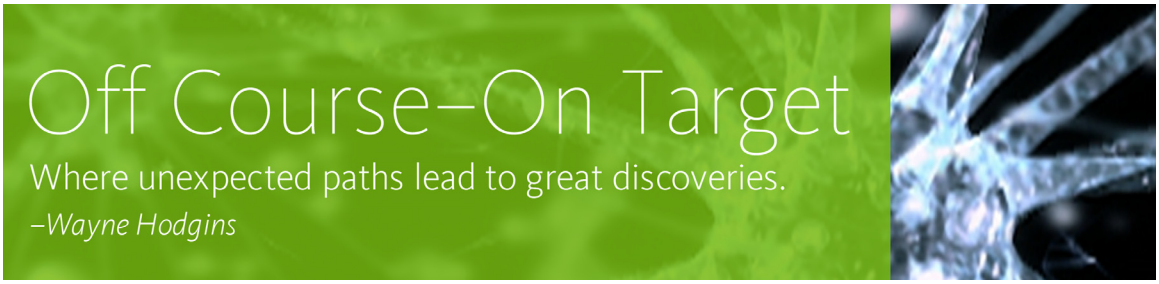

Living in a World of Exponential Change

January 25, 2007

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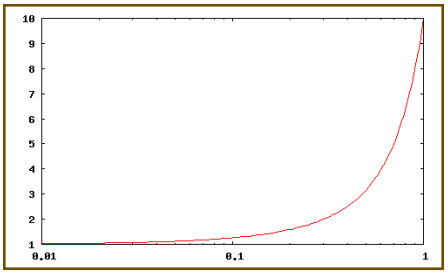
Wayne Hodgins, strategic futurist and "corporate evangelist" at Autodesk, brings his keen foresight and thought-provoking perspectives to his podcast series Off Course – On Target.

In this podcast, Wayne shows how our inability to see today's rapid change for what it is—exponential rather than linear—keeps us from adjusting to the challenges presented by technology and other factors. Understanding that difference now can help us develop new strategies, take control of our lives, and design a better future.

WAYNE HODGINS:

Welcome to "Off Course – On Target" where unexpected paths lead to great discoveries. Hello, I'm your host Wayne Hodgins and today I'd like to talk about living in a world of exponential change. Now I've been thinking and talking about this issue for several years and it seems to be more important and truer than ever, so I thought it'd be a great topic for today's podcast.

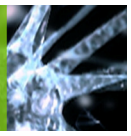


At their start, exponential curves appear to be linear or a straight line rising gradually. But after a certain point, the pitch of the curve rapidly approaches vertical. In human terms, our experience of change has been so gradual over the centuries that we had little awareness that it was occurring…but this is no longer the case. And this increased pace is now affecting all of us in many different ways. We're switching from a linear existence to a world of exponential change and we're completely unprepared because we have no prior frame of reference.

Just as it's difficult for a young person to understand how saving early (along with the benefits of compound interest) will help them later in life with retirement, the population as a whole is having great difficulty adjusting to the rapid changes created by technology and other factors. We need to learn to look farther down the road than we are used to doing, to regain or take control of our lives and therefore design our future much better than we have been.

Almost all of our prior thinking and planning is based on an expectation of linear rates of change and as we will see, this is rendering us increasingly unprepared and way off course in our planning and expectations for the near and the far term future. So as with the title of all of our sessions here at Off Course – On Target, we're going to try to get some "course correction" going on and get us back "on target."

Most of us are familiar with the basics of exponential curves from our past education in basic mathematics, and so you know when you plot out an exponential curve on a graph, it has that sort of curved, hockey-stick-like shape. Exponential growth has this curious characteristic of starting out deceptively slow and then getting really big, really fast. So what seems like gentle, if



slightly accelerated progress suddenly blasts off towards infinity. And it's this deceptive nature of exponential change that I want to focus on today.

My premise is that we have indeed been deceived by the initial portion of the curve, which appears to be more like a straight line that is gradually and steadily increasing, but this has led us to believe that it's going to remain linear. Yet recent experiences are trying to teach us that this is not the case and so we're increasingly being caught by surprise and very unprepared.

I think we've understood that the change is increasing, but it's doing so at this regular or linear rate. And even if we adjust the rate and expect it to change faster, which is what we've been doing for the past few decades, we're still expecting the change at this linear, flat line rate. If in other words if we showed it on a graph, the slope would be going upward, and we've just been increasing the angle of the slope. But as you may be noting, this is working less and less well. It's not a straight line at all. Changes are really increasing at exponential rates.

The idea of doubling all the time for example: once you start thinking about this (which is the purpose of a large part of the podcast), I think you'll start to see that this trend is more and more the case and we're going to see more and more instances of it. Now we're going to look at some fun examples of exponential change to make this more familiar. But to help you get started, imagine that there was a sidewalk that was created to follow the shape of an exponential curve and mimic that hockey-stick shape. And imagine you're walking along this sidewalk. At first it would seem like any other sidewalk, and at some point you might start to notice it's going up a bit of a hill and that hill is gradually increasing in its slope. But then, BAM! All of a sudden your nose hits the concrete as it suddenly turns to vertical.

This might sound like it's too severe and it wouldn't happen that quickly or you would notice it sooner, but as we explore some of these other examples, I think you're going to see that this is in fact exactly what is going on. To help with this initial understanding of exponential rates of growth, I'd like to consider a very old story that many of you have probably heard before about grains of rice on a chessboard.

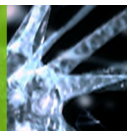
There are many versions of this story. I'll put links to several in the text transcript that we create for all of our podcasts so you can link to it and follow it more easily. The original story apparently leads back to ancient India and typically involves a scenario where the king or the emperor has lost a bet or for some other reason wants to make this enormous reward to a simple commoner or subject. His subject makes a very simple request; "I want one grain of rice on the first square of the chessboard, doubled for each square thereafter."

In other words, one grain of rice on the first square, two on the second, four on the third, etc. Now it doesn't sound like much of a prize does it? And it didn't to the emperor either, so he granted the wish. And for now, suffice it to say that what this ended up doing was bankrupting the emperor. To make my point that we're so extremely unfamiliar with such doublings or exponential growth, let's play a little bit of a game here within the podcast.

I'd like you to try to figure out in your head…don't pull the calculators out just yet but do a calculation in your head…of how many grains there will be by the time we get to that 64th square, doubling it each time. So take a few minutes right now.

[sound of clock ticking]

Okay, got a rough estimate? Write it down on a piece of paper placed beside you so you can reflect on it as we go through this example and we'll come back to it in a moment. What I'm going to do at various points throughout the podcast is I'll make this sound [bubbles] and I'll give an update to you around every 10th square of the chessboard and we'll just see how the count is doing as it progresses upward and you can see how your estimate is looking. So let's start right



now.

[bubbles]

[chime]

Okay, for our first count, after doubling the number of grains of rice on each square of the chessboard, on the 10th square there would be 1024 grains of rice. Probably not a tough calculation. I'd suspect most of you would have gotten that one pretty close. And if you still feel okay about your estimate, fine. If you'd like to revise it, you can do that too and we'll come back to it in a few more minutes.

Now I'll give you two other quick examples of doubling. These are going to be fun and they are things you could perhaps try out with friends and others around you. Both of them, I suspect, some of you would know, but just in case, let's quickly explore them. The first one is the way you can experience exponential growth by just simply folding a sheet of paper. So take an ordinary sheet of paper and fold it in half. Then fold that piece of paper in half again and then half again. And you get the idea; you can see how this doubles the thickness each time. After about seven folds, the paper is about the thickness of a notebook. If you keep the progression going, which is the point we want to make here, you'll find that after awhile it's impossible to fold it.

But mathematically… if you were able to do so… you'd find out that after about ten more folds, you would get to something about the height of your house. And ten more folds after that you'd get to the outer limits of the atmosphere. And after about 60 folds you'd be at the diameter of the solar system. So you can see how this kind of progression is something that we just aren't very good at estimating. You wouldn't expect (I don't think most people would expect) to get that kind of growth.

[bubbles]

[chime]

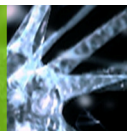
Okay, rice count time again, and we're up to the 20th square now. And at the 20th square, doubling each time, you would end up with just over a million grains of rice, or if you were weighing them, it would be about several dozen kilograms of rice. So check your estimate for the 64th square and we'll keep on going with our story and our game.

The other quick example turns out to be one that you can actually eat. This is the example that you know of, perhaps by something called hand-pulled or handmade noodles, or sometimes called dragon's beard noodles. And if you've never had the experience, I'd strongly recommend you find a restaurant in the area that offers these or perhaps just try it out for yourself at home. Because in addition to being a great gastronomic experience, it turns out that this will also help you witness, first hand, the power of exponential growth. And it's a pretty simple model.

Take this rice dough; roll it out into a long roll, maybe about two or three feet long and then start to spin it around a little like a skipping rope. Stretch it out as you lengthen your arms to the full arm's length. And then you take it, fold it half, put the ends together, grab the other end in the other hand and repeat the process. Spin it around like that skipping rope, stretch your arms out to full arm's length and fold it again. So you can see how it's just another example of doubling.

It turns out that in literally about two minutes time, you would've drawn out about four miles of very fine noodles. And if you did a mere forty-six doublings, mathematically, it turns out, you'd have enough noodles to be long enough to stretch from here to Pluto, and beyond…even if Pluto isn't a real planet anymore. And remember, we've got 64 squares on that chessboard.

[bubbles]



[chime]

Speaking of the chessboard, rice count time again, and so we're up to the 30th square. It turns out that there would be about a billion grains of rice, or about 10 metric tons of rice by weight. So again, look at that end estimate, and we'll keep on going.

To take this one final step further, it turns ouy that if you start to compound exponential change on top of exponential change, which is what I think, in fact, has been going on, you get what is mathematically referred to as singularity. Now, I'm not going to go singularity today, but I can strongly encourage you to check on a recent book that came out in 2006 by Ray Kurzweil, called *The Singularity is Near*. And while it may be a bit more than most of us want to read, it's been suggested by many that any responsible person would want to at least know what Ray means by singularity, as well as some of the underlying themes within the book. And if there is enough interest on this topic, I may bring it up in a separate podcast, and perhaps have an interview with Ray.

But for me, one of the big takeaways from the book was how Ray got to this observation. He started studying changes of all different kinds and plotting them out against the time frame of all human history. What he found was something pretty stunning. Literally every example he could find, no matter how different it was, when he started to study changes and rates of change over that much time, turned out every one he looked at was an exponential curve.

For example, one of the things Ray looked at was the mass use of inventions. He measured this by looking at the number of years it took before a quarter or 25 percent of the population was using the invention. He looked at things like the telephone, radio, television, PC, mobile phone, the web. It turns out that the telephone took about 35 years to reach 25 percent, the radio, 30, the PC, 16, and the Web, only about seven! So again, another example of something that turns out to be undergoing an exponential rate of change.

However, the real reason I wanted to focus on Ray's work was that he previously coined this phrase "the second half the chessboard" in reference to where an exponentially growing factor has greater and greater impact. In fact, as you can guess by his phrase, he used this chessboard example. It turns out that the number of grains of rice on the first half of the chessboard, after about 32 squares…which is about where we are in our little game count here…is about 100, 000 tons of rice. This total amount is about 1/1000th of the total rice production in India per year, according to statistics from 2005. So that would be economically viable for the emperor of India in the original story.

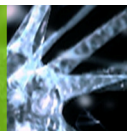
But, the total number of grains of rice on the second half of the chessboard turns out to be about 7, 000 times the entire weight of the Earth's biomass. So the point is, even after you've been amazed by the growth of the first half, you're still completely unprepared about how much this is dwarfed by the growth in the second half— another characteristic of exponential change and growth rates that we're just not accustomed to.

[bubbles]

[chime]

Okay, rice count time again, and we're at the 40th square now and it turns out there'd be one thousand million grains of rice, or about 13 thousand metric tons. So you see the kind of growth rate that's going on. Again, go ahead and adjust your estimate for the 64th square if you'd like to and we'll come back to this in a moment.

But at this point, you must be saying "So what? What does this have to do with me and why would I care?" Well, I am hoping that you can see that similar to the grains of rice on the chessboard, what starts out as a simple progression quickly compounds itself to these, literally,



unbelievable proportions. And that's precisely what I believe is happening in more and more examples in everyday life, personally and professionally.

Some everyday examples? Well, let's consider choices, or what Barry Schwartz called in his book, *The Paradox of Choice*. Have you noticed that for any given decision…let's say, making a purchasing decision, or deciding what to watch on TV, what song to listen to, what e-mail to read, or which article to look at on the Web, the total number of them has absolutely skyrocketed compared to the past? And if you've got the sense that it's going faster and faster, you're right, which is the whole point of this exponential change topic today. As Schwartz points out, this has also led to paralysis in not being able to make a good choice.

Now, I'm old enough to remember when there were only two TV stations, and they actually stopped broadcasting at night! They weren't even available 24/7. You go ahead and try to make that believable to anybody under the age of 20 today.

Maybe you think you've already dealt with this one and "Oh yeah, I know it's that way and I'm okay. I've got the latest and greatest technology. I got fancy recorders and tons of hard disk space." Well, think again, because you need to get ready for IPTV and other new technologies that are going to result in an exponential curve jump. You'll suddenly have thousands of channels to choose from and that's immediately followed by millions of shows to choose from.

So what's the solution? Well, it starts out with the macro level understanding that trying to solve exponential problems with linear solutions will not work. We need to think and approach things differently.

The answer to exponentially increasing (and seemingly infinite) choices is to get some assistance to reduce the number of them by focusing only on those that are relevant to you. The specific topic of choice is one for another day, but right now, I just want you to use some of these examples we've cited here to show strong evidence that we're already living in a world of exponential change and how we need to quickly understand this and change our perception of change and the solutions we need to develop to solve them.

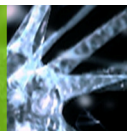
[bubbles]

[chime]

Okay, had enough of rice counting? Let's finish our game and see what we can learn from this process. So quickly, at the 50th square…where we're at right now… there would be one thousand billion grains of rice. Of course, we're still counting, so you've got one more chance to adjust your estimate. But to complete the original story, the emperor would go bankrupt because two to the 64th power turns out to be about 18 million billion grains of rice. Now this is a completely unfathomable number, I think, for most of us. So to put it in some perspective, 18 million billion grains of rice translates to trillions of tons of rice.

Or looking at it another way, if we wanted to figure out how many fields of rice it would take to grow this much rice, then with ten grains of rice per square inch in a rice field, you would have to cover the entire surface of the earth twice over (including the oceans) to have enough area to grow that much rice. Or, another fun calculation I found shows that if we assume that if all 6.4 billion of us on the planet were to survive by eating rice alone, we would have enough rice at the 64th square to feed the entire planet for 27 years…and all of this from just doubling 64 times on that original chessboard.

So, how did your estimate compare even after several chances to update it? Still off? By a little bit or by a lot? Well if you're like most of us, I'd suggest you're probably off by a lot! Maybe even by several quarters of magnitude.



I hope this game has been a bit of fun but the real takeaway from this experience is that even when we think we understand exponential curves and have shifted our thinking to take them into account, we've probably not done so. As we've just seen, even given repeated opportunities to update your estimate, even after repeated examples to show us how rapidly it was increasing, we still consistently underestimated and were way off.

So even when we think we understand exponential change, I think we're going to have to take into account that it's really hard to comprehend and it's going to take us some time to learn. So don't be too hard on yourself, but do please take on the very hard work of starting to make these changes and doing that shift in your thinking. This is the kind of stuff we hope to do for you all the time on *Off Course - On Target*.

The point I hope you're getting from all of this is that I think we need to rethink our approaches and our solutions and our methods so that they match the paradigm we're in because linear solutions, as I've suggested, cannot scale or solve exponential problems. Have you ever wondered why we're consistently bad at estimating things such as how long something will take to complete and how much it will cost? We've got enormous amounts of experiences, almost daily amounts of experience with exponential scaling and yet we don't seem to be getting any better.

Remember for example when the human genome-mapping project first hit the news and the experts at first estimated that it would take about 20 to 100 years to finish? It took less than two! You may not be working on mapping DNA, but hasn't the same thing happened to you when you estimate your last project at work…how long it will take, or how much it will cost? Or what about how long you told your significant other that it was going to take you to do that simple thing on your to-do list? Now I wonder if all of these wrong estimates might be because we do linear extrapolations to make them and yet the world we're living in is running on exponential laws.

So here are some points to ponder as we leave this topic for today. I wonder if your solutions are perhaps focusing on what I call “perfecting the irrelevant.” By this I mean if you're not considering that many of the problems and solutions you're working on will be affected by this exponential scaling, your solutions will probably be off severely, to the point of being useless. Consider the case of how you're dealing with management of your files…for instance everything from e-mails to digital photos to songs. Don't you have a sense that these numbers are increasing exponentially?

So consider the current approach that you and almost everybody else is taking, doing your best to name each one of these well, with equally well-named directories, and filing them away. Hopefully you'll actually be able to find what you want when you need it. So how's that working for you? Less and less well? Exponentially less well perhaps? I'd suggest that's because the solution of filing and naming things is a linear solution that simply does not scale exponentially.

David Gelernter, a brilliant computer scientist at Yale and founder of Mirror Worlds, had a great way of putting it. He said in an interview that if you had a couple of cows that you were raising, naming each one of them is probably a good idea, but if you've got a herd of 10,000 cattle, it's probably not a great model. So you kind of get the idea here I hope.

Or imagine the very positive version of this problem. Have you ever considered the problem of being what I call "the victim of success"? What would happen, for example, if you became successful beyond your wildest expectations with the product you were making, the solution you were producing, or anything you were working on either personally or professionally? What would you do and would your solution scale if it took off at this exponential rate? A nice problem to have, I'll grant you, but one that could equally be the downfall or death of the organization if it's not ready for it. And how are you going to adjust your strategy and your plan if fundamental assumptions or constraints change during the time of the project. Remember how deceiving

exponential curves are and keep that hockey-stick shape in mind.

And finally, lest I have left you depressed by thinking that living in an exponential world is nothing but a large headache from overwhelming problems, would you be interested to know that another example of living in an exponential world is that human lifespan is also increasing exponentially?

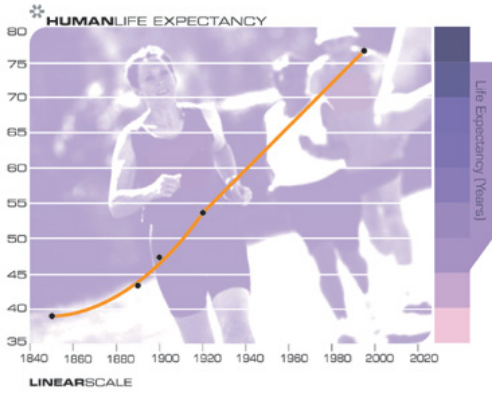


Chart courtesy of Ray Kurzweil article

Aha! Thought that might be of interest to some of you. For example, let's just cover this real quickly. Would you be able to guess the number of centenarians—people over the age of 100— who are alive today in the USA? Unfortunately I only have statistics for the US right now, but it will still make a point. I remember, for instance, when one of these people would have made the *Guinness Book of World Records*. Yet today, there are about 50,000 centenarians alive in the US alone. And it gets better for those of us who haven't reached this mark yet.

According to US estimates for centenarians, by 2010 there will be 131,000 of them. And by 2050 there will be 834,000—another exponential curve of growth. Now a century ago, to put this in perspective, most Americans only lived to be about 50, but you might be surprised…I was…to find that today people over the age of 100 make up the fastest growing segment of the population. Well, enough for now. Perhaps this is another topic we can take up and expand upon in future sessions, so make sure you send me e-mails or add comments to the blog or the podcast on Off Course - On Target for any of these things.

And so what am I doing about living in a world of exponential change? Well for one, I'm planning on this potential of living a whole lot longer. I've been really heartened by some of the recent medical studies that have suggested that a chemical called resveratrol, which is predominant in red wine, has been shown to reduce aging and prolong life, albeit in mice by as much as 70 percent. So with that, I'll raise my virtual glass of red wine to you and say, "Thanks for joining me here on Off Course - On Target for this session of “Living in a World of Exponential Change.” I'm Wayne Hodgins, and I hope you'll be back again soon to join me in taking more unexpected paths to great discoveries.

[closing music].

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http://waynehodgins.typepad.com/ontarget/files/exponential_change.mp3.

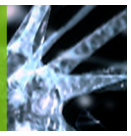
Exponential Growth references and exercises:

Examples of folding paper and hand-pulled noodles are explained well by Raju Varghese. He includes a handy table with exponential growth calculations worked out for 1-100 doublings.

Here’s a fun little online applet lets you experiment with simulations of exponential growth.

Storybooks at Amazon.com about the grains of rice on the chessboard:

The Kings Chessboard by David Birch



One Grain of Rice: A Mathematical Folk Tale by Demi

This reference to hand-made noodles can be found at Amazon.com:

The Ring of Truth: How we know what we know by Philip & Phylis Morrison