Preliminary Casualty Forecast
West Africa Ebola Epidemic: 2014/2015

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http://www.punchdown.org/rvb/ebola/

Introduction

As I was waking up on the morning of Saturday, August 23, 2014, I was listening to the radio about another news story about the Ebola epidemic where some poor volunteer from Medicines Sans Frontiers was explaining how overwhelmed they were, how the Ebola epidemic was technically straight-forward to solve, but how there was no international leadership in the effort. Therefore the epidemic was still out of control.

I couldn't believe what I was hearing. I remember when Katrina happened and we watched a disaster unfold on TV and the country stood by until it got too late for thousands of people who became stranded in a catastrophic flood (ultimately killing 1,833). I also remember the genocide in Rwanda when the world stood by and watched as 500,000 to 1,000,000 Africans were slaughtered in internecine violence.

I asked myself: Are we heading to another Katrina? Or even worse, could we be headed to another Rwanda? Could we be heading towards a humanitarian and moral disaster with hundreds of thousands of deaths because we may decide to wait until it is too late before we begin to really pay attention and act?

I felt compelled and obsessed to try to answer these questions, at least for myself. This document describes what I found. This little technical memorandum provides the forecast of possible Ebola epidemic casualties (cases and deaths) that could result if the world continues to stand by and not take the epidemic more seriously. It calculates a range of scenarios associated with different schedules for turning around the growth of the epidemic and getting it under control. Some of these scenarios are truly alarming.

The key result of my calculation is that if we do not organize an urgent response within the next 30-60 days, more than 100,000 people could die from the epidemic. My rough estimate is that between 1,000 to 10,000 people will die for every day that we delay the decision to make a very urgent and aggressive response to the epidemic. Also every day we delay the problem grows by 3% to 5% because there are that many more cumulative cases every day. Every week we wait, the problem gets 25% to 40% bigger.

My personal response to this calculation is disbelief, horror and dismay.

I asked myself: how could this be happening? One possibility, I concluded is that people may not fully realize how big of a problem this epidemic really presents. Or maybe they think that they cannot do anything about it. I wondered why the CDC and the responsible agencies in the Federal government were not stepping up to the plate and sounding the alarm bell. But I had spent three years doing technical work in Washington, and found that there is often a whole array of institutional disincentives for Federal technical workers to urge action internally. In a government bureaucracy, people often don't get rewarded for sticking their neck out and taking risks.

This means that if we as citizens really want to see this problem solved before it gets ten times bigger, we have to sound the alarm now, and as loudly as we possibly can.

In this memorandum, I share with you what I see in the numbers. If you agree that this problem is very very urgent, then you will sign the petition at:

http://wh.gov/lS7lN

I hope that signing the petition will help make sure that the US government takes this problem much more seriously and hopefully this will help give this emergency the attention that it deserves.

Data on the Ebola Epidemic

The data on the Ebola epidemic is compiled through the World Health Organization (WHO).[1] A rather convenient compilation of statistics is provided on Wikipedia.[2] The Wikipedia site provides some illustrative graphs of cumulative casualties (cases and deaths) and new casualties. What one can see from the Wikipedia graphs is that these numbers are increasing exponentially, but from the graphs on the current Wikipedia site is difficult to see where the epidemic might be in one to several months.

Figures 1 and 2 illustrate the Ebola epidemic statistics on what is called a semi-log graph. A semi-log graph has a logarithmic scale on the vertical axis and a linear scale on the horizontal axis. Exponential growth curves are straight lines on a semi-log graph where the slope of the line is the growth rate. Curves with a steep slope on a semi-log plot have a fast growth rate.

There are two very alarming features that we see in this data. The first is that in the statistics for total casualties, the growth rate for the exponential (i.e. the slope on a semi-log plot) is increasing over time. This means that the rate of spread of the epidemic may be accelerating (from 2.3%/day to 3.1%/day). The second thing we see is that the growth rate in Liberia is about twice as fast as the historical growth rate in June and July, about 4.5%/day.

Figure 3 illustrates how the May, June, and July growth rates for total epidemic casualties are recently converging in August toward the very high Liberian growth rates as Liberia becomes a larger fraction of total global casualties.

All of these growth rates are alarmingly fast because the problem with exponential growth is that it compounds over time. If an epidemic doubles twice, it then becomes four times as big.

The final size of the Ebola epidemic depends on how many doublings the epidemic goes through before it is controlled and growth rates are brought down to nearly zero.

At the current daily growth rates of 2.3%/day 3.1%/day, and 4.5%/day the corresponding doubling times for the epidemic are 30 days, 22 days and 15 days respectively.

[1] http://www.who.int/csr/don/archive/disease/ebola/en/, Site accessed 8/24/2014.
[2] http://en.wikipedia.org/wiki/2014_West_Africa_Ebola_virus_outbreak, Site accessed 8/24/2014

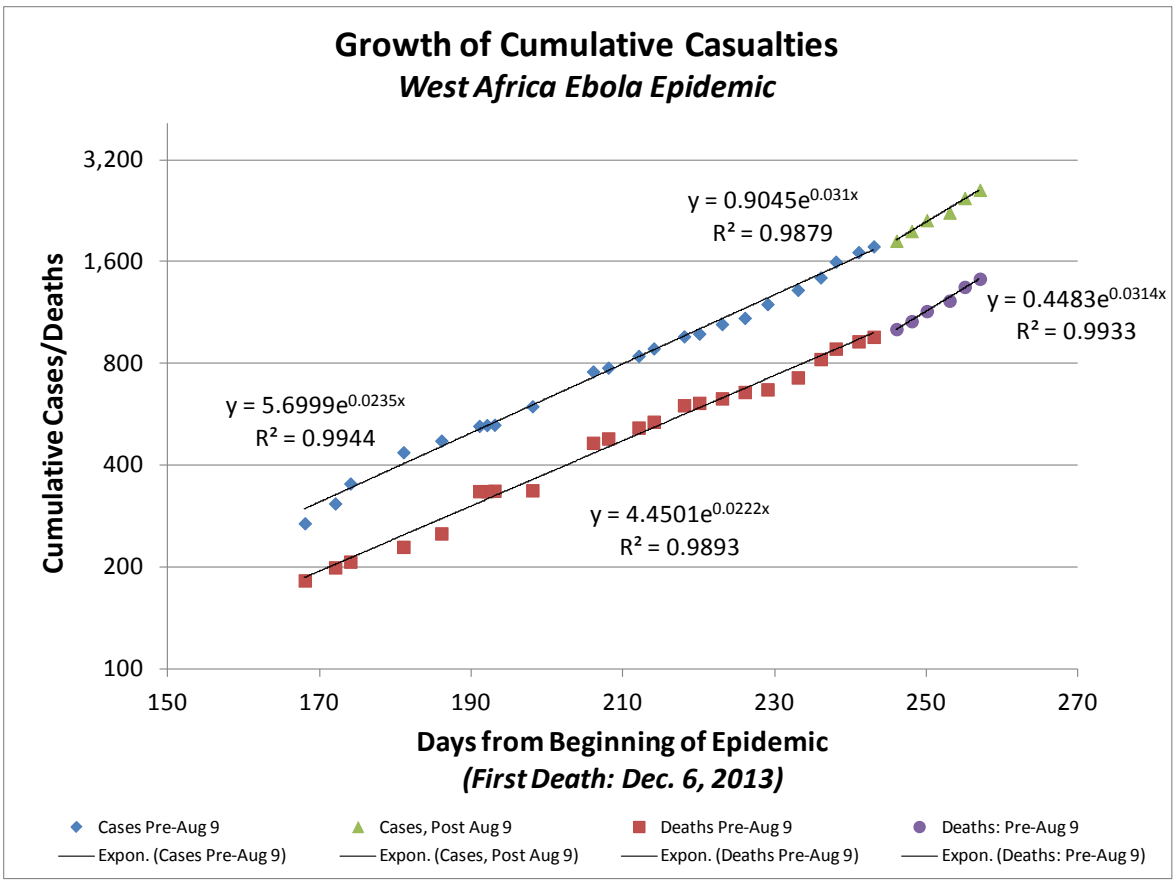

Figure 1: Official statistics of Ebola cases and deaths from May 3, 2014 through August 20, 2014. Statistics are compiled from Wikipedia. The upper curves are data for total cases, and the lower curve is data for deaths. Data pre- and post- August 9 are shown, illustrating an acceleration in the growth rate during August. Pre-August growth is between 2.2%/day to 2.4%/day. During mid-August, the growth appears to be slightly over 3%/day.

What is even more alarming than a fast doubling time is when the time for 10X (i.e. ten-times) expansion gets rather short. 10X growth occurs after approximately 3.3 doublings, and for daily growth rates of 2.3%/day 3.1%/day, and 4.5%/day, 10X growth occurs in 100, 74 and 51 days respectively.

Currently there have been more than 600 deaths in Liberia from Ebola. If the epidemic is allowed to stay out of control for another 100 days in Liberia…the deaths will grow 10X twice to 100X. This is the nightmare scenario. So far the epidemic has been completely out of control in Liberia for two months already, and according to news reports, the epidemic remains completely out of control there in Liberia with no clearly feasible plan to bring it under control yet made public or apparent in news reports.[3]

[3] See for example: http://www.newsweek.com/ebola-control-quarantines-hunger-and-death-liberia-265105

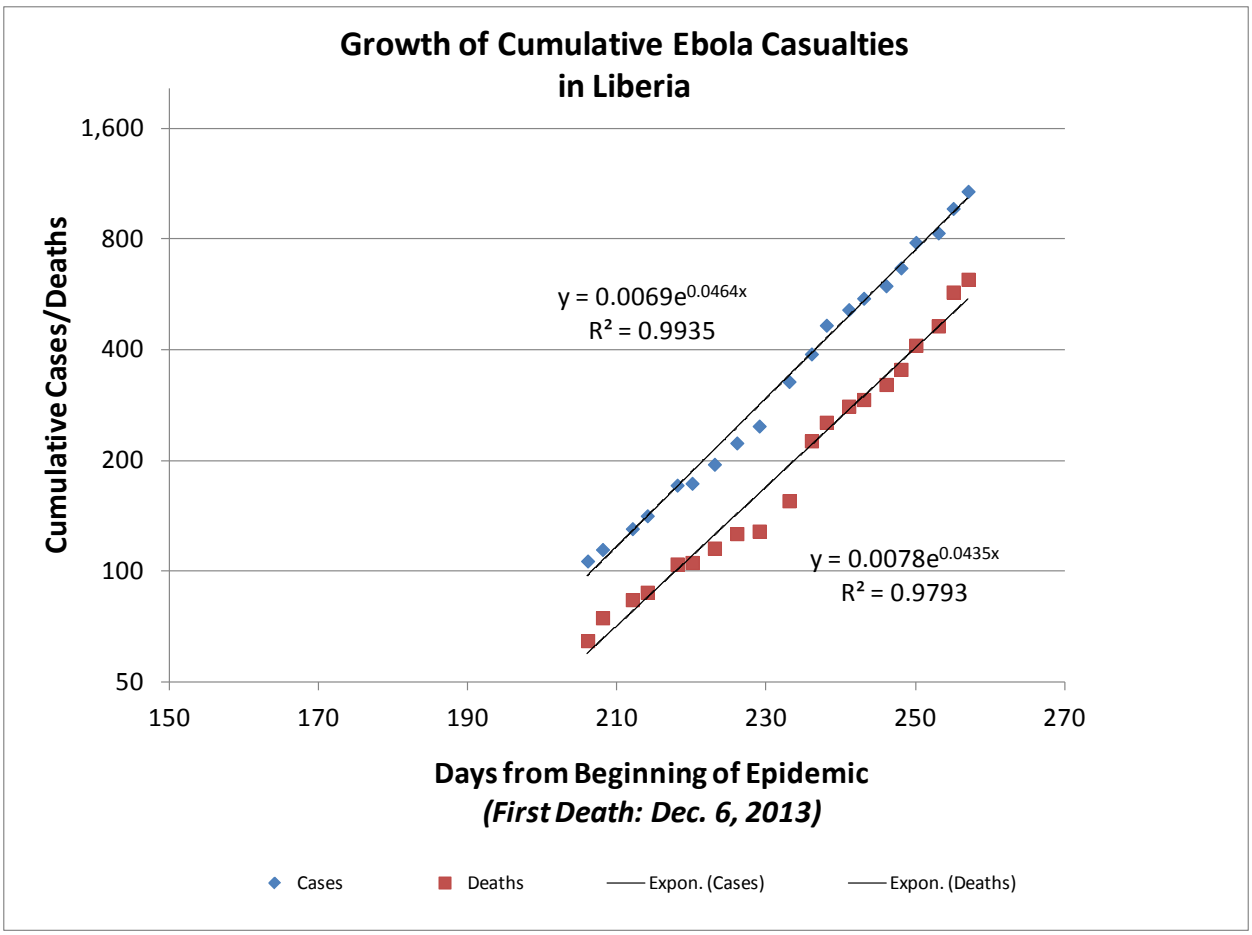

Figure 2: Official statistics of Ebola cases and deaths from June 30, 2014 through August 20, 2014 for Liberia. Statistics are compiled from Wikipedia which obtained the data from primarily WHO. The upper curves are data for total cases, and the lower curve is data for deaths.

Beyond bringing an epidemic under control, even after the growth of an epidemic has been brought under control, many deaths still occur in the time between controlling the epidemic and finally ending the epidemic many months later.

In the next section, we will present a forecast model or a calculation that projects possible epidemic deaths in an effort to provide some quantitative detail to how the Ebola epidemic might unfold over the next year. We will see that as many people may die in the long, arduous process of finally eliminating the epidemic as died in the time necessary to bring the epidemic growth under control.

We will use the calculation to estimate how the epidemic grows under different control scenarios and to estimate the approximate cost in lives of delaying a solution to the epidemic any more than absolutely necessary.

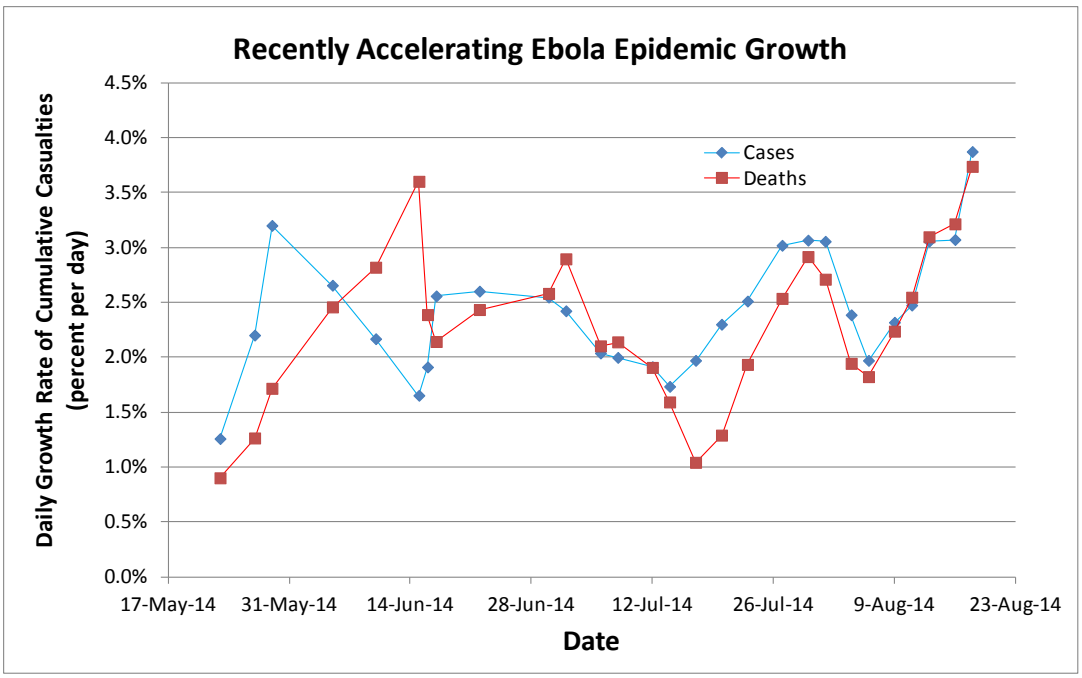

Figure 3: Moving average growth rate for cumulative Ebola epidemic casualties. This data illustrates the recent growth in casualty growth, where as Liberia becomes a larger fraction of the data, the growth rate for total global casualties is converging towards the Liberian growth rate.

Forecast Calculation of Global Casualties from the Ebola Epidemic

In this section, we build various forecast scenarios for how the Ebola Epidemic might unfold over the next 6-9 months. We characterize the scenarios by a few key parameters which include:

1. Days until the growth/spread of the epidemic is controlled
2. Days from the date that the epidemic stops spreading to the end of the epidemic
3. Current aggregate epidemic growth rate
4. Maximum epidemic growth rate when epidemic growth gets controlled

Given these four parameters, one can calculate scenarios for total Ebola cases and deaths, assuming that the growth rate for cumulative deaths is the same as the growth rate for cumulative cases, and assuming a particular functional form for changes in cumulative case growth rates over time.

Details of Scenario Definition and Calculations

Figure 4 below illustrates how we define the scenarios for the evolution of the epidemic in terms of the possible future trajectories of the growth rate for the cumulative cases/deaths statistics.

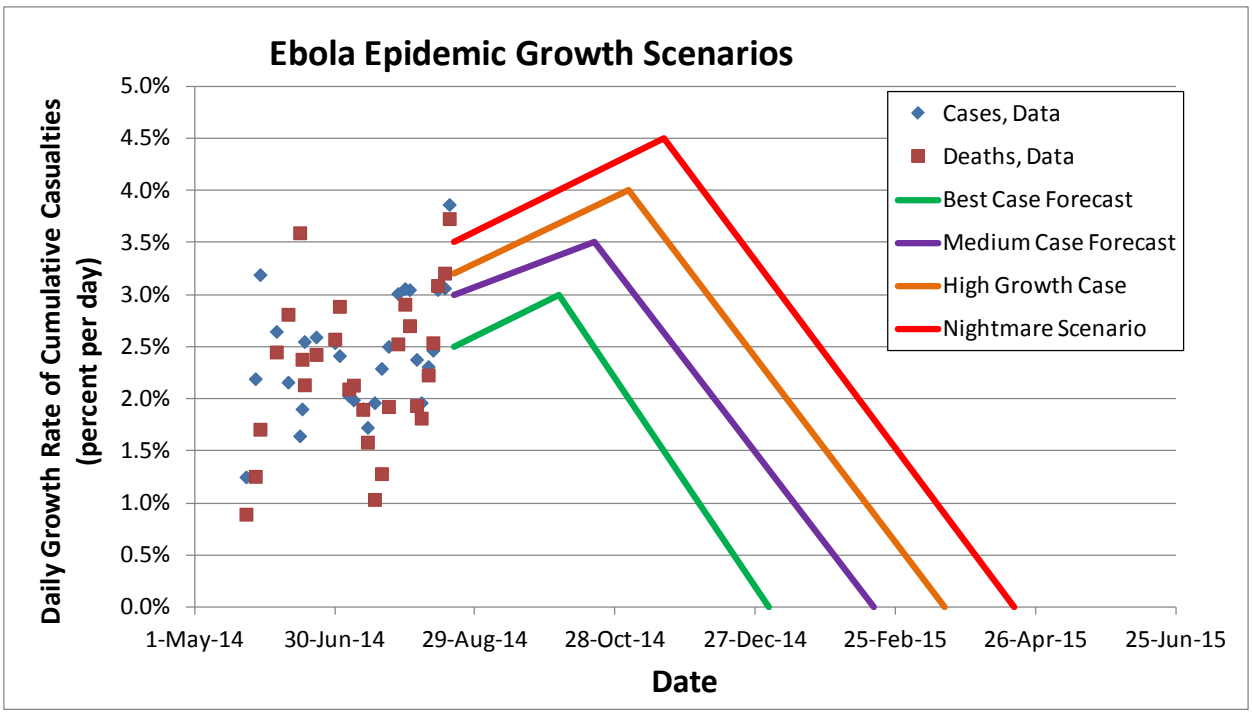

Figure 4: The symbols illustrated for May through August represent growth rates calculated from data. The four curves represent four possible future scenarios. In the **Best Case Scenario,** the initial growth rate is only 2.5%/day and it peaks at 3% per day when it comes under control on October 4. It then takes only 90 days to end the epidemic. In the **Medium Case Scenario**, the initial growth rate is 3%/day, and grows 3.5%/day by the time the growth of the epidemic is controlled on October 19. In this scenario it takes 120 days after this date to end the epidemic. In the **High Growth Scenario**, the initial growth is 3.2% and grows to 4.0% by the time the growth of the epidemic is brought under control on November 3. The scenario then assumes that it takes 135 days from that date to end the epidemic. In the **Nightmare Scenario**, the initial growth rate is 3.5% per day and grows to 4.5% per day by the time that the epidemic is brought under control on November 18. The scenario then assumes that it takes 150 days to end the epidemic. In the Nightmare scenario, more than a million people could die.

Figure 4 illustrates the four scenarios that we consider for the future evolution of the epidemic. The formulation of the four scenarios is pretty simple and straight-forward. Epidemic growth rates are currently accelerating as can be seen in the upward slope of the growth rates calculated from WHO data. There is a significant scatter in the data so there is considerable uncertainty in estimating the current growth rate, and the acceleration rate. In addition it is unknown how long it may take to bring the acceleration of the epidemic growth under control and what the growth rate might be when it is finally brought under control. If the cases in Liberia continue to grow at their current rate, then the nightmare scenario of a peak growth rate of 4.5%/day is possible. This we hope represents the upper bound of possibility. The last element of uncertainty is how long it will take to end the epidemic once the increasing growth is brought under control. We provide a range of 90 days to 150 days as the time between growth control and epidemic end. Given that Medecins Sans Frontieres has recently said that it will take "at least six months" to control the epidemic,[4] these estimates may be optimistic.

[4] See for example: http://www.bbc.com/news/world-africa-28807281

Table 1: Scenario Calculation Results (start date of forecast: August 20, 2014)

Scenario	Initial Growth Rate	Max Growth Rate	Time to Max. Growth (days)	Max. Growth to End (days)	Total Deaths	Total Cases	Marginal Cost of Delay (Deaths/day)
Best Case	2.5%	3.0%	45	90	18,396	33,710	795
Medium	3.0%	3.5%	60	120	77,457	141,941	3,825
High Growth	3.2%	4.0%	75	135	290,242	531,872	17,135
Nightmare	3.5%	4.5%	90	150	1,354,142	2,481,486	87,847

Once the growth scenarios are defined, it is simply a matter of mathematics to calculate the trajectories of total cases and deaths that correspond to those growth rates. Along with the posting of this report, the Excel spreadsheet that makes those calculations is being made available.

The results of these scenario calculations are provided in Table 1. These results illustrate that the total deaths from the Ebola epidemic could range from slightly less than 20,000 to more than a million. The most likely scenario is a total casualty count of one to several hundred thousand cases, with a fairly high probability of more than 100,000 deaths. Allowing the epidemic to grow to a level of more than 100,000 deaths is likely to be morally and politically unacceptable over the long term. It is therefore likely to be quite urgent to rapidly accelerate the response to this epidemic.

We also calculate the marginal cost of delay for each of the four scenarios. The marginal cost of delay is defined as the number of additional deaths that will accrue if the time to maximum growth rate is extended by one day along with the time to end of the epidemic being extended by one day. We find that all but the best case scenario that the marginal cost of delay is thousands of deaths per day to tens of thousands of deaths per day.

The key here is that while we are not currently seeing the deaths in the epidemic at this rate, it is quite predictable that current delays in accelerating the response to the epidemic will result in thousands of deaths in the future for every day of delay. Most people would consider such delays morally unacceptable.

Figures 5 and 6 provide the projections of cumulative deaths and cases for both the medium scenario and the high growth scenario. In both scenarios, total casualties remain below 10,000 through the month of September. But if officials wait until the end of September until a massive mobilization starts getting organized, and if it takes another 30 days to scale up the mobilization, the momentum of the epidemic will carry to the total casualty count substantially above the 100,000 level.

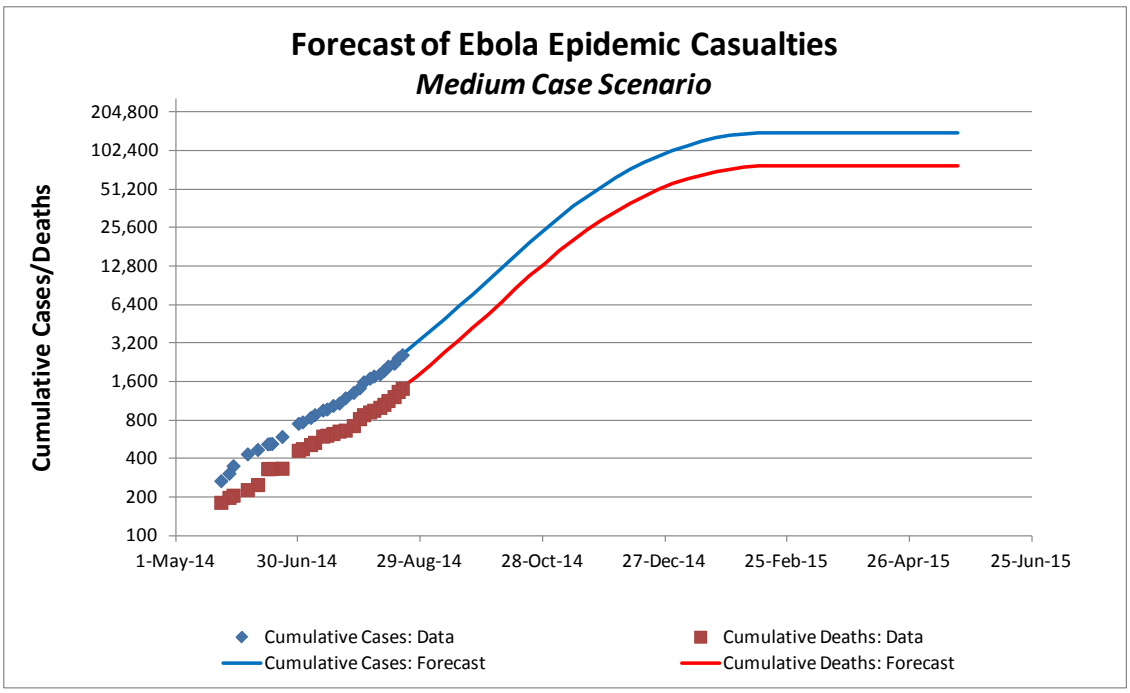

Figure 5: Forecast of Ebola epidemic casualties for the medium case scenario. In this scenario is assumed that current growth is 3%/day and peaks at 3.5%/day 60 days from August 20. After the peak growth time On October 19, the forecast assumes that the growth rate declines linearly to zero by February 16. Total deaths are 77,000 with a total of 142,000 cases in this scenario.

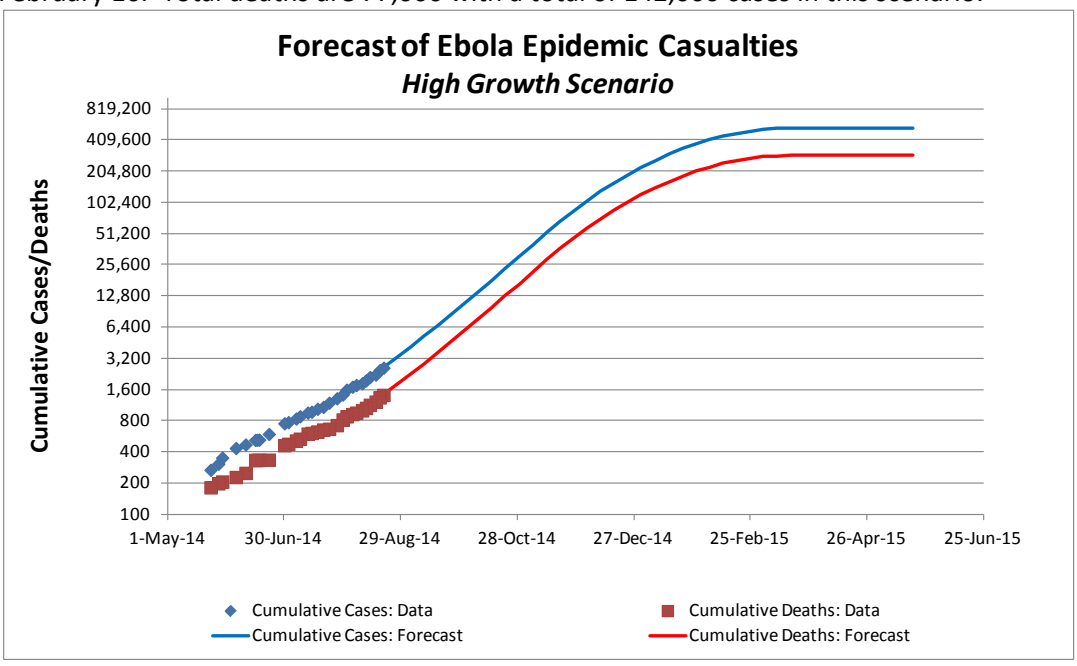

Figure 6: Forecast of Ebola epidemic casualties under a high growth scenario. In this scenario is assumed that current growth is 3.2%/day and peaks at 4.0%/day 75 days from August 20. After the peak growth time at November 3, the forecast assumes that the growth rate declines linearly to zero by March 18, 2014. While this scenario would not be as bad at the nightmare scenario, it would still be catastrophic with a total of 290,000 deaths and over half a million cases.

Conclusion

It appears that given current data on the growth rate of casualties in the Ebola epidemic, that there is a fairly high likelihood that total casualties could top 100,000 total cases. If the world is slow to mobilize, total deaths could conceivably exceed 1 million. The marginal benefit of accelerating a massive response to the epidemic is thousands of lives for every day the response can be accelerated.

We believe that these results, if widely known, would result in a public demand for much accelerated response to the epidemic. Each day of delay means that not only will the casualties from the epidemic increase by the thousands, but the cost of containing and controlling the epidemic will increase 2.5% to 4.5% for every day of delay.

(P.S. after this analysis was performed and posted, the WHO released an estimate of potentially 20,000 infections from the epidemic. The WHO estimate corresponds to somewhat better than the best case scenario presented in this report…we sincerely hope that the international community can keep total casualties below this level. We hope to provide updated forecasts and evaluations in the future to assist the international public in monitoring progress towards containing the epidemic.)