The US Army's Center for Strategy and Force Evaluation

MEMORANDUM REPORT
CAA-MR-98-10

TRENDS IN LAND COMBAT (TLC)

JUNE 1998

PREPARED BY
MODEL VALIDATION DIVISION

US ARMY CONCEPTS ANALYSIS AGENCY
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13. ABSTRACT (Maximum 200 words)

This is an annotated briefing on trends in land combat that have persisted for extended periods of time (decades or even centuries). It specifically addresses the following topics relative to land combat operations: (1) rates of advance, (2) battle durations, (3) personnel strengths and attrition, (4) evolution of U.S. Army force structure, (5) Lanchester parameter values, and (6) the frequency and severity of wars.

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TRENDS IN LAND COMBAT (TLC)

SUMMARY

THE REASON FOR PERFORMING THE QUICK REACTION ANALYSIS (QRA) was to assist the Office of Net Assessment of the Under Secretary of Defense for Policy in summarizing some of the lessons of land combat history and in using them to project selected aspects of the land combat environment to the near future.

THE QRA SPONSOR was Office of Net Assessment.

THE QRA OBJECTIVE was to describe trends in land combat that have persisted over extended periods of time (decades or centuries).

THE SCOPE OF THE QRA. Emphasis in this QRA is on:

(1) Long-term trends in rates of advance.

(2) Battle durations.

(3) Personnel strengths and attrition in battle.

(4) Evolution of US Army force structure from circa World War I to about 1985.

(5) Lanchester parameter values.

(6) Frequency, duration, and losses in wars.

THE MAIN ASSUMPTIONS of this QRA are that statistical patterns that have persisted for long periods of time will continue for at least the next few years.

THE PRINCIPAL FINDINGS of the QRA are:

(1) On the average, rates of advance have not changed much over the past 400 years and so are not likely to change much for at least the next few years.

(2) On the average, for the past 400 years, battle durations have tended to increase gradually and it is likely that this trend will continue for at least the next few years.

(3) On the average, over the past 400 years, personnel strengths in battles have declined a bit while personnel battle casualties have declined steadily and relatively steeply.

(4) Except for the Cold War period, the total active US military strength (all Services) has traditionally been about 0.1 to 0.3 percent of the nation's population. It is currently a little over 0.5 percent, and so further declines appear likely.

(5) Over the years the US Army's tooth-to-tail ratio has varied widely. Perhaps a reasonable goal for the near future would be to maintain a tooth-to-tail ratio in the 40 to 45 percent range.

(6) Over the years, the US Army traditionally has depended heavily on the Reserves and National Guard for additional forces when needed.

(7) On the average, over the past 400 years, casualty exchange ratios favoring the defender were essentially constant, with the defender consistently at a slight disadvantage. However, the intensity of battle declined steadily and steeply.

(8) Interstate war starts appear to be governed by a Poisson process with a constant rate parameter equal to about 0.7 interstate war starts per year. Projecting this rate to the period 2000-2010 we expect 7 (4 to 10) interstate wars to start. Based on interstate war data for the period 1820-1979, statistical projections can be made of the number of battle deaths, the durations, and the levels of total participation* anticipated for those interstate wars that start in the period 2000-2010.

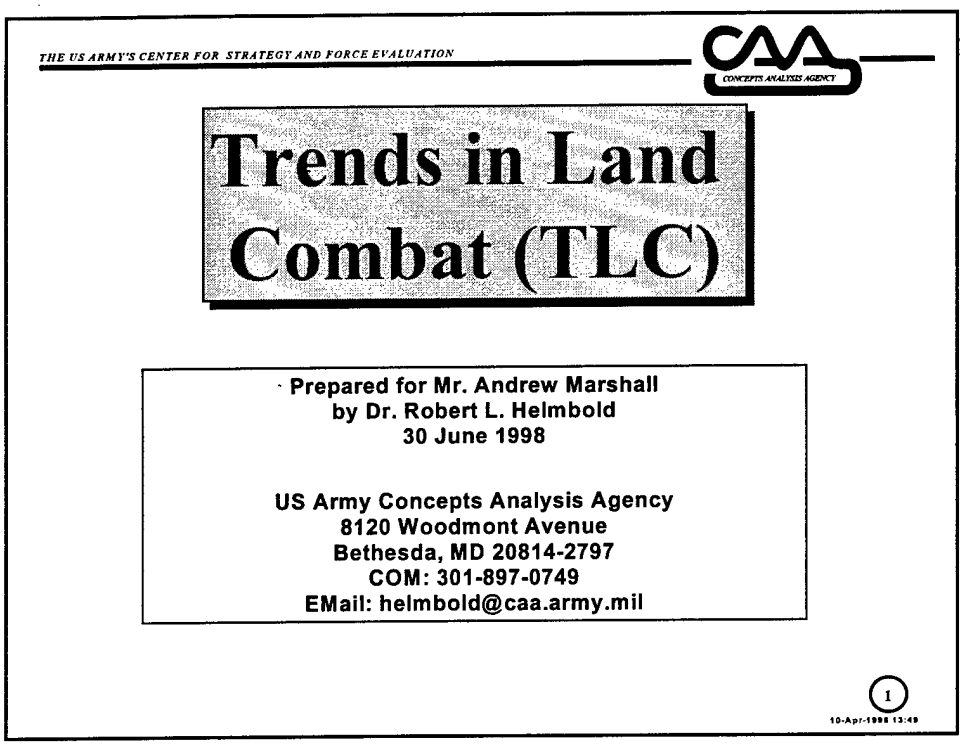
(9) Civil war starts appear to be governed by a Poisson process, but one with a gradually increasing rate parameter which currently is about one civil war start per year. Projecting the civil war rate to the period 2000-2010, we expect 10 (7 to 13) civil wars to start. Based on civil war data for the period 1820-1979, statistical projections can be made of the number of battle deaths, the durations, and the levels of total participation* anticipated for those civil wars that start in the period 2000-2010.

THE QRA EFFORT was directed by Dr. Robert L. Helmbold, Model Validation Division, US Army Concepts Analysis Agency (CAA).

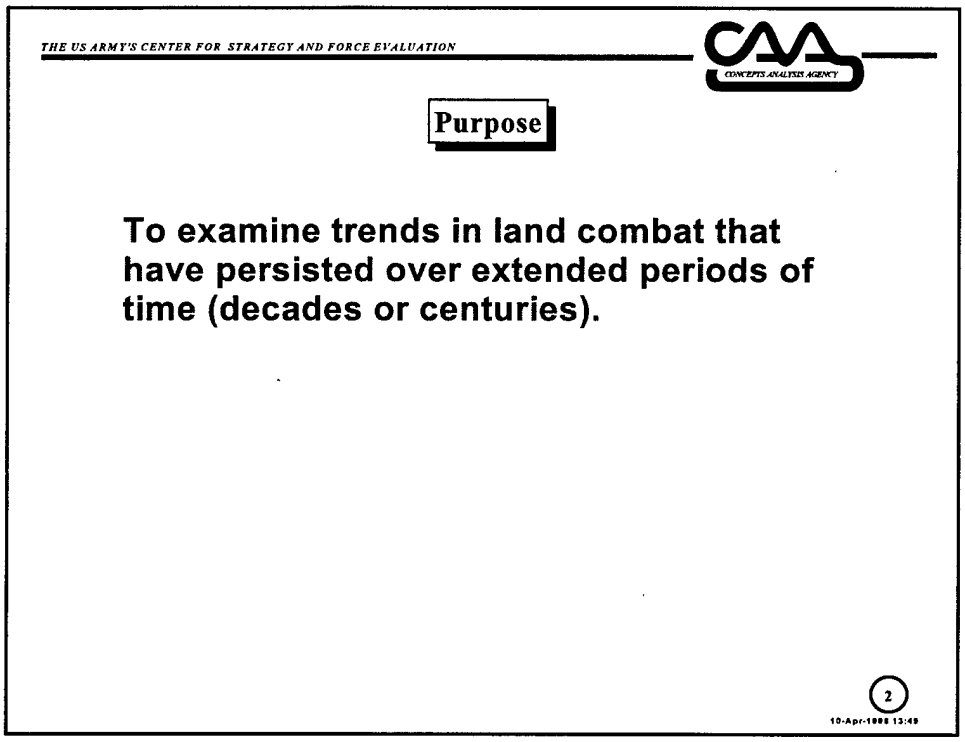
COMMENTS AND QUESTIONS may be sent to the Director, US Army Concepts Analysis Agency, 8120 Woodmont Avenue, Bethesda, MD 20814-2797.

* The participation of a nation is defined as the product of that nation's prewar population by the number of months it actively fought in the war. Participation ends when the nation surrenders or adopts a neutral posture, or the war ends. Participation once ended may be resumed if the nation is liberated or again adopts a belligerent posture. Total participation in a war is the sum of the participations of all the nations that actively fought in it.

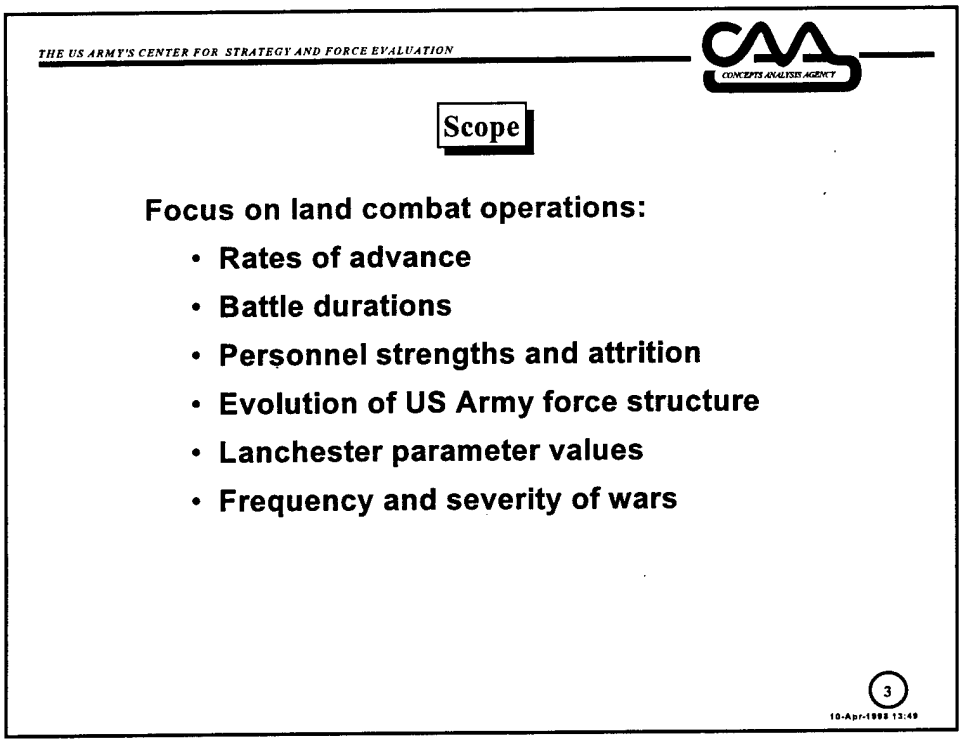
CONTENTS



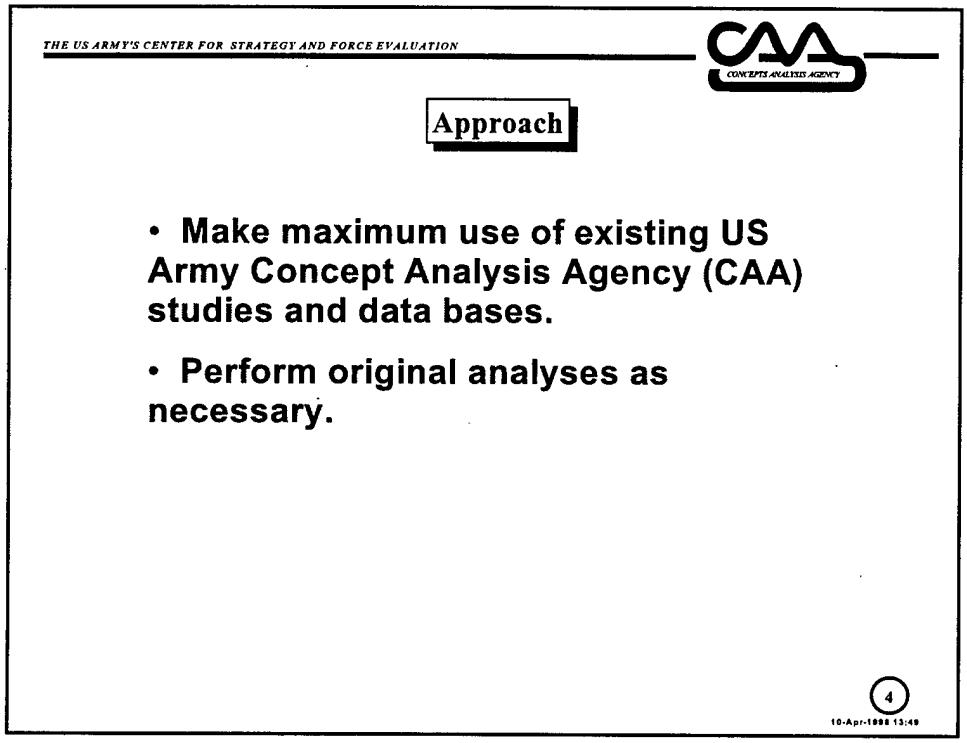
This briefing presents some selected trends in land combat. The work was done in the Model Validation Division of the US Army Concepts Analysis Agency (CAA) between 1 March and 30 June 1998. Results were provided to the Office of Net Assessment, one of the offices reporting to the Under Secretary of Defense for Policy.



The purpose of this effort is to examine some selected trends in land combat. Emphasis is on trends of long duration (decades or centuries), as these are sufficiently stable to serve as a basis for sound projections into the near future.

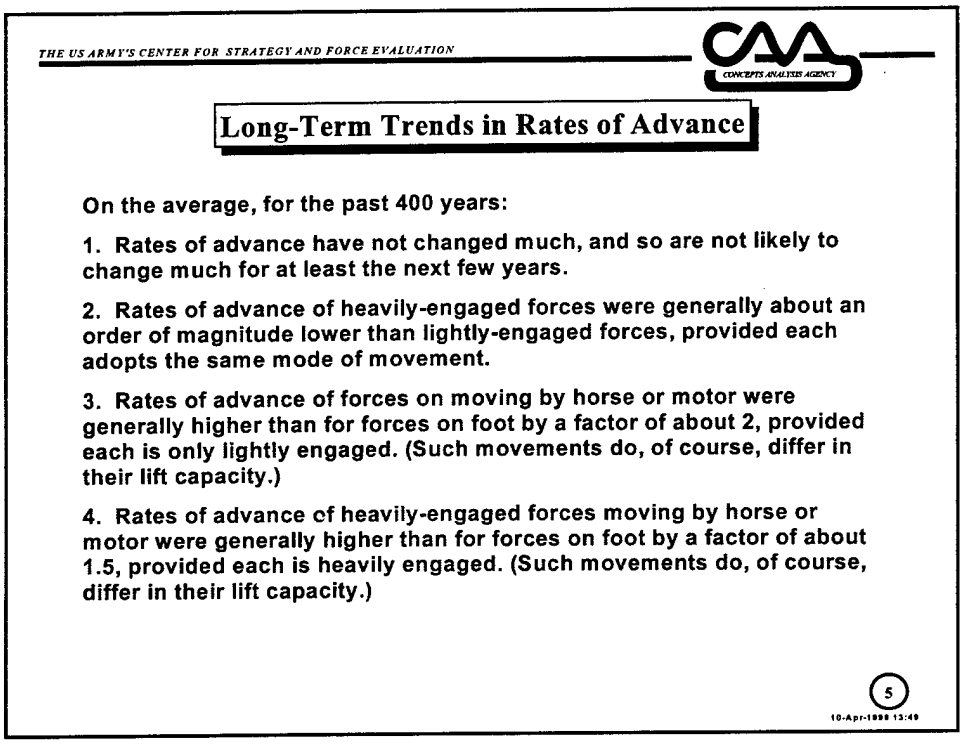


This presentation considers only land combat operations. Within that scope, it addresses the six major topics listed on this slide.



CAA' s previous historical studies produced a variety of important findings. In the course of those studies, over 300 earlier works were examined, cataloged, summarized, and critically reviewed. In addition, over 180 data bases were created or acquired.

Not all of these materials were germane to the TLC work, but a significant portion of them was invaluable.



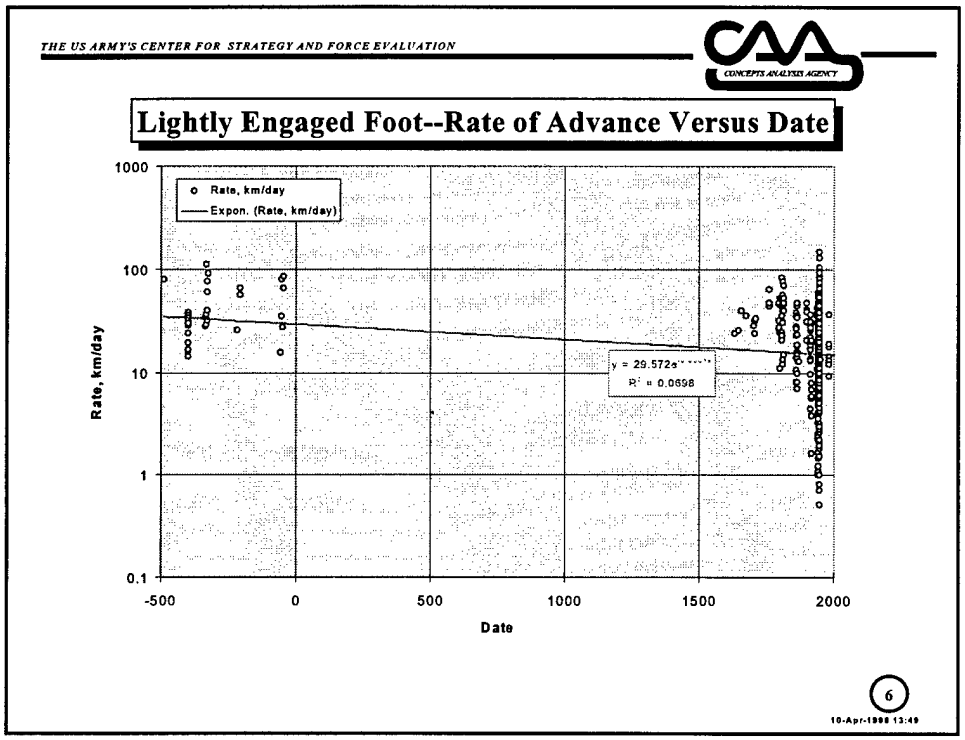
The main findings of this section are summarized on this slide.
The data used in this section are taken from:

- *A Survey of Past Work on Rates of Advance in Land Combat Operations,* US Army Concepts Analysis Agency Research Paper CAA-RP-90-3, February 1990, AD-A217 891.

- *A Compilation of Data on Rates of Advance in Land Combat Operations,* US Army Concepts Analysis Agency Research Paper CAA-RP-90-4, February 1990, AD-A220 426.

- *ROADATA–Rates of Advance Data (Computer Diskette),* US Army Concepts Analysis Data Base, February 1990, AD-M000 115.

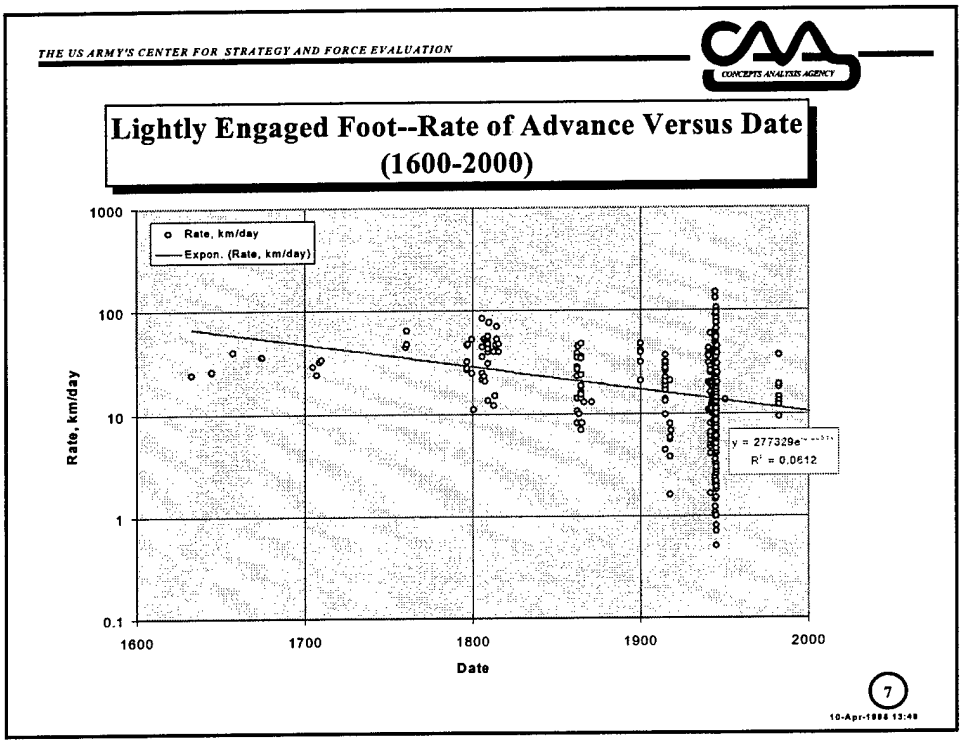
- *Rates of Advance in Historical Land Combat Operations,* US Army Concepts Analysis Agency Research Paper, CAA-RP-90-1, June 1990, AD-A225 635.



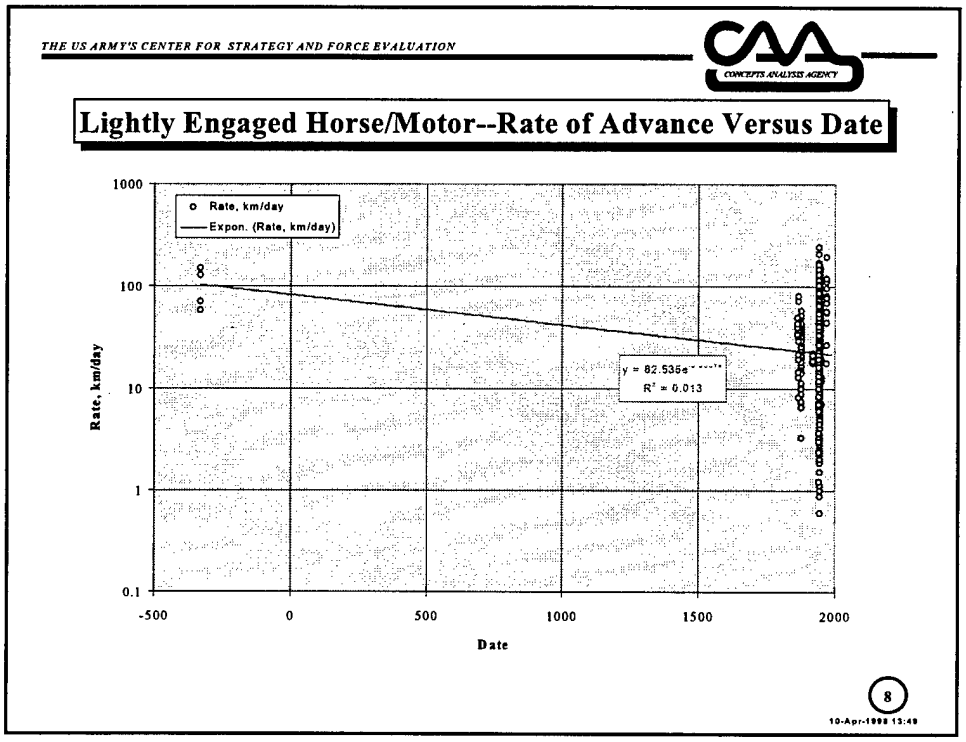
- Rates of advance of lightly engaged forces moving primarily on foot have not changed much for several centuries. The estimated average rate of decline is about 0.03 percent per year or 3 percent per century.

- Even that apparent decline in rate of movement is arguably due to a tendency to remember and record the most outstanding achievements of the ancients.

- Observe that the highest rates of movement in modern times equal the best ancient rates. However, the modern data contain many average and below-average rates.

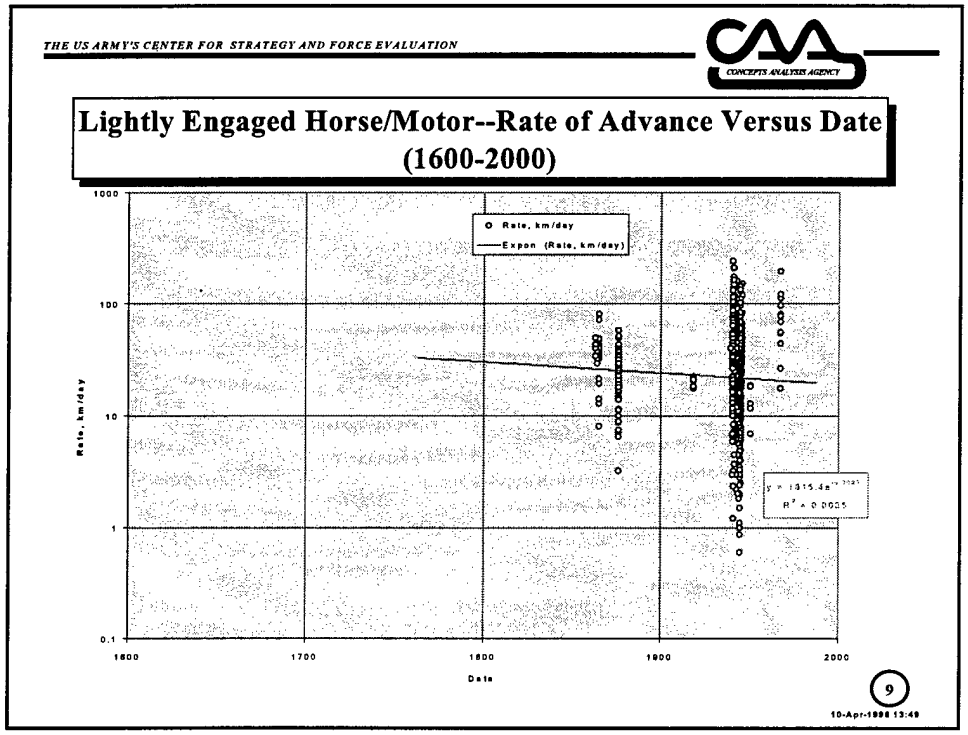


- This slide shows a blow-up of the 1600-2000 period for lightly engaged forces moving on foot. Here the estimated average rate of decline amounts to about 0.5 percent per year or 40 percent per century.
- It is provided for reference and comparison with other slides where the available data are limited to the 1600-2000 period.
- Even here, the seemingly rapid movements of earlier times are arguably more of an omission of the commonplace than a true reflection of the normal rates of advance.

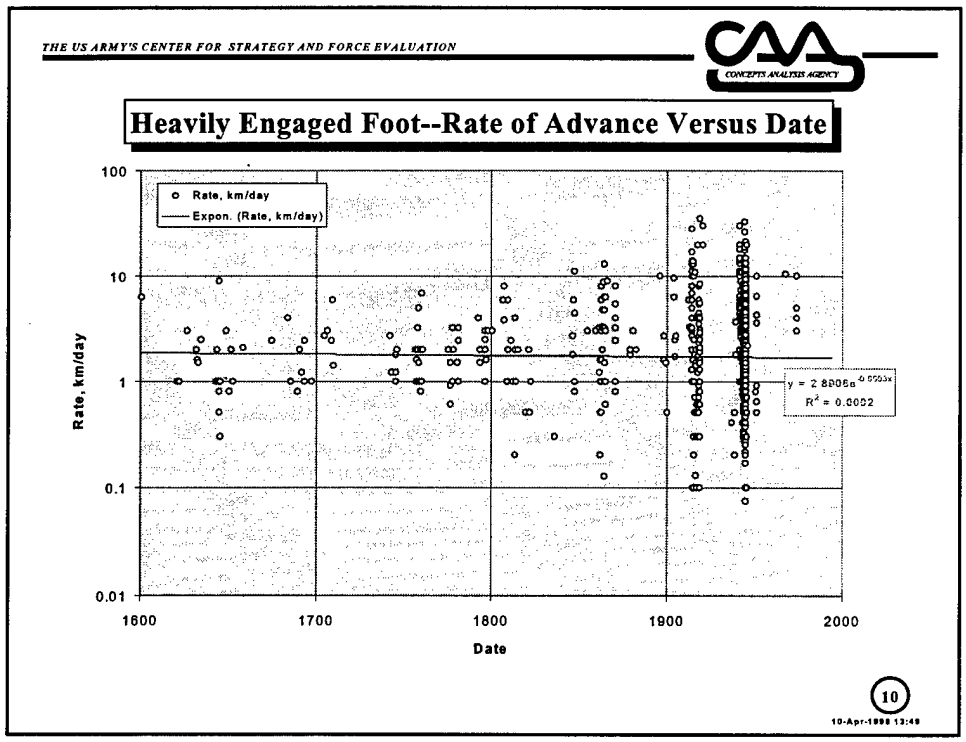


- Modern rates of movement of lightly engaged forces moving by horse or motor appear to be no higher than those achieved by the ancients. The estimated average rate of decline is about 0.07 percent per year or 7 percent per century. Again, however, we observe that modern forces can on occasion equal the exploits of the ancients.

- Hence, the apparent decline in rates is arguably due to selection of the most memorable and notable rates achieved by the ancients. Those values are not balanced by many cases of average and subaverage rates as is the case for the modern data.

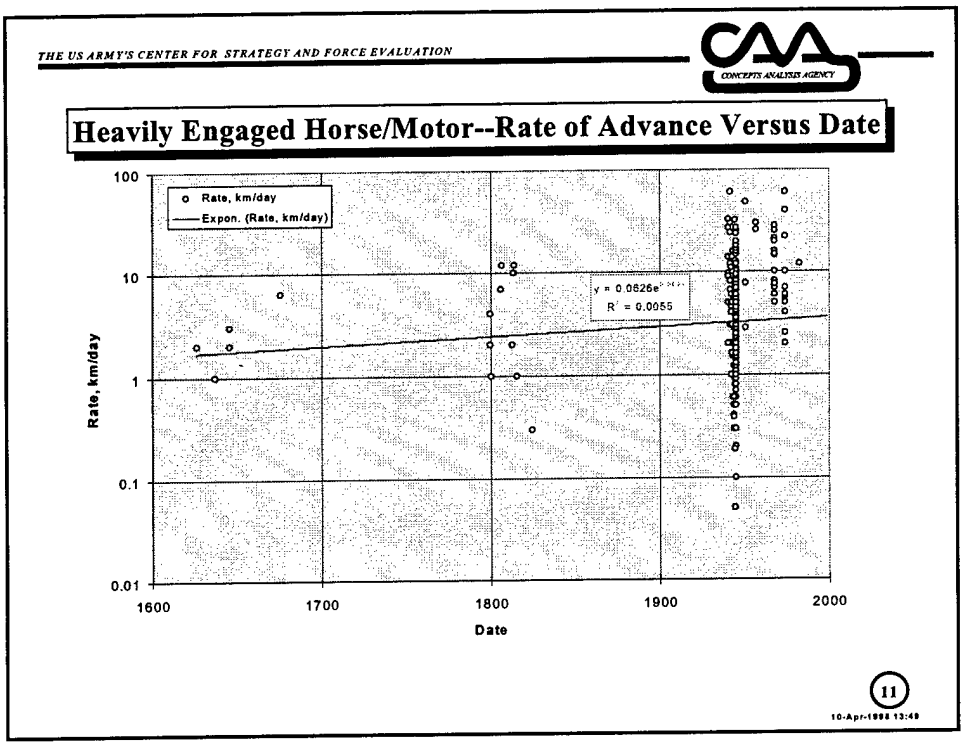


- This slide shows a blow-up of the 1600-2000 period for lightly engaged forces moving by horse or motor. Here the estimated average rate of decline amounts to about 0.23 percent per year or 20 percent per century.
- It is provided for reference and comparison with other slides where the available data are limited to the 1600-2000 period.
- Even here, the seemingly rapid movements of earlier times arguably are more of an omission of the commonplace than a true reflection of the normal rates of advance.



- On the average, rates of advance by heavily engaged forces moving on foot have changed very little over the past 400 years. The estimated average rate of decline is about 0.03 percent per year or 3 percent per century.

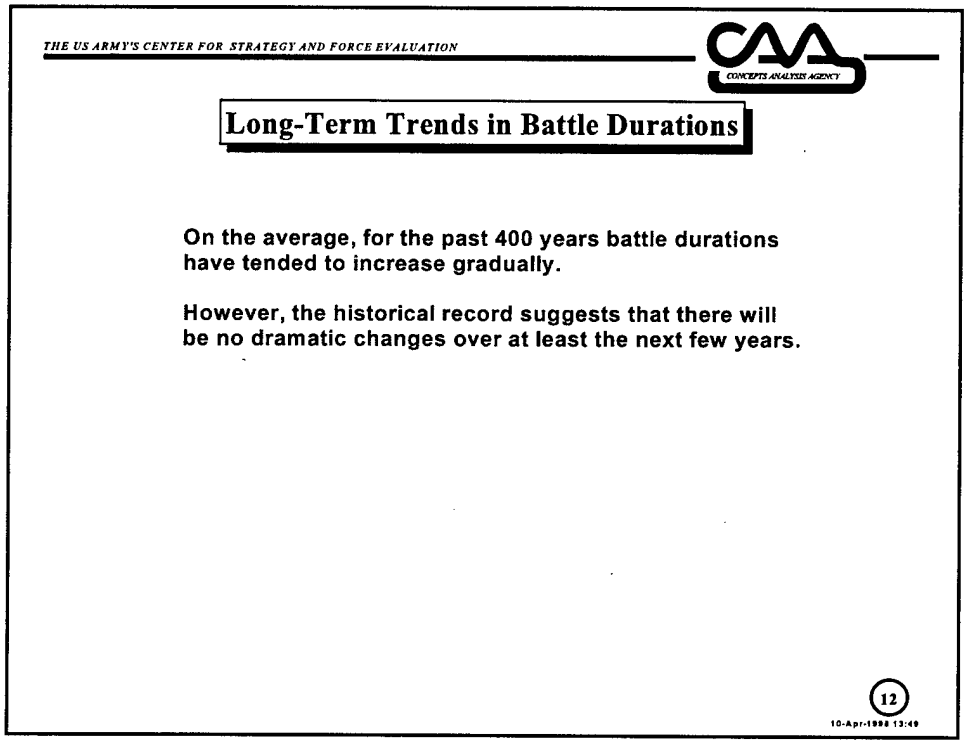
- Also, observe that rates of advance of heavily engaged forces moving on foot are about a factor of 5 to 10 lower than for lightly engaged forces moving on foot (compare slides 10 and 7).



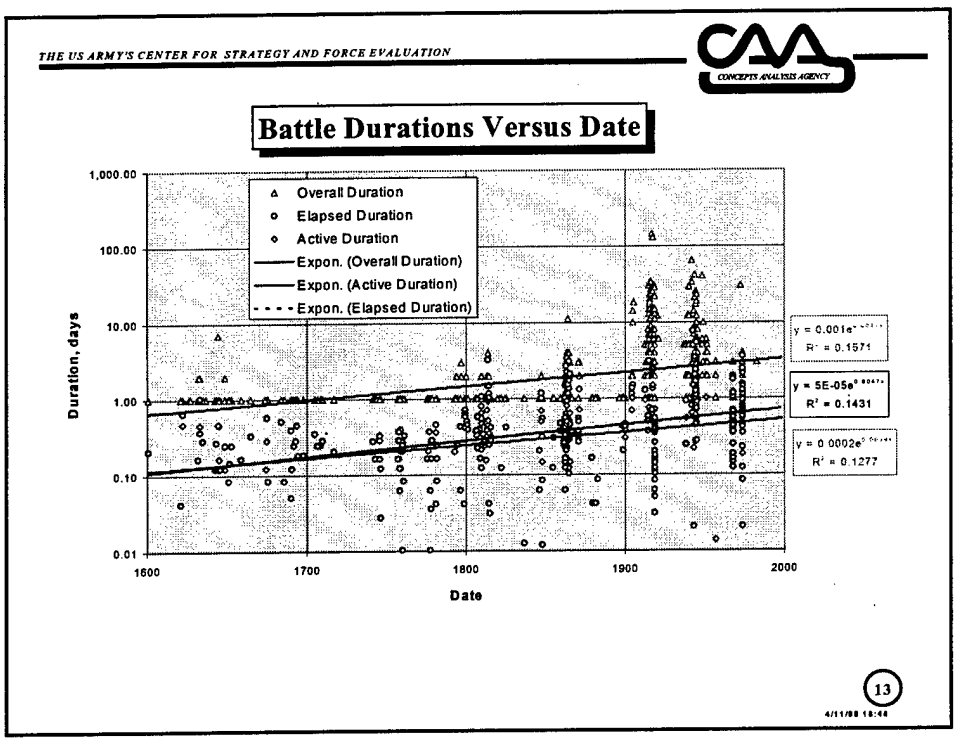
- Rates of advance of heavily engaged forces moving by horse or motor average about a factor of 5 to 10 lower than lightly engaged forces moving by horse or motor (compare slides 11 and 9).

- Rates of advance of such forces appear to have increased somewhat over the last 400 years. The estimated average rate of increase is about 0.2 percent per year or 18 percent per century.

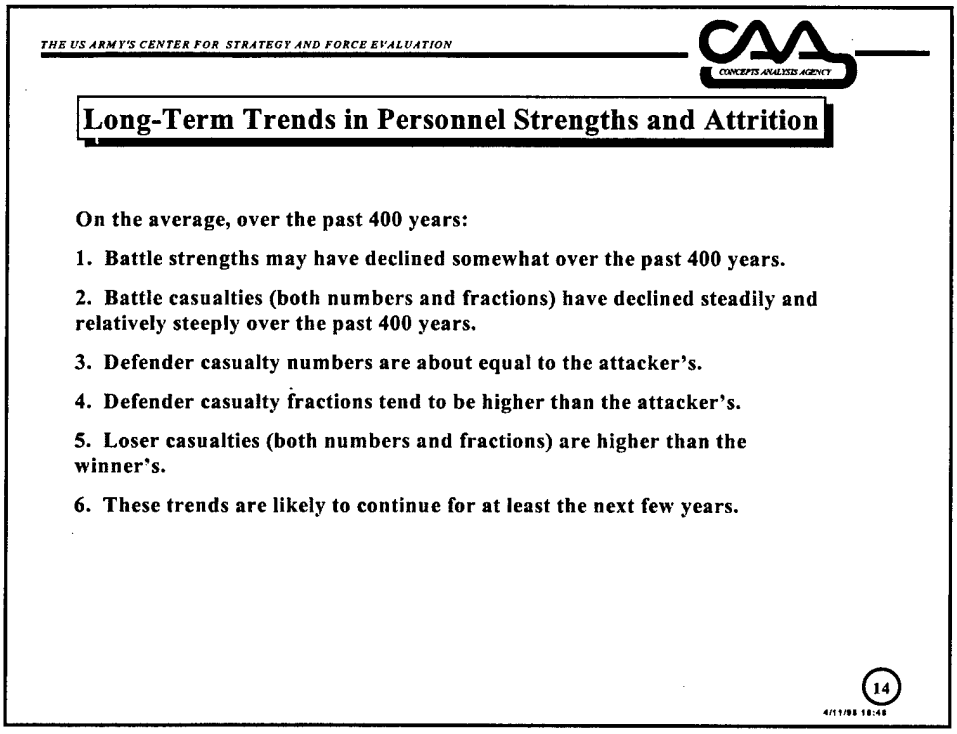
- It may be that modern armor permits faster movement than in the past centuries. It is not known whether improvements in antiarmor weaponry may in the near future moderate or even reverse this trend.



- The main findings of this section are summarized on this slide.
- The data used in this section are taken from:
- *Personnel Attrition Rates in Historical Land Combat Operations: Some Empirical Relations Among Force Sizes, Battle Durations, Battle Dates, and Casualties*, CAA Research Paper CAA-95-1, 1 March 1995, AD-A298-124.
- (And more particularly from the Filter0 case of CDB91DAT.xls.)



- This slide shows battle durations versus date, taken from the CAA data base of battles (CDB91DAT.xls).
- The various battle durations are defined as follows:
- Overall duration is the number of whole days from the first to the last day of the battle.
- Elapsed duration is the number of days and fractions thereof from the minute the battle started to the minute it ended.
- Active durations are the total number of minutes on which active combat took place. The active periods may or may not be contiguous. The active durations are expressed in days and fractions thereof.
- Battle durations have tended to increase with time. This is true whether the overall, elapsed, or active durations are used. The rate of increase with time is the same regardless of which kind of duration is considered. The estimated average rate of increase is about 0.4 percent per year or 33 percent per century.



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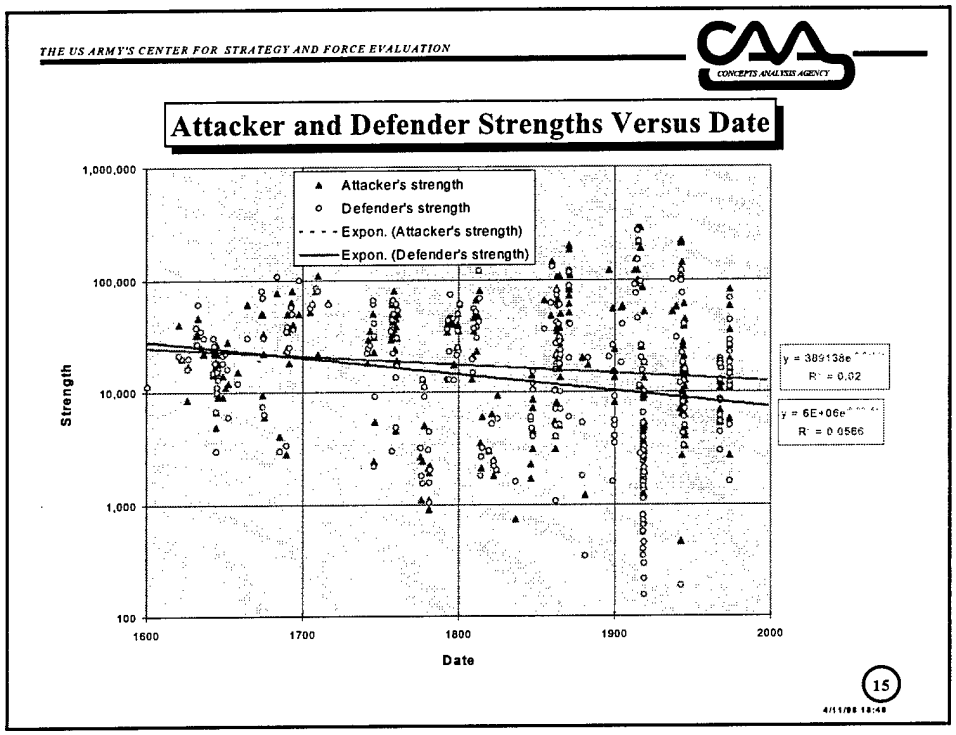
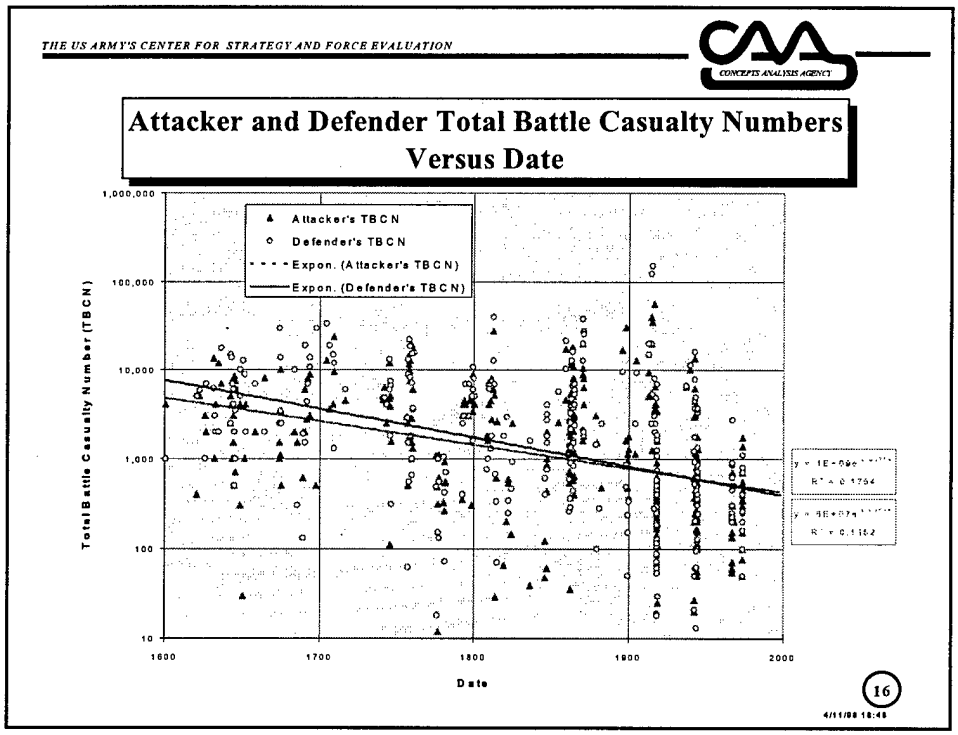


- This slide shows attacker's and defender's initial strengths versus date.
- Strengths may not actually have decreased with the passage of time, as the data on the older battles strongly tends to select for the larger and hence more notable battles. This is less true for the more recent engagements.
- In any case, the estimated rate of decrease is less than 0.35 percent per year or less than 30 percent per century, and the variation about the trendline is quite high compared to the rate of decrease.

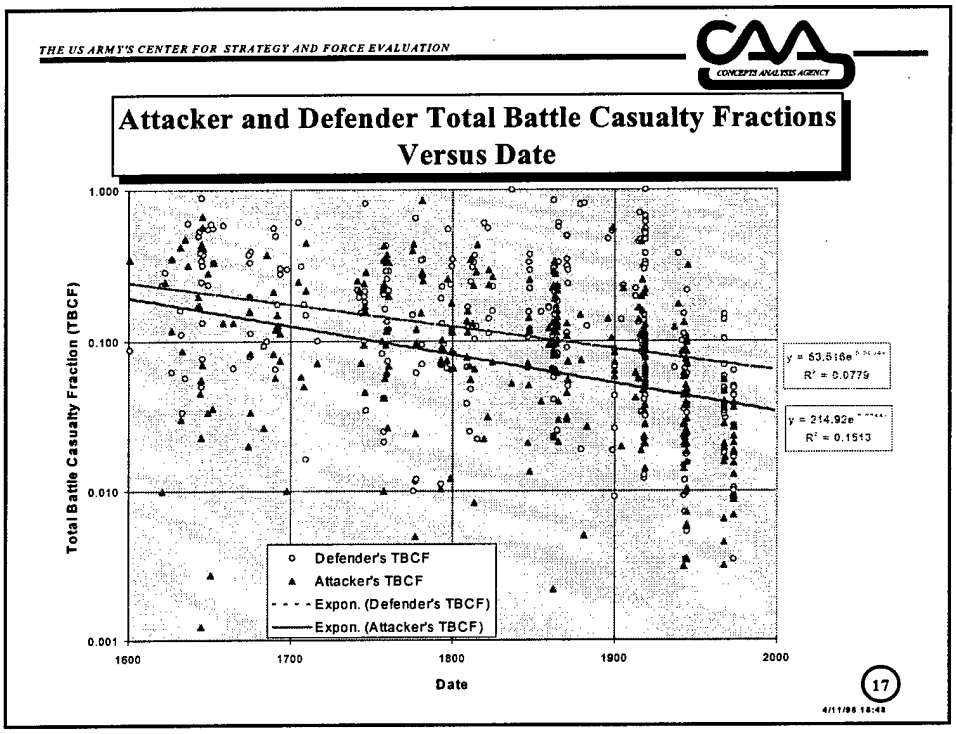


- This slide shows the attacker's and defender's total battle casualty numbers versus date. Here total battle casualties are defined to be the sum of the killed in action, wounded in action, missing in action, and captured.

- On the average, the attacker and the defender each take about the same number of casualties.

- On the average, the number of casualties on both sides has declined relatively steeply with the passage of time, despite the advances in weaponry. Despite the wide variability about the trendlines and the possible tendency to record larger and bloodier battles of long ago, this decline appears to be real. The estimated rate of decline is about 0.7 percent per year or 50 percent per century.

- Apparently, advances in protective measures (including armored vehicles, helmets, the use of field fortifications, dispersion, mobility, concealment, engaging at longer ranges, etc.) have outpaced the ability to seek out and destroy targets.

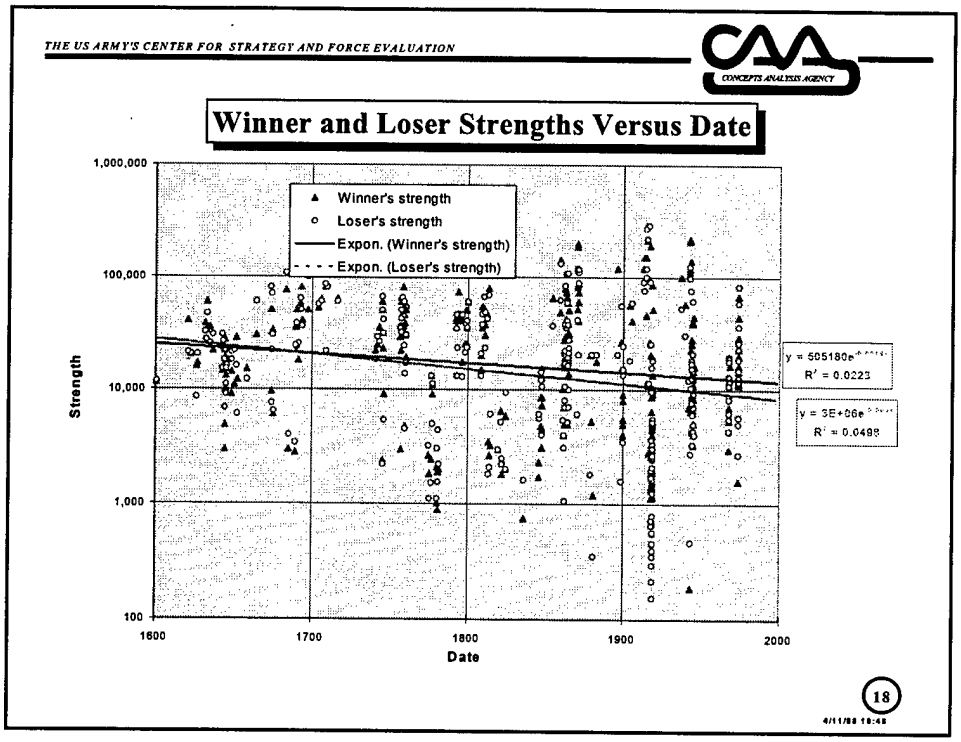


- This slide shows attacker and defender total battle casualty fractions versus date.

- Here the casualty fractions are relative to the initial strengths, and only battles with no significant reinforcements were used. (Otherwise, there would be an issue of what base to use for the fraction.)

- On the average, the casualty fractions of both sides appear to have declined at a moderate rate over the last 400 years. The estimated rate of decline is about 0.4 percent per year or 33 percent per century.

- Also, on the average, the defender' s casualty fraction tends to be somewhat higher than the attacker' s. However, a great many defender casualty fraction values are lower than the average attacker casualty fraction values, and vice versa. In other words, the attacker' s casualty fraction values (plotted as solid triangles) are well intermingled with the defender' s casualty fraction values (plotted as open circles).

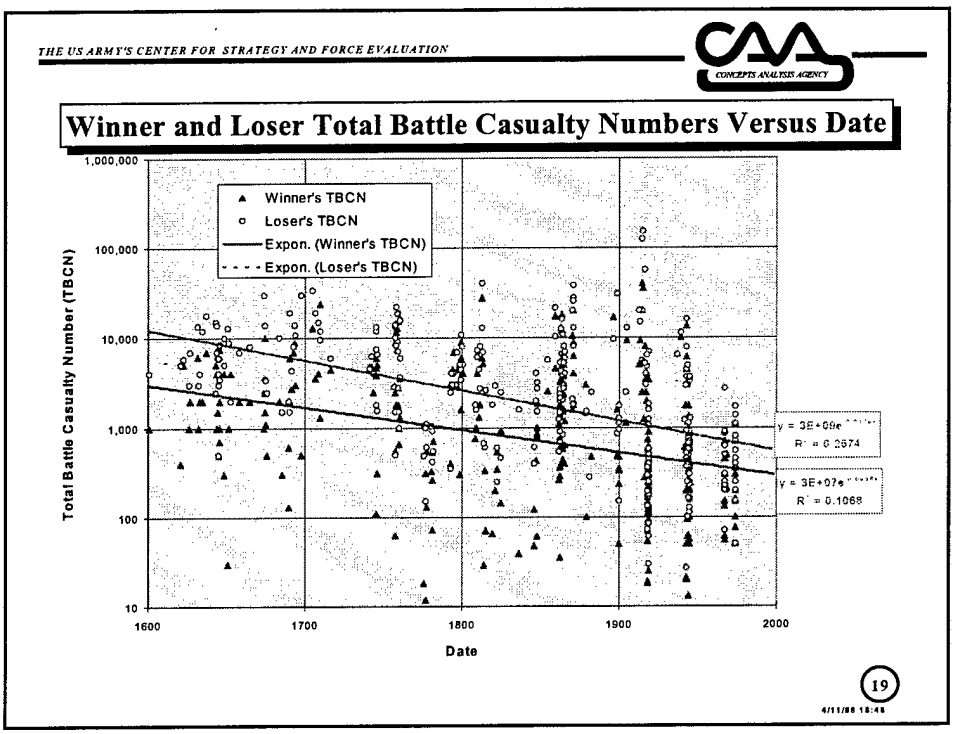


- The next series of slides shows the same data as in the previous slides, but using the winner and loser as the categories rather than the attacker and defender.

- On the average, winner and loser strengths have been about equal.

- On the average there has been a moderate decline in strengths with the passage of time over the last 400 years. The estimated average rate of decline is about 0.25 percent per year or 22 percent per century.

- However, the data scatter widely about the trendline, and the apparent decline may be due to a tendency to record larger and more notable battles in the past.

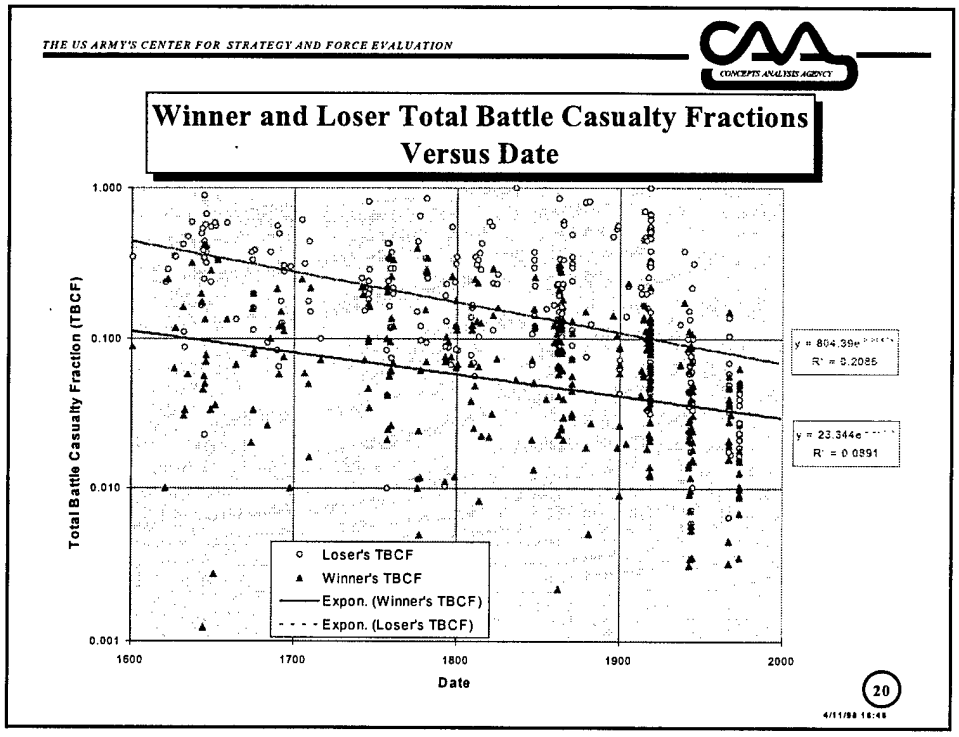


- This slide shows the winner's and loser's casualty numbers versus date. As before, total battle casualties are defined to be the sum of the killed in action, wounded in action, missing in action, and captured.

- On the average, the winner takes fewer casualties than the loser. However, the data scatter widely about the trendline, and the loser's data points (open circles) are well intermingled with the winner's data points (solid triangles).

- On the average, the number of casualties on both sides has declined relatively steeply with the passage of time, despite the advances in weaponry. Despite the wide variability about the trendlines and the possible tendency to record larger and bloodier battles of long ago, this decline appears to be real. The estimated rate of decline is about 0.7 percent per year of 50 percent per century.

- The reason is that advances in protective measures (including armored vehicles, helmets, the use of field fortifications, dispersion, mobility, concealment, engaging at longer ranges, etc.) have outpaced the ability to seek out and destroy targets.



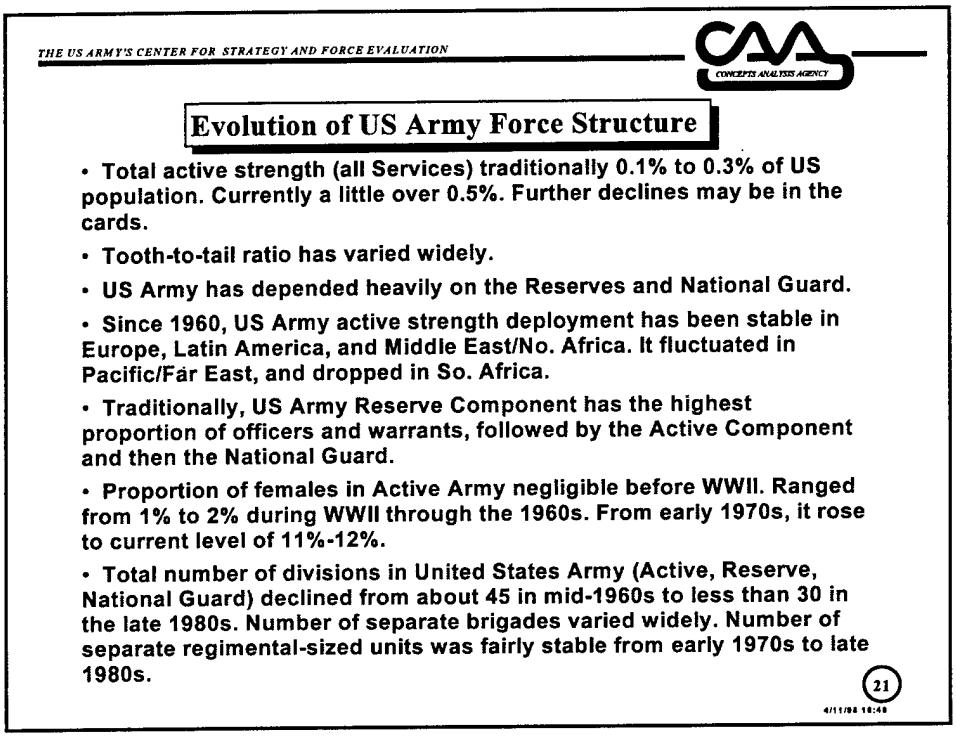
- This slide shows the winner's and loser's total battle casualty fractions versus date.

- Here the casualty fractions are relative to the initial strengths, and only battles with no significant reinforcements were used. (Otherwise, there would be an issue of what base to use for the fraction.)

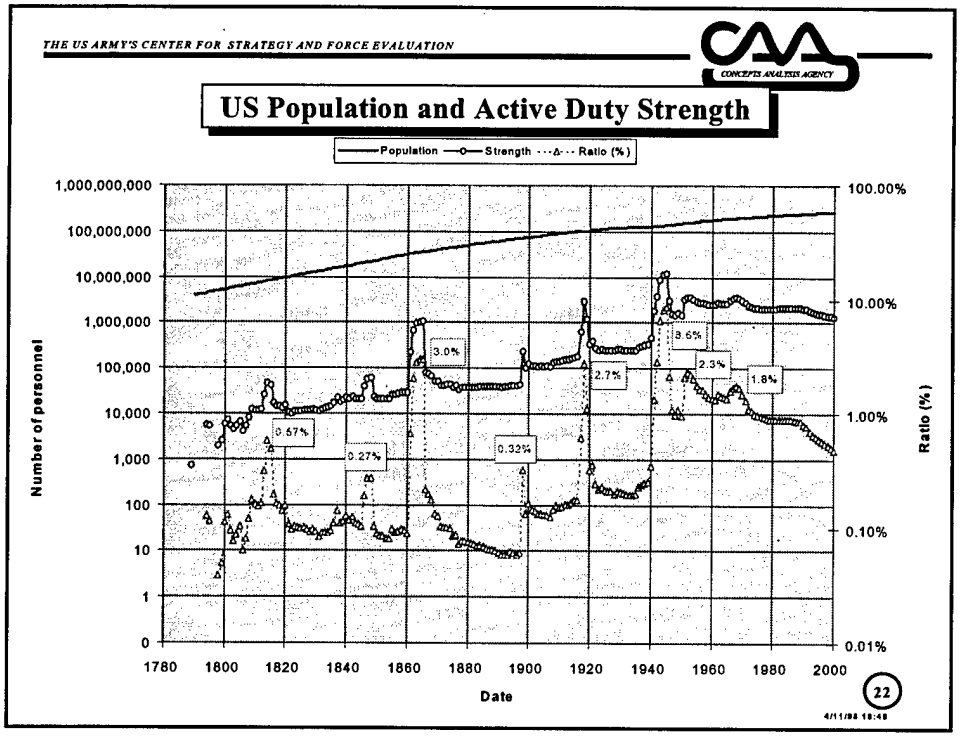
- On the average, the casualty fractions of both sides appear to have declined with the passage of time. The estimated rate of decline is about 0.4 percent per year or 33 percent per century.

- Also, on the average, the loser's casualty fraction is higher than the winner's. A few winner's casualty fraction values are lower than the average loser's casualty fraction value, and vice versa. However, the winner's casualty fraction values (plotted as solid triangles) are not as intermingled with the loser's casualty fraction values (plotted as open circles) as was the case in other slides.

- On the average, the loser's casualty fraction is more than double the winner's casualty fraction.



- The main findings of this section are summarized on this slide.
- The data used in this section are taken from:
- Various US Bureau of the Census publications, and
- *Evolution of US Army Force Structure (EUSAFS)*, Final Report, Science Applications International Company (SAIC) Report SAIC 89-1495, two volumes, 7 July 1989, UNCLASSIFIED.

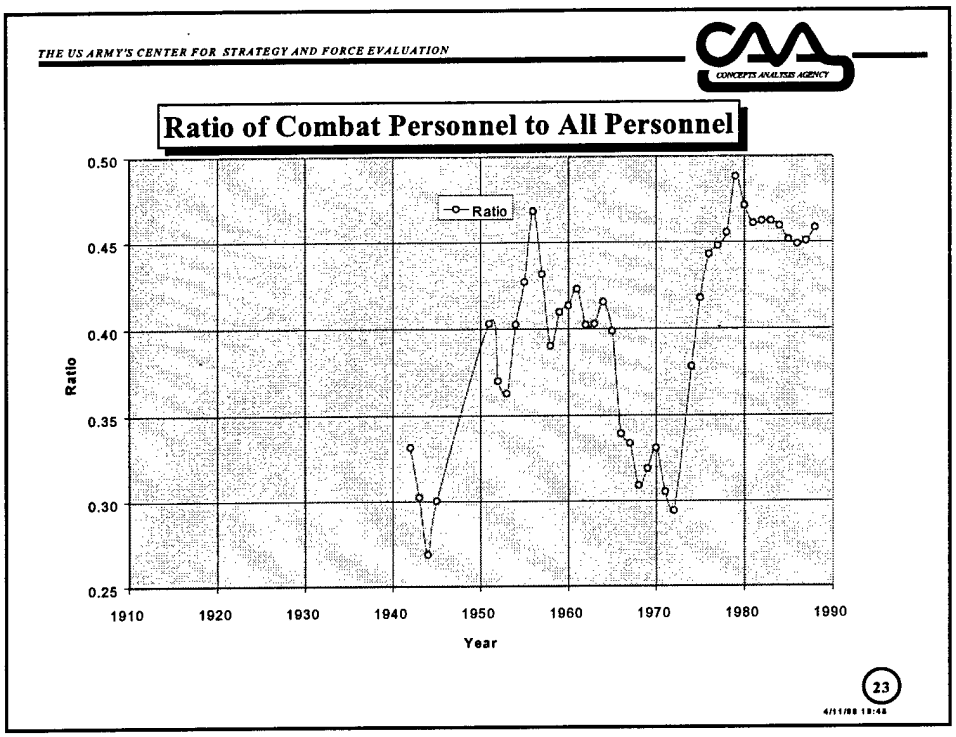


- This slide shows the US population size, the total active duty strength in all of the military forces (Army, Navy, Marine, and Air Force), and the ratio of active duty strength to the total population. Use the left-hand scale for the US population and active duty strength. Use the right-hand scale for the ratio (expressed as a percentage) of active duty strength to the population size.

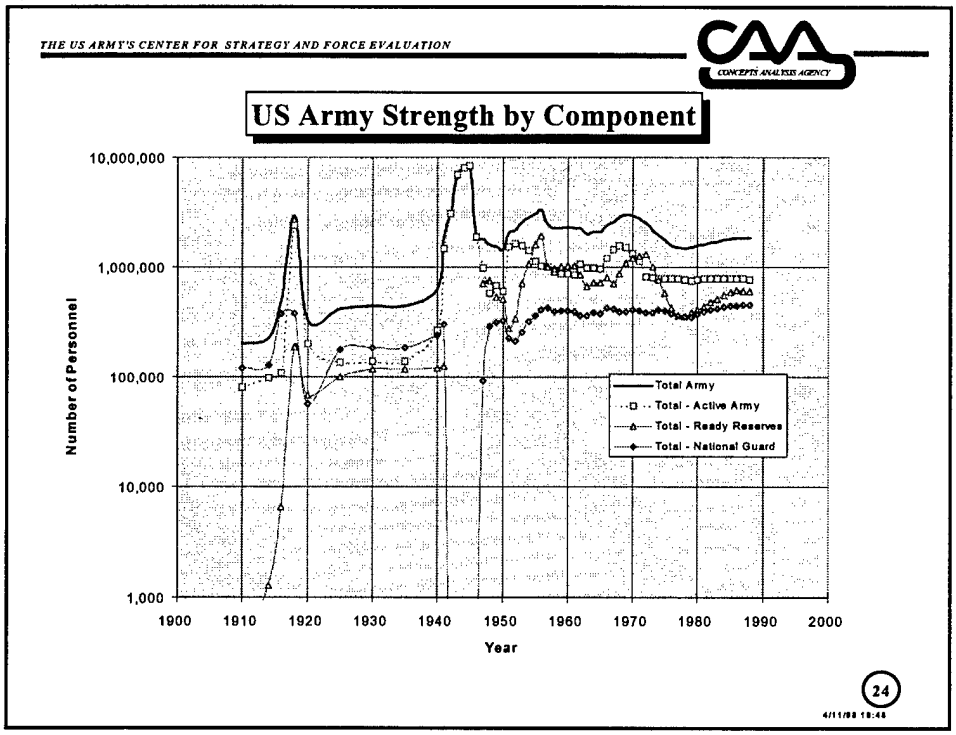
- This figure uses US Bureau of the Census data for past years, and DOD projections for near future years.

- As can be seen, except for the Cold War period, in peacetime the United States traditionally has maintained an active duty ratio of about 0.1 to 0.3 percent of its total national population. Currently, the active duty strength ratio is a little over 0.5percent of the national population and is scheduled to decline over at least the next few years.

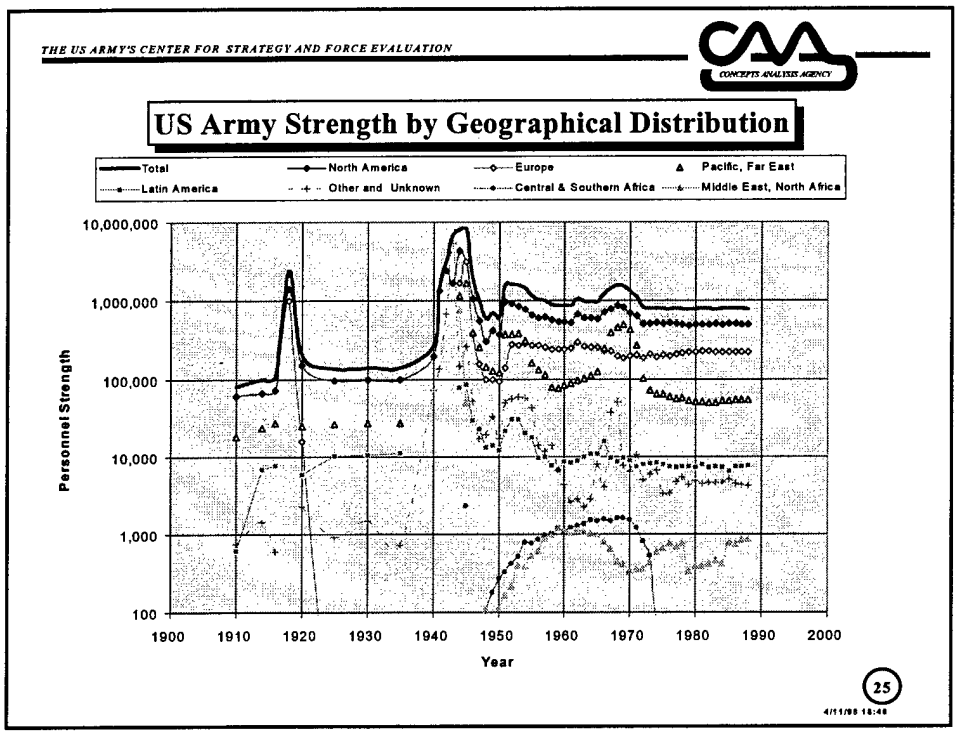
- One possible projection to the year 2010 would be to assume that current population growth rates continue but that by 2010 active duty strength declines to 0.3percent of the population. In that case, we might expect an active duty strength in 2010 of roughly 900,000, or 62 percent of the current active duty strength of about 1,430,000.



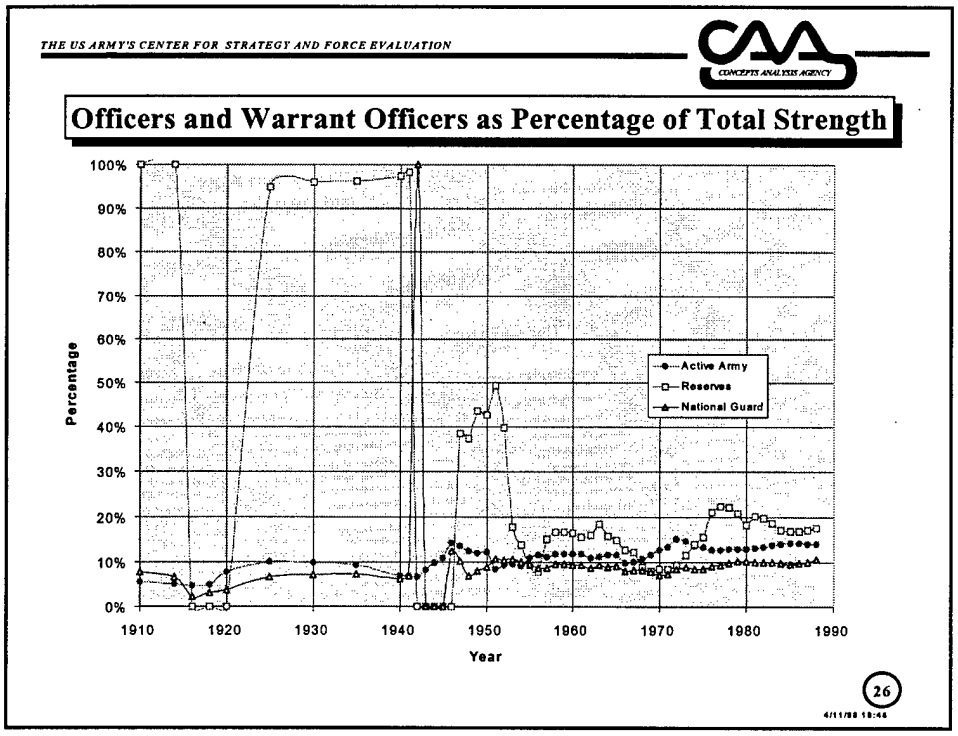
- This slide shows the "tooth-to-tail" ratio for the US Army as a whole.
- Here "Combat Personnel" include those in combat divisions and in non-divisional combat units.
- The total number of personnel are those in the Active Component.
- The ratio has varied over a wide range. However, a nominal figure of about 30 to 40 percent seems to be more or less typical for the period from 1950 onward.
- Perhaps a reasonable goal would be to attempt to keep the "tooth-to-tail" ratio in the 40 to 45 percent range.



- This slide shows the US Army strength by component.
- Note that the US Army has depended heavily on the Ready Reserve and National Guard Components for the entire period shown here.



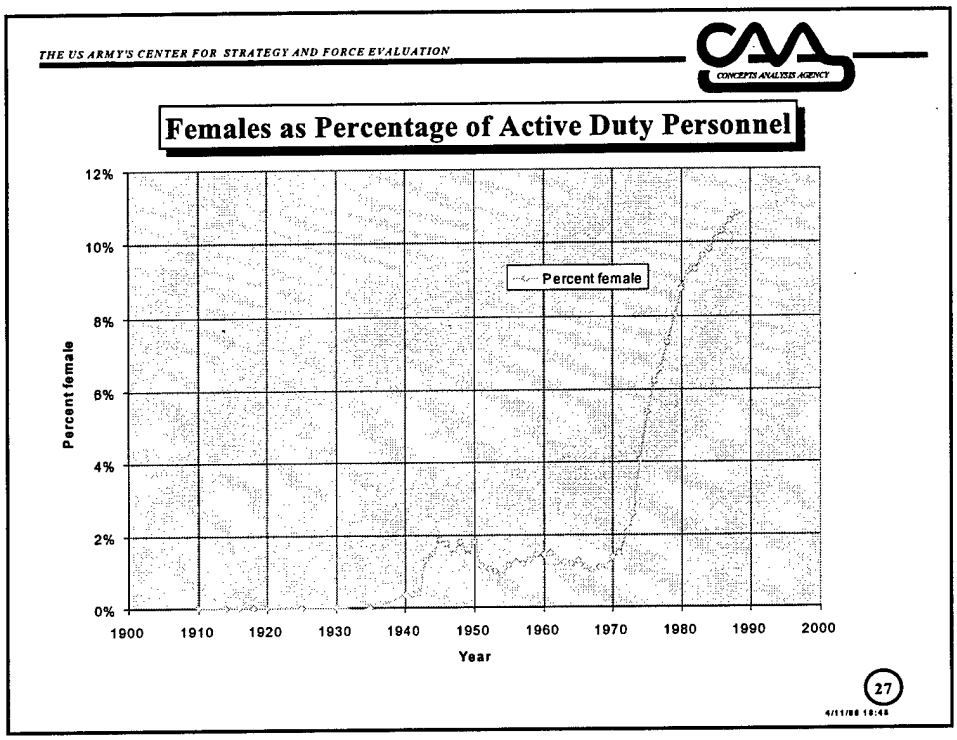
- This slide shows the US Army Active Component strength by geographical distribution.
- Note the decline of strength in Central and Southern Africa in the early 1970s and the general stability of strength in the Middle East/North Africa region since the mid-1950s.



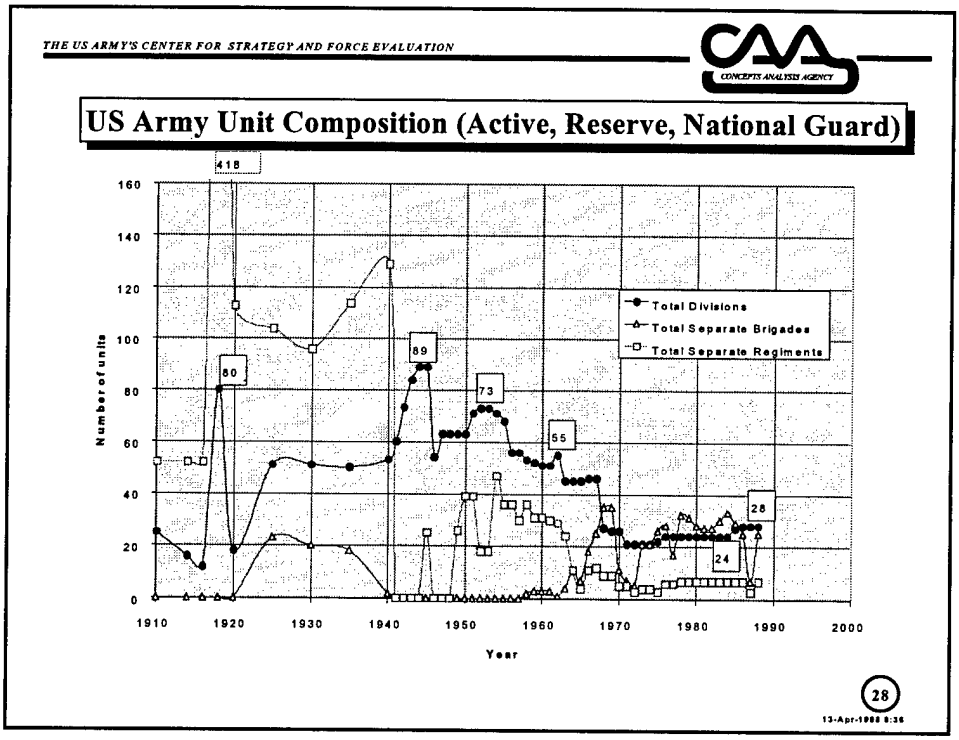
- In general, the Reserve Component has been relatively heavy on officers and warrants, while the National Guard has been relatively light on officers and warrants.

- This raises the interesting question: "What is the best mix of officers and enlisted for each of the various components?"

- The "spike" in the National Guard officer percentage in 1942 is due to the fact that there were only 50 men in the National Guard that year, all of them officers.



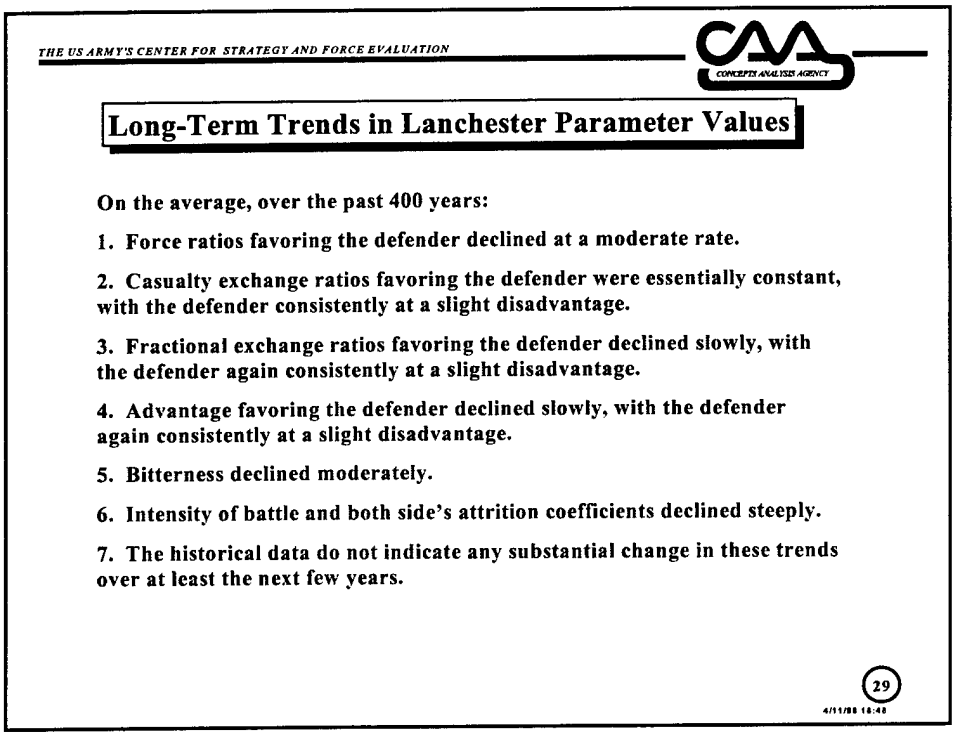
- The percent females in the active force was negligible until World War II. Then it stayed at a level of 1-2 percent for about three decades. Beginning in the early 1970s, the percentage of females began to rise dramatically, compared to its previous levels, reaching a level of about 11 percent in the late 1980s.



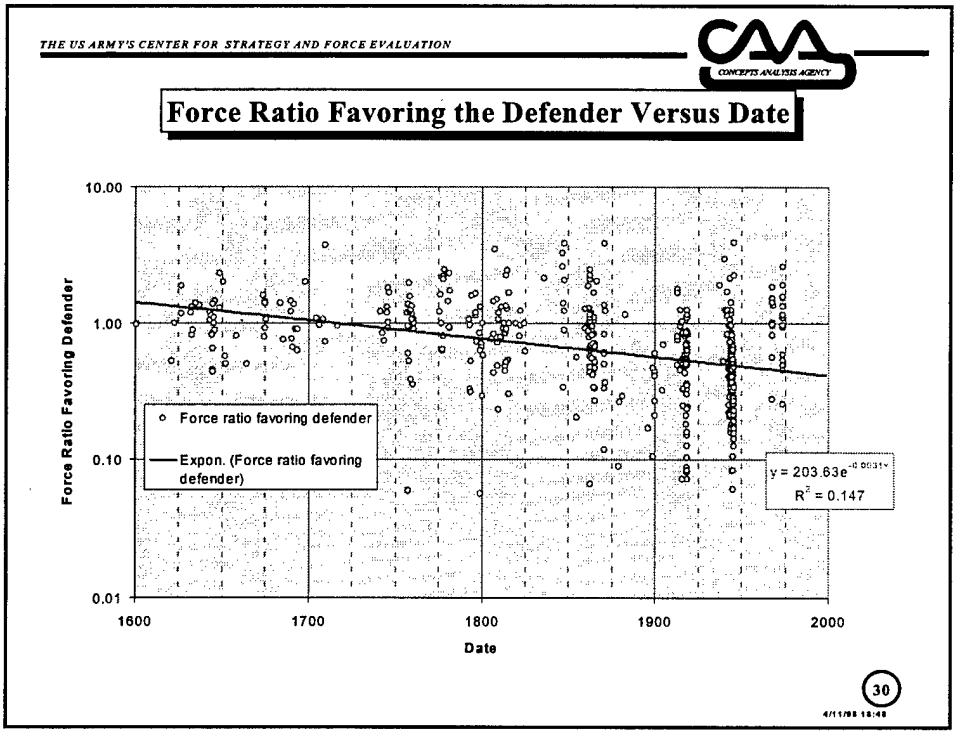
- The number of divisions in the United States Army (Active, Reserve, and National Guard) declined from about 45 in the mid-1960s to less than 30 in the late 1980s.

- The number of separate brigades has varied widely from 1960 to the present day. (To some extent this is the result of decisions to separate the components of certain divisions, or to regroup them into a divisional structure.)

- The number of separate regimental-sized units has remained fairly steady at about 7 from the early 1970s through the late 1980s.



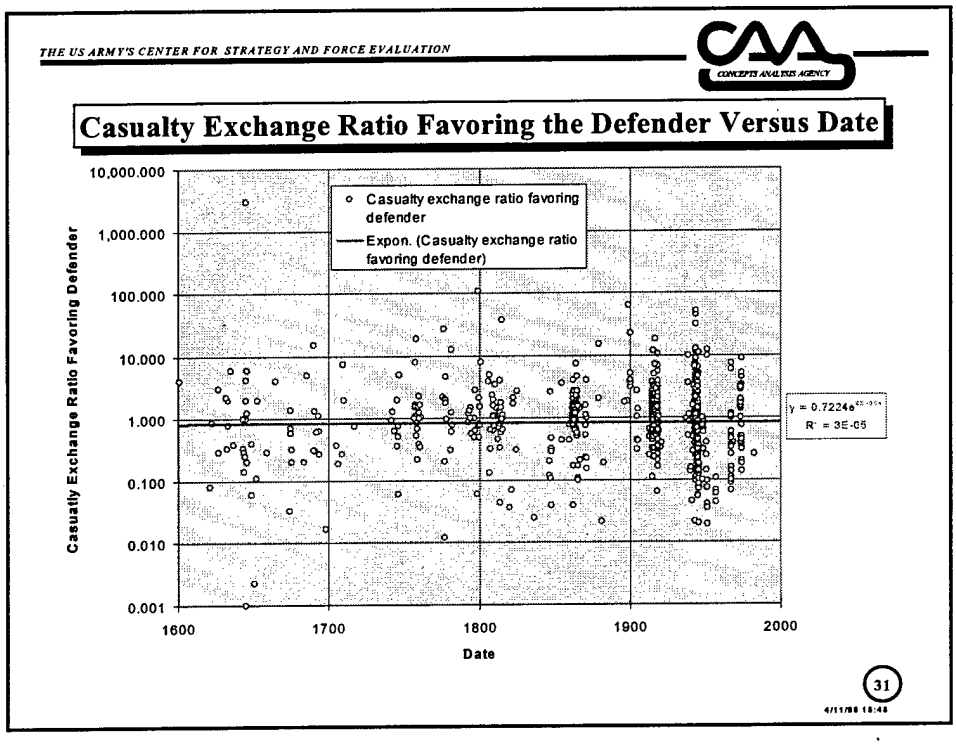
- The main findings of this section are summarized on this slide.
- The data used in this section are taken from:
- *Catalog of CAA's Computerized Historical Data Bases as of December 1997*, US Army Concepts Analysis Agency Memorandum Report CAA-MR-98-1, January 1998, UNCLASSIFIED/LIMITED, AD-(TBD).
- But especially from CDB91DAT.xls, the CAA data base of battles.



- On the average, the force ratio favoring the defender declined over the last 400 years. The estimated average rate of decline is about 0.3 percent per year or close to 25 percent per century.

- Compare this with slide 15, which shows that on average the strengths on both sides declined, but that on average the defender' s strength declined more steeply than the attacker' s did.

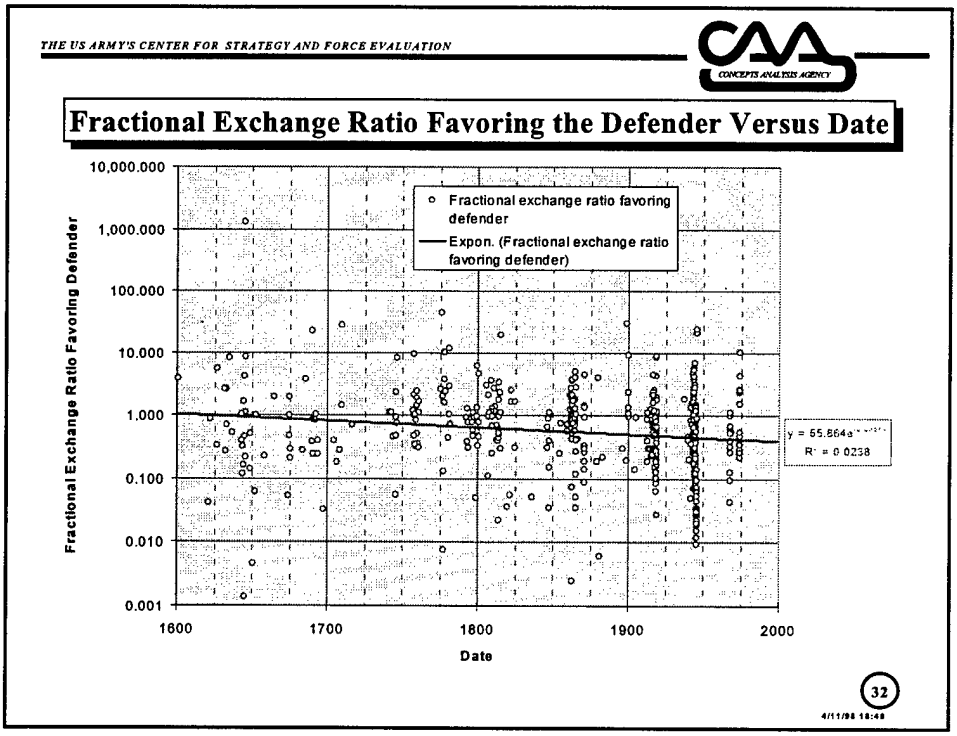
- There is a suspicion that the force ratio favoring the defender may have been fairly constant and near unity from 1600 to about the mid-1800s, and dropped off thereafter. However, the data offer only weak support for this suspicion.



- On the average, the casualty exchange ratio favoring the defender seems to have been constant for the last 400 years, with a median value of about 0.85.

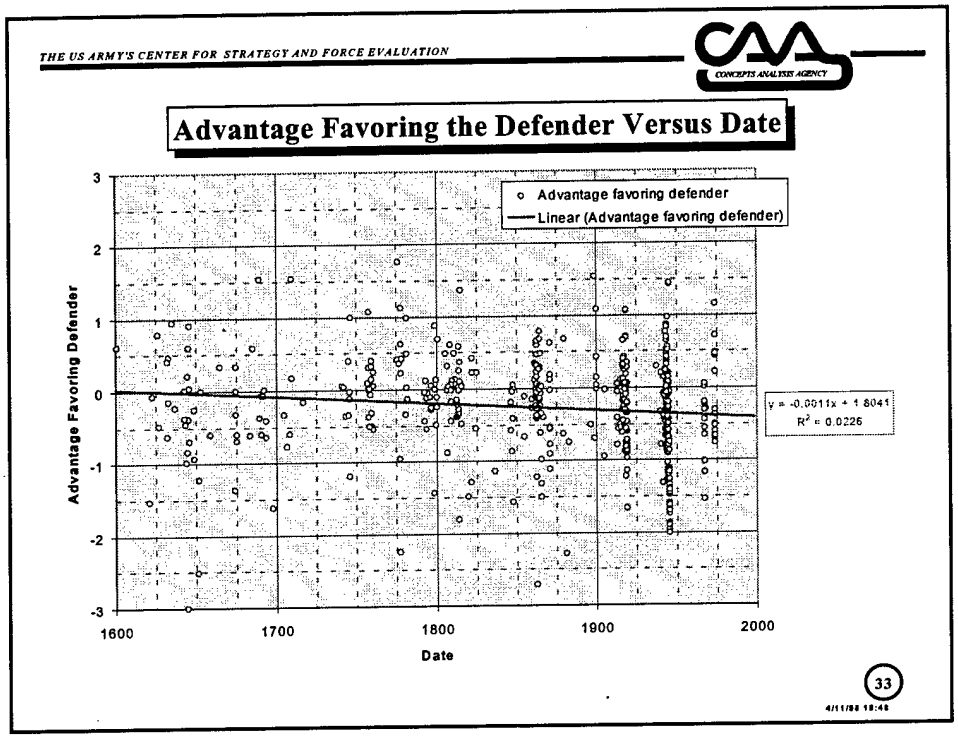
- From a casualty exchange ratio point of view, on the average the defender has consistently been at a slight disadvantage. This is counter to the oft-stated view that the defender has several inherent advantages over the attacker (such as the ability to select, study, and prepare the ground; better concealment and less exposure; less movement conducive to easier supply, etc.).

- Apparently, on the average, these defender advantages are subordinate to those possessed by the attacker (such as the ability to choose the time, place and manner of the attack, and to adjust these as the battle unfolds; greater freedom to break off the attack if it is unsuccessful, etc.).

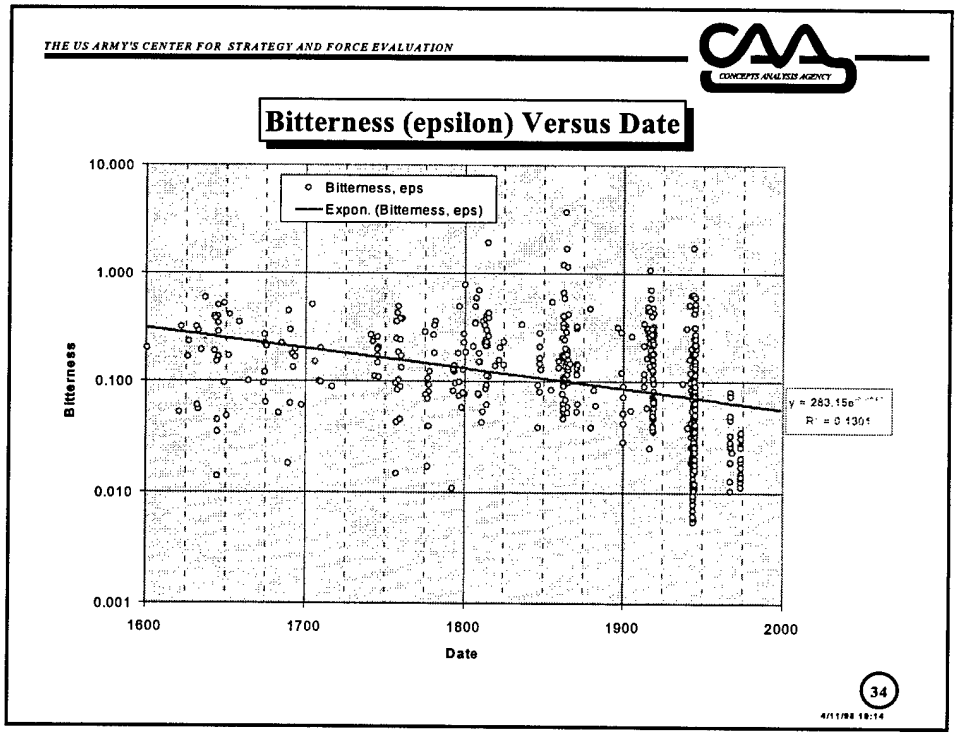


- On the average, the fractional exchange ratio favoring the defender has declined somewhat over the last 400 years. The estimated average rate of decline is about 0.25 percent per year, or close to 22 percent per century.

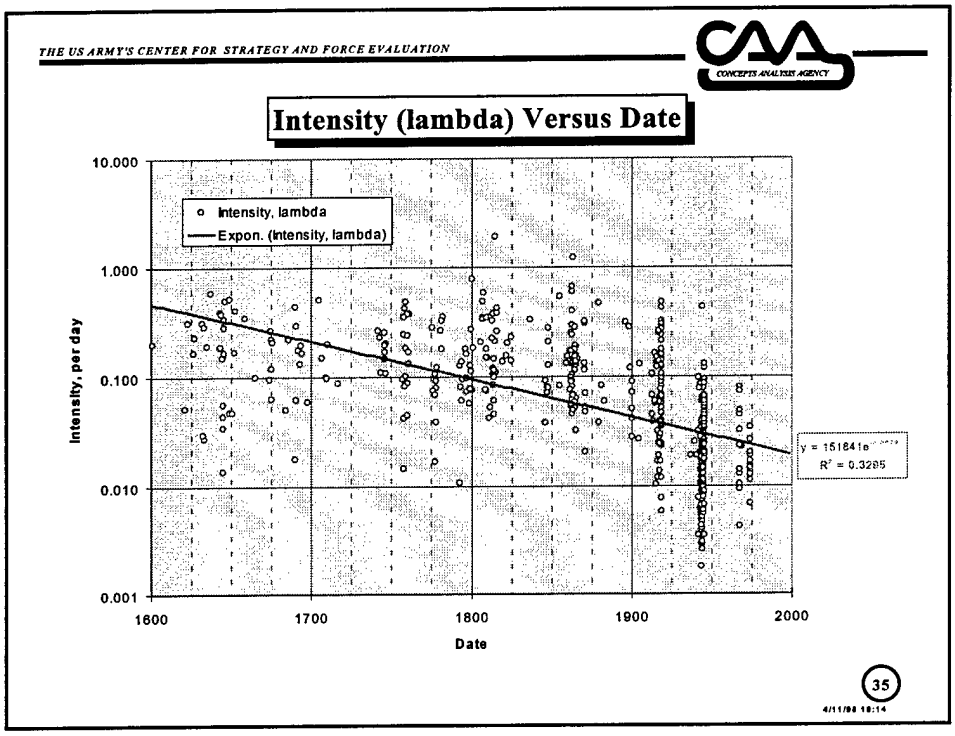
- There is a suspicion that it may have been relatively stable from 1600 to about the mid-1800s, after which it slowly declined. However, the data only weakly support this suspicion.



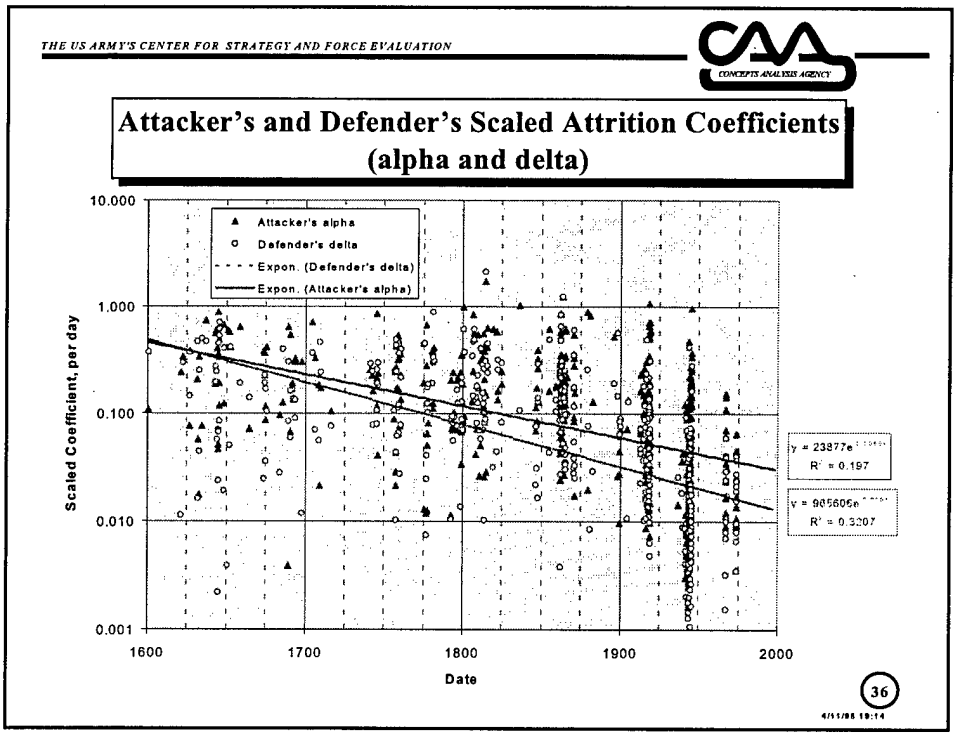
- The Lanchester square law advantage parameter favoring the defender has also declined slowly over the last 400 years.
- The estimated average rate of decline is about 0.1 percent per year (or 11 percent per century since here we are using a linear scale on the abscissa).
- There is a suspicion that it may have been relatively stable from 1600 to the mid-1800s, after which it dropped off. However, the data only weakly support this suspicion.



- The bitterness of a battle is approximately equal to the geometric mean of the casualty fractions on the two sides.
- The bitterness of battles has declined over the last 400 years. The rate of decline is about 0.43 percent per year or 35 percent per century.
- Again, there is some indication that the bitterness of battle may have been relatively stable from 1600 through the mid-1800s and dropped off thereafter. However, here as in the other cases, the data only weakly support that suspicion.

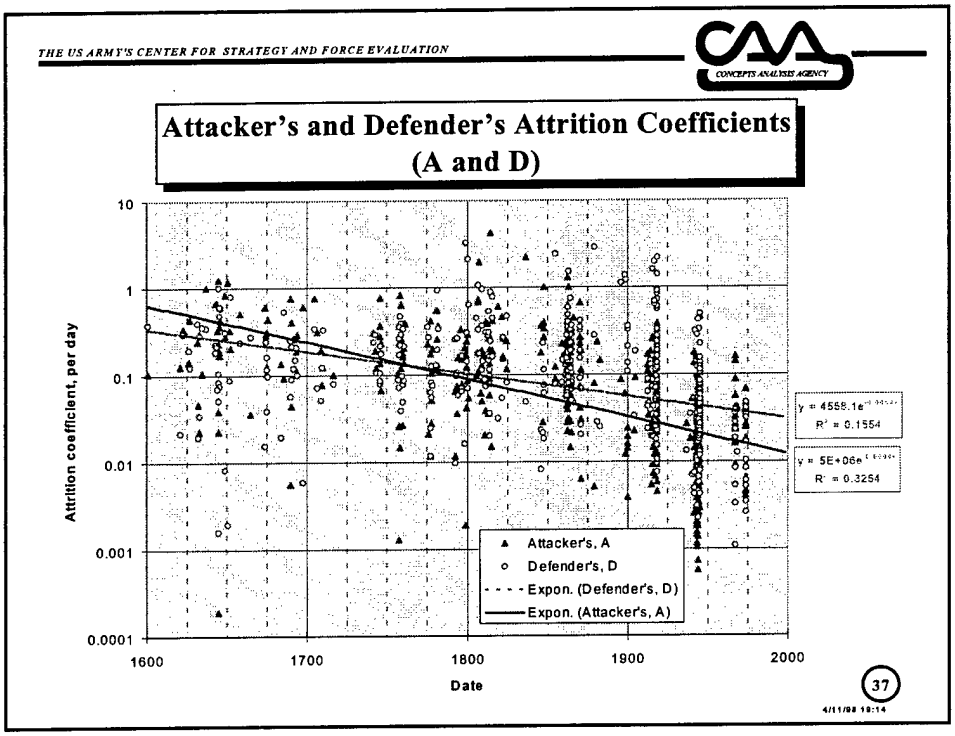


- The intensity of a battle is equal to its bitterness divided by its duration in whole days.
- On the average, the intensity of battle as measured by the lambda parameter declined relatively steeply over the last 400 years. The estimated average rate of decline is about 0.8 percent per year or about 55 percent per century.
- As in other cases, there is a suspicion that most of the decline occurred after the mid-1800s, but the data only weakly support this suspicion.



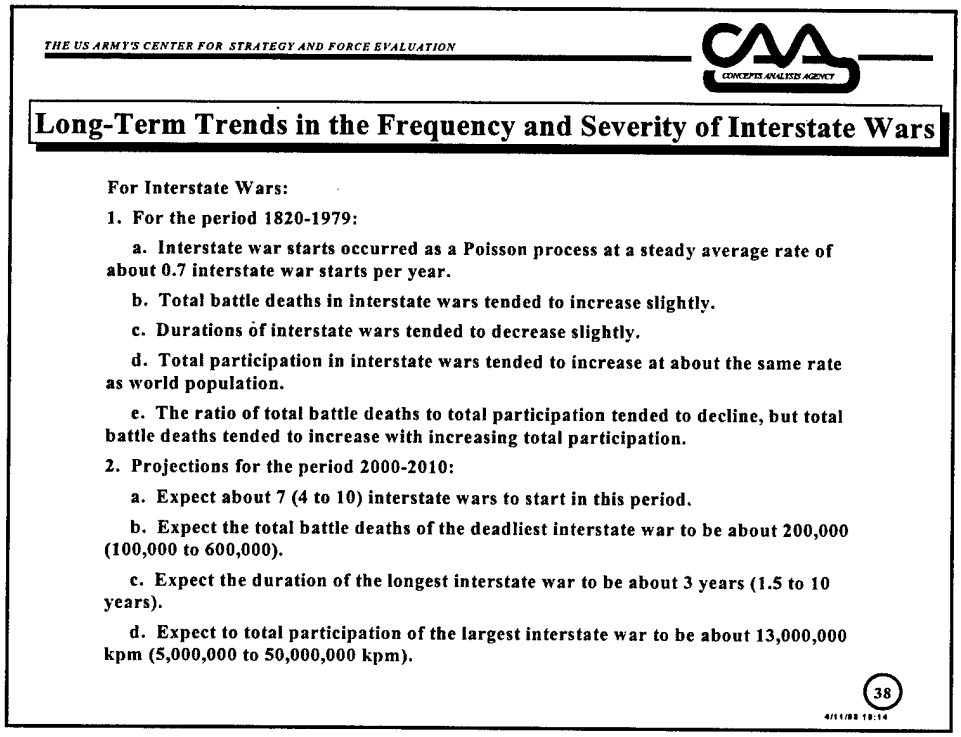
- On the average, the attacker's and defender's scaled attrition coefficients both declined relatively steeply over the last 400 years. The estimated average rate of decline is about 0.8 percent per year or 55 percent per century.

- There is some indication that most of the decline took place after the mid-1800s, but the data scatter so widely about the trendlines that no definitive conclusion can be supported.

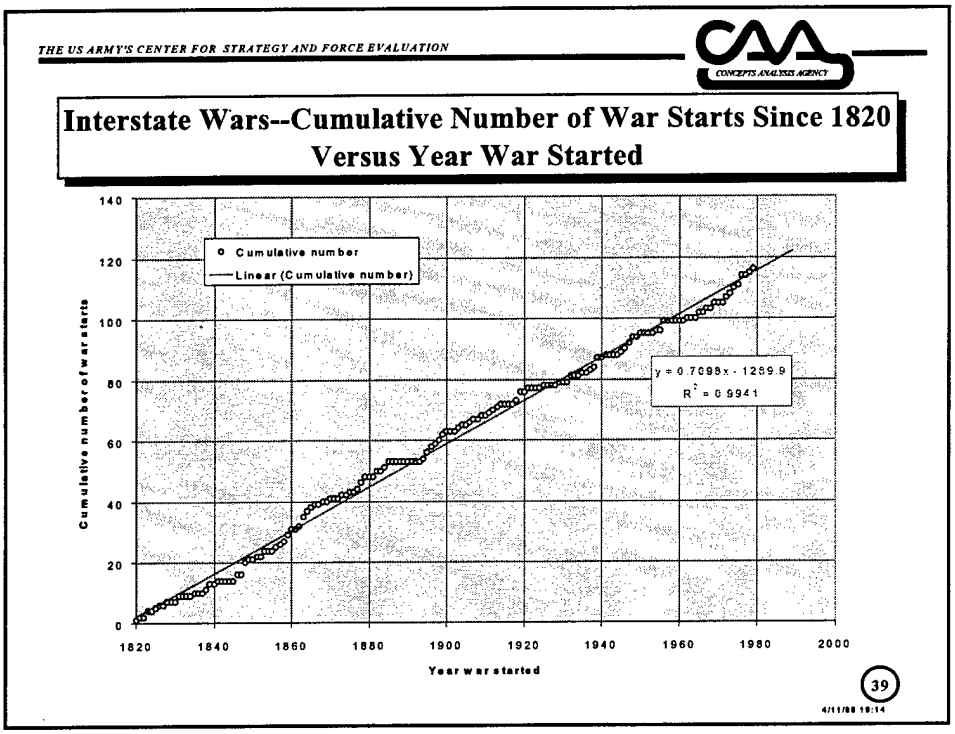


- On the average, the attacker's and defender's attrition coefficients declined over the last 400 years. The estimated average rate of decline is about 0.8 percent per year or 55 percent per century.

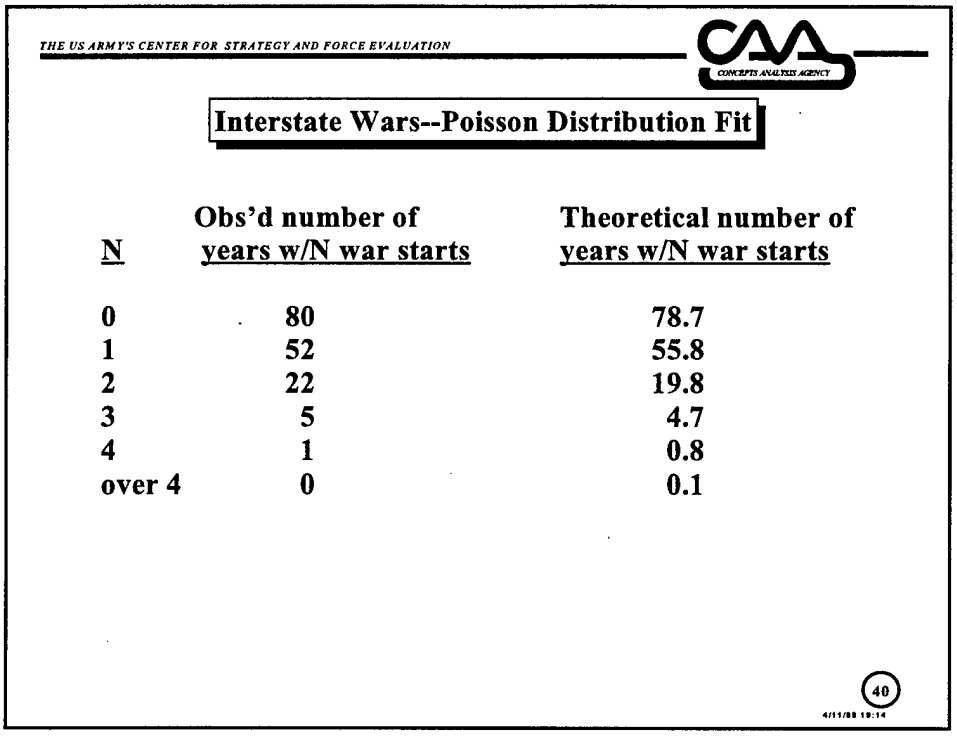
- It is possible that most of the decline took place after the mid-1800s, but the data scatter so widely about the trendlines that no definitive conclusion can be drawn.



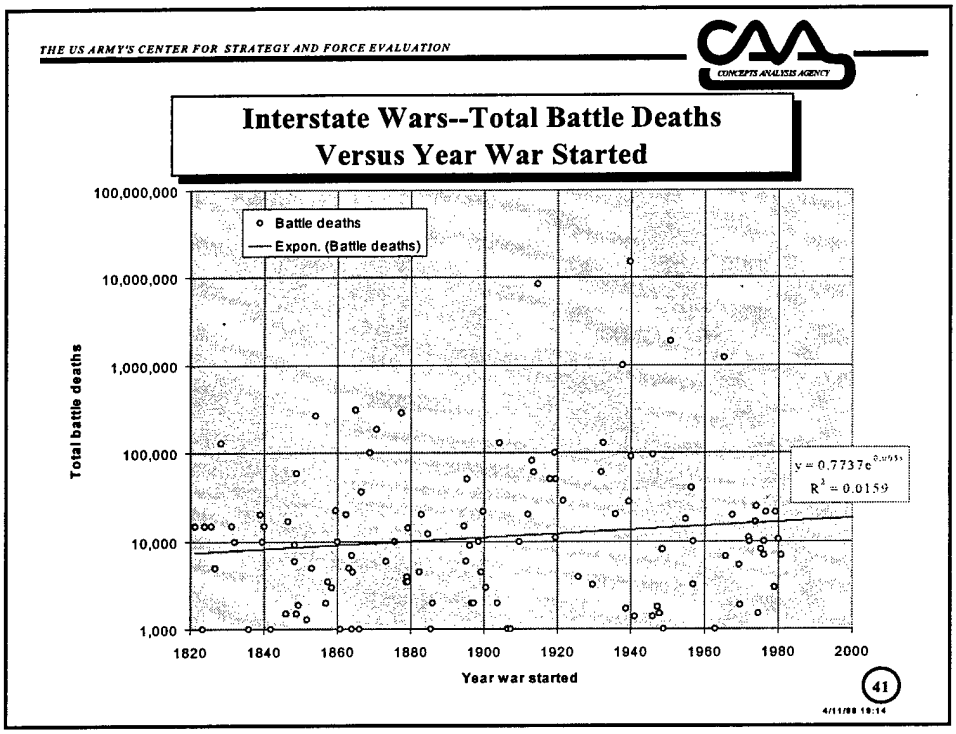
- The main findings of this section are summarized on this slide.
- Here an interstate war is one between entities, at least one of which is a state as formally recognized by the international community of states, and which involves at least 1,000 battle deaths.
- The total participation of a nation is defined as the product of that nation' s prewar population by the number of months that nation actively fought in the war. Participation ends when the nation surrenders or becomes a neutral, or the war ends. Participation once ended can be resumed if the nation is liberated or resumes its belligerent status. Total participation is the sum of the participations of all of the nations that actively fought in the war.
- The data used in this section are taken from the following data file, obtained from the Inter-University Consortium for Political and Social Research, Ann Arbor, Michigan:
- *Wages of War, 1816-1980: Augmented With Disputes and Civil War Data-- Part 1: Interstate Wars; Part 2: Civil Wars.* (ICPSR 9044), Principal Investigators: J. David Singer and Melvin Small, First ICPSR Edition, Winter 1984.



- Interstate wars have started at a very nearly constant rate from 1820 to 1979. (Our data base ends at 1979.)
- The rate at which interstate wars started was about 0.7 interstate war starts per year.
- There is no indication in these data that the rate is likely to change significantly over at least the next few years.

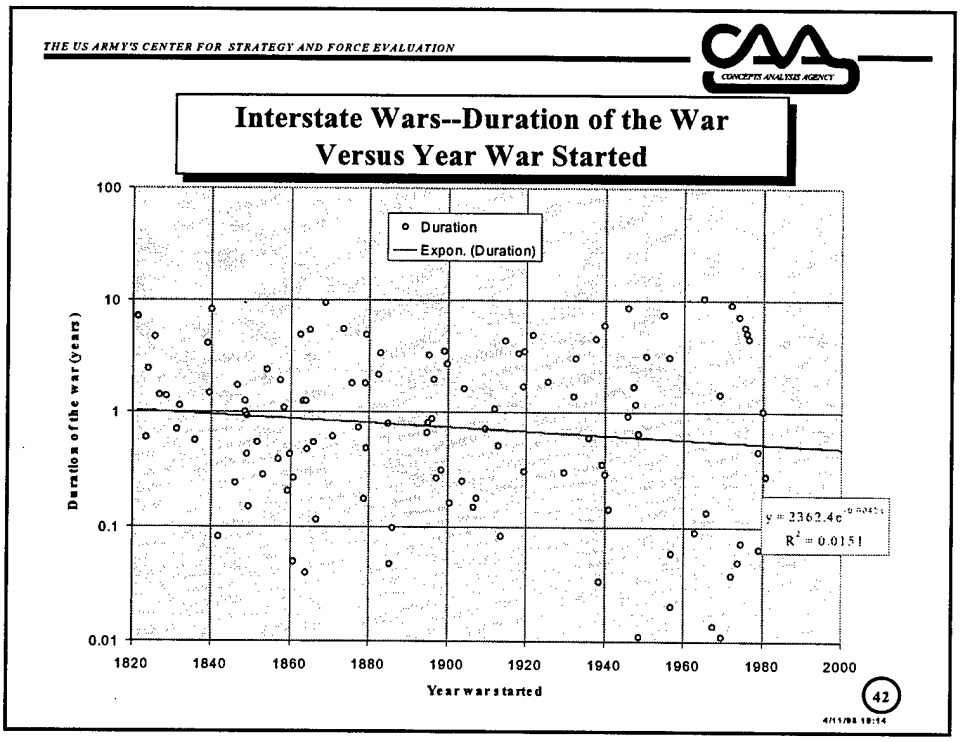


- This table shows that the observed number of years with N interstate war starts is reasonably consistent with a Poisson process and a constant rate of about 0.7 interstate war starts per year.
- The projections to be developed later assume that this statistical pattern will persist for at least the next few years.

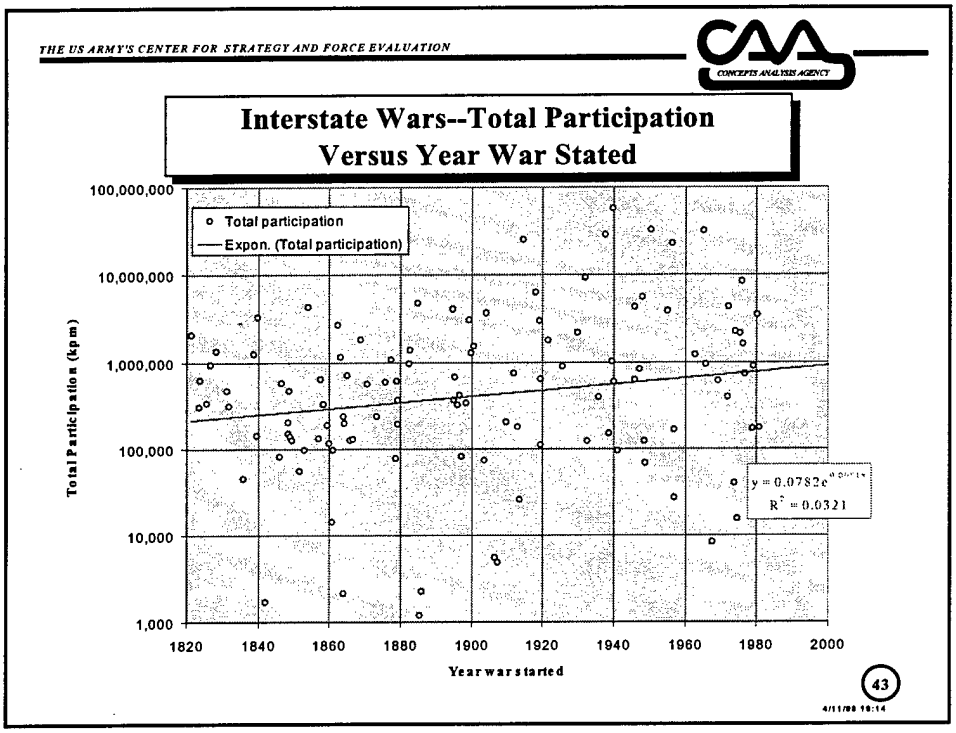


- Total battle deaths in interstate wars have tended to increase since 1820 at a rate of about 0.5 percent per year or about 40 percent per century.

- However, it may be that the 20th century' s world wars are outliers that increase the rate of increase beyond that which is real, or that interstate wars of the "Pax Brittanica" period of the late 19th Century were relatively less bloody than the norm.



- The duration of interstate wars has tended to decline somewhat with the passage of time. The average rate of decline is about 0.42 percent per year, or 34 percent per century.



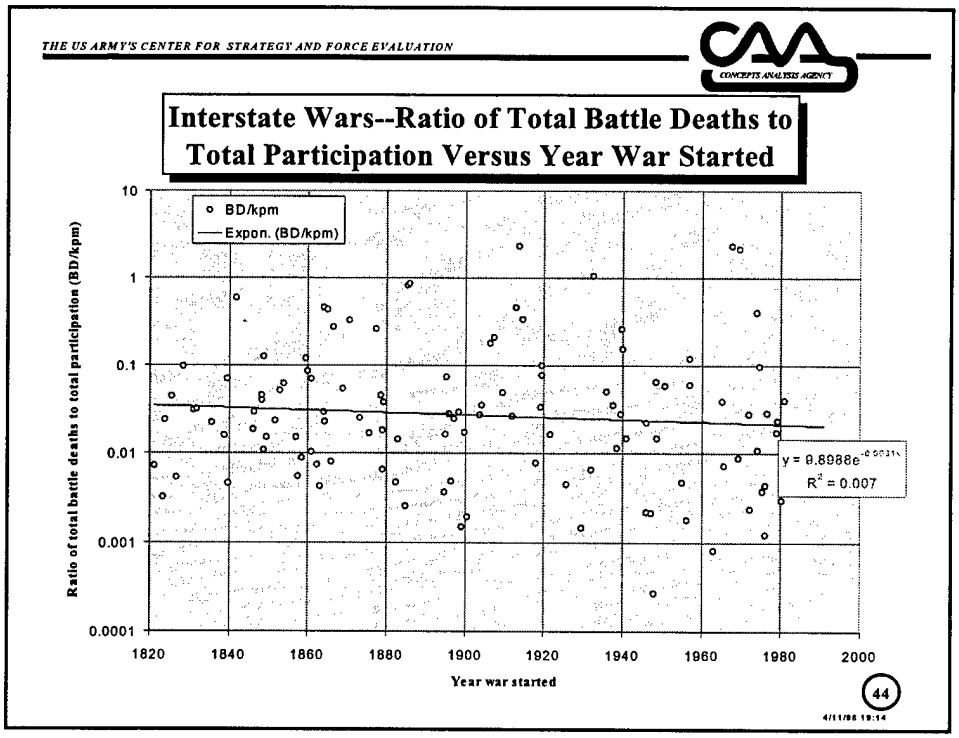
- The total participation of a nation is defined as the product of that nation' s prewar population by the number of months that nation actively fought in the war. Participation ends when the nation surrenders or becomes a neutral, or the war ends. Participation, once ended, can be resumed if the nation is liberated or resumes its belligerent status.

- Total participation for a war is the sum of the participations of all of the nations that actively fought in the war.

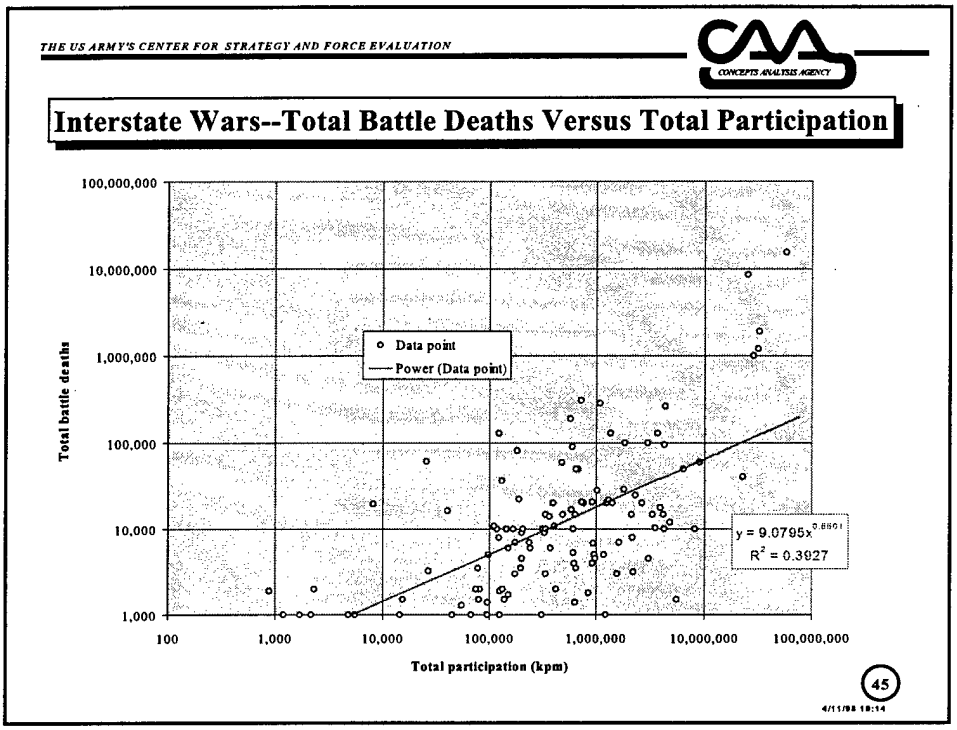
- The abbreviation "kpm" stands for "kilo-person-months" and indicates that the total participation is given in units of 1,000 person-months.

- The total participation in interstate wars increased relatively steeply over the period 1820-1979. The average rate of increase was 0.81 percent per year or 56 percent per century.

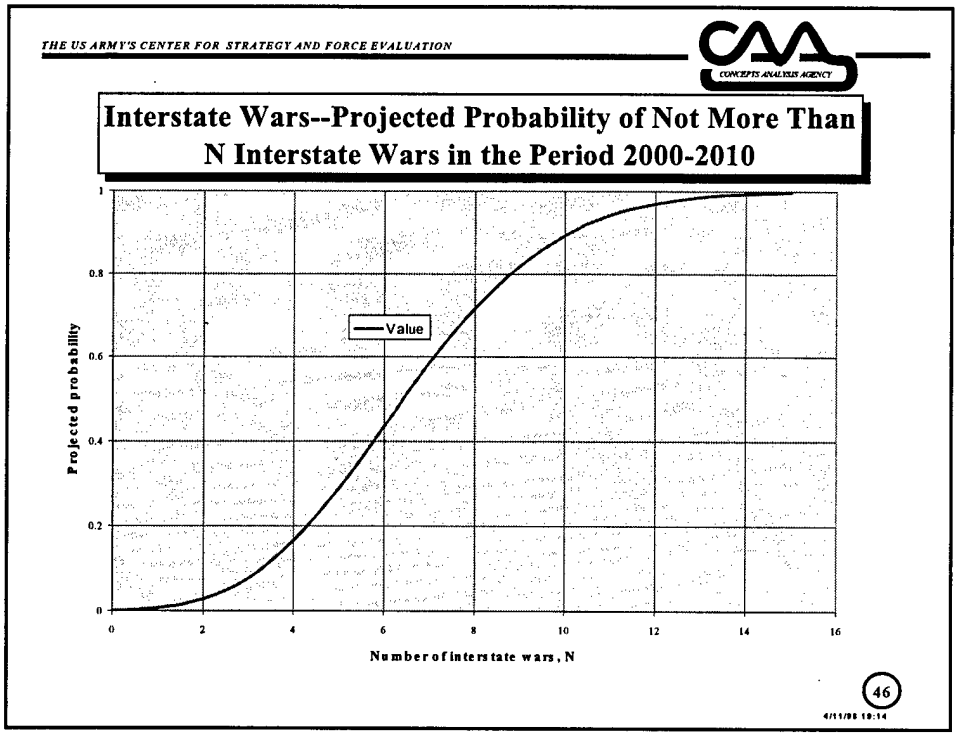
- This rate of increase is about the same as the average rate of growth of the world population over the same period of time. However, no causal relationship is known to exist between these quantities.



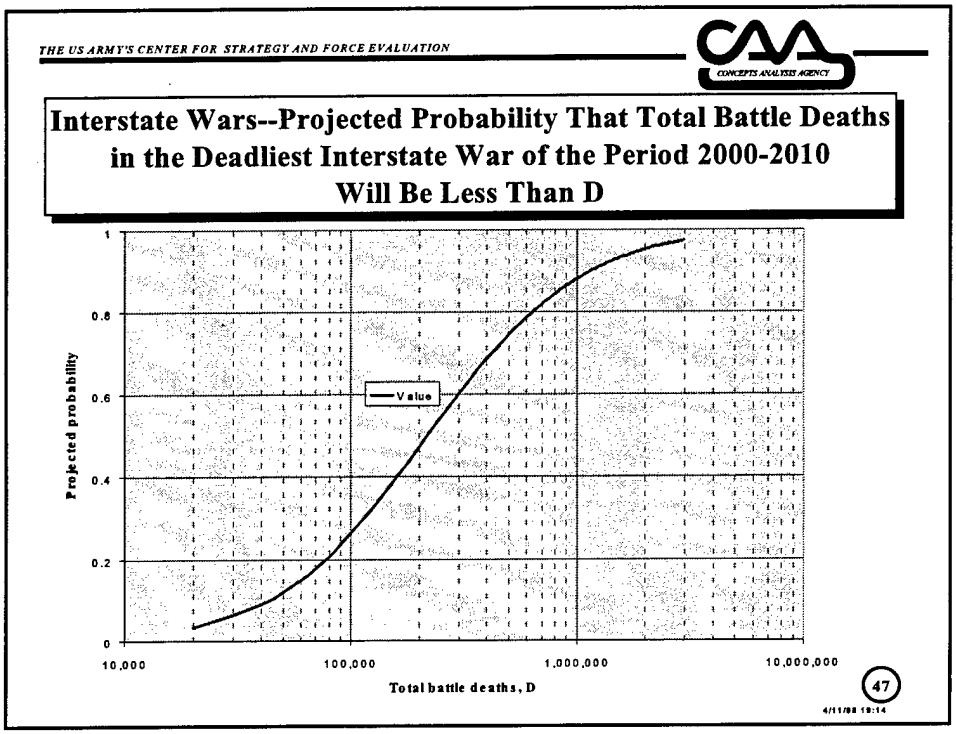
- This slide shows the ratio of total battle deaths to total participation for interstate wars of the period 1820-1979.
- On the average, this ratio decreased at a relatively moderate rate of about 0.31 percent per year or 27 percent per century.
- As in many other cases, the historical data show no sign of any imminent change in either the average rate of decrease or in the amount of scatter about the trendline. When we come to make projections, we will assume that the trendline and the scatter continue on their historical courses for at least the next few years.



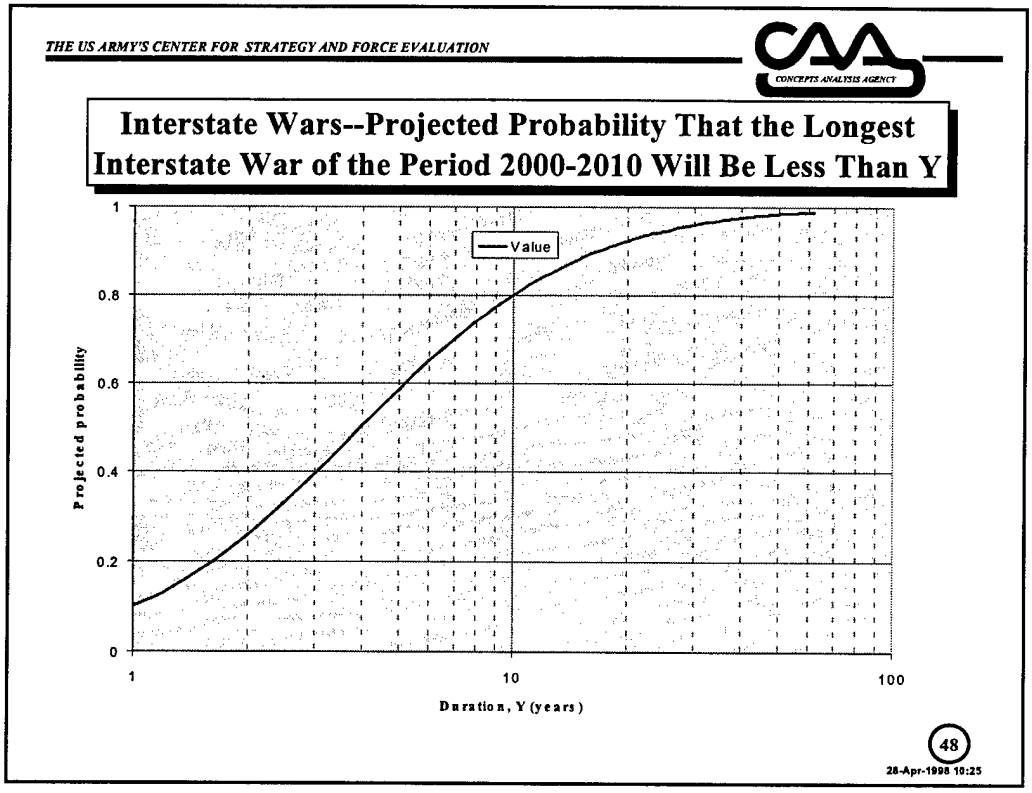
- This slide shows the total battle deaths versus total participation for interstate wars of the period 1820-1979. Evidently, total battle deaths increase as the total participation increases. However, the increase is not simply proportional, but instead is governed by a nonlinear relationship. Thus, total battle deaths are less than doubled when the participation is doubled.



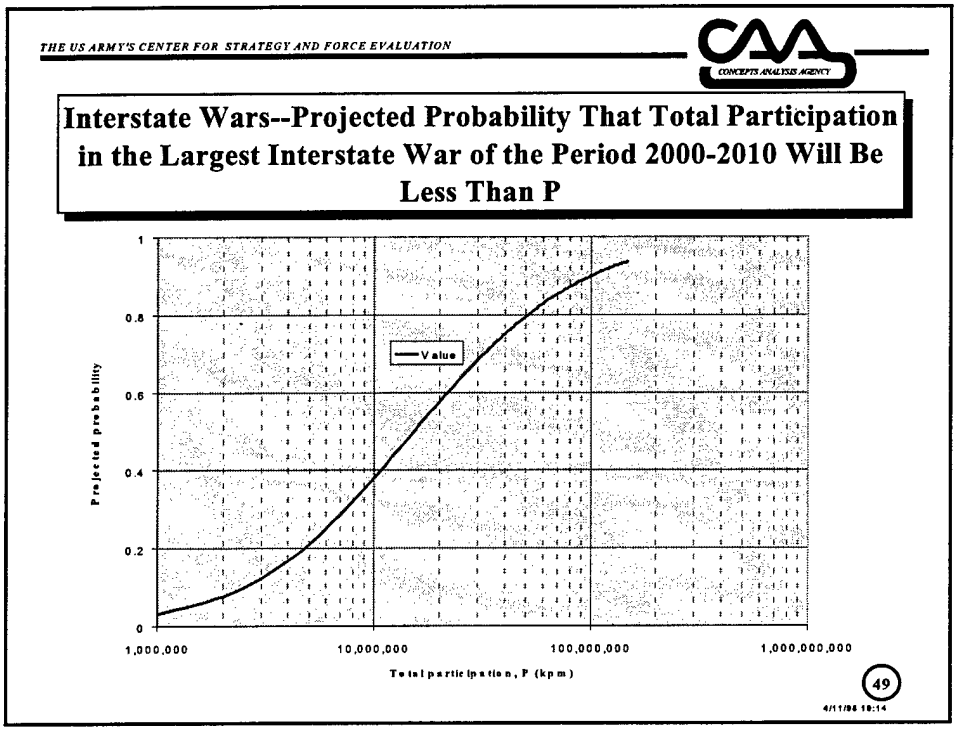
- This slide shows the projected probability that not more than N interstate wars will start during the period 2000-2010.
- This and analogous projections are based on the assumption that the statistics of interstate wars over at least the next few years will be similar to those of the period 1820-1979.



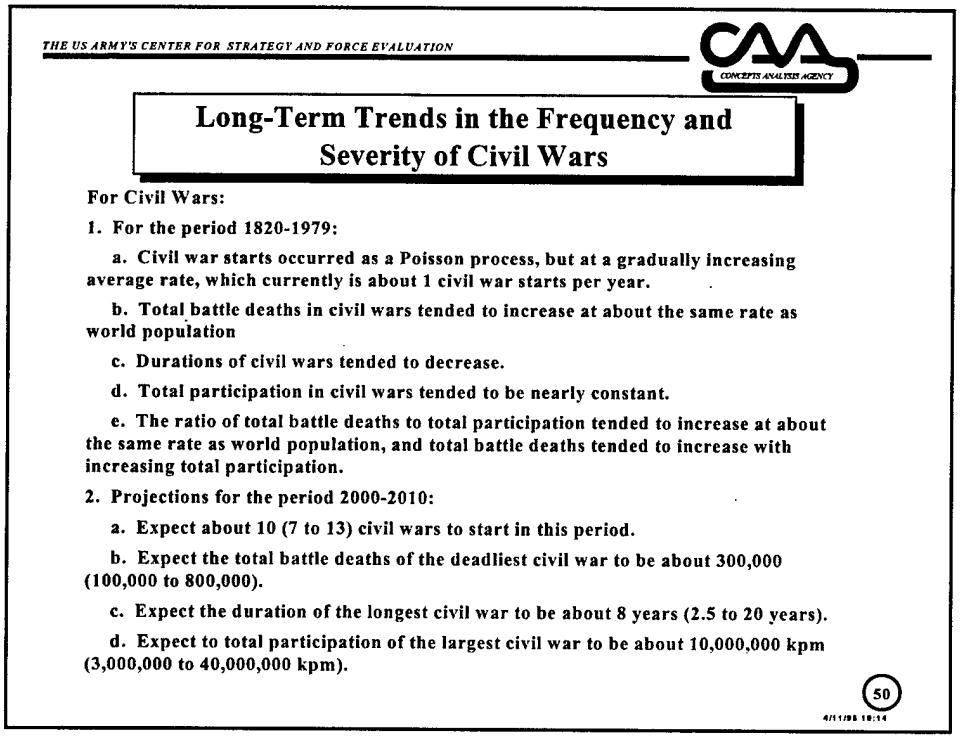
- This slide shows the projected probability that total battle deaths in the deadliest of the interstate wars started in the period 2000-2010 will be less than D.
- This and analogous projections are based on the assumption that the statistics of interstate wars over at least the next few years will be similar to those of the period 1820-1979.



- This slide shows the projected probability that the longest of the interstate wars started in the period 2000-2010 will be less than Y.
- This and analogous projections are based on the assumption that the statistics of interstate wars over at least the next few years will be similar to those of the period 1820-1979.



- This slide shows the projected probability that the largest of the interstate wars started in the period 2000-2010 will be less than P.
- Here the largest interstate war is considered to be the one with the largest value of total participation.
- The total participation of a nation is defined as the product of that nation' s prewar population by the number of months that nation actively fought in the war. Participation ends when the nation surrenders or becomes a neutral, or the war ends. Participation, once ended, can be resumed if the nation is liberated or resumes its belligerent status. Total participation is the sum of the participations of all of the nations that actively fought in the war
- This and analogous projections are based on the assumption that the statistics of interstate wars over at least the next few years will be similar to those of the period 1820-1979.



- The main findings of this section are summarized on this slide.
- Here a civil war is one between opposing entities within a nation and which involves at least 1,000 battle deaths.
- The total participation of a nation is defined as the product of that nation' s prewar population by the number of months that nation actively fought in the war. Participation ends when the nation surrenders or becomes a neutral, or the war ends. Participation, once ended, can be resumed if the nation is liberated or resumes its belligerent status. Total participation is the sum of the participations of all of the nations that actively fought in the war.
- The data used in this section are taken from the following data file, obtained from the Inter-University Consortium for Political and Social Research, Ann Arbor, Michigan:
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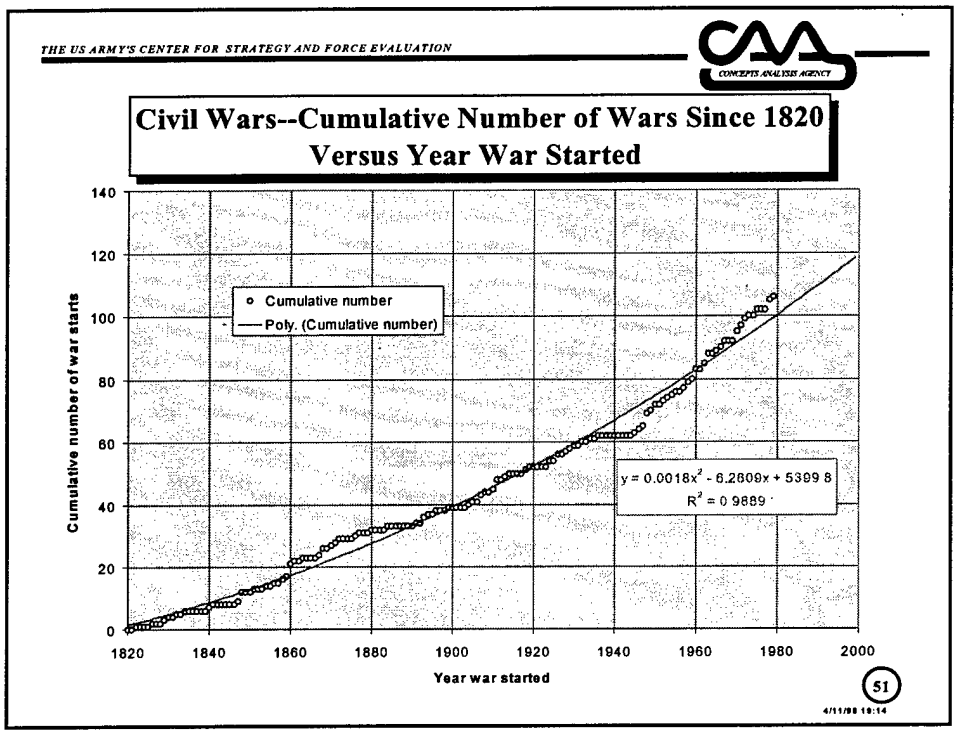
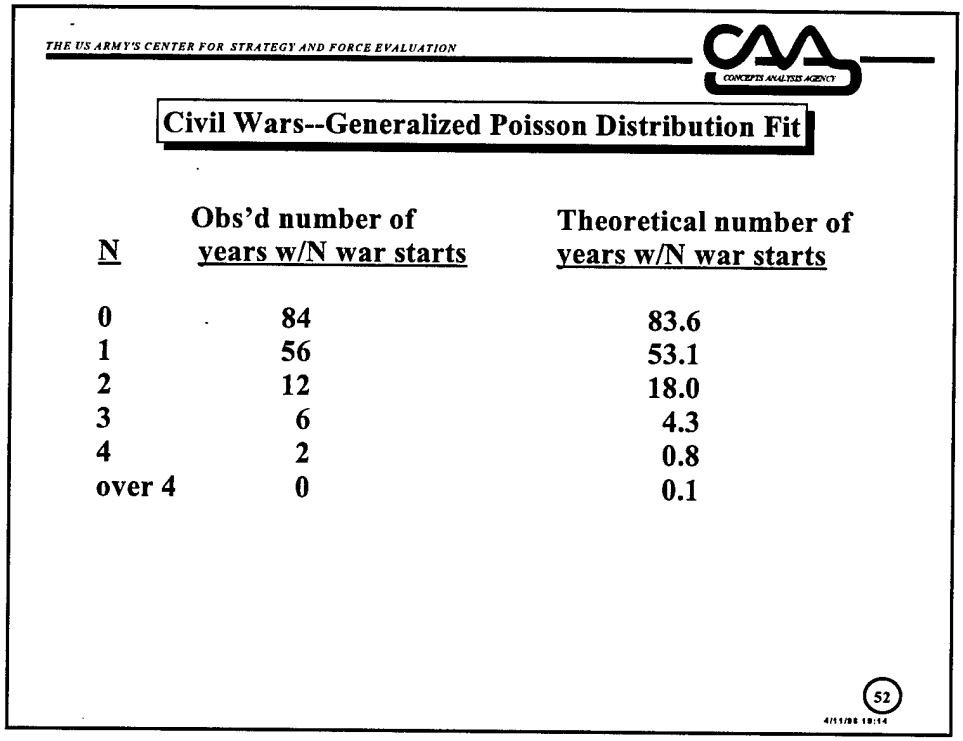
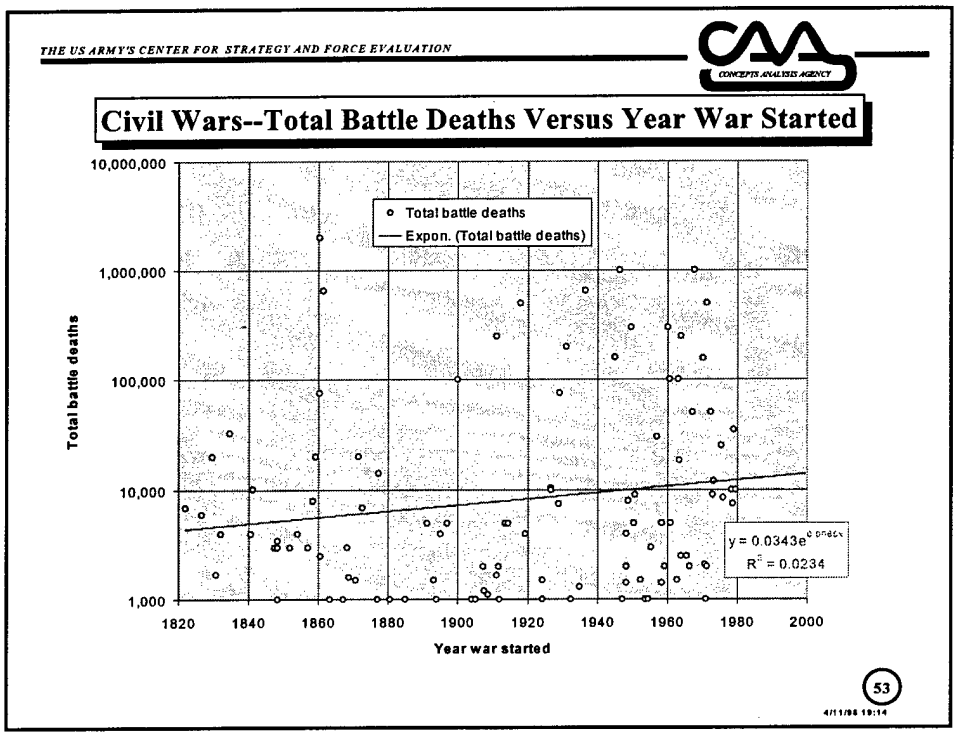


- Civil wars started at a varying and slowly increasing rate from 1820 to 1979. (Our data base ends at 1979.)
- Currently, the rate at which civil wars are starting is about one civil war start per year.
- Some simulation experiments convinced me that the varying rate of civil war starts is real. That is, the quadratic cumulative number of civil war starts shown in the historical data is not likely to arise from a Poisson process with constant rate.
- There is no indication in these data that the rate of civil war starts in at least the next few years will be less than that given by the slope of the quadratic expression shown on this slide.

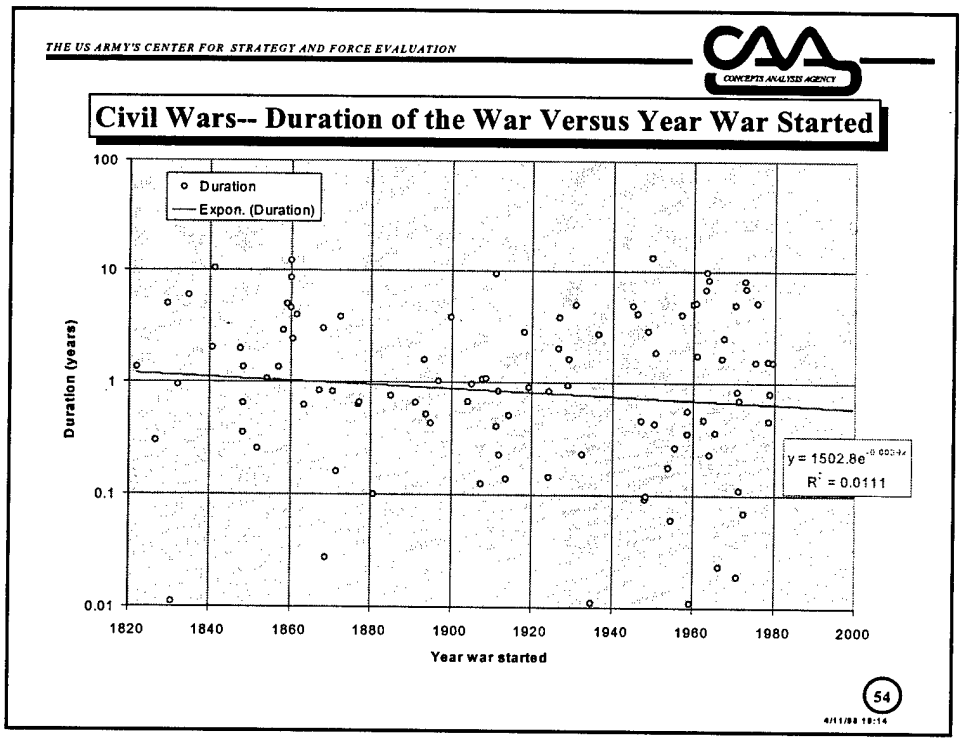


- This table shows that the observed number of years with N civil war starts is reasonably consistent with a Poisson process having a varying rate given by the instantaneous slope of the quadratic expression shown on the previous slide.

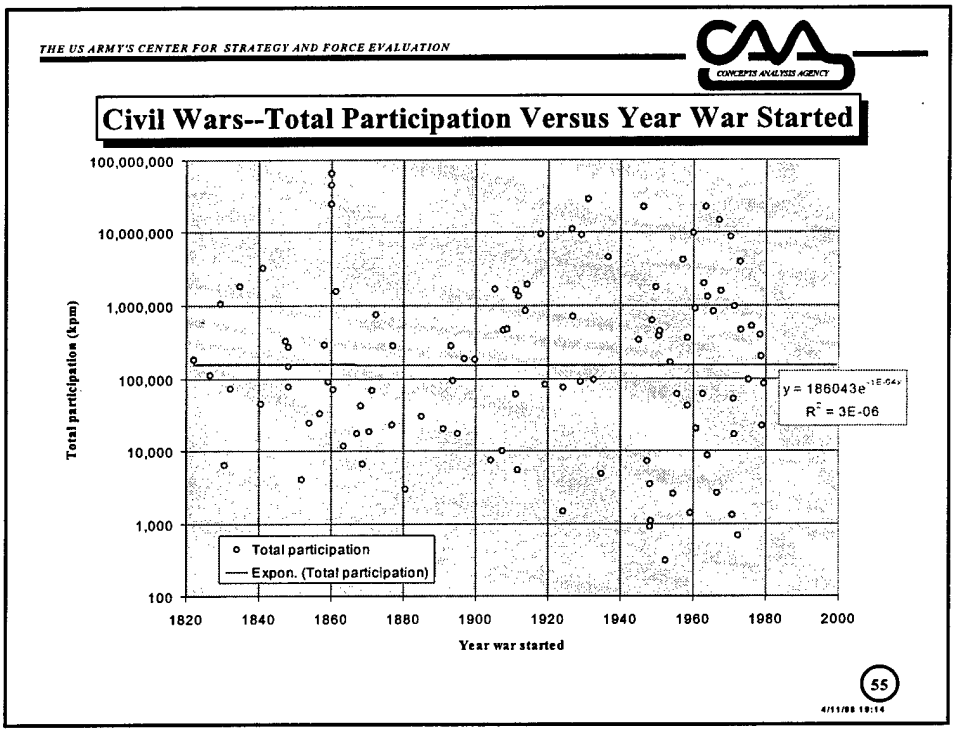
- The projections to be developed later assume that this statistical pattern will persist for at least the next few years.



- Total battle deaths in civil wars increased moderately since 1820. The average rate of increase is about 0.65 percent per year or about 48 percent per century.



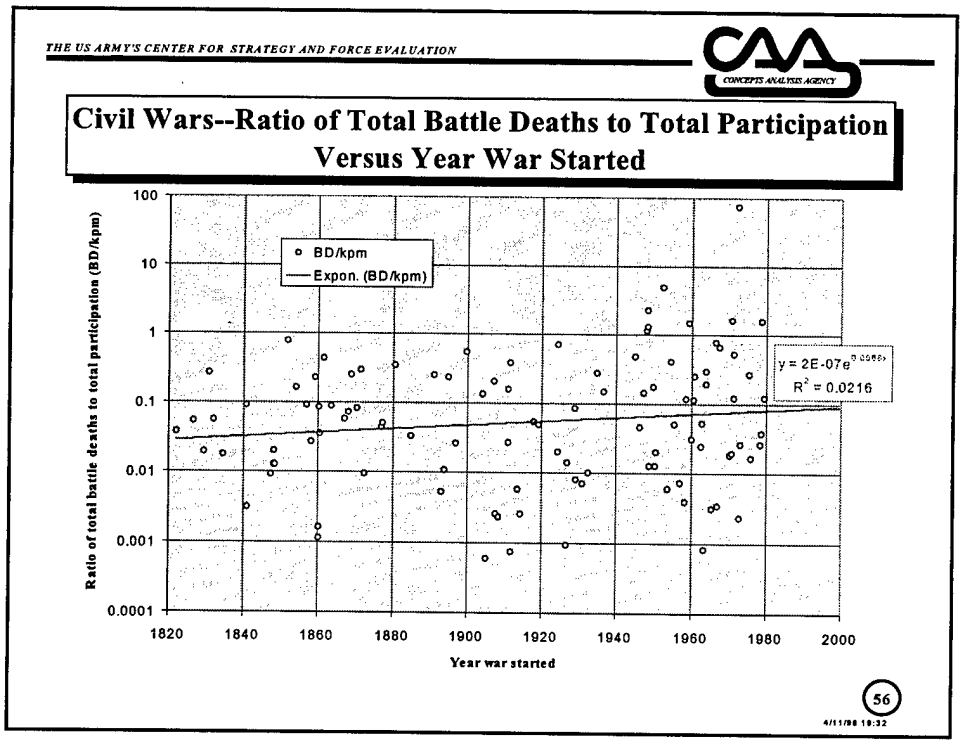
- The duration of civil wars has tended to decline somewhat with the passage of time. The average rate of decline is about 0.39 percent per year, or 32 percent per century.



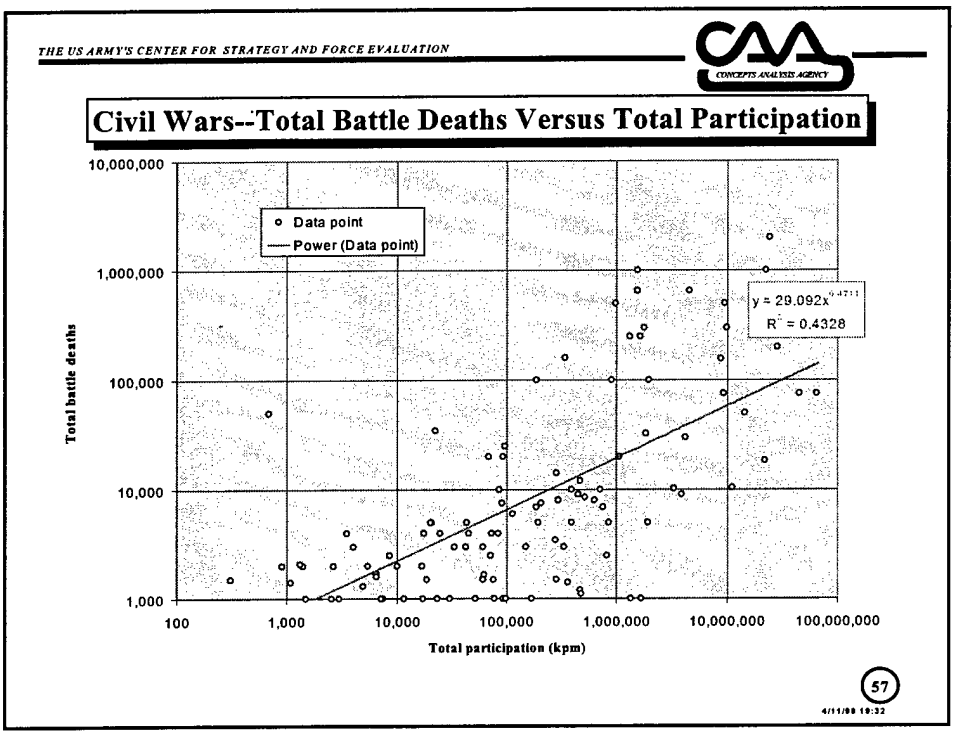
- The median total participation in civil wars of the period 1820-1979 was essentially constant at about 155,000 kpm.

- The total participation of a nation is defined as the product of that nation' s prewar population by the number of months that nation actively fought in the war. Participation ends when the nation surrenders or becomes a neutral, or the war ends. Participation, once ended, can be resumed if the nation is liberated or resumes its belligerent status. Total participation is the sum of the participations of all of the nations that actively fought in the war.

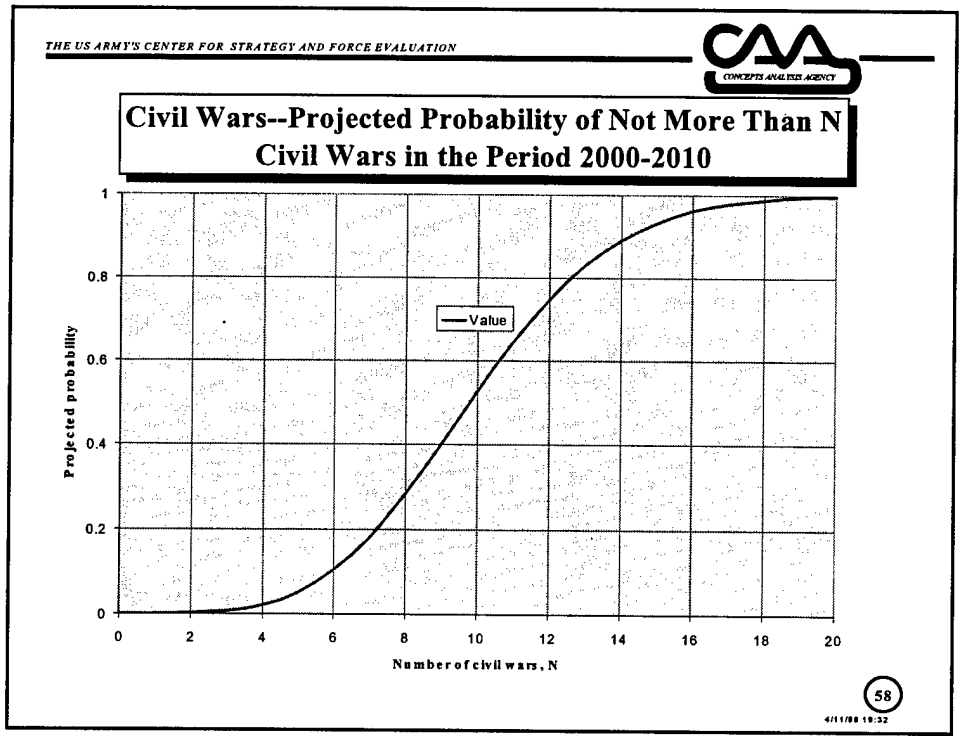
- The abbreviation "kpm" stands for "kilo-person-months" and indicates that the total participation is given in units of 1,000 person-months



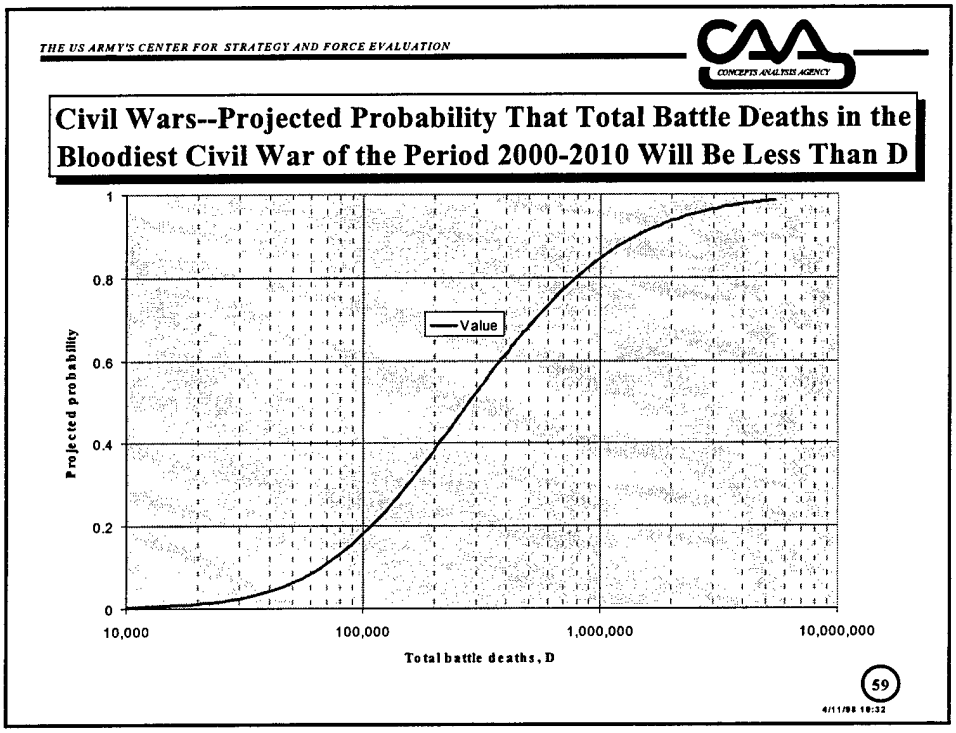
- This slide shows the ratio of total battle deaths to total participation for civil wars of the period 1820-1979.
- On the average, this ratio increased at a relatively rapid rate of about 0.66 percent per year, or 48 percent per century.
- As in many other cases, the historical data show no sign that a change in either the average rate of decrease or in the amount of scatter about the trendline. When we come to make projections, we will assume that the trendline and the scatter continue on their historical courses for at least the next few years.



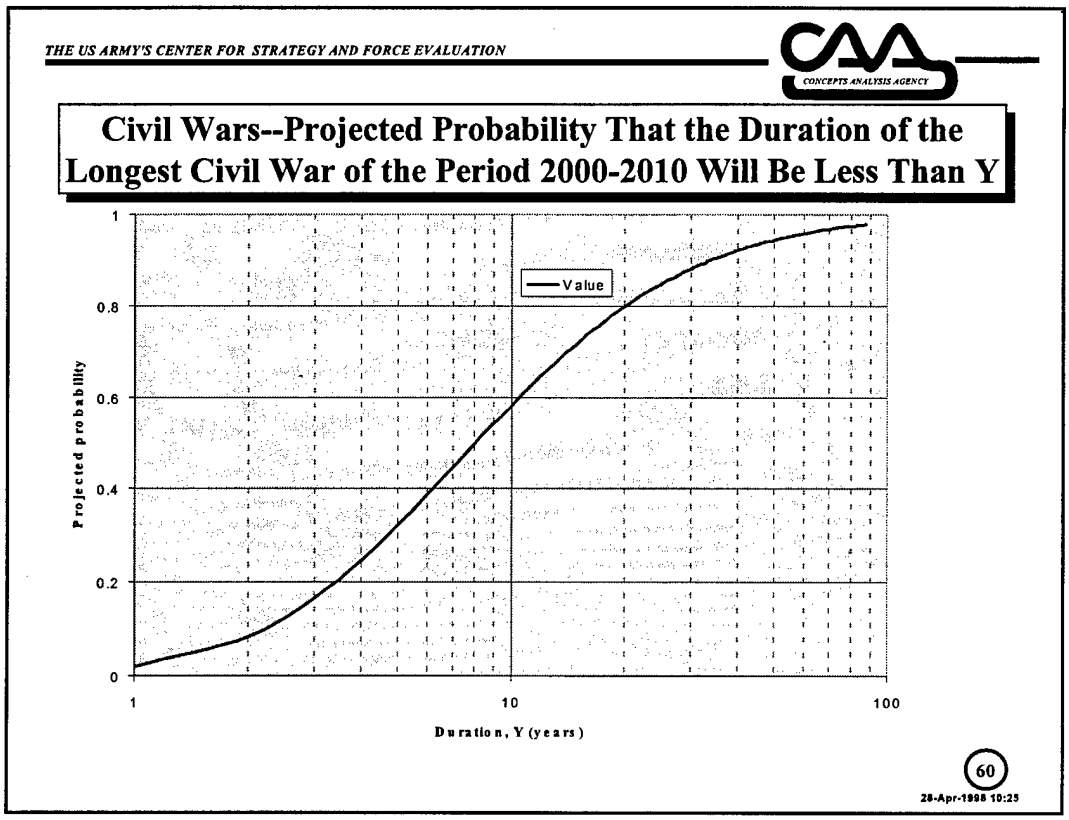
- This slide shows the total battle deaths versus total participation for civil wars of the period 1820-1979. Evidently, total battle deaths increase as the total participation increases. However, the increase is not simply proportional, but instead is governed by a nonlinear relationship. Thus, total battle deaths are less than doubled when the participation is doubled.



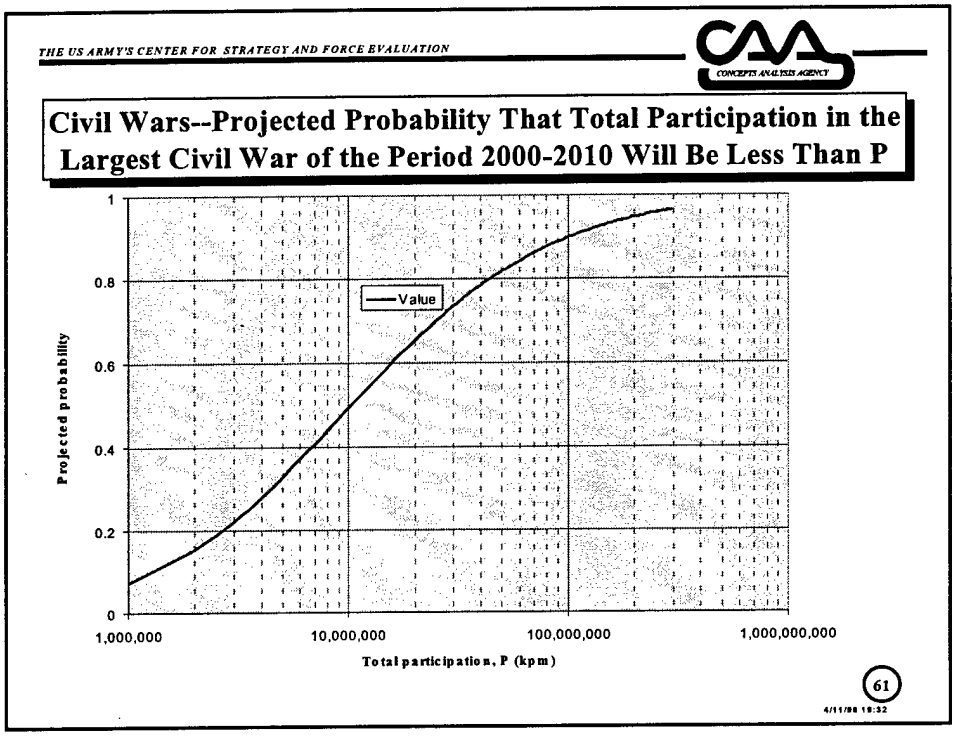
- This slide shows the projected probability that no more than N civil wars will start during the period 2000-2010.
- This and analogous projections are based on the assumption that the statistics of interstate wars over at least the next few years will be similar to those of the period 1820-1979.
- This statistical treatment does not, of course, indicate where these wars will be fought, who will be directly engaged in them, or the extent to which the United States may be involved.



- This slide shows the projected probability that total battle deaths in the deadliest of the civil wars started in the period 2000-2010 will be less than D.
- This and analogous projections are based on the assumption that the statistics of interstate wars over at least the next few years will be similar to those of the period 1820-1979.



- This slide shows the projected probability that the longest of the civil wars started in the period 2000-2010 will be less than Y.
- This and analogous projections are based on the assumption that the statistics of interstate wars over at least the next few years will be similar to those of the period 1820-1979.



- This slide shows the projected probability that the largest of the civil wars started in the period 2000-2010 will be less than P.
- Here the largest civil war is considered to be the one with the largest value of total participation.
- The total participation of a nation is defined as the product of that nation' s prewar population by the number of months that nation actively fought in the war. Participation ends when the nation surrenders or becomes a neutral, or the war ends. Participation, once ended, can be resumed if the nation is liberated or resumes its belligerent status. Total participation is the sum of the participations of all of the nations that actively fought in the war
- This and analogous projections are based on the assumption that the statistics of interstate wars over at least the next few years will be similar to those of the period 1820-1979.

APPENDIX A

CONTRIBUTORS

1. QRA TEAM

a. QRA Director. Dr. Robert L. Helmbold, Model Validation Division

b. Team Members. None

APPENDIX B

REQUEST FOR ANALYTICAL SUPPORT

PART 1

REQUEST FOR ANALYTICAL SUPPORT

1. Performing Directorate/ Division: TA			**2. Account Number:** 98094
3. Type Effort (Enter one): [Q]	**S** - Study **Q** - QRA **P** - Project **R** - RAA **M** - MMS	**4. Tasking (Enter one):** [V]	**F** - Formal Directive **I** - Informal **V** - Verbal
Mode (Contract=C) [ ]			
5. Title: Trends in Land Combat			
6. Acronym: TLC	**7. Date Request Received:** 02/25/98		**8. Date Due:** 06/30/98
9. Requester/Sponsor (i.e., DCSOPS): OSD/USD(P)			**10. Sponsor Division (i.e., SSW, N/A)** NA
11. Impact on Other Studies, QRA, Projects, RAA: Delay to HAMMUR			
12. Product Required: Scripted Briefing			
13. Estimated Resources Required:	a. Estimated PSM: 4.0		b. Estimated Funds: $0
c. Models Req'd: None			d. Other: None

14. Objective(s)/Abstract:
Describe trends in land combat that have persisted over extended periods of time (decades or centuries). Emphasis will be on long-term trends in rates of advance, battle durations, personnel strengths and attrition in battle, evolution of US Army force structure from circa WWI to circa 1985, Lanchester parameter values, and frequency/duration/losses in wars.

15. Study Director/POC:	Last Name: Helmbold	First: Robert	Date: 02/26/98
	Signature: Robert L. Helmbold		Phone#: 295-5278

GO TO BLOCK 20 *If this is A STUDY*. See Tab C of the Study Directors' Guide for preparation of a Formal Study Directive.

PART 2

16. Background/Statement of Problem*: Mr. Andrew Marshall verbally requested this effort.

17. Scope of Work*: Maximum use will be made of materials created or obtained during CAA's quantitative history work over the last several years. A few original analyses of the data bases used in that work may also be required.

18. Issues for Analysis*: Emphasis will be on long-term trends in rates of advance, battle durations, personnel strengths and attrition in battle, evolution of US Army force structure from circa WWI to circa 1985, Lanchester parameter values, and frequency/duration/losses in wars.

19. Milestones/Plan of Action*: TBD

20. Division Chief Concurrence:	E.B. Vandiver III	Date: 2/26/98
21. Sponsor (COL/DA Div Chief) Concurrence:	E.B. Vandiver III on behalf of	Date:
22. Sponsor Comments*:	Mr. Andrew Marshall per verbal request 2/20/98	

CAA Form 233 (1 May 95) * Continue on separate sheet Previous editions Obsolete

APPENDIX C

STATISTICAL MODEL OF WAR FREQUENCY AND MAGNITUDE

C-1. ASSUMPTIONS. The model is based on the following assumptions:

a. The occurrence of warlike events obeys a generalized Poisson process, in which the process intensity, $\lambda(t)$, may vary with time.

b. The magnitude, $M(t)$, of any warlike event occurring at time t is a random variable that is independent of the magnitude and/or occurrence of all other warlike events, and at each time t obeys the cumulative probability distribution function $F(x,t)$. That is, we have

$$\Pr(M(t) \le x) = F(x,t). \tag{1.1}$$

C-2. CONSEQUENCES. The following consequences can be derived from these assumptions:

a. The number of warlike events occurring in the interval [0, t) is a discrete random variable, $k(t)$, with probability function

$$\Pr(k(t) = n) = \frac{\Lambda(t)^n}{n!} e^{-\Lambda(t)} \tag{2.1}$$

where

$$\Lambda(t) \equiv \int_0^t \lambda(s)ds. \tag{2.2}$$

b. Let the time interval [0,t) be divided into J subintervals, each of length h, and label these intervals so that interval j starts at hj and ends at $h(j+1)$, $j = 0,1,\ldots,J-1$, so that $t = hJ$. Then the expected number of intervals that contain exactly k events, $k = 0,1,\ldots,\infty$ is:

$$E_k = \sum_{j=0}^{J-1} \frac{\Lambda_j^k}{k!} e^{-\Lambda_j} \tag{2.3}$$

where

$$\Lambda_j = \int_{hj}^{h(j+1)} \lambda(s)ds. \tag{2.4}$$

c. The probability $P_n(x,t)$ that n warlike events occur in the interval $[0, t)$, but that all n of them have magnitudes less than x, is:

$$P_n(x,t) = \frac{G(x,t)^n}{n!} e^{-\Lambda(t)} \tag{2.5}$$

where

$$G(x,t) = \int_0^t \lambda(s) F(x,s) ds \,. \tag{2.6}$$

d. The probability $Q(x,t)$ that all of the various number of warlike events occurring in the interval $[0, t)$ have magnitudes less than x (or, what is the same thing, the cumulative probability distribution function of the maximum magnitude of all of the warlike events that occur in the interval $[0, t)$) is given by

$$Q(x,t) = \exp\{G(x,t) - \Lambda(t)\}. \tag{2.7}$$

C-3. DEMONSTRATION. The proofs of the above statements are given below.

a. By the usual argument, it is easily seen that the differential-difference equation for $P_n(t)$ is

$$P_n'(t) = \begin{cases} -\lambda(t) P_0(t), \text{ if } n = 0 \\ -\lambda(t) P_n(t) + \lambda(t) P_{n-1}(t), n > 0 \end{cases}$$

and that the boundary conditions are that $P_0(0) = 1$ and all other $P_n(0) = 0$. It is readily confirmed by substitution that the expression (2.1) satisfies the boundary conditions and the differential-difference equation, which verifies (2.1).

b. By (2.1), the probability that interval j contains exactly k events is

$$P(k,j) = \frac{\Lambda_j^k}{k!} e^{-\Lambda_j} .$$

Consequently, the expected number of intervals containing exactly k events is

$$E_k = \sum_{j=0}^{J-1} P(k,j) ,$$

which verifies (2.3).

Observe that

$$\sum_{k=0}^{\infty} E_k = \sum_{j=0}^{J-1} e^{-\Lambda_j} \sum_{k=0}^{\infty} \frac{\Lambda_j^k}{k!} \equiv \sum_{j=0}^{J-1} e^{-\Lambda_j} e^{\Lambda_j} \equiv \sum_{j=0}^{J-1} 1 \equiv J,$$

as it should.

c. By an easy modification of the usual argument, it is easily seen that the differential-difference equation for $P_n(x,t)$ is

$$P_n'(x,t) = \begin{cases} -\lambda(t)P_0(x,t), \text{if } n=0 \\ -\lambda(t)P_n(x,t) + \lambda(t)F(x,t)P_{n-1}(x,t), n>0 \end{cases}$$

and that the boundary conditions are that $P_0(x,0)=1$ and all other $P_n(x,0)=0$. It is readily confirmed by substitution that the expression (2.5) satisfies the boundary conditions and the differential-difference equation, which verifies (2.5).

d. By (2.5) we have

$$Q(x,t) = \sum_{n=0}^{\infty} P_n(x,t) = \sum_{n=0}^{\infty} \frac{G(x,t)^n}{n!} e^{-\Lambda(t)} = \exp\{G(x,t) - \Lambda(t)\},$$

which confirms (2.7).

C-4. REMARKS

a. In this report, the cumulative distribution of magnitudes is always taken as a cumulative lognormal distribution with constant standard deviation and some mean drift. That is, $F(x,t)$ is always of the form:

$$F(x,t) = \Phi\left(\frac{\ln x - g(t)}{\sigma}\right)$$

where $\Phi(z)$ is the standard cumulative normal distribution function, σ is the standard deviation of the logarithm $\ln x$ of (assumed to be constant with respect to time, t), and $g(t)$ is the drift in the mean value of $\ln x$ as a function of time, t. Then $G(x,t)$ becomes

$$G(x,t) = \int_0^t \Phi\left(\frac{\ln x - g(s)}{\sigma}\right)\lambda(s)ds,$$

which is in a convenient form for numerical integration.

From this expression for $G(x,t)$ we see easily that:

$$G(0,t) = \int_0^t \Phi(-\infty)du \equiv 0$$

$$G(+\infty,t) = \int_0^t \Phi(+\infty)du \equiv \Lambda(t)$$

which, of course, are as they should be.

b. In this report, projected war frequencies and magnitudes were generated from the foregoing equations assuming that magnitudes were distributed as a lognormal random variable with drift. The specific parameter values used to project war frequencies and magnitudes are as tabulated below, where all times t are in years *anno domini* and for the projections in this report range from 2000 to 2010:

(1) For interstate war frequencies, $\lambda(t) = 0.7098$, independent of the time t.

(2) For interstate war magnitudes:

Magnitude	Standard deviation, σ	Drift, $g(t)$
Battle deaths	1.894	$-0.2566 + 0.005035t$
Duration, years	1.642745	$7.767412 - 0.00424885t$
Participation, kpm	2.14	$-2.549 + 0.00814t$

(3) For civil war frequencies, $\lambda(t) = -6.2609 + 0.003644t$ (which increases with time).

(4) For civil war magnitudes:

Magnitude	Standard deviation, σ	Drift, $g(t)$
Battle deaths	1.9774	$-3.3728 + 0.006458t$
Duration, years	1.75792	$7.315103 - 0.00392596t$
Participation, kpm	2.79433	$12.1337 - 9.51438 \quad 10^{-5}t$