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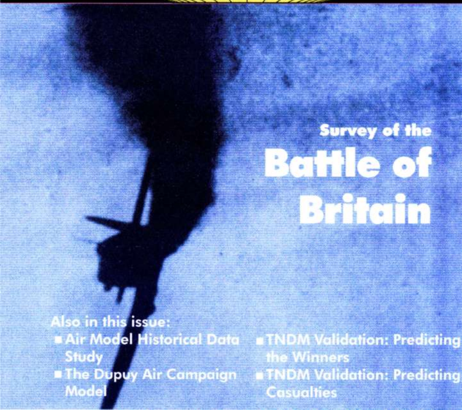
THE INTERNATIONAL TNDM NEWSLETTER



Survey of the Battle of Britain

Also in this issue:

- Air Model Historical Data Study
- The Dupuy Air Campaign Model
- TNDM Validation: Predicting the Winners
- TNDM Validation: Predicting Casualties

INTRODUCTION

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. In this fifth issue of our newsletter Christopher Lawrence, Dave Bongard, Richard Anderson, José Perez, Joe Bulger and Jay Karamales continue to provide information on these efforts.

As you, our readers, survey the pages of this issue, you may be curious about the total scope of work of TDI. The paragraphs below outline what is missing in applied military history and what TDI is doing to shore up that deficiency. In other words, here is *our core capability*:

1. TDI provides independent, objective, historically–based analyses of modern military campaigns. Operations research, as developed during and right after World War II, was based on recorded, detailed data from battles. It is now nearly extinct. It has been supplanted by weapons and systems effects and performance analyses totally devoid of human factors considerations. As a result the Services, particularly the Army, have only partial answers for the development of operational concepts, battle doctrine, weapons requirements, and organizations. Similarly, because they were not historically validated, the Service models and simulations are skewed. Striving for only measured weapons effects and technical systems capabilities, they miss (or significantly distort) the impact of leadership, training, organization, and psychological factors (such as fear of death) on military units in contact.

2. Over the years, TDI, a successor organization to the Historical Evaluation and Research Organization (HERO), both founded by the late Colonel Trevor N. Dupuy, has compiled a large database from modern military campaigns and battles. Using Colonel Dupuy's methodologies and some new techniques, TDI has developed the following capabilities:

a. Comparison of fighting capabilities of opposing forces (systemic strengths and weaknesses) based on:

(1) Command and organizational arrangements, leadership, force structure, intelligence, and logistics;

(2) Training, cultural and psychological profiles, and flow of information;

(3) Doctrinal flexibility or constraints in utilizing new weapons and technologies.

b. Validation of models or simulations and of scenarios for field exercises. Validation is a process, based on historical data and trends, that assists in determining whether a scenario, model, or simulation is an accurate representation of the real world. TDI has the capability to do this independently or to provide primary source historical data for agency in–house validations.

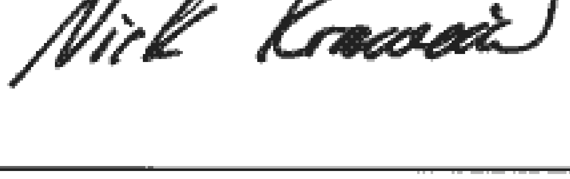
c. Estimating casualties for combat or other operations.

d. Providing lessons learned from studies of cause and effect chains among responsible players at the political, theater, operational, and tactical levels.

e. Analysis of group behavior (impact of various combat activities on units) and other human factors (historically–based aggregate measure of leadership, training, morale, organizational capacity, and cultural characteristics) in modern battles.

f. Studies, based on historic trends and experiential data, of the specific impact on combat caused by new technology and the improvement in weapons. This enables projections of ways in which future wars should be fought and understanding of what elements constitute "force multipliers."

3. The capabilities listed above merge operations research with historical trends, actual combat data, and real world perspectives creating applied military history in its most useful sense.



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IN HONOR OF THE MEMORY OF THE LATE

Trevor N. Dupuy

Col., USA, ret.

International TNDM Newsletter

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From the Editor...

Well, we are now back on "theme." This issue includes the material on the Dupuy Air Campaign Model (DACM) that was supposed to be in the last issue. We also have some of the material from the battalion–level validation. We have completed our analysis of the ability of the model to predict winners and the ability of the model to predict casualties. As a result of this validation we will be making some preliminary changes to the model. These are significant changes, and they are the first significant changes not done by Trevor Dupuy. This version it will known be version 2.0. This version should be considered "preliminary," but it will work the same as version 1.86 of the TNDM, except for WWI engagements, engagements of less than 4 hours, and engagements where one side is considered "casualty insensitive." This version is being sent to holders of our support contracts by a separate letter.

We have still to conduct our analysis of the advance rates and a summary conclusion. But we have seen enough to issue this preliminary revision to the model. We consider it a "preliminary" version because we have yet to test it to our second battalion–level validation database. We have assembled the data for 121 battles from 1914 through 1991. We need to program version 2.0 of the TNDM with the changes from the first validation. We then need to do two TNDM runs for each battle (one without CEV and one with). We need to put them in the Battalion–Level Operations Database (BLODB) so we can analyze the results and test the data. We then need to compare the results of the validation runs to the historical runs and write up the results. Finally, as the Battalion–Level Operations Database (BLODB) will now consist of 197 engagements, I would like to go back and perform the same analysis that I did with the 76–engagement database. It would also be useful to add these battles to the Land Warfare Data Base (LWDB).

In the Programmer's Cubicle, we have an article on how the data is laid out. This is intended as a supplement to the User's Guide. For "Who is TDI," we have assembled a little background on Col. Joseph Bulger, who took over management of the DACM effort from Trevor Dupuy. We finally got a real picture for a change, although it is not quite current.

The next issue will focus on the modeling of tanks and armored warfare. The cover article will be by Jay Karamales from his Tank/Antitank studies. His new book *Against the Panzers* was the book of the month selection for the Military Book Club. The issue will also include an article on the use of mines and fortifications at Kursk. We have a set of tables prepared by Richard Anderson on the effects of artillery on tanks. They are quite startling. This issue will also contain the rest of our material on the battalion–level validation and another article on measuring combat effectiveness values. We also have on hand our first article from outside the Institute, and we are expecting more. These will be published in the next issue.

We have also, courtesy of Major John Sloan, started our first subscription effort to the newsletter. Our subscription price of $30 a year ($6 an issue) really only covers our reproduction cost. This newsletter was not intended to be a subscription–type magazine and is not intended to be "profit making." It is intended to be part of our support efforts for TNDM users, but we are making the newsletter available to anyone who wishes to subscribe to it.

As a final note, I want to welcome Gene Visco to our board of advisors. Mr. Visco I believe is well known to many of you, as he worked for many years in the office of the Deputy Undersecretary of the Army, Operations Research.

That is all for now. If you have any questions, please contact me. Addresses, e-mail addresses, and phone numbers are in the masthead.

Air Model Historical Data Study

by Col. Joseph A. Bulger, Jr., USAF, Ret.

The Air Model Historical Study (AMHS) was designed to lead to the development of an air campaign model for use by the Air Command and Staff College (ACSC). This model, never completed, became known as the Dupuy Air Campaign Model (DACM). It was a team effort led by Trevor N. Dupuy and included the active participation of Lt. Col. Joseph Bulger, Gen. Nicholas Krawciw, Chris Lawrence, Dave Bongard, Robert Schmaltz, Robert Shaw, Dr. James Taylor, John Kettelle, Dr. George Daoust and Louis Zocchi, among others. After Dupuy's death, I took over as the project manager.

At the first meeting of the team Dupuy assembled for the study, it became clear that this effort would be a serious challenge. In his own style, Dupuy was careful to provide essential guidance while, at the same time, cultivating a broad investigative approach to the unique demands of modeling for air combat. It would have been no surprise if the initial guidance established a focus on the analytical approach, level of aggregation, and overall philosophy of the QJM and TNDM. It was clear that Trevor had no intention of steering the study into an air combat modeling methodology based directly on QJM/TNDM. To the contrary, he insisted on a rigorous derivation of the factors that would permit the final choice of model methodology.

At the time of Dupuy's death in June 1995, the Air Model Historical Data Study had reached a point where a major decision was needed. The early months of the study had been devoted to developing a consensus among the TDI team members with respect to the factors that needed to be included in the model. The discussions tended to highlight three areas of particular interest—factors that had been included in models currently in use, the limitations of these models, and the need for new factors (and relationships) peculiar to the properties and dynamics of the air campaign. Team members formulated a family of relationships and factors, but the model architecture itself was not investigated beyond the surface considerations.

Despite substantial contributions from team members, including analytical demonstrations of selected factors and air combat relationships, no consensus had been achieved. On the contrary, there was a growing sense of need to abandon traditional modeling approaches in favor of a new application of the "Dupuy Method" based on a solid body of air combat data from WWII.

The Dupuy approach to modeling land combat relied heavily on the ratio of force strengths (largely determined by firepower as modified by other factors). After almost a year of investigations by the AMHDS team, it was beginning to appear that air combat differed in a fundamental way from ground combat. The essence of the difference is that in air combat, the outcome of the maneuver battle for platform position must be determined before the firepower relationships may be brought to bear on the battle outcome.

At the time of Dupuy's death, it was apparent that if the study contract was to yield a meaningful product, an immediate choice of analysis thrust was required. Shortly prior to Dupuy's death, I and other members of the TDI team recommended that we adopt the overall approach, level of aggregation, and analytical complexity that had characterized Dupuy's models of land combat. We also agreed on the time–sequenced predominance of the maneuver phase of air combat. When I was asked to take the analytical lead for the contact in Dupuy's absence, I was reasonably confident that there was overall agreement.

In view of the time available to prepare a deliverable product, it was decided to prepare a model using the air combat data we had been evaluating up to that point—June 1995. Fortunately, Robert Shaw had developed a set of preliminary analysis relationships that could be used in an initial assessment of the maneuver/firepower relationship. In view of the analytical, logistic, contractual, and time factors discussed, we decided to complete the contract effort based on the following analytical thrust:

1. The contract deliverable would be based on the maneuver/firepower analysis approach as currently formulated in Robert Shaw's performance equations;
2. A spreadsheet formulation of outcomes for selected (Battle of Britain) engagements would be presented to the customer in August 1995;
3. To the extent practical, a working model would be provided to the customer with suggestions for further development.

During the following six weeks, the demonstration model was constructed. The model (programmed for a Lotus 1-2-3 style spreadsheet formulation) was developed, mechanized, and demonstrated to ACSC in August 1995. The final report was delivered in September of 1995.

The working model demonstrated to ACSC in August 1995 suggests the following observations:

* A substantial contribution to the understanding of air combat modeling has been achieved.
* While relationships developed in the Dupuy Air Combat Model (DACM) are not fully mature, they are analytically significant.

* The approach embodied in DACM derives its authenticity from the famous "Dupuy Method" thus ensuring its strong correlations with actual combat data.
* Although demonstrated only for air combat in the Battle of Britain, the methodology is fully capable of incorporating modern technology contributions to sensor, command and control, and firepower performance.
* The knowledge base, fundamental performance relationships, and methodology contributions embodied in DACM are worthy of further exploration. They await only the expression of interest and a relatively modest investment to extend the analysis methodology into modern air combat and the engagements anticipated for the 21st Century.

One final observation seems appropriate. The DACM demonstration provided to ACSC in August 1995 should not be dismissed as a perhaps interesting, but largely simplistic approach to air combat modeling. It is a significant contribution to the understanding of air combat relationships that will prevail in the 21st Century. The Dupuy Institute is convinced that further development of DACM makes eminent good sense. An exploitation of the maneuver and firepower relationships already demonstrated in DACM will provide a valid basis for modeling air combat with modern technology sensors, control mechanisms, and weapons. It is appropriate to include the Dupuy name in the title of this latest in a series of distinguished combat models. Trevor would be pleased.

AIR MODEL HISTORICAL DATA STUDY

August '95

NICK KRAWCIW	***President, TDI***
JOE BULGER	***Study Director***

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PURPOSE

- ASSESS IMPACT OF LOSS OF TREVOR DUPUY ON STUDY
- SUMMARIZE PROGRESS AND MAJOR ACCOMPLISHMENTS
- REPORT METHODOLOGY ISSUES
- RECOMMEND AIR CAMPAIGN MODEL DEVELOPMENT THRUST
- DISCUSS / RESOLVE CUSTOMER CONCERNS AND/OR PREFERENCES

OUTLINE

- STUDY CHRONOLOGY OVERVIEW
- PRELIMINARY MODEL ARCHITECTURE
  - QJM / TNDM OVERVIEW
  - METHODOLOGY ISSUES
  - DUPUY METHOD
- THE TDI AIR-TO-AIR CAMPAIGN MODEL
  - OVERVIEW - METHODOLOGY FLOW
  - SPREADSHEET (LOTUS) MECHANIZATION
  - FACTORS TO BE DERIVED FROM HISTORICAL DATA
- RECOMMENDATIONS FOR FUTURE DEVELOPMENT
  - AIR-TO-AIR CAMPAIGN MODEL CORRELATION
  - COLLATERAL AIR CAMPAIGN DEVELOPMENT
  - INFORMATION WARFARE MODEL DEVELOPMENT

AMHDS STATEMENT OF WORK - 1 Feb '94

START 15 JUNE '94

- OBJECTIVE
  - PRODUCE EQUATIONS (SPREADSHEET INCORPORATING EQUATIONS) TO
    - ISOLATE & QUANTIFY FACTORS
    - DETERMINE PATTERNS & RELATIONSHIPS
  - FOR COMBAT SITUATIONS
    - AIR TO AIR
    - SURFACE-TO-AIR
    - AIR-TO-SURFACE

- OCTOBER '94 GUIDANCE (SUPPLEMENTED IN JULY '95)
  - FOCUS ON AIR-TO-AIR WARFARE
  - HIGHLY AGGREGATED MODEL DESIRABLE
  - SPREADSHEET MECHANIZATION ATTRACTIVE
  - STUDENT PLANNING / RESEARCH TOOL NEEDED
  - RECOMMEND APPROACH FOR STRATEGIC PARALLEL WARFARE MODEL

STUDY FOCUS AND THRUST HAVE EVOLVED SIGNIFICANTLY

AMHDS MAJOR TASKS

TASK	PRINCIPAL CONTRIBUTORS	STATUS
REVIEW OF CURRENT MODELS & METHODOLOGIES	DUPUY* LAWRENCE SCHMALTZ	COMPLETED PH I REPORT
GATHER, PROCESS & ASSESS KURSK & BoB AIR COMBAT DATA	LAWRENCE BONGARD	COMPLETE . . . TO BE DELIVERED MID SEP '95
IDENTIFY AIR TO AIR COMBAT VARIABLES & RELATIONSHIPS	DUPUY* LAWRENCE BONGARD BULGER SCHMALTZ SHAW TAYLOR	COMPLETE . . . TO BE DELIVERED MID SEP '95
TREVOR DEATH JUN 5 '95		
DEVELOP METHODOLOGY APPROACH AND ARCHITECTURE FOR AIR-TO-AIR MODEL	KRAWCIW LAWRENCE BONGARD BULGER* SHAW SCHMALTZ TAYLOR KETTELLE	AIR-TO-AIR BRIEFED CUSTOMER PREFERENCE FOR FUTURE EFFORT TO BE DETERMINED

PROFOUND LOSS BUT STRONG TEAM & REAL KNOWLEDGE EMERGING

TDI

OVERVIEW

- **STUDY OVERVIEW**
  - STUDY ON COURSE, AIR-TO-AIR FOCUS
  - TREVOR'S DEATH . . . PROFOUND IMPACT
  - STRONG TEAM ASSEMBLED. . . SIGNIFICANT RESULTS ACHIEVED
- **PELIMINARY MODEL**
- **CURRENT TDI A/A MODEL**
- **RECOMMENDATIONS**

TDI

ORIGINS OF DUPUY AIR SUPERIORITY CAMPAIGN MODEL

(Reference: Dupuy, T.N.:*Understanding War,* Paragon house, New York, p 28-30, 1987.)

- **CLAUSEWITZ THEORY OF COMBAT. . . CONCEPTS**

GENIUS — STRENGTH IN DEFENSE
DESTRUCTION* OF ENEMY — FRICTION IN WAR
SPEED OF MANEUVER — *LAW OF NUMBERS*

- **DUPUY INTERPRETS CLAUSEWITZ LAW OF NUMBERS**

COMBAT POWER = (NUMBERS OF TROOPS) x (QUALITY OF FORCE) x (COMBAT VARIABLES)

NUMBERS OF TROOPS	QUALITY OF FORCE	COMBAT VARIABLES
Lethality of weapons employed on battlefield	Qualitative human factors influencing performance.	Variable circumstances affecting a combat force in battle.
WEAPONS FIGHTING MACHINES	LEADERSHIP MORALE TRAINING	TERRAIN WEATHER COMMUNICATIONS

Force Combat Power = P = (Σ Unit Weapon Lethalities) x (Composite Human Factors) x (Combat Operations Variables)
(S) (Q) (V)

$$\text{BATTLE OUTCOME} \sim \frac{P_{red}}{P_{blu}}$$

NOTE: BATTLE OUTCOME MEASURED BY SURVIVING COMBAT POWER

PRELIM TRIALS BASED ON QJM/TNDM WEAPON METHODOLOGY

PLATFORM & WEAPON COMBINED STRENGTH

GERMAN ACFT						AIR TO AIR COMBAT							
AIRCRAFT SYSTEM CONTRIBUTION TO PERFORMANCE FACTOR													
ACFT MISSION	WEAPON LETHALITY (OLI)	RANGE .14	CEILING .14	CLIMB TO 20 M .16	CRUISE SPEED .17	ENDUR-ANCE .03	WING LDNG .09	DURA-BILITY .02	COMM NAV .13	FCS/STAB AUGM .07	WPN DLV AUGM .05	APF (AIR to AIR)	STRENGTH (S)
AR-66C RECON	0	.26	.39	.53	.33	.26	.71	.70	1.00	1.00	.50	.54	0.00
FW-189A RECON	1.46	.34	.60	.51	.54	.34	.71	.70	1.00	1.00	.50	.62	.90
FW-190F GND ATTK	7.79	.19	.91	.84	1.00	.19	.65	.70	1.00	1.00	.50	.76	5.94
HE-111 H BOMBER	3.34	.71	.74	.33	.64	.71	.51	1.00	1.00	1.00	.70	.69	2.29
HS-123A GND ATTK	5.61	.31	.78	.68	.54	.31	1.00	1.00	1.00	1.00	.70	.71	3.97
HS-126B RECON	.21	.21	.71	.60	.56	.21	.77	1.00	1.00	1.00	.70	.21	.14
HS-129B2 GND ATTK	9.02	.25	.78	.50	.64	.25	.41	1.00	1.00	1.00	.70	.63	5.70
HS-129B2R3 GND ATTK	7.35	.25	.78	.50	.64	.25	.41	1.00	1.00	1.00	.70	.63	4.65
JU-52 BOMBER	0	.88	.47	.27	.45	.88	.40	.70	1.00	1.00	.50	.61	0.00
JU-87D STUKA	.83	.56	.63	.50	.64	.56	.48	.70	1.00	1.00	.50	.65	.54
JU-88A BOMBER	1.65	1.00	.71	.35	.71	1.00	.41	.70	1.00	1.00	1.00	.75	1.23
BF-109G FIGHTER	3.37	.33	1.00	1.00	.98	.33	.74	.70	1.00	1.00	.50	.83	2.79

- NUMBER OF FACTORS CAN PROBABLY BE REDUCED / COMBINED
- METHODOLOGY ATTRACTIVE - TRACTABLE - SPREADSHEET SUITABLE

METHODOLOGY REQUIRES VALIDATION / CORRELATION

PLATFORM & WEAPON COMBINED STRENGTH

GERMAN ACFT						AIR TO AIR COMBAT							
AIRCRAFT SYSTEM CONTRIBUTION TO PERFORMANCE FACTOR													
ACFT MISSION	WEAPON LETHALITY (OLI)	RANGE .14	CEILING .14	CLIMB TO 20 M .16	CRUISE SPEED .17	ENDUR-ANCE .03	WING LDNG .09	DURA-BILITY .02	COMM NAV .13	FCS/STAB AUGM .07	WPN DLV AUGM .05	APF (AIR to AIR)	STRENGTH (S)
AR-66C Recon	0	.26	.39	.53	.33	.26	.71	.70	1.00	1.00	.50	.54	0.00
FW-189A Recon	1.46	.34	.60	.51	.54	.34	.71	.70	1.00	1.00	.50	.62	.90
FW-190F Gnd Attk	7.79	.19	.91	.84	1.00	.19	.65	.70	1.00	1.00	.50	.76	5.94
HE-111H Bomber	3.34	.71	.74	.33	.64	.71	.51	1.00	1.00	1.00	.70	.69	2.29
HS-123A Gnd Attk	5.61	.31	.78	.68	.54	.31	1.00	1.00	1.00	1.00	.70	.71	3.97
HS-126B Recon	.21	.21	.71	.60	.56	.21	.77	1.00	1.00	1.00	.70	.21	.14
HS-129B2 Gnd Attk	9.02	.25	.78	.50	.64	.25	.41	1.00	1.00	1.00	.70	.63	5.70
HS-129B2R3 Gnd Attk	7.35	.25	.78	.50	.64	.25	.41	1.00	1.00	1.00	.70	.63	4.65
JU-52 Bomber	0	.88	.47	.27	.45	.88	.40	.70	1.00	1.00	.50	.61	0.00
JU-87D Stuka	.83	.56	.63	.50	.64	.56	.48	.70	1.00	1.00	.50	.65	.54
JU-88A Bomber	1.65	1.00	.71	.35	.71	1.00	.41	.70	1.00	1.00	1.00	.75	1.23
BF-109G Fighter	3.37	.33	1.00	1.00	.98	.33	.74	.70	1.00	1.00	.50	.83	2.79

- NUMBER OF FACTORS CAN PROBABLY BE REDUCED / COMBINED
- METHODOLOGY ATTRACTIVE - TRACTABLE - SPREADSHEET SUITABLE

METHODOLOGY REQUIRES VALIDATION/CORRELATION

METHODOLOGY ISSUES AND APPROACH

- AIR WARFARE IS NOT AN EXTENSION OF GROUND (WEAPON) RELATIONSHIPS
  PLATFORM (AIRCRAFT) PERFORMANCE DETERMINES WEAPON OPPORTUNITIES
  MUST FOCUS ON AIR COMBAT MANEUVERING EFFECTS
- WILL NOT ABANDON "DUPUY METHOD"
- "DUPUY METHOD" EVOLVED OVER 40 YEARS OF COMBAT ANALYSIS
  1. USE REAL WORLD EXPERIENCE (HISTORY).
  2. USE BEST PROFESSIONAL JUDGEMENT AVAILABLE TO QUANTIFY OTHERWISE UNDETERMINABLE VALUES.
  3. USE RATIONAL CURVE FITTING METHODOLOGY.
  4. VALIDATE AGAINST HISTORICAL DATA WHEREVER POSSIBLE.
- "DUPUY METHOD" CREATED *QJM* AND *TNDM* FOR GROUND WARFARE
- "DUPUY METHOD" WILL CREATE *DACM* FOR AIR WARFARE

DUPUY LEGACY OF EXCELLENCE WILL BE SUSTAINED

OVERVIEW

- STUDY OVERVIEW
  - STUDY ON COURSE, AIR-TO-AIR FOCUS
  - TREVOR'S DEATH . . . PROFOUND IMPACT
  - STRONG TEAM ASSEMBLED. . . SIGNIFICANT RESULTS ACHIEVED
- PELIMINARY MODEL
  - QJM / TNDM DEVELOPED FOR GROUND COMBAT
  - AIR CAMPAIGN DOMINATED BY PLATFORM PERFORMANCE
  - NEW MODEL ARCHITECTURE REQUIRED
- CURRENT TDI A/A MODEL

AIR TO AIR METHODOLOGY REVISIONS

- **BASIC DUPUY MODEL COMBAT RELATIONSHIP**

$$\text{Force Combat Power} = CP = \underset{(S)}{\left(\sum \text{Unit Weapon Lethalities}\right)} \times \underset{(Q)}{\left(\text{Composite Human Factors}\right)} \times \underset{(V)}{\left(\text{Combat Operations Variables}\right)}$$

GROUND COMBAT MODEL
(QJM / TNDM)

- **CAMPAIGN AGGREGATED BY PHASES**
  - MAJOR FORCE REINFORCEMENTS
  - OPN'L FACTORS...TERRAIN, WX...
- **OUTCOME BASED ON POWER RATIOS**
  - AGGREGATED FORCE COMBAT POWER
  - Σ UNIT LETHALITIES

AIR COMBAT MODEL
(DACM)

- **CAMPAIGN AGGREGATED BY ENGAGEMENT TYPES**
  - CHANGE IN ACFT TYPES ENGAGED
  - MISSIONS...INTERCEPT, ESCORT, SWEEP...
- **OUTCOME BASED ON KILLS (RATIO)**
  1. MANEUVER (ACFT TYPE DEPENDENT)
  2. WEAPON LETHALITY & TGT SURVIVABILITY

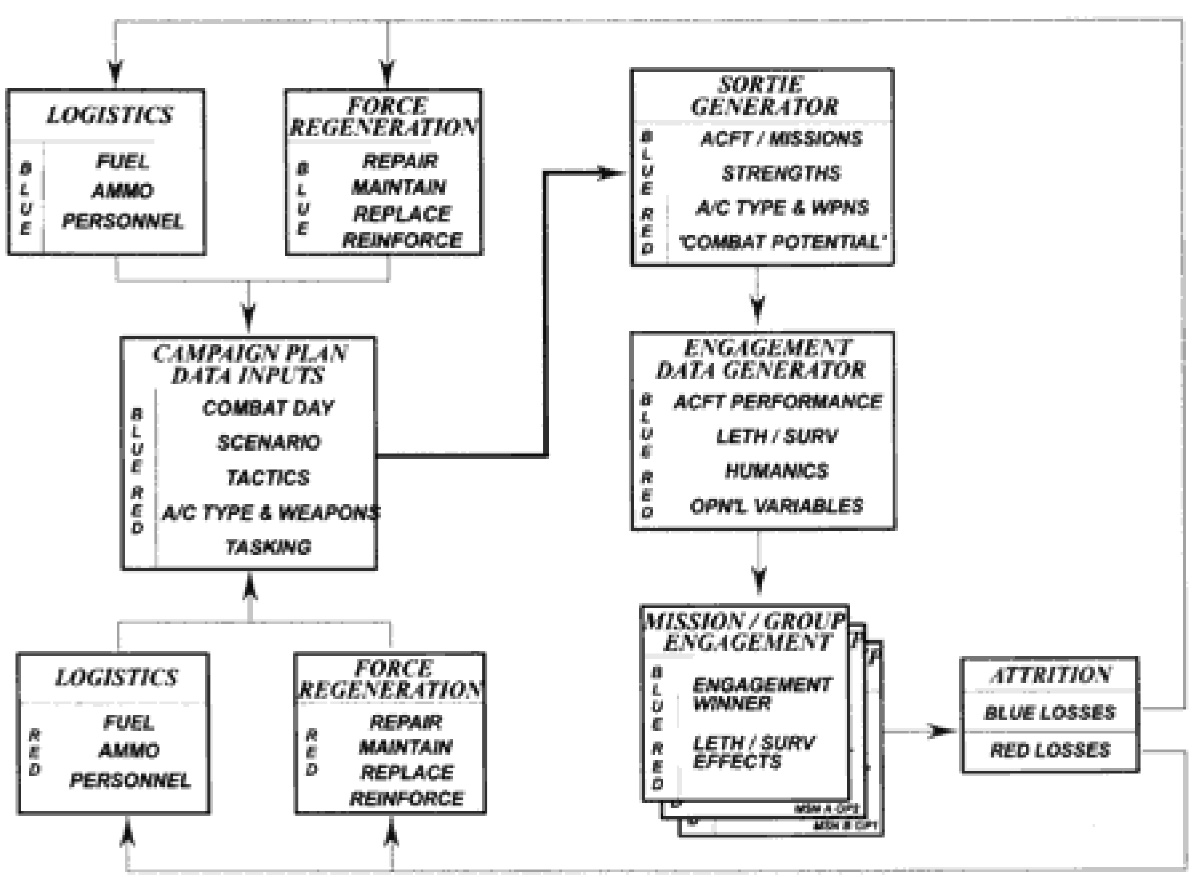
- **DUPUY AIR COMBAT MODEL (DACM) RELATIONSHIP**

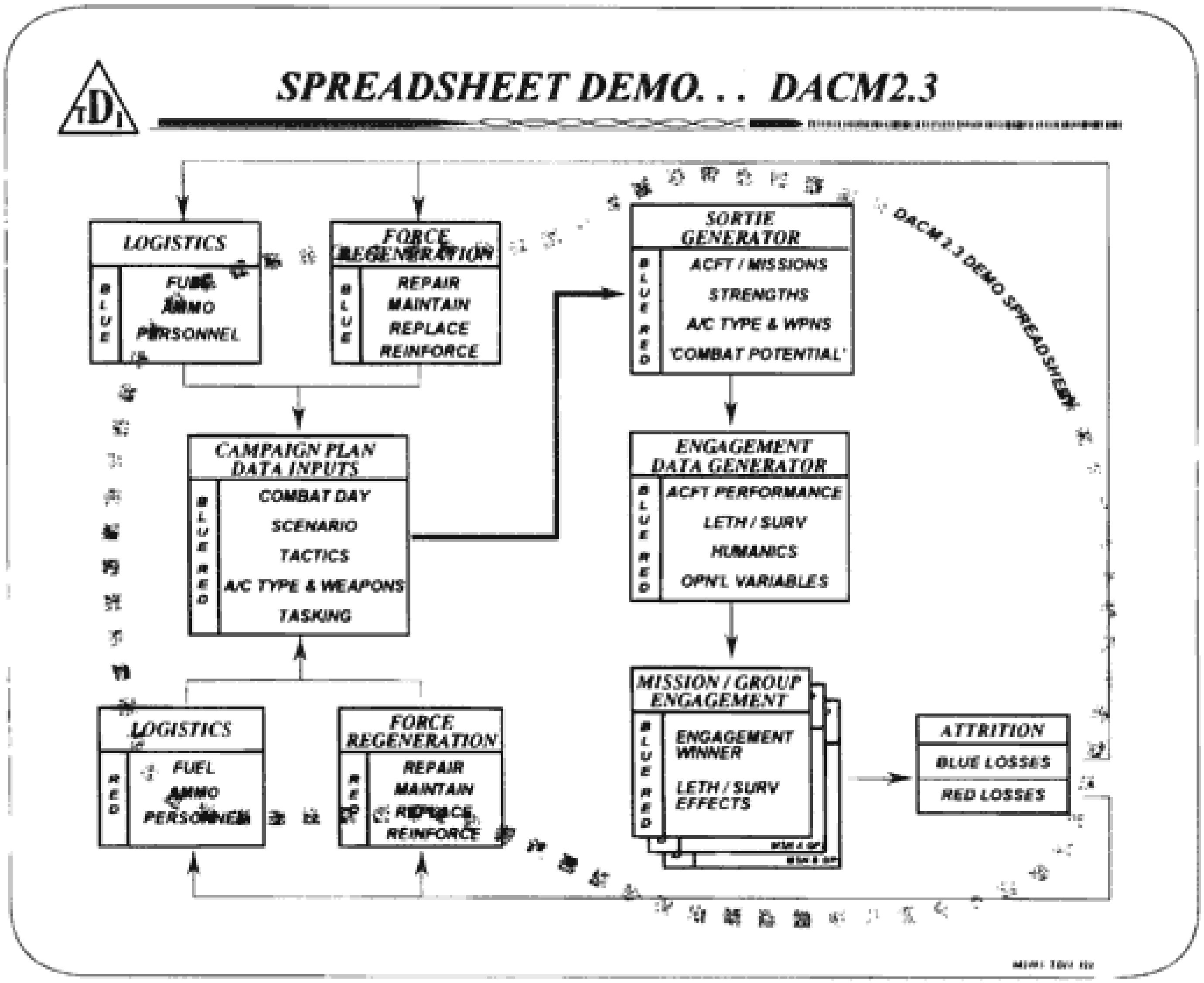
$$Kills_{Blue} \sim \underbrace{K \times \frac{AP_{Blue}}{AP_{Red}} \times \frac{Lethality_{Blue}}{Survivability_{Red}}}_{(S)} \times \ldots \underset{(Q)}{\left(\text{Composite Human Factors}\right)} \times \underset{(V)}{\left(\text{Combat Operations Variables}\right)}$$

NOTE: K DERIVED FROM HISTORICAL RECORDS

REVISED METHODOLOGY PRESERVES DUPUY APPROACH

PRELIMINARY AIR TO AIR LOGIC FLOW





DACM 2.3 SPREADSHEET DEMO OVERVIEW

PLANNER INPUTS AND ENGAGEMENT SUMMARY

	ALLOCATE SORTIES (S)		SURV	LETH	APF	KILLS	LOST	ERa	ERf
blu	HURRICANES	0	4.60	53.0	0.93	00.0	0.0	na	.51
	SPITFIRES	8	4.46	53.0	1.01	2.3	4.6	.51	
red	Bf-109E4	8	1.63	73.6	.99	4.6	2.3	1.97	1.97
	He-111	0							

TRIAL "K" FACTOR = 0.05

RECORD OF TRIALS TO DETERMINE HISTORICAL (BoB) CORRELATION

Run #	K	#H	#S	# Bf	Kh	Ks	Lh	Ls	ERh	ERs	ERfb	ERfr
1A	.05	0	8	8	0.0	2.3	0.0	4.6	na	0.51	0.51	1.97
2A	.05	4	4	8	0.6	1.6	1.7	2.3	0.32	0.72	0.55	1.82
3A	.05	8	0	8	0.8	0.0	4.9	0.0	0.16	na	0.16	6.20

Page 1. PLANNER INPUTS & ENGAGEMENT SUMMARY

Page 2. SCENARIO DESCRIPTION & OPNL FACTORS

Page 3. ACFT & WEAPON CHARACTERISTICS

Page 4. AERO PERFORMANCE FACTOR

Page 5. AIRCRAFT LETHALITY

Page 6. SORTIE PLANNING FACTORS

Page 7. HUMANICS (PILOT EXPERIENCE, TRAINING, & LEADERSHIP)

Page 8. KILLS, KILL RATIOS, EXCHANGE RATIOS

DACM (2.3) DEMO PROVIDES USEFUL RESEARCH TOOL

DACM PAGE 2. SCENARIO & HUMAN FACTORS

TABLE I. SCENARIO DESCRIPTION

ITEM	UNITS	BLUE	RED
Daily Operating Fraction	nd	0.5	0.5
Distance to Operating Area	nm	100	300
Max Speed for pacing Acft	mph	300	200
Mission Turn-Around Time	hrs	0.5	0.5
Mean Time Before Repair	hrs	20	20
Mean Time to Repair	hrs	20	20
* Sensor Paerformance	nd	1	1
* Avionics Performance	nd	1	1
Weight Factor - Aero Perf	nd	0.7	0.6
Weight Facror - Wpns Performance	nd	0.3	0.4
Weight Factor - Numbers	nd	0.5	0.5
Weight Factor - Tech Quality	nd	0.5	0.5

- ***MODEL PROVIDES PLANNER WITH DATA SUPPORTING LOGISTICS DECISIONS FOR NEXT ENGAGEMENT***

- ***HUMAN FACTORS VERY IMPORTANT IN AIR COMBAT***
- ***TABLE II. DEMO DATA PROVIDES GERMAN ADVANTAGE OVER BRITS OF APPROX 2:1***
- ***THIS RATIO PROBABLY REALISTIC IN AUG 1940***

TABLE II. HUMAN FACTORS

ITEM	UNITS	BLUE	RED
PILOT LIMITATIONS			
Pacing Acft Endurance	hrs	5	10
Max Allowable Fly Hrs per day	hrs	6	12
PILOT EXPERIENCE			
Relevant Combat Missions	msns	75	150
Relevant Training Missions	msns	200	350
Recency of Combat Experience	mos	1	1
Recency of Training Experience	mos	6	6
Missions in Current Combat Command	msns	100	300
Weight Factor - Combat Experience	nd	0.3	0.3
Weight Facror - Training	nd	0.2	0.2
Weight Factor - Currency	nd	0.1	0.1
Weight Factor - Leadership Quality	nd	0.1	0.1
Weight Factor - Aircrew Quality	nd	0.3	0.3

MODEL UNDERGOING REFINEMENT...SPREADSHEET IS A TOOL

DACM PAGE 3. ACFT & WPN CHARACTERISTICS

TABLE III. FORCE COMPOSITION & PERFORMANCE CHARACTERISTICS

AIRCRAFT	S	Msn #	Vmax mph	Hmax kft	Hend hrs	BHP fp/m	Aw sqf	Acrt sqf	Wt lbs
HURRICANES	0	3	311	35.0	2.0	1,030	258	56.1	6,252
SPITFIRES	8	3	355	37.0	2.0	1,030	242	54.2	5,481
Bf-109E4	8	3	348	35.0	2.5	1,175	174	106.6	5,205
He-111	0	1	252	27.9	5.0	1,000	942	550.0	19,136

TABLE IV. WEAPON CHARACTERISTICS

AIRCRAFT	WEAPONS #	Type	Fpos nd	Ng nd	Vmuz fps	Wp lbs	RoF rpm	Reff nd
HURRICANES	8	Br .303	1.00	2.83	2,600	0.022	1,200	0.957
SPITFIRES	8	Br .303	1.00	2.83	2,600	0.022	1,200	0.957
Bf-109E4	2	MG17 Syn	1.00	1.41	2,970	0.028	1,180	1.055
	2	MG 20mm	1.00	1.41	1,950	0.295	350	3.755
He-111	1	MG 20mm	1.00	1.00	1,950	0.295	350	3.755
	5	MG15 flex	0.25	.24	3,000	0.028	1,000	1.056

DACM(2.3) jab 08/07/95 rs tok 08/07/95 Page 3 of 8.

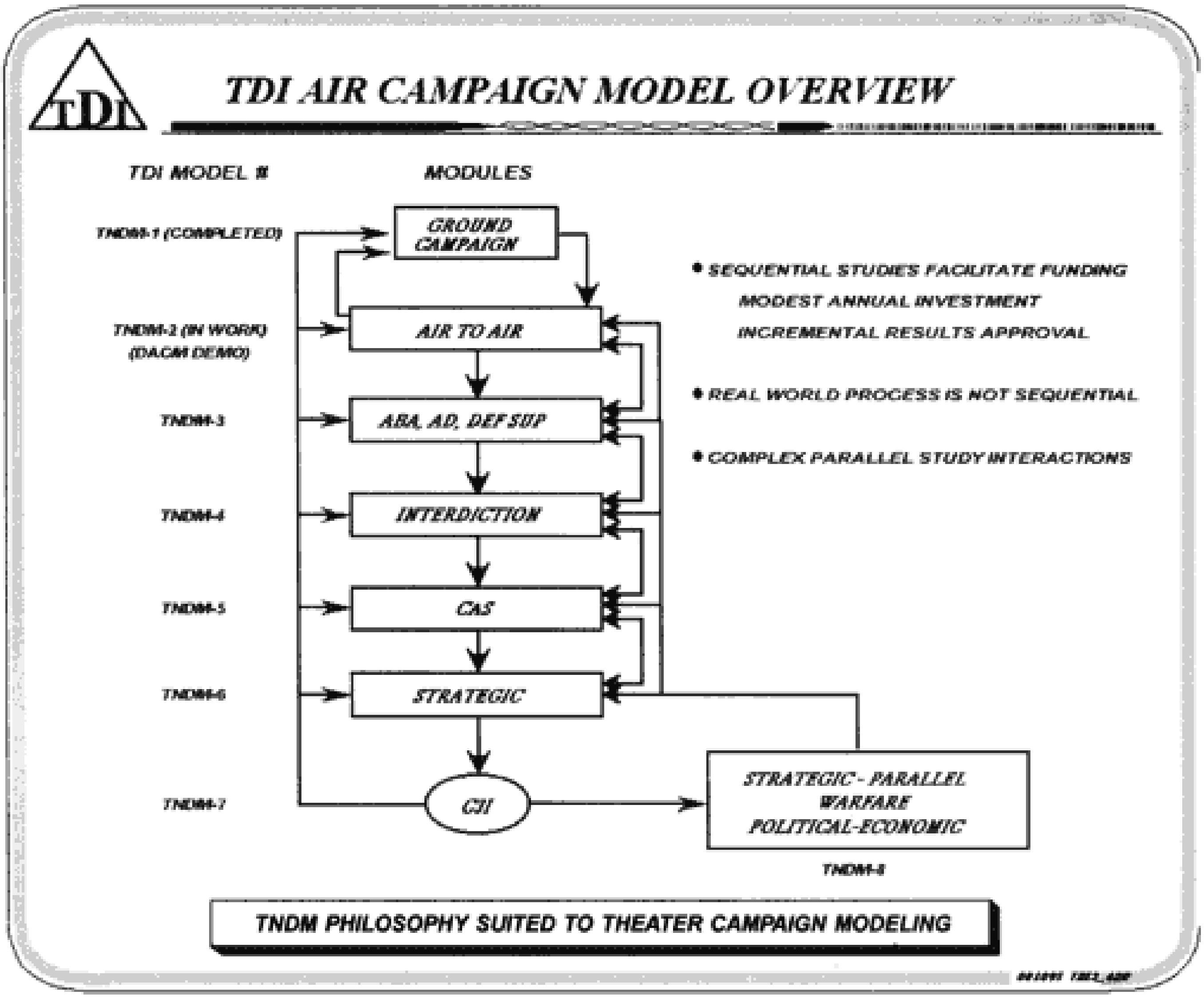
OVERVIEW

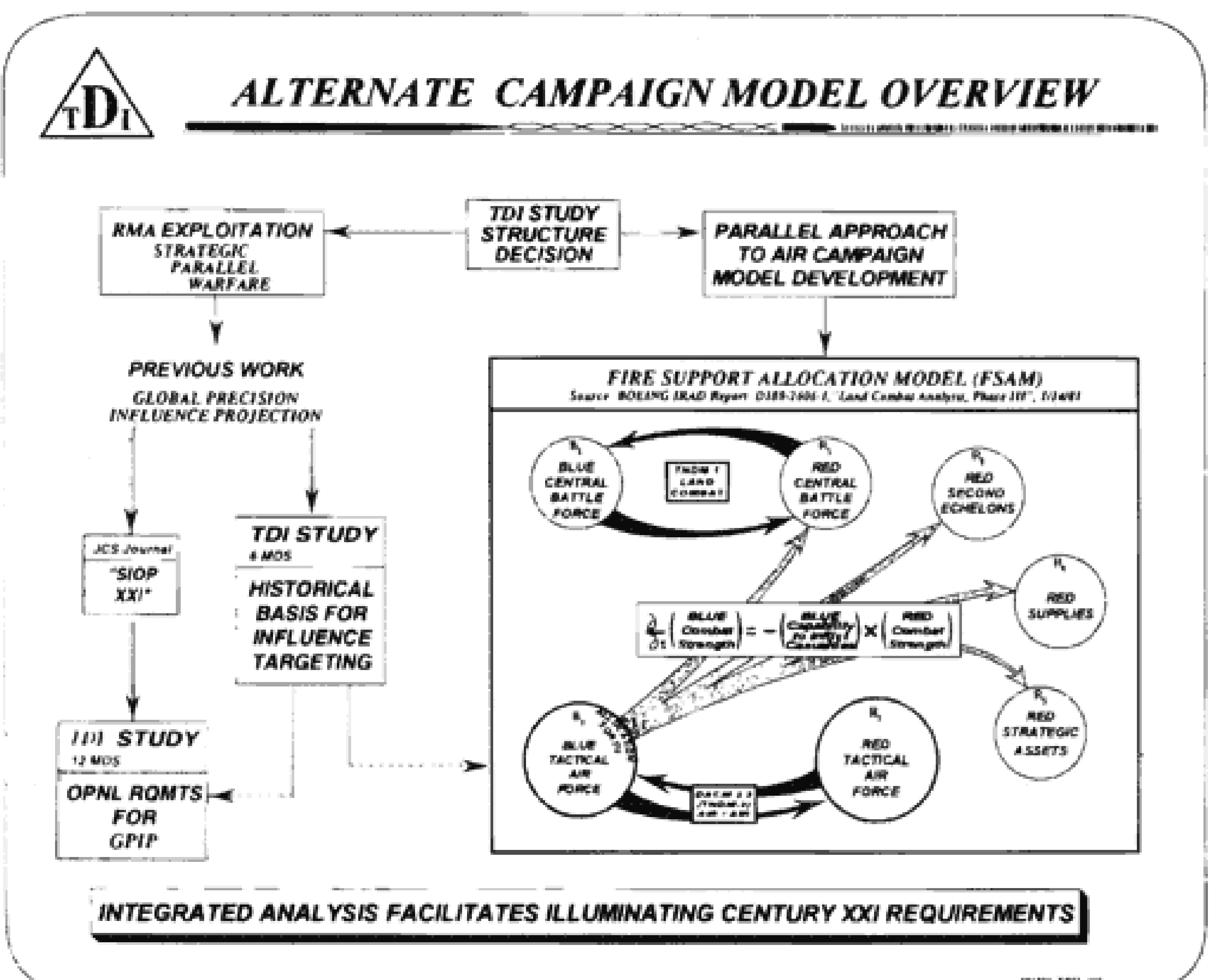
- STUDY OVERVIEW
  - STUDY ON COURSE, AIR-TO-AIR FOCUS
  - TREVOR'S DEATH . . . PROFOUND IMPACT
  - STRONG TEAM ASSEMBLED. . . SIGNIFICANT RESULTS ACHIEVED
- PELIMINARY MODEL
  - QJM / TNDM DEVELOPED FOR GROUND COMBAT
  - AIR CAMPAIGN DOMINATED BY PLATFORM PERFORMANCE
  - NEW MODEL ARCHITECTURE REQUIRED
- CURRENT TDI A/A MODEL
  - AIRCRAFT PERFORMANCE DETERMINES HOW LETHALITY EMPLOYED
  - HISTORICAL CORRELATION MECHANISM INCLUDED
  - SPREADSHEET MECHANZATION PROVIDED USEFUL TOOL
- RECOMMENDATIONS

SUMMARY OBSERVATIONS

- CONFIDENCE GROWING IN DACM METHODOLOGY
- MODEL DERIVATION FROM / CORRELATION WITH HISTORICAL EXPERIENCE SHOULD CONTINUE
- SPREADSHEET DEMO TOOL PERMITS AIR UNIVERSITY PARTICIPATION
  STUDENTS CAN PARTICIPATE IN MODEL IMPROVEMENT
- AIR-TO-AIR MODULE COMPLEMENTS QJM / TNDM GROUND MODEL
- AIR *CAMPAIGN* MODEL EXPANSION IS VERY COMPLEX

A GOOD START...NEXT LOOK AT BIG PICTURE


TDI
TDI AIR CAMPAIGN MODEL OVERVIEW
TDI MODEL #
MODULES
TNDM-1 (COMPLETED)
GROUND CAMPAIGN
TNDM-2 (IN WORK) (DACM DEMO)
AIR TO AIR
TNDM-3
ABA, AD, DEF SUP
TNDM-4
INTERDICTION
TNDM-5
CAS
TNDM-6
STRATEGIC
TNDM-7
C3I
STRATEGIC - PARALLEL WARFARE POLITICAL-ECONOMIC
TNDM-8
• SEQUENTIAL STUDIES FACILITATE FUNDING
MODEST ANNUAL INVESTMENT
INCREMENTAL RESULTS APPROVAL
• REAL WORLD PROCESS IS NOT SEQUENTIAL
• COMPLEX PARALLEL STUDY INTERACTIONS
TNDM PHILOSOPHY SUITED TO THEATER CAMPAIGN MODELING


TDI
ALTERNATE CAMPAIGN MODEL OVERVIEW
RMA EXPLOITATION
STRATEGIC PARALLEL WARFARE
TDI STUDY STRUCTURE DECISION
PARALLEL APPROACH TO AIR CAMPAIGN MODEL DEVELOPMENT
PREVIOUS WORK
GLOBAL PRECISION INFLUENCE PROJECTION
JCS Journal
"SIOP XXI"
TDI STUDY
HISTORICAL BASIS FOR INFLUENCE TARGETING
TDI STUDY
12 MOS
OPNL RQMTS FOR GPIP
FIRE SUPPORT ALLOCATION MODEL (FSAM)
BLUE CENTRAL BATTLE FORCE
RED CENTRAL BATTLE FORCE
RED SECOND ECHELONS
RED SUPPLIES
RED STRATEGIC ASSETS
BLUE TACTICAL AIR FORCE
RED TACTICAL AIR FORCE
INTEGRATED ANALYSIS FACILITATES ILLUMINATING CENTURY XXI REQUIREMENTS

INFLUENCE PROJECTION

INFLUENCE MECHANISM . . .

AN EVENT, ELEMENT, FACTOR, OR PROCESS WHICH HAS THE POTENTIAL TO CAUSE A DECISIVE CHANGE IN A COMBAT OUTCOME, A TREND IN CRISIS ESCALATION, OR A PATTERN OF NATIONAL BEHAVIOR

EXAMPLES

- LOSS OF PRINCIPAL LEADERSHIP
- FAILURE OF A MAJOR WEAPON SYSTEM
- LOSS OF CONTROL OR COMMAND CAPABILITY
- EXPLOITATION OF A TEMPORARY LOGISTICS VULNERABILITY

INFLUENCE OPERATIONS . . .

THE APPLICATION OF SPECIAL "PACKAGES" (WEAPONS, DEVICES, AND/OR FORCES), OFTEN PROJECTED FROM GREAT RANGE; TO EXCITE, INDUCE, OR EXACERBATE ONE OR MORE INFLUENCE MECHANISMS

RESEARCH NEEDED TO VALIDATE EXISTANCE AND TO BETTER DEFINE POTENTIAL INFLUENCE MECHANISMS

HISTORICAL OVERVIEW

- PRELIMINARY ASSESSMENT PROVIDED BY T. N. DUPUY (COL, USA, RET)

INFLUENCE CATEGORY	*EXAMPLE / EVENT*	*DATE*	*NOTES*
REMOVAL (LOSS) OF PRINCIPAL LEADERSHIP DURING ENGAGEMENT	JULIAN AT THE TIGRIS	363	DECISIVE DEFEAT
	HAROLD AT HASTINGS	1066	DECISIVE DEFEAT
	JOHN TALBOT AT CASTILLON	1453	PROB. LOST ANYWAY
	TURENNE AT NIEDER-SASBACH	1675	DECISIVE DEFEAT
	A. S. JOHNSON AT SHILOH	1862	PROB. LOST ANYWAY
FAILURE OF A MAJOR WEAPON SYSTEM	MACEDONIAN PHALANX AT CYNOSCEPHALAE	197 BC	
	THE LEGION AT ADRIANOPLE	378	
	ARMORED CAVALRY AT CRECY	1346	
	CROSSBOW AT CRECY	1346	
	FRENCH MITRAILLEUSE	1870	
	GERMAN MAGNETIC MINES	1939	
	GERMAN V-2	1944-45	
	IRAQI "SCUD"	1991	
LOSS OF CONTROL / COMMAND	PRINCE RUPERT AT NAESBY	1645	
	MCCLELLAND- SEVEN DAYS & ANTIETAM	1862	
	RUSSIANS AT TANNENBERG	1914	
	MOLTKE (YOUNGER) AT MARNE CAMPAIGN	1914	
	BRITISH AT FIRST GAZA	1917	
	FREDENDALL AT KASSERINE	1943	
	S. HUSSEIN IN DESERT STORM	1991	

POTENTIAL CRISIS AREAS

Projected crises are located by country of origin.
Indicated crises are conflicts which have reasonable expectation of evoking a U.S. reaction or response in which military action may be considered.

LEGEND
- POTENTIAL CRISES (42 TOTAL)
- 16 MOST DANGEROUS CRISES

Source: DUPUY, T.N.; "Global Trends in Historical Perspective", Historical Evaluation Research Organization/Boeing, Mar '90

1. BALTIC STATES
2. SOVIET CENTRAL ASIA
3. SLOVENIA
4. TRANSYLVANIA
5. BESSARABIA
6. GIBRALTAR
7. CYPRUS
- ★ PERSIAN GULF
8. BAGHDAD (NUC REACTOR)
9. ISLAMABAD (NUC REACTOR)
10. AZERBAIJAN
- ★ AFGHANISTAN
- ★ ISRAEL
- ★ LEBANON
- ★ MOSLEM COALITION
14. NEPAL
15. BURMA
- ★ KASHMIR
17. SRI LANKA
- ★ CAMBODIA
19. HONG KONG
- ★ SPRATLEY IS.
21. KURILES
- ★ KOREA
23. TAIWAN
- ★ PHILIPPINES
25. NEW CALEDONIA
26. TAHITI
27. FIJI
28. ETHIOPIA
- ★ ERITREA
30. SOMALIA
- ★ ANGOLA
32. ZAIRE
33. MOZAMBIQUE
- ★ SOUTH AFRICA
- ★ LIBYA
35. CUBA
36. HAITI
- ★ EL SALVADOR
38. NICARAGUA
39. PANAMA
- ★ PERU/COLOMBIA
41. BOLIVIA
42. FALKLAND IS.

STRATEGIC PARALLEL WARFARE

- CONCEPT OF STRATEGIC PARALLEL WARFARE IS CONSISTENT WITH *GLOBAL PRECISION INFLUENCE PROJECTION (GPIP)*

- PREVIOUSLY ACCOMPLISHED ANALYSIS ON GPIP HELPS BUILD STRONG FOUNDATION FOR NEW RESEARCH
  - INITIAL ASSESSMENTS OF INFLUENCE MECHANISMS EMERGING FROM DESERT STORM
  - PRELIMINARY VALIDATION FROM HISTORICAL PRECEDENTS
  - QUANTIFIABLE MEASURE OF TARGET PRIORITIES AND TIME SENSITIVITY

- SUBSTANTIAL DOCUMENTATION EXISTS FOR *GPIP*
  - EXPANDED EXPOSITORY BRIEFING
    - DR LABERGE. . . AMB KIRKPATRICK STAFF. . . JACKSON SCHOOL AT UW
  - "JOURNAL OF THE JCS" ESSAY CONTEST ON "REVOLUTION IN MILITARY AFFAIRS" (RMA)
    - 5000 WORD ESSAY "SIOP XXI". . . SUBMITTED AUG '95

- *SPW, RMA, GPIP* ARE COMPLEX . . . NO COMPREHENSIVE ANSWERS AVAILABLE

ATTRACTIVE OPPORTUNITY EXISTS TO BUILD ON PREVIOUS WORK

OVERVIEW

- **STUDY OVERVIEW**
  - STUDY ON COURSE, AIR-TO-AIR FOCUS
  - TREVOR'S DEATH . . . PROFOUND IMPACT
  - STRONG TEAM ASSEMBLED. . . SIGNIFICANT RESULTS ACHIEVED

- **PELIMINARY MODEL**
  - QJM / TNDM DEVELOPED FOR GROUND COMBAT
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  - NEW MODEL ARCHITECTURE REQUIRED

- **CURRENT TDI A/A MODEL**
  - AIRCRAFT PERFORMANCE DETERMINES HOW LETHALITY EMPLOYED
  - SPREADSHEET MECHANZATION PROVIDED USEFUL TOOL
  - HISTORICAL CORRELATION MECHANISM INCLUDED

- **RECOMMENDATIONS**
  - COMPLETE HISTORICAL CORRELATION FOR AIR-TO-AIR
  - SUPPORT JOINT PARTICIPATION
  - EXPAND EFFORT TO BUILD AIR CAMPAIGN MODEL
  - INITIATE STUDY ON STRATEGIC PARALLEL WARFARE BASED ON *GPIP* FOUNDATIONS

OVERVIEW

- **STUDY OVERVIEW**
  - STUDY ON COURSE, AIR-TO-AIR FOCUS
  - TREVOR'S DEATH . . . PROFOUND IMPACT
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  - SUPPORT JOINT PARTICIPATION
  - EXPAND EFFORT TO BUILD AIR CAMPAIGN MODEL
  - INITIATE STUDY ON STRATEGIC PARALLEL WARFARE BASED ON GPIP FOUNDATIONS

The Dupuy Air Campaign Model

by Col. Joseph A. Bulger, Jr., USAF, Ret.

The Dupuy Institute, as part of the DACM, created a draft model in a spreadsheet format to show how such a model would calculate attrition. Below are the actual printouts of the "interim methodology demonstration," which shows the types of inputs, outputs, and equations used for the DACM. If anyone has questions about specific details of this effort, the Institute can provide a copy of the final report. The spreadsheet format was created by Col. Bulger, while many of the formulae were the work of Robert Shaw.

```
                    DUPUY AIR COMBAT MODEL (DACM)
**********************************************************************
               INTERIM METHODOLOGY DEMONSTRATION
**********************************************************************
This demo file is loaded with aircraft and weapon data for Hurricane I,
Spitfire IA, Bf-109E4, and He-111. Two Blue acft types can engage the
Red force composed of variable numbers of Bf-109 acft.
======================================================================
Step GOTO  ALT   TABLE            Task
 1.   N4    s     I.   Input scenario data influencing sortie rates.
 2.   N24   h     II.  Input data & weights for human (pilot) factors.
     Note:  Tables I & II have been pre-loaded with preliminary data.
 3.   V3    a     III. Check aircraft performance data.
     Note:  Disregard number of sorties (#S).  Select later.
 4.   V24   w     IV.  Ckeck weapon characteristics data.
 5.   "Page Down" to go to engagement summary screen & begin runs.
 6.   Addl macros... \c > Calc scrn  \i > Input

**********************************************************************
               PLANNER INPUTS AND ENGAGEMENT SUMMARY
======================================================================
 ALLOCATE SORTIES (S)     |  SURV  LETH  APF   KILLS   LOST   ERa   ERf
======================================================================

                 *******
b  HURRICANES    *   0 *  |  4.60  53.0  0.93   0.0    0.0    na
l                *******  |                                         0.51
u  SPITFIRES     *   8 *  |  4.46  53.0  1.01   2.3    4.6   0.51
                 *******  |
____________________________________

                 *******  |
r   Bf-109E4     *   8 *  |  1.63  73.6  0.99   4.6    2.33  1.97   1.97
e                *******  |
d   He-111           0    |
======================================================================
                    TRIAL K FACTOR =    0.05
**********************************************************************
```

RECORD OF TRIALS TO DETERMINE HISTORICAL (BoB) CORRELATION

Run #	#H	#S	#Bf	Kh	Ks	Lh	Ls	ERh	ERs	ERfb	ERfr
1A	0	8	8	0.0	2.3	0.0	4.6	na	0.51	0.51	1.97
1B	4	4	8	0.6	1.6	1.7	2.3	0.32	0.72	0.55	1.82
1C	8	0	8	0.8	0.0	4.9	0.0	0.16	na	0.16	6.20

****

SCENARIO DESCRIPTION Title: Demo 1A,B,C

ITEM	SYMBOL	UNITS	BLUE	RED
Daily Operating Fraction	FRop	nd	0.5	0.5
Distance to Operating Area	DoA	nm	100	300
Max Speed for Pacing Acft	Vmax	mph	300	200
Mission Turn-around Time	Tta	hrs	0.5	0.5
Mean Time Before Failure	MTBF	hrs	20	20
Mean Time to Repair	MTTR	hrs	20	20
*Sensor Performance	SP	nd	1	1
*Avionics Performance	AV	nd	1	1
*Weight Factor...Aero Performance	Wap	nd	0.7	0.6
*Weight Factor...Weapons Performance	Wwp	nd	0.3	0.4
*Weight Factor...Numbers	Wn	nd	0.5	0.5
*Weight Factor...Tech Quality	Wq	nd	0.5	0.5

****

****

TABLE II. HUMAN FACTORS

PILOT LIMITATIONS			BLUE	RED
Pacing Acft max Endurance	ENDmax	hrs	5	10
MAx Allowable Flying Hours per Day	Hmax	hrs	6	12
PILOT EXPERIENCE				
Relevant Combat Missions	RCM	msns	75	150
Relevant Training Missions	RTM	msns	200	350
Recency of Combat Experience	RFc	mos	1	1
Recency of training Experience	RFt	mos	6	6
Missions in Current Combat Command	MCC	msns	100	300
HUMANICS WEIGHTING FACTORS				
Weight of Combat Experience	Wce	nd	0.3	0.3
Weight of Training	Wt	nd	0.2	0.2
Weight of Currency	Wc	nd	0.1	0.1
Weight of Leadership Quality	Wlq	nd	0.1	0.1
Weight of Aircrew Quality	Waq	nd	0.3	0.3

****

Notes:

****
TABLE III. FORCE COMPOSITION & PERFORMANCE CHARACTERISTICS

AIRCRAFT	S #	Msn mph	Vmax kft	Hmax hrs	Hend fp/m	BHP sqf	Aw sqf	Acrt lbs	Wt
Hurri I	0	3	311	35.0	2.0	1,030	258	56.1	6,252
Spit IA	8	3	355	37.0	2.0	1,030	242	54.2	5,481
Bf-109E4	8	3	348	35.0	2.5	1,175	174	106.6	5,205
He-111	0	1	252	27.9	5.0	1,000	942	550.0	19,136

****
Notes:

****
TABLE IV. WEAPON CHARACTERISTICS

AIRCRAFT	WEAPONS #	Type	Fpos nd	Ng nd	Vmuz fps	Wp lbs	RoF rpm	Reff nd
Hurri I	8	Br .303	1.00	2.83	2,600	0.022	1,200	0.957
Spit IA	8	Br .303	1.00	2.83	2,600	0.022	1,200	0.957
Bf-109E4	2	MG17syn	1.00	1.41	2,970	0.028	1,180	1.055
	2	MGFF20MM	1.00	1.41	1,950	0.295	350	3.755
He-111	1	MGFF20MM	1.00	1.00	1,950	0.295	350	3.755
	5	MG15flx	0.25	2.24	3,000	0.028	1,000	1.056

****

EQUATIONS FOR CALCULATING RELATIVE EFFECTIVE RANGE (Reff)

Reff = Wp^(1/3) x log(Vmuz) for machine guns

Reff = Wp^(1/3) x 23.5 x [log(Vmuz) - 3.05] for cannon

Notes:

TABLE V. CALCULATION OF AERO PERFORMANCE FACTOR (APF)

ACFT	Vmax mph	Vmax fps	Hmax kft	Reff	EGY kft	Efac nd	BHP khp	Aw sqf	Wt klb	STR	MSN TYP	APF
Hurri I	311	456	35.0	0.957	38.8	0.94	1.03	258	6.25	0.14	3	0.93
Spit Ia	355	521	37.0	0.957	41.7	1.01	1.03	242	5.48	0.16	3	1.01
Bf-109E4	348	510	35.0	3.755	41.1	0.99	1.18	174	5.21	0.15	3	0.99
He-111	252	370	27.9	1.056	30.6	0.74	1.00	942	19.1	0.09	1	0.74

EGY*=avg = 41.4 STR*=avg= 0.1557

EQUATIONS FOR CALCULATING AERO PERFORMANCE

EGY = (Vmax^2 / 2G) + Hmax + 557 x Reff for V in fps

STR = [SQRT(BHP x Aw) / Wt] x 1.75 for prop acft
STR = [SQRT(T x Aw) / Wt] for conventional jet acft
STR = [SQRT(T x Aw) / Wt] x 0.75 for delta-jet acft

APF = AP = Wegy x Efac + Wman x Tfac

Efac = EGY / EGY* where EGY* = average EGY of acft in engagement

Tfac = STR / STR* where STR* = average STR of acft in engagement

Wegy & Wman Factors

MISSION TYPE	Wegy	Wman
1. Interceptors v escorted bombers	.62	.38
2. Interceptors v non escorted bombers	.67	.33
3. Escort, fighter sweep	.57	.43
4. Bomber	1.00	0.00
5. Fighter-bomber	.57	.43

Notes:

1. For this methodology trial, all acft in same group (intcp, escort, etc) are of same type; EGY* and STR* are input by planner. In revised program, EGY* and STR* will be calculated based on average of all mixed type aircraft within same engagement.

****

TABLE VI. CALCULATION OF WEAPON BATTERY EFFECTIVENESS (EFF)

AIRCRAFT	WEAPONS Type	#	Fpos	Vmuz fps	RoF* rpm	EFF / 10^6	Ng	WE	Wp lbs	DESfac /10^6
Hurri I	Br .303	8	1.00	2,600	1,200	3.12	2.83	8.82	0.022	6.004
Spit Ia	Br .303	8	1.00	2,600	1,200	3.12	2.83	8.82	0.022	6.004
Bf-109E4	MG17syn	2	1.00	2,970	944	2.80	1.41	3.97	0.028	11.39
	MGFF20MM	2	1.00	1,950	350	0.68	1.41	0.97	0.295	197.3
He-111	MGFF20MM	1	1.00	1,950	350	0.68	1.00	0.68	0.295	33.96
	MG15flx	5	0.25	3,000	1000	0.75	2.24	0.42	0.028	11.73

****

EQUATIONS FOR CALCULATING WEAPON EFFECTIVENESS

EFF is relative capability of single weapon to hit a given target.

EFF = Fpos x Vmuz x RoF*

where RoF diminished by 20% for synch guns

WE is ability of a SET (battery) of weapons to hit target.

WE = Fpos x EFF x Ng*

where Ng* = sqrt (# guns)

DESfac is relative destructive power of a single hit.

DESfac= Wp x Vmuz^3/64.4 (machine guns)

DESfac= Vmuz x Wp x (Vmuz^2/64.4 + 28.4X10^4) (cannon)

****

TABLE VII. BATTERY LETHALITY (LETHbat) | TABL VIII. ACFT LETHALITY (LETH)

AIRCRAFT	WE	DESfac	LETH (bat)	|	EFF		LETH
Hurri I	8.82	6.00	52.99	|	3.12		52.99
Spit Ia	8.82	6.00	52.99	|	3.12		52.99
Bf-109E4	3.97	11.39	45.16	|	2.80	) combined	
	0.97	197.3	190.47	|	0.68	) leth	> 73.61
He-111	0.68	33.97	23.18	|	0.68	) combined	
	0.42	11.74	4.92		0.75	) leth	> 13.621

****

BATTERY LETHALITY

LETHbat is lethality of battery.

LETHbat = WE x DESfac

AIRCRAFT LETHALITY

LETH is combined lethality of all batteries on one aircraft.

$$\text{LETH} = \frac{\text{LETHbat1} \times \text{EFF1} + \text{LETHbat2} \times \text{EFF2} + \dots}{\text{EFF1} + \text{EFF2} + \dots}$$

Note: Incorporates Shaw revised Reff>>Eff for LETH eqn.

****

TABLE V. CALCULATION OF AIRCRAFT SORTIE LIMITS & NUMBERS (N)

AIRCRAFT	MSN #	MSN TYP	FRop	DoA nm	Vmax kts	MTTR/ MTBF	Tta hrs	END hrs	Hmax hrs	Smax ac	Smax crew	Rfac nd	N
Hurri I	3	FTR	0.50	100	270	1.00	0.5	5	6	2.2	4.1	0.753	N/A
Spit Ia	3	FTR	0.50	100	308	1.00	0.5	5	6	2.2	4.6	0.784	N/A
Bf-109E4	3	ESC	0.50	300	302	1.00	0.5	10	12	1.4	3.0	0.669	N/A
He-111	1	BMR	0.50	300	219	1.00	0.5	10	12	1.0	2.2	0.543	N/A

****

EQUATIONS FOR CALCULATING SORTIE LIMITATIONS

MISSION TYPE CODES

CODE MISSION TYPE

1. Interceptor v Escorted Bombers
2. Interceptor v Unescorted Bombers
3. Escort & Fighter Sweep
4. Bomber
5. Fighter-bomber

CONVERSION mph > kts

mph x 5280/6080 = kts

For bombers (strategic attack & interdiction) and fighter escorts;

$$Smax = 1 + \frac{24 \times FRop}{[(2 \times DoA / (.5 \times Vmax)] \times [1 + (MTTR/MTBF)] + Tta}$$

Smax = maximum sorties/day permissable for this type aircraft

For fighters, including sweeps, CAP, intercept, recce, etc;

$$Smax = 1 + \frac{24 \times FRop}{[(.5 \times END)] \times [1 + (MTTR/MTBF)] + Tta}$$

$$Rfac = [(.5 \times Hmax \times Vmax) - (2 \times DoA)] / (.5 \times Hmax \times Vmax)$$

$$N = S \times Rfac \times C3Ifac$$

Notes:

1. C3I factor not yet included in calculations...assumed = 1.0.
2. Number of Blue interceptors is a player input from page 1.
3. Number of Red sorties assumed a player input for demo case.

4. FOR DEMO CASE, N IS NOT CALCULATED...ADDN'L DERIVATION IN WORK.

TABLE VI. CALCULATION OF HUMANICS (H)

FORCE	Wce	RCM	RFc	Wt	RTM	RFt	AQ	MCC	Wc	LQ	Wlq	Waq	H
BLUE	0.3	75	1.0	0.2	200	6.0	29.2	100	0.1	39	0.1	0.3	12.7
RED	0.3	150	1.0	0.2	350	6.0	57	300	0.1	87	0.1	0.3	25.7

EQUATIONS FOR CALCULATING HUMANICS

Aircrew Quality (AQ) = Wce x RCM/RFc + Wt x (RTM/RFt)

Leadership Quality (LQ) = Wce x RCM/RFc + Wt x (RTM/RFt) +Wc x MCC

Humanics component (H) = Wlq x LQ + Waq x AQ

TABLE VII. CALCULATION OF COMBAT POTENTIALS (CP)

AIRCRAFT	Wap	AP	Wwp	WE/ 10^6	Q	Wq	Wn	N	H	CP	CP FORCE
Hurri I	0.70	0.93	0.3	3.12	1.5	0.5	0.5	N/A	12.67	10.1	20.483
Spit Ia	0.70	1.01	0.3	3.12	1.6	0.5	0.5	N/A	12.67	10.4	
Bf-109E3	0.60	0.99	0.4	2.80	1.7	0.5	0.5	N/A	25.7	22.0	31.173
He-111	0.60	0.74	0.4	0.68	0.7	0.5	0.5	N/A	25.7	9.2	

EQUATIONS FOR CALCULATING COMBAT POTENTIALS

Technical Quality = Q = [Wap x AP + Wwp x WE] x SP x AV

Note: Sensor performance (SP) and Avionics (AV) assumed = 1.0 for demo.

Combat Potential = CP = [Wn x N + Wq x Q] x H

Note: CPforce = Sum of CP for sorties within same mission.

Notes:

1. FOR THIS DEMO, COMBAT POTENTIAL NOT USED DIRECTLY...HUMANICS FACTORS SELECTED TO YIELD OVERALL (H) FACTOR FAVORING RED BY APPROX 2:1.

TABLE VIII. CALCULATION OF AIRCRAFT KILLS

AIRCRAFT	Aw sqf	Acr sqf	SURV nd	LETH nd	APF nd	S	N*	H	KILLS	LOST
Hurri I	258	56	4.60	52.99	0.93	0	0.00	12.7	0.0	0.0
Spit Ia	242	54	4.46	52.99	1.01	8	2.83		2.3	4.6
Bf-109E4	174	107	1.63	73.61	0.99	8	2.83	25.7	4.6	2.3
He-111	942	550	1.71	13.62	0.74	0	0.00			

EQUATIONS FOR CALCULATING AIRCRAFT KILLS

SURVIVABILITY = SURV = Aw / Acr

BLU KILLS=KILLSb=KxN* x (APFb/APFr) x (LETHb/SURVr) x (Hb/Hr) x N*/N*tot

Where K in a constant of proportionality to be determined by extraction from historical data.

K =0.05

N* is number of ENGAGEMENTS (1v1), a function of sorties (S). Until refined, N* will be sqrt of S, a player input.

TABLE IX. CALCULATION OF FORCE EXCHANGE RATIOS (ER)

AIRCRAFT	AP nd	LETH nd	SURV nd	H	FORCE EXCHANGE RATIOS BLUE	RED
Hurri I	0.93	52.99	4.60	12.7		
Spit Ia	1.01	52.99	4.46		0.51	
Bf-109E3	0.99	73.61	1.63	25.7		1.97
He-111	0.74	0.00	1.71			

ERb = (APFb/APFr)^2 x (LETHb/LETHr) x (Hb/Hr)^2 / (SURVr/SURVb)

ERr = 1 / ERb

Notes:
For calculation of blue losses in Table VIII, use red kill equation for each blue aircraft type, then sum blue losses to total red kills.

The Battle of Britain was the first "pure" air campaign, meaning that there were no concurrent land or naval actions which affected, or were affected by, aerial operations. There is some dissension concerning the precise start and end dates for the campaign, but most historians and writers accept a start date of 13 August 1940 (known as *Adlertag* or "Eagle Day" to the Luftwaffe) and an end date of 19 September 1940. This yields a campaign length of 37 days.

In basic terms, the Battle of Britain was an unsuccessful attempt by the German Luftwaffe's *Luftflotte* (Air Fleet, equivalent to U.S. numbered Air Forces) *2.*, headquartered at Brussels and operating from airfields in Belgium and far northeastern France, and *Luftflotte 3.*, headquartered at Paris and divided into three operational branches: Bomber Command, Coastal Command, and Fighter Command. Bomber Command controlled most bomber aircraft in Britain, while Coastal Command controlled an assortment of bomber, fighter, and reconnaissance aircraft tasked with operations over the sea areas around the British Isles. Fighter Command, of greatest import for the Battle of Britain, controlled most fighter aircraft in Britain, along with a network of radar sites and ground-based observers laid out to provide an integrated air defense system. This system was directed from Fighter Command headquarters at Stanmore, an RAF airfield some 45 km northwest of central London.

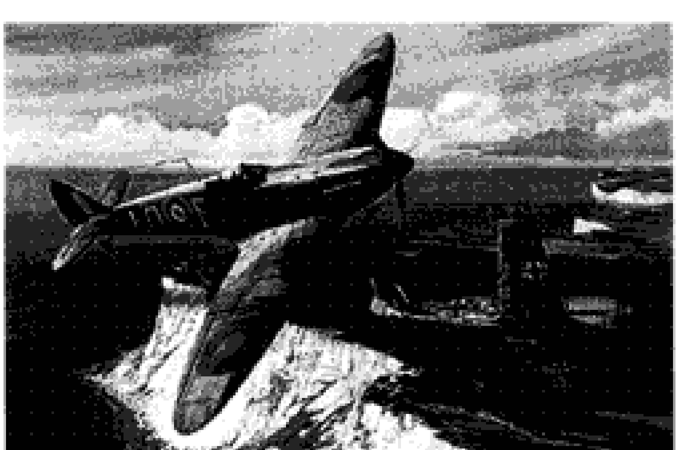
Operationally, Fighter Command was divided into total of 49 serviceable and 7 non-serviceable Hurricanes.

During the 39 days of the Battle of Britain, RAF Fighter Command lost 602 aircraft in combat, including 4 (0.66%) to British antiaircraft fire and 9 (plus one plane damaged, or 1.58%) to other RAF aircraft. The Luftwaffe lost 868 aircraft over the same period, of which 16 (1.84%) were downed by other German planes, and 37 (4.26%) fell to British antiaircraft fire. RAF Spitfires shot down an average of 3.88 German aircraft per 100 sorties, while Hurricanes downed 3.50 Germans, Blenheims downed barely 0.5 planes per 100 sorties, and the much-lamented Boulton-Paul Defiant downed an astonishing 11.2 German aircraft per 100 sorties. To put this last statistic into proper perspective, there were only 67 Defiant sorties during the entire period, and the Defiants lost 20.15 aircraft per 100 sorties. The Spitfire loss rate was 3.19 per 100 sorties, that for Hurricanes was 2.37 per 100 sorties, and that for the Blenheims (operating largely at night) was barely 0.3 per 100 sorties.

The Germans exhibited a rather different kill-rate and loss-rate picture. The Bf-109E, generally accounted the best fighter of the era, downed 4.79 RAF aircraft per 100 sorties, and lost 3.54 Bf-109Es per 100 sorties. The much-vaunted Bf-110Cs fared much worse, downing a respectable 2.72 RAF planes per 100 sorties, but losing an astonishing 6.52 *zerstörers* per 100 sorties. In that light, it is no great surprise that by early September, Luftwaffe commanders had been directed to screen Bf-110C missions with Bf-109Es, escorting their fighters with fighters!

German bombers, unfortunately for the Luftwaffe, suffered similarly. Although the slow, clumsy Ju-87 Stukas downed 1.49 RAF planes per 100 sorties while losing 4.91 of their own, the larger twin-engine bombers shot down 0.83 RAF planes per 100 sorties, and lost an appalling 3.09 of their own planes per 100 sorties. Especially for the bombers, the Germans lost the attrition struggle.

This loss imbalance occurred for several reasons. Primary among these was that when an RAF plane went down in the combat zone, its pilot was usually able to land safely on British soil, and rejoin his squadron within hours or (at most) a few days. For German aircrew, the situation was different. Even if they managed to escape the battle zone without destruction, they stood only about an even chance of reaching a German airfield safely. German aircrew that landed in the Channel were often picked up by the British, despite the determined and gallant efforts of the handful of German air-sea rescue units.



Second, the British had a major advantage in their integrated air defense system, coordinating radar early warning, ground observer confirmation, fighter interception, and antiaircraft fire. Although the British were sometimes outfoxed by the Germans (who twice staged dummy bombing raids, which turned back before reaching the British coast, to draw British fighters out into ambush by German fighter sweeps), in general they were able to attack every German raid, and claim a plane or two at the very least.

Third, the Germans had not conceived of a long-term campaign where replacement aircrew and aircraft would become an important factor, were ill-prepared for this, and after a few weeks, units had to stand down for a period to integrate new pilots and planes. The RAF, on the other hand, had created a comprehensive system to keep a steady stream of new pilots and aircraft flowing to the operational squadrons. In fact, as heavy as Fighter Command's losses were during the period (they lost almost 90% of their initial pool of serviceable aircraft), the serviceable aircraft totals in Fighter Command generally rose during the 39-day campaign, fed by steady production from Britain's aircraft factories.

Fourth, and most important from the German point of view, was a failure to recognize Fighter Command's points of vulnerability. Although the Germans directed a number of raids against the coastal radar sites, they had little indication of the success of these attacks, and (more important yet) did not comprehend how crucial these sites were to Fighter Command's resistance. Linked to this was a general failure by the Luftwaffe to coordinate and orchestrate its target selection: the Germans sent only one strike at Stanmore, and few raids at the regional Group headquarters (Uxbridge for No. 11 Group, and Box for No. 10).

The German failure to recognize the most important targets in Britain was ultimately very costly to them, since their considerable offensive effort was dissipated, directed against a variety of targets of varying importance, and leaving the vital command-and-control infrastructure of RAF Fighter Command essentially intact.

The data availability for the Battle of Britain is extraordinary. Not only are operational records for British forces intact, but considerable German material is available also, despite efforts by G÷ring and the senior Luftwaffe leadership to destroy the service's records at the end of the war. Moreover, there is an ongoing archaeological effort to identify and catalog the wrecked aircraft from the battle, scattered around the countryside of southern England, and in the shallow waters immediately offshore. As a result of years of effort, most of it by dedicated amateurs, nearly all of these wrecked planes have been identified by unit, crew, and (most of them) aircraft serial number. Consequently, it is possible for even modest secondary sources to provide an accurate minute-by-minute account of the principal actions.

There are some problems, not least the fact that the British were operating under Double Daylight Saving Time, so that British times are two hours off from German times. This must be borne in mind when reconstructing actions. Further, some minor mysteries remain, like planes lost at night over water and never recovered.

Numerical Adjustment of CEV Results: Averages and Means

by Christopher A. Lawrence and David L. Bongard

As part of the battalion–level validation effort, we made two runs with the model—one without CEV incorporated and one with the CEV incorporated. The printout of a TNDM run will have three CEV figures for each side: CEV_t, CEV_l and CEV_{ad}. CEV_t shows the CEV as calculated on the basis of battlefield results as an ratio of the performance of side a versus side b. It measures performance based upon three factors: mission accomplishment, advance, and casualty effectiveness. CEV_t is calculated according to the following formula:

$CEV_a = (R_a/R_d)/(P'_a/P'_d)$

$R_a = Mf_a + Esp_a + Ecas_a$ a = attacker

$R_d = Mf_d + Esp_d + Ecas_d$ d = defender

MF = Mission Factor
Assigned by judgement with a value ranging from 1 through 10 for each side.

Esp = Calculated spatial effectiveness factor

$Esp_a = \sqrt{[(S_a \times us_a)/(S_d \times us_d)]} \times (4Q + D_d)/3D_a$

Esp_d = as above, exchange "d" for "a"

S = Strength (total OLI)

us = is taken from Table 6 (Posture Factor for Force Strength)

Q = distance advanced

D = depth in kilometers occupied the troops of each side (see table 20).

Ecas = Calculated casualty effectiveness factor

$Ecas_a = v_d^2 \times \sqrt{[(Cas_d \times us_a/S_d)/(Cas_a \times us_d/S_a)} - \sqrt{100\, Cas_a/N_a}]$

$Ecas_d$ = as above, exchange "d" for "a".

v = Vulnerability score. v_d is calculated:

$v_d = 1 - (V_d/S_d)$

$v_d = N_d(uv/ru) \times S_a/S_d \times yv \times rv$

yv = Air superiority effect

rv = Shoreline vulnerability effect

Cas = Number of casualties

N = Number of Personnel

P' = Refined Combat Power Ratio (sum of the modified OLIs). The ' in P' indicates that this ratio has been "refined" (modified) by two behavioral values already, this is the factor for Surprise and the Set Piece Factor.

$CEV_d = 1/CEV_a$ (the reciprocal)

In effect the formula is relative results times modified combat power ratio. This is basically the formulation that was used for the QJM.

In the TNDM Manual, there is an alternate CEV method based upon comparative effective lethality. This methodology has the advantage that the user doesn't have to evaluate mission accomplishment on a ten point scale. The CEVl calculated according to the following formula:

$CEV_l = \sqrt{(L_a/L_d)}$

$L_a = K_a/(us_a \times ru_a \times hu_a \times zu_a \times (\sqrt{sz_a}))$

L_d = as above, exchange "d" for "a"

ru = terrain factor

hu = weather factor

zu = season factor

sz = size

In effect, CEV_t is a measurement of the difference in predicted results from actual results based upon three different factor (mission success, advance rates, and casualties), while CEV_l is a measurement of the difference in predicted casualties from actual casualties. The CEV_t and the CEV_l of the defender is the reciprocal of the one for the attacker.

Now the problem comes in when one creates the CEV_{ad}, which is the average of the two CEVs above. I simply do not know why it was decided to create a alternate CEV calculation from the old QJM method, and then average the two, but this is what is currently being done in the model. This averaging results in a revised CEV for the attacker and for the defender that are not reciprocals of each other, unless the CEV_t and the CEV_l were the same. We even have some cases where both sides had a CEV_{ad} of greater than one. Also, by averaging the two, we have heavily weighted casualty effectiveness relative to mission effectiveness and mission accomplishment.

What was done in these cases (again based more on tradition or habit, and not on any specific rule) was:

1. If CEV_{ad} are reciprocals, then use as is.

2. If one CEV is greater than one while the other is less than 1, then add the higher CEV to the value of the reciprocal of the lower CEV (1/X) and divide by two. This result is the CEV for the superior force, and its reciprocal is the CEV for the inferior force.

3. If both CEVs are above zero, then we divide the larger CEV_{ad} value by the smaller, and use its result as the superior force's CEV.

CEV_{ad} value by the smaller, and use its result as the superior force's CEV.

In the case of point three, this methodology usually results in a slightly higher CEV for the attacker side than if we used the average of the reciprocal (usually .1 or .2 higher). While the mathematical and logical consistency of the procedure bothered me, the logic used for the different procedure in point three was that the model was clearly having a problem with predicting the engagement to start with, but that in most cases when this happened before (meaning before the validation), a higher CEV usually produced a better fit than a lower one. As this is what was done before, I accepted it as is, especially if one looks at the example of Mediah Farm. If one averages the reciprocal with the US's CEV of 8.065, one would get a CEV of 4.13. By this methodology, one comes up with a more reasonable US CEV of 1.58.

The interesting aspect is that the rules manual explains how CEV_t, CEV_l and CEV_{ad} are calculated, but never is it explained which CEV_{ad} (attacker or defender) you should use. This is the first explanation of this process, and was based upon the "traditions" used at TDI. There is a strong argument to merge the two CEVs into one formulation. I am open to another methodology for calculating CEV. I am not satisfied with how CEV is calculated in the TNDM and intend to look into this further. Expect another article on this subject in the next issue.

The First Test of the TNDM Battalion–Level Validations: Predicting the Winners

by Christopher A. Lawrence

In the basic concept of the TNDM battalion–level validation, we decided to collect data from battles from three periods: WWI, WWII and Post–WWII. We then made a TNDM run of each battle exactly as the battle was laid out, with both sides having the same CEV. The results of that run indicated what the CEV should have been for the battle, and we then made a second run using that CEV. That was all we did. We wanted to make sure that there was no "tweaking" of the model for the validation, so we stuck rigidly to this procedure. We then evaluated each run for its fit in three areas:

1. Predicting the winner/loser
2. Predicting the casualties
3. Predicting the advance rate

We did end up changing two engagements around. We had a similar situation with one WWII engagement (Tenaru River) and one modern period engagement (Bir Gifgafa), where part–way through the battle the defender received reinforcements and counterattacked. In both cases we decided to run them as two separate battles (adding two more battles to our database), with the conditions from the first engagement being the starting strength, plus the reinforcements, for the second engagement. Based on our previous experience with running Goose Green, for all the Falklands Island battles we counted the Milans and Carl Gustavs as infantry weapons. That is the only "tweaking" we did that affected the battle outcome in the model. We also put in a casualty multiplier of 4 for WWI engagements, but that is discussed in the article on casualties.

This is the analysis of the first test, predicting the winner/loser. Basically, if the attacker won historically, we assigned it a value of 1, a draw was 0, and a defender win was -1. In the TNDM results summary, it has a column called "winner" which records either an attacker win, a draw, or a defender win. We compared these two results. If they were the same, this is a "correct" result. If they are "off by one," this means the model predicted an attacker win or loss, where the actual result was a draw, or the model predicted a draw, where the actual result was a win or loss. If they are "off by two" then the model simply missed and predicted the wrong winner.

The results are (the envelope please....):

	1st Run (CEV = 1.0)	2nd Run (CEV adjusted)
WWI		
Correct	13	18
Off by one	5	1
Off by two	5	4
WWII		
Correct	17	17
Off by one	2	5
Off by two	4	1
Modern		
Correct	22	29
Off by one	3	0
Off by two	5	1
	% Correct 1st Run	*% Correct 2nd Run*
WWI	57	78
WWII	74	74
Modern	73	97
TOTAL	**68**	**84**

It is hard to determine a good predictability from a bad one. Obviously, the initial WWI prediction of 57% right is not very good, while the Modern second run result of 97% is quite good. What I would really like to do is compare these outputs to some other model (like TACWAR) to see if they get a closer fit. I have reason to believe that they will not do better.

Most cases in which the model was "off by 1" were easily correctable by accounting for the different personnel capabilities of the army. Therefore, just to look where the model really failed, let's just look at where it simply got the wrong winner:

	% Dead Wrong 1st Run	% Dead Wrong 2nd Run
WWI	22	17
WWII	17	4
Modern	17	3
TOTAL	**18**	**8**

The TNDM is not designed or tested for WWI battles. It is basically designed to predict combat between 1939 and the present. The total percentages without the WWI data in it are:

	Less WWI
Percent Correct, 1st Run	74
Percent Correct, 2nd Run	87
Percent Dead Wrong, 1st Run	17
Percent Dead Wrong, 2nd Run	4

Overall, based upon this data I would be willing to claim that the model can predict the correct winner 75% of the time without accounting for human factors and 90% of the time if it does.

CEVs: Quite simply a user of the TNDM must develop a CEV to get a good prediction. In this particular case, the CEVs were developed from the first run. This means that in the second run, the numbers have been juggled (by changing the CEV) to get a better result. This would make this effort meaningless if the CEVs were not fairly consistent over several engagements for one side versus its other side. Therefore, they are listed below in broad groupings so that the reader can determine if the CEVs appear to be basically valid or are simply being used as a "tweak".

Now, let's look where it went wrong. The following battles were not predicted correctly:

Off by One 1st Run	Off by Two 1st Run	Off by One 2nd Run	Off by Two 2nd Run
WWI			
Hill 252	Hill 142	Mayache	La Neuville
West Woods I	North Woods I		North Woods I
Boureshes I	Chaudun		
West Wood II	Medeah Farm		Medeah Farm
Yvonne-Odette	Exermont		Exermont
WWII			
Edson's Ridge	Makin Raid	Edson's Ridge	VER-RDMX
Lausdell XRds		Lausdell XRds	
	VER-2ASX	VER-2ASX	
	VER-XHLX		
	VER-CHX	VER-CHX	
		VER-9CX	
Modern			
Goose Green	Tu-Vu		Tu-Vu
Two Sisters	Mapu		
Cuatir River	Bir Gifgafa II		
	Mt. Langdon		
	Tumbledown		

There are 19 night engagements in the data base, five from WWI, three from WWII, and 11 modern. We looked at whether the miss prediction was clustered among night engagements, and that did not seem to be the case. Unable to find a pattern, we examined each engagement to see what the problem was. See the attachments at the end of this article for details.

We did obtain CEVs that showed some consistency. These are shown below. The Marines in World War I record the following CEVs in these WWI battles:

Battle	Marine Regt	CEV	German Unit
Hill 142	*5th Marines*	*1.5*	*273rd Regt*
West Wood I	*5th Marines*	*0.4*	*461st Regt*
Bouresches I	*6th Marines*	*0.7*	*461st Regt*
West Wood II	*5th Marines*	*1.4*	*461st Regt*
North Wood I	*5th Marines*	*1.5*	*110th Gren Regt*
Bouresches II	5th Marines	1.2	109th Regt
North Wood III	5th Marines	1	347th Regt
North Wood IV	5th Marines	1.4	347th Regt
Essen Hook	5th Marines	0.9	2nd Koeln LS Abt
Average		**1.1**	
Median		**1.2**	

Compare those figures to the performance of the US Army:

Battle	Army Regt	CEV	German Unit
Yvonne-Odette	*9th Inf*	*0.5*	*Sturmgrp Grethe*
Cantigny	28th Inf	0.6 or 0.2	272nd Regt
North Wood II	7th Inf	0.7	347th Regt
St. Amand Farm	28th Inf	1.5	396th Regt
Beaurepaire Farm	23rd Inf	1.1	219th Regt
Chaudun	*18th Inf*	*2.5*	*109th Bav Gren Regt*
Berzy-le-Sec	28th Inf	0.8	109th Regt
Bunzancy Ridge	18th Inf	0.8	52nd Jaeger Regt
Medeah Farm	*9th Inf*	*1.6*	*235th Regt*
Exermont	*18th Inf*	*0.9*	*3rd Gds Regt*
Mayache Ravine	*26th Inf*	*0.7*	*170th Regt*
La Neuville	*28th Inf*	*0.7*	*1111th Regt*
Remlyal	16th Inf	0.9	6th Res Jaeger Bn
Hill 252	*16th Inf*	*1.5*	*14th Res Inf Div*
Average		**1.1**	
Average (less high & low)		**1**	
Median		**0.85**	

In the above two and in all following cases, the italicized battles are the ones with which we had prediction problems.

For comparison purposes, the CEVs were recorded in the battles in World War II between the US and Japan:

Battle	US Unit	CEV	Japanese Unit
Wake	1st Mar Def Bn	0.7	IJN Wake SNLF
Makin	*2nd Mar Rdr Bn*	*2.4*	*IJA Makin Garrison*
Tenaru I	1st Marine Rgt	1.4	IJA Ichiki Det
Tenaru II	1st Marine Rgt	1.3	IJA Ichiki Det
Edson Ridge	*1st Mar Rdr Bn*	*1.5*	*IJA Kawaguchi Force*
Engebi	22nd Marine Rgt	0.8	IJA/IJN Engebi Garr
Enipar	106th Inf Rgt	0.8	1st Amph Bde
Average		**1.3**	
Median		**1.3**	

For comparison purposes, the following CEVs were recorded in Operation Veritable:

Battle	Britsh Regt	CEV	German Unit
VER7BW	Black Watch	0.6	1062nd Inf Regt
VER57G	7th Gordn Hlndrs	0.7	1062nd Inf Regt
VER1BW	Black Watch	0.9	1222nd Inf Regt
VER1HL	Highland Light	0.8	84th ID
VER4RW	Royal Welch Fus	0.8	84th ID
VER10B	Ox & Bucks Lt	0.9	84th ID
VER1GH	Glasgow Hlndrs	0.7	84th ID
VER9C	*Cameronians*	*0.8*	*84th ID*
VER2AS	*Argyll & Sutherlnd*	*1.3*	*1222nd Inf Regt*
VERXHL	*Highland Light*	*1.3*	*1222nd Inf Regt*
VERRDM	*Rgt de Maisonn*	*0.6*	*1222nd Inf Regt*
VERCH	*Calgary Hlndrs*	*1.3*	*1222nd Inf Regt*
Average		**0.9**	
Median		**0.8**	

These are the other engagements versus Germans for which CEVs were recorded:

Battle	Army Division	CEV	German Unit
Chouigui Pass	1st AR/1st AD	1.6	10th PzD
Mte Maggiore	1st RCT/36th ID	1	15th PzGrD
Lausdell XRds	*9th Inf/2nd ID*	*1.1*	*KG Mueller/12th SS*
Assenois	CCR/4th AD	1.4	KG/26th VGD
Average		**1.3**	
Median		**1.3**	

For comparison purposes, the following CEVs were recorded in the post–WWII battles between Vietnamese forces and their opponents:

Battle	Opposing Force	CEV	German Unit
Tu-Vu	*French Moroccan*	*0.8*	*Vietminh*
Bindin	French	1.2	Vietminh
Longtan	Australian	1.2	VC
HL450	US (502nd Abn)	1.1	NVA
Prek Klok I	US (1st ID)	1.6	NVA
Prek Klok II	US (2nd Inf Regt)	1.4	VC
Buell	US (22nd Inf Regt	2.1	NVA
Ap Bau Bang	US (3/5th Cav)	3.2	VC
Lo Giang I	US (6th Inf Regt)	1.5	VC
Lo Giang II	US (6th Inf Regt)	2	VC
Nui Baden	US (22nd Inf Regt	1.4	VC
Average		**1.6**	
Median		**1.4**	

Battle	ARVN	CEV	VC
Caolan	ARVN	0.4	VC
Cainuoc	ARVN	1.1	VC
ZBO50963	ARVN	3.4	VC
Average		**1.6**	

Note that the Americans have a average CEV advantage of 1.6 over the NVA (only three cases) while having a 1.8 advantage over the VC (6 cases).

For comparison purposes, the following CEVs were recorded in the battles between the British and Argentines:

Battle	UK Regt	CEV	Argentine Unit
Goose Green	*Para Regt*	*2.4*	*12th Regt*
Mt Harriet	42nd RM Cdo	2.3	4th Regt
Two Sisters	*45th RM Cdo*	*1.7*	*4th Regt*
Mt Longdon	*Para Regt*	*2.3*	*7th Regt*
Mt Tumbledown	*Scots Guard*	*1.9*	*5th Marine Bn*
Wireless Ridge	Para	1.9	7th Regt
Average		**2.1**	
Median		**2.1**	

Battle	Expected Higher CEV Force	CEV	Expected Lower CEV Force
Mapu	*UK*	*2.6*	*Indonesia*
Bir Gifgafa I	Israel	1.5	Egypt
Bir Gifgafa II	*Israel*	*3.5*	*Egypt*
Hermon I	Israel	0.8	Syria
Salinas	US (75th Rngrs)	1.6	Cuba & Grenada
Pearls	US (USMC)	2.9	Grenada
Lomba	RSA	3.5	ANTISA
Cuatir River	*RSA*	*2.3*	*Angola*
Lipanda	RSA	3.6	Angola
TF Bayonet	US	1.2	Panama
Average		**2.4**	
Median		**2.5**	

CONCLUSIONS:

For the WWI battles, the nature of the prediction problems are summarized as:

Problem Engagement	Definition of Winner	Assign Proper CEV	Unexplained CEV Correction	Problem Result
Yvonne-Odette (N)	Y			
Hill 142		Y		
West Wood I			Y	
Bouresches I (N)	Y			
West Wood II		Y		
North Wood I		Y		
Chaudun			Y	
Medeah Farm				Y
Exermont				Y
Mayache Ravine				Y
La Neuville				Y
Hill 252			Y	
	2	3	3	4

CONCLUSION: In the case of the WWI runs, five of the problem engagements were due to confusion of defining a winner or a clear CEV existing for a side that should have been predictable. Seven out of the 23 runs have some problems, with three problems resolving themselves by assigning a CEV value to a side that may not have deserved it. One (Medeah Farm) was just off any way you look at it, and three suffered a problems because historically the defenders (Germans) suffered surprisingly low losses. Two had the battle outcome predicted correctly on the first run, and then had the outcome incorrectly predicted after CEV was assigned.

With 5 to 7 clear failures (depending on how you count them), this leads one to conclude that the TNDM can be relied upon to predict the winner in a WWI battalion–level battle in about 70% of the cases.

WWII (8 cases):

For the WWII battles, the nature of the prediction problems are summarized as:

Problem Engagement	Definition of Winner	Assign Proper CEV	Unexplained CEV Correction	Problem Result
Makin Raid		Y		
Edson's Ridge (N)	Y			
Lausdell XRds	Y			
VER-9CX				Y
VER-2ASX				Y
VER-XHLX			Y	
VER-RDMX				Y
VER-CHX				Y
	2	1	1	4

CONCLUSION: In the case of the WWII runs, three of the problem engagements were due to confusion of defining a winner or a clear CEV existing for a side that should have been predictable. Four out of the 23 runs suffered a problem because historically the defenders (Germans) suffered surprisingly low losses and one case just simply assigned a possible unjustifiable CEV. This led to the battle outcome being predicted correctly on the first run, then incorrectly predicted after CEV was assigned.

With 3 to 5 clear failures, one can conclude that the TNDM can be relied upon to predict the winner in a WWII battalion–level battle in about 80% of the cases.

Modern (8 cases):

For the post–WWII battles, the nature of the prediction problems are summarized as:

Problem Engagement	Definition of Winner	Assign Proper CEV	Unexplained CEV Correction	Problem Result
Tu-Vu				Y
Mapu		Y		
Bir Gifgafa II (N)		Y		
Goose Green		Y		
Two Sisters (N)		Y		
Mt Longdon (N)		Y		
Tumbledown		Y		
Cuatir River		Y		
		7		1

CONCLUSION: In the case of the modern runs, only one result was a problem. In the other seven cases, when the force with superior training is given a reasonable CEV (usually around 2), then the correct outcome is achieved.

With only one clear failure, one can conclude that the TNDM can be relied upon to predict the winner in a modern battalion–level battle in over 90% of the cases.

FINAL CONCLUSIONS: In this article, the predictive ability of the model was examined only for its ability to predict the winner/loser. We did not look at the accuracy of the casualty predictions or the accuracy of the rates of advance. That will be done in the next two articles. Nonetheless, we could not help but notice some trends.

First and foremost, while the model was expected to be a reasonably good predictor of WWII combat, it did even better for modern combat. It was noticeably weaker for WWI combat. In the case of the WWI data, all attrition figures were multiplied by 4 ahead of time because we knew that there would be a fit problem otherwise.

This would strongly imply that there were more significant changes to warfare between 1918 and 1939 than between 1939 and 1989.

Secondly, the model is a pretty good predictor of winner and loser in WWII and modern. Overall, the model predicted the winner in 68% of the cases on the first run and in 84% of the cases in the run incorporating CEV.

While its predictive powers were not perfect, there were 13 cases where it just wasn't getting a good result (17%). Over half of these were from WWI, only one from the modern period.

In some of these battles it was pretty obvious who was going to win. Therefore, the model needed to do a step better than 50% to be even considered. Historically, in 51 out of 76 cases (67%), the larger side in the battle was the winner. One could predict the winner/loser with a reasonable degree of success by just looking at that rule. But the percent of the time the larger side won varied widely with the period. In WWI the larger side won 74% of the time. In WWII it was 87%. In the modern period it was a counterintuitive 47% of the time, yet the model was best at selecting the winner in the modern period.

The model's ability to predict WWI battles is still questionable. It obviously does a pretty good job with WWII battles and appears to be doing an excellent job in the modern period. We suspect that the difference in prediction rates between WWII and the modern period is caused by the selection of battles, not by any inherit ability of the model.

RECOMMENDED CHANGES: While it is too early to settle upon a model improvement program, just looking at the problems of winning and losing, and the ancillary data to that, leads me to three corrections:

1. *Adjust for times of less than 24 hours.* Create a formula so that battles of six hours in length are not ¼ the casualties of a 24–hour battle, but something greater than that (possibly the square root of time). This adjustment should affect both casualties and advance rates.

2. *Adjust advance rates for smaller units* to account for the fact that smaller units move faster than larger units.

3. *Adjust for fanaticism* to account for those armies that continue to fight after most people would have accepted the result, driving up casualties for both sides.

CASE STUDIES: WHERE AND WHY THE MODEL FAILED CORRECT PREDICTIONS

World War I (12 cases):

Yvonne-Odette (Night)—On the first prediction, selected the defender as a winner, with the attacker making no advance. The force ratio was 0.5 to 1. The historical results also show the attacker making no advance, but rate the attacker's mission accomplishment score as 6 while the defender is rated as 4. Therefore, this battle was scored as a draw.

On the second run, the Germans (Sturmgruppe Grethe) were assigned a CEV of 1.9 relative to the US 9th Infantry Regiment. This produced a draw with no advance.

This appears to be a result that was corrected by assigning the CEV to the side that would be expected to have that advantage. There is also a problem in defining who is the winner.

Hill 142—On the first prediction the defending Germans won, whereas in the real world the attacking Marines won. The Marines are recorded as having a higher CEV in a number of battles, so when this correction is put in the Marines win with a CEV of 1.5. This appears to be a case where the side that would be expected to have the higher CEV needed that CEV input into the combat run to replicate historical results.

Note that while many people would expect the Germans to have the higher CEV, at this juncture in WWI the German regular army was becoming demoralized, while the US Army was highly motivated, trained and fresh. While I did not initially expect to see a superior CEV for the US Marines, when I did see it I was not surprised. I also was not surprised to note that the US army had a lower CEV than the Marine Corps or that the German Sturmgruppe Grethe had a higher CEV than the US side. As shown in the charts below, the US Marines' CEV is usually higher than the German CEV for the engagements of Belleau Wood, although this result is not very consistent in value. But this higher value does track with Marine Corps legend. I personally do not have sufficient expertise on WWI to confirm or deny the validity of the legend.

West Wood I—On the first prediction the model rated the battle a draw with minimal advance (.265 km) for the attacker, whereas historically the attackers were stopped cold with a bloody repulse. The second run predicted a very high CEV of 2.3 for the Germans, who stopped the attackers with a bloody repulse. The results are not easily explainable.

Bouresches I (Night)—On the first prediction the model recorded an attacker victory with an advance of .5 kms. Historically, the battle was a draw with an attacker advance of one km. The attacker's mission accomplishment score was 5, while the defender's was 6. Historically, this battle could also have been considered an attacker victory. A second run with an increased German CEV to 1.5 records it as a draw with no advance. This appears to be a problem in defining who is the winner.

West Wood II—On the first run, the model predicted a draw with an advance of .3 kilometers. Historically, the attackers won and advanced 1.6 kilometers. A second run with a US CEV of 1.4 produced a clear attacker victory. This appears to be a case where the side that would be expected to have the higher CEV needed that CEV input into the combat run.

North Woods I—On the first prediction, the model records the defender winning, while historically the attacker won. A second run with a US CEV of 1.5 produced a clear attacker victory. This appears to be a case where the side that would be expected to have the higher CEV needed that CEV input into the combat run.

Chaudun—On the first prediction, the model predicted the defender winning when historically, the attacker clearly won. A second run with an outrageously high US CEV of 2.5 produced a clear attacker victory. The results are not easily explainable.

Medeah Farm—On the first prediction, the model recorded the defender as winning when historically the attacker won with high casualties. The battle consists of a small number of German defenders with lots of artillery defending against a large number of US attackers with little artillery. On the second run, even with a US CEV of 1.6, the German defender won. The model was unable to select a CEV that would get a correct final result yet reflect the correct casualties. The model is clearly having a problem with this engagement.

Exermont—On the first prediction, the model recorded the defender as winning when historically the attacker did, with both the attacker's and the defender's mission accomplishment scores being rated at 5. The model did rate the defender's casualties too high, so when it calculated what the CEV should be, it gave the defender a higher CEV so that it could bring down the defender's losses relative to the attackers. Otherwise, this is a normal battle. The second prediction was no better. The model is clearly having a problem with this engagement due to the low defender casualties.

Mayache Ravine—The model predicted the winner (the attacker) correctly on the first run, with the attacker having an opposed advance of .8 km. Historically, the attacker had an opposed rate of advance of 1.3 kms. Both sides had a mission accomplishment score of 5. The problem is that the model predicted higher defender casualties that the attacker, while in the actual battle the defender had lower casualties that the attacker. On the second run, therefore, the model put in a German CEV of 1.5, which resulted in a draw with the attacker advancing .3 kms. This brought the casualty estimates more in line, but turned a successful win/loss prediction into one that was "off by one." The model is clearly having a problem with this engagement due to the low defender casualties.

La Neuville—The model also predicted the winner (the attacker) correctly here, with the attacker advancing .5 km. In the historical battle they advanced 1.6 kms. But again, the model predicted lower attacker losses than the defender losses, while in the actual battle the defender losses were much lower than the attacker losses. So, again on the second run, the model gave the defender (the Germans) a CEV of 1.4, which turned an accurate win/loss prediction into an inaccurate one. It still didn't do a very good job on the casualties. The model is clearly having a problem with this engagement due to the low defender casualties.

Hill 252—On the first run, the model predicts a draw with a distanced advanced of .2 kms, while the real battle was an attacker victory with an advance of 2.9 kms. The model's casualty predictions are quite good. On the second run, the model correctly predicted an attacker win with a US CEV of 1.5. The distance advanced increases to .6 km, while the casualty prediction degrades noticeably. The model is having some problems with this engagement that are not really explainable, but the results are not far off the mark.

World War II (8 cases):

Overall, we got a much better prediction rate with WWII combat. We had eight cases where there was a problem. They are:

Makin Raid—On the first run, the model predicted a defender win. Historically, the attackers (US Marines) won with a 2.5 km advance. When the Marine CEV was put in (a hefty 2.4), this produced a reasonable prediction, although the advance rate was too slow. This appears to be a case where the side that would be expected to have the higher CEV needed that CEV input into the combat run in order to replicate historical results.

Edson's Ridge (Night)—On the first run, the model predicted a defender win. Historically, the battle must be considered at best a draw, or more probably a defender win, as the mission accomplishment score of the attacker is 3 while the defender in 5.5. The attacker did advance 2 km, but suffered heavy casualties. The second run was done with a US CEV of 1.5. This maintained a defender win and even balanced more in favor of the Marines. This is clearly a problem in defining who is the winner.

Lausdell X-Roads (Night)—On the first run, the model predicted an attacker victory with an advance rate of .4 kms. Historically, the German attackers advanced .75 km, but had a mission accomplishment score of 4 versus the defender's mission accomplishment score of 6. A second run was done with a US CEV of 1.1, but this did not significantly change the result. This is clearly a problem in defining who is the winner.

VER-9CX—On the first run, the attacker is reported as the winner. Historically this is the case, with the attacker advancing 12 km although suffering higher losses than the defender. On the second run, however, the model predicted that the engagement was a draw. The model assigned the defenders (German) a CEV of 1.3 relative to the attackers in attempt to better reflect the casualty exchange. The model is clearly having a problem with this engagement due to the low defender casualties.

VER-2ASX—On the first run, the defender was reported as the winner. Historically, the attacker won. On the second run, the battle was recorded as a draw with the attacker (British) CEV being 1.3. This high CEV for the British is not entirely explainable, although they did fire a massive suppressive bombardment. In this case the model appears to be assigning a CEV bonus to the wrong side in an attempt to adjust a problem run. The model is still clearly having a problem with this engagement due to the low defender casualties.

VER-XHLX—On the first run, the model predicted that the defender won. Historically, the attacker won. On the second run, the battle was recorded an attacker win with the attacker (British) CEV being 1.3. This high CEV is not entirely explainable. There is no clear explanation for these model results.

VER-RDMX—On the first run, the model predicted that the attacker won. Historically, this is correct. On the second run, the battle recorded that the defender won. This indicates an attempt by the model to get the casualties correct. The model is clearly having a problem with this engagement due to the low defender casualties.

VER-CHX—On the first run, the model predicted that the defender won. Historically, the attacker won. On the second run, the battle was recorded as an attacker win with the attacker (Canadian) CEV being 1.3. Again, this high CEV is not entirely explainable. The model appears to be assigning a CEV bonus to the wrong side in an attempt to adjust a problem run. The model is still clearly having a problem with this engagement due to the low defender casualties.

Modern (8 cases):

Tu–Vu—On the first run, the model predicted a defender win. Historically, the attackers (Viet Minh) won with a 2.8 km advance. When the CEV for the Viet Minh was put in (1.2), the defender still won. The real problem in this case is the horrendous casualties taken by both sides, with the defending Moroccans losing 250 out of 420 people and the attacker losing 1200 out of 7000 people. The model predicted only 140 and 208 respectively. This appears to address a fundamental weakness in the model, which is that if one side is willing to attack (or defend) at all costs, the model simply cannot predict the extreme losses. This happens in some battles with non–first world armies, with the Japanese in WWII, and apparently sometimes with the WWI predictions. In effect, the model needs some mechanism to predict fanaticism that would increase the intensity and casualties of the battle for both sides. In this case, the increased casualties certainly would have resulted in an attacker advance after over half of the defenders were casualties.

Mapu—On the first run the model predicted an attacker (Indonesian) win. Historically, the defender (British) won. When the British are given a hefty CEV of 2.6 (as one would expect that they would have), the defender wins, although the casualties are way off for the attacker. This appears to be a case in which the side that would be expected to have the higher CEV needed that CEV input into the combat run.

Bir Gifgafa II (Night)—On the first run the model predicted a defender (Egyptian) win. Historically the attacker (Israel) won with an advance of three kilometers. When the Israelis are given a hefty CEV of 3.5 (as historically they have tended to have), they win, although their casualties and distance advanced are way off. These errors are probably due to the short duration (one hour) of the model run. This appears to be a case where the side that would be expected to have the higher CEV needed that CEV input into the combat run in order to replicate historical results.

Goose Green—On the first run the model predicted a draw. Historically the attacker (British) won. The first run also included the "cheat" of counting the Milans as regular weapons versus AT. When the British are given a hefty CEV of 2.4 (as one could reasonably expect that they would have) they win, although their advance rate is too slow. Casualty prediction is quite good. This appears to be a case where the side that would be expected to have the higher CEV needed that CEV input into the combat run.

Two Sisters (Night)—On the first run the model predicted a draw. Historically the attacker (British) won yet again. When the British are given a CEV of 1.7 (as one would expect that they would have) the attacker wins, although the advance rate is too slow and the casualties a little low. This appears to be a case where the side that would be expected to have the higher CEV needed that CEV input into the combat run.

Mt. Longdon (Night)—On the first run the model predicted a defender win. Historically the attacker (British) won as usual. When the British are given a CEV of 2.3 (as one would expect that they should have) the attacker wins, although as usual the advance rate is too slow and the casualties a little low. This appears to be a case where the side that would be expected to have the higher CEV needed that CEV input into the combat run.

Tumbledown—On the first run the model predicted a defender win. Historically the attacker (British) won as usual. When the British were given a CEV of 1.9 (as one would expect that they should have), the attacker wins, although as usual, the advance rate is too slow and the casualties a little low. This appears to be a case where the side that would be expected to have the higher CEV needed that CEV input into the combat run.

Cuatir River—On the first run the model predicted a draw. Historically, the attacker (The Republic of South Africa) won. When the South African forces were given a CEV of 2.3 (as one would expect that they should have) the attacker wins, with advance rates and casualties being reasonably close. This appears to be a case where the side that would be expected to have the higher CEV needed that CEV input into the combat run.

The Second Test of the TNDM Battalion–Level Validations: Predicting Casualties

by Christopher A. Lawrence

Actually, I was pretty pleased with the first test of the TNDM, predicting winners and losers. I wasn't too pleased with how it did with WWI, but was quite pleased with its prediction of post–WWII combat. But I knew from our previous analysis that we were going to have some problems with the casualty prediction estimates for WWI, for any battles that the Japanese were involved with, and for shorter engagements.

The problems in prediction of casualties, as related to certain nationalities, were discussed in *Numbers, Predictions, and War*. In the original QJM, as published in *Numbers, Predictions, and War*, three special conditions served as attrition multipliers. These were:

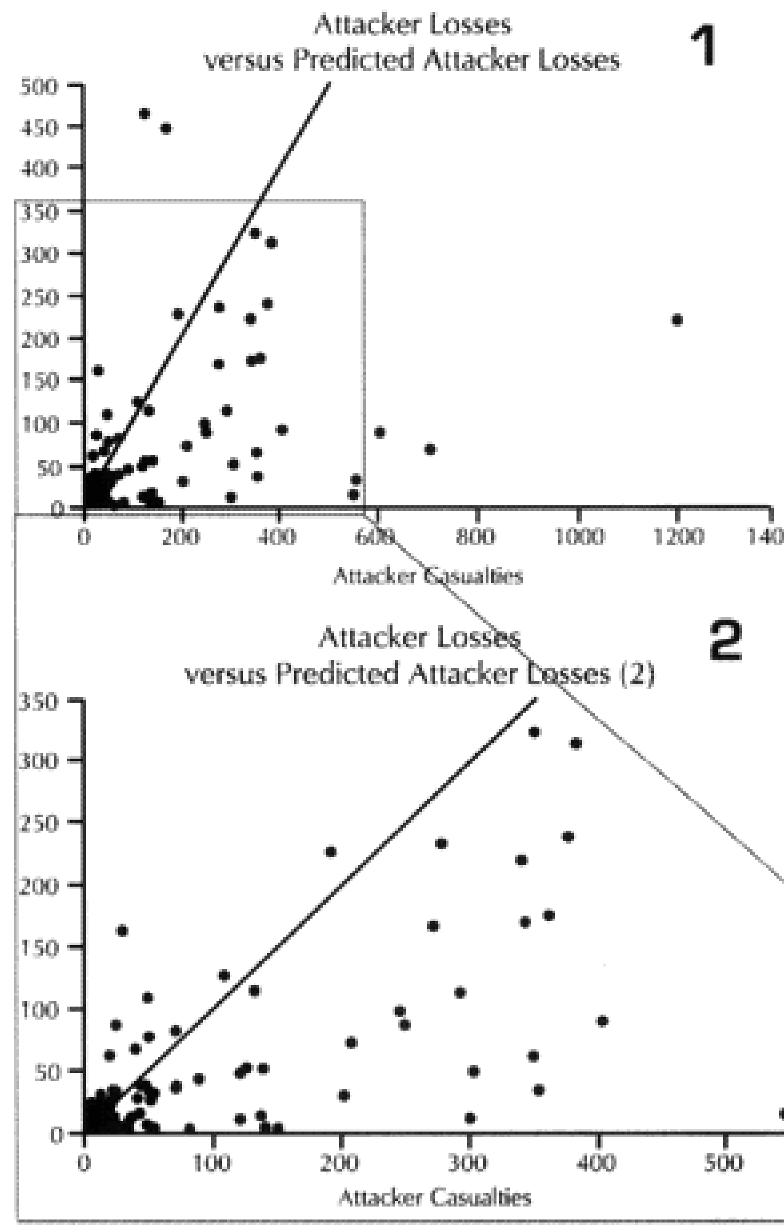
1. For period 1900–1945, Russian and Japanese rates are double those calculated.
2. For period 1914–1918, rates as calculated must be doubled; for Russian, Turkish, and Balkan forces they must be quadrupled.
3. For 1950–1953 rate as calculated will apply for UN forces (other than ROK); for ROK, North Koreans, and Chinese rates are doubled.

The attrition calculation for the TNDM is different from that used in the QJM. Actually the attrition calculations for the later versions of the QJM differ from the earlier versions. The base casualty rates that are used in the original QJM are very different from those used in the TNDM. See my articles in Volume 1, Issue 3. Basically the QJM starts with a based factor of 2.8% for attackers versus 4% for the TNDM, while its base factor for defenders is 1.5% versus 6% for the TNDM.

When Dave Bongard did the first TNDM runs for this validation effort, he automatically added in an attrition multiplier of 4 for all the WWI battles. This undocumented methodology was implemented by Mr. Bongard instinctively because he knew from experience that you need to multiply the attrition rates by 4 for WWI battles. I decided to let it stand and see how it measured up during the validation.

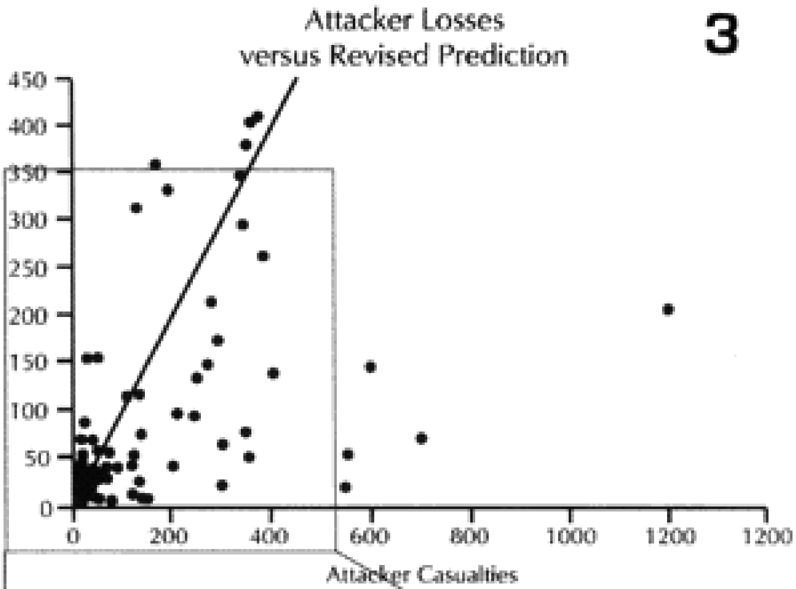
We then made our two model runs for each validation, first without the CEV, and a second run with the CEV incorporated. I believe the CEV results from this methodology are explained in the previous article on winners and losers.

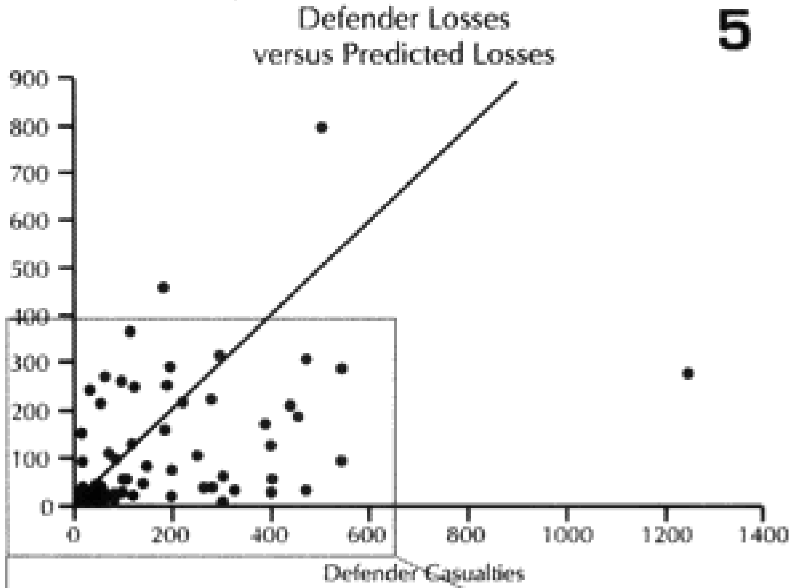
At the top of the next column is a comparison of the attacker losses versus the losses predicted by the model (graphs 1 and 2). This is in two scales, so you can see the details of the data. The diagonal line across these graphs and across the next seven graphs is the "perfect prediction" line, with any point on that line being perfectly predicted. The closer a point is to that line, the better the prediction. Points to the left of that line is where the model over–predicted casualties, while the points to the right is where the model under-predicted.

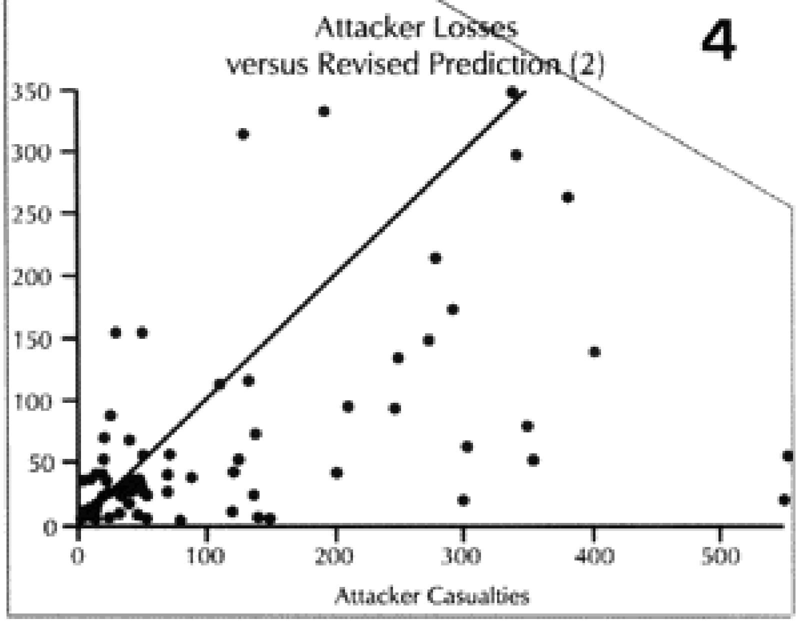


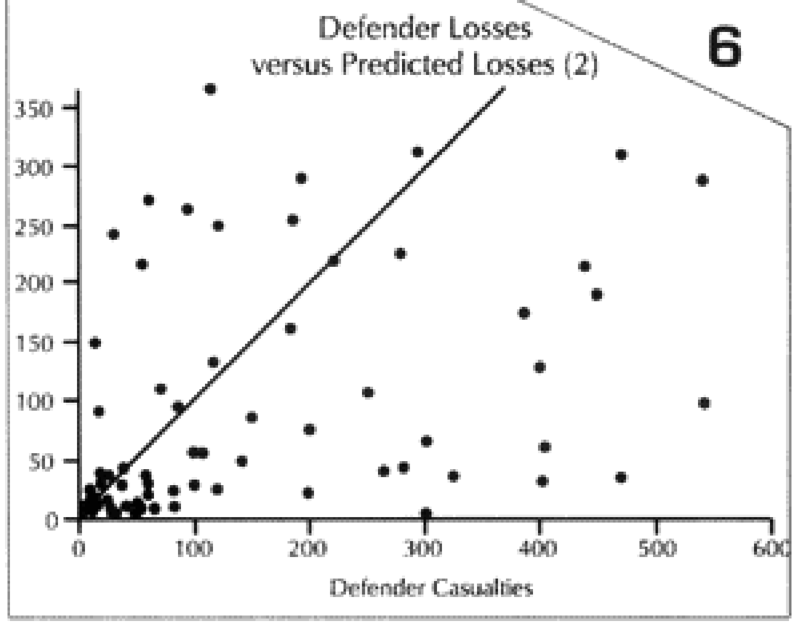
We also ran the model using the CEV as predicted by the model. This "revised prediction" is shown in the next graph (see graphs 3 and 4). We also have done the same comparison of total casualties for the defender (see graphs 5 through 8).

The model is clearly showing a tendency to under-predict. This is shown in the next set of graphs, where we divided the predicted casualties by the actual casualties. Values less than one are under-predictions. That means everything below the horizontal line shown on the graph (graph 9) is under-predicted. The same tests were done the "revised pre-









diction" (meaning with CEV) for the attacker and the both predictions for the defender (graphs 10–12).

I then attempted to do some work using the total casualty figures, followed by a series of meaningless tests of the data based upon force size. Force sizes range widely, and the size of forces committed to battle has a significant impact on the total losses. Therefore, to get anything useful, I really needed to look at percent of losses, not gross losses. These are displayed in the next 6 graphs (graphs 13–18).

Comparing our two outputs (model prediction without CEV incorporated and model prediction with CEV incorporated) to the 76 historical engagements gives the following disappointing results:

Attacker Percent Losses		
	Average	Std Dev
Actual	9.50	
Predicted	5.22	11.94
Predicted with CEV	5.75	10.73

Defender Percent Losses		
	Average	Std Dev
Actual	26.59	
Predicted	14.62	29.57
Predicted with CEV	17.93	27.49

The standard deviation was measured by taking each predicted result, subtracting from it the actual result, squaring it, summing all 76 cases, dividing by 76, and taking the square root. (see sidebar *A Little Basic Statistics* below.)

First and foremost, the model was under–predicting by a factor of almost two. Furthermore it was running high

A LITTLE BASIC STATISTICS:

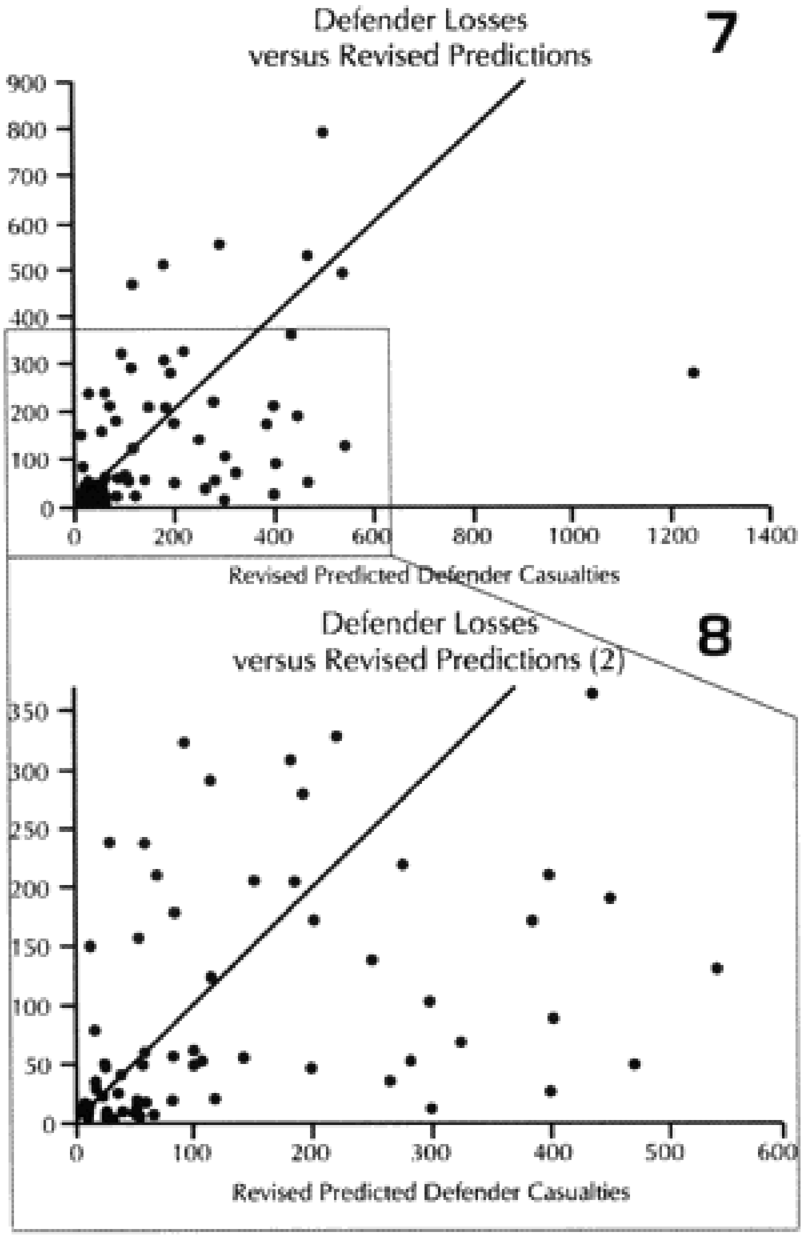
The mean is 5.75 for the attacker and 17.93 for the defender, the standard deviation is 10.73 for the attacker and 27.49 for the defender. The number of examples is 76, the degree of freedom is 75. Therefore the confidence intervals are:

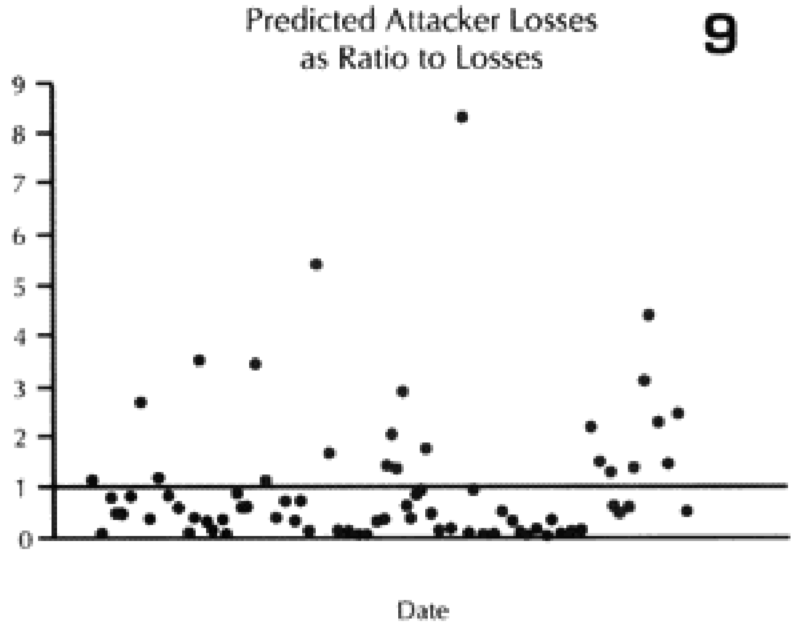
Attacker Confidence Interval	Average		T-stat	x	10.73 / 76	Confidence Interval Low	High
80%	5.75	+/-	1.295	x	1.231	4.16	7.34
85%	5.75	+/-	1.669	x	1.231	3.70	7.80
90%	5.75	+/-	1.994	x	1.231	3.30	8.20

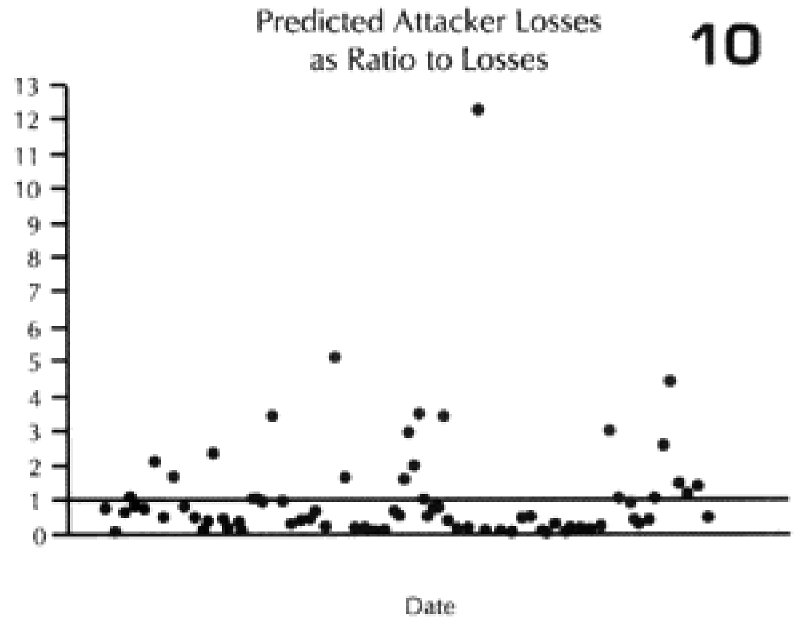
With the actual average being 9.50, we are clearly predicting too low.

Defender Confidence Interval	Average		T-stat	x	27.49 / 76	Confidence Interval Low	High
80%	17.93	+/-	1.295	x	3.153	13.85	22.01
85%	17.93	+/-	1.669	x	3.153	12.67	23.19
90%	17.93	+/-	1.994	x	3.153	11.64	24.22

With the actual average being 26.59, we are again clearly predicting too low.







standard deviations. This last result did not surprise me considering the nature of the battalion–level combats.

The addition of the CEVs did not significantly change the casualties. This is because in the attrition equations, the conditions of the battlefield play an important part in determining casualties. People in the past have claimed that the CEVs were some type of fudge factor. If that is the case, then it is a damned lousy fudge factor. If the TNDM is getting a good prediction on casualties, it is not because of a CEV "fudge factor."

TIME AND THE TNDM:

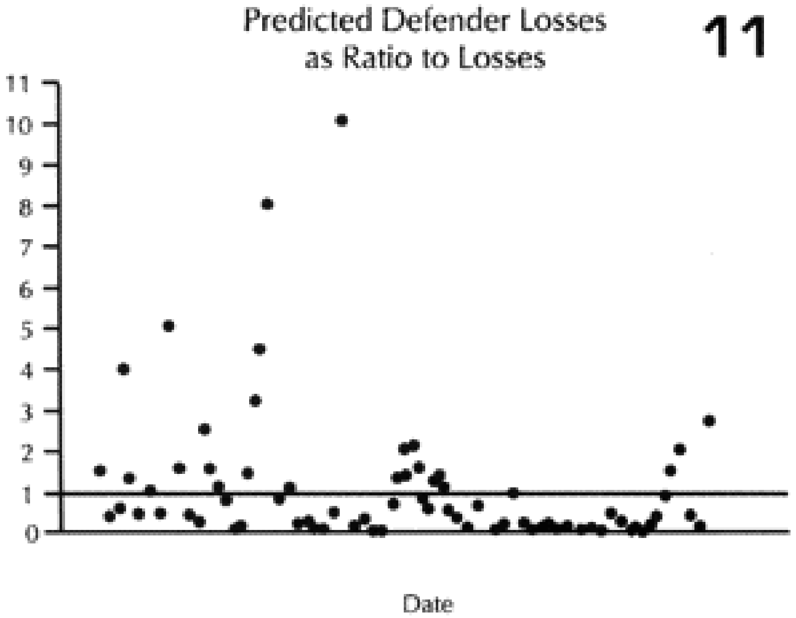
Before this validation was even begun, I knew we were going to have a problem with the fact that most of the engagements were well below 24 hours in length. This problem was discussed in depth in Volume 1, Number 3 of this newsletter. The TNDM considers the casualties for an engagement of less than 24 hours to be reduced in direct proportion to that time. I postulated that the relationship was geometric and came up with a formulation that used the square root of that fraction (i.e., instead of 12 hours being .5 times casualties, it was now .75 times casualties). Being wedded to this idea, I tested this formulation in all ways and for several days. I really wasn't getting a better fit. All I really did was multiply all the points so that the predicted average was closer. The top-level statistics were:

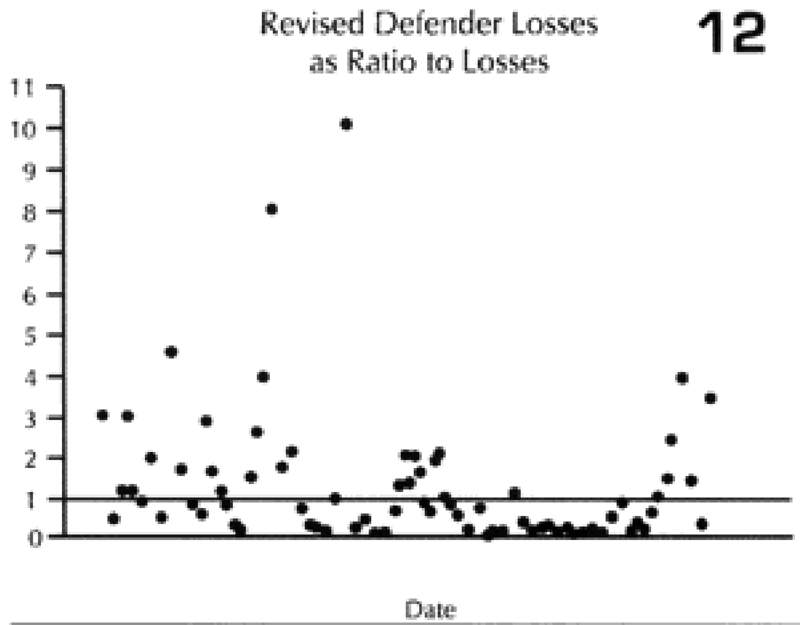
Attacker % Losses	*Average*	*Std Dev*
Predicted x TF	9.66	12.55
Revised Predicted x TF	10.95	12.17
Defender % Losses	*Average*	*Std Dev*
Predicted x TF	25.83	28.76
Revised Predicted x TF	30.57	29.22

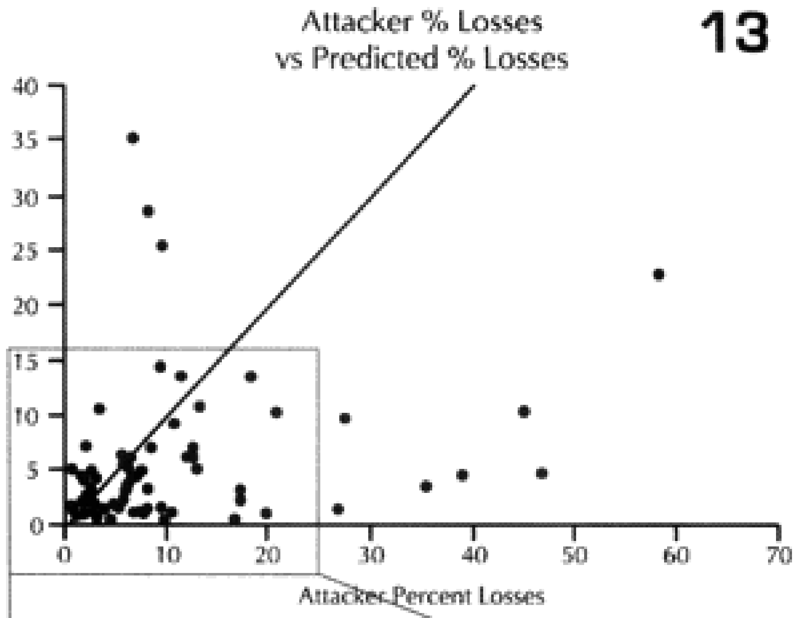
TF = Time Factor

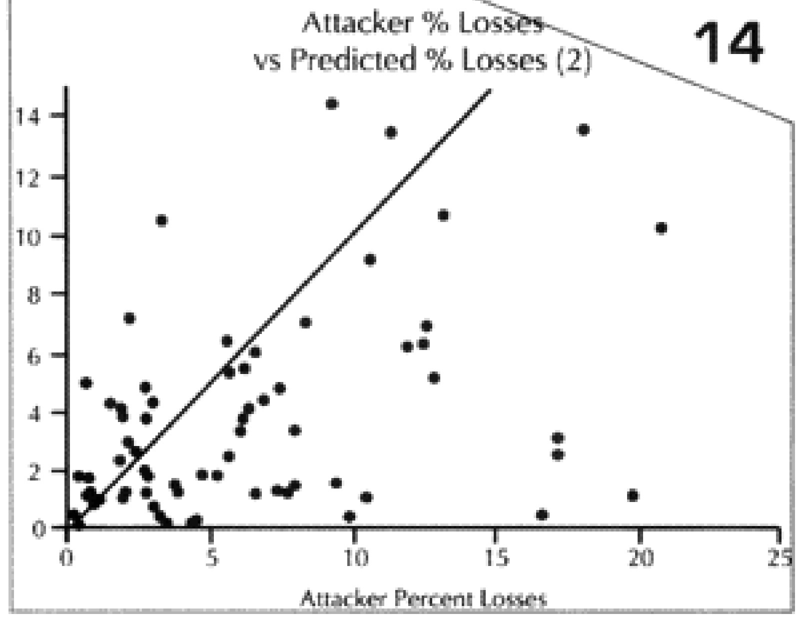
I also looked out how the losses matched up by one of three periods (WWI, WWII, and Post–WWII). When we used the time factor multiplier for the attackers, the WWI engagements average became too high, and the standard deviation increase, same with WWII, while the post–WWII averages were still too low, but the standard deviations got better. For the defender, we got pretty much the same pattern, except now the WWII battles were under–predicting, but the standard deviation was about the same. It was quite clear that all I had with this time factor was noise.

Like any good chef, my failed experiment went right down the disposal. This formulation died a natural death. But looking by period where the model was doing well, and where









it wasn't doing well is pretty telling. The results were:

Attacker % Losses	WWI		WWII		Post-WWII	
	Average	Std Dev	Average	Std Dev	Average	Std Dev
Actual	8.05		7.36		12.26	
Predicted	6.93	7.21	5.11	8.91	4.01	16.14
Revised Predicted	7.45	5.42	5.62	8.49	4.55	14.63

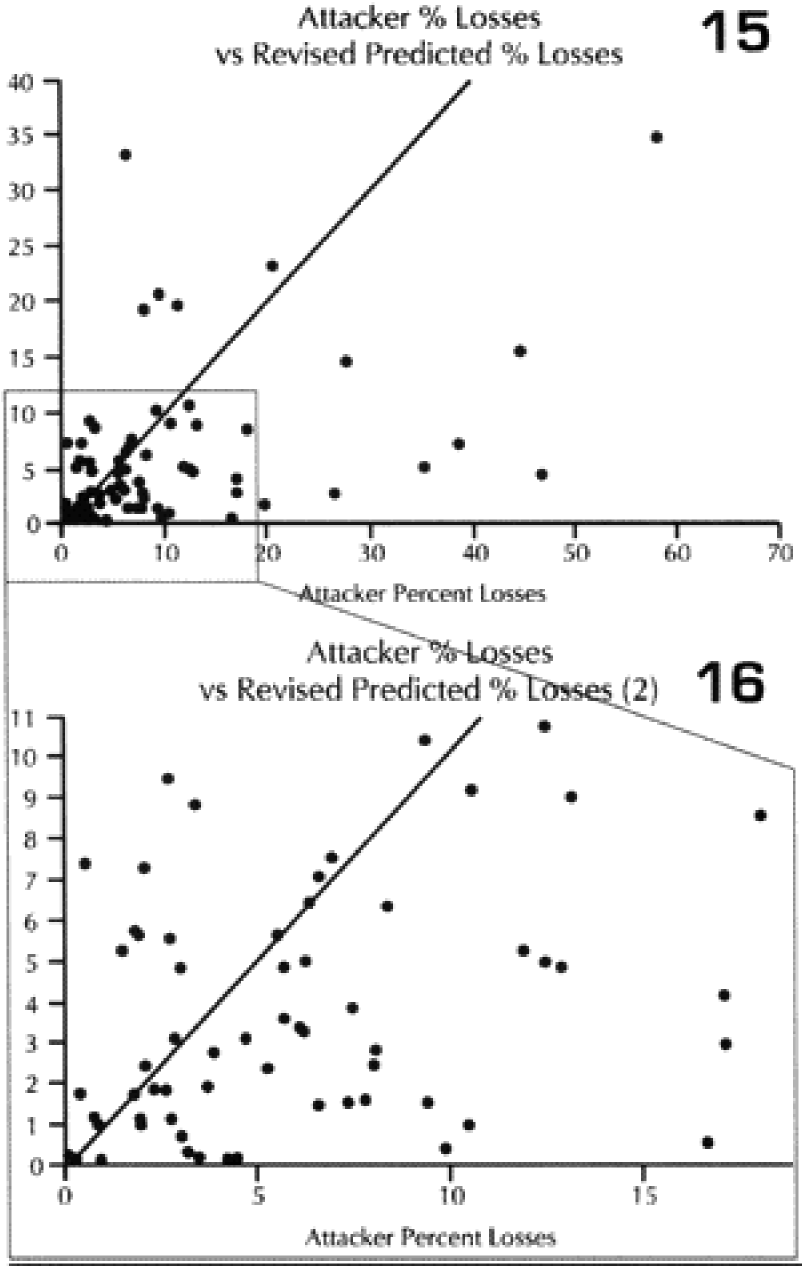
Defender % Losses	WWI		WWII		Post-WWII	
	Average	Std Dev	Average	Std Dev	Average	Std Dev
Actual	26.29		26.58		26.84	
Predicted	25.88	29.25	11.16	32.20	8.63	27.66
Revised Predicted	29.41	27.74	14.25	29.38	11.94	25.75

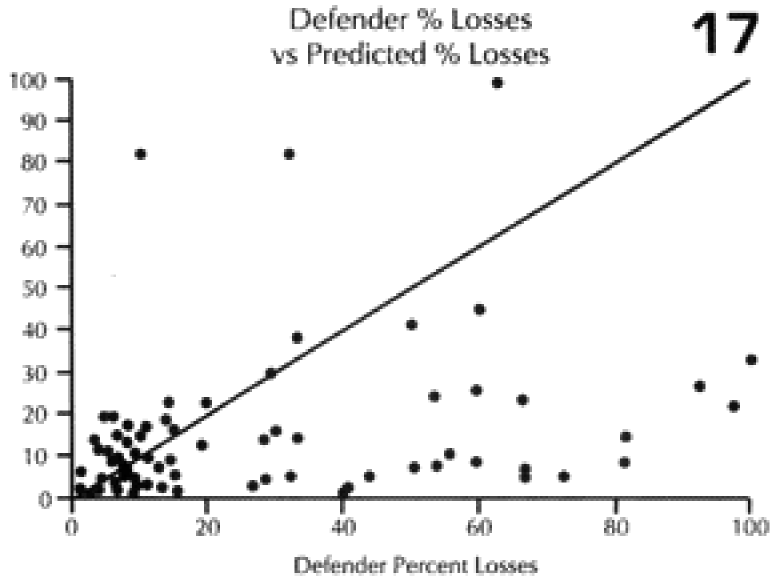
Looking at the basic results, I could see that the model was doing just fine in predicting WWI battles, although its standard deviation for the defenders was still poor. It wasn't doing very well with WWII, and performed quite poorly with modern engagements. This was the exact opposite effect to our test on predicting winners and losers, where the model did best with the post–WWII battles and worst with the WWI battles. Recall that we implemented an attrition multiplier of 4 for the WWI battles. So it was now time to look at each battle, and figure out where were we really off. In this case, I looked at casualty figures that were off by a significant order of magnitude. The reason I looked at significant orders of magnitude instead of percent error, is that making a mistake like predicting 2% instead of 1% is not a very big error, where as predicting 20%, and having the actual casualties 10%, is pretty significant. Both would be off by 100%.

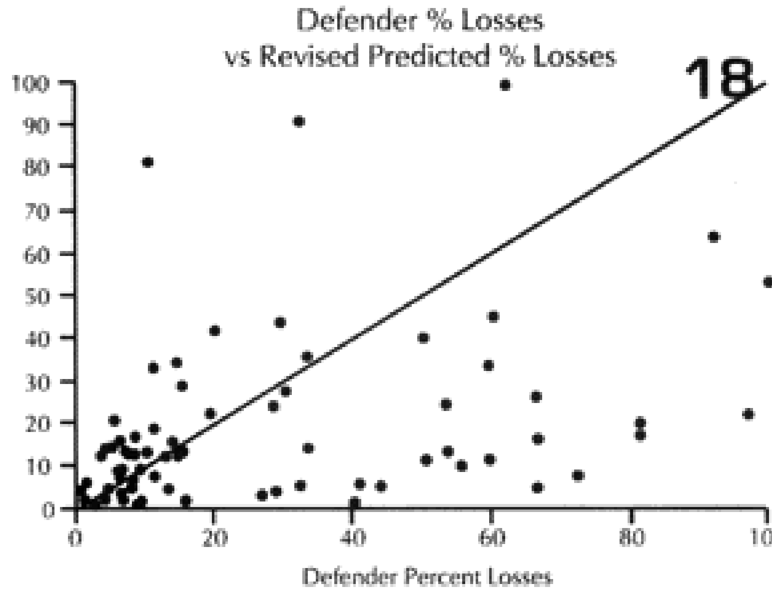
SO WHERE WERE WE REALLY OFF? (WWI)

In the case of the attackers, we were getting a result in the ball park in two–thirds of the cases, and only two cases—N Wood I and Chaudun—were really off. Unfortunately, for the defenders we were getting a reasonable result in only 40% of the cases, and the model had a tendency

World War I Attacker		
Predicted Casualties Off By:	**Predicted**	**CEV Predicted**
-10 to -25	West Wood I	
-5 to -10	Bouresches I	
	St Amand	St Amand
	Bouzancy Rdg	Bouzancy Rdg
	Medeah Farm	Medeah Farm
	Essen Hook	Essen Hook
-5 to +5	14 cases	15 cases
+5 to +10	Remilly	Remilly
		North Wood II
+10 to +25	North Wood I	North Wood I
	Chaudun	Chaudun







World War I Defender Predicted Casualties Off By:	*Predicted*	*CEV Predicted*
-25 or more	Cantigny	Cantigny
	St Amand	St Amand
	Medeah Farm	Medeah Farm
	Essen Hook	Essen Hook
-10 to -25	West Wood II	
	North Wood IV	
-5 to -10	Hill 142	
	Bouzancy Rdg	Bouzancy Rdg
-5 to +5	6 cases	9 cases
+5 to +10	Yvonne	
	Bouresches I	
	North Wood II	
		North Wood I
		Mayache Rvn
		La Neuville
		Hill 252
+10 to +25	West Wood I	
	Mayache Rvn	
	La Neuville	
		Yvonne
		North Wood I
+25 or more	Beaupre Farm	Beaupre Farm
	Chaudun	Chaudun
	Remilly	Remilly

to under– or over–predict. It is clear that the model understands attacker losses better than defender losses. I suspect this is related to the model having no breakpoint methodology. Also, defender losses may be more variable. I was unable to find a satisfactory explanation for the variation. One thing I did notice was that all four battles that were significantly under–predicted on the defender sides were the four shortest WWI battles. Three of these were also noticeably under–predicted for the attacker. Therefore, I looked at all 23 WWI engagements related to time. (*see table, top of next page*)

Looking back at the issue of time, it became clear the model was clearly under–predicting in battles of less than four hours. I therefore came up with the following time scaling formula:

If time of battle less than four hours, then multiply attrition by (4/(Length of battle in hours)).

3.75	1.07
3.5	1.14
3	1.33
2	2
.5	8

What this formula does is make all battles less than four hours equal to a four–hour engagement. This intuitively looks wrong, but one must consider how we define a battle. A "battle" is defined by the analyst after the fact. The start time is usually determined by when the attack starts (or when the artillery bombardment starts) and end time by when the attack has clearly failed, or the mission has been accomplished, or the fighting has died down. Therefore, a battle is not de-

Engagement Name	Hours	Attacker % Losses	CEV-Predicted Att % Losses	Defender % Losses	CEV-Predicted Def % Losses	Comment
18. Essen Hook	0.50	9.86	0.49	55.56	10.19	x 5
2. Cantigny	2.00	3.46	0.24	53.24	24.14	x 2
12. St Amand	2.00	10.43	1.04	100.00	53.25	x 2
17. Medeah Farm	2.00	12.86	4.89	53.55	13.55	x 2
8. Bouresches II	3.00	3.74	2.01	4.07	2.02	x 2
1. Yvonne-Odette	3.50	2.31	1.89	10.92	32.46	D high/A low
15. Berzy-le-Sec	3.75	5.25	2.40	33.14	35.43	A low
10. North Wood II	4.00	10.59	9.24	1.21	1.98	Good
13. Beaupre Farm	4.00	2.79	1.18	32.04	90.62	D high/A low
16. Bouzancy Ridge	4.00	6.60	1.51	49.82	40.07	A low
9. North Wood II	4.50	11.31	19.62	1.26	5.74	Too high
4. West Wood I	6.00	20.75	23.22	4.82	14.18	D high
5. Bouresches I	6.00	12.46	10.79	13.76	15.24	Good
3. Hill 142	8.00	13.15	9.03	19.16	21.81	Good
23. Hill 252	8.00	5.53	5.68	11.00	18.67	Good
11. North Wood IV	11.00	6.13	3.35	28.27	23.67	Good
6. West Wood II	12.00	8.33	6.42	30.09	27.53	Good
7. North Wood I	12.00	9.60	20.57	15.01	28.53	Too high
14. Chaudun	12.00	8.07	19.43	62.50	100.00	Too high
21. La Neuville	12.00	6.34	6.49	3.14	12.27	D high
22. Remilly	12.00	2.07	7.27	10.14	81.08	Too high
19. Exermont	14.00	6.60	7.10	5.90	8.62	Good
20. Mayache Ravine	14.00	6.93	7.54	6.00	15.43	D high

fined by time, but by resolution. As such, any battle that only lasts a short time will still have a resolution, and as a result of achieving that resolution there will be considerable combat experience. Therefore, a minimum casualty multiplier of 1/6 must be applied to account for that resolution. We shall see if this is really the case when we run the second validation using the new battles, which have a considerable number of brief engagements. For now, this seems to fit.

As for all the other missed predictions, including the over–predictions, I could not find a magic formula that corrected them. My suspicion was that the multiplier of x4 would be a little too robust, but even after adjusting for the time equation, this left 14 of the attacker's losses under–predicted and six of the defender actions under–predicted. If the model is doing anything, it is under–predicting attacker casualties and over–predicting defender casualties. This would argue for a different multiplier for the attacker than for the defender (higher one for the attacker). We had six cases where the attacker's and defender's prediction's were both low, nine where they were both high, and eight cases where the attacker's prediction was low while the defender's prediction was high. We had no cases where the attacker's prediction was high and the defender's prediction was low. As all these examples were from the western front in 1918, US versus Germans, then the problem could also be that the model is under–predicting the effects of fortifications, or the terrain for the defense. It could also be indicative of a fundamental difference in the period that gave the attackers higher casualty rates than the defenders. This is an issue I would like to explore in more depth, and I may do so after I have more WWI data from the second validation.

SO WHERE WERE WE REALLY OFF? (WWII)

In the case of the WWII results, we were getting results in the ball park in less than 60% of the cases for the attacker and in less than 50% of the cases in the case of the defenders. We were often significantly too low. Knowing that we were dealing with a number of Japanese engagements (seven), and they clearly fought in a manner that was different from most western European nations, we expected that they would be under–predicting, and some casualty adjustment would be necessary to reflect this. We also examined whether time was an issue (it was not). The under–predicted

World War II Attacker		
Predicted Casualties Off By:	Predicted	CEV Predicted
-10 to -25	Tenaru River I	Tenaru River I
	Edson's Ridge	Edson's Ridge
	Lausdell XRds	Lausdell Xrds
-5 to -10	Engebi I	Engebi I
	Eniwetok	Eniwetok
	VER-CHx	VER-CHx
		Wake II
		Makin Raid
-5 to +5	16 cases	13 cases
+5 to +10		VER-RDMx
+10 to +25		
+25 or more	Chouigui Pass	Chouigui Pass

World War II Defender		
Predicted Casualties Off By:	Predicted	CEV Predicted
-25 or more	Makin Raid	Makin Raid
	Tenaru River II	Tenaru River II
	Engebi	Engebi
	Lausdell XRds	Lausdell XRds
	Assenois	Assenois
-10 to -25	Edson's Ridge	Edson's Ridge
	Eniwetok	Eniwetok
-5 to -10	Chouigui Pass	
	VER-CHx	
-5 to +5	11 cases	11 cases
+5 to +10	VER-1BWx	VER-1BWx
	VER-4RWx	VER-4RWx
	VER-10Bx	
		Wake II
		VER-2ASx
		VER-HXLx

battles are listed in the next table:

Engagement	Hours	No. of Engagements That Are Shorter	Comment
Makin Raid	4	0	Fanatic!
Assenois	5	1	Way off
Lausedell XRds	5.75	2	Way off
Wake II	7	8	A low/D high
Tenaru Riv II	8.5	9	Fanatic!
Tenaru Riv I	9	10	Fanatic!
Edson's Ridge	12	11	Fanatic!
VER-CHx	12	11	A low
Eniwetok	23	20	Fanatic!
Engebi	24	21	Fanatic!

We temporarily defined the Japanese mode of fighting as "fanaticism." We decided to find a factor for fanatacism by looking at all the battles with the Japanese. They are listed below:

Engagement	Attacker	Predicted	%	CEV Predicted	%
Wake II	Japan	-4.60	0.43	-5.13	0.36
Makin Raid	US	-4.53	0.75	-9.50	0.48
Tenaru River I	Japan	-17.47	0.36	-12.74	0.54
Tenaru River II	US	-0.60	0.77	-0.76	0.71
Edson's Ridge	Japan	-14.51	0.15	-12.97	0.24
Engebi Island	US	-6.07	0.17	-5.80	0.21
Eniwetok	US	-6.52	0.16	-6.14	0.21
Average					**0.39**

Engagement	Defender	Predicted	%	CEV Predicted	%
Wake II	US	2.79	1.14	21.86	2.10
Makin Raid	Japan	-65.55	0.29	-27.78	0.70
Tenaru River I	US	-4.13	0.33	-4.56	0.30
Tenaru River II	Japan	-66.57	0.18	-61.60	0.24
Edson's Ridge	US	-24.13	0.16	-24.35	0.15
Engebi Island	Japan	-75.00	0.23	-75.00	0.23
Eniwetok	Japan	-19.04	0.43	-19.04	0.43
Average					**0.59**
Average less Wake II					**0.34**

Looking at what multiplier was needed, one notes that .39 times 2.5 = .975 while .34 times 2.5 = .85. This argues for a "fanatic" multiplier of 2.5. The non–fanatic opponent attrition multiplier is also 2.5. There was no indication that both sides should not be affected by the same multiplier.

We had now tentatively identified two "fixes" to the data. I am sure someone will call them "fudges," but I am comfortable enough with the logic behind them (especially the fanaticism) that I would dismiss such criticism. It was now time to look at the modern data, and see what would happen if these fixes were applied to it.

SO WHERE WERE WE REALLY OFF? (Post-WWII)

Post-World War II Attacker		
Predicted Casualties Off By:	Predicted	CEV Predicted
-25 or more	Long Tan	Long Tan
	Prek Klok I	
	Prek Klok II	Prek Klok II
	Ap Bau Bang II	Ap Bau Bang II
	Lo Giang I	Lo Giang I
-10 to -25	Tu-Vu	Tu-Vu
	Mapu	Mapu
	Buell II	Buell II
		Prek Klok I
-5 to -10	Lo Giang II	Lo Giang II
	Nui Ba Den	Nui Ba Den
	Mt. Longdon	Mt. Longdon
-5 to +5	17 cases	17 cases
+5 to +10	Goose Green	
	Salinas	Salinas
		Cau Lanh

Post-World War II Defender		
Predicted Casualties Off By:	Predicted	CEV Predicted
-25 or more	Tu-Vu	Tu-Vu
	Ninh Binh	Ninh Binh
	Cai Nuoc	Cai Nuoc
	ZDB050	ZDB050
	Hill 450	Hill 450
	Prek Klok I	Prek Klok I
	Ap Bau Bang II	Ap Bau Bang II
	Lo Giang II	Lo Giang II
	Mt Harriet	Mt Harriet
	Mt Longdon	Mt Longdon
-10 to -25	Cau Lanh	Cau Lanh
	Lo Giang I	Lo Giang I
	Nui Ba Den	Nui Ba Den
	Two Sisters	
	Lipanda	
-5 to -10	Mapu	Mapu
	Bir Gifgafa II	Bir Gifgafa II
	Goose Green	
	Tumbledown	
-5 to +5	8 cases	9 cases
+5 to +10	Pearls AFB	
	Lomba	
	TF Bayonet	
+10 to +25		Salinas
		Pearls AFB
		Lomba
		TF Bayonet

A total of 20 battles were noticeably under–predicted. We examined them to see if there was a pattern in this under–prediction.

FANATICISM and CASUALTY INSENSITIVE SYSTEMS:

It was quite clear from looking at the battalion–level data before we did the validation runs that there appeared to be two very different loss patterns, based upon—dare I say it—nationality. See the article in issue 4 of the newsletter, "Looking at Casualties Based Upon Nationality Using the BLODB." While this is clearly the case with the Japanese in WWII, it does appear that other countries were also operating in a manner that produced similar casualty results. So, instead of using the word fanaticism, let's refer to them as "casualty insensitive" systems. For those who really need a definition before going forward:

> "Casualty Insensitive" System: A social or military system that places a high priority on achieving the objective or fulfilling the mission and a low priority on minimizing casualties. Such systems tend to be "mission obsessive" versus using some form of "cost benefit" method of weighing whether the objective is worth the losses suffered to take it.

EXAMPLES OF CASUALTY INSENSITIVE SYSTEMS:

For the purpose of the database, casualty sensitive systems were defined as the Japanese and all highly motivated communist–led armies. These include:

Japanese Army, WWII
Viet Mihn
Viet Cong
North Vietnamese
Indonesian

We have included the Indonesians in this list even though it was based upon only one example.

In the WWII and post–WWII period, one would expect that the following armies would also be "casualty insensitive:"

Soviet Army in WWII
North Korean Army
Communist Chinese Army in Korea
Iranian "Pasdaran"

Data can certainly be found to test these candidates.

One could postulate that the WWI attrition multiplier of 4 that we used also incorporates the 2.5 "casualty insensitive" multiplier. This would imply that there was only a multiplier of 1.6 to account for other considerations, like adjusting to the impact of increased firepower on the battlefield. One could also postulate that certain nations, like Russia, have had "casualty insensitive" systems throughout their last 100 years of history. This could also be tested by looking of battles over time of Russians versus Germans compared to Germans versus British, US or French. One could easily carry this analysis back to the Seven Years' War. If this was the case, this would establish a clear cultural basis for the "casualty insensitive" multiplier, but to do so would require the TNDM to be validated for periods before 1900. This would all be useful analysis in the future, but is not currently budgeted for.

It was expected that the "casualty insensitive" multiplier of 2.5 derived from the Japanese data would be too high to apply directly to the armies. Much to our surprise, we found that this did not appear to be the case.

This partially or wholly explained the under–prediction of the 15 of our 20 significantly under–predicted post–WWII engagements. Time would explain another one, and four were not explained.

Engagement	Hours	No. of Engagements That Are Shorter	Comment
Lo Giang I	1	0	Casualty Insensitive
Cai Nuoc	1	0	Casualty Insensitive
ZBD050	1	0	Casualty Insensitive
Bir Gifgafa II	1	0	
Mapu	2	4	Casualty Insensitive
Nui Ba Den	2	4	Casualty Insensitive
Prek Klok II	3	7	Casualty Insensitive
Buell II	3	7	Casualty Insensitive
Prek Klok I	4	9	Casualty Insensitive
Lo Giang II	4	9	Casualty Insensitive
Two Sisters	4	9	
Ninh Binh	6	13	Casualty Insensitive
Long Tan	6	13	Casualty Insensitive
Lipanda	6		
Cau Lanh	8	16	Casualty Insensitive
Ap Bau Bang II	8	16	Casualty Insensitive
Mt Harriet	8	16	
Mt Longdon	9		
Tu-Vu	12		Casualty Insensitive
Hill 450	12		Casualty Insensitive

The model noticeably underestimated all the engagements under nine hours except Bir Gifgafa I (2 hours), Pearls AFB (4.5) and Wireless Ridge (8 hours). It noticeably under–estimated all the 15 "fanatic" engagements. If the formulations derived from the earlier data were used here (engagements less than 4 hours and fanatic), then there are 17 engagements in which one side is "casualty insensitive" or in which the engagement time is less than 4 hours. Using the above formulations then 17 engagements would have their casualty figures changed. These are shown at the top of the next page.

The modified percent loss figures are the CEV predicted percent loss times the factor for "casualty insensitive" systems (for those 15 cases where it applies) and times the formulation for battles less than 4 hours (for those 9 case where it applies).

Looking at the table at the top of the next page, it would appear that we are on the correct path. But to be safe, on the next page let's look at the predictive value of the 13 engagements for which we didn't redefine the attrition multipliers.

Engagement	Length	Attacker % Losses	CEV-Predicted Att % Losses	Modified Att % Losses	Defender %	CEV-Predicted Def % Losses	Modified Def % Losses	Comment
4. Cai Nuoc	1	3.20	0.40	4.00	40.00	1.33	13.33	4 x 25
5 ZBD050	1	1.00	0.00	0.00	40.83	5.83	58.83	4 x 25
13. Bir Gifgafa II	1	0.33	0.07	0.28	8.96	0.45	1.80	x 4
14. Lo Giang I	1	38.86	7.43	74.30	26.67	3.33	33.33	4 x 25
6. Mapu	2	26.50	3.00	15.00	9.33	1.33	6.65	2 x 25
13. Bir Gifgafa I	2	4.29	0.17	0.34	2.50	0.45	0.90	x 2
16. Nui Ba Den	2	8.00	2.50	12.50	15.56	1.67	8.35	2 x 25
10. Prek Klok II	3	35.40	5.30	17.67	2.56	0.63	2.10	1.33 2.5
11. Buell II	3	19.75	1.96	6.53	6.75	2.00	6.67	1.33 2.5
9. Prek Klok I	4	58.40	34.80	87.00	32.32	5.49	13.73	x 2.5
15. Lo Giang II	4	9.40	1.60	4.00	50.38	11.38	28.45	x 2.5
2. Ninh Binh	6	3.06	0.71	1.78	59.58	11.58	28.95	x 2.5
7. Long Tan	6	46.47	4.80	12.00	4.33	4.67	11.68	x 2.5
3. Cau Lanh	8	0.60	7.40	18.50	60.00	45.00	100.00	x 2.5
12. Ap Bau Bang	8	44.78	15.56	38.90	44.00	5.33	13.33	x 2.5
1. Tu-Vu	12	17.14	2.97	7.43	59.52	33.33	83.33	x 2.5
8. Hill 450	12	6.00	3.41	8.53	66.36	26.17	65.43	x 2.5
Average		**19.01**	**5.42**	**18.16**	**31.16**	**9.41**	**28.05**	
Sum of Squares			**6302.31**	**4407.47**		**12189.90**	**6120.02**	
Variance			**370.32**	**259.26**		**717.05**	**360.00**	
Std Deviation			**19.25**	**16.10**		**26.78**	**18.97**	

The 13 engagements left unchanged:

Engagement	Length	Attacker % Losses	CEV-Predicted Att % Losses	Defender % Losses	CEV-Predicted Def % Losses
17. Mt. Hermon	20	1.85	5.75	6.32	3.28
18. Goose Green	15	9.31	10.40	15.11	13.22
19. Mt. Harriet	8	1.76	1.76	81.25	17.75
20. Two Sisters	4	1.97	0.98	13.25	4.75
21. Mt. Longdon	9	12.50	5.00	66.67	16.33
22. Tumbledown	11.25	7.47	3.88	11.11	7.11
23. Wireless R.	8	2.12	2.42	9.23	9.38
24. Salinas	12	3.33	8.83	29.18	43.63
25. Pearls AFB	4.5	0.40	1.80	14.29	34.29
26. Lomba	24	0.75	1.17	5.30	20.76
27. Cuatir River	26	0.85	1.03	6.44	8.93
28. Lipanda	6	0.16	0.25	13.26	4.64
29. TF Bayonet	45	1.93	1.13	4.09	14.13
Average		**3.42**	**3.42**	**21.19**	**15.25**
Sum of Squares			**119.63**		**7696.01**
Variance			**9.20**		**592.00**
Std Deviation			**3.03**		**24.33**

So, we are definitely heading in the right direction now. We have identified two model changes—time and "casualty insensitive." We have developed preliminary formulations for time and for "casualty insensitive" forces. Unfortunately, the time formulation was based upon seven WWI engagements. The "casualty insensitive" formulation was based upon seven WWII engagements. Let's use all our data in the first validation database here for the moment to come up with figures with which we can be more comfortable:

Engagement	Length	Attacker % Losses	CEV-Predicted Att % Losses	x2.5 Modified Att % Losses	Defender % Losses	CEV-Predicted Def % Losses	x2.5 Modified Def % Losses
2. Makin Raid	4	18.10	8.60	21.50	92.22	64.44	100.00
9. Prek Klok I	4	58.40	34.80	87.00	32.32	5.49	13.73
15. Lo Giang II	4	9.40	1.60	4.00	50.38	11.38	28.45
2. Ninh Binh	6	3.06	0.71	1.78	59.58	11.58	28.95
7. Long Tan	6	46.47	4.80	12.00	4.33	4.67	11.68
1. Wake II	7	8.00	2.87	7.18	19.77	41.63	100.00
3. Cau Lanh	8	0.60	7.40	18.50	60.00	45.00	100.00
12. Ap Bau Bang	8	44.78	15.56	38.90	44.00	5.33	13.33
3. Tenaru Riv II	8.5	2.63	1.87	4.68	81.48	19.88	49.70
3. Tenaru Riv I	9	27.47	14.73	36.83	6.52	1.96	4.90
4. Edson's Rdg	12	17.14	4.17	10.43	28.59	4.24	10.60
1. Tu-Vu	12	17.14	2.97	7.43	59.52	33.34	83.33
8. Hill 450	12	6.00	3.41	8.53	66.36	26.17	65.43
8. Eniwetok	23	7.75	1.61	4.03	33.26	14.22	35.55
7. Engebi	24	7.35	1.55	3.88	97.18	22.18	55.45
Average		**18.29**	**7.11**	**17.78**	**49.03**	**20.77**	**46.74**
Sum of Squares			**3986.27**	**2667.56**		**20211.87**	**14509.26**
Variance			**265.75**	**177.84**		**1347.46**	**967.28**
Std Deviation			**16.30**	**13.34**		**36.71**	**31.10**

The highlighted entries in the table above indicate "casualty insensitive" forces. We are still struggling with the concept that having one side being casualty insensitive increases both sides' losses equally. We highlighted these in an attempt to find any other patterns we were missing. We could not.

Now, there may be a more sophisticated measurement of this other than the brute force method of multiplying both sides by 2.5. This might include different multipliers depending on whether one is the fanatic vs non–fanatic side or different multipliers for attack or defense. First, I cannot find any clear indication that there should be a different multiplier for the attacker or defender. A general review of the data confirms that. Therefore, we are saying that the combat relationships between attacker and defender do not change in high intensity or casualty insensitive battles from those experienced in the norm.

What is also clear is that our multiplier of 2.5 appears to be about as good a fit as we can get from a straight multiplier. It does not appear that there is any significant difference between the attrition multiplier for types of "casualty insensitive" systems, whether they are done because of worship of the emperor or because the commissar will shoot slackers. Apparently the mode of fighting is more significant for measuring combat results than how one gets there, although certainly having everyone worship the emperor is probably easier to "administer."

This still leaves us having to look at whether we should develop a better formulation for time. See the top of the next page.

"Non-Fanatic" Engagements of less than 4 hours:

Engagement	Length	Attacker % Losses	CEV-Predicted Att % Losses	xTime Modified Att % Losses	Defender % Losses	CEV-Predicted Def % Losses	xTime Modified Def % Losses
18. Essen Hook	0.5	9.86	0.49	3.92	55.56	10.19	81.52
13. Bir Gifgafa II	1	0.33	0.07	0.28	8.96	0.45	1.80
2. Cantigny	2	3.46	0.24	0.48	53.24	24.14	48.28
12. St Amand	2	10.43	1.04	2.08	100.00	53.25	100.00
17. Medeah Frm	2	12.86	4.89	9.78	53.55	13.55	27.10
13. Bir Gifgafa I	2	4.29	0.17	0.34	2.50	0.45	0.90
8 Bouresches II	3	3.74	2.01	2.68	4.07	2.02	2.69
1. Yvonne-Odet	3.5	2.31	1.89	2.16	10.92	32.46	37.10
15. Berzy-le-Sec	3.75	5.25	2.40	2.56	33.14	35.43	37.79
Average		***5.84***	***1.47***	***2.70***	***35.77***	***19.10***	***37.46***
Sum of Squares			***278.19***	***147.36***		***7240.85***	***2160.87***
Variance			***30.91***	***16.37***		***804.54***	***240.10***
Std Deviation			***5.56***	***4.05***		***28.36***	***15.50***

For fairly obvious reasons, we are still concerned about this formulation for battles of less than one hour, as we have only one example, but until we conduct the second validation, this formulation will remain as is.

Now the extreme cases:

List of all engagements less than 4 hours where one side was fanatic:

Engagement	Length	Attacker % Losses	CEV-Predicted Att % Losses	xTFx2.5 Modified Att % Losses	Defender % Losses	CEV-Predicted Def % Losses	xTFx2.5 Modified Def % Losses
4. Cai Nuoc	1	3.20	0.40	4.00	40.00	1.33	13.33
5. ZDB050	1	1.00	0.00	0.00	40.83	5.83	58.30
14. Lo Giang I	1	38.86	7.43	74.30	26.67	3.33	33.33
6. Mapu	2	26.50	3.00	15.00	9.33	1.33	6.65
16. Nui Ba Den	2	8.00	2.50	12.50	15.56	1.67	8.35
10. Prek Klok II	3	35.40	5.30	17.67	2.56	0.63	2.10
11. Buell II	3	19.75	1.96	6.53	6.75	2.00	6.67
Average		***18.96***	***2.94***	***18.57***	***20.24***	***2.30***	***18.39***
Sum of Squares			***2801.68***	***1899.25***		***3548.34***	***1120.23***
Variance			***400.24***	***271.32***		***506.91***	***160.03***
Std Deviation			***20.01***	***16.47***		***22.51***	***12.65***

It would appear that these formulations of time and "casualty insensitivity" have passed their initial hypothesis formulations tests. We are now willing to make changes to the model based upon this and run the engagements from the second validation data base to test it.

CONCLUSIONS:

With these two changes made, then the final fit for the battalion–level validation is:

Attacker Percent Losses	*Average*	*Standard Deviation*
Actual	9.5	
Predicted with CEV	5.75	10.73
Predicted with Modifications	9.44	9.18
Defender Percent Losses	*Average*	*Standard Deviation*
Actual	26.59	
Predicted with CEV	17.93	27.49
Predicted with Modifications	26.71	24.12

Attacker Percent Losses	*WWI Average*	*Standard Deviation*	*WWII Average*	*Standard Deviation*	*Post-WWI Average*	*Standard Deviation*
Actual	8.05		7.36		12.26	
Predicted with CEV	7.45	5.42	5.62	8.49	4.55	14.63
Predicted with Modifications	7.92	4.87	7.93	7.56	11.77	12.3
Defender Percent Losses	*WWI Average*	*Standard Deviation*	*WWII Average*	*Standard Deviation*	*Post-WWI Average*	*Standard Deviation*
Actual	26.29		26.58		26.84	
Predicted with CEV	29.41	27.74	14.25	29.38	11.94	25.75
Predicted with Modifications	36.52	23.44	22.41	27.81	22.49	21.45

And just to make sure that I'm not just tweaking the model in any old direction so that it fits better, let's look at the prediction of the ones that were not modified:

Attacker Percent Losses	*WWI (16 cases)*		*WWII (16 cases)*		*Post-WWII (13 cases)*	
	Average	***Std Dev***	***Average***	***Std Dev***	***Average***	***Std Dev***
Actual	8.58		5.06		3.42	
Predicted (unmodified)	9.90	5.09	5.87	8.44	3.42	3.03
Defender Percent Losses	*WWI (16 cases)*		*WWII (16 cases)*		*Post-WWII (13 cases)*	
	Average	***Std Dev***	***Average***	***Std Dev***	***Average***	***Std Dev***
Actual	18.38		15.77		21.19	
Predicted (unmodified)	31.59	25.66	9.95	22.65	15.25	24.33

The ones that were not modified were doing better in prediction that the ones that were modified before their modification. It appears that by focusing on two issues, time and "casualty insensitive" systems, we have improved those predictions in a rational manner, resulting in a better fit overall. This fit was based upon a rational analysis of combat and the data.

In general, we are getting reasonable average results and the model is holding up well across all periods, **once the two special considerations were accounted for.**

A LITTLE MORE BASIC STATISTICS:

For the entire set of data, the mean is 9.44 for the attacker and 26.71 for the defender; the standard deviation is 9.18 for the attacker and 24.12 for the defender. The number of examples is 76, the degree of freedom is 75. Therefore the confidence intervals are:

Attacker Confidence Interval	*Average*		*T-Stat*	*x*	*9.18/ √76*	*Confidence Interval Low*	*High*
80%	9.44	+ / -	1.295	x	1.053	8.08	10.80
90%	9.44	+ / -	1.669	x	1.053	7.68	11.20
95%	9.44	+ / -	1.994	x	1.053	7.34	11.54
Defender Confidence Interval	*Average*		*T-Stat*	*x*	*24.12/ √76*	*Confidence Interval Low*	*High*
80%	26.71	+ / -	1.295	x	2.767	23.13	30.29
90%	26.71	+ / -	1.669	x	2.767	22.09	31.33
95%	26.71	+ / -	1.994	x	2.767	21.19	32.23

Now, if this is based on modified data, I'm not sure what this really means statistically. The standard deviation is not of the sample, but of the error in the sample from the real world. But as I had already calculated the standard deviation for this sample, I figured this paper wouldn't be complete without a little more math.

TDI Profile: Joseph A. Bulger, Jr.

Col. Bulger graduated from the US Military Academy at West point in 1952 with a BS in Engineering, and went on to earn an MS in Aerospace Engineering from theuniversity of Michigan in 1960. He also attended the Armed Forces Staff College in 1967.

After serving 25 years in the US Air Force as a fighter pilot—including 269 combat missions over Vietnam in an F-100—and R&D staff officer, Col. Bulger spent 15 years with Boeing in the weapons performance analysis business. His engineering assignments included flight test engineering, development planning for tactical and strategic systems, manned military space programs (Dynasoar and Manned Orbiting Laboratory), and conventional (non–nuclear) weapons design and performance analysis. He was a consultant at the Dupuy Institute on the Dupuy Air Combat Model (DACM) project before taking over as project manager.
His assignments included:

* 1955-1958: Landstuhl AB, Germany; F-86 pilot
* 1959-1960: Univ. of Michigan, MS Aero/Astro Engineering
* 1960-1966: Edwards AFB, California; Flight Test Engineering (Research Simulation)
* 1966-1967: Armed Forces Staff College, Norfolk, Virginia
* 1967-1968: Bien Hoa, RVN; F-100 pilot (269 combat missions)
* 1968-1969: Los Angeles AFS, California; Manned Orbiting Laboratory, Crew Training
* 1969-1973: HQ AFSC, Andrews AFB, Maryland; Strategic Development Planning
* 1973-1977: Eglin AFB, Florida; Tactical Weapons Planning and Development
* 1977-1992: Boeing, Seattle, Washington; Manager, Theater Warfare Systems Analysis

Col. Bulger maintains an extensive and lively discussion on the future of warfare on his Web page at http://www.halcyon.com/jbulger.

How Data is Laid Out (Supplement for the User's Guide)

by José Perez

The TNDM Database

The individual data files used in the TNDM will be referred to as tables: the rows represent different records and the columns represent the fields that make up each record. When linked together, these tables make up the TNDM database.

The Data Tables

Currently there are a small number of data tables in the TNDM. They are, by name and contents:

COUNTRY.DBF: Countries
ENG_FOR.DBF: The units assigned to an attacker/defender in an engagement.
ENG_TOE.DBF: For those units manually created for an engagement, this table contains the weapons list for each OLI category. This includes a count of the number of weapons.
FORCE.DBF: Units listed by country. The data includes the count of weapon systems and OLI value for each weapon category: Armor, Infantry, Antitank, Towed artillery, SP Artillery, Anti-Air, Fixed wing aircraft, and Rotary wing aircraft; and the mobility systems: Trucks, Motorcycles, Tracked vehicles, Fixed wing aircraft and Rotary wing aircraft.
OLI.DBF: Weapon systems listed by country within weapon category. Includes weapon components such as bombs, rockets, tank guns, etc. Data includes various weapon characteristics.
UNIT_TOE.DBF: For those units created with the aid of the OLI database (OLI.DBF), this database contains the weapons list for each OLI category. This includes a count of the number of weapons.

The engagement data is in a different type of file. The data for each engagement is stored in a file that is unique to that engagement. For example, if an engagement is named Antietam, its data file is called ANTIETAM.DAT. If an engagement is being continued, it might be saved as ANTIETAM.CNT; a CNT file contains the status of both sides as of the end of the engagement.

Database Organization

The relationships between these tables is shown in the table at the bottom of this page.

More on the Tables

If you refer to the *TNDM User's Guide*, you will note that a great deal of information is stored in the engagement file: terrain, weather, recovered equipment, force strengths, reinforcements, etc. This information is sufficient to run the engagement even if the associated records in ENG_FOR.DBF (Engagement Forces) and ENG_TOE.DBF (Engagement Forces TO&E) are missing.

The Country table is used primarily for reference. It is automatically updated when new countries are added to the Units table (FORCE.DBF).

The Engagement Forces table was created to make increase the flexibility of the TNDM. It is used to store information about each unit in the attacking and defending forces in an engagement. When manually created units are used in an engagement, they can be recalled from the Engagement Forces table and changed to meet the analyst's needs. This also allows the analyst to modify "standard" units within the engagement without having to change a unit's data in FORCE.DBF.

The Engagement Forces TO&E table was created to make it easier to create units

	Engagement	Country	Eng_For	Eng_TOE	Force	OLI	Unit_TOE
Engagement	—	N/A	By nation, unit, A/D, and Eng	By nation, unit, A/D, and Eng	N/A	N/A	N/A
Country	N/A	—	N/A	N/A	N/A	N/A	N/A
Eng_For	By Eng	N/A	—	By Eng, nation, and unit	N/A	N/A	N/A
Eng_TOE	By Eng	N/A	By Eng, unit, category, & wpn	—	N/A	N/A	N/A
Force	N/A	Nation	N/A	N/A	—	N/A	By nation and unit
OLI	N/A	N/A	N/A	By nation and weapon	N/A	—	By nation and weapon
Unit_TOE	N/A	N/A	N/A	N/A	By nation and unit	N/A	—

manually. It is similar to Unit_TOE.DBF (Unit TO&E), which is used to document the weapons that compose each combat system category. This enables the analyst to use the weapons database (OLI.DBF) to create and modify units. However, if the analyst has already calculated the OLI scores for each weapon category, he has the option to enter total OLI scores and strengths manually.

FORCE.DBF is the table which contains summary information about all of the "standard" units used in the model. These units are organized by nation. Because of how aircraft are handled by the TNDM, helicopters and airplanes are included in this table as individual units. Because it is now linked to the OLI (Weapons) table, it is now possible to create and modify units without having to calculate the OLI score and strength manually. Also, using this approach documents the composition of weapons in each category by recording the weapons in the Unit TO&E table.

OLI.DBF is the Weapons table. It contains the characteristics for a wide variety of weapons: artillery, infantry weapons, armored vehicles, airplanes, helicopters, bombs, etc. It can be used to create new units; it can also be used to store hypothetical weapons.

Future Data Organization

At this time, there is no need to create links between engagements. However, the TNDM could be modified to allow the user to analyze battles by treating different sections of the front line as engagements. These sections could then be combined or broken down into even more sections. The results could then be combined to calculate an overall result for the entire battle. This would require creating a table that records which engagements compose a battle.

Another possible change would be to alter the TNDM to allow the withdrawal of individual units. Currently, the TNDM does not make it easy to withdraw units; the current strength of the unit must be calculated and the analyst must manually subtract it from the force. A better alternative would be to record each unit individually in a Daily Strength table. When the unit was withdrawn, the TNDM would look up the unit in the Daily Strength table and automatically subtract it from the force.

It is also possible to create a table that links together the various engagement files that depict the various phases of a battle. For example, a specific battle might be broken up into three engagements. The first engagement would be the initial contact between opposing sides; the second would begin when reinforcements arrive; and the third would begin when the losing side begins to withdraw.

Summary

This article has not covered any of the reference tables that are used to calculate engagement results and weapon scores. But in reviewing the data used in the TNDM it is clear that there are large amounts of it. Some of it is calculated and then discarded after the results of an engagement are generated. Other data is saved and presented in the engagement report. But it is how the data is connected to tables or other data in the TNDM that makes it useful. In considering how to change the TNDM to make it more useful, one needs to consider the data that is already present and how it is linked together. In some cases, data tables had to be created in order to create links. As a database programmer, I am well aware that information has no real value if the data is incoherent and disorganized. But sometimes all you need to create a structure for that data is to start drawing lines between data points.

I hope this article will encourage you to look at the documentation in the *User's Guide* and consider how a different view of the TNDM data might make your work easier.