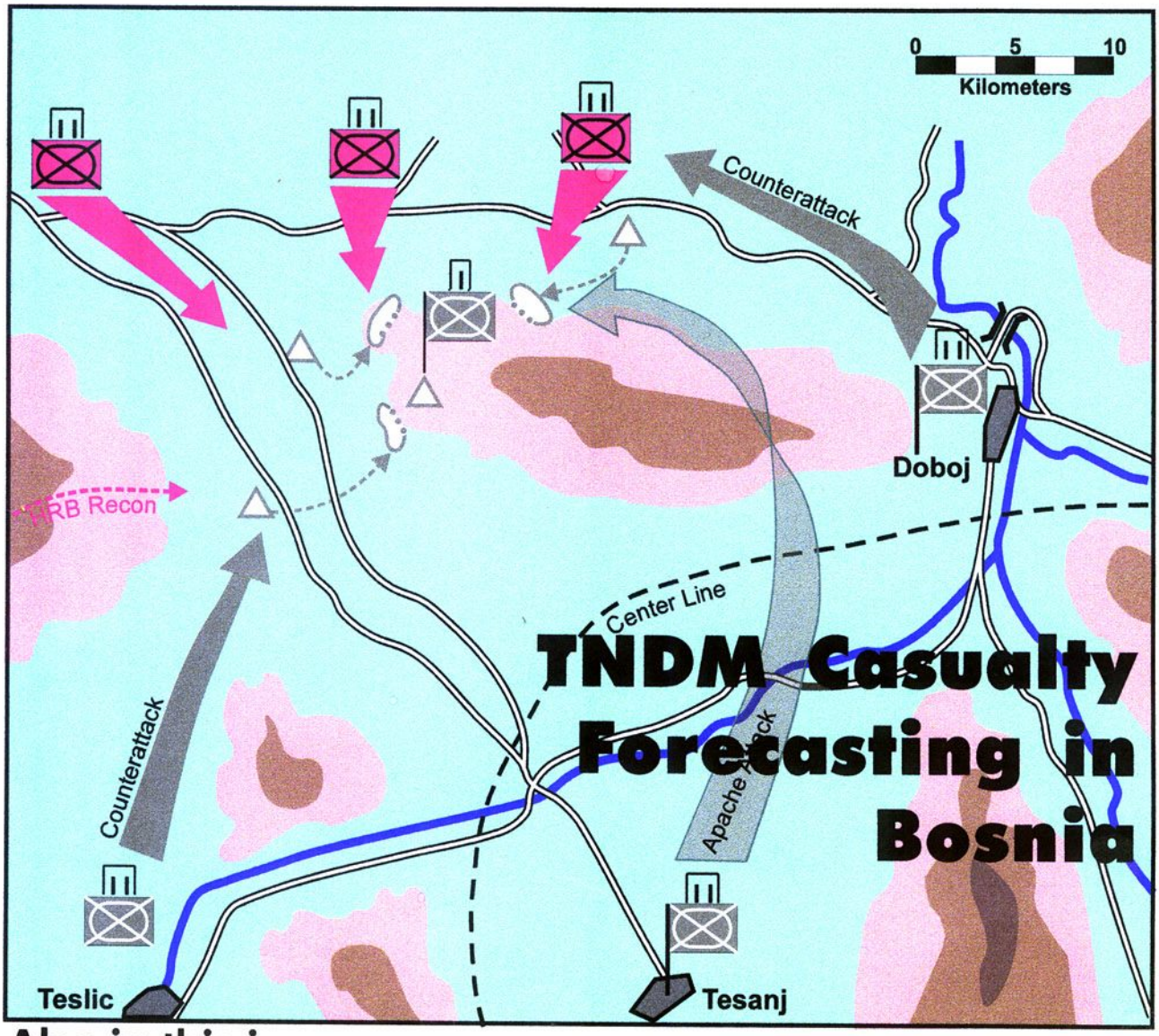
Volume 1, Number 1 August 1996

THE INTERNATIONAL TNDM NEWSLETTER



TNDM Casualty Forecasting in Bosnia

Also in this issue:

- TNDM Revision History
- Simulating Suppression
- How the TNDM Measures Fortifications

INTRODUCTION

The most remarkable achievement of Colonel Trevor Dupuy as a military historian was the development of the Quantified Judgment Model (QJM) and later the Tactical Numerical Deterministic Model (TNDM). Underpinning these models with a vast amount of historical data and with some reasonably quanitifed judgments, Trevor pioneered history's entry into the world of social and behavioral science. He took the study of military history out of the realm of story telling and simplistic interpretation into a realm of systematic and impartial analysis of available recorded data. Over the years, the QJM and the TNDM have proven to be more faithful representations of what happened in the past or what could occur in future contemporary campaigns. Furthermore, historical data provided by The Dupuy Institute (TDI) is now being used to improve and validate two US Army combat simulation models.

Today, in tribute to what Trevor Dupuy pioneered and in an effort to pursue what he wanted to achieve, TDI continues to amass historical data and strives to refine the combat variables which go into the TNDM. This newsletter provides information on these efforts.

All of us at TDI hope that this publication will be of use and interest to you, its readers. Your comments are welcome.

Best wishes.

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From the Editor...

This is the first newsletter written as part of the Support Contract efforts for the TNDM. This newsletter will come out every two months, and will address topics and subject related to the TNDM and to modeling combat. It is a product of The Dupuy Institute, headed by Nicholas Krawciw, Major General, USA, Rtd. General Krawciw replaced Trevor N. Dupuy as president of the Institute after Trevor's unfortunate death in June of 1995. I will be serving as the editor of this newsletter until I can enlist a more qualified editor to take my place. This newsletter is intended to be a permanent part of our support efforts for the TNDM. In the past, Col. Dupuy took care of support activities as a labor of love.

Our support efforts over the next year will include trying to update the documentation on the model and making at least one revision to the model. We are also looking to establish a regular interface with all the users of the model so as to develop a dialog about its usage, problems and future development.

The Tactical Numerical Deterministic Model (TNDM) was created in 1990 and 1991 by Col. Dupuy. It was a new model that stemmed from the original Quantified Judgement Model (QJM) that Trevor had created in the early 1970s and documented in his book *Numbers, Predictions and War*. The Tactical Numerical Deterministic Model now consists of the following:

1. Computerized version 1.85, dated 23 June 1996
2. Manual of Rules and Procedures, dated October 1994
3. User's Guide, dated October 1994
4. Guide to TNDM Versions and Enhancements, dated 1 August 1996 (included in this newsletter)

If anyone who has a current support contract with The Dupuy Institute does not have the most recent editions of these, please contact me and we will forward updated versions to you immediately.

I expect this newsletter to evolve. I am very interested in knowing what you are looking for and need from the TNDM. I hope that I can improve this newsletter to better fulfill your needs, but we do need to know what those needs are.

One of the concepts behind the newsletter is that we are preparing it using much "off the shelf" material. In two of the articles of this issue, we wrote a brief introduction, explaining what the attached material is and where it came from. We then reprinted the material from the referenced study without any further editing. This allows us to minimize the effort to produce the newsletter.

This first issue is much thicker than originally planned. Part of this is due to the extensive multi-page history of the versions of the TNDM that José Perez produced. Since this may be a useful source document for some users, it was included here in its entirety. It is the only list showing the changes to the model since the documentation was last updated in October 1994.

"The Programmer's Cubicle" is intended to be a regular feature, and will address all the software concerns brought up by the people working with the software. José Perez, the column's editor, is intimately familiar with the model, having programmed the original QJM and the TNDM. He is *the* expert on all programming aspects of the model.

Also in this issue we have two papers prepared by David Bongard. The first paper describes how the TNDM was used to support the casualty estimates that we provided for the Joint Chiefs of Staff (JCS) for the Bosnia intervention. Included are the 18 pages from that report that relate to the TNDM. We have purposely left out any other material from the report, including our final estimates. We may release them at a later date.

The second paper is a discussion of how the TNDM is being used to support a study on the suppressive effects of artillery that is being done by JHF and TDI.

I have also added copies of the material that we prepared for a brief study on the effectiveness of mines that we did for the JCS. Prior to this study, I had never looked at how

the defensive factors in the TNDM were developed. This report may be enlightening for the reader.

To make sure that everyone involved in this effort is given their due, I wish to also thank Dr. George Daoust, our Chairman of the Board, for supporting the TNDM and his help with The Dupuy Institute; John Kettelle, Chairman of the Board of Advisors, for his continued contributions and alternative views; our office manager, Yun Zhang; and Jay Karamales, who produced the graphics for this newsletter and the excellent maps from the Bosnia study that are reprinted here.

We expect all issues of the newsletter to be at least 20 pages, and knowing the inherent verbosity of most historians, we expect to regularly exceed that. I am also interested in any letters or contributions you may have for this newsletter. As this is a limited distribution newsletter, it is a good forum in which to develop and publish new ideas.

The next issue will include a description of the use of mines and fortifications at Kursk, including some measurement of their effectiveness; a discussion on the use of Lanchester equations in the TNDM; a discussion of the weather factors used in version 1.84 (The Swedish version); an analysis of Goose Green using TNDM and modern history; and a discussion of the improvements planned for the TNDM.

In future issues we are looking at including an article written by Col. Dupuy that has never been published called "Technology and the Human Factor in War." I have also talked to Dr. James Taylor about producing an article or two. He was the one who developed the application of the Lanchester equations as used in the TNDM. We will also have articles on model validation issues, reflecting "stealth" in TNDM OLIs, our first attempts to create an model of the Air Campaign, and Trevor's original analysis of what would be involved in creating a "Naval QJM." I am also trying to get some people in the operations research community to write up a critique of the TNDM. With RAND's permission, I will be assembling a brief description of the RAND Strategy Assessment System (RSAS). RSAS has a Main Theater Warfare Model that is very similar in concept to the TNDM and uses some factors adopted from the QJM. Finally, I expect to be publishing a series of preliminary papers and having an open discussion on how we can model low intensity operations, contingency operations, and peacekeeping operations. The TNDM is fundamentally designed for division-level force-on-force operations. Making estimations for casualties in peacekeeping operations like Bosnia requires looking at elements other than force-on-force models. We have already started work on some of these other methodologies.

Finally, thanks to Arnold C. Dupuy of NOVA Publications, we have arranged for everyone receiving this newsletter to also receive a copy of *If War Comes...How to Defeat Saddam Hussein*. This book came out 4 days before the start of the Gulf War air campaign in 1991 and provided the lowest public estimates of US losses in the Gulf War. These estimates were developed using the TNDM and is a very interesting book to read after the war. In exchange for his favor, I have included a copy of his current catalog with this mailing.

In the future, I will serve as the point of contact at The Dupuy Institute for all TNDM related questions. If you have any questions, please call me at (703) 356-1151.

The TNDM and Casualty Forecasting for Bosnia Peacekeeping

by Dave Bongard

Late last autumn, The Dupuy Institute (TDI) prepared a brief study about potential casualties in a multinational peacekeeping operation in Bosnia. Part of the scenario TDI developed for the peacekeeping operation involved a relatively large-scale conventional attack by indigenous Bosnian Serb or Bosnian Moslem-Croatian forces against U.S. or NATO forces.

As part of the study, 15 TNDM runs were performed, each comprising 3 sub-elements to reflect the governing scenario. The scenarios varied considerably, on the basis of (1) enemy forces, either a "heavy brigade or a "light" brigade; (2) rolling rugged vs. rolling gentle terrain; (3) substantial, minor, and no surprise; (4) forest vs. "mixed" vs. open vegetation-ground cover.
[Slides 1 to 5]

The scenarios were separated into two groups: ten covering an attack on U.S. IFOR units by a renegade "heavy" (mechanized) brigade, and five dealing with a similar attack by a renegade "light" (non-motorized infantry) brigade, with a small mechanized battalion attached to the brigade. The U.S. forces were the same in all 15 scenarios.
[Slides 6 to 8]
Each scenario comprised a total of six hours of combat action. In the first ten scenarios, an indigenous mechanized brigade attacked a position heldby a U.S. company Task Force. In the first period (15 minutes) the US force received support from a direct-support 24-tube M-109A6 155mm howitzer battalion. The second period, of 45 minutes, saw the arrival of air support in the form of 4 F-16C fighters and an attack helicopter company (7 AH-64D attack and 4 OH-58D observation/reconnaissance helicopters). The third period, 5 hours long, covered the appearance of a "tank-heavy" company-sized reaction force dispatched from brigade headquarters, comprising 14 M-1A2 tanks, an M-2A2 mechanized infantry platoon, a section of 2 self-propelled 120mm mortars, 4 Avenger AD HMMWVs, and 8 "heavy" recon HMMWVs with machineguns and 40mm automatic grenade launchers. That force had 8 F-16C and 4 A-10 aircraft in support, along with a second attack helicopter company.

U.S. forces received a 1.5 Combat Effectiveness Value (CEV), reflecting superior doctrine, training, leadership, and C3I. This could easily be a conservative estimate, considering the evident 3.0-4.0 CEV which Coalition had over the Iraqis during the Kuwait War of January-February 1991.
[Slide 9]

The indigenous mechanized or "heavy" brigade contained about 2,200 personnel. Among its major weapons were 35 T-72 tanks, 40 BMP-2 type IFVs, 40 tracked APCs, 6 self-propelled and 12 towed 122mm howitzers, 6 120mm mortars, 4 SA-9 SAMs, and 16 20mm and 30mm AA guns.
[Slides 10, 12-15]

The other five scenarios concerned an attack by an indigenous infantry brigade against a US strongpoint held by a standard mechanized infantry company task force. The infantry brigade contained roughly 1,800 personnel, and disposed of 16 105mm howitzers, 8 76mm mountain guns, 21 60mm and Slmm mortars, 12 20mm AA guns, and a small mechanized force with 10 T-72 tanks and 30 IFVs and APCs. The event sequence for the "light" brigade attack is slightly different than in the first 10 scenarios.
[Slides 11, 16-18]

The conditions and results of the TNDM runs for the two scenarios are outlined on Slides 19 and 20. Unlike ordinary TNDM outputs, the data presented on those two slides show only personnel deaths, not simply casualties, and further show armored fighting vehicle losses rounded to the nearest whole number. Personnel deaths for the indigenous, or renegade, forces was calculated by dividing total personnel battle casualties by 3.5 (28.6% KIA), meaning that 5 out of 7 personnel casualties were wounded. U.S. personnel deaths were calculated in a similar fashion, dividing total personnel battle casualties by 6 (16.7% KIA), so that 5 casualties in 6 werewounded. The much lower proportion of fatal U.S. battle casualties is due both to widespread employment of kevlar body armor, and to notably superior trauma and shock treatment in forward aid stations, a good helicopter-borne casualty evacuation system, and generally superior medical care. Both of these considerations were based on evaluation of U.S. battle casualties from the Kuwait War and Operation JUST CAUSE in Panama (1989).
[Slides 19, 20]

As the slides do not provide the complete casualty figures, but only battle fatalities (KIA), a condensed version of the original TNDM results is provided here; armor losses were rounded to the nearest whole number.

The scenarios disclosed several interesting results. First, the indigenous forces never did very well. In large measure this was because of the 1.5 CEV provided to U.S. forces, but probably more important was the superior weaponry of U.S. forces (especially their antitank weapons and artillery), along with their airpower assets. Indigenous force advances (not shown on these slides) were, when they occurred at all, quite minor (under 250 meters). Moreover, their personnel losses were generally two to three times as high as those of U.S. units, and the imbalance in armor

Scenario	Surprise	Topography	Cover	Weather	Attacker Personnel	Attacker AFVs	Defender Personnel	Defender AFVs
Heavy 1	Substantial	Gentle	Open	Clear	67	5	39	1
Heavy 2	Substantial	Gentle	Mixed	Clear	30	1	27	1
Heavy 3	Substantial	Rugged	Forest	Clear	50	4	28	1
Heavy 4	Minor	Rugged	Mixed	Lt Snow	30	2	11	0
Heavy 5	None	Gentle	Mixed	Clear	73	3	21	2
Heavy 6	None	Gentle	Mixed	Lt Snow	59	5	34	1
Heavy 7	None	Gentle	Forest	Hvy Snow	31	4	8	0
Heavy 8	None	Rugged	Mixed	Clear	36	2	16	0
Heavy 9	None	Rugged	Forest	Clear	53	4	14	0
Heavy 10	None	Rugged	Forest	Hvy Snow	26	2	7	0
Light 1	Substantial	Rugged	Forest	Clear	72	4	18	0
Light 2	Substantial	Rugged	Forest	Socked In	54	3	16	0
Light 3	Minor	Rugged	Forest	Socked In	44	2	13	0
Light 4	Minor	Gentle	Mixed	Clear	82	4	17	0
Light 5	None	Rugged	Forest	Socked In	43	2	12	0

losses was usually even higher. Finally, snowy weather, along with rugged or more heavily wooded terrain, meant fewer casualties all around, and smaller advances.

The TNDM scenarios, and their analysis, were only part of TDI's analysis of potential casualties for peacekeeping in Bosnia. TDI's analysis also considered casualties from several other sources: those suffered during the entry into Bosnia by road and air, losses to road accidents and landmines during the peacekeeping operation, losses from small-scale terrorist attacks and ambushes, and losses due to harrassing fire by mortars. None of these sources of casualties was capable of being modelled by the TNDM, so TDI employed other methodologies for those elements.

List of relevant slides/pages from final report appearing on the following pages:

1. The Tactical Numerical Deterministic Model (TNDM)
2. General Characteristics of the TNDM
3. Essence of the TNDM
4. Weapon Characteristics for Operational Lethality Index
5. TNDM Outputs
6. Deaths Resulting from Renegade Brigade Attacks (section title slide)
7. Terrain and Road Net (color map)
8. U.S. Brigade Sector and Battalion Areas of Operation (color map)
9. U.S. Company Team Organization and Reinforcement Schedule
   A couple of corrections need to be made on this slide, to wit: the initial mechanized company TF should have only 5 M-113s, not 7; The reinforcing armored company TF should have only 8, not 9, F-16C aircraft in support.
10. Renegade "Heavy" Brigade Organization (Main Combat Elements)
11. Renegade "Light" Brigade Organization (Main Combat Elements)
12. "Heavy" Renegade Brigade ~HRB) Attack — 1
13. "Heavy" Renegade Brigade ~HRB) Attack — 2
14. Attack by Heavy Renegade Brigade on U.S. Company ~color map)
15. IFOR Support to Tusla (color map)
16. "Light" Renegade Brigade (LRB) Attack — 1
17. "Light" Renegade Brigade (LRB) Attack — 2
18. Attack by Light Renegade Brigade on U.S. Company (color map)

The Tactical Numerical Deterministic Model (TNDM)

1. It is both a model and a theory of combat, developed by Trevor N. Dupuy over a period of twenty years.

2. It is a qualified judgement method that:
   - Applies historically-conditioned professional military judgement to an historical engagement database, and
   - Assigns, then refines, standard values for weapons and variables in order to:
     - Compute the relative combat power of opposing forces
     - Explain or predict respective combat losses

3. The next four charts describe the TNDM.

General Characteristics of the TNDM

- A computer-assisted, numerical, validated model of combined-arms combat
- A transparent, deterministic simulation
- A closed system; *all* outcomes reflect effects of *all* factors on *all* inputs
- Human behavioral factors are expressly considered and represented
- An aggregated model, operated usually at the level of division or corps

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Essence of the TNDM

- Basic input: "proving ground" weapons values
- Modified to reflect all identifiable variables
  - Environmental (weather and terrain)
  - Operational (posture and mobility)
  - Behavioral (surprise and effectiveness)
- Combat Power (P) - Wx variables
  - P(Attacker) / P(Defender) > 1: Theoretical Success
  - P(Attacker) / P(Defender) < 1: Theoretical Failure

Weapons Characteristics for Operational Lethality Index

"Proving Ground" Values

- Rate of fire
- Number of potential targets per strike
- Effective range (or muzzle velocity)
- Accuracy
- Reliabilty
- Mobile fighting systems (i.e., tanks and aircraft)
  - Battlefield mobility
  - Radius of action
  - Punishment factor
- Dispersion factor

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TNDM Outputs

Explicit

1. Mission success or failure (PA/PD ratio)
2. Personnel casualties (numbers and rates)
3. Tank losses and recovery (numbers and rates)
4. Artillery and other material losses and recovery
5. Attacker's advance (distance and rate)
6. Effects of suppression: artillery and air support
7. Effects of surprise

Implicit*

1. Human performance in combat
2. Effects of environment
   a. Weather
   b. Terrain
   c. Season/Climate
3. Tactics below those specified in level of aggregation

*Embedded in Outcome

Deaths Resulting From Renegade Brigade Attacks

Illustrative Assumptions:

- During the Winter 1995-1996, armed elements within both Bosnian states who are in opposition to what has happened, form renegade brigades intent on disrupting the peace arrangement by attacking American units.
- One of these brigades is a tank/mechanized unit on the Bosnian Serb side. Due to the terrain, weather, and its training needs, it could not be ready for action before Spring 1996.
- The other, a rebel light infantry brigade or a light partially armored Serb brigade, becomes a threat by mid-Winter.

American forces would have at least an hour's warning of an impending attack by the heavy brigade, but might have only 5 to 15 minutes' warning (virtual surprise) of the attack by one of the light brigades.

(Note: see the sequence of maps on the following slides)

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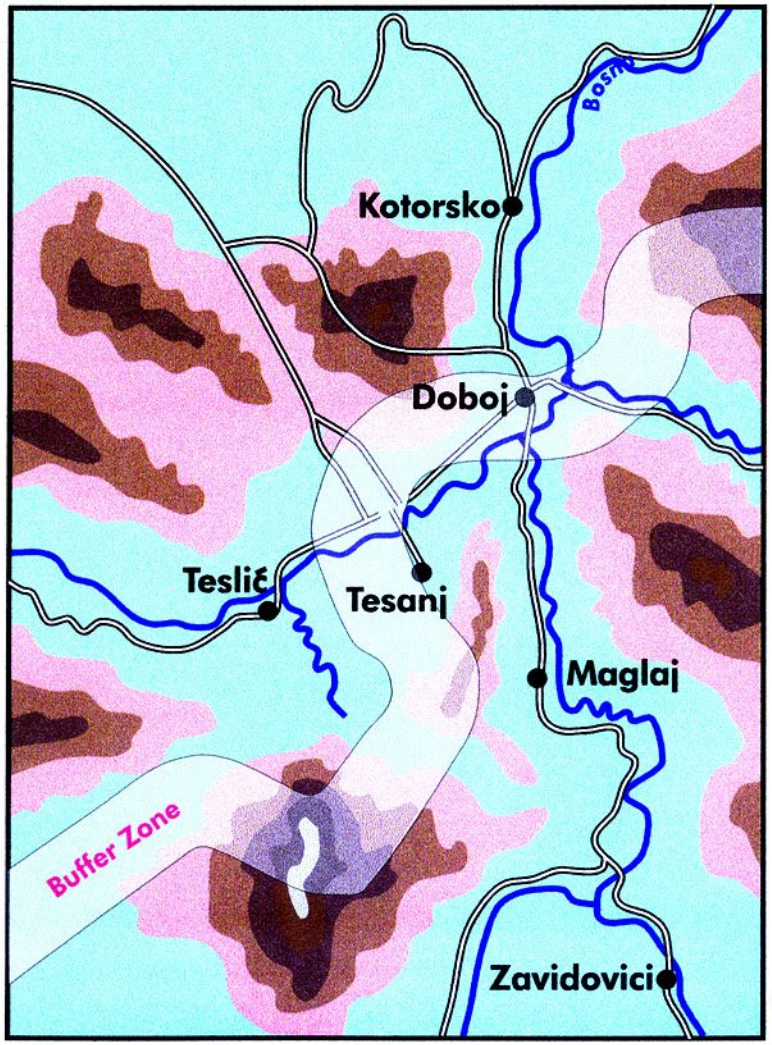
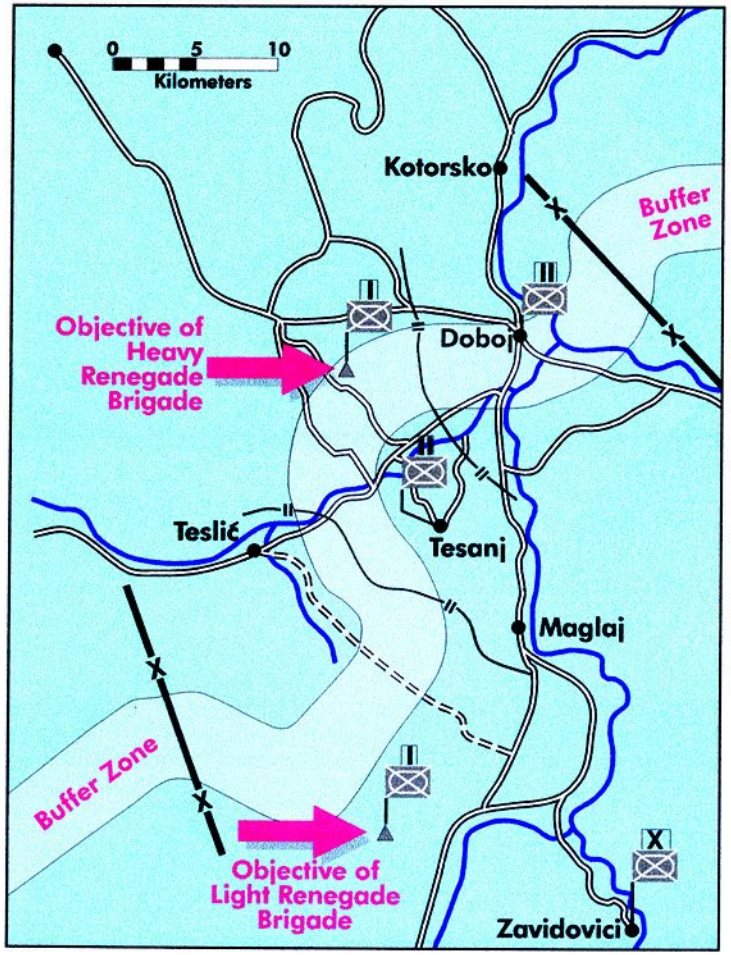
Terrain and Road Net



U.S. Brigade Sector and Battalion Areas of Operation



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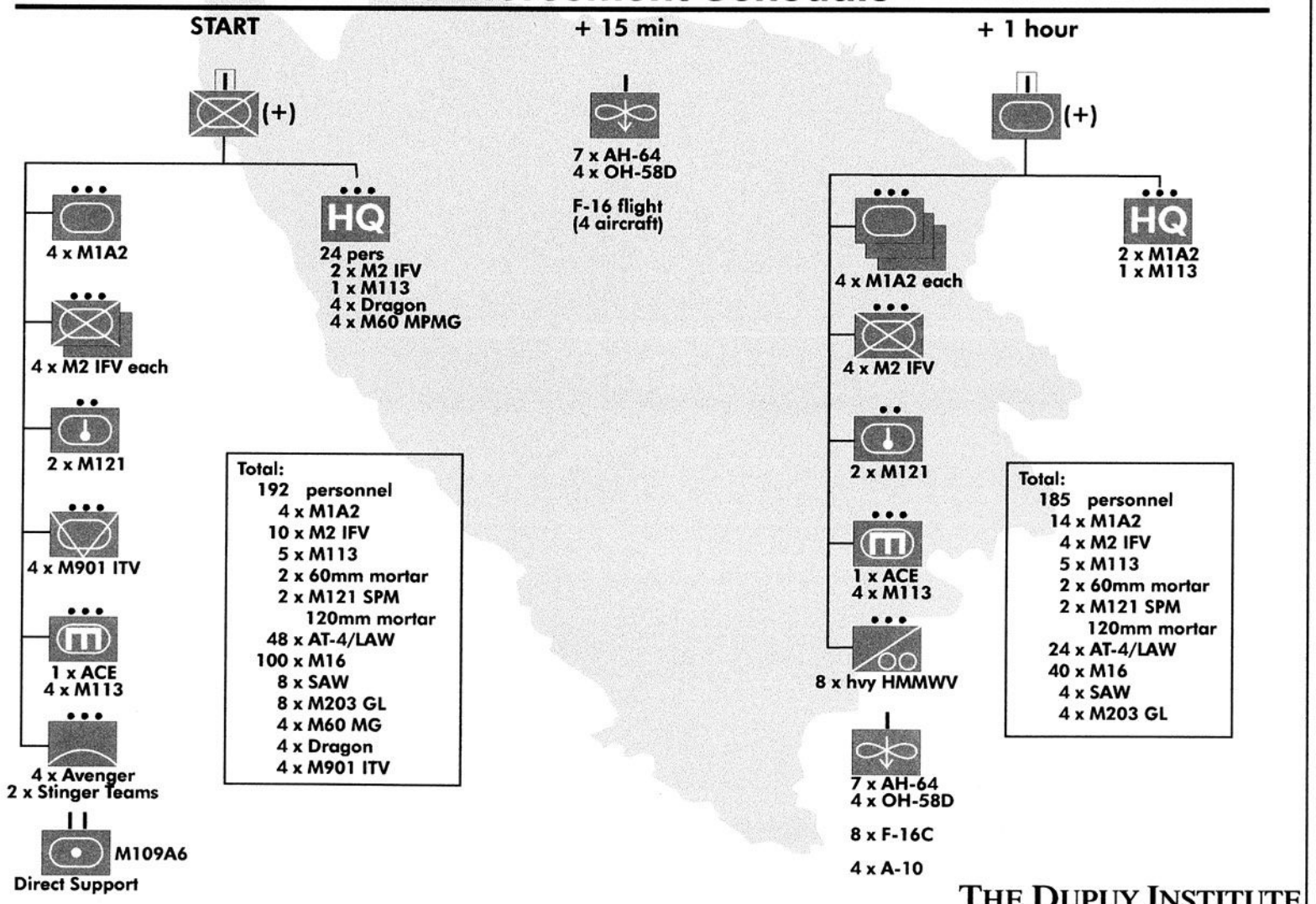
U.S Company Team Organization and Reinforcement Schedule



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Renegade "Heavy" Brigade Organization (Main Combat Elements)

See attached organizational chart for complete organization

1 tank battalion	35 T-72 tanks
2 mechanized infantry battalions	80 BMP/APC infantry fighting vehicles
1 motorized infantry battalion on trucks	
1 mixed artillery battalion	6 self-propelled 122mm howitzers 12 towed 122 mm howitzers
1 mortar battalion	6 120 mm mortars 12 81 mm mortars
1 air defense battalion	8 towed 20 mm AA guns 4 twin 30 mm AA guns 4 triple 20 mm AA guns 4 SA-9 surface-to-air missile launchers
Brigade strength	2,200

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"Heavy" Renegade Brigade (HRB) Attack (1)

Sequence of Events:

(After the "Heavy" Renegade Brigade finishes planning its attack on a US tank/mech infantry company team's position in the buffer zone)

1. HRB starts moving out from hide areas 30 km east of Banja Luka (H-3)
2. US intelligence reports movement (H-2)
3. Units in US brigade sector are alerted (H-1)
4. US company team pulls back from outposts to prearranged fighting positions (H-45 min)
5. US brigade commander formulates and starts executing one of his prearranged battle plans. US battalion commander assumes control of action in the battle area (H-45 min)
6. Reaction forces (air, Army aviation, and 3 company team reaction forces) start moving out (H-30 min)
7. HRB begins artillery fire (H-20 min)

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"Heavy" Renegade Brigade (HRB) Attack (2)

8. US responds with counter-battery fire. US Army aviation begins air defense search and suppression (H-15 min)

9. As leading elements of HRB approach their objective, US artillery and US Army aviation strikes intensify. IFOR air begins systematic devastation of HRB columns (H-15 min)

10. As the battle is joined in front of the US company team's positions, reaction forces begin their attacks into the flanks of enemy columns while US artillery, IFOR air, and US Army aviation continue their attacks (H-Hour)

11. Surviving elements of HRB attempt to break contact and to withdraw (H+15 min)

12. Reaction forces sweep battle area and pursue defeated HRB (H+15 until recalled)

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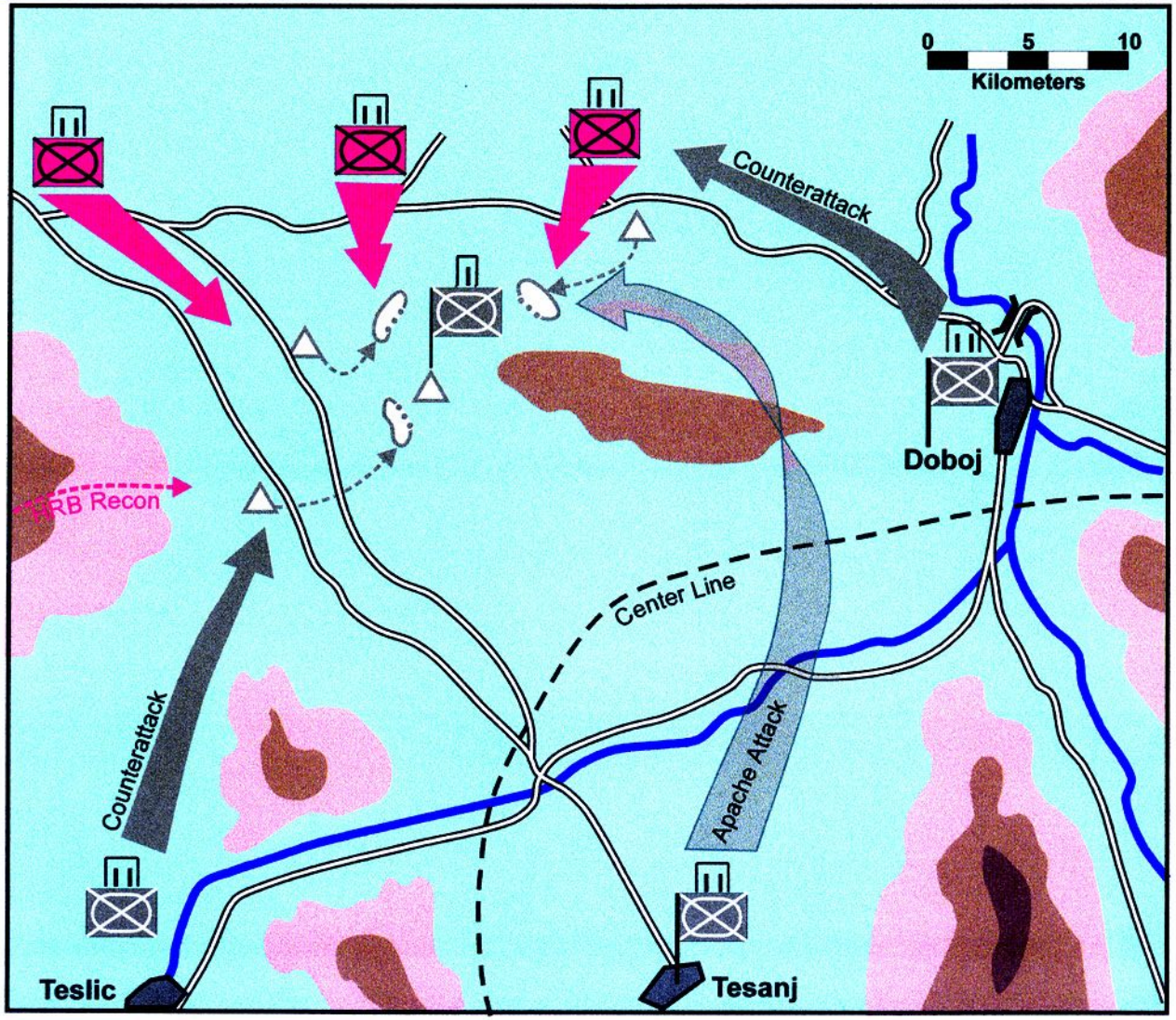
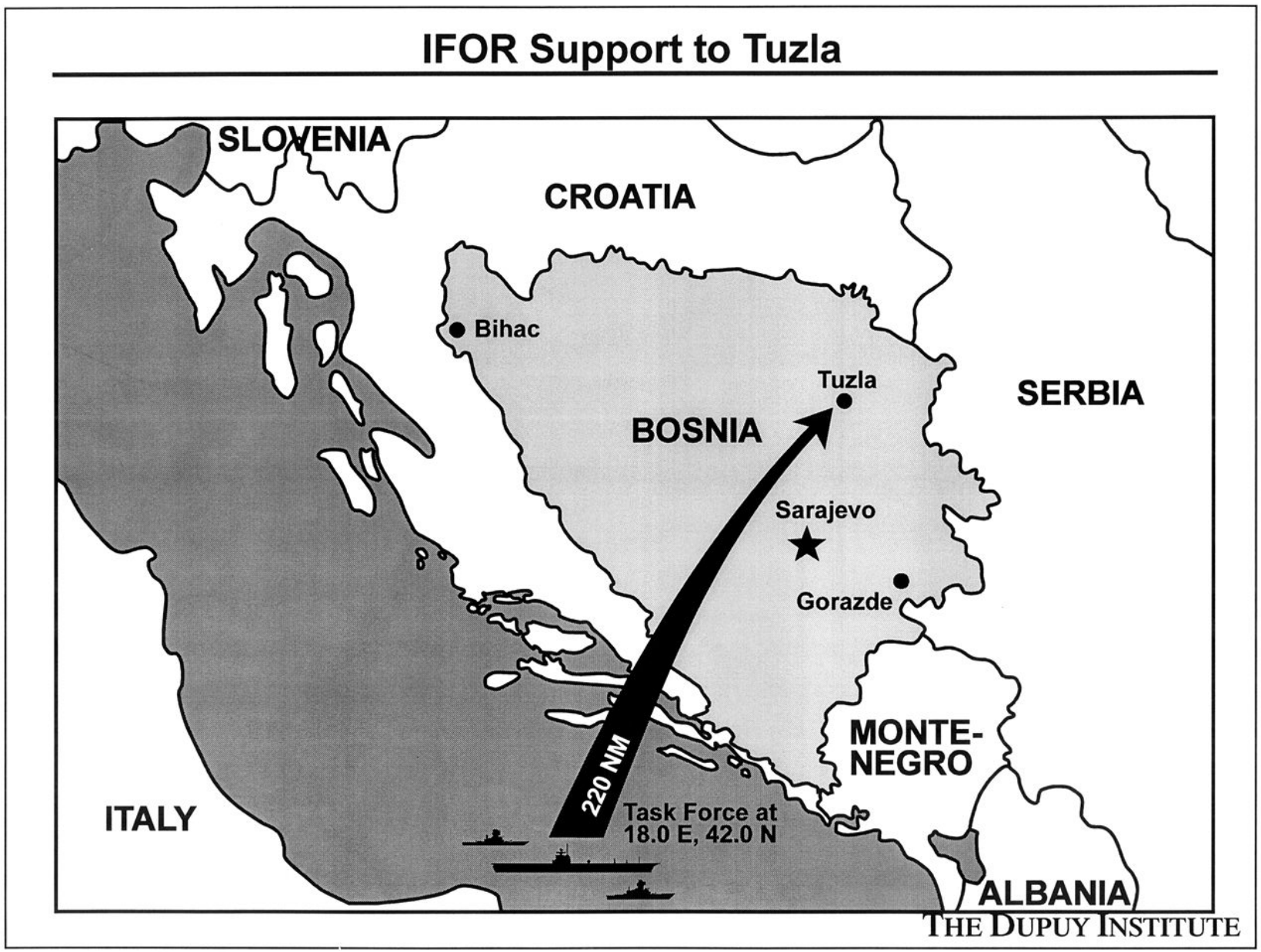
Attack by Heavy Renegade Brigade on U.S. Company




IFOR Support to Tuzla
SLOVENIA
CROATIA
Bihac
Tuzla
SERBIA
BOSNIA
Sarajevo
Gorazde
MONTE-
NEGRO
220 NM
ITALY
Task Force at
18.0 E, 42.0 N
ALBANIA
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Renegade "Light" Brigade Organization (and Main Equipment)

(Possesses 65 miscellaneous trucks and jeeps)

3 infantry battalions (bn)..... (approx. 500 men per bn)	machine guns, assault rifles antitank grenade launchers (RPG-7) shoulder-fired ground-to-air missiles (SA-7) antitank recoilless rifles (82 mm)
1 towed artillery bn.....	16 105 mm howitzers 8 76mm howitzers
1 medium mortar battery.....	12 81 mm mortars 9 60 mm mortars
1 air defense battery.....	4 triple 20 mm AA guns (M-55) 8 20 mm AA guns (M-75)
Brigade strength.....	1,800

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"Light" Renegade Brigade (LRB) Attack (1)

Sequence of Events:
(After extensive reconnaissance of a selected US tank/mechanized company team's positions, operational procedures, and security habits)

1. At midnight of their attack day (H - 5 hours), LRB moves out of its dispersed hide areas.

2. LRB assembles in forward assembly areas by H - 2 hours, occupies nearby battalion attack positions by H - 1 hour. LRB brings mortars and artillery to concealed firing positions.

3. LRB begins attack by direct and indirect (mortars and artillery) fire (H - 15 min)

4. LRB assault elements from two battalions begin attack along two axes of advance (H - 10 min)

5. Defending US company team employs massive direct and indirect fire on attacking forces now fully visible on thermal sights of M-1 tanks and Bradley fighting vehicles.

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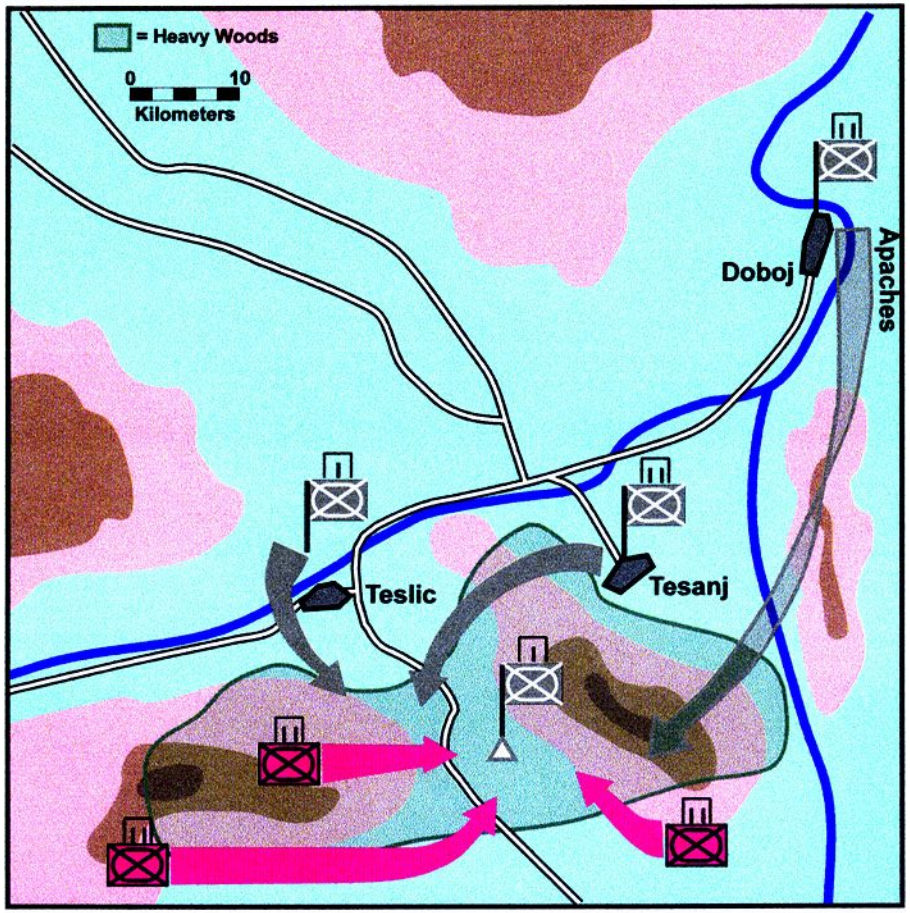
"Light" Renegade Brigade (HRB) Attack (2)

6. US quick reaction elements (Apache attack helicopters) arrive over battle area and engage attacking LRB forces (H - Hour).

7. US battalion and brigade ground reaction elements break up LRB assault by flank attacks (H+15 min to H+30 min). IFOR joins the battle.

8. Pursued by US Army air and ground forces, LRB retreats to concealed positions (H+30 min to H+2 hours).

Attack by Light Renegade Brigade on U.S. Company



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Guide to TNDM Versions and Enhancements

by José Perez

This is not a comprehensive listing of all the TNDM versions. It does include all the versions shipped to clients. It also includes some internal versions used only within The Dupuy Institute or its predecessor, T. N. Dupuy Associates. There are a number of undocumented changes; they do not appear in here.

The versions are listed in order by the release date, not by version number. Some of the version numbers were not recorded, so an arbitrary version number was assigned when the release date was recorded without a version number. These versions are indicated by an asterisk (*).

In general, version numbers used for development are in the form of X.yyy. Versions shipped to a client are usually numbered X.y or X.yy. Only in the case of the customized version update for Sweden was a version in the form X.yyy used.

TNDM version 0.1 Release date: 19 November 1990

Change: Convert TNDM from BASIC into Turbo Pascal.

Notes:

- This version does not have the capability to handle historical engagements. Since this is a desirable feature, it will be added when the more basic features of the model have been fully implemented.
- The method by which a user verifies that an engagement selected for modification/reprint/continuation is the correct one, is clumsy.
- When an engagement is continued, the days printed in the continuation are incorrect. Instead of starting on the day after the engagement ended, the continuation prints "Day 1." The loss calculations are correct but this can cause some confusion.
- If the report frequency is not evenly divisible into the maximum elapsed time of the engagement, the calculated results become incorrect. For example, if the report frequency is every 24 hours, but the engagement is running for only 36 hours, the losses during the last 12 hours are not computed. The results are correct if the report frequency is changed to every 12 hours.
- Only a few help screens have been typed in.
- The software used to display the help screens has not been registered. This causes a reminder message to appear at the top of the screen whenever Help is accessed. There is an alternate software program for displaying the help screens that I plan to explore as soon as possible.
- After using help, it is necessary to press the Esc (Escape) key twice in order to return to the screen being used.
- Because of changes that I made, the entry fields for the CEV and Set-Piece Factors for both the X and Y Forces need to go into an entry screen that is separate from the manual units entry screen. Currently, it is not possible to change the CEV or Set-Piece Factors if the analyst is not entering a unit manually.
- Setting the Weapons Sophistication is not an option.
- When I incorporated the Posture uar (Advance Rate) factor table into the model, I had to make several assumptions in order to make it match Dr. Taylor's adaptation of the Posture Table. I am not entirely sure that my assumptions were correct and it may account for casualty rates being higher than expected.
- This model does not make allowances for differences in certain factors over time. For example, the mobility equation for World War II engagements should produce lower values than 1980-1990 engagements.
- This model does not allow the analyst to enter the depth or width of the front.
- This model does not differentiate between fixed wing and rotary wing aircraft. The loss rates for all aircraft are assumed to be the same.
- Casualties are not broken down by branch (Armor, Infantry, Artillery and Other).
- This model does not adjust the loss rates when there is an extremely large number of tanks to personnel in a force.
- The calculations for non-battle personnel losses have not been included.

TNDM v. 0.2 Release date: 12 December 1990

Addition: Historical Results equations have been added.
Change: The method by which an engagement is selected and verified for modification/re-print/continuation has been changed. If the selected engagement is the correct one, the user only has to press Enter to continue. If it is not correct, the user must press the letter N to select another engagement.
Correction: The calculation of hours elapsed since the engagement has been corrected for continuations.
Change: The report frequency period no longer has to be evenly divisible maximum duration of the engagement. However, this does require additional testing to verify that it is working properly.
Change: The help software has been changed to another product. However, the help software has been implemented only in the Main Menu.
Change: It is no longer necessary to press the Esc key twice in order to return to the screen being used.
Change: I have tentatively moved the data entry fields for the CEV and Set Piece Factors to a screen separate from the manual units entry screen. This CEV may now be redundant because of other changes that were requested.
Addition: Weapons Sophistication is now an option. The user must enter a complete engagement date in order for a correct Weapons Sophistication factor to be assigned.
Addition: The Posture var (Advance Rate) factor table has been recreated to match the factors used in *Numbers, Prediction and Warfare*.
Change: The constant used to calculate the Mobility Constant used in the Mobility Factor equation is set to 20 for ? - 1945, 15 for 1945 - 1960, and 12 for 1960 - present. Weapons Sophistication is now assigned by year. Surprise is adjusted by year also.
Change: The Front Density calculation was not working properly. Until I have determined why the problem was occurring, the user will be able to enter depth information only for historical information. Otherwise, the user will not enter the width of the front or the depth of each force.
Change: Rotary-wing aircraft and fixed-wing aircraft are now in separate weapons categories. This will allow the user to see a higher loss rate for the more vulnerable helicopters than for fixed-wing aircraft.
Change: Casualties are now broken down by branch (Armor, Infantry, Artillery and Other).
Change: The Unbalanced Force Factor is now applied when the ratio of tanks to personnel is extremely high or extremely low.
Change: Calculations for non-battle losses have been included. However, this requires a complete engagement date.
Correction: An error in the Distance calculation was found and corrected.
Change: The default answer to "Do you want to continue this engagement?" was changed to N. The user has to press the letter Y if the engagement is to be continued.
Correction: An error in the Advance Rate calculation was found and corrected.
Change: The unit TO&E was modified to include all infantry weapons in one category. Also, three unnamed categories were added to allow future expansion of the TNDM.
Addition: A Surprise Adjustment factor was added to all surprise factors to reduce the impact of surprise in historical engagements.
Change: The Velocity Attrition Factor was added to the Personnel Loss Rate calculation.
Addition: All Terrain factors, including the Casualty factor, have been added.
Addition: All Weather factors, including the Casualty factor, have been added.
Change: Some modifications were made to the Season/Climate table to correct minor errors. Also, the Season Casualty factor was added.
Addition: The Mission/Posture Armor Attrition Factor was added to the Armor Loss Rate calculation.
Addition: All of the terrain types have been implemented.
Change: The option to increase/decrease Combat Intensity has been replaced with the option to modify the Combat Power, Personnel Loss Rate, Armor Loss Rate, Artillery Loss Rates and Advance Rate. This may make it unnecessary to enter a CEV for both forces.
Change: Today's Date is now a separate entry field from the Engagement Date. The Engagement Date has been left blank for the user to fill in. Since some of the calculations require a correct date, the Engagement Date must be entered.
Change: The X designation has been changed to Attacker and Y has been changed to Defender. However, the Defender retains the capability to attack. This should lay the groundwork for a counterattack model in a future version of the

TNDM.
Change: Coordinates are entered as five-digit numbers with two decimal places.
Change: The Force Mission/Posture options have been put in to one menu. The Static Defense option has been removed. The Mission/Posture tables have been revised to reflect this change.
Change: Main Zone was changed to Main Effort in the TNDM User's Guide.
Change: The description of Delay was changed to "is using delay tactics" in the TNDM User's Guide.
Change: The description of Medium Artillery Fire was changed from 8-inch to 6-inch in the TNDM User's Guide.
Change: The River/Stream Width Menu now appears even if a Shoreline Vulnerability Factor was not selected.
Change: All OLI's/Firepower scores in the Forces Database are now totals rather than averages in each weapon category.
Change: In the TO&E Summary, Forces Database, and Manual Units Entry, "Number of armored, non-fighting vehicles" was changed to "Number of non-armor tracked vehicles."

TNDM v. 0.21 Release date: 4 January 1991

Change: This version is compatible with version 0.2, except, if a Lighting Level of Limited Visibility or Night was used, it will have to be re-entered.
Change: Losses are computed for both the strength levels (number of weapons and vehicles) and the OLI scores in each weapon category. This allows the user to enter OLI scores for Infantry Weapons, Anti-Tank, Artillery, and Aircraft, without entering the number of weapons in each of those categories.
Correction: If more than one unit was assigned to either the attacking or defending force, only the name of the last unit entered/selected was being printed in the report.
Correction: If the TO&E for a force was entered manually, it was not possible to enter the force's trucks, tracked vehicles, organic aircraft and motorcycles.
Correction: There were two errors in the Force Strength Calculations.
Change: Strength levels, instead of OLI scores, were being used.
Correction: The Quantity Factor was not being applied to Armor and Infantry.
Change: The size of the data entry field for Armor OLI in the Forces Database has been increased to hold a maximum value of 9,999,999.99.
Correction: In the Manual Data Entry Screen, the data entry fields for Trucks were incorrectly labeled. The data entry field for APCs, SPs, and non-fighting tracked vehicles was also mislabeled. The label for the data entry field for APCs, SPs, etc. has been changed to "APCs, Self-Propelled Weapons Platforms, Tracked Vehicles".
Change: It appears the data entry field for the CEV in the data entry screen for CEV and Set Piece Factors is redundant. The entry for the Set Piece Factor will be moved to another screen in version 0.3.
Correction: An error in the Velocity Attrition Factor Table was affecting the Personnel Loss Rate.
Correction: An error in the Standard Advance Rates Table was producing abnormally low advance rates when the attacker had a very large P/P ration (greater than 4:1).
Change: The standard armor loss rate has been changed to 6.0 for the attacker and 3.0 for the defender. The Armor Loss Rate originally in the TNDM was producing loss rates that were much too high for both the attacker and the defender once the Force Strength was being calculated properly.
Change: The Day/Night Factors for 24-Hour Period, Night Only, Daylight Only, Mixed Day and Night (Mostly Day), Mixed Day and Night (Mostly Night) and Mixed Day and Night (Half Day) are now being used.
Change: At Arnold Dupuy's request, an OLI Database has now been implemented in the TNDM. This Database is used only for storing OLI scores. It cannot be used to calculate OLIs for weapons.
Change: When adding a unit to the Force Database or updating an existing unit, the user can use the OLI database to calculate the OLI scores for each weapon category. However, this is possible only if the desired weapons' OLIs have already been stored in the OLI Database. To use this feature, the user has to have a complete TO&E for the unit, broken down by the weapon categories used in the TNDM: Armor, Infantry, Anti-Tank, Towed Arty, SP Arty, Air Defense, Fixed-Wing Aircraft and Rotary-Wing Aircraft. When a category is selected, all the weapons in that category are displayed. The user enters the number of weapons in the category such as 25 LAVs and 50 M60A3s, and presses the Escape Key. The computer will display the original and new strengths and OLIs in the category. If the user presses Y, the new values will be assigned to the unit.
Change: The user can now use the OLI Database to enter a force manually for either the attacker or the defender. The procedure for using the OLI Database to create a force is identical to the procedure used to create a unit in the Force

Database.
Addition: A new option, CHANGE ATTACKER'S/DEFENDER'S TO&E, has been added to the Create Attacking/ Defending Force Menu. This option can be used to make manual adjustments to the force's TO&E.
Correction: The problem of inconsistent results when re-running an engagement appears to have been corrected by the changes and corrections in the Armor Loss Rate calculations.
Correction: An error in the calculation of Recovered Aircraft was causing large errors in Force Strength, etc.
Correction: When the attacker does not have sufficient combat power superiority to advance, the attacker's position always printed as 0,0 even if the starting position was not 0,0.

TNDM v. 0.22 Release date: 5 January 1991

Correction: The only difference between this version and version 0.21 is that version 0.22 has been corrected to save and read engagements correctly when running the TNDM on a floppy disk. The Runtime error number 005 should no longer be occurring.

TNDM v. 0.23* Release date: 11 January 1991

Addition: Added code to trap any errors that might occur and display a descriptive error message on the screen.

TNDM v. 0.24* Release date: 3 February 1991

Change: Road Quality/Density is now listed under Environmental factors.
Change: All factors are printed out when a detailed report is requested.
Change: The actual losses for each time period are displayed in the report.
Change: The vehicle numbers and combat systems numbers are rounded to the nearest whole numbers after losses have been subtracted.
Change: After the TNDM software is started, it notifies the user of the default locations for the OLI and Force databases, engagement files, and the Help file. It then asks if the user wants to change these locations.
Change: The CEVq, CEVl, and CEVad results are now calculated for historical engagements.
Change: The layout of the report has been changed.
Change: The listing of the countries used in selecting units from the Force database has been sped up. The pause should now be almost unnoticed.
Change: The user is now asked if he wants a "long report" instead of a "detailed report".
Change: The user is now asked if he wants to "print the report" instead of "Do you want the results on the screen?".
Correction: The last three letters of Horse Cavalry were not displayed in the Force Type Menu.
Change: If one force is in the Holding posture, the other side is automatically set to the Holding posture.
Change: If Weapons Sophistication is set to Unknown for one force, it is automatically set to Unknown for the other side.
Change: The descriptions for Shoreline Vulnerability Distance were changed.
Change: The Clock on Operation in Shoreline Vulnerability was removed.
Change: When the error message prints, it now asks the user to "Notify T. N. Dupuy Associates" instead of TNDM Associates.
Correction: The ISI factor calculation has been updated to match the calculation described in the latest copy of the Rules and Procedures.
Change: The Delete Units option was changed to prevent any of the values from becoming negative.
Correction: The force inventory for continuations was corrected to show the inventory before the engagement was continued. Previously, the inventory displayed by a continuation was the force at the beginning of the engagement.
Correction: If a force is entered manually with only OLI values, the OLI values were being dropped.
Correction: When a unit name is deleted from a force, the last three characters of the name were not always erased from the screen.
Change: The default Maximum duration of an engagement has been changed from 72 hours to 24 hours.
Change: All titles in items such as Road Quality/Density, Force Type, etc. have been changed to uppercase.
Change: In the report, when surprise was selected, the surpriser was described as "A Force" or "D Force". This has been changed to "Attacker Force" or "Defender Force".
Change: Total OLI is now printed in the TNDM report.

Correction: When a unit was selected from the Force Database, the one after it was added to the force.
Change: When the user enters the date of the engagement, he will not be allowed to proceed until he has entered a valid date in the form of 01/01/1991.
Change: When the engagement start time is entered, the user will not be able to continue until a valid starting time has been entered.

TNDM v. 0.3 Release date: 25 March 1991

Addition: The analyst now has the option of disabling the ISI and IDI factors when running an engagement to analyze weapons performance.
Change: The menu used to select units to create a force has been changed to perform in the same manner that the weapons menu performs when a unit is being created.
Addition: The analyst now has the option of entering the number of days the attacker or defender has been in combat immediately prior to the engagement.
Addition: After setting the width of a river/stream, the analyst must indicate whether the river/stream is fordable or unfordable.
Correction: Corrected errors in the strength calculations.
Correction: Corrected the error that occurred when trying to print the TNDM results report.

TNDM 1.0 Release date: 9 April 1991

Correction: In engagements with Surprise, Advance Rate, Vulnerability, Personnel Loss Rate and Armor Loss Rate were calculated incorrectly. This has been fixed.
Correction: A Shoreline factor is listed when this option was not selected.
Correction: Summary of losses showed all values as 0.0.
Correction: Display of attacker personnel strength on the screen is incorrect.
Addition: If a CEV value is entered by the analyst, it is printed in the engagement report.
Addition: The user can now select a fraction of a unit: one-half, 1.3, etc.
Addition: The user can now enter Attacker or Defender CEV.
Addition: Artillery Loss Rates are now included in the engagement report.

TNDM 1.01* Release date: 14 April 1991

Addition: I have also changed the software to calculate the engagement results and then ask if the user wants to print the report. If the answer is N, the results are displayed on the screen, otherwise they are printed.
Correction: The main reason for most of the errors was that the software was expecting a four-digit year in the starting date of the engagement. The software has been changed to require a four-digit year. If an incorrect date is entered, the computer will beep and prevent the user from proceeding until a correct date is entered.
Correction: In reviewing Jim Taylor's approach to the Personnel Loss equation, I discovered that his new table was just the Posture Casualty Factor multiplied by the standard casualty rate of 0.04. I have changed the Posture Casualty Factor table to allow for this.
Addition: The title "INPUT DATA" has been inserted into the Results Report. It will precede the listing of Environmental Variables and Operational Variables.
Correction: The Attacker CEV was being printed in the Combat Power factor list. I have added it to the Operational Variables list in the Results Report.
Change: "ATTACKER'S TO&E" and "DEFENDER'S TO&E" have been changed to "ATTACKER'S ORDER OF BATTLE" and "DEFENDER'S ORDER OF BATTLE". Also, the display of the number of units has been changed to allow three digits behind the decimal point. This will allow the display of unit fractions, such as 0.667.
Correction: The error that was causing the Attacker Personnel to be set to zero (0) whenever the defender's forces

were changed or selected, has been corrected.
Change: In the Mobility and Vulnerability Factors Listings, "W/ SURPRISE" has been changed to "WITH SURPRISE".
Change: The Artillery Loss Rates Listing has been rearranged to group the Towed Factors and the Self-propelled Factors together.
Correction: Correction: The listing of the Attacker and Defender losses has been corrected.
Correction: The Final Inventory Listing has been corrected.

TNDM v. 1.02* Release date: 19 April 1991

Change: The Print option has been changed to ask the user if a pause between pages is required. If the answer is Y, the software will pause after each page is printed and will not print anything else until the Enter key is pressed. This should allow you to print the results on your Canon printer.
Correction: The Engagement/Continuation Selection option was not using the Location Settings to locate engagements and continuations.
Correction: The repetition of countries in the country listing has been corrected.
Change: The Loss Rates in the Results Summary have been changed to percentages.
Correction: The incorrect mobility factor was being printed in the Combat Power Factors Listing when surprise was present.
Correction: The Opposition Factor for P/P ratios between 0.1 and 0.15 was being calculated incorrect.
Change: The method by which an engagement is continued has been changed slightly. When an engagement is continued, the continuation will be saved, but the user will not be asked for a new name at that time. When the Continuation option is selected, the user will not be asked to enter a name for the continuation until after the "Begin Continuation" option is selected. After the name is entered, the user will be asked how many hours the continuation should run.
Change: When an engagement or a continuation of an engagement is run for more than one day, the detailed listing for the second and successive days will contain only those factors that have changed since the previous day.

TNDM v. 1.03* Release date: 21 April 1991

Correction: The Print option has been corrected to avoid feeding a new page through the printer, if the user has asked for the printer to pause after printing each page.
Correction: The adjustment to the Opposition Factor calculation has been corrected so that P/P ratios between the range of 0.1 and 1.0 will be correct. I have not verified the Opposition Factor for P/P ratios greater than 1.0.
Correction: Pam Hilton reported a problem about two weeks ago when I was in McLean. When the location of the engagement files is set to "A:\" and a floppy is not in the A-drive, the TNDM will not run. I have corrected this problem. An error message will now appear at the bottom of the screen asking the user to insert a diskette or to change the location. The Change Locations entry screen will then appear. If a diskette is put into the A-drive, there is no need to change the location of the engagement files.
Change: A minor change was made to the Historical Yes-or-No question. I was unable to duplicate the problem which you experienced, but I hope that this change will solve the problem for you.

TNDM v. 1.04* Release date: 24 April 1991

Change: When Surprise is in effect, Vulnerability With Surprise will be printed in the Combat Power Factors list.
Correction: The Surprise Effect calculation has been corrected.
Correction: Pam Hilton reported that it is possible to create engagements with eight-character names, such as TRYMORES, but it is not possible to modify, reprint or continue them.
Change: Pam suggested changing the colors used when editing the Forces Database and the OLI Database. When a unit is being edited, when the cursor is on Armor OLI for example, the Armor OLI value has the same color as the rest of the screen.
Change: Pam also noted that when an attacking or defending force is being created using the OLI Database, the line reading "Esc=Exit Return=Select ..." is not easy to read on the screen. The area around this line will be cleared and it

will now appear in a box.
Change: The option EXIT has been added to the Create, Modify and Continue Menus. This option will allow the user to exit and return to the Main Menu without saving the engagement.
Change: When Create A New Engagement is run, the second data entry screen will display the percentage of space remaining on the disk where the engagement files are being stored.

TNDM v. 1.05* Release date: 27 April 1991

Correction: Fixed problems in calculating Advance Rate and Distance.
Correction: Fixed the problem of the beginning and ending inventories being identical in a continuation.

TNDM v. 1.06* Release date: 28 May 1991

Correction: The Reinforcement option does appear to be working.
Change: Added more space for the engagement description in the Make New Engagement.
Change: In the Continue Engagement option, gave user the option of entering a new engagement description.
Change: In Modify Engagement, gave the user the option of changing the name or designation of the engagement or its description as in the Continue Engagement option.
Correction: When a fraction of a unit is entered to three decimal places and is later deleted, it is possible to only delete the equivalent of two decimal places.
Addition: Gave user the option of printing a two-page "short report".
Correction: Fatigue Factor calculation was not working.
Correction: Recovery of lost tanks is not being calculated.
Correction: Coordinates are not being calculated properly.
Correction: In small unit engagements without an armored component, got a "divide by zero" error.
Correction: R - R and R/R are not being calculated correctly.
Correction: Rewrote OLI program to fix multitude of errors and user interface.

TNDM v. 1.5 Release date: 20 July 1991

Addition: The Non-Battle Loss Rate will now be printed after the Personnel Factors.
Correction: There was an error in the calculation of Defender Casualties by Branch.
Change: The labels for P/P and P'/P' have been changed from Ratio and P' to P/P Ratio and P'/P' (IMBALANCE) respectively.
Addition: P'/P' (IMBALANCE) and P'/P' (SURPRISE) have been added to the TNDM report. Since Surprise Effect is calculated before P'/P' (SURPRISE) is adjusted when it is greater than 3.0, it is not always possible to verify that the Surprise Effect is correct by using the values displayed in the report.
Change: The label "Order of Battle" has been changed to "Force & Equipment Inventory" in the TNDM report.
Change: The losses detail has been removed from the Short Report. There is a Beginning Inventory and a Final Inventory immediately after the Strength and Power listing.
Change: Most of the changes are visual; all menus now appear in a box.
Change: Also, for those using a color monitor, the colors have been livened up a bit.
Change: The OLI option has been changed to include the calculations of OLIs for single weapons and Mobile Fighting Machines (MFM). Most of the steps involved are identical to those used in the original OLI program except that this version does not ask for a file name; the weapon name should be used to describe the weapon. For example, T-80X would be given the full name of "T-80 125mm with Reactive Armor."
Change: In the calculation of single weapon OLIs, the analyst will be asked the weight of the projectile, missile, mortar, bomb, etc. If the weight is entered, the analyst will then be asked to select the category the weapon fits: small arms, machine gun, tank gun, aircraft gun, bomb, etc. Based on the selected category, its equivalent caliber in millimeters will be calculated. The analyst will have the option of using the calculated caliber or entering another value. If a weight of zero is entered, the analyst will have to supply the caliber.
Change: In the calculation of single weapon OLIs, the analyst will be given a list of weapon categories and their respective accuracies. If the selected accuracy is not correct, the analyst will be given the option to enter his own value.
Change: In the calculation of single weapon OLIs, the Burst Area will be calculated from the caliber for calibers of 15mm or greater. This version allows the analyst to change the Burst Area.
Change: In the calculation of MFM OLIs, the analyst will not have to enter the Vehicle Punishment Factor. This

factor will be calculated based on the MFM's weight.
Change: In the calculation of MFM OLIs, the analyst will first have to enter the factor for each of the primary, secondary, etc. weapons. Presently, these weapons should all be entered in the category of Infantry Weapons. Once these weapons are entered, the analyst will select the MFM's weapons from a list of weapons. This should it make it easier to calculate OLIs for aircraft with different bomb loads and configurations. When the report for an MFM is printed/displayed, the factors for the primary, secondary, etc. weapons will not be printed. The analyst will have to print the report for that particular weapon if the factors are desired.
Change: If a weapon's OLI has already been calculated and stored, the Report option in the OLI Menu can be used to display or print an individual weapon's factors and OLI. The Report option can also be used to print a summary report of all Weapons' OLIs in the OLI Database.
Addition: Included on the diskette is a file called OLI.RPT. This file is used by the OLI Report option to print/display a summary report of the Weapons' OLI. It can be used with any version of the TNDM.
Addition: I have created a program called OldToNew. This program is designed to convert the old OLI database for use with TNDM version 1.5. Before converting the old OLI database, it will rename it from OLI.DBF to OLDOLI.DBF.

TNDM v. 1.51* Release date: 1 August 1991

Correction: TNDM.INI no longer has to be deleted after the TNDM is copied from a hard disk to a floppy or vice versa.
Correction: Some minor problems in the OLI portion of the software were fixed.
Change: Made new version of OLDTONEW.EXE to update TNDM and OLI databases.

TNDM v. 1.52* Release date: 11 August 1991

Correction: Reinforcements. After reinforcements were added to a continuation, the reinforcements were not being included in the force inventory.
Correction: Division by Zero Error. All of the equations have been reviewed and changed to prevent any equation with a division operation from dividing by zero.
Change: The Weapons Sophistication Menu has been modified to show Israeli and Arab rather than Arab and Arab.

TNDM v. 1.53* Release date: 13 August 1991

Correction: Addition of reinforcements to the defender in a continuation. The OLIs of the reinforcing units were added correctly, but the equipment amounts (armor, infantry, artillery, etc.) were being added to the attacker's equipment. In other words, if the defender was given reinforcements of 10 tanks with a total OLI of 9000, the defender's armor OLI increased by 9000, but the defender's tanks did not increase.

TNDM v. 1.6 Release date: 22 September 1991

Change: Added Visibility, Low-light Capability, Power Traverse, Stabilization, Range Finding and Ballistic Computer factors for the calculation of armored fighting vehicles.
Correction: The Strength-Size Factor and Opposition Factor calculations in the TNDM have been corrected.
Change: The TNDM report has been changed to print the Vulnerability and Mobility Surprise factors.
Change: The "Set Options" selection in the Main Menu now brings up a menu with the options of Directory Locations, Color Settings and Reindex Databases.
Change: Updated OLDTONEW.EXE to convert earlier versions of OLI database to the 1.6 version.

TNDM v. 1.61* Release date: 7 November 1991

Change: Make OLI data entry more user-friendly.
Correction: User was not able to enter a Muzzle Velocity for a weapon.
Change: Option 8, Set Options, will now display another menu that has an option called "Color Settings". This option allows anyone to change the color setting of each "color" used in TNDM.

TNDM v. 1.62* Release date: 15 December 1991

Change: Modified the equation for calculating the Mobility Modifier. It now has a slightly higher value than it previously did.

TNDM v. 1.63* Release date: 12 January 1992

Change: The Air OLI coefficient in the Mobility calculation has been changed to 15.
Correction: Item 5 in the Day/Night Menu was incorrectly labeled "Mixed Day and Night, Half Day." It should have been labeled "Mixed Day and Night, Mostly Night." If item 5 was selected, the value for Mostly Night would have been used.
Correction: Item 3 in the Season/Climate Menu was incorrectly labeled "Tropical." It should have been "Semi-Tropical".
Correction: Also, item 4, "Tropical", was not listed as an option. If item 3 was selected, the values for Semi-Tropical would have been used; it was not possible for the Tropical values to be used because of this error.

TNDM v. 1.64* Release date: 22 January 1992

Change: The Air and Artillery OLI coefficients in the Mobility calculation have been changed to 20.
Change: Also, I have made some changes to the help file (TNDM.HLP) and the database conversion utility (OLDTONEW.EXE, OLDTONEW.PAS).

TNDM v. 1.65* Release date: 17 February 1992

Correction: Updated the Aircraft Loss equation.
Correction: Corrected Penetration Factor equation.
Correction: Modified the OLI calculations for missiles to allow a Minimum Arming Range as small as 1 meter.
Change: Changed the Penetration Factor equation to calculate values for penetrations of less than 500 mm.

TNDM v. 1.66* Release date: 5 May 1992

Change: The headings, field labels, etc. have all been set to change to display Personnel, Infantry, Artillery and Horses whenever the year of the engagement is 1900 or earlier.
Addition: When calculating the OLI for an armored fighting vehicle, reduce speed by 10% and mobility by 10% when the vehicle weighs more than 60 tons.

TNDM v. 1.67* Release date: 12 May 1992

Change: Advance rate is now calculated as: Advance Rate = 1.6 * Sr * me * rm * hm * RQ * RD * St * uar * dn * Su * ff
Change: The casualty rate is now calculated as: Casualty Rate = CN * N * uc * DEVd * Su * op * tz * rc * hc * zc * vl * ShD * dn * ff
Change: The standard tank loss rate is now calculated as: a) for the attacker, 4.0 * the attacker's personnel casualty rate; and b) for the defender, 1.5 * the defender's personnel casualty rate.

TNDM v. 1.54 Release date: 13 August 1992

When this version was released for internal evaluation, I referred to the documentation for version 1.53 and it was

mislabeled as version 1.54. It probably should have been labeled as version 1.68. To maintain consistency, the numbering sequence for follow-on versions uses 1.54 as the starting basis.

Change/ Correction: It has a number of problems, but all the corrections and changes to the OLI calculations have been made. For the purposes of adding/updating weapon OLIs, it should run without any problems.
Note: If you wish to run an engagement, do not attempt to use any of the Manual Units options when creating a force. I am in the process of revising these options and none of the changes appear to work reliably at this time.
Additions: As a result of suggestions and requests made by KIDA (Korean Institute for Defense Analyses), some options have been added to several menus and menus have been added to the OLI section.

TNDM v. 1.541* Release date: 28 August 1992

Change: Change the x, y coordinates to hold 4-digit numbers.
Change: When creating an engagement, make it possible to backup to a previous menu.
Addition: Add North Korea and South Korea to the Weapons Sophistication Menus.:
Correction: Fix PageUp and PageDown when creating a unit manually and using the OLI database.
Change: When creating or updating a unit's OLIs, save the original OLI value and give analyst the option of adding the new OLI to the original OLI or replacing the old OLI.
Change: When creating a unit, save the Table of Equipment for each category, but only in the Force Menu.
Addition: When creating an engagement, if a unit is created manually, give the analyst the option of saving it into the force database.
Addition: Add the option to save an engagement when creating an engagement.
Correction: When an engagement runs for 48 hours, why don't the results for second 24 hour period print?
Change: Why are there several weapons with the same name, such as 81mm mortars, that have different OLIs? Display the Country name to help distinguish weapons with similar names but different OLIs.
Change: In the OLI calculation, use the Weight of Bomb/Warhead only for bombs and rocket/missile warheads.
Correction: The Rate of Fire calculation is incorrect.
Change: Change ER in the OLI Rate of Fire tables to display as "Estimated Range."
Change: Make it possible to backup to a previous menu when entering a weapon's factors.
Change: Change the default value for the Rate of Fire Multiplier to 1.0.
Change: Use the Rules of Thumb Table only when cyclic rate of fire is used.
Addition: When creating an MFM, obtain the rate of fire for the primary weapon from the OLI database. Allow the analyst to override this value.
Change: In the Force menu, PageUp/PageDown are too slow when moving through the weapons list for any weapon category.
Addition: Should the user forget to select any units for an engagement, either prompt the user for attacker/defender units or avoid "divide by zero" errors when dividing by zero personnel.
Correction: Correct the error that occurs when non-standard date formats are used. User should be able to use any date format regardless of how computer is set up. Not sure that it works properly.
Addition: Add an Exit/Abort option to the OLI menus.
Correction: Use the Rate of Fire multiplier only for automatic weapons in the OLI calculation.
Correction: For the Rate of Fire Multiplier, use the table on page C-14 of the Rules and Procedures Manual.
Change: For calibers of less than 15 mm, calculate the burst area.

TNDM v. 1.542* Release date: 21 September 1992

Correction: A number of errors in the TNDM software were discovered in the process of updating the User's Manual

TNDM v. 1.543* Release date: 7 November 1992

Correction: Reinforcements are now added in before the results for an engagement continuation are calculated.
Change: The OLI Weapons' Summary Report has been modified to print the weapon type and nation.
Change: The Screen Display of reports has been modified. The changes are cosmetic and do not affect its operation.

TNDM v. 1.544* Release date: 17 November 1992

Change: "CEVq" was changed to "CEVt".
Change: The Combat Power Factors, Attrition Rate Factors, etc. are now printed between the Historical Factors and the Units List.
Correction: CEVl is now calculated as the square root of $Casualties_A / (0.01 * Personnel_D)$
Change: R/R was being printed as P"/P". This has been changed to R"/R" and has been moved after Historical Results.
Correction: Incorrect P/P. This has been corrected and the calculated P/P matches the results which you obtained manually.
Correction: When an engagement is continued, the final inventory was not being saved.

TNDM v. 1.545* Release date: 21 January 1993

Change: Modified menu system to allow analyst to translate menu options, help, etc. with affecting calculations.

TNDM v. 1.55* Release date: 14 March 1993

Correction: If a new unit is created using the OLI database, all of the OLI scores of weapons in each category are lumped together and saved into the category.

TNDM v. 1.591* Release date: 1 August 1993

This version of the TNDM was used to evaluate changes in the OLI calculations for Armored Fighting Vehicles in the TNDM software. A number of changes were made to follow-on versions. One set of changes included making it possible for the analyst to modify factors that are normally not user-accessible. The bulk of the analysis and evaluation was performed by Chip Sayers.

Change: Battlefield Mobility Factor = 0.035 * SQRT[(Horsepower/Weight) * Speed / Ground Pressure], where SQRT = square root of
Change: Vehicle Punishment Factor = Weight / (2 * Height * Length)
Change: Radius Factor = 0.1 * Radius
Change: Vehicle Supply Factor = SQRT[6 * Load / ((6 * Load) + Firing Rate of Primary Weapon)], where SQRT = square root of
Change: Both the Battlefield Mobility Multiplier (0.035) and the Radius Factor Multiplier (0.1) can be changed when a weapon's OLI is calculated. Please note the Radius Multiplier for other weapons has been given a value of 0.14.
Addition: All of the new factors (Height, Length, Ground Pressure and Horsepower) can be entered in the Weight option of Armored Vehicles. Height, Length and Ground Pressure must be values between 0.001 and 100.0; Horsepower must be between 0.001 and 10,000.
Correction: In a recent letter, Trevor mentioned that Dave Bongard had encountered an error in the Vehicle Punishment Factor (VPF): all vehicles were being given a VPF of 1.0.
Addition: You will note that one of the changes in this version is the appearance of a Comment box on the OLI screen. If you wish to enter a comment for a weapon, select the Comment option. When the Comment box appears, enter your comments and press the Control-End keys. Press the F1 key to get an explanation of the Comment editing commands.
Change: When entering a new weapon, set all the applicable factors to a default value. This will allow the analyst to skip items that are rarely used, such as the Naval Gunfire Factor.
Addition: Add the ability to create a new weapon by copying the OLI factors of an existing weapon into a new weapon and then modifying them to fit the new weapon. This would be useful for entering weapons that are updated models or

variations on older weapons.
Addition: Add the ability to add new weapons to an OLI database by copying them to a floppy, taking the floppy to another computer and then adding the new weapons from a floppy.
Change: Change View to list all factors in all weapons.
Change: On Armored Fighting Vehicles, allow the selection of Reactive Armor as either an add-on to the existing armor type or as the only armor type.
Change: When using the Search option, make it go to the top automatically if last record is reached.
Change: When entering MFM Components, do not ask if the weapon is an MFM Component twice.
Change: Attacker Mission. Remove the question "Is this an All-out Attack?". Change Main Effort to All-out Attack.

TNDM v. 1.551* Release date: 16 August 1993

Correction: Dave Bongard reported getting an "Invalid floating point" error message. The error message "Invalid floating point operation" usually means a calculation in an equation is generating a number too large for the computer to hold. The only solution was to break up the Combat Strength calculations into several steps, one for each of the weapon categories (Armor, Infantry, Anti-tank, etc.).
Correction: User is unable to enter a starting time later than 0959 when creating an engagement.
Correction: Found that if the defender in a historical engagement was given a negative advance (for example, if the attacker advanced 20 kilometers, the defender advanced -20 kilometers), the Spatial Effect equation caused the "Invalid floating point operation" message to appear. The Spatial Effect equation had to be re-written to ignore negative numbers when using the square root operation.

TNDM v. 1.552* Release date: 20 August 1993

Correction: Dave Bongard reported getting error 215 (Arithmetic overflow error) when trying to print an engagement report. If the problem re-occurs, there is a work-around solution. When the Print options appear on the screen (Screen, Printer, File), select File. Then enter a file name to save the engagement report, such as ANTIETAM.RPT. To print the report, exit from TNDM and then enter the command: TYPE ANTIETAM.RPT >LPT1: This will cause the contents of the file ANTIETAM.RPT to be printed.
Note: Unable to recreate the problem encountered when entering fractional Mission Accomplishment scores.

TNDM v. 1.57 Release date: 11 October 1993

This version was customized for National Defence Research Establishment of Sweden. The most current version is 1.571, but I was unable to find a record of the changes/corrections made for 1.571.

Addition: Add three (3) weather conditions: Sunshine, deep snow; Overcast, deep snow; and Blizzard, deep snow. In other versions of the TNDM, when calculating the Non-Battle Losses, I have considered "Wet, Heavy, Temperate" weather to indicate tropical conditions. This is the only "tropical" condition remaining in the Swedish version of the TNDM. Because they asked to replace the "Wet, Heavy, ..." weather conditions with variations on "Heavy Snow" and remove any dealing with tropical conditions, I do not know if this is still appropriate. However, it will remain in their version of the TNDM unless you or they indicate otherwise.

TNDM v. 1.592* 30 November 1993

Again, this is the version series that Chip Sayers was using to evaluate changes to the OLI calculations for Armored Fighting Vehicles. He expanded his work to include aircraft.

Change: Change "Range" to "Radius" for aircraft.
Change: Make the Aircraft Attack Factor a value entered by the analyst, rather than calculating it from the air speed.
Change: The Aircraft Vulnerability Factor should be a value entered by the analyst.
Correction: For helicopters, calculate the Radius of Action Factor as 0.0656 x Square Root of the radius.
Change: For vehicles, calculate the Radius of Action Factor as 0.14 x Square Root of the range.
Change: For fixed-wing aircraft, calculate the Radius of Action Factor as the Square Root of (0.0656 x the radius).
Change: For armored fighting vehicles, give the analyst the option of applying the Square Root to the Battlefield Mobility Factor, Radius of Action Factor, Vehicle Protection/Punishment Factor and the Vehicle Supply Factor. Please note that Vehicle Supply Factor is the result of a Square Root operation.
Change: For armored fighting vehicles, give the analyst the option of changing the modifiers used to calculate the Battlefield Mobility Factor, Radius of Action Factor, Vehicle Protection/Punishment Factor and Vehicle Supply Factor.
Change: To change the number of rounds/bombs/rockets/etc. carried by an aircraft, edit the list of weapons mounted on the aircraft. The right-hand column contains the number of rounds, etc. for each weapon. Changing that number will change the weapon's OLI.
Note: To enter a comment about a weapon, select the comment option on the menu. Type your comments in the box that appears on the screen. When you are done, press the Ctrl-End or Ctrl-W keys to save your comment. If you do not want to save the comment, press the Escape key. If you want additional information about how to use the comment box, press the F1 key when the comment box appears on the screen.
Change: Make it possible to change the modifier for the Aircraft Radius of Action Factor.

TNDM v. 1.593* Release date: 31 January 1994

Change: Modified the Vehicle Supply Factor calculation to apply the square root operation only when selected.
Addition: Added a multiplier for the Vehicle Punishment/Protection Factor.
Change: Modified the Radius of Action Factor so that changes to it will "hold" until it is changed again. Please note that the value of the Radius of Action Factor is not the same for Armored Fighting Vehicles and Aircraft; you will have to make sure that the value is correct when calculating the OLI for an Aircraft.
Change: The Visibility Factor now defaults to 0.9.
Change: The Vehicle Punishment/Protection Factor has been changed to allow the use of a multiplier.
Change: If the Armor Type is Super Hard, the Mobility and Speed values will be left as is. Previously, these values were reduced by 10% whenever Super Hard armor was selected.

TNDM v. 1.594* Release date: 11 April 1994

Change: The second multiplication of the Armor Type has been removed.
Change: Disabled error checking because of a problem reported by Chip Sayers. I have been unable to duplicate the problem that he experienced with the T-80 MBT with 125mm gun; it may be related to some error checking in the software.

TNDM v. 1.595* Release date: 12 June 1994

Addition: The new factors have been labeled as "Morale." Morale is in the Rate Factors Menu and is applied to the Combat Power calculation in the same manner as the CEV.

TNDM v. 1.81 Release date: 17 August 1994

The last version update sent to Chip Sayers was 1.8. This was in the series used to evaluate changes to the OLI calculations. I was unable to find any documentation that identified when version 1.8 was released. Version 1.81 merges the

changes made by Chip Sayers with the mainstream version of the TNDM.

Change: The lower limit for Rate of Advance modifier has been changed from 0.5 to 0.1
Correction: The software has been corrected to allow the times throughout the whole 24-hour clock.
Change: For mobile fighting machines, the listing of the weapons mounted on the MFM has been improved so that the weapons do not have to be re-selected each time that an MFM's weapons are changed.
Change: Armor OLI calculations have been modified to include horsepower, ground pressure, height and length as factors.
Addition: Comments about each weapon can now be entered. The command for saving a comment is CTRL-W: press the Control key, hold it down and then press the W key. To get a description of the other functions that can be used while editing a comment, press the F1 key while editing a comment.

TNDM v. 1.82* Release date: 23 October 1994

This version is probably numbered correctly, but the documentation did not verify it.

Correction: Fixed the problem that Dave Bongard found in the printouts of engagements. The label for Anti-Air Defense was in the wrong place; it was appearing where Towed Artillery should have been and the SP Artillery label was appearing where Anti-Air Defense should have been.
Change: The Radius of Action equation used for Armored Fighting Vehicles (AFV) is the same one used for other Mobile Fighting Machines (MFM). The changes that were made to the Radius of Action equation affects all MFMs.

TNDM v. 1.83* Release date: 31 December 1994

This version is probably numbered correctly, but the documentation did not verify it.

Correction: Division by zero error when running an OLI report.
Correction: In the OLI menu, nothing happened when Previous was selected.
Correction: In the OLI menu, nothing happened when Search was selected.
Correction: In the OLI menu, Clean seems to run forever.
Correction: In the Force menu, nothing happens when Report is selected.
Correction: In the Force menu, nothing happens when Next is selected.
Correction: In the Force menu, nothing happens when Previous is selected.
Correction: In the Force Menu, Clean seems to run forever.

TNDM v. 1.831* Release date: 20 January 1995

Correction: The appearance of "4 =" before Shoreline Vulnerability is an error that I forgot to correct earlier.
Correction: The starting point in the report indicates the original starting point in the beginning engagement, not the starting point for the current engagement. I have corrected this to show the starting position for the continuation after the original starting position..
Changed: Prior Days of Combat has been modified to included Elapsed Time. Elapsed Time is hours of combat that occurred before the continuation. Prior Days of Combat is days of combat that occurred before the first engagement.
Correction: The reason that Location and Total Distance Advanced on page 3 did not match the start location on page 1 is that start location indicates the starting position for the first engagement. The correction made to show the starting point of the continuation corrects this problem.
Change: The Results Summary printed at the beginning of the report is only for the first day. There is currently no way of calculating a Results Summary for the entire engagement because results are calculated for each 24-hour period. The report has been modified to print a Results Summary for each period of combat.

TNDM v. 1.832* Release date: 1 February 1995

Correction: T. N. Dupuy reported an error that occurred when trying to run an engagement which was created with an

carlier version of the TNDM.

TNDM v. 1.84 Release date: 23 June 1996

Unable to modify or re-print an engagement after it has been saved. Fixed
Delete all of the files ending in .IND
Anti-tank factor is not being calculated correctly. Fixed
Modified calculation to limit IGI to the range of 1.0 - 2.5
Mobility factor is not being calculated correctly. Needs additional research.
Equation in the software is not the same as that used to calculate the results manually. See #1 below.
Vulnerability factor is not being calculated correctly. Needs additional research
Equation in the software is not the same as that used to calculate the results manually. See #2 below.
Order of weapon types in engagement report is incorrect. Fixed; this problem was fixed in version 1.82.
When entering manual units, program tracks weapons entered, but always reports total score as 0. When user presses ESC to exit, the system asks "Do you want to add this to your previous score?" User assumes Y, resulting in doubling/ tripling/etc of score. Fixed.
Removed the question "Do you want to add this to your previous score?" It is assumed that user will want to replace the existing OLI score for this weapon type.
Editing of manual units has been modified to allow the user to modify weapon counts, remove weapons or add other weapons.
When entering manual units, program does not clear buffer even if a new unit is added. Fixed.
When editing manual units, values in the summary first screen do not change when inventory is modified, even if inventory is changed manually from the menu. Fixed.
Values in factor tables do not always match factors listed in printed. Example: Terrain, Rugged Bare has an RM value of 0.5, but 0.6 is in the printout. Requires additional research.
Comparison of terrain table in software shows that it has more terrain types that in the February 1991 Rules & Procedures Manual. Factor values are also different. See #3 below.
Range check error #202 at 0032:81B2, 002F:5AAF, and 002F:5B1F. Unable to duplicate; requires additional testing.
Long Report does not always print the Attacker and Defender losses near the end of the report. Need an example to fix the problem.
When entering units from the Force database, if user adds one or more units, then pages up or down and returns to the original unit list screen, the numbers of the units are too far to the left. Fixed.

1. The Mobility equation currently in the TNDM software is:

$$M = \frac{(Na + 12Ja + Wia + 20Wga + 20Wya) \times yma / Na}{(Nd + 12Jd + Wid + 20Wgd + 20Wyd) \times ymd / Nd}$$

where 12 is replaced by 15 if year is before 1970 or by 20 if the year is before 1950.

2. The Vulnerability equation currently in the TNDM software is:

$$V_d = N_d \times (Uv_d / vu_d) \times \sqrt{\frac{S_a}{S_d}} \times yv_d \times rv_d$$

3. Factor Tables. Some changes were made to the Terrain Factor Table around the time that the customized version of the TNDM was made for the Swedes. Some additional changes were also made for the Gulf War analyses, such as adding additional desert terrain types.

TNDM v. 1.85 Release date: 23 June 1996

Correction: Col. Wagner, South Africa Army College, reports that error 200 (Division by zero) occurs consistently when the Calculate OLI option is selected while trying to edit a weapon.

The TNDM and Simulating Suppression

by Dave Bongard

The Dupuy Institute, in partnership with JHF, Inc. of Vienna, Va, secured a contract with the Field Element of the Human Research Laboratory-Human Resources Engineering Directorate (HRL-HRED) at Fort Sill, OK, part of the Field Artillery School there. The purpose of the contract, awarded in late 1993, was to examine the mechanism and effects of battlefield suppression (Phase I), with a further goal of providing one or more computer combat models currently used by the U.S. Army with a mechanism simulating suppression in combat (Phase II). Phase I was completed with the submission of the final report to HRL-HRED in November 1994. Phase II began in late spring 1995, is still in progress and due to be completed in December this year.

The central concept to this study is that of "suppression". Suppression may be defined as the transitory or temporary degradation of operation capability of an individual or military unit, as a result of the proximity of impact of hostile firepower. This includes both psychological and physical effects impairing normal combat performance of individuals or units who have not been rendered casualties by the firepower impact. In pithier terms, it is the non-lethal effect of firepower, especially from indirect fire, on individuals and units in combat.

The methodology employed for Phase I was to examine a number of battles from both the Pacific and European-Mediterranean theaters in World War II. The battles examined were mostly divisional-level, and were separated into "high suppression" (with large quantities of artillery and air support for one side, usually the attacker) and "low suppression" engagements. Comparing the computed CEVs for high suppression engagements with the CEVs for low suppression engagements would provide a correlation between CEV and firepower superiority, thus demonstrating both that suppression existed as a battlefield phenomena, and that it could be quantified.

The battles examined were limited to World War II engagements for two main reasons. First was the issue of data availability: engagements since 1945 often do not have decent or useful primary-source material for both sides, such as the case of the Korean War (1950-53) and the Iran-Iraq (1981-89) or Kuwait wars (1990-91). Second was the issue of relevance, since it was more likely that the customer would accept World War II data than anything earlier.

Accordingly, a total of over forty engagements were examined, listed here:

European

Low suppression

1) Sele-Calore, US 45th Inf Div (12-13 Sep 1943)
2) Caiazzo
3) Santa Maria Infante, US 88th Inf Div (12-13 May 1944)
4) San Martino, US 85th In Div (12-13 May 1944)
5) Velletri, US 36th Inf Div (+) (26 May 1944)
6) Campoleone Station, US 34th & 45th Inf Divs (26-28 May 1944)
7) Fosse di Campoleone, 45th Inf & 1st Armd Divs (29-31 May 1944)
8) Krinkelt-Rocherath, US 1st & 99th Inf Divs (16-17 Dec 1944)
9) Sauer River, US 4th Inf Div (-/+) (16-17 Dec 1944
10) Celles, US 2d Arm Div (+) 24-25 Dec 1944)

High suppression

11) Anzio Breakout, US 1st Arm Div (23 May 1944)
12) Cisterna II, US 3d Inf Div (23 May 1944)
13) GOODWOOD, UK I & VIII Corps (1st day: 18 Jul 1944)
14) COBRA-St. Lo, US VII Corps (1st day: 25 Jul 1944)
15) Boulougne, Cdn 3d Inf Div (+) (19 Sep 1944)
16) Assensois, US CCR/4th Arm Div (26 Dec 1944)
17) VERITABLE, UK XXX Corps (1st day: 8 Feb 1945)
18) Roer River 1, US XIX Corps (1st day: 23 Feb 1945)
19) Roer River 2, US XIII Corps (1st day: 23 Feb 1945)

Pacific

Low suppression

20) Eniwetok, US 106th Inf Reg't (2d day: 20 Feb 1944[1])
21) Eniwetok, US 106th Inf Reg't (3d day: 21 Feb 1944)
22) Parry, US 22d Marine Reg't (+) (22 Feb 1944)
23) Torokina Point, US XIV Corps (10-11 Mar 1944)
24) Tomb Hill-Ouki, US 7th Inf Div (9-11 Apr 1945)
25) Kochi Ridge-Onaga A, US 7th Inf Div (25-27 Apr 1945)
26) Kochi Ridge-Onaga B, US 7th Inf Div (28-29 Apr 1945)
27) Kochi Ridge-Onaga C, US 7th Inf Div (30 Apr-1 May 1945)
28) Kochi Ridge-Onaga D, US 7th Inf Div (2-3 May 1945)
29) Shuri East Flank A, US 96th Inf Div (11-13 May 1945)
30) Shuri East Flank B, US 96th Inf Div (14-18 May 1945)
31) Shuri East Flank C, US 96th Inf Div (20-21 May 1945)

[1] Although the initial assault on Eniwetok Island was a "high suppression" battle, with extensive air and naval gunfire support, the 2d and 3d days (which were treated as separate engagements because of U.S. reinforcements) were relatively "low-suppression" with minor air support and only 1 destroyer for naval gunfire support.

32) Shuri Envelopment 1, US 7th In Div (20-23 May 1945)
33) Advance to Yaezu-Dake, US 96th Inf Div (6-9 June 1945)
34) Yaezu-Dake I, US 96th Inf Div (10-11 June 1945)

High suppression
35) Tarawa, elements US 2d Marine Div (20 Nov 1943)
36) Roi-Namur, US 4th Marine Div (31 Jan 1944)
37) Kwajalein, US 7th Inf Div (1 Feb 1944)
38) Engebi, US 1 & 2/22d Marine Reg't (18 Feb 1944)
39) Eniwetok, US 1 & 3/106th Inf Reg't (19 Feb 1944)
40) Saipan, US 2d & 4th Marine Divs (15 Jun 1944)
41) Guam-Asan (N), US 3d Marine Div (21 Jul 1944)
42) Guam-Agat (S), US 1st Prov Marine Bde (21 Jul 1944)
43) Tinian, US 2d & 4th Marine Divs (24 Jul 1944)
44) Iwo Jima, US 4th & 5th Marine Divs (19 Feb 1945)

The results of these TNDM engagement analyses are appended to this article as a series of tables.

Key to tables:
Engmt name — engagement name
Suc — successful side, or winner
Nat/Ndf — number of attackers (personnel) divided by number of defenders Historical results (what actually happened)
A cas — attacking force casualties per day
D cas — defending force casualties per day
%atC/%dfC — ratio of casualties (in percent) of attacking force to casualties (in percent) of defending force
D adv — distance advanced by attackers, in kilometers
Pat/Pdf — attacking force Combat Power divided by defender Combat Power
TNDM results (what the model said would happen, with historical inputs) — same categories as in "Historical results"
CEV — model-calculated Combat Effectiveness Value for attacking force
CEV-CEVav — numerical difference between average attacker's CEV and engagement CEV (only for high suppression engagements)
N Attk — number of personnel in attacking force
N Dfnd — number of personnel in defending force
P Att — Combat Power of attacking force
P Def — Combat Power of defending force
P/N Att — Combat Power per individual in attacking force
P/N Def — Combat Power per individual in defending force
Pg/N A — Combat Power of Artillery per individual attacker
Py/N A — Combat Power of Air Support per individual attacker
FPxs — "excess firepower", measured in Combat Power (P)
Pgy/N A — Combat Power of Artillery and Air Support per individual attacker
Pyg A/P D — Combat Power of Attacker Artillery and Air Support divided by Defender's Combat Power

		Historical Results						TNDM-Derived Results															
Engmt Name	Suc?	Nat/Ndf	A Cas	D Cas	%atC/%df	D adv	Pat/Pdf	At Cas	Df Cas	atC/dfC	D adv	CEV	CEV-CEVav	N Attk	N Dfnd	P Atk	P Def	P/N Att	P/N Def	Pg/N A	Py/N A	FP xs	Pgy/N A	Pyg Att	Pyg A/P
Low Supp ETO																									
Sele-Calore	Def	1.460	251	60	2.865	3.70	0.690	425	292	1.455	0.00	0.880	-0.066	12,447	8,525	57,706	83,632	4.636	9.810	1.13	0.00		1.130	14,065	0.1682
Caiazzo	Atk	2.830	146	52	0.992	1.60	2.600	359	350	1.026	4.80	0.680	-0.266	18,210	6,435	94,547	36,364	5.192	5.651	1.31	0.15		1.460	26,587	0.7311
Anzio Breakout	Atk	1.870	173	280	0.33	3.20	4.450	111	318	0.349	11.50	1.590	0.644	21,499	11,495	168,124	37,781	7.820	3.287	1.03	2.33		3.349	72,008	1.9059
S. Maria Infante	Atk	2.020	265	518	0.253	7.00	3.120	234	396	0.591	2.70	0.960	0.014	18,702	9,258	170,655	54,697	9.125	5.908	2.60	1.83		4.440	83,037	1.5181
San Martino	Def	2.210	987	360	1.241	0.00	3.110	228	359	0.635	2.70	0.580	-0.366	17,970	8,131	98,158	31,562	5.462	3.882	1.68	0.88		2.540	45,644	1.4462
Spigno	Atk	2.250	172	365	0.209	2.40	2.940	165	342	0.482	4.80	0.930	-0.016	18,308	8,137	120,504	40,988	6.582	5.037	1.69	0.49		2.190	40,095	0.9782
Campoleone	Def	1.800	172	193	0.495	1.10	1.630	439	515	0.852	3.20	0.800	-0.146	19,047	10,582	82,990	50,914	4.357	4.811	0.92	0.00		0.920	17,523	0.3442
F. Di Campo	Def	1.880	435	460	0.503	0.90	1.140	673	535	1.258	1.30	0.560	-0.386	29,711	15,804	123,394	108,240	4.153	6.849	0.72	0.29		1.020	30,305	0.2800
Chartres	Atk	1.880	113	579	0.104	0.00	5.890	80	305	0.262	4.90	1.019	0.073	15,646	8,322	98,601	16,740	6.302	2.012	2.41	0.00		2.410	37,707	2.2525
Krinkelt-Rocherat	Atk	1.693	571	823	0.41	0.00	1.095	255	1051	0.243	0.00	1.056	0.110	55,026	32,496	177,992	162,560	3.235	5.002	1.34	0.00		1.336	73,528	0.4523
Celles	Atk	1.269	53	203	0.206	8.00	2.903	101	221	0.457	11.93	1.349	0.403	18,347	14,455	177,219	61,054	9.659	4.224	1.10	0.38		1.479	27,128	0.4443
AVERAGES:		**1.924**	**303**	**354**	**0.692**	**2.54**	**2.688**	**279**	**426**	**0.692**	**4.35**	**0.946**		**22,265**	**12,149**	**124,535**	**62,230**	**6.048**	**5.134**	**1.45**	**0.58**		**2.025**	**42,512**	**0.9565**

		Historical Results						TNDM-Derived Results															
Engmt Name	Suc?	Nat/Ndf	A Cas	D Cas	%atC/%df	D adv	Pat/Pdf	At Cas	Df Cas	atC/dfC	D adv	CEV	CEV-CEVav	N Attk	N Dfnd	P Atk	P Def	P/N Att	P/N Def	Pg/N A	Py/N A	FP xs	Pgy/N A	Pyg Att	Pyg A/P
High Supp ETO																									
Cisterna	Atk	2.040	814	539	0.740	2.40	5.968	157	600	0.262	0.60	1.210	27.907	24,275	11,900	203,228	34,054	8.372	2.862	2.75	3.07	1.80	5.830	141,523	4.1558
GOODWOOD-1	Def	3.514	750	1200	0.178	8.85	24.372	344	503	0.684	38.76	0.620	-34.461	58,500	16,650	#######	74,722	31.131	4.488	1.22	26.00	13.26	27.218	#######	21.3093
Boulogne	Atk	2.470	100	75	0.540	1.00	9.240	125	391	0.320	2.90	1.540	62.791	21,465	8,690	264,313	28,605	12.314	3.292	0.49	11.67	4.83	12.160	261,014	9.1248
VERITABLE	Atk	2.790	232	900	0.092	6.00	7.010	185	294	0.629	2.30	1.560	64.905	35,580	12,753	290,967	41,507	8.178	3.255	2.82	4.04	2.28	6.850	243,723	5.8719
Roer River-A	Atk	4.830	410	400	0.212	4.00	4.450	553	286	1.934	9.40	1.090	15.222	47,059	9,743	347,605	78,113	7.387	8.017	5.28	0.97	1.52	5.250	247,060	3.1629
Roer River-B	Atk	2.640	540	600	0.341	4.00	3.670	770	760	1.013	6.90	1.020	7.822	48,264	18,282	323,476	88,214	6.708	4.825	3.73	1.29	1.43	5.070	244,698	2.7739
AVERAGES:		**3.047**	**474**	**619**	**0.351**	**4.38**	**9.118**	**356**	**472**	**0.807**	**10.14**	**1.173**		**39,191**	**13,003**	**541,789**	**57,536**	**12.348**	**4.457**	**2.72**	**7.84**	**4.19**	**10.396**	**455,048**	**7.7331**

		Historical Results						TNDM-Derived Results															
Engmt Name	Suc?	Nat/Ndf	A Cas	D Cas	%atC/%df	D adv	Pat/Pdf	At Cas	Df Cas	atC/dfC	D adv	CEV	CEV-CEVav	N Attk	N Dfnd	P Atk	P Def	P/N Att	P/N Def	Pg/N A	Py/N A	FP xs	Pgy/N A	Pyg Att	Pyg A/P
Low Supp PTO																									
Eniwetok-2	Atk	4.216	135	447	0.072	1.20	31.641	91	487	0.187	1.57	1.036	-0.238	3,423	812	36,746	1,168	10.735	1.438	0.88	6.02		6.902	23,624	20.2260
Eniwetok-3	Atk	10.252	135	447	0.029	1.20	50.278	90	325	0.277	1.54	0.816	-0.458	3,332	325	35,798	712	10.744	2.191	0.90	6.01		6.911	23,028	32.3421
Eniwetok-4	Atk	8.357	508	779	0.078	2.10	53.183	100	638	0.157	1.57	0.751	-0.523	6,510	779	52,758	992	8.104	1.273	3.07	1.65		4.718	30,711	30.9587
Shuri Line E	Def	3.731	167	1346	0.033	0.30	19.604	363	678	0.535	0.40	1.280	0.077	19,714	5,264	203,514	10,381	10.323	1.965	3.89	2.95		6.832	134,688	12.9745
Shuri Line E-B	Atk	4.409	118	886	0.030	0.10	26.892	335	693	0.483	3.86	1.314	0.111	20,973	4,757	270,078	10,043	12.877	2.111	5.44	4.14		9.584	201,008	20.0147
Shuri Line E-C	Atk	4.627	167	1511	0.024	0.50	18.981	252	392	0.643	0.20	1.414	0.211	19,558	4,227	163,235	8,600	8.346	2.035	3.99	0.80		4.816	94,184	10.9516
Kochi River-O A	Def	2.919	90	441	0.070	0.00	11.838	159	358	0.444	2.06	0.821	-0.382	14,594	5,000	129,248	10,918	8.856	2.184	3.35	0.95		4.297	62,715	5.7442
Kochi River-O B	Def	3.552	91	407	0.063	0.00	23.365	242	727	0.333	3.86	0.858	-0.345	15,986	4,500	239,258	10,240	14.967	2.276	7.94	2.68		10.609	169,590	16.5615
Kochi River-O C	Atk	3.892	100	969	0.027	0.10	40.899	161	524	0.307	2.97	2.179	0.976	15,764	4,050	375,819	9,189	13.840	2.269	13.90	5.74		19.640	309,607	33.6932
Kochi River-O D	Atk	2.939	57	732	0.026	0.70	20.300	217	670	0.324	3.43	2.432	1.229	15,109	5,140	249,383	12,285	16.506	2.390	8.02	3.88		11.893	179,698	14.6274
Tomb H-Ouki	Def	6.037	155	426	0.06	0.10	22.839	120	250	0.480	1.37	1.062	-0.141	18,111	3,000	189,015	8,276	10.436	2.759	3.81	2.41		6.217	112,594	13.6049
Shuri Env 1	Atk	4.806	85	239	0.074	0.50	9.152	214	277	0.773	1.52	0.613	-0.590	16,043	3,338	63,215	6,907	3.940	2.069	1.84	0.46		2.301	36,910	5.3439
Adv Yaezu Dake	Atk	4.694	112	200	0.119	0.50	20.630	383	609	0.629	3.43	0.946	-0.257	18,777	4,000	142,636	6,914	7.596	1.729	1.19	2.90		4.085	76,712	11.0952
Yaezu Dake	Atk	4.395	44	533	0.019	0.25	22.815	287	658	0.436	3.80	1.316	0.113	18,680	4,250	120,328	5,274	6.442	1.241	2.87	0.00		2.869	53,593	10.1617
AVERAGES:		**4.916**	**140**	**669**	**0.052**	**0.54**	**26.601**	**215**	**520**	**0.429**	**2.26**	**1.203**		**14,755**	**3,533**	**162,217**	**7,279**	**10.265**	**1.995**	**4.36**	**2.90**		**7.262**	**107,762**	**17.0214**

		Historical Results					TNDM-Derived Results																	
Engmt Name	Suc?	Nat/Ndf	A Cas	D Cas	%atC/%df	D adv	Pat/Pdf	At Cas	Df Cas	atC/dfC	D adv	CEV	CEV-CEVav	N Attk	N Dfnd	P Atk	P Def	P/N Att	P/N Def	Pg/N A	Py/N A	FP xs	Pgy/N A	Pyg Att	Pyg A/P
High Supp PTO																								
Tarawa	Atk	1.034	1500	1618	0.897	0.20	16.589	1384	1921	0.720	0.50	1.750	45.470	5,000	4,836	257,981	15,551	51.596	3.216	27.94	21.04	5.71	48.983	244,916	15.7492
Roi-Namur	Atk	4.074	408	1828	0.055	0.80	72.943	416	2645	0.157	0.97	0.938	-6.481	14,708	3,610	291,187	3,992	19.798	1.106	16.73	0.97	1.42	17.704	260,390	65.2280
Kwajalein	Atk	3.273	263	2030	0.040	1.00	55.669	301	695	0.433	1.36	0.707	-41.230	9,656	2,950	338,298	6,077	35.035	2.060	27.29	4.98	3.42	32.275	311,643	51.2824
Engebi	Atk	3.233	203	1240	0.051	2.83	74.614	126	1276	0.099	5.47	1.156	-3.907	4,125	1,276	141,542	1,897	34.313	1.487	27.00	3.37	3.16	30.372	125,283	66.0427
Eniwetok-1	Atk	1.928	135	447	0.157	1.20	59.154	92	535	0.172	1.59	1.067	-11.305	2,597	1,347	95,888	1,621	36.923	1.203	24.19	8.26	3.44	32.444	84,257	51.9784
Saipan	Atk	10.075	765	1200	0.063	4.50	52.789	105	679	0.155	2.42	0.784	-34.830	40,300	4,000	417,346	7,906	10.356	1.977	7.40	0.45	0.08	7.581	316,410	40.0215
Guam-North	Atk	2.616	308	950	0.124	8.00	18.100	115	1242	0.093	8.85	1.408	17.041	9,550	3,650	152,622	8,432	15.981	2.310	12.75	0.93	0.87	13.681	130,652	15.4948
Guam-South	Atk	3.638	205	600	0.094	8.00	18.258	104	1144	0.091	8.85	1.370	13.882	8,350	2,300	103,999	5,696	12.455	2.477	0.62	0.90	0.44	10.527	87,897	15.4314
Tinian	Atk	1.384	227	956	0.172	2.59	9.478	124	801	0.155	2.60	1.515	25.935	11,900	8,600	208,150	21,962	17.492	2.554	12.79	1.66	0.98	14.452	171,975	7.8306
Iwo Jima	Atk	0.618	2000	2904	1.115	0.80	36.623	161	1424	0.113	4.31	2.049	70.324	11,305	18,300	########	69,032	223.631	3.772	118.31	103.73	29.26	220.993	########	36.1909
AVERAGES:		**3.187**	**601**	**1377**	**0.277**	**2.99**	**41.422**	**293**	**1236**	**0.219**	**3.69**	**1.274**		**11,749**	**5,087**	**453,516**	**14,217**	**45.758**	**2.216**	**27.50**	**14.63**	**4.88**	**42.901**	**423,175**	**36.5250**

An examination of the results shown in these tables shows that in engagements where the attacker possessed a large imbalance of firepower score, the TNDM model generally predicts a smaller margin of victory than actually occurred. The correlation is more clear with European–Mediterranean theater engagements. This may be due to the fact that all of the high–suppression Pacific engagements are amphibious assaults, and that in several cases (Saipan and especially Iwo Jima) the Japanese defenders were so heavily dug–in as to be nearly subterranean.

Still, the fact that "excess" firepower does more than simply cause greater physical losses is crucial. It means that a heavy firepower imbalance has a discreet, arithmetically definable, non–physical effect. While the defenders under suppression suffer relatively little additional physical damage, their capacity to resist is notably reduced, and they are able to inflict less damage on the attacker's forces. Essentially, these results show that the defending forces are being rendered temporarily incapable of functioning efficiently. That is, the side which suffers the firepower disadvantage is being suppressed.

How the TNDM Measures Fortifications

by Christopher A. Lawrence

In April of this year, members of the Joint Chiefs of Staff (JCS) requested that we prepare a study on the military impact of the international convention to ban anti-personnel mines. Our first draft was delivered within eight days of the request, with further material submitted later. We also prepared considerable analysis after that, but no further work was contracted for, as a decision had been made by the President on the subject. We therefore ceased work on this effort.

As part of this effort, we attempted to use the TNDM to measure the impact of fighting conventional actions with AP mines and without AP mines. This led me to first conduct an analysis of how mines are modeled within the TNDM. I prepared two brief papers on the subject. One was titled "Estimating the Impact of Mines as Measured by the TNDM" and the other was called "Estimating the Impact of Mines on Force Vulnerability as Measured by the TNDM".

The first paper was included in our report "Military Consequences of Landmine Restrictions" as part of Attachment 2, "TNDM Analysis," to our report. We may issue out the results of this analysis at a later date.

The second paper was not included in our report as it was too esoteric and inconclusive for any deliverable product. We have included it here just to spark some interest in understanding the internal workings of the model. Quite simply, until now, I had never bothered to look at how the TNDM measures vulnerability. There are some surprisingly sophisticated, if not idiosyncratic, formulations in this model.

Estimating the Impact of Mines as Measured by the TNDM

5 April 1996

1. The measurements for fortification and defense factors that are used in the TNDM comes from a study done for the US Army Concepts Analysis Agency called *Historical Evaluation of Barrier Effectiveness* prepared in March 1974.

2. The study confirmed Clausewitz's assertion that "the defense is the stronger form of conducting war" and indicated that the combat capabilities of a military force is enhanced, or multiplied by a factor ranging from 1.15 to 1.6, depending upon the extent to which the defensive position has been prepared or fortified.

3. According to the study, the preparation of the defensive position involves four major kinds of efforts:

1. The construction of entrenchments and other forms of field fortifications.
2. The preparation of demolitions to block pas sage of roads, defiles, or bridges
3. The preparations of various forms of constructed obstacles to block limited or broad avenues of movement.
4. The emplacement of mines or other explosive charges to impeded hostile progress across oth erwise favorable, generally broad, avenues of movement.

4. The study claimed that the historical records did not provided any direct evidence of the relative contribution of each of the four components, but the study claimed that field fortifications made up half of the defensive value. It claimed that the defensive value of the other three components (mines, obstacles and demolitions) are approximately equal.

5. When a defense is fully developed, the total bonus is 60%. Of these field fortifications account for 30%, demolitions account for 10%, mines account for 10%, and constructed obstacles account for 10%. This ratio only applies after all have been fortified.

6. In *Numbers, Predictions and Wars* , the following posture table is used:

	Force Strength	Vulnerability
Attack	1.0	1.0
Defense (hasty)	1.3	0.7
Defense (prepared)	1.5	0.6
Defense (fortified)	1.6	0.5
Withdrawal	1.15	0.85
Delay	1.2	0.65

7. In figure V-24 of the study, the component parts of the defensive value are:

	Value	Demo.	Mines	Obstacles	Field Fortifications
Withdrawal	1.15	0.055	0.05	0.0225	0.0225
Delay	1.2	0.07	0.06	0.035	0.035
Hasty	1.3	0.09	0.08	0.06	0.07
Prepared	1.5	0.1	0.1	0.1	0.2
Fortified	1.6	0.1	0.1	0.1	0.3

Note: all these figures are hypothetical, and none are directly supported by data.

8. Therefore, making an assumption, collaborated by measures of effectiveness derived from historic data (see Attachment 4), that AP mines and booby traps make up half of the mine effects accounted for, the reduction in defensive posture values for the following postures are:

	Old Value	Degradation Amount	New Value	Percent Degradation
Withdrawal:	1.15	.03*	1.12	2.6 %
Delay:	1.2	.03	1.17	2.5 %
Hasty:	1.3	.04	1.26	3.1 %
Prepared:	1.5	.05	1.45	3.3 %
Fortified:	1.6	.05	1.55	3.1 %

** rounded up to the nearest .01.*

9. While booby-traps are used to some extent in protecting barriers and obstacles, the measurable impact on conventional combat is considered low enough to be entirely ignored for purposes of this study. ⊕

Estimating the Impact of Mines on Force Vulnerability as Measured by the TNDM

5 April 1996

1. The measurements for fortification and defense factors that are used in the TNDM comes from a study done for the US Army Concepts Analysis Agency called *Historical Evaluation of Barrier Effectiveness* prepared in March 1974.

2. This study does not address the vulnerability factors that are used in the TNDM. It only addresses the defense factors. No study has been located that discusses how the vulnerability factors were derived. In *Numbers, Predictions and War*, Col. Dupuy states that the formula concerning vulnerability came from considerable experimentation with WWII data. In that formula, the posture vulnerability factor (some number one or smaller) was divided by the terrain factor for the defensive posture (some number 1 or greater). In the case of attackers, this posture factor is one.

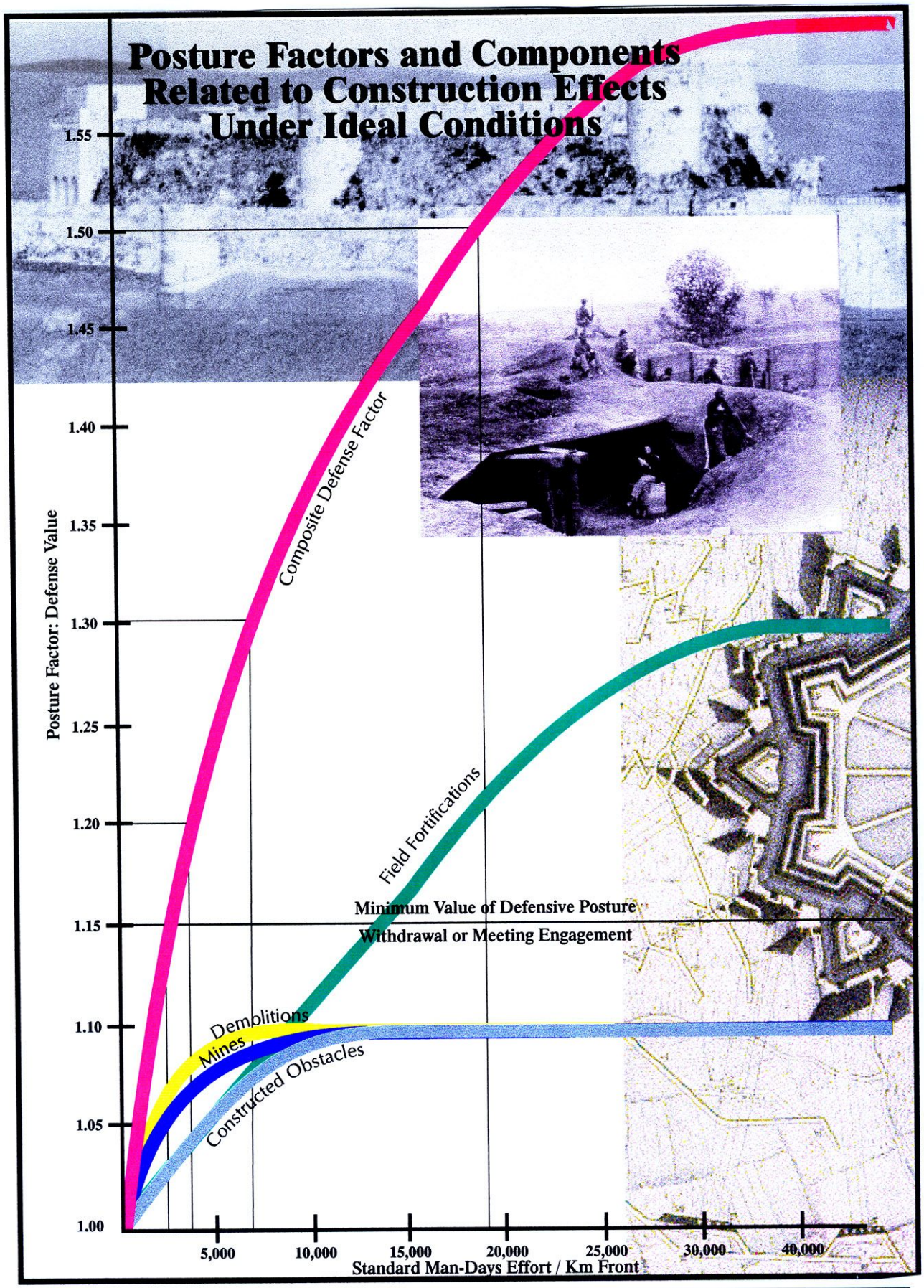
3. The end result of this formulation is intuitively that people in defense suffered lower losses if all other factors were equal. Also, people defending in rough terrain suffered lower losses than those that are not. The two reductions in vulnerability were multiplied together. There was then a second formula that effectively reduces the impact of the casualty reduction by some amount tied to the firepower scores of the weapons for a side. It also reverses the value of the numbers so that more vulnerable forces have a smaller multiplier and therefore a lower firepower score. This multiplier is then applied to the firepower scores for each side in determining the victor, and later the opposing sides vulnerability modifier is used to reduce casualties. The reasoning behind these last three steps are not fully understood.

5. In *Numbers, Predictions and Wars* , the following posture table is used:

	Force Strength	**Vulnerability**
Attack	1.0	1.0
Defense (hasty)	1.3	0.7
Defense (prepared)	1.5	0.6
Defense (fortified)	1.6	0.5
Withdrawal	1.15	0.85
Delay	1.2	0.65

6. The reductions in vulnerability scores for hasty, prepared and fortified postures seems to be tied, and probably should be tied to the amount of entrenching that has been done. The lower vulnerability for withdrawal and delay appear to be clearly tied to the posture and have nothing to do with mines.

7. Therefore, no modifications need to be made to the vulnerability factors to account for banning AP (or for that matter AT) mines. ⊕


Posture Factors and Components Related to Construction Effects Under Ideal Conditions
Posture Factor: Defense Value
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
1.05
1.00
Composite Defense Factor
Field Fortifications
Minimum Value of Defensive Posture Withdrawal or Meeting Engagement
Demolitions
Mines
Constructed Obstacles
5,000
10,000
15,000
20,000
25,000
30,000
40,000
Standard Man-Days Effort / Km Front