ASSOCIATION OF PROFESSIONAL FUTURISTS

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SPECIAL EDITION (2018)

The limits to growth

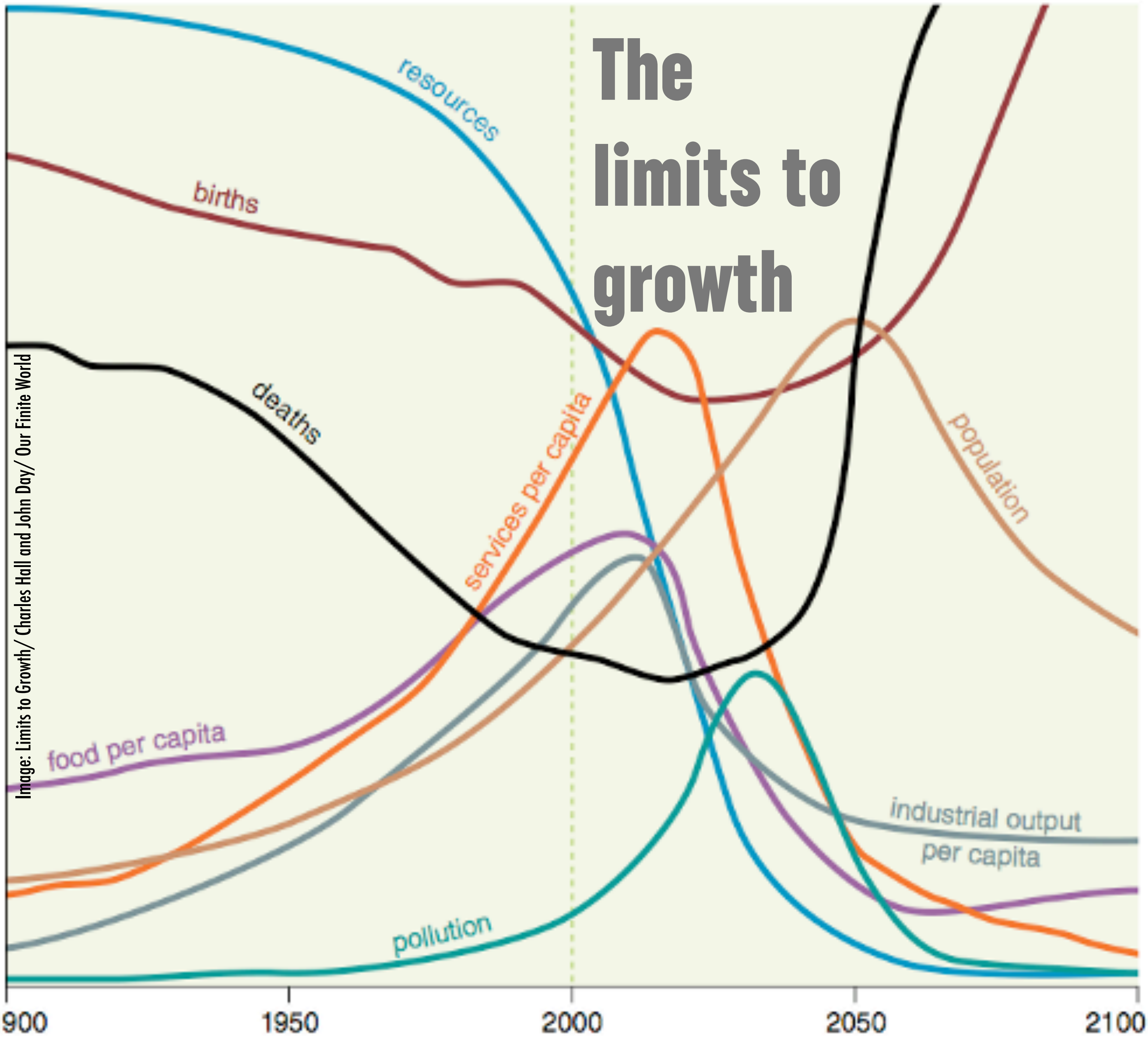


Image: Limits to Growth/ Charles Hall and John Day/ Our Finite World

The clock of the Limits to Growth's World3 model keeps on ticking. Its 'standard run' scenario projects industrial decline in the 2020s and population decline in the 2030s—a run that has tracked the world economy closely for 40 years.

This special edition of Compass brings together a set of articles about The Limits to Growth.

Joel Barker offers a personal account of his involvement in an 1973 workshop to study the model; Andrew Curry re-reads the 30-year update of the book; Ugo Bardi relates the history of the book's critical reception; Anthony Hodgson explores Limits to Growth through the lens of the Three Horizons method; and there is an account by Jay Forrester of system dynamics.

(Andrew Curry, editor)

Learning about the Limits to Growth

by Joel Barker

In 1973, APF member Joel Barker, fresh out of college, was invited by his neighbour Dennis Meadows to join an international two week workshop in Copenhagen designed to test the assumptions of the Limits to Growth's World3 model. This account has been substantially edited from an anline presentation Joel gave of that experience to APF members.

The Limits to Growth team was Donella (Dana) Meadows, the lead writer, her husband Dennis, project manager, Jørgen Randers from Norway, and Bill Behrens and Roger Nail from the USA. Dennis was two years older, my next door neighbour in Rochester since I was six, and we had gone to school together.

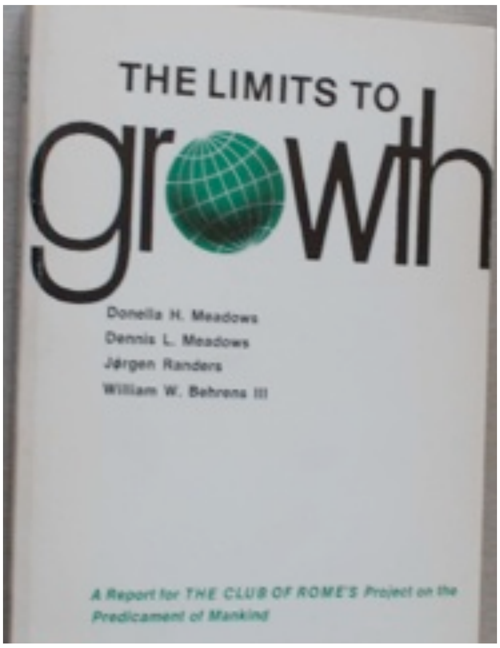
Late in '72 the *Limits* team put out a manuscript of the book before it was published by a little company in Washington DC. They sent one to a friend of theirs in The Netherlands and within two months there were at least two thousand Xerox copies of that manuscript scattered across Europe. The Europeans were already dealing with their own limits to growth, so they identified very rapidly with the book. In the USA when it came out, it got excoriated.

By 1973 the book had been out for about six-months. I had received a fellowship to study how to teach futures in the K through 12 environments. I called Dennis and asked, "Dennis, I'm getting into the futures field from this angle, have you got any suggestions?" One of his suggestions was that I should go to Copenhagen that June to participate in a two week intensive study of *Limits to Growth*.

IBM wholly sponsored the European discussion of *Limits to Growth*. They rewrote the Meadows program, so it would run on IBM computers. They were serious about how important this discussion was going to be. The participants were from all over the world; everybody was high level and there were a hundred of them. Everybody else had PhDs and more, I had only a BSc degree, and Donella and Dennis made sure that I got the additional education that I needed to understand what was going on.

On the first day, Donella Meadows got up and asked a very simple question: "How many of you believe that the World3 model on which limits to growth is based is useful for considering long term changes ahead?" Two hands went up. The rest stayed down. That didn't depress or upset Donella, but then we knew how many sceptics had come to this meeting. I thought it was interesting that they showed up anyway; clearly, they were open to discussion.

The first edition of Limits to Growth.



Donella talked about how they'd been using the World3 model to help leaders and politicians think about the future. They had a fascinating exercise where they would have these high powered, intelligent people come to their World3 headquarters at MIT, and they would talk to them about the model. They'd suggest that they could make one change of any size to any one of the four sectors of the model. The sectors were population, capital formation and industry (in the sense of making things), non-renewable resources and pollution.

Some tried reducing population growth dramatically, some tried changing the access to energy so that energy was for all intents and purposes free. Some tried replacement of materials so that there was always enough. And some envisioned a pollution free economy. With only one tweak, they put in dramatic numbers, and they found out it didn't make a difference in the long term. They got short-term benefits through the model, but over the long term, the model returned to what was called 'overshoot and collapse'. This meant it would shoot beyond the capacity of the planet, and then human population collapse would occur.

We learned there was no silver bullet, no single solution that fixed everything. One of our lessons was that when you have a complex system you manage it by doing lots of small things in each sector on a continuous basis, and if you're allowed to

The Limits team. Left to right: Jørgen Randers, Jay W. Forrester, Donella Meadows, Dennis Meadows, Bill Behrens. Source: The Club of Rome

do that, you're able to manage the model, which allows you to create a sustainable world, living within its limits.

Donella shared one of the faulty criticisms of the model: that clearly it was a bad model because when you ran it backwards it didn't predict what had already happened in history.

This person obviously did not understand the systems dynamics process. In a systems dynamic model, you generate equations, those equations are captured with feedback loops. There are negative and positive feedback loops. As we all remember, a negative feedback loop is not necessarily a bad feedback loop, it's a feedback loop that stabilises itself. A thermostat in your house is a negative feedback loop system, it tries to keep the temperature the same. World3 had slightly over 200 negative feedback loops and four positive feedback loops.

Positive feedback loops are systems that feed upon themselves in such a way that they grow rapidly and exponentially. Putting a microphone in front of a loudspeaker produces a positive feedback loop because the sound from the speaker goes into the microphone, gets amplified, comes out of this speaker again much louder, goes into the microphone, goes through the amplification and we know how quickly it becomes a screaming screech.

Donella's point was if you reverse the model, all the negative feedback loops become positive and the positive feedback loops become negative. Yet there were some people who were critiquing it that way.

The team talked about where they got the sector data from, the data's strengths and weaknesses, so that everybody understood what was going on. In response to the criticism about inaccurate data, there were some places where we couldn't get what we needed.

Donella oversaw the population data and parsed her population data twice as fine as demographers require for accuracy, since they work in two-year increments. She used one-year increments in her model just to make sure that she had captured all the information that was needed.

With that introduction done, they laid out the agenda for the next two weeks: we would learn to think in systems dynamics models, be taught causal loop diagrams and the next level of modelling. We would disassemble the model once we understood how it was put together, look at all the operating assumptions behind the model, and then rebuild it, changing some of the operating assumptions if we wished. One of the nice things was that the model was flexible.

Modelling causal loop diagrams shows the way we think the interactions work between various elements of a system. We were to pick a very small model that we could figure out ourselves, something we had experience with. I chose to model the sale of bicycles. This is a pretty simple model except that I realized half way through that there's a problem with resource clouds, from which comes whatever you need to make the bicycles and make that system work.

My bicycle model actually had two resource clouds. The purchase resource cloud was created by parents buying their kids bikes and the kids riding those bikes; out of it came a set of bikes that went into the bicycle environment. I also realized (because I'd just had it happen) that there were a fair number of bikes that get stolen; these put into a stolen bicycle cloud which also feeds back into the purchase of bikes, except this time there's no capital investment involved. I remember taking Dana through this and she said, "Oh, what an interesting causal loop diagram you've created!" I'm proud of that is because I'm a guy with a Bachelor of Science and Education, who had never done economics before and I found something that was unique that I added to the capacity of systems dynamics.

This process began with a simulation game that Dennis Meadows had built in which teams sat around a table and we made decisions about manufacturing and distribution. As we worked our way through this game. two things became clear: What we thought would be an easy game was much more complex than we'd thought, and it was easy to miscommunicate what you needed. That's when we started learning about delays and some of the other key effects in causal loop diagrams.

After the simulation game, we spent several days learning to work, write and think in systems dynamics language. Years later I asked Dennis, "Why aren't you doing computer simulations?", and he said, "Joel, if you do the computer simulation, you don't learn enough". He was focusing on games that are simple enough that you don't need a computer to run them, but you need a good brain and you learn to think in new ways. Even though World3 was an extraordinarily important computer simulation, Dennis believed you can learn to think systemically without computers.

What were they trying to teach us? Five things:

1. Models are simpler than real life and they must be. If they were as complex as real life they'd take the same amount of time to run as real life, and we can't wait that long.
2. Models can show you essential changes that happen in real life, so that you do learn from them, even though they're simpler.
3. Your brain can become much more sophisticated in thinking about complex situations than you think it can.
4. Complex situations are filled with delays, and delays are the hidden threat of complex systems because things take longer to unfold than people expect them to; they don't think there's a threat or a problem, or a benefit waiting out in the long term.
5. The real world is full of complex systems that interact in very powerful ways. If humans are to become sophisticated enough to sustain for the next thousand years, we're going to have to get very good at thinking about these complex systems.

Complex situations are filled with delays, which blind us to large scale change.

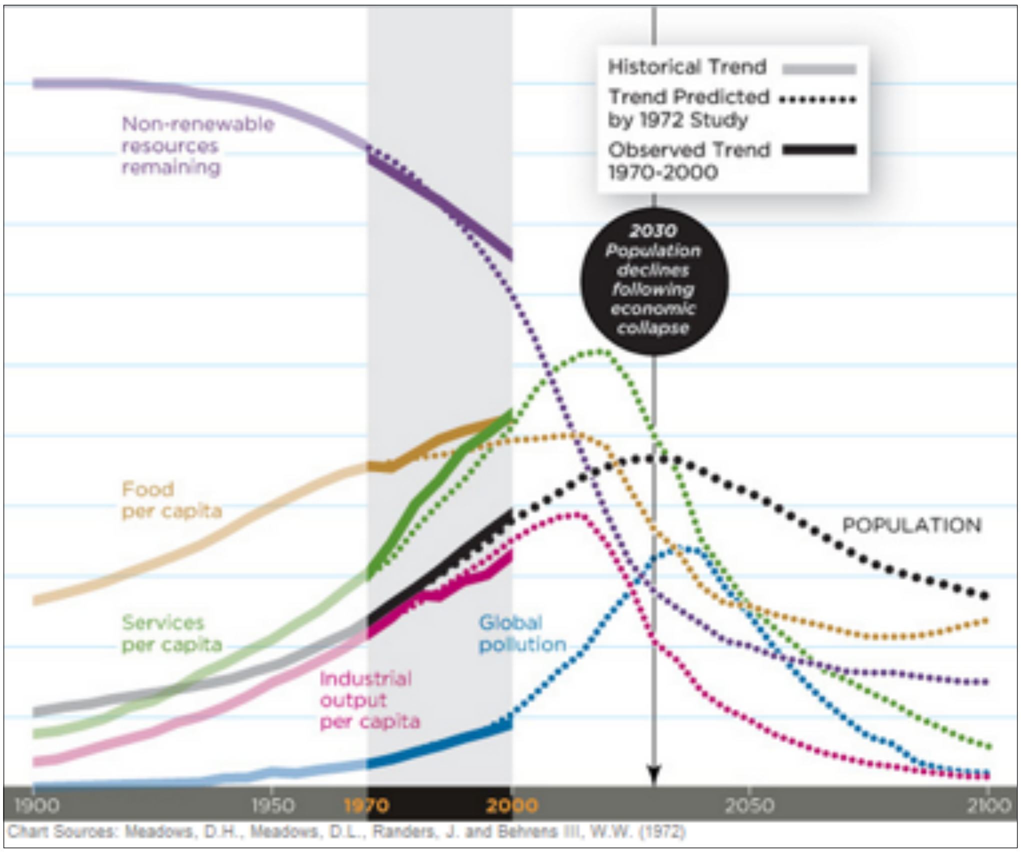
By the end of the first week we were ready to explore the World3 model and critique it. As we took the model apart we understood what was going on. A typical day was nine to nine. We took a one-day break on Saturday. The second week, we analyzed and summarized each sector. Even though we weren't experts, we understood what we were doing and were able to read the diagrams and make sense of them. We had one tremendous advantage: the authors were right there providing wonderful clarification when needed.

So 40 years later, what do I remember that has stuck with me this whole time? What did I learn?

1. Population is the key to everything because it drives the rest of the model, and if you look at what the Meadows said from 40 years ago to today, you'll see that in fact population does exactly what they said it does. If you can limit and reduce population, you can limit and reduce the ecological footprint of human beings.
2. Carrying capacity is a really important measure. I used the term 'ecological footprint', that's new language. In 2007, when they won the Japan Prize, Dennis and Jørgen Randers gave wonderful speeches on what they know now, after watching what's been going on since.
3. Long delays blind us so that we do not understand the really large change that is waiting to affect us. Overshoot and collapse is bad; our dilemma is that if we don't do things now, then there is a higher likelihood of overshooting the planetary capacity, and having the planet

collapse our population to what is sustainable.

4. Simulations simplify, but give us useful insights. They're not perfect and the Meadows constantly made this point. In their books their position has always been: we are not predicting, we are giving alternative scenarios based on the interactions of these four elements that we've discussed.
5. Fixing one sector a lot, never solves the problem long term: there is no silver bullet. Short term thinking is a choke point. The key message that Dennis and Dana were trying to get to futurists was this: **futurists are really important because we do think about the long term; we try to get our clients, our friends and our students to think about the long term.** Jørgen Randers expresses this in the 2012 video he made with Dennis on the 40th anniversary of *Limits*. He said, "40 years later I still see the short term thinking of financial types when they do not understand the long-term consequences of their actions."
6. Finally, human beings can learn to think in complex systems in a matter of days if it is done right. By the end of the first week I was able to read the causal loops, and I have never lost the systems thinking capacity I gained in the first week.



The Limits to Growth standard run scenario: industrial and service decline in the 2020s, population decline in the 2030s. The shaded area shows outcomes between 1970 and 2000. Be scared. Chart by Linda Eckstein

We finished up our reports

on the Thursday morning. Then Dana got up and said, "Okay, we've got some work to do this afternoon, but I want to ask a question: How many of you now feel that the World3 model is valid and has useful applications for thinking about the world?" 99 hands went up. They converted very smart sceptics to very smart advocates in that two-week period. I think if you have great teachers, important stuff to share, and people are open to listening, you can change minds dramatically.

Then Dana asked, "So what are we going to do?" Dennis liked to identify Dana as the optimist of the group, himself as the realist, Jorgen as the pessimist and Roger as a great guy. Everybody said they were going to take what they learnt and share it.

Something interesting occurred as everyone responded in turn: the group leader of the Danes stood up and said, "We were talking at lunch about what we should do. We're a small country and we don't have much influence, we can do some things locally but that's about all we can do".

Next was the lead person from The Netherlands. He said, "I think we need to change the world. We will go back, we will talk Shell and to our major corporations and we will get funding from them to begin to have an important discussion, we need to change the world and we will do our part in that."

I thought to myself you're the same size, almost identical population. The Danes are saying, there's not much we can do, the Dutch are getting ready to lead the charge to the rest of the world. It really reflected on my work on vision because I felt the Dutch had a vision of what they needed to do, and the Danes did not.

I'd just been told I was going to be hired by the Science Museum of Minnesota and that my job—based on my fellowship - was to train teachers to teach students how to

We have already overshot the planetary capacity. We have to figure out how to bring it back into the limits as gently as possible.

think about the future. I said I would be joining the Science Museum of Minnesota in the spring, and that I would begin a series of workshops throughout Minnesota.

They turned out to be national workshops because they were so popular, and in four years we trained 3,500 teachers how to teach their students about the future. It was a two-week intensive workshop, nine to nine, where we deeply exposed teachers to everything, including *Limits to Growth*, which was specifically a large section in the discussion. I promised that I would do whatever I could to get as many teachers knowledgeable about *Limits to Growth* as I could.

There were some good results over those two weeks, and some high-powered people understood things they hadn't before, but if you watched Dennis's speech in 2012, his concern was that if you look at the hard actions that we should have taken, we only actually succeeded with one: the ozone layer. He says this proves that we can operate on a global level with global agreements doing something that's transnational, and do it successfully. We protected the ozone from being destroyed. "It's not that we can't do it, it's that we haven't agreed to the comprehensiveness of things that needed to be done".

Dennis is convinced beyond a shadow of a doubt that we have already overshot the planetary capacity. He said, "Now what we have to do is figure out how to bring it back into the limits sustainably, as gently as possible". He says that it is likely that if we do it right, the world can have the same standard of living as the lower income European countries have, countries like Greece, Italy, Spain and Slovakia. I've visited those countries and it's a pretty good life. But it's not crazy rich like Japan or the USA or some of the wealthier European countries.

On reflection here's what Dennis said: if we had acted in 1973, started doing the right things, we'd be looking at what would have been considered Utopian historically and we would have been able to run at a level that would have been Utopian. Now what we're going to do is run at a level that's sustainable and acceptable but only if we do the right things, that's what it comes down to. But we don't have much time. ◀

Further reading

Meadows, Donella, Randers, Jørgen, Meadows, Dennis, (2004), Limits to Growth: The 30-Year Update, Chelsea Green, Vermont.

Meadows, Donella (2008), Thinking in Systems. Chelsea Green.

Videos

Meadows, Dennis (2012), 'Perspectives on the Limits of Growth: It is too late for sustainable development'

Randers, Jørgen (2012), 'Club of Rome'.

Joel Barker is a futurist who did pioneering work on paradigms, vision, and long term implications. He has authored two books, one on paradigms and one on five different visions of the future with Dr. Scott Erickson. He is currently finishing up a plausible, utopian novel with Gifford Pinchot III.

Some basic concepts in system dynamics

by Jay W. Forrester

In its full development, system dynamics is a discipline with the scope of science, education, law, engineering, or medicine. On the other hand, it is becoming clear that teachers in ordinary K-12 schools can make enough progress in two or three years to achieve major improvement in students' thinking, self reliance, and enthusiasm for learning.

1. The nature of systems

Many principles form the foundation of system dynamics and become a basis for thinking in all endeavors.

1.1. Feedback Loops

People seldom realize the pervasive existence of feedback loops in controlling everything that changes through time.

Most people think in linear, non-feedback terms. For example, in Figure 1, people see a problem, decide on an action, expect a result, and believe that is the end of the issue. Figure 1 illustrates the framework within which most discussions are debated in the press, business, and government. However, a far more realistic perception would be Figure 2 in which a problem leads to action that produces a result that creates future problems and actions. There is no beginning or end.

We live in a complex of nested feedback loops. Every action, every change in nature, is set within a network of feedback loops. Feedback loops are the structures within which all changes occur.

Filling a glass of water (Figure 3) is not merely a matter of water flowing into the glass. There is a control of how much water. That control is the feedback loop from water level to eye to hand to faucet to water flow and back to water level. Such closed loops control all action everywhere.

1.2. Simplest Feedback Loop

Figure 4 shows the simplest possible feedback system. In the figure are two symbols—a stock, and a flow. The stock is an accumulation, or integration, or level, to choose terminology from different fields. The flow changes the amount in the stock. The flow is determined by a statement that tells how the flow is controlled by the value of the stock in comparison to a goal.

All systems, everywhere, consist of these two kinds of concepts—stocks and flows—and none other. Such a statement, that there are two and only two kinds of variables in a system, is powerful in simplifying our view of the world.

People familiar with accounting statements, as in annual reports of corporations, will recognize the two classes of variables. A financial report is presented on two different pages—the balance sheet and the profit and loss statement. All numbers on the balance sheet are stocks representing accumulations that have evolved over time. The profit and loss statement represents the flows that cause the stocks to change.

There is no comparably important third page, only the page representing stocks

Figure 1. (Jay W. Forrester)

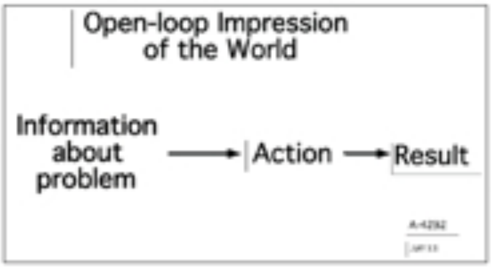


Figure 2. (Jay W. Forrester)

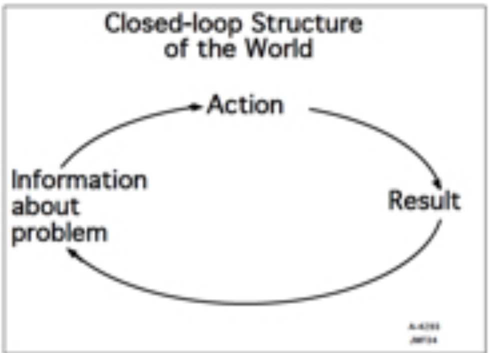


Figure 3. (Jay W. Forrester)

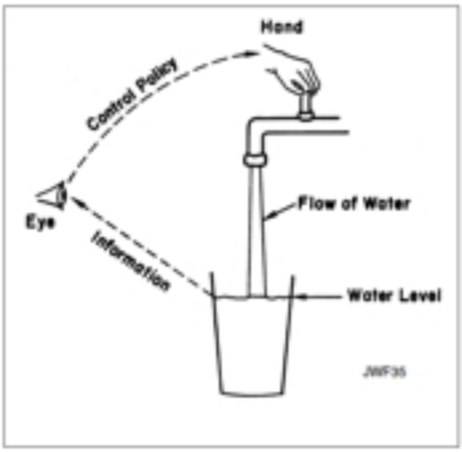
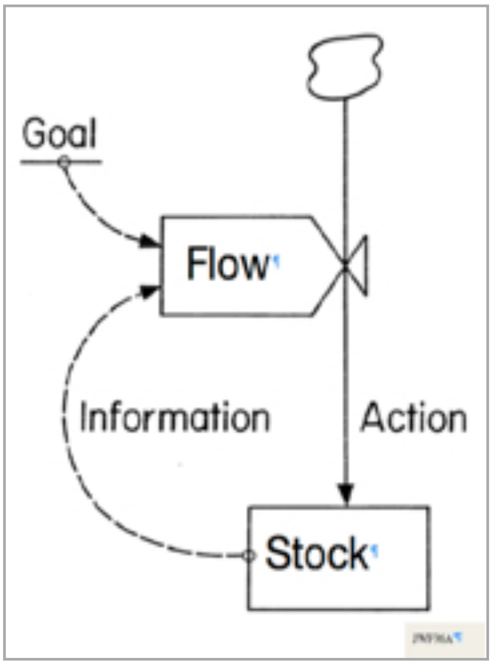


Figure 4. (Jay W. Forrester)



and the page representing flows. That structure of an accounting statement represents a fundamental truth about all systems. Water in a bathtub is a stock; the flow of water changes the stock. A person's reputation is a stock that is changed by the flow of good and bad actions by that person. The degree of frustration in a group is a stock that gradually changes in response to surrounding pressures.

2. From simple to complex systems

The basic feedback loop in Figure 4 is too simple to represent real-world situations. But simple loops have more serious shortcomings—they are misleading and teach the wrong lessons. Most of our intuitive learning comes from very simple systems. The truths learned from simple systems are often completely opposite from the behavior of more complex systems. A person understands filling a water glass, as in Figure 3. But, if we go to a system that is only five times as complicated, as in Figure 5, intuition fails. A person cannot look at Figure 5 and anticipate the behavior of the pictured system.

Figure 5 from World Dynamics is five times more complicated than Figure 4 in the sense that it has five stocks—the rectangles in the figure. The figure shows how rapidly apparent complexity increases as more system stocks are added.

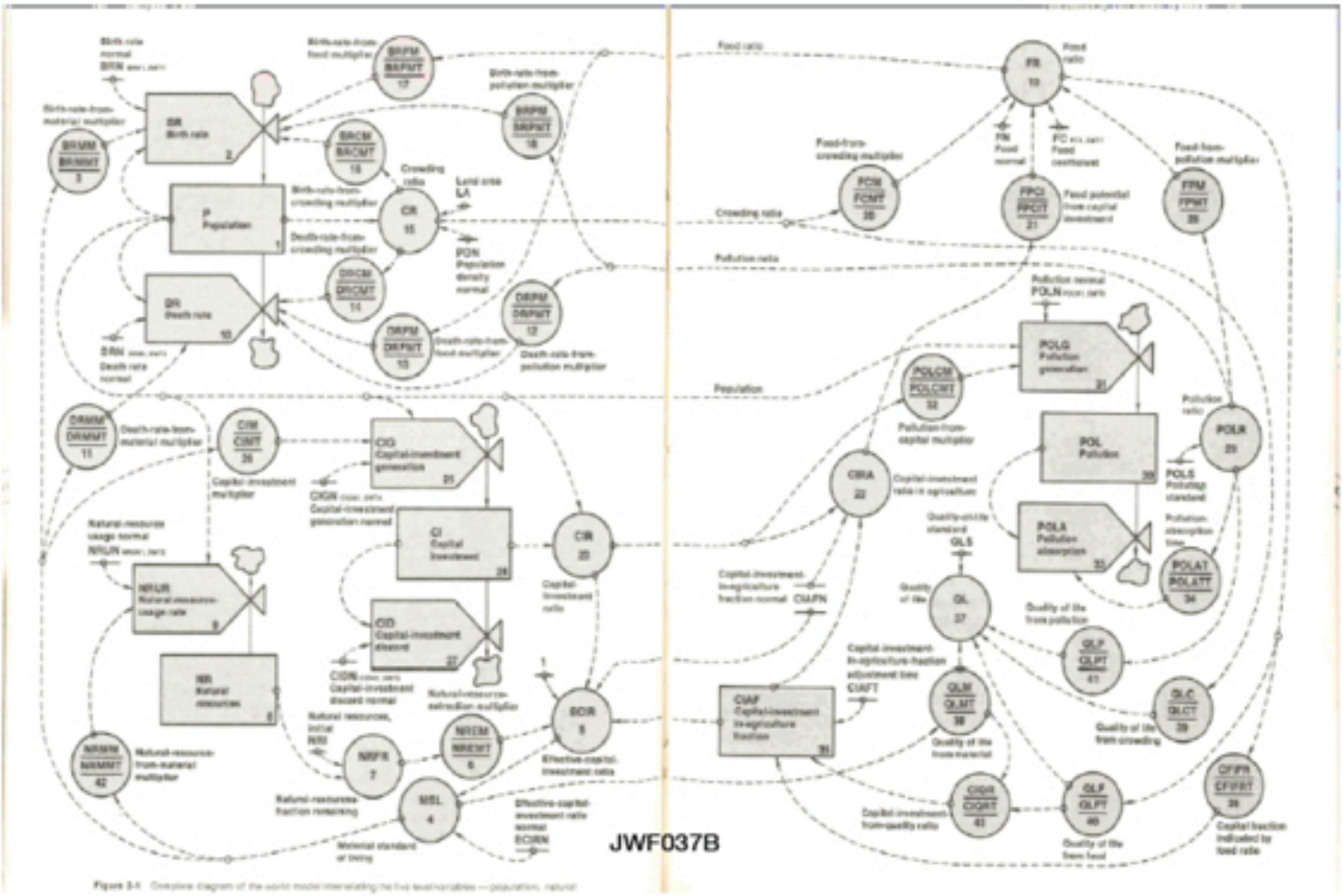
Mathematicians would describe Figure 5 as a fifth-order, nonlinear, dynamic system. No one can predict the behavior by studying the diagram or its underlying equations. Only by using computer simulation can the implied behavior be revealed.

Figure 5 displays interactions between population, capital equipment, agriculture, resources, and pollution. The diagram links multiple disciplines. A proper study of systems must usually break down the boundaries between academic disciplines. As stated by Gordon S. Brown, former dean of engineering at MIT, "The message is in the feedback, and the feedback is inherently interdisciplinary."

3. Everyone uses models

I sometimes ask an audience how many use models for all their decisions. No one responds. How then, I ask, do they make decisions? They quickly see that all

Figure 5. World Dynamics (Source:Jay W. Forrester)



decisions are made on the basis of mental models. No one's head contains a family, city, school, country, or business. Decisions are based only on assumptions about separate parts of real systems, and trying by intuition to fit those fragments of knowledge into an estimate of how things change and what will be the consequences of a proposed action.

3.1. Computer Models and Mental Models

System dynamics builds two-way communication between mental models and simulation models. Mental models are the basis for everyday decisions.

Mental models contain tremendous stores of information. But the human mind is unreliable in understanding what the available information means in terms of behavior. Computer simulation meshes nicely with mental models by taking the mentally stored information and then displaying the dynamic consequences.

Such mental models belong to the same class as the computer models used in system dynamics. In fact a system dynamics model is often built from assumptions in the mental models. Mental models are rich and often sufficiently accurate about the pieces of a system—what information is available, who is connected to whom, what are different people trying to achieve. But mental models are entirely unreliable in deducing what behavior will result from the known pieces of a complex system. On the other hand, a computer simulation can, without doubt, reveal the behavior implicit in the structure from which it is constructed.

4. Working with computer models

The translation of a mental model to a system dynamics simulation model moves through several stages.

1. A model must be created with no logical inconsistencies. All variables must be defined. None can be defined more than once. Equations must be unambiguous. Units of measure should be the same on both sides of an equation. Most system dynamics software applications check for and find such logical errors.
2. When a model is first simulated, the results may be absurd. Simulated behavior may be impossible. Inventories, or water in a bathtub, or students in the school may go negative; negative values often have no real-world meaning. One goes back to refine the model and make the structure more realistic and more robust.
3. As a model becomes better, surprising behavior often does not reveal model errors but instead begins to tell something about real life that was not previously realized. I have usually had such new insights from models.

One example arose from the model in my *Urban Dynamics* book dealing with the growth and stagnation in cities. One weekend I added a job-training program to the model. It was a perfect job-training program in the sense that it simply took people out of the unskilled and underemployed category and put them in skilled labor; and, furthermore, no charge was assigned so it cost nothing. The perfect job-training program caused unemployment in the model to go up.

The increase in unemployment surprised me until I spent a day discovering what the model was doing, after which the result seemed plausible. I took the computer runs back to former mayor John Collins and the several people from Boston business and politics that had been working with me. They looked at the rising unemployment as a result of introducing job training in silence for several minutes until one said, "Oh, Detroit has the best job-training program in the country and the most rapidly rising unemployment rate!"...

The job-training program in the model was defeated by three forces:

1) Before the program, businesses had been dipping into the unskilled and unemployed pool as necessary to obtain employees. The job-training program substituted for the training that businesses would have done, so training by businesses stopped. About half of the training program was neutralized by such substitution;

2) The program increased the number of skilled workers thereby increasing unemployment among skilled workers and resulted in increased downward flow back to the unskilled-unemployed pool. Nearly another half of the training was lost through the increased downward mobility;

3) And last, the training program had high public visibility and attracted unemployed from other cities, even though the program had not created significant new jobs. Forces within the system neutralized the training program and the public visibility of the program attracted additional people who would increase the number of unemployed...

5. Sources of information

Consider the available databases, or sources of information from which we can build computer simulation models.

I suggest that the world's store of information lies primarily in people's heads—the mental database. As a test of that statement, consider any institution, for example, your corporation or your school system. Imagine that at 10 o'clock some morning every person suddenly leaves and is replaced by a person who can read but has no experience in the system. You instruct your replacement to follow the instructions and policy statements in your office and carry on for you. Chaos would result. Our families, schools, businesses and countries operate on the information in people's heads gained from participation, apprenticeship, and on-the-job learning.

The mental database is vastly richer than the written database in the form of books, magazines, and newspapers. In turn, the written database is far more informative about how society operates than the numerically recorded information.

System dynamics modeling should build on all available information, including the voluminous mental database. By contrast, most analyses in the social sciences have been limited to information that has been numerically recorded. The numerical information is an extremely small part of all the information that is available.

6. Generic or transferable structures

Many structures of levels and rates are found repeatedly. They are "generic structures" because they are found in many different situations, even in entirely different fields of application. If a particular structure is understood in one setting, it is understood in all settings. Generic structures provide a person with power to move between situations with the learning in one area being applied to other situations.

In education, after understanding a collection of basic dynamic structures, a student can quickly draw on one to understand a new situation if its structure has been encountered previously.

6.1. Generic Structure of a Clock and Economic Business Cycle

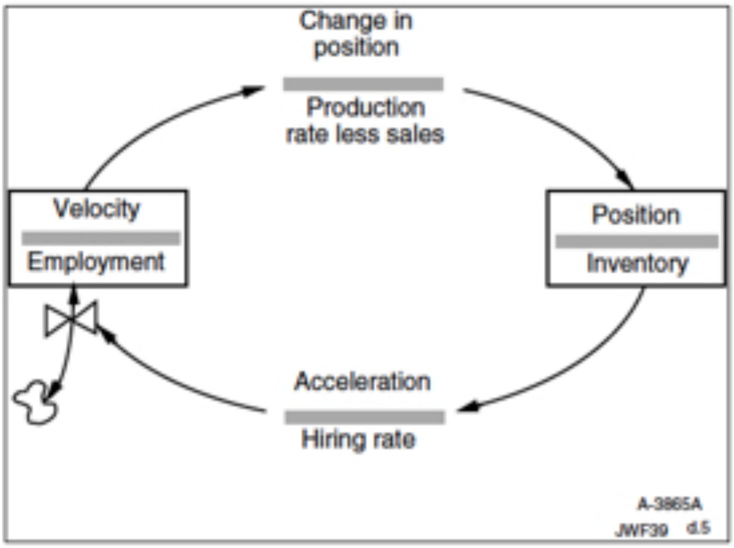


Figure 7. (Jay W. Forrester)

Figure 7 shows two sets of nomenclature. The labels above the bars relate to the swinging pendulum of a clock. The labels below the bars describe inventory and employment in manufacturing.

With appropriate choices of parameter values, the structure will exhibit the oscillation of a one-second clock pendulum, or alternatively the several-year interval between peaks of a business cycle. The single loop with two levels as in Figure 7 results in only a sustained oscillation. Additional structure is necessary to represent friction in a pendulum or the forces that might change the amplitude of business cycles. A swinging pendulum and the central core of the production-inventory business cycle have the same oscillatory structure.

For dramatic, personal-experience learning, computer structures can be converted into games with people making the decisions that would control the flows in a model. A distribution system from manufacturer, through distributor and retailer, to customers has been played by hundreds of thousands of people around the world to drive home the way in which people can interact to create instability. Other games show the dynamics of producing great depressions some 45 to 80 years apart, and still others show how companies can grow so rapidly that they cause their own failure. ◀

Jay Forrester (1918-2016), the founder of system dynamics, spent his entire career at MIT, joining the MIT Sloan School of Management in 1956.

More information, and systems dynamics study materials, can be found at the Creative Learning Exchange.

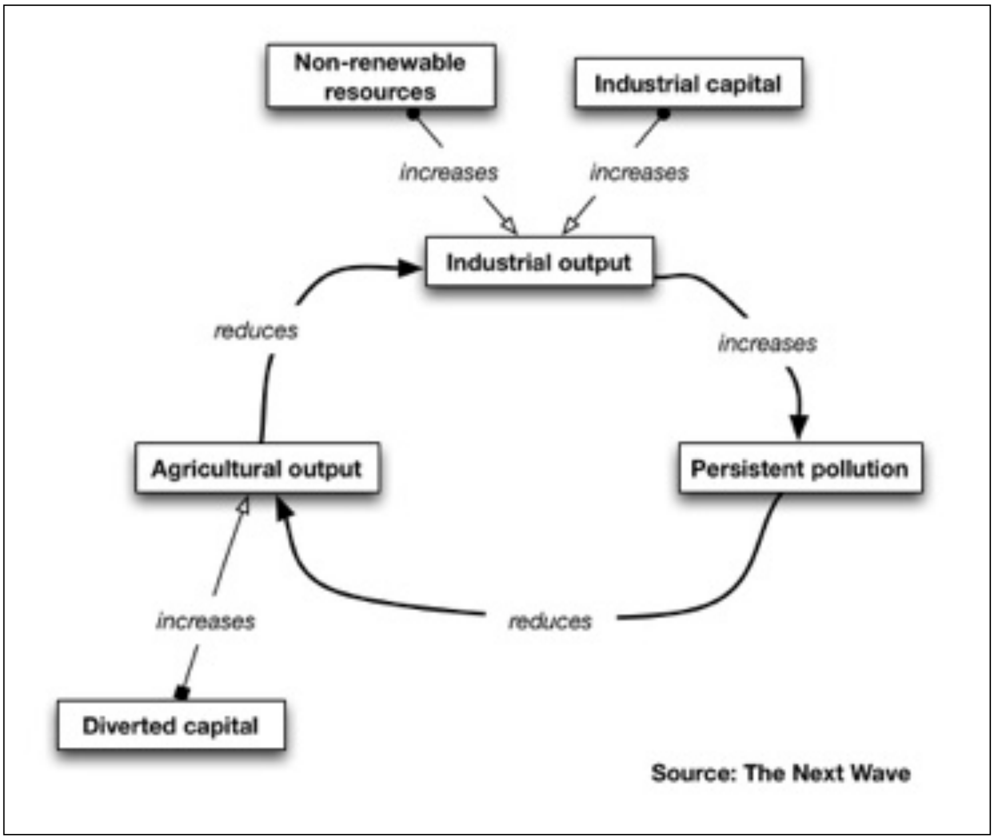
Re-reading The 30-Year Update

by Andrew Curry

It was a short post on the Smithsonian blog that prompted me to go back to read *The Limits to Growth: The 30-Year Update*. The Smithsonian post reported on an evaluation of the *Limit*'s 1972 main case projections against actual consumption to 2000, which had found them depressingly close.

Since the most common outcome of the model is 'overshoot and collapse', in around over a decade's time, it seemed a good idea to understand it a bit better. Quotes and page numbers are from the *30-Year Update* edition, published by Earthscan in London in 2005.

The argument of *Limits to Growth* is built on a model, World3, which has evolved over time, and all models are simplifications. Specifically, it is a systems dynamics model, built around notions of stocks, flows and sinks. Systems models also include delays, which are sometimes poorly understood by economists and technologists—who were among the noisiest critics of the original *Limits to Growth* book—because their mental and theoretical models assume rapid corrections to systems shortfalls.



Delays, complexity, and non-linear behaviour

To write this piece, I went back through *Limits to Growth*, pulling out important parts of the argument. So first, the components of the model. World3 simplifies the world into these main components: population, industrial capital, non-renewable resources, industrial output, pollution, and agricultural production. Because it is a systems dynamics model, there is feedback between different elements, which, when combined with delays, create complexity and non-linear behaviour.

My own large simplification of the model that sits behind World3 can be seen above (and to be clear, this does not come from *Limits to Growth)*.

In summary, industrial capital and non-renewable resources combine to create industrial output, which in turn creates persistent pollution. This then reduces food production—and so capital is diverted from industrial production to agricultural production, and so, in turn, industrial output declines.

From this, the *Limits to Growth* team developed 10 scenarios, representing different paths and making different assumptions about rates of population growth and industrial output. The most common outcome, after thousands of runs of the model, is 'overshoot and collapse', with industrial output declining in the 2020s and population declining in the 2030s. As they say, you don't necessarily need a model to understand this, but a model enables you to be clear about your assumptions about the world.

Collapse is not inevitable

But (and these are important buts) collapse is not inevitable, even though we have now overshot, with the human footprint exceeding the resources of the planet. Growth does not, inevitably, lead to collapse; it depends on how you organise the growth.

It is possible, even now, to get to 'overshoot and oscillation', a pattern in which production and consumption are re-stabilised at a level within the carrying capacity of the planet. But to achieve this, the system needs to retain enough capacity to repair itself.

The model has some assumptions in it which have been borne out by events since, both of which lead to non-linear outcomes—in the model and, it seems, in the actual world [*pp 145,147*]:

- First, it becomes much more expensive to extract a resource as it becomes scarcer, and the amount of energy involved climbs sharply.
- Second, the quality of the remaining resources declines as the quantity of key resources declines.

Limits and technology

Now, as mentioned above, *The Limits to Growth* is famous for the sceptical response it generated. Broadly, the argument was criticised by people who thought it underplayed the impact of technological innovation, and underestimated the response of markets to price signals generated by shortages. They take this on directly.

> *"For many economists technology is a single exponent in some variant of the Cobb-Douglas production function—it works automatically, without delay, at no cost, free of limits, and produces only desirable outcomes. ... In the "real world," however, we cannot find technology with those wonderful properties. The technologies we see are highly specific to particular problems; they cost money and take a long time to develop" [p210].*

In other words, adjustment mechanisms are not free: they have costs, and these costs tend to increase in a non-linear fashion as limits are approached. Second, both markets and innovation tend to serve the goals and aims of their societies. If society is still geared to unsustainable growth, then markets and innovation will be so geared. Third, the signals to which markets and technologists respond are not clear: they are riddled with feedback, 'noise', and delays. And finally, as they observe, "*Time* is in fact the ultimate limit in the World3 model—and, we believe, in the 'real world.'"

And more: the more successfully a society postpones problems, the more likely it is to run into multiple simultaneous problems later. Postponing the crisis, in other words, makes it bigger: "the world system ... runs out of *the ability to cope*" [*p223*, italics in original]. Equally, as we postpone the crisis, the number of viable pathways to the future diminishes as options are closed off by the increasing level of overshoot.

Systems pursue their own goals

A decade on from the financial crisis, perhaps it is no longer controversial to suggest that systems tend to pursue goals which are not necessarily good for the common wealth. (Although even now people seem to overlook the point that Upton Sinclair made during the last great recession). There is a striking passage from the book—a quote from a Japanese journalist—that underlines the point:

> *"You are thinking of the whaling industry as an organization that is interested in maintaining whales; actually it is better viewed as a huge quantity of [money] capital attempting to earn the highest possible return" [p233].*

Although the *Limits to Growth* team were attacked for being pessimistic, their own view is that there are many features of the model which make it too optimistic [*p150*]. It lacks many social limits, such as corruption, crime, and protest. It also treats the world as a single entity, whereas in practice uneven distribution of impacts of change across different countries with different levels of income mean there will be even longer delays between changes in the environment and response [*p221*].

> *"World3 ... does not distinguish the rich parts of the world from the poor. All signals of hunger, resource scarcity and pollution are assumed to come to the world as a whole and to elicit responses that draw on the coping capabilities of the world as a whole. That simplification makes the model very optimistic. ... So is the assumption that political decisions are made without cost and*

The Limits to Growth team were attacked for being pessimistic. Their view is that there are features of the World3 model that make it too optimistic.

The more successfully a society postpones problems, the more likely it is to run into multiple simultaneous problems later. In other words, postponing the crisis makes it worse.

without delay. We have to remember, too, that the World3 model has no military sector to drain capital and resources from the productive economy. … The model represents the uppermost possibilities for the "real world."

A clash of worldviews

Looking back at the storm which followed the publication of *The Limits to Growth* with the benefits of 40 years of hindsight, it's clear now that it was about a clash of worldviews. The project took the preferred tools of mainstream strategy and analysis (data and modelling) and used them to produce a set of outputs that were profoundly challenging to the mainstream.

We were, in 1972, just ahead of the oil price shock that dominated the rest of the '70s, still in a world that believed in metaphors of abundance and plenty. At the time we were still living comfortably within the planet's environmental limits.

No more. But the political problems that come with talk of overshoot and limits have not gone away: if anything they have become more acute. "Any talk of reducing growth feeds into a bitter argument about distribution," they write [*p124*]. Yet although our choices have narrowed, we do still have choices. As the Rocky Mountain Institute argues, even within the current system there is considerable scope to reduce the impacts of affluence and the throughout of materials in production processes. But although this is valuable, it seems to me unlikely to be enough without a change in goals, and by extension, in worldviews. In *The Limits to Growth*, the authors set some store by changes in information, including changes in rules and goals—which are themselves a form of information: "When its information flows are changed, any system will behave differently" [p270].

But systems always resist such changes, strongly, as we have seen repeatedly since the financial crisis. In the end, the difference between overshoot and collapse, and overshoot and oscillation, comes down to politics. ◀

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A version of this review first appeared on his blog, The Next Wave.

Reading

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For other perspectives on The Limits to Growth, see also Peter Bishop's combined review from 2006 of *Limits to Growth*, the 20-year edition *Beyond the Limits*, and *The 30-Year Update* in *Technological Forecasting & Social Change*, which can be accessed here.

Andy Hines' 2005 review of *The 30-Year Update*, originally published in *Foresight*, can be downloaded from Andy's website.

The critical storm over 'Limits to Growth'

by Ugo Bardi

In 1972, *The Limits to Growth* study arrived in a world that had known more than two decades of unabated growth after the end of the Second World War. It was a time of optimism and faith in technological progress that, perhaps, had never been so strong in the history of humankind.

With nuclear power on the rise, with no hint of scarcity of mineral resources, with population growing fast, it seemed that the limits to growth, if such a thing existed, were so far away in the future that there was no reason to worry. And, even if these limits were closer than generally believed, didn't we have technology to save us? If we could reach the Moon, as we did, in 1969, what was the problem with such trifles as resource depletion and pollution? The future could only be shiny for ever and ever.

Against that general feeling, the results of *The Limits to Growth* were a shock. The future was not to be shiny at all. The authors had developed a model that could keep track of a large number of variables and of their interactions as the system changed with time. They found that the world's economy tended to collapse at some time in 21st century. The collapse was caused by a combination of resource depletion, overpopulation, and growing pollution (this last element we would see today as related to global warming). Only specific measures aimed a curbing growth and limit population could avoid collapse.

There is a legend lingering around the first *Limits* book that says that it was laughed off as an obvious quackery immediately after it was published. It is not true. The study was debated and criticized, as it is normal for a new theory or idea. But it raised enormous interest and millions of copies were sold.

Evidently, despite the general optimism of the time, the study had given visibility to a feeling that wasn't often expressed but that was in everybody's minds. Can we really grow forever? And if we can't, for how long can growth last? The study provided an answer to these questions; not a pleasant one, but an answer nevertheless.

> **Limits to Growth had all the ingredients to become a major scientific advance. But by the 1990s, it had become a laughing stock.**

The Limits to Growth study had everything that was needed to become a major advance in science. It came from a prestigious institution, the MIT; it was sponsored by a group of brilliant and influential intellectuals, the Club of Rome; it used the most modern and advanced computation techniques and, finally, the events that were taking place a few years after publication, the great oil crisis of the 1970s, seemed to confirm the vision of the authors.

Yet, the study failed to generate further research and, a couple of decades after the publication, the general opinion about it had completely changed. Far from being considered the scientific revolution of the century, by the 1990s *The Limits to Growth* had become everyone's laughing stock: little more than the rumination of a group of eccentric (and probably slightly feebleminded) professors who had really thought that the end of the world was near. In short, Chicken Little with a computer.

The reversal of fortunes of *The Limits to Growth* was gradual and involved a debate that lasted for decades. At first, critics reacted with little more than a series of statements of disbelief.

Just a few early papers contained more in-depth criticism, notably by William Nordhaus (1973) and by a group of researchers of the university of Sussex that went under the name of the "Sussex Group" (Cole 1973). Both studies raised a number of interesting points but failed in their attempt of demonstrating that the Limits study was flawed in its basic assumptions.

These early papers by Nordhaus and by the Sussex group already showed an acrimonious streak that became common in the debate from the side of the critics.

Political criticism, personal attacks and insults, as well as breaks of the basic rules of the scientific debate. For instance, the editor of the journal that had published Nordhaus' 1973 paper attacking "Limits" refused to publish a rebuttal.

With time, the debate on the Limits book veered more and more to the political. In 1997, the Italian economist Giorgio Nebbia noted that the reaction against the study had arrived from at least four different fronts. One was from those who saw the book as a threat to the growth of their businesses and industries. A second set was that of professional economists, who saw it as a threat to their dominance in advising on economic matters. The Catholic Church provided further ammunition for the critics, being piqued at the suggestion that overpopulation was one of the major causes of the problems. And the political left in the Western world saw the study as a scam of the ruling class, designed to trick workers into believing that the proletarian paradise was not a practical goal.

And this is an incomplete list; it does not include the political right, the believers in infinite growth, politicians seeking for easy solutions to all problems, and many others. All together, these groups formed a formidable coalition that guaranteed a strong reaction against the Limits to Growth study. This reaction eventually succeeded in demolishing the study in the eyes of both the majority of the public and of specialists.

The fall of the Limits to Growth was greatly helped by a factor that initially had bolstered the credibility of the study: the world oil crisis of the 1970s. The crisis had peaked in 1979 but, in the years that followed, new oil resources started flowing abundantly from the North Sea and from Saudi Arabia. With oil prices plummeting down, it seemed to many that the crisis had been nothing but a scam; the failed attempt of a group of fanatic sheiks of dominating the world using oil as a weapon. Oil, it seemed, was, and had always been, plentiful and was destined to remain so forever. With the collapse of the Soviet Union in 1991 and the "New Economy" appearing, all worries seemed to be over. History had ended and all what we needed to do was to relax and enjoy the fruits that our science and our technology would provide for us.

And so, by the late 1980s, all what was remembered of the *Limits to Growth* book, published almost two decades before, was that it had predicted some kind of catastrophe at some moment in the future. If the world oil crisis had been that catastrophe, as it had seemed to many, the fact that it was over was the refutation of the same prediction. This factor had a major effect on people's perception.

The book was attacked for being 'as wrong headed as it is possible to be'

The change in attitudes spanned a number of years but we can probably locate a specific date and an author for the actual turning point. It happened in 1989 when Ronald Bailey, science editor of *Forbes* magazine, published a sneering attack (Bailey, 1989) against Jay Forrester, the father of system dynamics, the method behind the Limits study. The attack was also directed against the Limits book. Bailey said the book was, "as wrong-headed as it is possible to be". To prove his point Bailey revived an observation that had already been made in 1972 by a group of economists on the "New York Times" (Passel, 1972). Bailey said that:

> *"Limits to Growth" predicted that at 1972 rates of growth the world would run out of gold by 1981, mercury by 1985, tin by 1987, zinc by 1990, petroleum by 1992, copper, lead and natural gas by 1993.*

Bailey reiterated his accusations in 1993 in the book titled *Ecoscam*. This time, he stated that *none* of the predictions of the 1972 Limits study had turned out to be correct.

Of course, Bailey's accusations are just plain wrong. What he had done was to extract a fragment of the text of the book and then criticized it out of context. In Table 4 of the second chapter of the book, he had found a row of data (column 2) for the duration, expressed in years, of some mineral resources. He had presented these data as the only "predictions" that the study had made and he had based his criticism on them, totally ignoring the rest of the book.

Reducing a book of more than a hundred pages to a few numbers is not the only fault with Bailey's criticism. The fact is that *none* of the numbers he had selected was a prediction, and nowhere in the book it was stated that these numbers were supposed to be read as such. Table 4 was there only to illustrate the effect of a hypothetical continued exponential growth on the exploitation of mineral resources.

Even without bothering to read the whole book, the text of chapter 2 clearly stated that continued exponential growth was not to be expected. The rest of the book, then, showed various scenarios of economic collapse that in no case took place before the first decades of 21st century.

It would have taken little effort to debunk Bailey's claims. But it seemed that, despite the millions sold, all the copies of *Limits to Growth* had ended up in the recycling bin. Bailey's criticism was wrong, but it was successful; it became an urban legend.

We all know how persistent urban legends can be, no matter how silly they are. At the time of Bailey's article and book, the Internet as we know it didn't exist yet, but word of mouth and the press were sufficient to spread and multiply the story of the "wrong predictions."

To give just one example, Bailey's text even reached the serious scientific literature. In 1993, William Nordhaus published a paper titled "Lethal Models" which was meant as an answer to the second edition of *Limits*, published in 1992 with the title *Beyond the Limits*.

Nordhaus' paper was accompanied by a series of texts by various authors grouped under the title "Comments and Discussion". A better definition of that section would have been "feeding frenzy" as the criticism by this distinguished group of academic economists clearly span out of control. Among these texts, we find one by Robert Stavins, an economist from Harvard University, where we can read that:

> *If we check today to see how the Limits I predictions have turned out, we learn that (according to their estimates) gold, silver, mercury, zinc, and lead should be thoroughly exhausted, with natural gas running out within the next eight years. Of course, this has not happened.*

All this is, obviously, taken straight from Bailey's paper in *Forbes*. Apparently, the excitement of a "Limits-bashing" session had led Stavins to forget that a serious scientist should check the reliability of the sources that he or she cites.

Unfortunately, this paper by Nordhaus enshrined the legend of the "wrong predictions" in a serious academic journal.

The criticism was factually wrong. but it became an urban legend

With the 1990s, and in particular with the development of the Internet, the dam burst, and a true flood of criticism swamped the book and its authors.

Scientists, journalists, and whoever felt entitled to discuss the subject, started repeating the same line over and over: *Limits to Growth* had predicted a catastrophe that failed to occur and therefore the whole idea was wrong. After a while, the concept of "wrong predictions" became so widespread that it wasn't any more necessary to state in detail what these wrong predictions were.

Some of the criticism also became weird, as when the authors were accused of being part of a conspiracy designed to create "a kind of fanatic military dictatorship" (Gloub and Townsend, 1977), or aggressive. One critic declared that the authors of the book should be killed, cut to pieces, and their organs sent to organ banks.

Today, we can find Bailey's legend repeated on the Internet literally thousands of times in various forms. Sometimes it is exactly the same text, cut and pasted as it is; in others it is just slightly modified.

At this point, we may ask ourselves if this wave of slander had arisen by itself, as the result of the normal mechanism of urban legends, or if it had been masterminded by someone. Can we think of a conspiracy organized against the authors of the *Limits* book or against their sponsors, the Club of Rome? On this point there is an analogy with an earlier case; that of Rachel Carson, well known for her 1962 book *Silent Spring*, in which she criticized the over-use of DDT and other pesticides. Carson's book was also strongly criticized, even demonized.

Kimm Groshong has reviewed the story and she tells us in her 2002 study that:

> *The minutes from a meeting of the Manufacturing Chemists' Association, Inc. on May 8, 1962, demonstrate this curious stance. Discussing the matter of what was printed in Carson's serialization in the New Yorker, the official notes read: "The Association has the matter under serious consideration, and a meeting of the Public Relations Committee has been scheduled on August 10 to discuss measures which should be taken to bring the*

matter back to proper perspective in the eyes of the public."

Whether we can call that a "conspiracy" is open to discussion, but clearly there was an organized effort on the part of the chemical industry against Rachel Carson's ideas. By analogy, we could think that, in some smoke-filled room, representatives of the world's industry had gathered in the early 1970s to decide what measures to take against the Limits to Growth in order to "bring the matter back to proper perspective in the eyes of the public."

The recent story of the campaign against climate science, as told for instance by Hoggan and Littlemore (2010) and by Oreskes and Conway (2010), tells us that these kinds of things have occurred and still occur. We have no data indicating that something like that took place against *The Limits to Growth* but it may be the case.

Propaganda techniques are effective because they play on some of the natural tendencies of the human mind. The 1989 article by Ronald Bailey and other attacks were only catalysts that unleashed our tendency to believe what we want to believe and to disbelieve what we don't want to believe. We don't like inconvenient truths.

Now, in the 21st century, the general attitude towards the concepts of the *Limits* book seems to be changing again. The war, after all, is won by those who win the last battle.

One of the first cases of reappraisal of the Limits study was the review done by Matthew Simmons (2000), an expert on crude oil resources. It seems that the "peak oil movement" has been instrumental in bringing back to attention the *Limits* study. Indeed, oil depletion can be seen as a subset of the world model used in the study (Bardi 2008). Climate studies have also brought the limits of resources back to our attention; in this case intended as the limited capability of the atmosphere to absorb the products of human activities.

But it is not at all obvious that a certain view of the world, one that takes into account the finite amount of resources, is going to become prevalent, or even just respectable. The success of the smear campaign of the 1980s shows the power of propaganda and of urban legends in shaping the public perception of the world, exploiting our innate tendency of rejecting bad news. Because of our tendency of disbelieving bad news, we chose to ignore the warning of impending collapse that came from the *Limits* study.

In so doing, we have lost more than 30 years. Today, we are ignoring the warnings that come from climate science and we may be making an even worse mistake. There are signs that we may be starting to heed the warnings, but we are still doing too little, too late. Cassandra's curse is still upon us. ◀

Ugo Bardi is a professor at the University of Florence who writes on energy and environmental issues. A version of this article was first published on his blog, 'Cassandra's Legacy,' in 2011, and it is reprinted here with his permission. His book, The Limits to Growth Revisited, was published by Springer, also in 2011.

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Limits, paradigms, and transformations

Reflections on Limits to Growth and Jay Forrester's contribution

by Anthony Hodgson

Limits to Growth (LTG) introduced a challenge to consider the global *problematique* as a total system structured with multiple interacting feedback loops. As such, it pointed out that linear views such as those that prevail in mainstream economics are deeply flawed in their assumptions which are basically 'flat earth economics'. Such is the ingrained and self-serving momentum of the linear limitless worldview that LTG was roundly rejected and the linear exponential paradigm still dominates politically.

Efforts to learn and create circular economic systems remain marginal. I believe this is because of an underlying attitude which rejects transformational thinking about the future, rather than because of its use of systems dynamics. The change required is a paradigm shift, or reality will impose corrections at great cost and suffering (global climate change, species extinction, critical earth resource depletion, human urban viability and so on).

How can we do futures thinking when facing a necessary paradigm shift where extrapolation and trend analysis, however current, will be trapped in the dominant paradigm? This is a brief excursion into contexualising the LTG project in the futures method, Three Horizons.

A strength of system dynamics is that, deeper than cause-effect, structure drives behaviour. Through emulating some of the key structures in our situation the world model simulates multiple futures based on the structure of current reality, and ways in which that reality might be restructured. In the *30-Year Update*, Meadows *et al* stress that this is not about prediction:

> *"We are simply presenting a range of alternative scenarios .... to encourage learning, reflection, and personal choice."*[1]

My own personal choice is the inevitability of one of the 'Overshoot' scenarios, if things do not radically change. Call the current dynamic structure Pattern A. Tweaking Pattern A may delay some unwelcome consequences but it does not fundamentally change the dynamic behaviour. Consider a Pattern B which is restructured to be 'fit for the purpose' of a viable human-planet system.

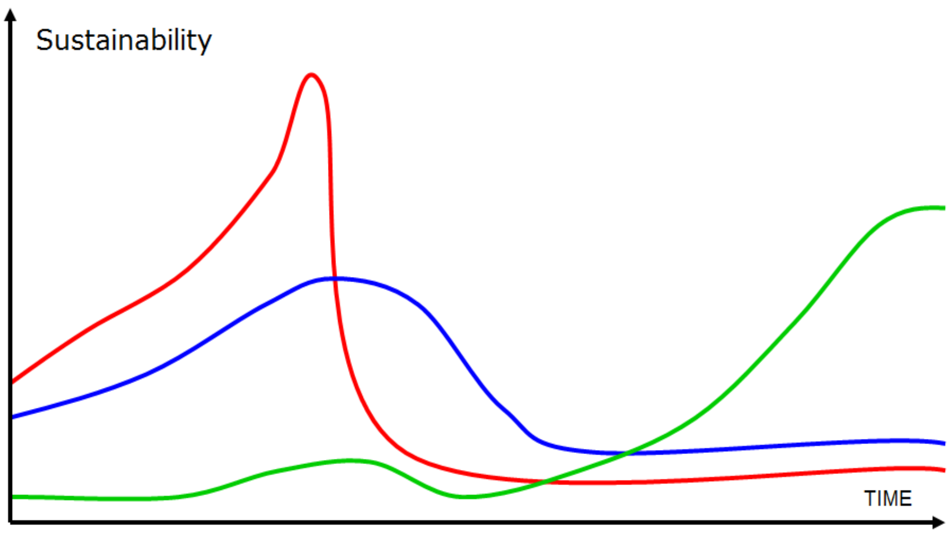
It is a massive discontinuity from Pattern A. It cannot be reached without deconstruction and reconstruction. The changeover needs transformation—metamorphosis, if you like.

In the three horizons method:

- Horizon 1 is Pattern A, degrading in radically changing planetary context.
- Horizon 3 is Pattern B, which has realized a new viability.
- Horizon 2 is different. It is the navigation pathways of paradigm shift through the seeming chaos of uncertainty, complexity, emergence and conflict resolution which demands extraordinary innovation on all levels, not just technological.

Modifying the standard way of drawing the three horizons we get Figure 1.

Figure 1 : Overshoot variant of the three horizons



In this variant the supremacy of the **Horizon 1** paradigm creates runaway success but at the expense of some critical condition. Failure to capture coupled with weaker innovation in **Horizon 2** this leads to sudden collapse. Horizon 2 is unable to make up for this.

In the background **Horizon 3** continues to develop and after the initial upset and chaos of the collapse demonstrates its ability to match the new conditions and emerges as the next viable paradigm.

Source: Anthony Hodgson

In this horizon scenario there are three weaknesses to be addressed if it is to be avoided. Firstly, the seeming successes of Horizon 1 are being bolstered by innovative 'fixes' that delay some limits being reached, but bring forward others. Secondly, the attempts to create 'pockets of the future in the present' of Horizon 3 are too weak and too peripheral. Thirdly, the contribution to transition by Horizon 2 is subject to 'capture' by Horizon 1 (H2-) and a strong transformative innovation (H2+) is denied.

Interestingly, Meadows *et al* present their own equivalent of H2+ in a number of themes they consider essential if we are to head off collapse. They are:

Networking:

" .. a web of connections among equals, held together not by force, obligation, material incentive, or social contract, but by shared values..."[2]

Truth-Telling:

"A system cannot function well if its information streams are corrupted by lies."[3]

Learning:

"Learning means exploring a new path with vigor and courage, being open to other people's explorations of other paths, and being willing to switch paths if one is found that leads more directly to the goal."[4]

Loving:

"Collapse cannot be avoided if people do not learn to view themselves and others as part of one integrated global society. Both will require compassion, not only with here and now, but with the distant and future as well. Humanity must learn to love the idea of leaving future generations a living planet."[5]

Compared to what is needed it seems there is proportionately very little direct R&D in the field of regenerative approaches that are both set in the context of the needed fundamental change and linked by widely shared systemic thinking. H2+ is still starved of resources that are locked up in Horizon 1. The scale, complexity and urgency of the challenge is still underestimated.

Reflections such as these have stimulated myself and a group to set up a 'university for the third horizon'[6] to stimulate and catalyse such thinking and practice. Without educational development consistent with the real characteristics of Horizon 2 transformation, most good efforts will run into the desert of Horizon 1 and not be able to fulfill their promise.

We are exploring new ways of combining futures methods, systems thinking, cognitive facilitation and co-creative learning methods in application to fundamental challenges.[7,8,9] This is another small challenge the hegemony of Pattern A! ◀

Anthony Hodgson is a founder member of the International Futures Forum and a founding trustee of H3Uni. His practice over several decades has been in facilitating strategic, systems and scenario thinking. He is also an Honorary Research Fellow at the University of Dundee.

Footnotes

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The Limits to Growth was part of a larger project by the Club of Rome–'the Project on the Predicament of Mankind'. This is from William Watts' 1972 (and gendered) foreword to the original edition of *The Limits to Growth*.

"The intent of the project is to examine the complex of problems surrounding troubling men of all nations: poverty in the midst of plenty; degradation of the environment; loss of faith in institutions; uncontrolled urban spread; insecurity of employment; alienation of youth; rejection of traditional values; and inflation and other economic disruptions. These seemingly divergent parts of the "world problematique," as the Club of Rome calls it, have three characteristics in common: they occur to some degree in all societies; they contain technical, social, economic and political elements; and, most important of all, they interact."

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