		1.11	1.08	1.08	1.06	1.06	1.03
Gunner							
	VCS	11.9	10.2	8.2	7.3	6.8	6.6
	MASH	11.6	10.0	8.1	7.2	6.8	6.6
$\frac{GPF_{VCS}}{GPF_{MASH}}$		1.03	1.02	1.01	1.01	1.00	1.00
Loader							
	VCS	9.1	7.8	6.3	5.7	5.4	5.2
	MASH	8.4	7.3	6.2	5.6	5.4	5.4
$\frac{GPF_{VCS}}{GPF_{MASH}}$		1.08	1.07	1.02	1.02	1.00	0.96
Driver							
	VCS	25.6	22.4	18.1	16.1	15.1	14.6
	MASH	14.5	14.8	14.8	15.1	15.6	16.2
$\frac{GPF_{VCS}}{GPF_{MASH}}$		1.77	1.51	1.22	1.07	0.97	0.90

Table 12. Comparison of Average VCS and MASH Neutron Protection Factors as a Function of Vehicle Orientation for the M60A1 in the "Battlefield Condition" Vehicle Configuration.

Detector Position	Code System	Vehicle Orientation Towards Source			
		Rear On	Right Side On	Front On	Left Side On
Commander					
	VCS	1.2	1.2	1.4	1.3
	MASH	1.2	1.2	1.4	1.3
$\frac{NPF_{VCS}}{NPF_{MASH}}$		1.00	1.00	1.00	1.00
Gunner					
	VCS	2.1	1.7	1.8	2.0
	MASH	2.0	1.6	1.8	1.9
$\frac{NPF_{VCS}}{NPF_{MASH}}$		1.05	1.06	1.00	1.05
Loader					
	VCS	1.8	1.9	1.7	1.5
	MASH	1.7	1.8	1.7	1.4
$\frac{NPF_{VCS}}{NPF_{MASH}}$		1.06	1.06	1.00	1.07
Driver					
	VCS	5.1	3.3	2.7	3.4
	MASH	3.7	2.7	2.3	2.7
$\frac{NPF_{VCS}}{NPF_{MASH}}$		1.38	1.22	1.17	1.26

Table 13. Comparison of Average VCS and MASH Gamma Protection Factors as a Function of Vehicle Orientation for the M60A1 in the "Battlefield Condition" Vehicle Configuration.

Detector Position	Code System	Vehicle Orientation Towards Source			
		Rear On	Right Side On	Front On	Left Side On
Commander					
	VCS	3.8	4.1	5.7	3.4
	MASH	3.2	3.4	5.7	3.7
$\frac{GPF_{VCS}}{GPF_{MASH}}$		1.19	1.21	1.00	0.92
Gunner					
	VCS	8.2	6.2	13.5	7.4
	MASH	8.5	5.9	13.2	7.3
$\frac{GPF_{VCS}}{GPF_{MASH}}$		0.96	1.05	1.02	1.01
Loader					
	VCS	7.5	6.7	8.3	4.3
	MASH	7.4	6.7	8.9	4.0
$\frac{GPF_{VCS}}{GPF_{MASH}}$		1.01	1.00	0.93	1.08
Driver					
	VCS	35.2	15.8	15.7	14.6
	MASH	23.7	12.9	13.5	14.1
$\frac{GPF_{VCS}}{GPF_{MASH}}$		1.49	1.22	1.16	1.04

Table 14. Comparison of Overall VCS and MASH Neutron and Gamma Protection Factors Averaged over all Source/Vehicle Ground Ranges and Vehicle Orientations for each Crew Member of the M60A1 in the "Battlefield Condition" Vehicle Configuration.

Detector Position	VCS Calculation		MASH Calculation		$\frac{NPF_{VCS}}{NPF_{MASH}}$	$\frac{GPF_{VCS}}{GPF_{MASH}}$
	NPF	GPF	NPF	GPF		
Commander	1.3	4.1	1.3	3.8	1.00	1.08
Gunner	1.9	8.1	1.8	8.0	1.06	1.01
Loader	1.7	6.3	1.6	6.2	1.06	1.02
Driver	3.4	17.9	2.7	15.1	1.26	1.19

sets (symmetric S_8 for VCS and 240 angle forward biased for MASH), axial and radial mesh, and cross section data as the most likely causes.

3.2 In-Vehicle Dose

A comparison of the absolute in-vehicle neutron and gamma doses presented in Tables A-1 through A-8, indicate reasonably good agreement between VCS and MASH for most of the individual contributors (e.g. direct neutron, vehicle (n,γ), etc.) to the total in-vehicle dose at a given crew member location. Both VCS and MASH indicate the same trends relative to vehicle orientation and source/vehicle ground range for all crew member locations. As in the case of the free-field data, the direct neutron dose calculated with VCS is approximately 5% to 20% greater than the direct neutron dose calculated with MASH. Furthermore, the degree of difference follows the trend evident in the free-field data relative to source/vehicle ground range. This probably indicates that the differences observed here are due to the differences observed in the free-field data. The vehicle secondary gamma (vehicle (n,γ)) results show MASH calculates considerably more dose than VCS at most of the crew member locations. The magnitude of the difference ranges from approximately a factor of two for the driver location to less than 5% for the loader location at 680 meters ground range. The vehicle secondary gamma results do not indicate any apparent trend relative to source/vehicle ground range, vehicle orientation, or crew member location. The primary reasons for these differences may be due to spectral differences between the VCS and MASH free-field dose, and cross section data (especially secondary gamma production in iron). It is interesting to note, that for all crew locations except the driver, the comparisons of the sums of the direct neutron and vehicle secondary gamma doses for VCS and MASH are in excellent agreement for all source/vehicle ground ranges and vehicle orientations. The driver location indicates agreement within approximately 30% or less for this result.

The absolute dose due to secondary gamma production from the air, i.e. air (n,γ) dose, calculated using VCS and MASH, also compares well for most of the crew locations, vehicle orientations, and source/vehicle ground ranges. The agreement diminishes slightly at longer source/vehicle ground ranges. This probably occurs because of differences in the cross section data, angular quadrature, and mesh spacing used in the VCS and MASH air-over-ground calculations. The largest discrepancy between VCS and MASH occurs in the contribution to the dose from secondary gamma production with the ground, i.e. ground (n,γ). MASH predicts an order of magnitude more dose than VCS for the commander, gunner, and loader crew locations. Furthermore, MASH calculates over two orders of magnitude more dose than VCS at the driver location. In the VCS calculations, the contribution from the secondary gamma production in the ground is negligible for all crew member locations. In the MASH calculations, this hold true for the commander and gunner locations, mostly true for the loader location, but not for the driver location. At the driver location, the ground secondary gamma production is approximately 30% of the total dose due to ground and air secondary gamma production. Intuitively, this appears to be too high based on all previous VCS vehicle calculations, and considering the energy and number of ground gammas which might penetrate the armor and contribute to the dose. It should be noted that the VCS calculations all utilized the same quadrature, mesh, and cross sections in the air-over-ground analyses. The increasing magnitude of the difference as the crew member location gets closer to the ground indicates a possible error in the material specifications of the M60A1 tank in one of the geometry models used in the VCS or MASH analyses. The model used in the MASH analysis may not correspond to the final model used in the VCS analyses.

3.3 Neutron and Gamma Protection Factors

The protection factor results presented in Tables A-1 through A-8 indicate the amount of protection against initial nuclear radiation provided by the M60A1 tank. In particular, both the MASH and VCS neutron protection factor (NPF) results show approximately 30% more protection for the commander, 80% to 90% more protection for the gunner, 60% to 70% more protection for the loader, and approximately a factor of three increase in protection for the driver (3.5 for VCS, and 2.8 for MASH). The decrease in the NPF as a function of crew elevation in the vehicle indicates a large fraction of the dose enters from the top of the vehicle. The gamma protection factor (GPF) results ranged from approximately 3 to 36 for the VCS calculations and 3 to 32 for the MASH calculations, depending on crew member location, vehicle orientation, and source/vehicle ground range.

In essence, the NPF represents the degree of protection afforded by the M60A1 tank against initial radiation. For all cases in which the in-vehicle total radiation dose (neutrons and secondary gammas) exceeds 100-cGy (distances less than or equal to 1020 meters source/vehicle ground range), the neutron dose (including vehicle secondary gamma radiation dose) to the crew members comprises greater than 90% of the total initial radiation dose. As the in-vehicle dose increases (vehicle moving closer to the source), the effective contribution from air and ground secondary gamma radiation decreases. At 170 meters ground range, the neutron dose contribution (direct neutron and vehicle secondary gamma production) in all configurations exceeds 98% of the total dose. Therefore, even though the gamma protection factors range from approximately 3 to 35, they represent protection from an insignificant portion of the total dose and are not representative of the degree of protection afforded the crew members in the M60A1 tank.

The comparison of the VCS and MASH protection factors in Tables A-1 through A-8 shows excellent agreement for almost all crew member locations, source/vehicle ground ranges, and vehicle orientations. Typical agreement is within ±10% for the commander, gunner, and loader. The driver location exhibited ±10% to ±30% for the neutron protection factors, and ±10% to factors of two for the gamma protection factors. The average VCS and MASH neutron and gamma protection factors shown in

Tables 10 and 11, indicate source/vehicle ground range has a negligible effect on all crew member positions. The driver position indicates a consistent 25% difference between VCS and MASH in the NPF. This difference is attributable to the difference in the vehicle secondary gamma production component of the total dose as calculated by VCS and MASH (see Table A-7). The gamma protection factor results indicate a slight decrease as a function of source/vehicle ground range in both the VCS and MASH results. The driver location gamma protection factor ratio ranges from 1.80 at 170 meters source/vehicle ground range to 0.90 at 1700 meters source/vehicle ground range. This difference is attributable to the large discrepancy in the ground secondary gamma production component to the total dose predicted by each code system. It should be noted, that had the ground secondary gamma production been significant for the other three crew member locations, a similar trend in the VCS/MASH GPF ratio would have been shown in Tables 10 and 11.

In Tables 12 and 13, comparisons of average VCS and MASH calculated neutron and gamma protection factors as a function of vehicle orientation are presented for each crew member location. Both the VCS and MASH results indicate vehicle orientation and crew member position present noticeable variations in the protection factors. Such changes most likely occur due to mutual shielding of the commander, gunner, and loader and to location in the vehicle with respect to the source in the case of the driver. The driver has the greatest protection when the rear of the M60A1 is facing the source, and the least amount of protection when the front of the M60A1 (where the driver is located) is facing the source.

Comparisons of the overall average VCS and MASH neutron and gamma protection factors (averaged over all source/vehicle ground ranges and vehicle orientations) for each crew member location, presented in Table 14, indicate excellent agreement between VCS and MASH. The commander, gunner, and loader positions show agreement within 10%, and the driver position shows agreement within 30%. The possible causes of the discrepancy at the driver position have been discussed above.

The final comparison between VCS and MASH is the neutron and gamma protection factors averaged over all source/vehicle ground ranges, vehicle orientations, and crew member locations. These factors represent the M60A1 "vehicle" protection factors and are indicative of the vehicle average independent of position. VCS calculated a NPF of 1.8 and a GPF of 6.9, and MASH calculated a NPF of 1.7 and a GPF of 6.5. This indicates excellent agreement between VCS and MASH (within 10%) for the analysis of the M60A1 tank in the given radiation field.

4.0 MONTE CARLO STATISTICAL UNCERTAINTY

Analysis of the VCS MORSE escape history tapes in DRC for the four crew member positions yielded statistical uncertainties on the order of ±10% to ±20% for integral neutron fluence(dose), gamma-ray fluence(dose), and total fluence(dose) for all contributions except the ground secondary gamma production, i.e. ground (n,γ).[2] Differential fluence(dose) results also exhibited statistical uncertainties typically between ±10% to ±20% for most of the energy groups which make a significant contribution to the response.[2]

Analysis of the MASH MORSE escape history tapes in DRC for the four crew member positions yielded statistical uncertainties on the order of ±2% to ±5% for integral neutron fluence(dose), gamma-ray fluence(dose), and total fluence(dose) for all contributions except the ground secondary gamma production, i.e. ground (n,γ). The statistical uncertainty of the ground (n,γ) dose ranged from ±25% to ±50%. Differential fluence(dose) results exhibited statistical uncertainties typically between ±5% to ±15% for neutron energies between 10 MeV and thermal, and gamma energies between 10 MeV and 100 keV. These energy ranges contain the energy groups in the DABL69 group structure which make a significant contribution to the response.

5.0 CONCLUSIONS

The overall objective of this task was to re-assess the nuclear radiation shielding characteristics of the U. S. M60A1 medium tank utilizing the new MASH code system. Furthermore, the MASH results were to be compared with results previously calculated and documented by the BRL using VCS. In general, the neutron protection factor (NPF) results show approximately 30% more protection for the commander, 80% to 90% more protection for the gunner, 60% to 70% more protection for the loader, and approximately a factor of three increase in protection for the driver. The gamma protection factor (GPF) results ranged from approximately 3 to 35 depending on crew member location, vehicle orientation, and source/vehicle ground range. Neutron protection factor changes versus vehicle range relative to point of burst are negligible, whereas variation of the vehicle orientation relative to the source can have a significant effect on both the neutron and gamma protection factors.

Analysis of the neutron and gamma dose and protection factor results indicate excellent agreement between VCS and MASH. VCS calculated a NPF of 1.8 and a GPF of 6.9, and MASH calculated a NPF of 1.7 and a GPF of 6.5. These factors represent the M60A1 "vehicle" protection factors and are indicative of the vehicle average independent of position. The results from both codes systems also exhibited the same trends relative to crew member location, source/vehicle ground range, and vehicle orientation. Slight differences were seen in the neutron free field doses, and neutron and gamma doses at the driver location. The principal differences seen in the doses at the crew member locations was due to vehicle secondary gamma production (vehicle (n,γ)), and ground secondary gamma production (ground (n,γ)).

There are several possible/probable reasons for the differences evidenced in the VCS and MASH results. In particular, different quadrature, spatial mesh, and cross section data were used in the air-over-ground analyses. The VCS calculations utilized a symmetric S_8 quadrature and a 58 group (37n - 21γ) ENDF/B-IV cross section library. The MASH calculations used a forward biased 240 angle quadrature and the DABL69 69 group (46n - 23γ) ENDF/B-V cross section library. Significant changes were made in the ENDF/B cross sections (especially the secondary gamma production cross sections for iron) in going from ENDF/B version IV to version V. This would effect all of the dose due to secondary gamma production (especially in the vehicle). Another possible source for the differences between the VCS and MASH results is the vehicle geometry model used in the two analyses. Unsuccessful efforts were made to recover the geometry input description used in the original VCS analysis. Consequently, the vehicle geometry description (and material description) used in the MASH analysis might not match the description used in the original VCS analysis. Finally, the possibility exist that the "binning" algorithms in VCS and MASH could be different. More specifically, in all the variations of VCS, the way in which a secondary gamma production was counted, e.g. vehicle, air, or ground, changed.

Consequently, a contributing secondary gamma may have been counted as an air (n,γ) in the VCS calculation and a ground (n,γ) in the MASH calculation. This would yield differences in the VCS and MASH individual secondary gamma production results but indicate reasonable agreement in the total secondary gamma production results. An examination of the dose results presented in Appendix A support this possibility to some extent.

To better understand the causes of the differences in the results of the VCS and MASH analyses of the M60A1 tank would require spectral comparisons of the free-field and in-vehicle data. Unfortunately, the original VCS data no longer exist and such a comparison cannot be made.

6.0 RECOMMENDATIONS

A comparison of VCS and MASH integral dose results was made for the U. S. M60A1 medium tank in an initial radiation environment. An exact comparison was not possible due to the lack of information available from the original VCS analysis. However, based on the results of the comparisons between the existing VCS analysis and new MASH analysis of the M60A1 medium tank, it is the opinion of the authors that MASH should be recommended to the NATO Panel VII Ad Hoc Group of Shielding Experts for replacing VCS as the reference code of choice for future armored vehicle nuclear vulnerability calculations. Additional comparisons should be made with VCS if sufficient information (input decks, geometry descriptions, spectral data, etc.) about the original VCS analysis is available. Otherwise, MASH should be further verified and validated through comparisons with experimental measurements.

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APPENDIX A

Comparison of VCS and MASH Neutron and Gamma Doses and Protection Factors for all Crew Members, all Source/Vehicle Ground Ranges, and all Vehicle Orientations Used in the Original VCS Analysis of the U. S. M60A1 "Battlefield Condition" Vehicle Configuration

Table A-1. Comparison of VCS and MASH Neutron Doses and Protection Factors as a Function of Source/Vehicle Ground Range and Vehicle Orientation for the M60A1 Commander in the "Battlefield Condition" Vehicle Configuration.

Range (m)	VCS Calculation Direct n (cGy)	VCS Calculation Vehicle n-γ (cGy)	VCS Calculation Sum (cGy)	VCS Calculation NPF	MASH Calculation Direct n (cGy)	MASH Calculation Vehicle n-γ (cGy)	MASH Calculation Sum (cGy)	MASH Calculation NPF	NPF_{VCS} / NPF_{MASH}
170									
RO	2.92+05[a]	2.50+04	3.17+05	1.2	2.69+05	3.88+04	3.08+05	1.2	1.00
RSO	2.91+05	2.47+04	3.16+05	1.2	2.60+05	3.81+04	2.98+05	1.2	1.00
FO	2.53+05	2.48+04	2.78+05	1.3	2.17+05	3.53+04	2.52+05	1.4	0.93
LSO	2.46+05	2.73+04	2.73+05	1.4	2.39+05	3.69+04	2.76+05	1.3	1.08
340									
RO	4.98+04	4.55+03	5.44+04	1.2	4.19+04	6.57+03	4.85+04	1.2	1.00
RSO	4.86+04	4.54+03	5.31+04	1.2	4.08+04	6.44+03	4.72+04	1.2	1.00
FO	4.03+04	4.89+03	4.52+04	1.4	3.49+04	6.09+03	4.10+04	1.4	1.00
LSO	4.23+04	4.68+03	4.70+04	1.4	3.83+04	6.34+03	4.46+04	1.3	1.08
680									
RO	2.52+03	2.41+02	2.76+03	1.2	2.04+03	3.27+02	2.37+03	1.2	1.00
RSO	2.49+03	2.40+02	2.73+03	1.2	1.95+03	3.21+02	2.28+03	1.2	1.00
FO	2.09+03	2.49+02	2.34+03	1.4	1.74+03	3.04+02	2.04+03	1.4	1.00
LSO	2.18+03	2.46+02	2.43+03	1.4	1.88+03	3.16+02	2.20+03	1.3	1.08
1020									
RO	1.80+02	1.76+01	1.97+02	1.2	1.46+02	2.34+01	1.69+02	1.2	1.00
RSO	1.78+02	1.76+01	1.95+02	1.2	1.40+02	2.30+01	1.63+02	1.2	1.00
FO	1.53+02	1.78+01	1.71+02	1.4	1.25+02	2.18+01	1.47+02	1.4	1.00
LSO	1.58+02	1.79+01	1.76+02	1.3	1.35+02	2.26+01	1.57+02	1.3	1.00
1360									
RO	1.57+01	1.54+00	1.72+01	1.2	1.28+01	2.02+00	1.48+01	1.2	1.00
RSO	1.55+01	1.54+00	1.71+01	1.2	1.24+01	1.98+00	1.44+01	1.2	1.00
FO	1.34+01	1.53+00	1.50+01	1.4	1.10+01	1.88+00	1.29+01	1.4	1.00
LSO	1.39+01	1.56+00	1.54+01	1.3	1.19+01	1.94+00	1.38+01	1.3	1.00
1700									
RO	1.55+00	1.49-01	1.69+00	1.2	1.30+00	1.98-01	1.50+00	1.2	1.00
RSO	1.53+00	1.48-01	1.68+00	1.2	1.26+00	1.94-01	1.46+00	1.2	1.00
FO	1.33+00	1.46-01	1.48+00	1.4	1.12+00	1.84-01	1.31+00	1.4	1.00
LSO	1.38+00	1.50-01	1.53+00	1.3	1.21+00	1.91-01	1.40+00	1.3	1.00

[a]Read as 2.92 x 10^5.

Table A-2. Comparison of VCS and MASH Gamma Doses and Protection Factors as a Function of Source/Vehicle Ground Range and Vehicle Orientation for the M60A1 Commander in the "Battlefield Condition" Vehicle Configuration.

	VCS Calculation				MASH Calculation				
Range (m)	Air n-γ (cGy)	Ground n-γ (cGy)	Sum (cGy)	GPF	Air n-γ (cGy)	Ground n-γ (cGy)	Sum (cGy)	GPF	GPF_{VCS} / GPF_{MASH}
170									
RO	4.04+03[a]	2.45+00	4.04+03	5.8	4.21+03	3.71+01	4.25+03	5.2	1.12
RSO	3.90+03	2.45+00	3.91+03	6.0	4.10+03	4.47+01	4.14+03	5.4	1.11
FO	3.41+03	2.45+00	3.41+03	6.9	3.52+03	3.97+01	3.56+03	6.2	1.11
LSO	3.82+03	2.45+00	3.82+03	6.1	3.87+03	3.94+01	3.90+03	5.7	1.07
340									
RO	1.08+03	3.60-01	1.08+03	4.8	1.07+03	6.10+00	1.07+03	4.3	1.12
RSO	1.02+03	3.60-01	1.02+03	5.1	1.02+03	7.13+00	1.03+03	4.5	1.13
FO	8.43+02	3.60-01	8.44+02	6.2	7.96+02	7.28+00	8.03+02	5.8	1.07
LSO	1.06+03	3.60-01	1.06+03	4.9	9.57+02	6.69+00	9.64+02	4.8	1.02
680									
RO	1.13+02	1.84-02	1.13+02	3.9	1.11+02	3.04-01	1.12+02	3.3	1.18
RSO	1.06+02	1.84-02	1.06+02	4.1	1.05+02	3.39-01	1.05+02	3.6	1.14
FO	7.89+01	1.84-02	7.89+01	5.5	6.87+01	3.34-01	6.90+01	5.4	1.02
LSO	1.21+02	1.84-02	1.21+02	3.6	9.62+01	3.49-01	9.66+01	3.9	0.92
1020									
RO	1.56+01	1.37-03	1.56+01	3.4	1.68+01	2.15-02	1.68+01	2.9	1.17
RSO	1.44+01	1.37-03	1.44+01	3.7	1.57+01	2.46-02	1.57+01	3.1	1.19
FO	1.00+01	1.37-03	1.00+01	5.3	8.75+00	2.40-02	8.78+00	5.5	0.96
LSO	1.77+01	1.37-03	1.77+01	3.0	1.43+01	2.61-02	1.43+01	3.4	0.88
1360									
RO	2.74+00	1.24-04	2.74+00	3.1	3.15+00	1.83-03	3.15+00	2.6	1.19
RSO	2.52+00	1.24-04	2.52+00	3.4	2.94+00	2.13-03	2.94+00	2.8	1.21
FO	1.63+00	1.24-04	1.63+00	5.3	1.45+00	2.08-03	1.45+00	5.6	0.95
LSO	3.30+00	1.24-04	3.30+00	2.6	2.67+00	2.36-03	2.67+00	3.1	0.84
1700									
RO	5.68-01	1.26-05	5.68-01	3.0	6.90-01	1.78-04	6.91-01	2.5	1.20
RSO	5.15-01	1.26-05	5.15-01	3.3	6.45-01	2.11-04	6.45-01	2.6	1.27
FO	3.13-01	1.26-05	3.13-01	5.5	2.91-01	2.04-04	2.91-01	5.9	0.93
LSO	7.09-01	1.26-05	7.09-01	2.4	5.84-01	2.28-04	5.85-01	2.9	0.83

[a]Read as 4.04×10^3.

Table A-3. Comparison of VCS and MASH Neutron Doses and Protection Factors as a Function of Source/Vehicle Ground Range and Vehicle Orientation for the M60A1 Gunner in the "Battlefield Condition" Vehicle Configuration.

	VCS Calculation				MASH Calculation				
Range (m)	Direct n (cGy)	Vehicle n-γ (cGy)	Sum (cGy)	NPF	Direct n (cGy)	Vehicle n-γ (cGy)	Sum (cGy)	NPF	NPF_{VCS} / NPF_{MASH}
170									
RO	1.55+05[a]	1.97+04	1.75+05	2.1	1.51+05	2.70+04	1.78+05	2.0	1.05
RSO	1.89+05	2.20+04	2.11+05	1.7	1.94+05	3.04+04	2.25+05	1.6	1.06
FO	1.90+05	2.34+04	2.13+05	1.7	1.66+05	2.90+04	1.95+05	1.8	0.94
LSO	1.67+05	2.06+04	1.88+05	2.0	1.63+05	2.76+04	1.90+05	1.9	1.05
340									
RO	2.59+04	3.66+03	2.96+04	2.2	2.39+04	4.60+03	2.85+04	2.0	1.10
RSO	3.34+04	4.07+03	3.75+04	1.7	2.97+04	5.14+03	3.48+04	1.7	1.00
FO	3.03+04	4.21+03	3.45+04	1.9	2.61+04	4.86+03	3.10+04	1.9	1.00
LSO	2.75+04	3.75+03	3.12+04	2.1	2.48+04	4.64+03	2.94+04	2.0	1.05
680									
RO	1.34+03	1.95+02	1.54+03	2.1	1.18+03	2.32+02	1.41+03	2.0	1.05
RSO	1.71+03	2.17+02	1.93+03	1.7	1.45+03	2.52+02	1.70+03	1.6	1.06
FO	1.57+03	2.22+02	1.79+03	1.8	1.27+03	2.41+02	1.51+03	1.8	1.00
LSO	1.43+03	2.01+02	1.63+03	2.0	1.22+03	2.31+02	1.45+03	1.9	1.05
1020									
RO	9.76+01	1.43+01	1.12+02	2.1	8.54+01	1.66+01	1.02+02	2.0	1.05
RSO	1.21+02	1.58+01	1.37+02	1.7	1.03+02	1.79+01	1.21+02	1.6	1.06
FO	1.15+02	1.61+01	1.31+02	1.8	9.12+01	1.72+01	1.08+02	1.8	1.00
LSO	1.04+02	1.46+01	1.19+02	2.0	8.82+01	1.65+01	1.05+02	1.9	1.05
1360									
RO	8.57+00	1.25+00	9.82+00	2.1	7.57+00	1.43+00	9.00+00	1.9	1.11
RSO	1.05+01	1.38+00	1.19+01	1.7	9.11+00	1.54+00	1.06+01	1.6	1.06
FO	1.01+01	1.39+00	1.14+01	1.8	8.06+00	1.48+00	9.54+00	1.8	1.00
LSO	9.12+00	1.27+00	1.04+01	2.0	7.85+00	1.42+00	9.27+00	1.9	1.05
1700									
RO	8.45-01	1.20-01	9.65-01	2.1	7.75-01	1.40-01	9.15-01	1.9	1.11
RSO	1.04+00	1.35-01	1.17+00	1.7	9.28-01	1.51-01	1.08+00	1.6	1.06
FO	9.92-01	1.33-01	1.13+00	1.8	8.22-01	1.45-01	9.67-01	1.8	1.00
LSO	8.99-01	1.22-01	1.02+00	2.0	8.05-01	1.40-01	9.45-01	1.9	1.05

[a]Read as 1.55×10^5.

Table A-4. Comparison of VCS and MASH Gamma Doses and Protection Factors as a Function of Source/Vehicle Ground Range and Vehicle Orientation for the M60A1 Gunner in the "Battlefield Condition" Vehicle Configuration.

	VCS Calculation				MASH Calculation				
Range (m)	Air n-γ (cGy)	Ground n-γ (cGy)	Sum (cGy)	GPF	Air n-γ (cGy)	Ground n-γ (cGy)	Sum (cGy)	GPF	GPF_{VCS} / GPF_{MASH}
170									
RO	2.06+03[a]	2.55+00	2.06+03	11.4	1.92+03	5.12+01	1.97+03	11.3	1.01
RSO	2.09+03	3.29+00	2.09+03	11.2	2.01+03	5.16+01	2.06+03	10.8	1.04
FO	1.77+03	2.85+01	1.79+03	13.1	1.66+03	5.70+01	1.71+03	13.0	1.01
LSO	1.96+03	4.75+00	1.96+03	11.9	1.83+03	6.39+01	1.90+03	11.7	1.02
340									
RO	5.29+02	3.90-01	5.30+02	9.8	4.52+02	9.46+00	4.61+02	10.0	0.98
RSO	5.80+02	5.13-01	5.81+02	9.0	5.34+02	8.54+00	5.42+02	8.5	1.06
FO	4.18+02	2.57+00	4.20+02	12.4	3.69+02	9.06+00	3.78+02	12.3	1.01
LSO	5.18+02	7.47-01	5.19+02	10.1	4.60+02	9.15+00	4.69+02	9.9	1.02
680									
RO	5.37+01	2.00-02	5.38+01	8.1	4.38+01	4.17-01	4.42+01	8.4	0.96
RSO	6.64+01	2.63-02	6.64+01	6.6	5.84+01	4.17-01	5.88+01	6.3	1.05
FO	3.59+01	1.16-01	3.60+01	12.2	3.09+01	4.31-01	3.13+01	11.9	1.03
LSO	5.66+01	3.81-02	5.66+01	7.7	4.84+01	4.25-01	4.88+01	7.6	1.01
1020									
RO	7.20+00	1.50-03	7.21+00	7.4	6.16+00	2.93-02	6.19+00	7.8	0.95
RSO	9.64+00	1.96-03	9.64+00	5.5	9.24+00	2.97-02	9.27+00	5.2	1.06
FO	4.11+00	7.96-03	4.11+00	12.9	3.72+00	3.06-02	3.76+00	12.8	1.01
LSO	7.99+00	2.83-03	7.99+00	6.6	7.33+00	3.00-02	7.36+00	6.5	1.02
1360									
RO	1.23+00	1.39-04	1.23+00	7.0	1.09+00	2.50-03	1.09+00	7.5	0.93
RSO	1.78+00	1.81-04	1.78+00	4.8	1.79+00	2.54-03	1.79+00	4.6	1.04
FO	5.88-01	6.87-04	5.89-01	14.7	5.73-01	2.63-03	5.75-01	14.2	1.04
LSO	1.45+00	2.60-04	1.45+00	6.0	1.38+00	2.55-03	1.38+00	5.9	1.02
1700									
RO	2.47-01	1.45-05	2.47-01	6.9	2.31-01	2.45-04	2.31-01	7.4	0.93
RSO	3.80-01	1.89-05	3.80-01	4.5	4.00-01	2.51-04	4.00-01	4.3	1.05
FO	1.01-01	6.82-05	1.01-01	16.9	1.07-01	2.59-04	1.07-01	15.7	1.08
LSO	3.07-01	2.71-05	3.07-01	5.6	3.04-01	2.49-04	3.05-01	5.6	1.00

[a]Read as 2.06×10^3.

Table A-5. Comparison of VCS and MASH Neutron Doses and Protection Factors as a Function of Source/Vehicle Ground Range and Vehicle Orientation for the M60A1 Loader in the "Battlefield Condition" Vehicle Configuration.

	VCS Calculation				MASH Calculation				
Range (m)	Direct n (cGy)	Vehicle n-γ (cGy)	Sum (cGy)	NPF	Direct n (cGy)	Vehicle n-γ (cGy)	Sum (cGy)	NPF	NPF_{VCS} / NPF_{MASH}
170									
RO	1.88+05[a]	2.55+04	2.14+05	1.7	1.80+05	3.12+04	2.11+05	1.7	1.00
RSO	1.60+05	2.61+04	1.86+05	2.0	1.69+05	3.01+04	2.00+05	1.8	1.11
FO	1.82+05	2.88+04	2.11+05	1.7	1.79+05	3.13+04	2.11+05	1.7	1.00
LSO	2.18+05	3.72+04	2.55+05	1.4	2.18+05	3.59+04	2.54+05	1.4	1.00
340									
RO	3.01+04	4.63+03	3.48+04	1.8	2.83+04	5.24+03	3.35+04	1.7	1.06
RSO	2.76+04	4.58+03	3.22+04	2.0	2.62+04	5.09+03	3.13+04	1.8	1.11
FO	3.14+04	5.32+03	3.68+04	1.7	2.80+04	5.33+03	3.33+04	1.7	1.00
LSO	3.65+04	5.89+03	4.24+04	1.5	3.47+04	5.92+03	4.06+04	1.4	1.07
680									
RO	1.56+03	2.46+02	1.80+03	1.8	1.39+03	2.62+02	1.65+03	1.7	1.06
RSO	1.44+03	2.41+02	1.68+03	2.0	1.31+03	2.54+02	1.56+03	1.8	1.11
FO	1.62+03	2.77+02	1.90+03	1.7	1.36+03	2.66+02	1.62+03	1.7	1.00
LSO	1.87+03	3.01+02	2.17+03	1.5	1.66+03	2.88+02	1.94+03	1.4	1.07
1020									
RO	1.14+02	1.80+01	1.32+02	1.8	1.00+02	1.87+01	1.19+02	1.7	1.06
RSO	1.05+02	1.76+01	1.23+02	1.9	9.45+01	1.82+01	1.13+02	1.8	1.06
FO	1.17+02	2.00+01	1.37+02	1.7	9.86+01	1.90+01	1.18+02	1.7	1.00
LSO	1.33+02	2.16+01	1.55+02	1.5	1.18+02	2.05+01	1.39+02	1.4	1.07
1360									
RO	1.00+01	1.56+00	1.16+01	1.8	8.92+00	1.61+00	1.05+01	1.7	1.06
RSO	9.24+00	1.54+00	1.08+01	1.9	8.38+00	1.57+00	9.94+00	1.8	1.06
FO	1.02+01	1.74+00	1.19+01	1.7	8.78+00	1.63+00	1.04+01	1.7	1.00
LSO	1.17+01	1.87+00	1.35+01	1.5	1.05+01	1.77+00	1.22+01	1.4	1.07
1700									
RO	9.90-01	1.51-01	1.14+00	1.8	9.10-01	1.57-01	1.07+00	1.7	1.06
RSO	9.12-01	1.49-01	1.06+00	1.9	8.56-01	1.54-01	1.01+00	1.8	1.06
FO	1.00+00	1.68-01	1.17+00	1.7	8.99-01	1.60-01	1.06+00	1.7	1.00
LSO	1.15+00	1.81-01	1.33+00	1.5	1.07+00	1.70-01	1.24+00	1.4	1.07

[a]Read as 1.88 x 10^5.

Table A-6. Comparison of VCS and MASH Gamma Doses and Protection Factors as a Function of Source/Vehicle Ground Range and Vehicle Orientation for the M60A1 Loader in the "Battlefield Condition" Vehicle Configuration.

	VCS Calculation				MASH Calculation				
Range (m)	Air n-γ (cGy)	Ground n-γ (cGy)	Sum (cGy)	GPF	Air n-γ (cGy)	Ground n-γ (cGy)	Sum (cGy)	GPF	GPF_{VCS} / GPF_{MASH}
170									
RO	2.60+03[a]	5.46-01	2.60+03	9.0	2.48+03	1.73+02	2.65+03	8.4	1.07
RSO	2.42+03	2.89+00	2.42+03	9.7	2.23+03	1.80+02	2.41+03	9.2	1.05
FO	2.45+03	6.74-01	2.45+03	9.6	2.31+03	1.67+02	2.47+03	9.0	1.07
LSO	2.81+03	7.99+00	2.82+03	8.3	2.83+03	1.66+02	3.00+03	7.4	1.12
340									
RO	6.52+02	7.78-02	6.52+02	8.0	5.77+02	2.70+01	6.04+02	7.7	1.04
RSO	6.29+02	2.45-01	6.29+02	8.3	5.49+02	2.87+01	5.78+02	8.0	1.04
FO	6.03+02	1.71-01	6.03+02	8.6	5.26+02	2.72+01	5.53+02	8.4	1.02
LSO	8.04+02	5.73-01	8.05+02	6.5	7.64+02	3.15+01	7.96+02	5.8	1.12
680									
RO	6.16+01	4.25-03	6.16+01	7.1	5.27+01	1.32+00	5.41+01	6.9	1.03
RSO	6.48+01	1.04-02	6.48+01	6.8	5.39+01	1.35+00	5.52+01	6.8	1.00
FO	5.58+01	9.50-03	5.58+01	7.8	4.53+01	1.31+00	4.66+01	8.0	0.98
LSO	9.45+01	2.24-02	9.45+01	4.6	8.54+01	1.33+00	8.67+01	4.3	1.07
1020									
RO	7.71+00	3.53-04	7.71+00	6.9	6.91+00	9.46-02	7.01+00	6.8	1.01
RSO	8.66+00	8.39-04	8.66+00	6.1	7.73+00	9.61-02	7.83+00	6.1	1.00
FO	6.86+00	6.70-04	6.86+00	7.7	5.57+00	9.36-02	5.66+00	8.5	0.91
LSO	1.40+01	1.55-03	1.40+01	3.8	1.36+01	9.49-02	1.37+01	3.5	1.09
1360									
RO	1.22+00	3.47-05	1.22+00	7.1	1.14+00	8.19-03	1.15+00	7.1	1.00
RSO	1.50+00	8.23-05	1.51+00	5.7	1.40+00	8.30-03	1.41+00	5.8	0.98
FO	1.07+00	6.12-05	1.07+00	8.0	8.64-01	8.09-03	8.72-01	9.4	0.85
LSO	2.63+00	1.29-04	2.63+00	3.3	2.61+00	8.20-03	2.62+00	3.1	1.06
1700									
RO	2.28-01	3.73-06	2.28-01	7.5	2.25-01	8.12-04	2.25-01	7.6	0.99
RSO	3.09-01	8.81-06	3.09-01	5.5	3.01-01	8.23-04	3.01-01	5.7	0.96
FO	2.01-01	6.27-06	2.01-01	8.5	1.61-01	8.02-04	1.62-01	10.6	0.80
LSO	5.65-01	1.15-05	5.65-01	3.0	5.82-01	8.12-04	5.83-01	2.9	1.03

[a]Read as 2.60 x 10^3.

Table A-7. Comparison of VCS and MASH Neutron Doses and Protection Factors as a Function of Source/Vehicle Ground Range and Vehicle Orientation for the M60A1 Driver in the "Battlefield Condition" Vehicle Configuration.

	VCS Calculation				MASH Calculation				
Range (m)	Direct n (cGy)	Vehicle n-γ (cGy)	Sum (cGy)	NPF	Direct n (cGy)	Vehicle n-γ (cGy)	Sum (cGy)	NPF	NPF_{VCS} / NPF_{MASH}
170									
RO	6.08+04[a]	1.07+04	7.15+04	5.2	6.88+04	2.28+04	9.16+04	3.9	1.33
RSO	1.00+05	1.38+04	1.14+05	3.2	1.09+05	2.68+04	1.36+05	2.6	1.23
FO	1.32+05	1.43+04	1.46+05	2.5	1.35+05	2.89+04	1.64+05	2.2	1.14
LSO	1.07+05	1.22+04	1.19+05	3.1	1.09+05	2.67+04	1.35+05	2.6	1.19
340									
RO	1.03+04	1.96+03	1.22+04	5.3	1.14+04	3.88+03	1.53+04	3.8	1.39
RSO	1.72+04	2.34+03	1.95+04	3.3	1.70+04	4.45+03	2.14+04	2.7	1.22
FO	2.14+04	2.71+03	2.44+04	2.7	2.05+04	4.78+03	2.53+04	2.3	1.17
LSO	1.62+04	2.38+03	1.86+04	3.5	1.67+04	4.37+03	2.11+04	2.7	1.30
680									
RO	5.42+02	1.03+02	6.45+02	5.1	5.67+02	1.95+02	7.62+02	3.6	1.42
RSO	8.79+02	1.22+02	1.00+03	3.3	8.13+02	2.19+02	1.03+03	2.7	1.22
FO	1.08+03	1.41+02	1.22+03	2.7	9.69+02	2.33+02	1.20+03	2.3	1.17
LSO	8.23+02	1.27+02	9.49+02	3.5	8.01+02	2.15+02	1.02+03	2.7	1.30
1020									
RO	3.99+01	7.58+00	4.75+01	5.0	4.14+01	1.40+01	5.53+01	3.6	1.39
RSO	6.21+01	8.90+00	7.10+01	3.3	5.81+01	1.55+01	7.36+01	2.7	1.22
FO	7.66+01	1.01+01	8.67+01	2.7	6.93+01	1.66+01	8.59+01	2.3	1.17
LSO	5.90+01	9.18+00	6.82+01	3.5	5.75+01	1.54+01	7.28+01	2.7	1.30
1360									
RO	3.53+00	6.56-01	4.18+00	5.0	3.68+00	1.20+00	4.88+00	3.6	1.39
RSO	5.43+00	7.72-01	6.20+00	3.3	5.10+00	1.33+00	6.43+00	2.7	1.22
FO	6.72+00	8.78-01	7.59+00	2.7	6.12+00	1.42+00	7.54+00	2.3	1.17
LSO	5.17+00	8.05-01	5.97+00	3.5	5.08+00	1.32+00	6.40+00	2.7	1.30
1700									
RO	3.48-01	6.26-02	4.11-01	5.0	3.76-01	1.17-01	4.93-01	3.6	1.39
RSO	5.38-01	7.45-02	6.13-01	3.3	5.20-01	1.30-01	6.50-01	2.7	1.22
FO	6.68-01	8.52-02	7.53-01	2.7	6.26-01	1.39-01	7.65-01	2.3	1.13
LSO	5.11-01	7.86-02	5.89-01	3.5	5.19-01	1.29-01	6.48-01	2.7	1.30

[a]Read as 6.08×10^4.

Table A-8. Comparison of VCS and MASH Gamma Doses and Protection Factors as a Function of Source/Vehicle Ground Range and Vehicle Orientation for the M60A1 Driver in the "Battlefield Condition" Vehicle Configuration.

	VCS Calculation				MASH Calculation				
Range (m)	Air n-γ (cGy)	Ground n-γ (cGy)	Sum (cGy)	GPF	Air n-γ (cGy)	Ground n-γ (cGy)	Sum (cGy)	GPF	$\frac{GPF_{VCS}}{GPF_{MASH}}$
170									
RO	6.72+02[a]	1.31+00	6.74+02	34.8	7.85+02	4.95+02	1.28+03	17.4	2.00
RSO	9.45+02	4.43+00	9.49+02	24.7	1.05+03	5.76+02	1.62+03	13.7	1.80
FO	1.06+03	1.05+01	1.07+03	21.8	1.21+03	5.08+02	1.72+03	13.0	1.68
LSO	9.38+02	2.17+01	9.60+02	24.4	1.03+03	4.99+02	1.53+03	14.6	1.67
340									
RO	1.53+02	1.82-01	1.53+02	34.1	1.62+02	8.22+01	2.44+02	19.1	1.79
RSO	2.46+02	3.68-01	2.46+02	21.2	2.47+02	8.71+01	3.34+02	13.9	1.53
FO	2.78+02	1.36+00	2.79+02	18.7	2.76+02	8.55+01	3.61+02	12.9	1.45
LSO	2.50+02	1.49+00	2.51+02	20.7	2.37+02	8.40+01	3.21+02	14.5	1.43
680									
RO	1.27+01	9.09-03	1.27+01	34.4	1.19+01	4.07+00	1.60+01	23.3	1.48
RSO	2.69+01	1.55-02	2.70+01	16.2	2.41+01	4.27+00	2.83+01	13.1	1.24
FO	2.88+01	7.24-02	2.89+01	15.2	2.57+01	4.19+00	2.99+01	12.5	1.22
LSO	2.83+01	6.55-02	2.84+01	15.4	2.25+01	4.13+00	2.66+01	14.0	1.10
1020									
RO	1.50+00	6.89-04	1.50+00	35.4	1.44+00	2.89-01	1.73+00	27.6	1.28
RSO	3.77+00	1.14-03	3.77+00	14.1	3.51+00	3.05-01	3.82+00	12.5	1.13
FO	3.82+00	5.44-03	3.83+00	13.9	3.38+00	2.98-01	3.68+00	13.0	1.07
LSO	4.08+00	5.02-03	4.09+00	13.0	3.17+00	2.95-01	3.47+00	13.8	0.94
1360									
RO	2.40-01	6.40-05	2.40-01	36.0	2.43-01	2.46-02	2.67-01	30.5	1.18
RSO	6.71-01	1.04-04	6.71-01	12.9	6.35-01	2.62-02	6.62-01	12.3	1.05
FO	6.29-01	5.23-04	6.30-01	13.7	5.45-01	2.55-02	5.70-01	14.3	0.96
LSO	7.51-01	4.81-04	7.52-01	11.5	5.65-01	2.51-02	5.90-01	13.8	0.83
1700									
RO	4.68-02	6.56-06	4.68-02	36.4	5.14-02	2.38-03	5.38-02	31.6	1.15
RSO	1.39-01	1.04-05	1.39-01	12.3	1.36-01	2.56-03	1.39-01	12.3	1.00
FO	1.21-01	5.59-05	1.21-01	14.1	1.03-01	2.48-03	1.06-01	16.1	0.88
LSO	1.60-01	5.10-05	1.60-01	10.7	1.19-01	2.43-03	1.21-01	14.0	0.76

[a]Read as 6.72×10^2.

APPENDIX B

Sample Input Decks for GIP, GRTUNCL, DORT, VISTA, MORSE, and DRC Used in the MASH Analysis of the U. S. M60A1 "Battlefield Condition" Vehicle Configuration

```
gip ground and air mixtures for the M60A1 comparisons -- p5  forward

1$$  69 3 4 72 42   /igm,iht,ihs,ihm,ms
     0 144 156 0 5   /mcr,mtp,mtm,ith,isct
     1 2 2 120   /iprt,iout,idot,nbuf
e t

10$$ 4i145 150 3q6  4i151 156 2q6
 /    aprf ground        air

11$$  4i1 6 4i31 36 10i49 60  / aprf ground

      10i25 36 4i79 84  / air

12**   /number densities (atoms/b-cm)
      6r9.75-03 6r3.48-02 6r4.88-03 6r1.16-02 /grnd; brl report no. 1998

      6r4.19-05 6r1.13-05 6r2.51-07   /air; brl report no. 1998

13$$  1 2 3 4 5 6 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
      61 62 63 64 65 66 67 68 69 70 71 72 79 80 81 82 83 84 85 86 87 88
      89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107
      108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
      124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 157
      158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173
      174 175 176 177 178 179 180 181 182 183 184 185 186 199 200 201
      202 203 204 205 206 207 208 209 210 223 224 225 226 227 228
 / h,b10,b11,c,n,o,na,mg,al,si,p,s,cl,ar,k,ca,mn,fe,co,ni,cu,zr,nb,sn

  t
```

Figure B-1. Sample GIP Input for the Boosted Fission Weapon Air-Over-Ground Analysis Used in the MASH Analysis of the M60A1 "Battlefield Condition" Vehicle Configuration.

```
' air-over-ground using boosted fission weapon neutron source
' 100m source height, simple topography out to 1700m test site
' ground data, and air data from brl report number 1998

1$$ 0 5 6 140 175   / ith,isct,izm,im,jm
    69 3 4 72 0   / igm,iht,ihs,ihm,ms
    0 12 12 2 0   / mcr,mtp,mt,idatl,noa
    4 1 0 23 2   / imode,iprtc,nflsv,npso,iprtf
    0 0 0 500 0   / iprts,iz3,idfac,nbuf,ntnpr

2** 0 10000.0 0   / xnf,zpt,rpt
t
1** f0   /fission spectrum

2**   /axii (jm+1)
  -80 -75 -70 -65 -60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 -2.5
  -1 0 50 150 250 350 450 550 700 950 1100 1300 1600 2000 2500 3100
  3800 4572 5825 6788 7529 8100 8538 8875 9136 9335 9488 9606 9697
  9767 9821 9862 9894 9918 9937 9952 9963 9971 9978 9983 9987 9990
  9992 9993.5 9995 10000 10005 10006.5 10008 10010 10013 10017 10022
  10029 10037 10048 10063 10082 10106 10138 10179 10233 10303 10394
  10512 10665 10865 11125 11462 11900 12471 13212 14175 15428 17056
  18700 20500 22500 25000 27500 30000 32500 35000 37500 40000 42500
  45000 47500 50000 52500 55000 57500 60000 62500 65000 67500 70000
  72500 75000 77500 80000 82500 85000 87500 90000 92500 95000 97500
  100000 103000 106000 109000 112000 115000 118000 121000 124000
  127000 130000 133000 136000 139000 142000 145000 148000 151000
  154000 157000 160000 163000 166000 169000 172000 175000 178000
  181000 184000 187000 190000 193000 196000 199000 202000 205000
  208000 211000 214000 217000 220000 223000 226000 229000 232000
  235000 238000 241000 244000 247000 250000

4**   /radii (im+1)
  0 5 6.5 8 10 13 17 22 29 37 48 63 82 106 138 179 233 303 394 512 665
  865 1125 1462 1900 2471 3212 4175 5428 7056 9000 11000 13000 15000
  16500 17500 19000 21000 23000 25000 27000 29000 31000 32500 33500
  34500 35500 37000 39000 41500 44000 46500 49000 51500 54000 56500
  59000 61500 64000 66000 67500 68500 70000 72000 74500 77000 79500
  82000 84500 87000 89500 92000 94500 97000 99000 100500 101500 102500
  103500 105000 107000 109500 112000 114500 117000 119500 122000
  124500 127000 129500 132000 134000 135500 136500 138000 140000
  142500 145000 147500 150000 152500 155000 157500 160000 162500
  165000 167000 168500 169500 170500 171500 173000 175000 177500
  180000 182500 185000 187500 190000 192500 195000 197500 200000
  202500 205000 207500 210000 212500 215000 217500 220000 223000
  226000 229000 232000 235000 238000 241000 244000 247000 250000
```

Figure B-2. Sample GRTUNCL Input for the Boosted Fission Weapon Neutron Source Used in the MASH Analysis of the M60A1 "Battlefield Condition" Vehicle Configuration.

```
8$$   / zone numbers by interval
' zones 1, 2, & 3 - ground, 4 , 5, & 6 - air
  140r1 11q140             /j-ints 1-12
  33r2 3r3 7r2 3r3 13r2 3r3 13r2 3r3
  13r2 3r3 13r2 3r3 5r2 25r1 5q140   /j-ints 13-18
  33r5 3r6 7r5 3r6 13r5 3r6 13r5 3r6
  13r5 3r6 13r5 3r6 5r5 25r4 4q140   /j-ints 19-23
  115r5 25r4 70q140          /j-ints 24-94
  140r4 80q140               /j-ints 95-175

9$$ 3r-1 3r-7   / mat by zone

15**    / boosted fission weapon neutron source by energy group
  0.000e+00  0.000e+00  0.000e+00  3.833e-03  1.945e-02  4.568e-03
  7.066e-03  4.391e-03  3.981e-03  4.513e-03  9.542e-03  1.264e-02
  2.418e-02  7.972e-03  2.167e-02  3.472e-02  8.330e-02  1.052e-02
  6.473e-02  5.448e-02  5.922e-02  3.253e-02  3.126e-02  1.811e-02
  3.349e-02  2.886e-02  5.877e-02  5.883e-02  5.006e-02  2.597e-02
  5.013e-02  2.050e-02  1.074e-02  3.285e-03  3.262e-02  3.166e-02
  2.417e-02  5.825e-02  0.000e+00  0.000e+00  0.000e+00  0.000e+00
  0.000e+00  0.000e+00  0.000e+00  0.000e+00  23r0.0
t
```

Figure B-2. (continued)

```
' dort - aog for tactical/boosted fission weapon neutron source, mm=240
' 100m source height, simple topography out to 1700m ground range
' ground data, and air data from brl report number 1998

61$$ 0 21 4 0 23   / ntflx,ntfog,ntsig,ntbsi,ntdsi
     0 0 0 0 22   / ntfci,ntibi,ntibo,ntnpr,ntdir
     0 e   / ntdso

62$$ 0 5 6 140 175   / iadj,isctm,izm,im,jm
     69 3 4 72 0   / igm,iht,ihs,ihm,mixl
     0 12 12 0 240   / mcr,mtp,mtm,idfac,mm
     1 1 0 0 0   / ingeom,ibl,ibr,ibb,ibt
     1 -4 0 4 0   / isrmx,ifxmi,ifxmf,mode,ktype
     2 0 0 0 0   / iacc,kalf,igtype,inpfxm,inpsrm
     0 0 0 0 0   / njntsr,nintsr,njntfx,nintfx,iact
     6 0 1 1 2   / ired,ipdb2,ifxprt,icsprt,idirf
     13 27 120 11 1   / jdirf,jdirl,nbuf,iepsbz,minblk
     1 1 1 1 1   / maxblk,isbt,msbt,msdm,ibfscl
     4 50 2 0 0  / intscl,itmscl,nofis,ifdb2z,iswp
     19 28 0 0 0   / keyjn,keyin,nsigtp,norpos,normat
     0 0 1500 0 -30   / mstmax,negfix,locobj,lcmobj,nkeyfx
     4 46 0 0 0   / ncndin,neut,itally,ispl,isp2
     e

63** 300 0.0 1-4 1-2 0.0   / tmax,xnf,eps,epp,epv
     1-3 1.0 0.2 1.5 10.0   /epf,ekobj,evth,evchm,evmax
     1.0 1.0 -1.0 0.3 10.0   /evkmx,evi,devdki,evdelk,sormin
     1.0 1-4 1-2 0.3 -1.5   /conacc,conscl,coneps,wsoloi,wsolii
     1.5 0.6 0.0 1-60 0.0   /wsolcn,orf,fsnacc,flxmin,smooth
     1-2 0.2 0.9   / epo,extrcv,theta
     e  t
     t

81**      / wts mm240
   0 2r102900-8 0 2r307825-8 0 2r510200-8 0 2r708425-8 0
   2r901350-8 0 563869-8 316131-8 n2 0 641385-8 359590-8 n2 0
   714976-8 400849-8 n2 0 784547-8 439853-8 n2 0 857529-8
   480771-8 n2 0 642875-8 293289-8 479164-8 n3 0 681415-8
   310872-8 507890-8 n3 0 716550-8 326901-8 534077-8 n3 0
   745915-8 340298-8 555965-8 n3 0 775565-8 353825-8 578064-8
   n3 0 489468-8 386282-8 513536-8 364389-8 n4 0 500102-8
   394674-8 524693-8 372306-8 n4 0 508580-8 401365-8 533587-8
   378617-8 n4 0 515474-8 406806-8 540820-8 383750-8 n4 0
   517107-8 408094-8 542534-8 384965-8 n4 q120
```

Figure B-3. Sample DORT Input for the Boosted Fission Weapon Neutron Source Used in the MASH Analysis of the M60A1 "Battlefield Condition" Vehicle Configuration.

```
82**      / mus mm240
   -641230-7 -421582-7 ml -142963-6 -939923-7 ml -229252-6
   -150724-6 ml -315291-6 -207291-6 ml -399349-6 -262555-6 ml
   -472796-6 -411087-6 -143488-6 m2 -537046-6 -466952-6
   -162988-6 m2 -598374-6 -520275-6 -181600-6 m2 -656401-6
   -570729-6 -199211-6 m2 -711034-6 -618231-6 -215791-6 m2
   -761567-6 -713133-6 -470428-6 -164201-6 m3 -807567-6
   -756207-6 -498843-6 -174119-6 m3 -849108-6 -795106-6
   -524503-6 -183075-6 m3 -885925-6 -829582-6 -547246-6
   -191013-6 m3 -917890-6 -859514-6 -566991-6 -197905-6 m3
   -944812-6 -922954-6 -765692-6 -505099-6 -176303-6 m4
   -966490-6 -944130-6 -783260-6 -516688-6 -180348-6 m4
   -982847-6 -960108-6 -796516-6 -525433-6 -183400-6 m4
   -993815-6 -970823-6 -805405-6 -531297-6 -185447-6 m4
   -999313-6 -976194-6 -809860-6 -534236-6 -186473-6 m4 q120

83**       / etas mm240
   3r-.997942 3r-.989728 3r-.973367 3r-.948995 3r-.916799
   5r-.881172 5r-.843553 5r-.801217 5r-.754412 5r-.703158
   7r-.648086 7r-.589776 7r-.528222 7r-.463828 7r-.396835
   9r-.327613 9r-.256704 9r-.184425 9r-.111045 9r-.037054 g120

84$$ 1 2 3 4 5 6   / reg nos by zone
     t
1** f0   / fission spectrum

2**   /axii (jm+l)
  -80 -75 -70 -65 -60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 -2.5
  -1 0 50 150 250 350 450 550 700 950 1100 1300 1600 2000 2500 3100
  3800 4572 5825 6788 7529 8100 8538 8875 9136 9335 9488 9606 9697
  9767 9821 9862 9894 9918 9937 9952 9963 9971 9978 9983 9987 9990
  9992 9993.5 9995 10000 10005 10006.5 10008 10010 10013 10017 10022
  10029 10037 10048 10063 10082 10106 10138 10179 10233 10303 10394
  10512 10665 10865 11125 11462 11900 12471 13212 14175 15428 17056
  18700 20500 22500 25000 27500 30000 32500 35000 37500 40000 42500
  45000 47500 50000 52500 55000 57500 60000 62500 65000 67500 70000
  72500 75000 77500 80000 82500 85000 87500 90000 92500 95000 97500
  100000 103000 106000 109000 112000 115000 118000 121000 124000
  127000 130000 133000 136000 139000 142000 145000 148000 151000
  154000 157000 160000 163000 166000 169000 172000 175000 178000
  181000 184000 187000 190000 193000 196000 199000 202000 205000
  208000 211000 214000 217000 220000 223000 226000 229000 232000
  235000 238000 241000 244000 247000 250000
```

Figure B-3. (continued)

```
4**   /radii (im+1)
  0 5 6.5 8 10 13 17 22 29 37 48 63 82 106 138 179 233 303 394 512 665
  865 1125 1462 1900 2471 3212 4175 5428 7056 9000 11000 13000 15000
  16500 17500 19000 21000 23000 25000 27000 29000 31000 32500 33500
  34500 35500 37000 39000 41500 44000 46500 49000 51500 54000 56500
  59000 61500 64000 66000 67500 68500 70000 72000 74500 77000 79500
  82000 84500 87000 89500 92000 94500 97000 99000 100500 101500 102500
  103500 105000 107000 109500 112000 114500 117000 119500 122000
  124500 127000 129500 132000 134000 135500 136500 138000 140000
  142500 145000 147500 150000 152500 155000 157500 160000 162500
  165000 167000 168500 169500 170500 171500 173000 175000 177500
  180000 182500 185000 187500 190000 192500 195000 197500 200000
  202500 205000 207500 210000 212500 215000 217500 220000 223000
  226000 229000 232000 235000 238000 241000 244000 247000 250000

5** f1   / energy group boundaries

8$$   / zone numbers by interval
' zones 1, 2, & 3 - ground, 4 , 5, & 6 - air
  140r1 11q140               /j-ints 1-12
  33r2 3r3 7r2 3r3 13r2 3r3 13r2 3r3
  13r2 3r3 13r2 3r3 5r2 25r1 5q140   /j-ints 13-18
  33r5 3r6 7r5 3r6 13r5 3r6 13r5 3r6
  13r5 3r6 13r5 3r6 5r5 25r4 4q140   /j-ints 19-23
  115r5 25r4 70q140          /j-ints 24-94
  140r4 80q140               /j-ints 95-175

9$$ 3r1 3r7   / mat by zone

24** 1.-10 1.-1 1.0 1.-10 1.-1 1.0   / importance by zone

28$$ 35r10 11r25 23r8   / inners by grp

29$$ 6r19 6r20 6r21 6r22 6r23   / key flx j-pos's

30$$ 35 45 61 77 93 109 4q6   / key flx i-pos's

     t
```

Figure B-3. (continued)

```
'aog/1020m g.r./100m sh/M60A1 tank anlysis/boosted fission source

 1$$ 1 13 27 0 0   /nip,jpl,jpu,ned,norm
     69 21 22 23 24   /isgrp,nflsv,naft,nuncl,ndata
     5 6 13 27 3   /n5,n6,njl,njm,naftm
     0 46 0   /ntype,neui,ngamx
     e t

 2** 10000.0 0 e   /sh,hsa

 4$$ 77 e    /ival
     t
```

Figure B-4. Sample VISTA Input for the Boosted Fission Weapon Neutron Source Used in the MASH Analysis of the M60A1 "Battlefield Condition" Vehicle Configuration.

```
M60-A1 Armored Tank without liner  - Commander's head -6/30/90
$$ 1000 1500  100    1   46    23    46   69    0    1  220   13    0
$$   0   69    1    0
** 1.0    1.0-05    1.0+04    0.0    2.2+05
** -86.80 -65.0 115.0   0.0    0.0    0.0    0.0
** 69r1.0
** 8r1.0 11r2.0 8r4.0 3r2.0 16r1.0  3r3.0 12r6.0  8r3.0
** 1.9640+7  1.6905+7  1.4918+7  1.4191+7  1.3840+7  1.2523+7  1.2214+7
   1.1052+7  1.0000+7  9.0484+6  8.1873+6  7.4082+6  6.3763+6  4.9658+6
   4.7237+6  4.0657+6  3.0119+6  2.3852+6  2.3069+6  1.8268+6  1.4227+6
   1.1080+6  9.6164+5  8.2085+5  7.4274+5  6.3927+5  5.5023+5  3.6883+5
   2.4724+5  1.5764+5  1.1109+5  5.2475+4  3.4307+4  2.4788+4  2.1875+4
   1.0595+4  3.3546+3  1.2341+3  5.8295+2  2.7536+2  1.0130+2  2.9023+1
   1.0677+1  3.0590+0  1.12535+0 4.1399-1  2.0000+7  1.4000+7  1.2000+7
   1.0000+7  8.0000+6  7.0000+6  6.0000+6  5.0000+6  4.0000+6  3.0000+6
   2.5000+6  2.0000+6  1.5000+6  1.0.00+6  7.0000+5  4.5500+5  3.0000+5
   1.5000+5  1.0000+5  7.0000+4  4.5000+4  3.0000+4  2.0000+4
   0365475134631321
$$   1    1    0    0    0    1   69    1
$$   1    1   69    1    1    1   **     5.0+00    5.0-02    2.0-01    0.0
$$  -1   9r0
$$   0    0    0    0
** 23r1.0
0000000000      0.001      0.001     0     0     0
   1   68
  20   40   44   46   48   49   50   51   52   53   54   55   56   57
  58   59   60   61   62   63   64   72   73   78   82   86   89  105
 110  113  119  120  169  171  173  179  180  181  182  183  184  185
 186  187  189  190  214  217  219  221  224  227  229  232  248  262
 264  266  268  294  295  296  297  298  299   92   96  100
   2    1
 300
   3  148
   1    2    3    4    5    6    7    8    9   10   11   12   13   14
  15   16   17   18   19   21   22   23   24   25   26   27   28   29
  30   31   32   33   34   35   36   37   38   39   41   43   45   47
  65   66   67   68   71   74   75   76   77   79   83   87   90   91
 104  108  112  114  117  118  124  125  126  127  128  129  130  131
 132  133  134  135  136  137  138  139  140  141  142  143  144  145
 146  147  148  149  150  151  152  153  154  155  156  157  158  159
 160  161  162  163  164  165  166  167  168  170  172  174  175  176
 177  178  188  207  208  210  211  212  216  218  225  226  233  234
 251  253  254  256  257  258  259  260  277  278  279  280  281  282
 283  284  285  286  287  288  302  303
```

Figure B-5. Sample MORSE Input for the Commander Position Used in the MASH Analysis of the M60A1 "Battlefield Condition" Vehicle Configuration.

4	11												
93	94	95	97	98	99	101	102	103	249	250			
5	10												
222	230	261	263	265	267	269	271	273	275				
6	4												
270	272	274	276										
7	8												
109	111	209	213	215	223	231	235						
8	1												
255													
9	34												
42	191	192	193	194	195	196	197	198	199	200	201	202	203
204	205	206	236	237	238	239	240	241	242	243	244	245	246
247	289	290	291	292	293								
10	7												
80	81	84	85	88	106	107							
11	2												
220	228												
12	6												
115	116	121	122	123	252								
13	2												
69	70												
0	1												
301													
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1					

Figure B-5. (continued)

```
69 group cross sections for the m60a tank
 $$  46   46   23   23   69   72    4   21   13   61    6    3    0   3
 $$  7z   -2   3z
m60a armored tank 46n-23g gps/ingb=1
 **   1.0
 $$   2    1
```

Figure B-5. (continued)

```
  M60A1 Tank Rotated 0 degrees, Commander's Head, RO at 1020 m BFS
 **  102000.0  175.3 -205.3 154.50    0.0  115.0  22    0
46n-23g Snyder-Auxier Neutron, Claiborne-Trubey Gamma Tissue Dose
 -- 1=neut  2=veh n-g 3=grd n-g 4=photons
MASH 46n/23g group flat response function (fluence)
 ** 69r1.0
Snyder-Auxier Neutron - Claiborne-Trubey Gamma Tissue Dose (46n-23g)
 **
  7.8500e-09 7.7800e-09 7.7400e-09 7.7100e-09 7.4900e-09 7.2100e-09
  6.8900e-09 6.4900e-09 6.2300e-09 6.1000e-09 5.9700e-09 5.8200e-09
  5.5700e-09 5.3400e-09 5.0900e-09 4.5600e-09 4.0000e-09 3.8200e-09
  3.7400e-09 3.5200e-09 3.5200e-09 2.9400e-09 2.9400e-09 2.9400e-09
  2.9400e-09 2.9400e-09 1.6900e-09 1.6900e-09 1.6900e-09 9.7200e-10
  7.4500e-10 5.8900e-10 5.8900e-10 5.1300e-10 4.4900e-10 4.2100e-10
  4.7900e-10 5.2500e-10 5.5800e-10 5.5800e-10 5.9400e-10 6.1800e-10
  6.2800e-10 6.2200e-10 6.0000e-10 5.1700e-10
  0.0000e+00 3.0500e-09 3.0500e-09 2.4300e-09 2.1200e-09 1.9200e-09
  1.7100e-09 1.5000e-09 1.2700e-09 1.0900e-09 9.5900e-10 8.1300e-10
  6.4100e-10 4.8200e-10 3.6000e-10 2.4800e-10 1.6400e-10 1.0100e-10
  7.4400e-11 7.7300e-11 1.1700e-10 2.2300e-10 6.2600e-10
energy group totals
  M60A1 Tank Rotated 90 degrees, Commander's Head, LSO at 1020 m BFS
 **  102000.0  175.3 -205.3 154.50   90.0  115.0  00    0
  M60A1 Tank Rotated 180 degrees, Commander's Head, HO at 1020 m BFS
 **  102000.0  175.3 -205.3 154.50  180.0  115.0  00    0
  M60A1 Tank Rotated 270 degrees, Commander's Head, RSO at 1020 m BFS
 **  102000.0  175.3 -205.3 154.50  270.0  115.0  00    0
```

Figure B-6. Sample DRC Input for the Commander Position Used in the MASH Analysis of the M60A1 "Battlefield Condition" Vehicle Configuration.

APPENDIX C

GIFT5 Geometry Input to MORSE for the U. S. M60A1

"Battlefield Condition" Vehicle Configuration

Used in the MASH Analysis

```
cm     m60 tank (retyped april 2, 1990)
  301  303
001  arb8  -63.50000  84.27700  93.00000-202.47400  84.80000  93.00000 turret top
          -220.68600    .00000  93.00000 -63.50000    .00000  93.00000 left
           -63.50000  84.27700  95.54000-202.47400  84.80000  95.54000 sec 1
          -220.68600    .00000  95.54000 -63.50000    .00000  95.54000
002  arb8  -63.50000    .00000  93.00000-220.68600    .00000  93.00000 turret top
          -202.47400 -84.80000  93.00000 -63.50000-110.00000  93.00000 right
           -63.50000    .00000  95.54000-220.68600    .00000  95.54000 sec 1
          -202.47400 -84.80000  95.54000 -63.50000-110.00000  95.54000
003  arb8     .00000  82.95640  93.00000 -63.50000  84.27700  93.00000 turret top
           -63.50000-110.00000  93.00000    .00000-102.38700  93.00000 sec 2
              .00000  82.95640  95.54000 -63.50000  84.27700  95.54000
           -63.50000-110.00000  95.54000    .00000-102.38700  95.54000
004  arb8     .00000 131.30000    .00000-205.00000 101.60000  25.42901 turret
          -230.30000    .00000  24.01800  -.02087    .00000  -6.09681 bottom
             -.37560 131.43339  -2.87250-205.37561 101.73340  22.55650 left
          -230.70881    .00000  21.14360  -.39646    .00000  -8.97525 sec 1
005  arb8  -63.50000    .00000   2.20500-230.30000    .00000  24.01800 turret
          -205.00000-101.60000  25.42901 -63.50000-133.34200   8.39910 bottom
           -63.87556    .00000   -.67338-230.70881    .00000  21.14366 right
          -205.37560-101.73340  22.55650 -63.87560-133.47540   5.52660 sec 1
006  arb8    -.02087    .00000  -6.09681 -63.50000    .00000   2.20500 turret
           -63.50000-133.34200   8.39910  -.00005-131.30001   -.00029 bottom
             -.39645    .00000  -8.97520 -63.87561    .00000   -.67379 right
           -63.87560-133.47540   5.52660  -.37560-131.43340  -2.87239 sec 2
007  arb6 -205.00000 101.60000  25.42900-202.47400  84.80000  95.54000 turret
          -197.06140  83.45930  95.02370-199.58740 100.25930  24.91280 rear left
          -230.30000    .00000  24.01800-224.88740  -1.34070  23.50170 secl
008  arb6 -220.68600    .00000  95.54000-230.30000    .00000  24.01800 turret
          -224.87150  -1.16580  23.28830-215.25750  -1.16580  94.81030 rear left
          -202.47400  84.80000  95.54000-197.04550  83.63420  94.81030 sec 2
009  arb6 -202.47400 -84.80000  95.54000-205.00000-101.60000  25.42900 turret
          -199.58740-100.25930  24.91280-197.06140 -83.45930  95.02370 rear rt
          -230.30000    .00000  24.01800-224.88740   1.34070  23.50170 sec 1
010  arb6 -230.30000    .00000  24.01800-220.68600    .00000  95.54000 turret
          -215.25750   1.16580  94.81030-224.87150   1.16580  23.28830 rear rt
          -202.47400 -84.80000  95.54000-197.04550 -83.63420  94.81030 sec 2
011  arb6 -202.47400  84.80000  95.54000-205.00000 101.60000  25.42900 turret
          -204.44640  96.77210  24.25220-201.92040  79.97210  94.36320 left side
           -63.50000 122.10390   7.87700 -62.94640 117.27600   6.70020 sec 1
012  arb6  -63.50000  84.27700  95.54000 -63.50000 122.10390   7.87700 turret
           -63.51730 117.51310   5.89600 -63.51730  79.68620  93.55900 left side
          -202.47400  84.80000  95.54000-202.49130  80.20920  93.55900 sec 2
013  arb6  -63.50000 122.10390   7.87700 -63.50000  84.27700  95.54000 turret
           -63.59550  79.68700  93.55940 -63.59550 117.51390   5.89640 left side
              .00000  82.95640  95.54000  -.09550  78.36640  93.55940 sec 3
```

Figure C-1. GIFT5 Geometry Input to MORSE for the U. S. M60A1 "Battlefield Condition" Vehicle Configuration.

```
014  arb6     .00000 131.30000    .00000    .00000  82.95640   95.54000 turret
              .36510  78.50690  93.28860    .36510 126.85050   -2.25140 left side
           -63.50000 122.10390   7.87700 -63.13490 117.65440    5.62560 sec 4
015  arb6  -63.50000-133.34200   8.39900 -63.50000-110.00000   95.54000 turret
           -62.55110-104.76700  94.13830 -62.55110-128.10900    6.99730 right side
          -202.47400 -84.80000  95.54000-201.52510 -79.56700   94.13830 sec 1
016  arb6 -202.47400 -84.80000  95.54000-205.00000-101.60000   25.42900 turret
          -203.97870 -96.35290  24.13490-201.45270 -79.55290   94.24590 right side
           -63.50000-133.34200   8.39900 -62.47870-128.09490    7.10490 sect 2
017  arb6  -63.50000-133.34200   8.39900 -63.50000-110.00000   95.54000 turret
           -64.13270-104.72260  94.12640 -64.13270-128.06460    6.98540 right side
              .00000-102.38700  95.54000   -.63270 -97.10960   94.12640 sect 3
018  arb6     .00000-102.38700  95.54000    .00000-131.30000     .00000 turret
             -.37910-126.04830  -1.58930   -.37910 -97.13530   93.95070 right side
           -63.50000-133.34200   8.39900 -63.87910-128.09030    6.80970 sec 4
019  rcc      .00000    .00000    .00000    .00000    .00000   11.00000 turret
           131.30000    .00000    .00000    .00000    .00000     .00000 ring outsi
020  rcc      .00000    .00000 -20.00000    .00000    .00000   40.00000 turret
           106.60000    .00000    .00000    .00000    .00000     .00000 ring insid
021  arb8   12.70000  74.62500  94.13400    .00000  82.95640   95.54000 turret top
              .00000-102.38700  95.54000  12.70000 -98.47600   94.13400 tapered
            12.09480  74.62500  88.66740   -.27950  82.95640   93.01540 strip at
             -.27950-102.38700  93.01540  12.09480 -98.47600   88.66740 bend
022  arb8   12.70000  74.62500  94.13400  12.70000 -98.47600   94.13400 turret top
           101.60000 -55.47400  68.71900 101.60000  47.70000   68.71900 slanted
            11.18820  74.62500  88.84590  11.18820 -98.47600   88.84590 face plate
           100.08820 -55.47400  63.43090 100.08820  47.70000   63.43090
023  arb6   12.70000 -98.47600  94.13400    .00000-102.38700   95.54000 turret
              .00000 -91.59200  95.54000  12.70000 -85.80000   94.13400 front
              .00000-131.30000  11.00000    .00000-123.55300   11.00000 sec 1 ri
024  arb6     .00000-131.30000  11.00000  25.40000-130.20000   11.00000 turret
            25.40000-118.59200  11.00000    .00000-123.55300   11.00000 front
            12.70000 -98.47600  94.13400  12.70000 -85.80000   94.13400 sec 2 ri
025  arb6   50.80000 -80.06120  83.24190  12.70000 -98.47600   94.13400 turret
            12.70000 -85.80000  94.13400  50.80000 -60.42700   83.24190 front
            25.40000-130.20000  11.00000  25.40000-118.59200   11.00000 sec 3 rl
026  arb6   25.40000-130.20000  11.00000  50.80000-122.60000   11.00000 turret
            50.80000-105.35300  11.00000  25.40000-118.59200   11.00000 front
            50.80000 -80.06120  83.24190  50.80000 -60.42760   83.24190 sec 4 rl
027  arb6   76.20000 -67.76760  75.98040  50.80000 -80.06120   83.24190 turret
            50.80000 -60.42700  83.24190  76.20000 -47.52360   75.98040 front
            50.80000-122.60000  11.00000  50.80000-105.35300   11.00000 sec 5 rl
028  arb6   50.80000-122.60000  11.00000  76.20000-109.10000   11.00000 turret
            76.20000 -92.97000  11.00000  50.80000-105.35300   11.00000 front
            76.20000 -67.76760  75.98040  76.20000 -47.52360   75.98040 sec 6 rl
029  arb6  101.60000 -55.47400  68.71900  76.20000 -67.76760   75.98040 turret
            76.20000 -47.52360  75.98040 101.60000 -35.00200   68.71900 front
            76.20000-109.10000  11.00000  76.20000 -92.97000   11.00000 sec 7 rl
```

Figure C-1. (continued)

030	arb6	76.20000	-109.10000	11.00000	101.60000	-92.37800	11.00000	turret
		101.60000	-76.42700	11.00000	76.20000	-92.97000	11.00000	front
		101.60000	-55.47400	68.71900	101.60000	-35.00200	68.71900	sec 8 rl
031	arb6	12.70000	74.62500	94.13400	.00000	82.95640	95.54000	turret
		.00000	72.11000	95.54000	12.70000	65.76000	94.13400	front
		.00000	131.30000	11.00000	.00000	122.96900	11.00000	sec 9 left
032	arb6	.00000	131.30000	11.00000	25.40000	128.50000	11.00000	turret
		25.40000	120.16900	11.00000	.00000	122.96900	11.00000	front
		12.70000	74.62500	94.13400	12.70000	65.76000	94.13400	sec 10 le
033	arb6	50.80000	63.07700	83.24190	12.70000	74.62500	94.13400	turret
		12.70000	65.76000	94.13400	50.80000	48.38700	83.24190	front
		25.40000	128.50000	11.00000	25.40000	120.26900	11.00000	sec 11 le
034	arb6	25.40000	128.50000	11.00000	50.80000	121.63800	11.00000	turret
		50.80000	106.60000	11.00000	25.40000	120.16900	11.00000	front
		50.80000	63.07700	83.24190	50.80000	48.38700	83.24190	sec 12 le
035	arb6	76.20000	55.38300	75.98040	50.80000	63.07700	83.24190	turret
		50.80000	48.38700	83.24190	76.20000	37.66800	75.98040	front
		50.80000	121.63800	11.00000	50.80000	106.60000	11.00000	sec 13 le
036	arb6	50.80000	121.63800	11.00000	76.20000	107.50000	11.00000	turret
		76.20000	91.54800	11.00000	50.80000	106.60000	11.00000	front
		76.20000	55.38300	75.98040	76.20000	37.66800	75.98040	sec 14 le
037	arb6	101.60000	47.70000	68.71900	76.20000	55.38300	75.98040	turret
		76.20000	37.66800	75.98040	101.60000	27.48200	68.71900	front
		76.20000	107.50000	11.00000	76.20000	91.54800	11.00000	sec 15 le
038	arb6	76.20000	107.50000	11.00000	101.60000	89.95400	11.00000	turret
		101.60000	72.88500	11.00000	76.20000	91.54800	11.00000	front
		101.60000	47.70000	68.71900	101.60000	27.48200	68.71900	sec 16 le
039	arb8	142.70000	76.69617	11.00000	101.60000	89.95400	11.00000	front end
		101.60000	-92.37800	11.00000	142.70000	-81.49303	11.00000	of front
		142.70000	43.50000	56.34600	101.60000	47.70000	68.71900	
		101.60000	-55.47400	68.71900	142.70000	-52.50000	56.34600	
040	rpp	101.60000	142.70000	-46.20000	41.80000	20.00000	62.90000	gun port
041	rcc	-68.53400	37.53640	93.00000	.00000	.00000	2.54000	loaders
		31.35000	.00000	.00000	.00000	.00000	.00000	hatch
042	rpp	-100.00000	-37.10000	6.00000	26.00800	93.00000	97.80000	dummy body
043	rcc	-63.50000	-55.60000	93.00000	.00000	.00000	6.70000	cupola
		47.20000	.00000	.00000	.00000	.00000	.00000	ring out
044	rcc	-63.50000	-55.60000	90.00000	.00000	.00000	9.70000	cupola
		43.50000	.00000	.00000	.00000	.00000	.00000	ring in
045	trc	-63.50000	-55.60000	109.55500	.00000	.00000	-12.39500	cupola
		65.07500	57.80000	.00000	.00000	.00000	.00000	bottom
046	trc	-63.50000	-55.60000	109.55500	.00000	.00000	-9.85500	in cupola
		60.66882	54.88462	.00000	.00000	.00000	.00000	bottom
047	trc	-63.50000	-55.60000	109.55500	.00000	.00000	27.30000	cupola top
		65.07500	50.40000	.00000	.00000	.00000	.00000	
048	trc	-63.50000	-55.60000	109.55500	.00000	.00000	24.76000	cupola top
		60.76077	47.48339	.00000	.00000	.00000	.00000	inside

Figure C-1. (continued)

```
049  arb8  101.60000 -37.33500  68.71900  76.20000 -48.96000  75.98040 air between
            76.20000 -92.97000  11.00000 101.60000 -76.42700  11.00000 n sections
           101.60000  27.48200  68.71900  76.20000  37.66800  75.98040 7 8 and 15
            76.20000  91.54800  11.00000 101.60000  75.34100  11.00000 16
050  arb8   76.20000 -56.24640  75.98040  50.80000 -60.42700  83.24190 air betwee
            50.80000-105.35300  11.00000  76.20000 -96.65660  11.00000 n sections
            76.20000  39.18640  75.98040  50.80000  48.38700  83.24190 5 6 and 13
            50.80000 106.60000  11.00000  76.20000  91.54800  11.00000 14
051  arb8   50.80000 -76.75690  83.24190  12.70000 -90.80000  94.13400 air betwee
            25.40000-123.09200  11.00000  50.80000-110.35346  11.00000 n 250  26
            50.80000  53.42400  83.24190  12.70000  65.76000  94.13400 and 33   34
            25.40000 120.16900  11.00000  50.80000 106.60000  11.00000
052  arb8   12.70000 -89.64300  94.13400    .00000 -91.59200  95.54000 air betwee
              .00000-123.55300  11.00000  25.40000-118.59200  11.00000 n 31   32
            12.70000  71.55580  94.13400    .00000  72.11000  95.54000 and 23   24
              .00000 122.96900  11.00000  25.40000 120.16900  11.00000
053  arb6  -63.50000 122.10390   7.87700 -63.50000  84.27700  95.54000 air inside
           -63.50000    .00000  95.54000 -63.50000    .00000   7.87700 solid 13
              .00000  82.95640  95.54000    .00000    .00000  95.54000
054  arb6  -63.50000-133.34200   8.39910 -63.50000-111.00000  95.54000 air inside
           -63.50000    .00000  95.54000 -63.50000    .00000   8.39910 solid 17
              .00000-102.38700  95.54000    .00000    .00000  95.54000
055  arb6     .00000  82.95640  95.54000    .00000 131.30000    .00000 air betwee
              .00000    .00000    .00000    .00000    .00000  95.54000 n 14  18
           -63.50000 122.10391   7.87700 -63.50000    .00000   7.87700 left
056  arb6 -205.00000-101.60000  25.42901-202.47400 -84.80000  95.54000 air betw
          -202.47400    .00000  95.54000-205.00000    .00000  25.42901 11 and 16
           -63.50000-133.34200   8.39910 -63.50000    .00000   8.39910 right sec2
057  arb6  -63.50000-133.34200   8.39910 -63.50000-110.00000  95.54000 air betw
           -63.50000    .00000  95.54000 -63.50000    .00000   8.39910 12 and 15
          -202.47400 -84.80000  95.54000-202.47400    .00000  95.54000 right sec 2
058  arb5 -224.88740  -1.34070  23.50170-215.25750  -1.16580  94.81030 air opposi
          -197.06140  -1.16580  94.81030-197.06140  -1.34070  23.50170 t bod 8
          -197.06140  83.45930  95.02370    .00000    .00000    .00000 tur rear
059  arb5 -197.06140  83.45930  95.02370-199.58740 100.25930  24.91280 air rear
          -199.58740-100.25930  24.91280-197.06140 -83.45930  95.02370 bet sec 7
          -224.88740   1.34070  23.50170    .00000    .00000    .00000 9
060  arb6 -202.47400  84.80000  95.54000-205.00000 101.60000  25.42901 air betw
          -205.00000    .00000  25.42901-202.47400    .00000  95.54000 11 and 16
           -63.50000 122.10391   7.87700 -63.50000    .00000   7.87700 left sec 1
061  arb8  -63.50000 122.10391   7.87700 -63.50000    .00000   2.20500 air in
           -63.50000-133.34297   8.39910 -63.50000    .00000   8.39910 bottom
              .00000 120.23313   -.51410    .00000    .00000  -6.09920 under 13
              .00000-131.30000    .00000    .00000    .00000    .00000 17  14 18
062  arb6  -63.50000 122.10391   7.87700 -63.50000  84.27700  95.54000 air betw
           -63.50000    .00000  95.54000 -63.50000    .00000   7.87700 12 and 15
          -202.50000  84.80000  95.54000-202.50000    .00000  95.54000 left sec 1
```

Figure C-1. (continued)

063	arb6	-63.50000	.00000	8.39900	-63.50000	-133.34200	8.39900	air bottom
		-205.00000	-101.60000	25.42901	-229.71056	.00000	28.40305	turret bus
		-63.50000	.00000	2.20500	-230.30000	.00000	24.01800	tle right
064	arb6	-63.50000	.00000	7.87700	-63.50000	122.10391	7.87700	air bottom
		-205.00000	101.60000	25.42901	-229.69852	.00000	28.49268	turret bus
		-63.50000	.00000	2.20500	-230.30000	.00000	24.01800	tle left
065	rcc	110.49000	53.34000	34.69400	.00000	-109.22000	.00000	front mid
		26.75200	.00000	.00000	.00000	.00000	.00000	of gunport
066	trc	82.36680	.00000	34.69400	30.70000	.00000	.00000	gun fr cup
		20.92500	17.24200	.00000	.00000	.00000	.00000	gun breech
067	rcc	82.36680	.00000	34.69400	-100.96500	.00000	.00000	gun breech
		21.59000	.00000	.00000	.00000	.00000	.00000	
068	rpp	-4.50000	46.70000	-26.61200	-21.59000	4.72940	36.78650	arm of wgt
069	rpp	-50.22000	-4.50000	-28.70500	-21.59000	4.72940	45.07300	bal wgts
070	rpp	18.56000	33.80000	21.59000	34.29000	6.49100	46.49600	l bal wgt
071	rpp	89.60000	142.70000	-39.30000	35.00000	20.00000	56.34600	gun shield
072	rcc	-82.50000	-58.80000	136.85500	.00000	.00000	-3.00000	cmdr hatch
		28.80000	.00000	.00000	.00000	.00000	.00000	
073	rec	155.00000	.00000	-15.00000	.00000	.00000	-10.00000	driver
		.00000	-45.20000	.00000	-20.00000	.00000	.00000	hatch
074	rpp	142.70000	165.70000	-55.80000	53.30000	11.00000	72.00000	f gun shld
075	arb8	142.70000	-55.80000	56.34600	104.60000	-55.80000	67.81590	top portio
		104.60000	-55.80000	72.00000	142.70000	-55.80000	72.00000	n of gun
		142.70000	53.30000	56.34600	104.60000	53.30000	67.81590	shield
		104.60000	53.30000	72.00000	142.70000	53.30000	72.00000	
076	trc	113.06680	.00000	34.69400	424.14320	.00000	.00000	gun
		11.34140	7.81470	.00000	.00000	.00000	.00000	barrel
077	rcc	231.06290	.00000	36.93820	53.50000	.00000	.00000	gun exhaus
		12.42300	.00000	.00000	.00000	.00000	.00000	t collar
078	rcc	-5.90000	.00000	34.69400	543.11000	.00000	.00000	barrel
		6.74690	.00000	.00000	.00000	.00000	.00000	rifling
079	rpp	22.90000	41.30000	-80.80000	-40.60000	49.00000	102.70000	g periscop
080	rpp	24.90000	41.30000	-78.80000	-42.60000	90.67800	96.28800	out prism
081	rpp	22.90000	39.30000	-78.80000	-42.60000	53.00000	58.00000	in prism
082	rpp	24.90000	39.30000	-78.80000	-42.60000	58.00000	90.67800	in air
083	rpp	-52.90000	-36.40000	-82.76480	-47.22690	115.20000	153.50000	cmdr scope
084	rpp	-49.90000	-36.40000	-77.68480	-52.30690	142.88000	150.50000	out prism
085	rpp	-52.90000	-39.40000	-77.68480	-52.30690	112.20000	119.82000	in rism
086	rpp	-49.90000	-39.40000	-77.68480	-52.30690	119.82000	142.88000	air in cav
087	rpp	-52.90000	-42.74000	-57.38690	-47.22690	106.31000	115.20000	small ipc
088	rcc	-53.20000	-52.28690	110.75500	6.35000	.00000	.00000	small
		2.00000	.00000	.00000	.00000	.00000	.00000	eyepeice
089	rcc	-186.66100	-63.62000	95.54000	.00000	.00000	-5.00000	dummy body
		15.50000	.00000	.00000	.00000	.00000	.00000	
090	rcc	-186.66100	-63.62000	98.08000	.00000	.00000	2.54000	blower
		24.10000	.00000	.00000	.00000	.00000	.00000	cover
091	rcc	-186.66100	-63.62000	98.08000	.00000	.00000	-41.91000	blower
		14.23000	.00000	.00000	.00000	.00000	.00000	motor

Figure C-1. (continued)

092	sph	-86.80000	-65.00000	115.00000	8.50000	.00000	.00000	cmdr head
093	rpp	-97.50000	-76.10000	-84.25000	-45.75000	36.30000	106.50000	cmdr torso
094	rpp	-97.50000	-40.20000	-81.00000	-49.00000	20.30000	36.30000	cmdr thigh
095	rpp	-53.40000	-40.20000	-78.20000	-51.80000	-17.50000	20.30000	cmdr legs
096	sph	-11.00000	-60.20000	55.50000	8.50000	.00000	.00000	gunnr head
097	rpp	-21.70000	-.30000	-79.45000	-40.95000	-23.20000	47.00000	gun torso
098	rpp	-21.70000	35.60000	-76.20000	-44.20000	-39.20000	-23.20000	gun tighs
099	rpp	22.40000	35.60000	-73.40000	-47.00000	-77.00000	-39.20000	gunnr legs
100	sph	-36.00000	60.23500	57.50000	8.50000	.00000	.00000	loadr head
101	rpp	-55.25000	-16.75000	49.53500	70.93500	-21.17500	49.02500	load torso
102	rpp	-52.00000	-20.00000	13.63500	70.93500	-37.17500	-21.17500	load thigh
103	rpp	-49.20000	-22.80000	13.63500	26.83500	-74.97500	-37.17000	load legs
104	rcc	161.54700	-31.85000	51.01550	-120.30000	.00000	.00000	sight
		4.60000	.00000	.00000	.00000	.00000	.00000	telescope
105	rcc	161.54700	-31.85000	51.01550	-120.30000	.00000	.00000	inside
		3.96850	.00000	.00000	.00000	.00000	.00000	scope
106	rcc	158.54700	-31.85000	51.01550	-7.00000	.00000	.00000	forwar
		3.96850	.00000	.00000	.00000	.00000	.00000	lens
107	rcc	40.84700	-31.85000	51.01550	4.56000	.00000	.00000	inside
		3.96850	.00000	.00000	.00000	.00000	.00000	lens
108	arb8	-182.05100	73.77200	89.86500	-190.26300	21.56500	89.86500	105 mm
		-116.26300	15.36300	89.86500	-107.38878	79.38771	89.86500	ammo rack
		-179.08509	92.62751	30.19717	-190.26300	21.56500	28.35797	in turret
		-116.26300	15.36300	18.39272	-104.36901	101.17442	20.82338	bustle
109	arb8	-181.28011	73.20264	89.01500	-189.28132	22.33570	89.01500	105 mm ammo
		-178.70868	21.44960	89.01500	-171.43273	73.94331	89.01500	explosive
		-178.39214	91.56263	30.91523	-189.28132	22.33570	29.12354	
		-178.70868	21.44960	27.69977	-168.83912	92.65542	29.71672	
110	arb8	-162.97996	74.02555	88.26500	-171.23020	21.57546	88.26500	105mm ammo
		-149.76432	19.77638	88.26500	-142.02652	75.60155	88.26500	air space
		-160.05019	92.65126	29.32437	-171.23020	21.57546	27.48482	
		-149.76432	19.77638	24.59411	-139.33496	95.02091	26.72546	
111	arb8	-140.75108	76.65695	89.56500	-149.90161	18.48333	89.56500	105mm ammo
		-117.26962	15.74842	89.56500	-108.49100	79.08339	89.56500	propellant
		-137.55521	96.97437	25.27100	-149.90161	18.48333	23.23954	
		-117.26962	15.74842	18.84514	-105.50300	100.64088	21.24977	
112	rcc	-190.80000	52.20000	64.00000	91.00000	.00000	.00000	sleeve
		16.85290	.00000	.00000	.00000	.00000	.00000	ammo air
113	rcc	-190.80000	52.20000	64.00000	91.00000	.00000	.00000	ammo air
		16.15290	.00000	.00000	.00000	.00000	.00000	
114	arb8	-12.27100	92.12700	48.90000	77.74800	47.65200	48.90000	ammo box
		90.20000	72.31400	14.88000	3.34400	116.62200	13.33906	left front
		-14.57070	87.47233	44.68397	75.44830	42.99733	44.68397	of turret
		87.90030	67.65933	10.66397	1.04430	111.96733	9.12304	
115	rcc	-25.50000	71.30000	84.00000	.00000	-168.00000	.00000	range
		8.08500	.00000	.00000	.00000	.00000	.00000	finder
116	rpp	78.30000	98.62000	-102.80000	-82.50000	15.00000	35.32000	computer

Figure C-1. (continued)

117	arb5	-224.88740	-1.34070	23.50170	-215.25750	-1.16580	94.81030	air opposi
		-197.06140	-1.16580	94.81030	-197.06140	-1.34070	23.50170	t bod 10
		-197.06140	-83.45930	95.02370	.00000	.00000	.00000	tur rear
118	sph	-200.00000	-50.00000	120.00000	2.00000	.00000	.00000	dumb air 1
119	sph	-200.00000	50.00000	120.00000	2.00000	.00000	.00000	dumb air 2
120	arb8	104.40097	80.00000	81.15929	155.14927	80.00000	46.42397	
		155.14927	-80.00000	46.42397	104.40097	-80.00000	81.15929	
		104.40097	80.00000	120.00000	155.14927	80.00000	120.00000	
		155.14929	-80.00000	120.00000	104.40097	-80.00000	120.00000	
121	rpp	-28.00000	-14.50000	78.30000	90.00000	20.00000	32.70000	ldr interc
122	rpp	76.70000	89.40000	-65.00000	-56.00000	40.00000	52.50000	gun interc
123	rpp	-95.30000	-82.60000	-95.20000	-84.30000	60.00000	72.70000	com interc
124	arb8	288.00000	107.30000	-63.20000	277.40000	107.30000	-72.70000	tip of
		261.70000	107.30000	-63.20000	274.70000	107.30000	-54.50000	front
		288.00000	-107.30000	-63.20000	277.40000	-107.30000	-72.70000	glacis
		261.70000	-107.30000	-63.20000	274.70000	-107.30000	-54.50000	
125	arb8	274.70000	107.30000	-54.50000	261.70000	107.30000	-63.20000	upper
		173.40000	107.30000	-17.80000	187.60000	107.30000	-15.60000	glacis
		274.70000	-107.30000	-54.50000	261.70000	-107.30000	-63.20000	
		173.40000	-107.30000	-17.80000	187.60000	-107.30000	-15.60000	
126	arb8	277.40000	107.30000	-72.70000	201.50000	107.30000	-126.20000	lower
		185.90000	107.30000	-126.20000	261.70000	107.30000	-63.20000	glacis
		277.40000	-107.30000	-72.70000	201.50000	-107.30000	-126.20000	
		185.90000	-107.30000	-126.20000	261.70000	-107.30000	-63.20000	
127	arb8	187.60000	107.30000	-15.60000	173.40000	107.30000	-17.80000	top plate
		126.40000	107.30000	-14.20000	126.40000	107.30000	-10.40000	over
		187.60000	-107.30000	-15.60000	173.40000	-107.30000	-17.80000	driver
		126.40000	-107.30000	-14.20000	126.40000	-107.30000	-10.40000	
128	rpp	-135.85273	126.40000	-107.30000	107.30000	-14.20000	-10.40000	top sec 1
129	arb6	225.10000	107.30000	-36.70000	225.10000	107.30000	-103.20000	side left
		225.10000	90.30000	-103.20000	225.10000	90.30000	-36.70000	sec 1
		263.40000	107.30000	-63.20000	263.40000	90.30000	-63.20000	
130	arb6	225.10000	-107.30000	-36.70000	225.10000	-107.30000	-103.20000	side right
		225.10000	-90.30000	-103.20000	225.10000	-90.30000	-36.70000	sec 1
		263.40000	-107.30000	-63.20000	263.40000	-90.30000	-63.20000	
131	arb8	225.20000	107.30000	-103.20000	185.90000	107.30000	-126.20000	hull side
		187.60000	107.30000	-15.60000	225.20000	107.30000	-36.70000	sec 2 lt
		225.20000	101.90000	-103.20000	185.90000	101.90000	-126.20000	
		187.60000	101.90000	-15.60000	225.20000	101.90000	-36.70000	
132	arb8	225.20000	-107.30000	-103.20000	185.90000	-107.30000	-126.20000	hull side
		187.60000	-107.30000	-15.60000	225.20000	-107.30000	-36.70000	sec 2 rt
		225.20000	-101.90000	-103.20000	185.90000	-101.90000	-126.20000	
		187.60000	-101.90000	-15.60000	225.20000	-101.90000	-36.70000	
133	arb8	188.40000	107.30000	-126.20000	126.40000	107.30000	-126.20000	hull side
		126.40000	107.30000	-13.70000	187.60000	107.30000	-15.60000	sec 3 lt
		188.40000	101.90000	-126.20000	126.40000	101.90000	-126.20000	
		126.40000	101.90000	-13.70000	187.60000	101.90000	-15.60000	

Figure C-1. (continued)

```
134  arb8  188.40000-107.30000-126.20000 126.40000-107.30000-126.20000 huill side
            126.40000-107.30000 -13.70000 187.60000-107.30000 -15.60000 sec 3 rt
            188.40000-101.90000-126.20000 126.40000-101.90000-126.20000
            126.40000-101.90000 -13.70000 187.60000-101.90000 -15.60000
135  rpp    126.40000 201.50000-107.30000 107.30000-126.20000-123.60000 hull bot
136  rpp   -298.80000 126.50000 101.90000 107.30000 -40.50000 -10.40000 side sec4l
137  rpp   -298.80000 126.50000-107.30000-101.90000 -40.50000 -10.40000 side sec4r
138  arb8   126.40000 124.40000 -60.70000-298.80000 124.40000 -60.70000 side sec 5
           -298.80000 107.30000 -40.50000 126.40000 107.30000 -40.50000 left
            126.40000 121.65232 -63.02601-298.80000 121.65232 -63.02601
           -298.80000 102.58327 -40.50000 126.40000 102.58327 -40.50000
139  arb8   126.40000-124.40000 -60.70000-298.80000-124.40000 -60.70000 side sec 5
           -298.80000-107.30000 -40.50000 126.40000-107.30000 -40.50000 right
            126.40000-121.65232 -63.02601-298.80000-121.65232 -63.02601
           -298.80000-102.58327 -40.50000 126.40000-102.58327 -40.50000
140  rpp   -298.80000 126.40000 119.00000 124.40000 -78.20000 -60.70000 side sec6l
141  rpp   -298.80000 126.40000-124.40000-119.00000 -78.20000 -60.70000 side sec6r
142  arb8   126.40000  47.40000-126.20000-298.80000  47.40000-126.20000 side sec7
           -298.80000 124.40000 -78.20000 126.40000 124.40000 -78.20000 left
            126.40000  45.76007-123.56929-298.80000  45.76007-123.56929
           -298.80000 122.23106 -74.72068 126.40000 122.23106 -74.72068
143  arb8   126.40000 -47.40000-126.20000-298.80000 -47.40000-126.20000 side sec7
           -298.80000-124.40000 -78.20000 126.40000-124.40000 -78.20000 right
            126.40000 -45.76007-123.56929-298.80000 -45.76007-123.56929
           -298.80000-122.23106 -74.72068 126.40000-122.23106 -74.72068
144  rpp   -298.80000 126.40000 -47.40000  47.40000-126.20000-123.66000 floor s2
145  arb8   126.40000 101.90000 -91.70000 126.40000 124.40000 -78.20000 front end
            126.40000 124.40000 -60.70000 126.40000 101.90000 -40.50000 of bulge
            120.40000 101.90000 -91.70000 120.40000 124.40000 -78.20000 lt
            120.40000 124.40000 -60.70000 120.40000 101.90000 -40.50000
146  arb8   126.40000-101.90000 -91.70000 126.40000-124.40000 -78.20000 front end
            126.40000-124.40000 -60.70000 126.40000-101.90000 -40.50000 of bulge
            120.40000-101.90000 -91.70000 120.40000-124.40000 -78.20000 rt
            120.40000-124.40000 -60.70000 120.40000-101.90000 -40.50000
147  arb6   126.40000 107.30000 -88.70000 126.40000 107.30000-126.20000 filler lt
            120.40000 107.30000-126.20000 120.40000 107.30000 -88.70000 front
            126.40000  47.00000-126.20000 120.40000  47.00000-126.20000
148  arb6   126.40000-107.30000 -88.70000 126.40000-107.30000-126.20000 filler rt
            120.40000-107.30000-126.20000 120.40000-107.30000 -88.70000 front
            126.40000 -47.00000-126.20000 120.40000 -47.00000-126.20000
149  rpp   -376.60000-373.30000 -91.50000  91.50000 -58.70000 -10.40000 rear sec1
150  box   -376.60000  91.50000 -58.70000    .00000-183.00000    .00000 rear sec2
             16.40000    .00000 -27.30000   2.82880    .00000   1.69930
151  arb8 -360.20000  91.50000 -86.00000-298.80000  47.40000-126.20000 rear sec3
           -298.80000 -47.40000-126.20000-360.20000 -91.50000 -86.00000
           -358.39239  91.50000 -83.23911-296.99239  47.40000-123.43911
           -296.99239 -47.40000-123.43911-358.39239 -91.50000 -83.23911
```

Figure C-1. (continued)

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152  rpp  -376.60000-298.80000  87.90000  91.50000 -58.70000 -10.40000 side sec8l
153  rpp  -376.60000-298.80000 -91.50000 -87.90000 -58.70000 -10.40000 side sec8r
154  arb8 -298.80000  91.50000 -58.70000-298.80000  91.50000 -86.00000 side sec9
          -360.20000  91.50000 -86.00000-376.60000  91.50000 -58.70000 lt rear
          -298.80000  87.90000 -58.70000-298.80000  87.90000 -86.00000
          -360.20000  87.90000 -86.00000-376.60000  87.90000 -58.70000
155  arb8 -298.80000 -91.50000 -58.70000-298.80000 -91.50000 -86.00000 side sec9
          -360.20000 -91.50000 -86.00000-376.60000 -91.50000 -58.70000 rt rear
          -298.80000 -87.90000 -58.70000-298.80000 -87.90000 -86.00000
          -360.20000 -87.90000 -86.00000-376.60000 -87.90000 -58.70000
156  arb6 -298.80000  89.07477 -83.33950-298.80000  44.97477-123.53950 side sec10
          -298.80000  47.40000-126.20000-298.80000  91.50000 -86.00000 lt rear
          -360.20000  89.07477 -83.33950-360.20000  91.50000 -86.00000
157  arb6 -298.80000 -89.07477 -83.33950-298.80000 -44.97477-123.53950 side sec10
          -298.80000 -47.40000-126.20000-298.80000 -91.50000 -86.00000
          -360.20000 -89.07477 -83.33950-360.20000 -91.50000 -86.00000
158  rpp  -298.80000-292.80000  87.90000 107.30000 -40.50000 -10.40000 filler s1l
159  rpp  -298.80000-292.80000-107.30000 -87.90000 -40.50000 -10.40000 filler s1r
160  arb8 -298.80000  87.90000 -60.70000-298.80000 124.40000 -60.70000 filler
          -298.80000 107.30000 -40.50000-298.80000  87.90000 -40.50000 sec 2 lt
          -292.80000  87.90000 -60.70000-292.80000 124.40000 -60.70000
          -292.80000 107.30000 -40.50000-292.80000  87.90000 -40.50000
161  arb8 -298.80000 -87.90000 -60.70000-298.80000-124.40000 -60.70000 filler
          -298.80000-107.30000 -40.50000-298.80000 -87.90000 -40.50000 sec 2 rt
          -292.80000 -87.90000 -60.70000-292.80000-124.40000 -60.70000
          -292.80000-107.30000 -40.50000-292.80000 -87.90000 -40.50000
162  rpp  -298.80000-292.80000  87.90000 124.40000 -78.20000 -60.70000 filler s3l
163  rpp  -298.80000-292.80000-124.40000 -87.90000 -78.20000 -60.70000 filler s3r
164  arb8 -298.80000  87.90000 -78.20000-298.80000 +87.90000 -86.00000 filler
          -298.80000 111.88750 -86.00000-298.80000 124.40000 -78.20000 sec 4 lt
          -292.80000  87.90000 -78.20000-292.80000  87.90000 -86.00000
          -292.80000 111.88750 -86.00000-292.80000 124.40000 -78.20000
165  arb8 -298.80000 -87.90000 -78.20000-298.80000 -87.90000 -86.00000 filler
          -298.80000-111.88750 -86.00000-298.80000-124.40000 -78.20000 sec 4 rt
          -292.80000 -87.90000 -78.20000-292.80000 -87.90000 -86.00000
          -292.80000-111.88750 -86.00000-292.80000-124.40000 -78.20000
166  arb6 -292.80000  87.90000 -86.00000-292.80000 111.88750 -86.00000 filler
          -298.80000 111.88750 -86.00000-298.80000  87.90000 -86.00000 sec 5 lt
          -292.80000  43.80000-126.20000-298.80000  43.80000-126.20000
167  arb6 -292.80000 -87.90000 -86.00000-292.80000-111.88750 -86.00000 filler
          -298.80000-111.88750 -86.00000-298.80000 -87.90000 -86.00000 sec 5 rt
          -292.80000 -43.80000-126.20000-298.80000 -43.80000-126.20000
168  arb6 -215.30000  75.50000  14.40000-215.30000  91.50000 -10.40000 top rear
          -215.30000 -91.50000 -10.40000-215.30000 -75.50000  14.40000 sec 1
          -126.40000  91.50000 -10.40000-126.40000 -91.50000 -10.40000
169  arb6 -215.30000  74.17854  11.76302-215.30000  88.47726 -10.40000 top rear
          -215.30000 -88.47726 -10.40000-215.30000 -74.17854  11.76302 sec 1
          -135.85273  88.47726 -10.40000-135.85273 -88.47726 -10.40000 inside
```

Figure C-1. (continued)

```
170  arb8 -215.30000 -75.50000  14.40000-215.30000 -91.50000 -10.40000 top rear
          -215.30000  91.50000 -10.40000-215.30000  75.50000  14.40000 sec 2
          -298.80000 -78.46774   9.80000-298.80000 -91.50000 -10.40000
          -298.80000  91.50000 -10.40000-298.80000  78.46774   9.80000
171  arb8 -215.30000 -74.11845  11.85615-215.30000 -88.47726 -10.40000 top rear
          -215.30000  88.47726 -10.40000-215.30000  74.11845  11.85615 sec 2
          -296.26000 -76.99592   7.39608-296.26000 -88.47726 -10.40000 inside
          -296.26000  88.47726 -10.40000-296.26000  76.99592   7.39608
172  arb8 -376.60000  78.46774   9.80000-376.60000  91.50000 -10.40000 top rear
          -376.60000 -91.50000 -10.40000-376.60000 -78.46774   9.80000 sec 3
          -298.80000  78.46774   9.80000-298.80000  91.50000 -10.40000
          -298.80000 -91.50000 -10.40000-298.80000 -78.46774   9.80000
173  arb8 -373.30000  77.08371   7.26000-373.30000  88.47726 -10.40000 top rear
          -373.30000 -88.47726 -10.40000-373.30000 -77.08371   7.26000 sec 3
          -298.80000  77.08371   7.26000-298.80000  88.47726 -10.40000 inside
          -298.80000 -88.47726 -10.40000-298.80000 -77.08371   7.26000
174  rpp  -298.80000-126.40000  88.47726 107.30000 -12.94000 -10.40000 top rear4l
175  rpp  -298.80000-126.40000-107.30000 -88.47726 -12.94000 -10.40000 top rear 4r
176  rpp  -276.60000-156.60000  95.50000 100.00000 -16.20000 -10.40000 grill topl
177  rpp  -276.60000-156.60000-100.00000 -95.50000 -16.20000 -10.40000 grill topr
178  rpp  -376.60000-369.60000 -86.00000  86.00000 -53.20000 -10.40000 grill rear
179  arb6  187.60000 107.30000 -15.60000 185.90000 107.30000-126.20000 crew air
           185.90000-107.30000-126.20000 187.60000-107.30000 -15.60000 front
           288.00000 107.30000 -63.20000 288.00000-107.30000 -63.20000
180  arb8  185.90000 107.30000-126.20000 126.40000 107.30000-126.20000 crew air
           126.40000 107.30000 -10.40000 187.60000 107.30000 -15.60000 front sec2
           185.90000-107.30000-126.20000 126.40000-107.30000-126.20000
           126.40000-107.30000 -10.40000 187.60000-107.30000 -15.60000
181  rpp  -298.80000 126.40000-107.30000 107.30000 -40.60000 -10.40000 crw air s3
182  arb8  126.40000-107.30000 -40.50000 126.40000-124.40000 -60.70000 air sec 4
           126.40000 124.40000 -60.70000 126.40000 107.30000 -40.50000
          -298.80000-107.30000 -40.50000-298.80000-124.40000 -60.70000
          -298.80000 124.40000 -60.70000-298.80000 107.30000 -40.50000
183  rpp  -298.80000 126.40000-124.40000 124.40000 -78.20000 -60.70000 air sec 5
184  arb8  126.40000-124.40000 -78.20000 126.40000 -47.40000-126.20000 air sec 6
           126.40000  47.40000-126.20000 126.40000 124.40000 -78.20000
          -298.80000-124.40000 -78.20000-298.80000 -47.40000-126.20000
          -298.80000  47.40000-126.20000-298.80000 124.40000 -78.20000
185  rpp  -376.60000-298.80000 -91.50000  91.50000 -58.70000 -10.40000 air sec 7
186  arb8 -298.80000 -91.50000 -58.70000-298.80000 -91.50000 -86.00000 air sec 8
          -298.80000  91.50000 -86.00000-298.80000  91.50000 -58.70000
          -376.60000 -91.50000 -58.70000-360.20000 -91.50000 -86.00000
          -360.20000  91.50000 -86.00000-376.60000  91.50000 -58.70000
187  arb6 -298.80000  91.50000 -86.00000-360.20000  91.50000 -86.00000 air sec 9
          -360.20000 -91.50000 -86.00000-298.80000 -91.50000 -86.00000
          -298.80000  47.40000-126.20000-298.80000 -47.40000-126.20000
```

Figure C-1. (continued)

188	rcc	.00000	.00000	.00000	.00000	.00000	-14.20000	tur mount
		126.40000	.00000	.00000	.00000	.00000	.00000	
189	rcc	.00000	.00000	.00000	.00000	.00000	-10.40000	tur mount
		121.00000	.00000	.00000	.00000	.00000	.00000	inside
190	rcc	.00000	.00000	-10.40000	.00000	.00000	-3.80000	tur mount
		101.90000	.00000	.00000	.00000	.00000	.00000	inside
191	rcc	155.80000	116.50000	-130.30000	.00000	56.10000	.00000	road wheel
		33.30000	.00000	.00000	.00000	.00000	.00000	1 lt
192	rcc	72.10000	116.50000	-130.30000	.00000	56.10000	.00000	road wheel
		33.30000	.00000	.00000	.00000	.00000	.00000	2 lt
193	rcc	-11.60000	116.50000	-130.30000	.00000	56.10000	.00000	road wheel
		33.30000	.00000	.00000	.00000	.00000	.00000	3 lt
194	rcc	-95.30000	116.50000	-130.30000	.00000	56.10000	.00000	road wheel
		33.30000	.00000	.00000	.00000	.00000	.00000	4 lt
195	rcc	-179.00000	116.50000	-130.30000	.00000	56.10000	.00000	road wheel
		33.30000	.00000	.00000	.00000	.00000	.00000	5 lt
196	rcc	-262.90000	116.50000	-130.30000	.00000	56.10000	.00000	road wheel
		33.30000	.00000	.00000	.00000	.00000	.00000	6 lt
197	rcc	155.80000	-116.50000	-130.30000	.00000	-56.10000	.00000	road wheel
		33.30000	.00000	.00000	.00000	.00000	.00000	1 rt
198	rcc	-349.10000	180.10000	-64.70000	.00000	-71.10000	.00000	drive
		27.70000	.00000	.00000	.00000	.00000	.00000	wheel lt
199	rcc	-349.10000	-180.10000	-64.70000	.00000	71.10000	.00000	drive
		27.70000	.00000	.00000	.00000	.00000	.00000	wheel rt
200	rcc	237.00000	170.00000	-75.10000	.00000	-51.00000	.00000	idler
		33.30000	.00000	.00000	.00000	.00000	.00000	wheel lt
201	rcc	237.00000	-170.00000	-75.10000	.00000	51.00000	.00000	idler
		33.30000	.00000	.00000	.00000	.00000	.00000	wheel rt
202	rcc	72.10000	-116.50000	-130.30000	.00000	-56.10000	.00000	road wheel
		33.30000	.00000	.00000	.00000	.00000	.00000	2 rt
203	rcc	.00000	.00000	-92.56000	.00000	.00000	-.63500	turret
		93.30000	.00000	.00000	.00000	.00000	.00000	plateform
204	rcc	.00000	.00000	-92.56000	.00000	.00000	33.00000	platform
		16.70000	.00000	.00000	.00000	.00000	.00000	hub
205	arb8	-22.40000	-15.10000	-92.56000	-96.00000	-15.10000	-92.56000	smallround
		.00000	-93.00000	-92.56000	.00000	-27.00000	-92.56000	ammo box
		-22.40000	-15.10000	-73.46000	-96.00000	-15.10000	-73.46000	on turret
		.00000	-93.00000	-73.46000	.00000	-27.00000	-73.46000	platform
206	rpp	-8.80000	21.20000	-76.90000	-42.50000	-45.20000	-39.20000	gunn seat
207	rcc	6.20000	-59.70000	-92.56000	.00000	.00000	47.36000	pedestal
		3.30000	.00000	.00000	.00000	.00000	.00000	for seat
208	rpp	-11.60000	40.40000	27.80000	88.80000	-92.56000	-1.56000	ammo box 1
209	rpp	-10.70000	39.60000	28.70000	61.10000	-36.56000	-1.96000	hep explos
210	rpp	-11.60000	40.40000	27.80000	88.80000	-38.66000	-36.56000	air space
211	rpp	-11.30000	40.10000	28.10000	88.50000	-91.51000	-38.66000	propellant
212	rpp	3.20000	25.70000	47.10000	69.60000	-92.56000	-1.56000	sleeve air
213	rpp	3.80000	25.10000	47.70000	69.00000	-92.56000	-1.56000	air space

Figure C-1. (continued)

```
214  rpp    82.80000 174.20000 -93.30000 -47.50000 -92.60000 -27.20000 hull ammor
215  rpp   158.60000 174.20000 -93.30000 -47.50000 -92.60000 -27.20000 air fr amo
216  rpp   143.20000 157.50000 -92.20000 -89.00000 -91.50000 -28.30000 proj tip
217  rpp   143.20000 157.50000 -89.00000 -48.60000 -91.50000 -28.30000 air tip
218  rpp   141.40000 143.20000 -93.30000 -47.50000 -92.60000 -27.20000 alum space
219  rpp    84.25000 141.40000 -93.00000 -47.80000 -92.30000 -27.50000 propellant
220  rpp    82.80000 174.20000 -82.60000 -61.20000 -71.40000 -48.40000 air space
221  rpp    82.80000 174.20000 -83.00000 -60.80000 -71.80000 -48.00000 sleeve air
222  rpp    87.40000 174.20000  38.10000  93.30000 -92.60000 -27.20000 hull ammol
223  rpp   163.20000 174.20000  38.10000  93.30000 -92.60000 -27.20000 air front
224  rpp   147.80000 162.10000  89.70000  92.20000 -91.50000 -28.30000 tip ammo
225  rpp   147.80000 162.10000  39.20000  89.00000 -91.50000 -28.30000 air tip
226  rpp   146.00000 147.80000  38.10000  93.30000 -92.60000 -32.20000 alum space
227  rpp    88.45000 146.00000  38.40000  93.00000 -92.30000 -27.50000 propellant
228  rpp    87.40000 174.20000  52.40000  78.70000 -71.40000 -48.40000 air space
229  rpp    87.40000 174.20000  52.80000  79.10000 -71.80000 -48.00000 sleeve air
230  rpp   -11.60000  40.40000  60.20000  61.10000 -36.56000  -1.96000 expl parti
231  rpp   -10.70000  39.50000  61.10000  87.90000 -36.56000  -1.96000 wp explosi
232  rpp  -279.38559 169.70166 109.00000 180.10000-175.30000-163.60000 track botl
233  box   169.70166 180.10000-175.30000    .00000 -71.10000    .00000 track frnt
            92.60742    .00000  62.99187  -6.58030    .00000   9.67410 slope lt
234  box  -279.38559 180.10000-175.30000    .00000 -71.10000    .00000 track rear
           -95.16121    .00000  80.51990   7.55430    .00000   8.93420 slope lt
235  box  -349.10000 180.10000 -37.00000    .00000 -71.10000    .00000 track top
           586.10000    .00000  -4.80000    .09580    .00000  11.69960 lt
236  rcc  -349.10000 180.10000 -64.70000    .00000 -71.10000    .00000 track arou
            39.40000    .00000    .00000    .00000    .00000    .00000 nd drivelt
237  arb8 -349.10000 180.10000 -16.20000-349.10000 180.10000 -64.70000 drive trck
          -416.60000 180.10000-144.47384-416.60000 180.10000 -16.20000 dummy
          -349.10000-180.10000 -16.20000-349.10000-180.10000 -64.70000
          -416.60000-180.10000-144.47384-416.60000-180.10000 -16.20000
238  rcc   237.00000 180.10000 -75.10000    .00000 -71.10000    .00000 track arou
            45.00000    .00000    .00000    .00000    .00000    .00000 nd idlerlt
239  arb8  293.40000 180.10000 -16.20000 293.40000 180.10000-172.71943 idler trck
           237.00000 180.10000 -75.10000 237.00000 180.10000 -16.20000 dummy
           293.40000-180.10000 -16.20000 293.40000-180.10000-172.71943
           237.00000-180.10000 -75.10000 237.00000-180.10000 -16.20000
240  rpp  -279.38559 169.70166-180.10000-109.00000-175.30000-163.60000 track botr
241  box   169.70166-180.10000-175.30000    .00000  71.10000    .00000 track frnt
            92.60742    .00000  62.99187  -6.58030    .00000   9.67410 slope rt
242  rcc   138.70000 170.00000 -57.40000    .00000 -45.50000    .00000 trk supprt
            16.40000    .00000    .00000    .00000    .00000    .00000 roller 1 l
243  rcc   -58.50000 170.00000 -55.80000    .00000 -45.50000    .00000 trk supprt
            16.40000    .00000    .00000    .00000    .00000    .00000 roll59 l
244  rcc  -192.00000 170.00000 -54.90000    .00000 -45.50000    .00000 trk supprt
            16.40000    .00000    .00000    .00000    .00000    .00000 rolle9 3 l
```

Figure C-1. (continued)

```
245  rcc   138.70000-170.00000 -57.40000    .00000  45.50000    .00000 trk su--rt
            16.40000    .00000    .00000    .00000    .00000    .00000 roller lrt
246  rcc   -58.50000-170.00000 -55.80000    .00000  45.50000    .00000 trk supprt
            16.40000    .00000    .00000    .00000    .00000    .00000 roller 2rt
247  rcc   237.00000 182.50000 -75.10000    .00000-365.00000    .00000 idler dum
            33.30000    .00000    .00000    .00000    .00000    .00000
248  sph   151.40000    .00000 -32.86000   8.50000    .00000    .00000 driverhead
249  rpp   140.70000 162.10000 -24.00000  24.00000 -95.56000 -41.36000 driv torso
250  rpp   140.70000 198.00000 -16.00000  16.00000-111.56000 -95.56000 driv thigh
251  rpp   175.40000 193.18000  38.10000  91.40000 -81.20000 -40.56000 fire extin
252  rpp   143.24000 153.40000 -37.34000 -27.18000 -51.52000 -41.36000 dr interco
253  rcc    62.20000 -51.85000 -92.56000    .00000    .00000  63.50000 oil
            12.10000    .00000    .00000    .00000    .00000    .00000 cylinder
254  rcc    78.80000 -29.00000 -92.56000    .00000    .00000  55.90000 gas
             9.52500    .00000    .00000    .00000    .00000    .00000 cylinder
255  rpp    33.10000  89.60000 -40.40000  40.40000-122.10000 -98.20000 batteries
256  arb8 -114.80000 -31.40000-105.00000-114.80000  31.40000-105.00000 engine
          -114.80000  96.60000 -20.90000-114.80000 -96.60000 -20.90000 block
          -289.00000 -31.40000-105.00000-289.00000  31.40000-105.00000
          -289.00000  96.60000 -20.90000-289.00000 -96.60000 -20.90000
257  rpp  -289.00000-114.80000 -31.40000  31.40000-114.67000-105.00000 oil pan
258  arb8 -289.00000  44.50000-120.50000-339.00000  44.50000 -91.90000 tranmissi
          -370.00000  44.50000 -32.10000-289.00000  44.50000 -18.30000 on
          -289.00000 -44.50000-120.50000-339.00000 -44.50000 -91.90000
          -370.00000 -44.50000 -32.10000-289.00000 -44.50000 -18.30000
259  rpp   131.90000 161.70000 -20.80000  20.80000-116.64000-111.56000 driverseat
260  rpp   -86.60000 -71.40000 -60.00000 -27.00000-110.20000 -97.50000 gun contro
261  rpp  -286.10000-105.10000    .00000  98.40000 -40.50000 -20.90000 left tank
262  rpp  -285.95000-105.25000    .00000  98.25000 -40.50000 -21.05000 fuel left
263  arb8 -286.10000    .00000 -60.70000-286.10000 115.50000 -60.70000 left fuel
          -286.10000  98.40000 -40.50000-286.10000    .00000 -40.50000 tank tier
          -105.10000    .00000 -60.70000-105.10000 115.50000 -60.70000 2
          -105.10000  98.40000 -40.50000-105.10000    .00000 -40.50000
264  arb8 -285.95000    .00000 -60.70000-285.95000 115.30347 -60.70000 fuel in
          -285.95000  98.20347 -40.50000-285.95000    .00000 -40.50000 tier 2
          -105.25000    .00000 -60.70000-105.25000 115.30347 -60.70000
          -105.25000  98.20347 -40.50000-105.25000    .00000 -40.50000
265  rpp  -286.10000-105.10000    .00000 115.50000 -74.70000 -60.70000 tank tier3
266  rpp  -285.95000-105.25000    .00000 115.35000 -74.70000 -60.70000 fuel tier3
267  arb8 -286.10000    .00000-118.70000-286.10000  45.50000-118.70000 left fuel
          -286.10000 115.50000 -74.70000-286.10000    .00000 -74.70000 tank tier
          -105.10000    .00000-118.70000-105.10000  45.50000-118.70000 4
          -105.10000 115.50000 -74.70000-105.10000    .00000 -74.70000
268  arb8 -285.95000    .00000-118.55000-285.95000  45.45677-118.55000 fuel in
          -285.95000 115.21814 -74.70000-285.95000    .00000 -74.70000 tier 4
          -105.25000    .00000-118.55000-105.25000  45.45677-118.55000
          -105.25000 115.21814 -74.70000-105.25000    .00000 -74.70000
```

Figure C-1. (continued)

```
269  rpp  -286.10000-105.10000 -98.40000    .00000 -40.50000 -20.90000 right tank
270  rpp  -285.95000-105.25000 -98.25000    .00000 -40.50000 -21.05000 fuel right
271  arb8 -286.10000    .00000 -60.70000-286.10000-115.50000 -60.70000 right fuel
          -286.10000 -98.40000 -40.50000-286.10000    .00000 -40.50000 tank tier
          -105.10000    .00000 -60.70000-105.10000-115.50000 -60.70000 2
          -105.10000 -98.40000 -40.50000-105.10000    .00000 -40.50000
272  arb8 -285.95000    .00000 -60.70000-285.95000-115.30347 -60.70000 fuel in
          -285.95000 -98.20347 -40.50000-285.95000    .00000 -40.50000 tier 2
          -105.25000    .00000 -60.70000-105.25000-115.30347 -60.70000
          -105.25000 -98.20347 -40.50000-105.25000    .00000 -40.50000
273  rpp  -286.10000-105.10000-115.50000    .00000 -74.70000 -60.70000 tank tier3
274  rpp  -285.95000-105.25000-115.35000    .00000 -74.70000 -60.70000 fuel tier3
275  arb8 -286.10000    .00000-118.70000-286.10000 -45.50000-118.70000 right fuel
          -286.10000-115.50000 -74.70000-286.10000    .00000 -74.70000 tank tier
          -105.10000    .00000-118.70000-105.10000 -45.50000-118.70000 4
          -105.10000-115.50000 -74.70000-105.10000    .00000 -74.70000
276  arb8 -285.95000    .00000-118.55000-285.95000 -45.45677-118.55000 fuel in
          -285.95000-115.21814 -74.70000-285.95000    .00000 -74.70000 tier 4
          -105.25000    .00000-118.55000-105.25000 -45.45677-118.55000
          -105.25000-115.21814 -74.70000-105.25000    .00000 -74.70000
277  rpp  -388.60000 282.00000 107.30000 181.00000 -21.20000 -20.70000 fender lt
278  rpp  -388.60000 282.00000-181.00000-107.30000 -21.20000 -20.70000 fender rt
279  rpp  -388.60000-298.80000  91.50000 107.30000 -21.20000 -20.70000 fender lt
280  rpp  -388.60000-298.80000-107.30000 -91.50000 -21.20000 -20.70000 fender rt
281  rpp   -95.40000  96.60000 108.00000 180.00000 -20.70000  -2.20000 tool boxll
282  rpp   -95.40000  96.60000-180.00000-108.00000 -20.70000  -2.20000 tool boxlr
283  rpp  -227.90000-114.10000 108.00000 180.00000 -20.70000   6.30000 exhaust
284  rpp  -227.90000-114.10000-180.00000-108.00000 -20.70000   6.30000 tool box2r
285  rpp  -329.70000-253.60000 108.00000 180.00000 -20.70000  -2.20000 tool box2l
286  rpp  -329.70000-253.60000-180.00000-108.00000 -20.70000  -2.20000 tool box3r
287  rcc      .00000 108.20000  -7.00000    .00000    .00000  18.00000 gear
            12.70000    .00000    .00000    .00000    .00000    .00000 motor
288  rpp  -160.00000 160.00000-160.00000 160.00000 -50.00000    .00000 dummy
289  rcc   -11.60000-116.50000-130.30000    .00000 -56.10000    .00000 road wheel
            33.30000    .00000    .00000    .00000    .00000    .00000 3 rt
290  rcc   -95.30000-116.50000-130.30000    .00000 -56.10000    .00000 road wheel
            33.30000    .00000    .00000    .00000    .00000    .00000 4 rt
291  rcc  -179.00000-116.50000-130.30000    .00000 -56.10000    .00000 road wheel
            33.30000    .00000    .00000    .00000    .00000    .00000 5 rt
292  rcc  -262.90000-116.50000-130.30000    .00000 -56.10000    .00000 road wheel
            33.30000    .00000    .00000    .00000    .00000    .00000 6 rt
293  box  -279.38559-180.10000-175.30000    .00000  71.10000    .00000 track rear
           -95.16121    .00000  80.51990   7.55430    .00000   8.93420 slope rt
294  box  -349.10000-180.10000 -37.00000    .00000  71.10000    .00000 track top
           586.10000    .00000  -4.80000    .09580    .00000  11.69960 rt
295  rcc  -349.10000-180.10000 -64.70000    .00000  71.10000    .00000 drive trck
            39.40000    .00000    .00000    .00000    .00000    .00000 rt
```

Figure C-1. (continued)

```
296  rcc    237.00000-180.10000 -75.10000    .00000  71.10000    .00000 idler trck
              45.00000    .00000    .00000    .00000    .00000    .00000 rt
297  rcc   -192.00000-170.00000 -54.90000    .00000  45.50000    .00000 trk support
              16.40000    .00000    .00000    .00000    .00000    .00000 rolle 3rtt
298  arb6       .00000-102.38700  95.54000    .00000-131.30000    .00000 air betwee
                .00000    .00000    .00000    .00000    .00000  95.54000 14  18
             -63.50000-133.34200   8.39910 -63.50000    .00000   8.39910 right
299  rpp   -389.00000 538.00000-182.00000 182.00000-175.30000 154.50000 enclosing
300  rpp   -389.00000 538.00000-182.00000 182.00000-205.30000-175.30000 ground
301  rpp   -399.00000 548.00000-192.00000 192.00000-215.30000 164.50000 enclose
    1      1   -41                                                       tur t les 1
    2      2   -43    -44    -91                                         tur t les 1
    3      3   -41    -43    -44                                         tur t sec 2
    4      4    -5     -6    -19    -20   -288                           tur botls 1
    5      5   -19    -20   -288                                         tur botrs 1
    6      6   -19    -20   -288                                         tur botrs 2
    7      7    -8     -1     -4     -5                                  tur re ls 1
    8      8    -1     -4     -5     -2                                  tur re ls 2
    9      9   -10     -2     -4     -5     -7     -8                    tur re rs 1
   10     10    -1     -2     -4     -5     -7     -8    -16             tur re rs 2
   11     11    -4     -1     -7     -8                                  tur l sis 1
   12     12   -11     -1     -4     -7     -8     -3    -19    -20      tur sis 2
   13     13    -1     -3     -4    -12    -11    -19    -20             tur l sis 3
   14     14   -13     -3     -4    -11    -12    -19    -20             tur l sis 4
   15     15    -9    -10     -2     -3     -5     -6                    tur r sis 1
   16     16   -15     -2     -3     -5     -6     -9    -19    -20      tur r sis 2
   17     17   -16    -15     -2     -3     -5     -6    -19    -20      tur sis 3
   18     18   -17    -16    -15     -3     -2     -6    -19    -20      tur sis 4
        -288
   19     19   -20    -70    -75                                         tur ring ou
   20     20    19   -101    -97    -78    -68    -69    -95   -287      tur ringair
         -70
   21     21    -3    -14                                                taper strip
   22     22   -21    -71    -82    -79                                  face plate
   23     23   -21    -22    -18    -17                                  sec 1 right
   24     24   -18    -17    -21    -22                                  sec 2 right
   25     25   -21    -22    -82    -79                                  sec 3 right
   26     26   -22                                                       sec 4 right
   27     27   -22                                                       sec 5 right
   28     28   -22                                                       sec 6 right
   29     29   -22    -40    -65    -71                                  sec 6 right
   30     30   -22    -71                                                sec 7 right
   31     31   -14    -13    -21    -22                                  sec 8 right
   32     32   -14    -22    -21                                         sec 9 left
   33     33   -22    -40                                                sec 10 left
   34     34   -22                                                       sec 11 left
   35     35   -22                                                       sec 12 left
                                                                         sec 13 left
```

Figure C-1. (continued)

36	36	-22								sec 14 left
37	37	-22	-40	-65	-71					sec 15 left
38	38	-22	-40	-65	-71					sec 16 left
39	39	-40	-71	-66	-65					turretfront
40	40	-49	39	-71	-76	-66	-65	-78	-104	gun port
41	41	-42								loaderhatch
42	242									roller 1lt
43	43	-44	-93							cupola ring
44	44	-13	-93	-115						ring air
45	45	-46	-43							cupola bot
46	46	-87	-92	-93	-88					bot inside
47	47	-48	-83	-86	-72					cupola top
48	48	-83	-87	-88	-85	-92				top inside
49	49	-38	-37	-29	-30	-22	-65	-66	-67	air bet sec
	-68	-69	-70	-71	-104	-105	-114	-116	-122	7 8 - 15 16
50	50	-35	-36	-27	-28	-22	-65	-66	-67	air bet sec
	-68	-69	-70	-78	-51	-114	-104	-105		5 6 - 13 14
51	51	-33	-34	-25	-26	-22	-66	-67	-68	air bet bod
	-69	-70	-78	-79	-96	-97	-98	-99	-100	ies 25 26
	-101	-102	-103	-107	-104	-114				and 33 34
52	52	-31	-32	-23	-24	-21	-66	-67	-68	air bet bod
	-69	-70	-78	-79	-96	-97	-98	-99	-100	ies 31 32
	-101	-102	-103	-22	-114	-14	-287	-121		and 23 24
53	53	-13	-17	-3	-4	-5	-6	-19	-92	air bet bod
	-93	-94	-95	-18	-96	-97	-98	-99	-100	ies 13 17
	-101	-102	-103	-69	-108	-287	-121	-115	-44	
54	54	-13	-17	-3	-4	-5	-6	-19	-92	air inside
	-93	-94	-95	-18	-96	-97	-98	-99	-100	solid 17
	-101	-102	-103	-69	-108	-287	-121	-115	-44	
	-15									
55	55	-14	-18	-3	-4	-5	-6	-19	-13	air bet bod
	-17	-92	-93	-94	-95	-96	-97	-98	-99	ies 14 and
	-100	-101	-102	-103	-61	-67	-78	-68	-69	15
	-108	-114	-115	-287	-121	-21				
56	56	-1	-2	-3	-4	-5	-6	-7	-8	air between
	-9	-10	-11	-12	-15	-16	-19	-91	-92	11 and 16
	-93	-94	-95	-57	-58	-59	-123			right
57	57	-1	-2	-3	-4	-5	-6	-7	-8	air between
	-9	-10	-11	-12	-15	-19	-91	-92	-93	12 and 15
	-94	-95	-62	-123	-44					right ssc 2
58	58	-8	-10	-1	-2	-4	-5	-11	-12	inside air
	-15	-16	-59	-60	-64	-91	-9			
59	59	-7	-9	-1	-2	-4	-5	-11	-12	inside air
	-10	-15	-16	-8	-91	-60	-57			tur rear
60	60	-1	-2	-3	-4	-5	-6	-7	-8	air between
	-9	-10	-11	-12	-15	-16	-19	-91	-62	11 and 16 1
	-108									

Figure C-1. (continued)

61	61	-4	-5	-6	-17	-18	-13	-14	-19	air bot mid
	-11	-12	-15	-16	-19	-91	-101	-288		
62	62	-1	-2	-3	-4	-5	-6	-7	-8	air between
	-9	-10	-11	-12	-15	-16	-19	-91	-64	12and15 l
	-108	-58	-13							
63	63	-4	-5	-6	-7	-8	-9	-10	-11	air bottom
	-12	-15	-16	-19	-59	-58	-117			tur bustler
64	64	-4	-5	-6	-7	-8	-9	-10	-11	air bottom
	-12	-15	-16	-19	-59	-108				tur bustlel
65	65	-71	-78	-19	-30	-118	-66	-104	-119	mid gunport
	-120									
66	66	-76	-78							105 mm gun
67	67	-78								gun breech
68	68									arm of wgt
69	69									bal wgts
70	70	-78								2 bal wgts
71	71	-76	-66	-104						gun shield
72	247	238	-200							air fillr l
73	247	296	-201							air fillr r
74	74	-39	-40	-76	-65	-104				f gun shld
75	75	-39	-74							t gun s
76	76	-78								gun barrel
77	77	-76								exhaustcoll
78	78									barrel rifl
79	79	-80	-81	-82						gun scope
80	80									out prism
81	81									in prism
82	82									in air
83	83	-84	-85	-86						cmdr scope
84	84									out prism
85	85	-87								in prism
86	86									air cavity
87	87	-88								small eyepc
88	88									small eyepc
89	118									dumb air l
90	90	-91								blow cover
91	91									blow motor
92	92									cmdr head
93	93									cmdr torso
94	94									cmdr thighs
95	95									cmdr legs
96	96									gunnr head
97	97									gunnr torso
98	98									gunnr thigh
99	99									gunner legs
100	100									loader head
101	101									load torso

Figure C-1. (continued)

102	102	-103								load thighd
103	103									load legs
104	104	-105								sight scope
105	105	-106	-107							insid scope
106	106									front lens
107	107									back lens
108	108	-109	-110	-111	-112	-113				105mm ammo
109	109	-112								105mm explo
110	110	-112								air space
111	111	-112								105mm prope
112	112	108	-113							sleeve ammo
113	113	112	108							ammo air
114	114	-19								ammo box
115	115	-14								rnge finder
116	116	49	-29	-30						computer
117	42	1	41							filler secl
118	42	3	41							filler sec3
119	117	-8	-10	-1	-2	-4	-5	-11	-12	air opposit
	-15	-16	-59	-60	-64	-91	-56	-9	-57	bod 10 rear
120	119									dumb air 2
121	121									ldr interco
122	122	-19	-29							gun interco
123	123									com interco
124	124									tip glacis
125	125									top gracos
126	126									bot glacis
127	127	-73								top ov drvr
128	128	-174	-175	-190	-136	-137	-188			top sec 1
129	129	-124	-125	-126						side lt s1
130	130	-124	-125	-126						side rt s1
131	131	-125	-126	-129	-135					side lt s2
132	132	-125	-126	-130	-135					side rt s2
133	133	-125	-126	-131	-127	-135				side lt s3
134	134	-125	-126	-132	-127	-135				side rt s3
135	135	-126								hull bottom
136	136	-133	-188	-127	-135					side lt s4
137	137	-134	-188	-127	-135					side rt s4
138	138									side lt s5
139	139									side rt s5
140	140	-138								side lt s6
141	141	-139								side rt s6
142	142	-140								side lt s7
143	143	-141								side rt s7
144	144	-142	-143							hull floor
145	145	-138	-140	-142						frnt bulge
146	146	-139	-141	-143						frnt bulge
147	147	-144	-142							filler lt f

Figure C-1. (continued)

148	148	-144	-143							filler rt f
149	149	-178								rear sec 1
150	150	-149	-156	-157						rear sec 2
151	151	-150	-142	-143	-144					rear sec 3
152	152	-149	-150							side sec8 l
153	153	-149	-150							side sec8 r
154	154	-150	-151	-156						side sec9 l
155	155	-150	-151	-157						side sec9 r
156	156	-151	-144							side sec10l
157	157	-151	-144							side sec10r
158	158	-136								filler lrl
159	159	-137								filler rrl
160	160	-138								filler lr2
161	161	-139								fille rr2
162	162	-140	-138	-142						filler lr3
163	163	-141	-139	-143						filler rr3
164	164	-142								filler lr4
165	165	-143								filler rr4
166	166	-154	-156	-142	-151	-144				filler lr5
167	167	-155	-157	-143	-151	-144				filler rr5
168	168	-169								top rear s1
169	169									air
170	170	-171								top rear s2
171	171									air
172	172	-173								top rer s3
173	173									air
174	174	-136	-158	-152	-176					top rear 41
175	175	-137	-159	-153	-177					top rear 4r
176	176	174								grill top l
177	177	175								grill top r
178	178	149								grill rear
179	179	-124	-125	-126	-129	-130	-131	-132	-135	crew air s1
	-251	-250								
180	180	-125	-127	-135	-133	-134	-214	-222	-250	crew air s2
	-251	-248	-249	-252	-259					
181	181	-128	-136	-137	-174	-175	-158	-159	-214	crew air s3
	-222	-206	-208	-209	-210	-248	-249	-250	-252	
	-259	-95	-97	-98	-99	-101	-102	-103	-269	
	-256	-258	-261	-254	-253	-182				
182	182	-138	-139	-145	-146	-160	-161	-214	-222	crew air s4
	-206	-207	-208	-204	-256	-258	-261	-262	-263	
	-264	-265	-266	-267	-268	-269	-270	-271	-272	
	-273	-274	-275	-276	-99	-103	-253	-254		
183	183	-138	-139	-140	-141	-142	-143	-162	-163	crew air s5
	-145	-146	-214	-222	-206	-207	-208	-204	-205	
	-253	-254	-256	-258	-261	-262	-263	-264	-265	
	-266	-267	-268	-269	-270	-271	-272	-273	-274	
	-275	-276	-260	-103	-99					

Figure C-1. (continued)

184	184	-142	-143	-145	-146	-147	-148	-144	-164	crew air s6
	-165	-166	-167	-151	-156	-157	-214	-222	-203	
	-99	-103	-208	-275	-256	-267	-205	-253	-207	
	-204	-255	-254	-257	-258	-260				
185	185	-149	-152	-153	-258	-150				eng air s1
186	186	-150	-154	-155	-151	-156	-157	-258		eng air s2
187	187	-151	-156	-157	-144	-258				eng air s3
188	188	-189	-190							tur mount
189	189	-208	-209	-95	-97	-98	-99	-101	-102	air
	-103	-287	-190							
190	190	-208	-95	-97	-98	-99	-101	-102	-103	air
191	191									road whl 11
192	192									road whl 12
193	193									road whl 13
194	194									road whl 14
195	195									road whl 15
196	196									road whl 16
197	198									drive whl l
198	199									drive whl r
199	200									idlr whl l
200	201									road whl 1r
201	197									road whl 1r
202	202									road whl 2r
203	289									road whl 3r
204	290									road whl 4r
205	291									road whl 5r
206	292									road whl 6r
207	203									turr platfo
208	204									plat hub
209	205									plat ammo r
210	206									gunner seat
211	207									seat pedestr
212	208	-209	-210	-211	-212	-231				ammo box le
213	209	-212	-232	-230						hep explosi
214	210	-212								air space
215	211	-212								propellant
216	212	-213								sleeve air
217	213									air space
218	214	-215	-216	-217	-218	-219	-221			hull ammo r
219	215	-221								air fr ammo
220	216	-221								proj tip
221	217	-221								air opp tip
222	218	-221								alum spacer
223	219	-221								propellant
224	220									air space
225	221	-220								sleeve air
226	222	-223	-224	-225	-226	-227	-229	-228		hull ammo l

Figure C-1. (continued)

227	223	-229	-228		air front
228	224	-229	-228		tip ammo
229	225	-229	-228		air tip
230	226	-229	-228		alum spacer
231	227	-229	-228		propellant
232	228				air space
233	229	-228			sleeve air
234	230	209	-212		expl partit
235	231	-212			wp explosiv
236	232	-234	-233		track bot l
237	233	-239			t frnt slpl
238	234	-237			t rear slpl
239	235				track top l
240	236	-235	237	-198	r arnd drvl
241	238	-235	239	-247	t arnd idll
242	240	-241	-293		track bot r
243	241	-239			t frnt slpr
244	293	-237			t rear slpr
245	294				track top r
246	295	237	-199	-294	drive trckr
247	296	239	-247	-294	idler trckr
248	248				driver head
249	249				drivertorso
250	250				driver thigh
251	251				fire exting
252	252				dr intercom
253	253				oil cylinde
254	254				gas cylinde
255	255				batteries
256	256				engine bloc
257	257				oil pan
258	258				transmission
259	259				driver seat
260	260				gun control
261	261	-256	-262		left fuel t
262	262	-256			fuel
263	263	-256	-264		left fuel t
264	264	-256			fuel
265	265	-256	-266	-273	left fuel t
266	266	-256	-274		fuel
267	267	-256	-257	-268	left fuel t
268	268	-256	-257		fuel
269	269	-256	-270		right tank
270	270	-256			fuel
271	271	-256	-272		right tank
272	272	-256			fuel
273	273	-256	-274		right tank

Figure C-1. (continued)

274	274	-256								fuel
275	275	-256	-257	-276						right tank
276	276	-256	-257							fuel
277	277									fender lt
278	278									fender rt
279	279									fender lt
280	280									fender rt
281	281	-188								tool box 1l
282	282	-188								tool box 1r
283	283	-188								exhaust
284	284	-188								tool box 2r
285	285									tool box 2l
286	286									tool box 3r
287	287	-19	-20							gear motor
288	287	20								gear motor
289	243									roller 2lt
290	244									roller 3lt
291	245									roller 1rt
292	246									roller 2rt
293	297									roller 3rt
294	236	-237	-235	-234	-198					filler 100
295	295	-237	-294	-293	-199					filler 100
296	238	-239	-235	-233	-247					filler 100
297	296	-239	-294	-241	-247					filler 100
298	298	-14	-18	-3	-4	-5	-6	-19	-13	air between
	-17	-92	-93	-94	-95	-96	-97	-98	-99	bodies
	-100	-101	-102	-103	-61	-67	-78	-68	-69	14 18
	-108	-114	-115	-287	-121	-21				
299	299	-1	-2	-3	-4	-5	-6	-7	-8	enclosing
	-9	-10	-11	-12	-13	-14	-15	-16	-17	medium
	-18	-19	-20	-21	-22	-23	-24	-25	-26	
	-27	-28	-29	-30	-31	-32	-33	-34	-35	
	-36	-37	-38	-39	-41	-43	-45	-47	-49	
	-50	-51	-52	-53	-55	-56	-57	-58	-59	
	-60	-61	-62	-63	-64	-65	-74	-75	-76	
	-77	-79	-83	-90	-91	-104	-117	-124	-125	
	-126	-127	-128	-129	-130	-131	-132	-133	-134	
	-135	-136	-137	-138	-139	-140	-141	-142	-143	
	-144	-145	-146	-147	-148	-149	-150	-151	-152	
	-153	-154	-155	-156	-157	-158	-159	-160	-161	
	-162	-163	-164	-165	-166	-167	-168	-169	-170	
	-171	-172	-173	-174	-175	-179	-180	-181	-182	
	-183	-184	-185	-186	-187	-188	-191	-192	-193	
	-194	-195	-196	-197	-198	-199	-200	-201	-202	
	-232	-233	-234	-235	-236	-238	-240	-241	-242	
	-243	-244	-245	-246	-277	-278	-279	-280	-281	
	-282	-283	-284	-285	-286	-289	-290	-291	-292	

Figure C-1. (continued)

```
        -293   -294   -295   -296   -297    -71   -106    -54    -69
         -94   -298   -119   -118    -67    -78    -44    -72    -73
 300     300                                                           ground
 301     301   -299   -300                                             enclosing
 302      73    127                                                    drvr hatch
 303      72     47                                                    cmdr hatch
  -1
   1  101     0     3     0
   2  102     0     3     0
   3  103     0     3     0
   4  104     0     3     0
   5  105     0     3     0
   6  106     0     3     0
   7  107     0     3     0
   8  108     0     3     0
   9  109     0     3     0
  10  110     0     3     0
  11  148     0     3     0
  12  112     0     3     0
  13  113     0     3     0
  14  114     0     3     0
  15  115     0     3     0
  16  116     0     3     0
  17  117     0     3     0
  18  118     0     3     0
  19  119     0     3     0
  20  150     1     1     0
  21  120     0     3     0
  22  121     0     3     0
  23  122     0     3     0
  24  123     0     3     0
  25  124     0     3     0
  26  125     0     3     0
  27  126     0     3     0
  28  127     0     3     0
  29  128     0     3     0
  30  129     0     3     0
  31  130     0     3     0
  32  131     0     3     0
  33  132     0     3     0
  34  133     0     3     0
  35  134     0     3     0
  36  135     0     3     0
  37  136     0     3     0
  38  137     0     3     0
  39  138     0     3     0
  40  150     1     1     0
```

Figure C-1. (continued)

41	139	0	3	0
42	519	0	9	0
43	140	0	3	0
44	150	1	1	0
45	141	0	3	0
46	150	1	1	0
47	141	0	3	0
48	150	1	1	0
49	150	1	1	0
50	150	1	1	0
51	150	1	1	0
52	150	1	1	0
53	150	1	1	0
54	150	1	1	0
55	150	1	1	0
56	150	1	1	0
57	150	1	1	0
58	150	1	1	0
59	150	1	1	0
60	150	1	1	0
61	150	1	1	0
62	150	1	1	0
63	150	1	1	0
64	150	1	1	0
65	142	0	3	0
66	400	0	3	0
67	401	0	3	0
68	402	0	3	0
69	403	0	13	0
70	404	0	13	0
71	143	0	3	0
72	100	1	1	0
73	100	1	1	0
74	144	0	3	0
75	144	0	3	0
76	405	0	3	0
77	406	0	3	0
78	150	1	1	0
79	145	0	3	0
80	900	0	10	0
81	901	0	10	0
82	150	1	1	0
83	146	0	3	0
84	902	0	10	0
85	903	0	10	0
86	150	1	1	0
87	815	0	3	0

Figure C-1. (continued)

88	904	0	10	0
89	100	1	1	0
90	147	0	3	0
91	816	0	3	0
92	10	0	4	0
93	11	0	4	0
94	12	0	4	0
95	13	0	4	0
96	14	0	4	0
97	15	0	4	0
98	16	0	4	0
99	17	0	4	0
100	18	0	4	0
101	19	0	4	0
102	20	0	4	0
103	21	0	4	0
104	817	0	3	0
105	150	1	1	0
106	905	0	10	0
107	906	0	10	0
108	314	0	3	0
109	315	0	7	0
110	150	1	1	0
111	316	0	7	0
112	317	0	3	0
113	150	1	1	0
114	318	0	3	0
115	818	0	12	0
116	819	0	12	0
117	101	0	3	0
118	103	0	3	0
119	150	1	1	0
120	100	1	1	0
121	821	0	12	0
122	822	0	12	0
123	823	0	12	0
124	151	0	3	0
125	152	0	3	0
126	153	0	3	0
127	154	0	3	0
128	155	0	3	0
129	156	0	3	0
130	157	0	3	0
131	158	0	3	0
132	159	0	3	0
133	160	0	3	0
134	161	0	3	0

Figure C-1. (continued)

135	162	0	3	0
136	163	0	3	0
137	164	0	3	0
138	165	0	3	0
139	166	0	3	0
140	167	0	3	0
141	168	0	3	0
142	169	0	3	0
143	170	0	3	0
144	171	0	3	0
145	172	0	3	0
146	173	0	3	0
147	174	0	3	0
148	175	0	3	0
149	176	0	3	0
150	177	0	3	0
151	178	0	3	0
152	179	0	3	0
153	180	0	3	0
154	181	0	3	0
155	182	0	3	0
156	183	0	3	0
157	184	0	3	0
158	185	0	3	0
159	186	0	3	0
160	185	0	3	0
161	186	0	3	0
162	185	0	3	0
163	186	0	3	0
164	185	0	3	0
165	186	0	3	0
166	185	0	3	0
167	186	0	3	0
168	187	0	3	0
169	150	1	1	0
170	188	0	3	0
171	150	1	1	0
172	189	0	3	0
173	150	1	1	0
174	190	0	3	0
175	191	0	3	0
176	192	0	3	0
177	193	0	3	0
178	194	0	3	0
179	150	1	1	0
180	150	1	1	0
181	150	1	1	0

Figure C-1. (continued)

182	150	1	1	0
183	150	1	1	0
184	150	1	1	0
185	150	1	1	0
186	150	1	1	0
187	150	1	1	0
188	195	0	3	0
189	150	1	1	0
190	150	1	1	0
191	503	0	9	0
192	504	0	9	0
193	505	0	9	0
194	506	0	9	0
195	507	0	9	0
196	508	0	9	0
197	509	0	9	0
198	510	0	9	0
199	511	0	9	0
200	512	0	9	0
201	513	0	9	0
202	514	0	9	0
203	515	0	9	0
204	516	0	9	0
205	517	0	9	0
206	518	0	9	0
207	800	0	3	0
208	801	0	3	0
209	802	0	7	0
210	803	0	3	0
211	804	0	3	0
212	300	0	3	0
213	301	0	7	0
214	150	1	1	0
215	302	0	7	0
216	303	0	3	0
217	150	1	1	0
218	304	0	3	0
219	150	1	1	0
220	305	0	11	0
221	150	1	1	0
222	306	0	5	0
223	307	0	7	0
224	150	1	1	0
225	308	0	3	0
226	309	0	3	0
227	150	1	1	0
228	310	0	11	0

Figure C-1. (continued)

229	150	1	1	0
230	311	0	5	0
231	312	0	7	0
232	150	1	1	0
233	313	0	3	0
234	314	0	3	0
235	315	0	7	0
236	501	0	9	0
237	501	0	9	0
238	501	0	9	0
239	501	0	9	0
240	501	0	9	0
241	501	0	9	0
242	502	0	9	0
243	502	0	9	0
244	502	0	9	0
245	502	0	9	0
246	502	0	9	0
247	502	0	9	0
248	22	0	4	0
249	23	0	4	0
250	24	0	4	0
251	805	0	3	0
252	806	0	12	0
253	807	0	3	0
254	808	0	3	0
255	809	0	8	0
256	700	0	3	0
257	701	0	3	0
258	702	0	3	0
259	810	0	3	0
260	811	0	3	0
261	200	0	5	0
262	150	1	1	0
263	202	0	5	0
264	150	1	1	0
265	204	0	5	0
266	150	1	1	0
267	206	0	5	0
268	150	1	1	0
269	208	0	5	0
270	209	0	6	0
271	210	0	5	0
272	211	0	6	0
273	212	0	5	0
274	213	0	6	0
275	214	0	5	0

Figure C-1. (continued)

276	215	0	6	0
277	824	0	3	0
278	825	0	3	0
279	826	0	3	0
280	827	0	3	0
281	828	0	3	0
282	829	0	3	0
283	830	0	3	0
284	812	0	3	0
285	813	0	3	0
286	814	0	3	0
287	820	0	3	0
288	820	0	3	0
289	520	0	9	0
290	521	0	9	0
291	522	0	9	0
292	523	0	9	0
293	524	0	9	0
294	100	1	1	0
295	100	1	1	0
296	100	1	1	0
297	100	1	1	0
298	150	1	1	0
299	150	1	1	0
300	650	0	2	0
301	99	1	0	0
302	831	0	3	0
303	832	0	3	0

Figure C-1. (continued)

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220 7th Street NE
Charlottesville, VA 22901-5396

68. Los Alamos National Laboratory
ATTN: Dr. Paul Whalen
C-DOT MS-B281
Los Alamos, NM 87545

69. Dr. Mary F. Weeler
Department of Mathematical Sciences
Rice University
P. O. Box 1892
Houston, Tx 77204-3476

70. Commander, U.S. Army Tank Automotive Command
ATTN: AMSTA-RSK (Mr. Greg Wolfe)
Bldg. 200
Warren, MI 48317-5000

71. Science Applications International Corporation
ATTN: Dr. William Woolson
10260 Campus Point Drive
San Diego, CA 92121

72. Director, Defense Nuclear Agency
ATTN: RARP (Dr. Robert Young)
6801 Telegraph Road
Alexandria, VA 22310-3398

73. Office of the Assistant Manager for Energy Research and Development
Department of Energy, Oak Ridge Operations
P.O. Box 2001
Oak Ridge, TN 37831

74-83. Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37830