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Recommendations for a New and Improved ORCA Modeling System Blast Module

by Owen P. Litt

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14. ABSTRACT

The blast module of the Operational Requirement-based Casualty Assessment (ORCA) modeling system computer software package was reviewed and compared to the WRAIR blast injury model (INJURY). As a result, recommendations are presented in this report to improve ORCA by expanding its capabilities consistent with INJURY results and to expand the ORCA input-output capabilities. The recommended improvements include incorporating a newly developed ORCA mathematical lethality/injury blast effects model and its computer implementation, ORCA model changes, and expanded user interaction capabilities.

15. SUBJECT TERMS

ORCA model, casualty assessment, blast overpressure, lung injury, lethality, mathematical computer module, injury severity, human estimates

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Contents

List of Figures

List of Tables

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1. Introduction

The Operational Requirement-based Casualty Assessment (ORCA)[1,2] modeling system is a computer software package that provides a comprehensive standardized casualty assessment methodology associated with weapon-induced injuries. With it, anatomical damage and the effect on individual performance can be determined for exposure to fragments, chemical agents, and blast shock waves. Each of these sources of injury is modeled and analyzed in an independent computer code module. Each module characterizes bioresponse to these sources of injury and estimates soldier performance degradation.

The ORCA blast module has been reviewed in order to determine which changes and additions should be made to improve and expand its capabilities. The current blast module was compared to the Walter Reed Army Institute of Research (WRAIR) blast injury model (INJURY). Five recommendations resulted from this review, which include a new ORCA mathematical model (which has been completed) and its computer implementation, ORCA model changes, and expanded user interaction capabilities. These recommendations follow.

1. Incorporate the newly developed mathematical/computer model, which calculates "lung injury" and the likelihood of lethality for all levels of blast overpressure (BOP) in the ORCA input time history data files. The values obtained by the model are equivalent to those in INJURY.

2. Expand the data file headers with which the user is able to select input options with respect to the experimental setup. These options include the following:

   - BOP inputs in different units of time and overpressure,

   - target and gauge orientation with respect to the blast shock wave, and

   - the target mass and ambient air pressure as a user input.

3. Improve and expand the display of results in order to include all the added and modified features.

4. Include an option to generate a permanent folder of computer files consisting of selected elements, including the input parameters, of a given case study.

5. Develop a simple procedure by which to make hard copies of selected parts of the ORCA inputs and results.

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[1] Kaltenbach, E.; Kilion, E.; Partch, J.; Streit, B. *Operational Requirements-Based Casualty Assessment (ORCA) User's Manual;* ARA Project No. 0573; Applied Research Associates, Inc.: Albuquerque, NM, 2001.

[2] Applied Research Associates, Inc. *ORCA Computer Software Computer Code, version 2.43a;* Albuquerque, NM, 2000.

The term "lung injury" refers to the fractional, or percentage of, loss of respiratory function.

INJURY was developed by WRAIR and Jaycor.[3] It is a computer software package developed from a mathematical model and its associated computer code. Its purpose is to predict auditory injury and lung injury for blast shock-wave anterior impacts. A description of the model and its computer code are not presently available. The only document at our disposal is a user's manual published by Jaycor in May 1995.[4] It is the baseline model against which ORCA results are compared for correctness. The inputs to INJURY are BOP time history data files.

The analysis of the BOP data yields "normalized work" (n-work)—a result from which lung damage and likelihood of lethality can be determined. The n-work is calculated from the peak overpressure and specific impulse (impulse per unit area) as a measure of lung damage resulting from incident blast shock waves.

ORCA follows the same initial process of analysis as INJURY—the determination of n-work from a BOP time history data file. Beyond the determination of n-work, the two models are different. For each value of n-work, INJURY calculates probability distributions for five levels of lung injury and the likelihood of lethality. There are no corresponding values of likelihood of lethality in ORCA. ORCA presently generates a table of five levels of lung injury, which correspond to five values of n-work. These five levels are not all consistent with the lung damage levels in INJURY. In ORCA, the five lung injury levels are presented for the purpose of display. The injury levels and corresponding incapacitation are determined by n-work at each of the five injury thresholds. The most obvious inconsistency in the ORCA lung injury levels is the highest injury threshold, the lethal lung damage threshold, at which ORCA assigns 100% lung injury at n-work = 2. In INJURY, the likelihood of lethality, at n-work = 2, is 47%. This obviously does not correspond to 100% lung injury. As a result, it is necessary that changes will be made to the five n-work thresholds, which correspond to five levels of incapacitation. For consistency, these thresholds should also correspond to the five levels of lung injury in ORCA.

At present, the data file header consists of the number of lines of BOP time history data to be processed. In addition, time history data files must be read in units of milliseconds and pounds per square inch (psi). The BOP data is assumed to be in one of the four possible load (reflective) modes with no user option for the other three or for the two possible incident (side-on) modes. To increase the generality of the user input, the data file should begin with an options header. This header should include time units, BOP units, the target mass, and the ambient air pressure. In addition, it should be able to include target orientation and pressure gauge orientation (side-on or incident mode). However, the model is presently based on the configuration of an experimental thorax model with pressure gauges only on the anterior side. It is not clear that

[3] Walter Reed Army Institute of Research (WRAIR). *Applied Science and Engineering Technology*; INJURY Software Computer Code, version 4.00 Beta; WRAIR: Washington, DC, 1995.

[4] Jaycor. *Applied Science and Engineering Technology;* INJURY User's Manual, version 4.00 Beta; Jaycor: San Diego, CA, 1995.

including other target orientations is presently feasible. In INJURY, side-on pressure gauge orientations are included, but the inputs are converted to the BOP as measured with experimental thorax-model pressure gauges. This means that it is assumed that the BOP always impacts a target that faces the blast source.

It is easy to display the result, but it is difficult to make hard copies. Also, there is not presently a procedure for storing the inputs and results of a specific case study. If this capability is added to ORCA, a library for case studies could be developed in which several inputs or results could be directly observed.

The five sections of this report address the five recommendations listed in section 1. The first consists of a discussion of the data file header in its present and expanded format.

Section 2 begins with a discussion of the present analysis methodology. The strengths and weaknesses are described, and a new analysis model which eliminates the present limitations in the blast module of ORCA is introduced.

Section 3 consists of recommended displays of new and modified features. This includes the specifics of the expanded data file header format. Also, it includes displays of the suggested target configuration options. Additionally, it presents suggested tabular and graphic displays of the improved analysis model, which is described in section 2.

Sections 4 and 5 consist of a brief description of improvements, which would result in enhanced user conveniences. In section 4, development of an ORCA case-studies computer library is suggested. This would make it possible for the user to look up past studies instead of having to rerun them. In section 5, a procedure with which to easily generate sets of hard copies is recommended.

2. New Injury and Lethality Algorithms

New algorithms of lung damage and the likelihood of lethality have been developed for application in ORCA. This section briefly describes a comparison between INJURY and ORCA and the inconsistencies between the two models. It is assumed that where INJURY and ORCA disagree, that INJURY is correct because ORCA was developed with the methodology used in INJURY. The new formulations provide corrections to these inconsistencies.

INJURY predicts the likelihood of lethality and the probability of five levels of lung injury for all levels of n-work. The levels of lung injury are none, trace, slight, moderate, and severe. The total probability of lung injury at any of these levels is the sum of the value at that level plus the value(s) of all levels beneath. The total probabilities are as follows: severe lung injury is the sum of the values of moderate, slight, trace, and none; slight lung injury is the sum of the values of slight, trace, and none; trace lung injury is the sum of the values of trace and none; and no lung injury is the value of no lung injury. The extent of lung injury, or lung damage, or loss of respiratory function is not addressed. Therefore, the lung injury labels are a qualitative designation of increasing levels of lung injury, or lung damage, or loss of respiratory function.

Lung injury levels in ORCA are qualitative, as in INJURY, and not directly related to resulting incapacitation. Incapacitation is determined by five threshold values of n-work, which correspond to four of the five levels of lung injury that are found in INJURY, and a fifth level (lethal injury), which does not correspond to an injury level in INJURY. The five levels of lung injury and their corresponding values of n-work are trace-0.09, slight-0.25, moderate-0.60, severe-1.58, and lethal-2.08. These five levels of lung injury do not appear to be consistent with corresponding values of lung injury in INJURY.

In developing more representative injury levels corresponding to n-work and the corresponding values of likelihood of lethality, it is suggested that these values be changed. The values of n-work correspond to the maximum values, in the INJURY lung injury probability distributions (found in figure 1), of trace, slight, moderate, and severe lung injury, and the n-work value corresponding to a 99% likelihood of lethality, in INJURY, for lethal lung injury in ORCA. The new values were derived from a consultation with Dr. Edward Davis of the U.S. Army Research Laboratory.[5] They are more representative of the loss of respiratory function corresponding to the likelihood of lethality at a given n-work level. The lung injury labels (trace, slight, moderate, severe, and lethal), the n-work levels, the corresponding levels of likelihood of lethality (lth), and the new suggested lung injury levels (L) are shown in table 1.

These values of L are obtained by applying the probabilities (which are normalized to 1) of each level of INJURY, which corresponds to a specific value of n-work, to calculate an injury level in ORCA. In INJURY, each level of lung injury has a probability value (P_i) as follows:

- $P_1 =$ probability of severe injury;
- $P_2 =$ probability of moderate injury;
- $P_3 =$ probability of slight injury; and
- $P_4 =$ probability of both no injury and trace injury.

For each value of n-work, the total probability of all levels of injury is 1:

$$P_1 + P_2 + P_3 + P_4 = 1. \quad (1)$$

The equation for lung damage is as follows:

$$L = 0.56 + 0.4 * \tanh(0.32 * n - work). \quad (2)$$

[5] Davis, E. U.S. Army Research Laboratory, Aberdeen Proving Ground, MD. Technical consultation, 2002.

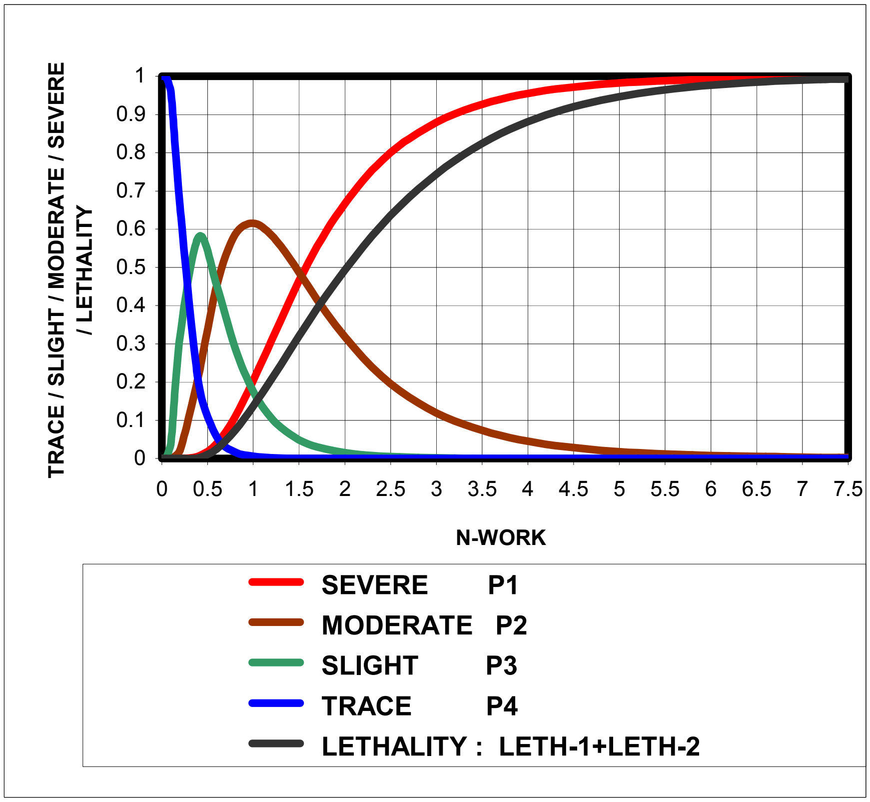

Figure 1. Lethality/lung injury levels vs. n-work.

Table 1. Lung injury/lethality and n-work.

Lung Injury	N-Work	Lth	L
Trace	0.10	0.0000	0.57
Slight	0.40	0.0014	0.61
Moderate	1.00	0.1400	0.68
Severe	2.40	0.6100	0.82
Lethal	6.60	0.9900	0.95

The likelihood of lethality is also calculated in INJURY. The following equations, in which H is the likelihood of lethality, have been developed in order to yield similar results in ORCA:

$For \quad n-work \leq 0.5,$

$$H = 0. \tag{3}$$

$For \quad n-work > 0.5,$

$$H_1 = \tanh(0.42 * n-work - 0.3)\,, \tag{4}$$

Table 2 consists of selected levels of likelihood of lethality and the probability distribution of the four levels of lung injury (loss of respiratory function), in INJURY, as functions of n-work.

Table 2. INJURY: n-work vs. lung injury.

N-Work (N)	Lethality (Lth – 1 + Lth – 2)	Severe (P_1)	Moderate (P_2)	Slight (P_3)	Trace + No Injury (P_4)	Total Injury Distribution ($P_1 + P_2 + P_3 + P_4$)
0.01	0	0	0	0	1	1
0.05	0	0	0	0.003	0.997	1
0.1	0	0	0.0006	0.0464	0.953	1
0.2	0	0	0.022	0.32	0.658	1
0.4	0.001407725	0.006	0.218	0.579	0.197	1
0.6	0.024834704	0.039	0.453	0.452	0.056	1
0.8	0.072865096	0.108	0.585	0.29	0.017	1
1	0.136675136	0.203	0.615	0.176	0.006	1
1.2	0.208662512	0.31	0.583	0.105	0.002	1
1.4	0.283260378	0.414	0.522	0.064	0	1
1.6	0.356831498	0.511	0.451	0.038	0	1
1.8	0.427189219	0.595	0.381	0.024	0	1
2	0.493104182	0.667	0.318	0.015	0	1
2.2	0.55394055	0.728	0.2626	0.0094	0	1
2.4	0.609430137	0.778	0.216	0.006	0	1
2.6	0.659542755	0.819	0.177	0.004	0	1
2.8	0.70441027	0.852	0.1453	0.0027	0	1
3	0.744276973	0.8791	0.1191	0.0018	0	1
3.2	0.77946274	0.9012	0.0976	0.0012	0	1
3.4	0.810333659	0.919	0.081	0	0	1
3.6	0.837278422	0.934	0.066	0	0	1
3.8	0.86068987	0.9453	0.0547	0	0	1
4	0.880951268	0.955	0.045	0	0	1
4.2	0.898426694	0.963	0.037	0	0	1
4.4	0.913454894	0.969	0.031	0	0	1
4.6	0.926345874	0.9744	0.0256	0	0	1
4.8	0.937379569	0.9787	0.0213	0	0	1
5	0.946806013	0.9822	0.0178	0	0	1
5.2	0.954846537	0.985	0.015	0	0	1
5.4	0.961695611	0.9875	0.0125	0	0	1
5.6	0.967523047	0.9895	0.0105	0	0	1
5.8	0.972476366	0.9912	0.0088	0	0	1
6	0.976683167	0.9925	0.0075	0	0	1
6.2	0.980253424	0.9936	0.0064	0	0	1
6.4	0.98328163	0.9945	0.0055	0	0	1
6.6	0.985848768	0.9953	0.0047	0	0	1
6.8	0.988024097	0.996	0.004	0	0	1
7	0.989866741	0.9966	0.0034	0	0	1
7.2	0.991427094	0.9971	0.0029	0	0	1
7.4	0.992748054	0.9975	0.0025	0	0	1
7.5	0.993330385	0.9977	0.0023	0	0	1

$$H_2 = 0.9417 * \exp(-(n - work + 1)^2), \quad (5)$$

and

$$H = H_1 + H_2. \quad (6)$$

The first column consists of a range of values of n-work corresponding to trace or no injury and 0 likelihood of lethality to nearly 100% likelihood of both severe lung injury and lethality. The second column is the predicted likelihood of lethality as a function of n-work. The third, fourth, fifth, and sixth columns are the probabilities of severe, moderate, slight, and trace and no lung injury. The last column is the sum of the four levels of lung injury; the total is 1. This is expected since the four levels represent all possible injury levels—none and trace, slight, moderate, and severe.

Figure 1 is a graph generated from table 2. The probability distributions of the injury levels and the likelihood of lethality are graphed as functions of n-work. These are consistent with the values of lung injury probabilities and lethality likelihoods found in INJURY. The lung injury and lethality levels were obtained from extensive BOP studies applied to INJURY. In these studies, both ambient air pressure and target mass were varied for selected external BOP time history data files. The results provided a sufficient number of injury and lethality results to generate a smooth curve in the range of n-work corresponding to likelihoods of lethality between 0 and almost 1.

As part of this effort, an algorithm was developed, as previously described, in order to generate the INJURY values of likelihood of lethality as a function of n-work for application in ORCA. The lung injury levels, which correspond to the likelihood of lethality values, were applied to the development of an algorithm with which to calculate lung injury as a function of n-work. Table 3 consists of many of these results. Figure 2 is a graph generated from table 3. Lung injury and lethality are graphed as functions of n-work.

The lung injury algorithm is the result of improved estimates. It is therefore assumed that they are well within error bar limits. This method of determining lung injury makes it possible to select a good estimate of lung injury for determining levels of incapacitation, which result from blast shock-wave impacts.

Table 3 consists of lethality and lung damage likelihoods as a function of n-work. Figure 2 graphs levels of lethality likelihood and lung injury as functions of n-work. The lethality likelihood levels are the same as those in INJURY for corresponding values of n-work. The levels of lung injury were developed as a result of consultations with Dr. Davis.[5] Note that the likelihood of lethality is nearly 0 at a lung injury level of 0.6, and that the likelihood of lethality is nearly 1 at a lung injury level of 0.95.

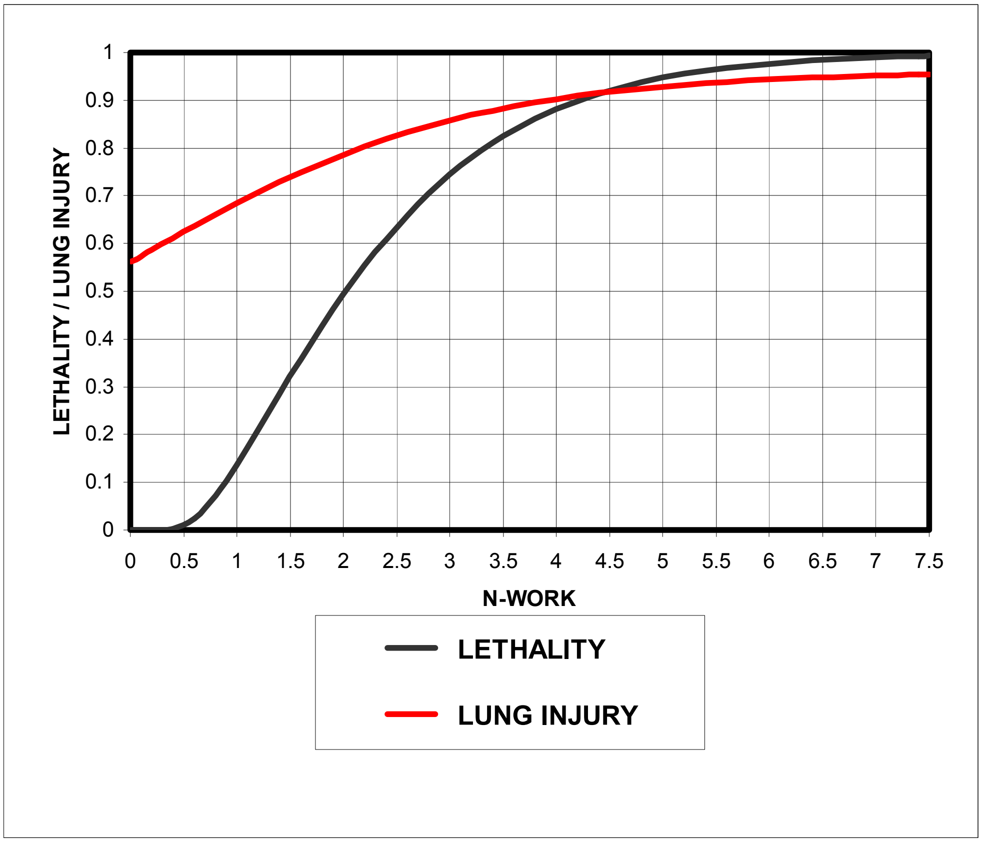

Figure 2. Lethality/lung injury vs. n-work.

3. Data File Headers

In order to implement the first objective, a list of user data file header input options would appear as a user menu. For each header input, a list of available units would appear to be selected by the user. After completing the selection of input options, the list would appear with all of the user selections. The user would have the choice of entering the selected options as the data file header or of changing any of the header-input options. The options would be entered by adding them as a header to the data file or perhaps as a separate header file.

The list of header inputs would include the following user options:

- OVERPRESSURE: (available units).
- TARGET MASS: (number, available units).
- AMBIENT PRESSURE: (number, available units).
- TARGET ORIENTATION: (one of six possibilities).

Table 3. Lethality/lung injury vs. n-work.

Lth-1 **Tanh(0.42*N – 0.3)**	**Lth-2** **0.9417*Exp(– (N+1)^^{2})**	**Lethality** **(Lth 1 + Lth-2)**	**Lung Injury** **0.56 + 0.4*Tanh(0.32*N)**	**N-WORK** **N**
0	0	0	0.561279996	0.01
0	0	0	0.566399454	0.05
0	0	0	0.572795633	0.1
0	0	0	0.585565105	0.2
–0.13123865	0.132646375	0.001407725	0.6109222	0.4
–0.04796317	0.072797874	0.024834704	0.635869993	0.6
0.035984456	0.03688064	0.072865096	0.660220163	0.8
0.119427299	0.017247837	0.136675136	0.683802768	1
0.201216439	0.007446073	0.208662512	0.706470476	1.2
0.280292976	0.002967402	0.283260378	0.728101447	1.4
0.355739852	0.001091646	0.356831498	0.748600815	1.6
0.4268185	0.000370718	0.427189219	0.767900828	1.8
0.492987967	0.000116215	0.493104182	0.785959821	2
0.553906919	3.36308E-05	0.55394055	0.80276024	2.2
0.609421153	8.98397E-06	0.609430137	0.818305992	2.4
0.65954054	2.21542E-06	0.659542755	0.83261938	2.6
0.704409766	5.04313E-07	0.70441027	0.845737846	2.8
0.744276867	1.05974E-07	0.744276973	0.857710747	3
0.779462719	2.05569E-08	0.77946274	0.868596299	3.2
0.810333655	3.68105E-09	0.810333659	0.878458804	3.4
0.837278421	6.08473E-10	0.837278422	0.887366221	3.6
0.86068987	9.2847E-11	0.86068987	0.895388113	3.8
0.880951268	1.30783E-11	0.880951268	0.902593966	4
0.898426694	1.70055E-12	0.898426694	0.909051862	4.2
0.913454894	2.0412E-13	0.913454894	0.914827468	4.4
0.926345874	2.26171E-14	0.926345874	0.919983315	4.6
0.937379569	2.31338E-15	0.937379569	0.924578306	4.8
0.946806013	2.18429E-16	0.946806013	0.928667422	5
0.954846537	1.90385E-17	0.954846537	0.932301587	5.2
0.961695611	1.53183E-18	0.961695611	0.935527656	5.4
0.967523047	1.13775E-19	0.967523047	0.938388496	5.6
0.972476366	7.80074E-21	0.972476366	0.940923128	5.8
0.976683167	4.93723E-22	0.976683167	0.943166922	6
0.980253424	2.88461E-23	0.980253424	0.945151823	6.2
0.98328163	1.55577E-24	0.98328163	0.946906584	6.4
0.985848768	7.74575E-26	0.985848768	0.948457015	6.6
0.988024097	3.55989E-27	0.988024097	0.949826229	6.8
0.989866741	1.51031E-28	0.989866741	0.951034875	7
0.991427094	5.91496E-30	0.991427094	0.95210137	7.2
0.992748054	2.13842E-31	0.992748054	0.95304211	7.4
0.993330385	3.94581E-32	0.993330385	0.953469943	7.5

ORCA would have header file input codes with which to convert the selected units to the units of the existing ORCA code. Other inputs, such as target mass, ambient pressure, and target orientation, are presently fixed in ORCA. These sections of the code would need to be rewritten in order to accommodate the new user options.

4. Display of New and Modified User Interface Features

In order to introduce new display options, existing menus need to be expanded to include them. The additions and modifications include the data file header inputs and the contents of table 3 and figure 2 (n-work as a function of lung damage levels—fractional loss of respiratory function—and the likelihood of lethality). They might also include the contents of table 2 and figure 1 (n-work as a function of the probability distribution of lung damage levels and the likelihood of lethality). This last option demonstrates clearly that there is a range of possible lung damage levels from a blast shock-wave impact on a soldier. The possible difficulty with it is that it was generated in INJURY for the values of n-work listed in table 1. If in ORCA, the lung injury probability distribution is to be displayed for a value of n-work, which is not included in table 1, there is no present algorithm to generate the results. If this is considered important for clarification, or some other purpose, one of two methods can be applied. The first is an embedded look-up table of n-work, as a function of the probability distribution of lung damage levels and the likelihood of lethality, which can be generated. It would be applied by displaying the closest value of n-work (in the look-up table) to the value obtained in ORCA. The second is an algorithm, which could be developed and added to ORCA.

The data file header menu display would consist of two parts. The first is the user-options menu. The second is a display, as it will be applied to the BOP time history data file. The options menu might look something like the following:

OVERPRESSURE (UNITS)

- *kPa*
- *Pa*
- kg/m^2
- g/cm^2
- *db*

TARGET MASS (AMOUNT, UNITS**)**

- *lb*
- *kg*
- *g*

<u>AMBIENT PRESSURE (</u><u>AMOUNT</u>**<u>)</u>**

- *psi*
- *kPa*
- *Pa*
- kg / m^2
- g / cm^2
- *mm*

<u>TARGET ORIENTATION (</u><u>OPTIONS</u>**<u>)</u>**

- ANTERIOR (FRONT)
- POSTERIOR (BACK)
- LATERIAL-LEFT (LEFT SIDE)
- LATERIAL-RIGHT (RIGHT SIDE)
- SUPERIOR (TOP)
- INFERIOR (BOTTOM)

The suggested target orientation menu consists of six target-impact orientations with respect to the direction from the location of the blast shock-wave source. For a given BOP time history, left and right, front and back, and top and bottom cannot be assumed to yield the same levels of lung damage because of the nonsymmetrical structure of the lungs and the anatomical elements that surround them.

This target orientation menu cannot presently be implemented because the present lung damage experimental target, from which the n-work algorithm was developed, has pressure gauges only on the front surface. Its implementation would require the design and fabrication of a new experimental target, an experimental program, and the development of five new n-work algorithms.

Expanding the target orientation choices from one to six would be a significant improvement to ORCA. However, the most likely scenario is an oblique blast shock-wave impact. Therefore, BOP data from the pressure gauges on the surfaces of as many as three of the six principle directions would contribute to the determination of n-work. It is not clear if these BOP time histories would contribute independently or synergistically to the determination of n-work. This can be determined by an expanded experimental program, which would include oblique directions from the blast shock-wave source and the target. If this were implemented, the target orientation options menu would be replaced with a new user input, which includes the position and orientation of the target with respect to the blast shock-wave source.

<u>TARGET CONFIGURATION (</u><u>OPTIONS</u>**<u>)</u>**

- STANDING
- LYING DOWN
- SITTING
- DESCRIPTIONS AND LOCATIONS OF NEARBY SURFACES

At present, n-work is determined from the unlikely scenario of a perpendicular blast shock-wave impact on the front surface of a target. It does not include secondary reflected shock waves. At best, this can only result in a crude approximation of a blast shock-wave impact on a target.

The target-configurations menu is important because of the secondary blast effects that can result from nearby surfaces and objects. Nearby surfaces and objects are sources of reflected shock waves. These reflected shock waves could be a significant added source of BOP shock-wave impact on the target. These added shock waves would impact the target from directions, and with BOP time histories, according to the locations, distances, orientations, structural configurations, masses, and sizes of the reflecting surfaces.

The configuration of the target is also important. Standing, lying down, or sitting can alter the BOP time history characteristics of an impacting blast shock wave.

The second display of the data file header options would include the same header titles and the options selected by the user.

<u>DATA FILE HEADER (</u><u>OPTIONS)</u>

- **OVERPRESSURE (**UNITS)
- **TARGET MASS (**AMOUNT, UNITS**)**
- **AMBIENT PRESSURE (**AMOUNT**)**
- **TARGET ORIENTATION (**OPTIONS**)**
- **TARGET CONFIGURATION (**OPTIONS**)**

Upon review, the user would have the option of applying the selected data file header options to the BOP time history data file or returning to the user-options menu.

The n-work as a function of lung damage and lethality, could also be displayed in two parts—the graph in figure 2 and the specific values which correspond to the value of n-work calculated by ORCA for a given BOP data file and the user-selected header options. The display could be in a form like table 4.

Table 4. Lethality/lung damage vs. selected n-work.

Lethality (Lth)	Lung Damage (L)	N-Work (N)
0.00141	0.611	0.40

For n-work as a function of the lung damage probability distribution, the simplest way to add it in ORCA, as previously stated, is to use INJURY to obtain more n-work results. The results could be added to table 2. For any n-work result in ORCA, the values of the lung damage probability distribution, corresponding to the closest value of n-work in the augmented version of Table 2, would be displayed. The display could be in a form like table 5.

Table 5. Lethality/lung damage levels vs. selected n-work.

N-Work (N)	Lethality (Lth)	Severe (P_1)	Moderate (P_2)	Slight (P_3)	Trace + No Injury (P_4)
0.40	0.0014	0.006	0.218	0.579	0.197

5. Need for Orca Model Case Studies Computer Library for Analysts

In order to develop a library of ORCA studies, a system of computer files and folders can be developed, in which the results of these studies are stored and retrieved. A method with which to easily transfer ORCA inputs and results is an important element. Perhaps one or more menus with selection and transfer options would be very helpful to the analyst. As displayed inputs and outputs appeared on the monitor, the menu would be used to transfer selected items to existing folders and files or to create new folders and/or files. An option to transfer selected items to more than one folder and/or file should also be included.

For each selected category, there should be one or more layers of more specific sublevels. An initial suggestion is to select the highest level categories as folder labels. The inputs to the development of a list of categories could begin with the following list:

- blast shock-wave description,
- target description,
- blast/target interface description, and
- blast/target environment description.

The following list consists of some of the suggested files within each folder:

- BOP time histories,
- BOP header files,

- configuration diagrams, and
- descriptive text files.

The folders and files would be generated and developed from three sources—ORCA library folder and file menus, external files, and library folder and file procedures for internal editing. In addition, an index with pointers would provide a relatively simple method with which to search for and access information addressing specific blast/target configurations.

6. Need to Obtain Computer Hard Copy Outputs

It is presently difficult to generate hard copies of selected displayed results of ORCA studies. Therefore, it is recommended that the method of selection and printing of results be simplified. There are so many displayed results connected to any ORCA study that a procedure of at least two steps may be necessary in order to select a desired combination of hard copies. These steps include generating temporary files by selecting from the displays in an ORCA study. These temporary files could be reviewed and changed until the desired combination of displayed results is achieved. A user-options menu could then be used by the user to print the selected results and/or to save them in a permanent file. A similar procedure could be applied to the case studies library previously described.

A hard copy options menu could also be developed with which to generate view graphs, document sections, or selected hard copy pages from ORCA displays or from the case studies library. This menu would be included as one of the hard copy options menus.

Sections 1 and 2 describe the most important of the suggested changes to the blast module of ORCA. They are also the easiest of the suggested changes to implement. The values of n-work in ORCA have been confirmed to be the same as those of INJURY for the same BOP time history data files. The improvements will result in a new calculation and display in ORCA—the likelihood of lethality, which results from the loss of respiratory function (lung injury), for each value of n-work. It will also result in the improved prediction of levels of loss of respiratory function, which is consistent with the corresponding levels in INJURY.

The expanded header will add capabilities to ORCA in processing BOP time history files. It will also make it possible for the user to specify the ambient pressure and the mass of the target.

The suggestions for an expanded analysis, including target orientations options and nearby reflective-surfaces options, are relatively ambitious. Their implementation would require the development of experimental targets, a matrix of experiments, and the development of mathematical models for application in ORCA.

7. Conclusion

The ORCA Modeling System is presently in its final stages of its validation, verification, and accreditation process. At the completion of this process, ORCA will be operational and usable for many types of casualty assessment studies. This report describes suggested improvements for the ORCA Modeling System blast module. Implementation of any or all of these improvements will simplify the procedures and expand the capability of the module.

Some of the recommended changes are not presently applicable. For example, the target orientation options assume instrumentation and analysis applications, which don't presently exist.

If none of the additions and/or changes described in this report are implemented, ORCA will still be an important and useful tool. After a review of the recommendations in this report, the decision to implement none, or some, or all of them will be based on the merit, usefulness, cost, necessary recourses, required time, and future objectives to which ORCA could be applied.

List of Abbreviations, Acronyms, and Symbols

WRAIR	Walter Reed Army Institute of Research
ORCA	Operational Requirement-based Casualty Assessment
INJURY	Blast Effects Injury Computer Software Package
BOP	Blast Over Pressure
n-work	Normalized work
Lth	Lethality
L	Lung injury
P_1	Probability of severe injury
P_2	Probability of moderate injury
P_3	Probability of slight injury
P_4	Probability of trace injury
H	Probability of lethality
H_1	First of two elements of probability of lethality
H_2	Second of two elements of probability of lethality
tanh	Inverse tangent function
exp	Exponential function
kPa	Kilopascal
Pa	Pascal
kg/m^2	Kilograms per meter squared
g/cm^2	Grams per centimeter squared
db	Decibels
lb	Pounds
kg	Kilograms
g	Grams
Psi	Pounds per square inch
mm	millimeters

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