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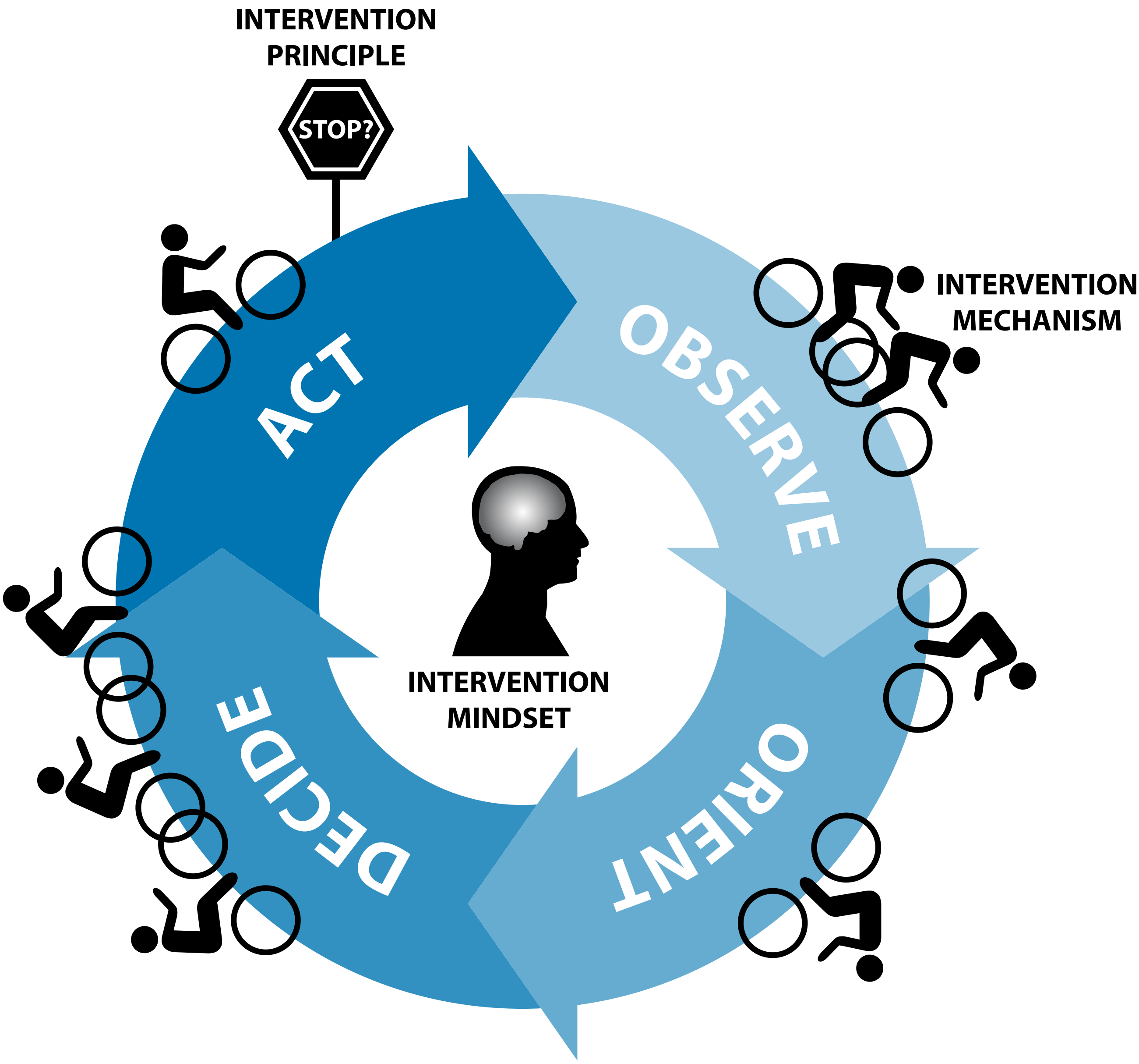
Manifesto for

SMARTER INTERVENTION IN COMPLEX SYSTEMS

Mark Fell, Managing Director, Carré & Strauss
with an Introduction by
Hanne Melin, Policy Strategy Counsel, eBay Inc.



About the Author

Mark Fell is the Managing Director of Carré & Strauss, a firm that specialises in decision support systems for professional strategists. During the course of a career in strategy and governance he has advised a wide range of organisations, including Arup, BSkyB, Chiquita, Diageo, eBay, Estée Lauder, Europe's blank recording-media industry, the European Cancer Organisation, the European Cooperative Movement, Hydro, Knauf Insulation, LVMH Group, Mastercard, Nutricia, PayPal, Richemont Group, Shecco, UPS and Vodafone. Mark holds a Masters Degree in European Politics and Administration from the College of Europe, Bruges, a First Class Honours Degree in Politics from Edinburgh University and has studied at the Institut d'Etudes Politiques, Strasbourg. In his free time he enjoys testing himself through endurance running, having completed races at the North Pole, in Antarctica, the Sahara, Amazon, Himalaya and Alps, as well as an Ironman Triathlon.

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Executive Summary

'Smarter Intervention in Complex Systems' means pursuing a new intervention mindset, mechanism and principle.

This manifesto is a call for better decision making in our social, technological, environmental, economic and political systems.

It marshals a series of disparate concepts into a framework. This framework aims to facilitate 'Smarter Intervention in Complex Systems'. It is a methodology.

In doing so the manifesto draws extensively on the ideas, words and images of many professionals from a wide array of disciplines. 'Systems Dynamics' and 'Complexity Theory' helps to guide us through this process.

'Smarter Intervention' is based on three tenets:

(1) **MINDSET:** The systems we are seeking to shape are often 'complex'. They are 'nonlinear'. A does not always lead to B to C to D to E. Instead they can be full of surprises. We cannot 'predict-and-control' their behaviour. Instead we need to pursue a far more iterative 'trial-and-error' approach. One in which the decisions that we take are survivable.

(2) **MECHANISM:** The 'OODA Loop' ('Observe-Orient-Decide-Act') is a practical method for actioning this trial-and-error approach. We can cycle this loop by using experts or non-experts. They may be individuals or groups of individuals - i.e. 'crowds'. Increasingly the loop is being cycled by software algorithms. Each of these 'Intervention Agents' has its strengths and weaknesses. These are examined at length in this Manifesto. Agents can emanate from either the public or the private sector. The key message is that none of these agents is the panacea to cycling the loop. In each specific case we need to identify the appropriate combination of these agents. We require an 'Intervention Mix'.

(3) **PRINCIPLE:** To achieve this mix a new 'Intervention Principle' is proposed. To the extent that a system can successfully self-organise, it should be left to do so. Where intervention is necessary, then the case has to be made for why a given intervention agent should be involved in the OODA loop - i.e. the best agent to solve this type of problem. The aim is to get all of these different agents cycling around the loop as a team, at the right tempo and to be able to hold them to account.

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Introduction by Hanne Melin

"While all other sciences have advanced, that of government is at a standstill - little better understood, little better practiced now than three or four thousand years ago."

John Adams
Second President of the United States

In the early 1980s, commercial attempts to develop mobile phone services in Sweden were resisted. The reason being the frightening legal uncertainty when a new technology was not covered by existing rules. Experience has surely taught us to better cope with change but have we actually found the policy framework for doing so with confidence?

The European Commission launched in 2005 the Better Regulation agenda aimed at improving lawmaking in a fast moving Europe. In 2010, the Commission evolved this agenda into a Smart Regulation strategy to more effectively embed the objectives of Better Regulation into the whole policy cycle.

These are the right steps but I am convinced that more evolution – in fact transformation – now needs to happen in the area of policymaking in order to not only step into the 21st Century but keep moving in synch with it.

Take robotic technologies, expected by many to revolutionise our lives even more profoundly than the mobile phone. How should the law think about robots, asks a recent essay from Washington University. The authors warn that "*the law almost always considers new technology as merely a new form of something else*",[1] which sounds a lot like what happened in Sweden in 1981.

Indeed, two interrelated questions – both at the heart of good lawmaking in changing times - have been discussed for years.

The first is finding the right tools for problem-solving. *"Regulation is one of the many ways of implementing public policy but it is not necessarily the best way of solving a given problem nor is it the only way"*, stressed the 2001 Mandelkern Group report that formed the basis for the EU Better Regulation agenda.[2]

The second is involving the appropriate actors in decision-making. A 2006 study commissioned by the European Commission and carried out by the Hans-Bredow-Institut stressed that in increasingly complex and rapidly changing societies knowledge is held by different actors.[3]

The traditional answers to these two questions have been co-regulation and consultations with the public. But are these the best answers when today's world requires us to think less in 'form' and more about 'function'?

Last summer, I was listening to Spotify founder Daniel Ek on the radio. Why think about the music album as something fixed to 12 tracks, he asked. When artists can simply release songs once finalised, function rather than form matters.

We could approach policymaking with a similar mentality. If we freed ourselves of the constraints of traditional form, how would we go about releasing the outcome we'd like to see?

The Hans-Bredow-Institute study pointed towards the need for a system governance approach to *"work out better ways to achieve the policy goals under changing conditions"* in view of it being impossible to control social systems.

Indeed, the European Parliament embarked in 2011 on an exercise to identify changes needed to prepare for the complex environment resulting from a *"multi-polar world where governance is more and more a multi-level one, involving multiple actors in decision making and implementation"*[4] and where technologies are accelerating change.

In parallel, the European Commission has reorganized one of its Directorates-General to better *"face the challenges of the next ten years in a digital world"*[5] by inter alia setting up a Complex Systems unit.

I see these actions as products of an evolution in policy thinking on how to *"grapple with far more complexity than before"* – as Chan Lai Fung, then Chairman of Singapore's Smart Regulation Committee, defined the challenge already in 2006.[6]

So where do we go from here? European Commissioner Neelie Kroes is right when she says that we need *"new legal frameworks and a new way of thinking"*.[7] We need the framework that pulls together the evolution in thinking and importantly lets also policymaking detach from form, rigid division between regulators and the public, and a preference for control.

To my knowledge, no one has yet proposed that framework. Now, with this Manifesto someone finally has!

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A Manifesto for Change

"… the challenges we face are real. Finance is in tumult, and while worries about a banking crisis may have ebbed, fears of a crisis in public finances are running high. Even without additional financial reversals, overall economic prospects look bleaker than just a few years ago. The global order also seems more uncertain. Prosperity and power are shifting to new places and peoples. Old political doctrines and divisions no longer seem viable. Technology and media are changing before our eyes. So, apparently is the natural environment itself."

Pankaj Ghemawat, World 3.0[1]

Time and again we are failing to manage 'complex systems' in an increasingly interdependent world, be they complex social, technological, environmental, economic or political systems. This is unsustainable.

This Manifesto therefore makes the case for 'Smarter Intervention in Complex Systems'.

Not because Smarter Intervention is the panacea for a more sustainable future, but because without it, the chances of success are even slimmer.

To do so this Manifesto:

(1) Begins by framing the big picture, namely defining the global system in which we operate and from which our challenges emanate

(2) Proceeds to introduce 'Systems Dynamics' as a lense through which to understand any system, be it social, technological, environmental, economic or political

(3) Identifies 12 'Leverage Points' that have surfaced over the decades as experts have studied all kinds of different systems

(4) Sets out a methodology for practically applying this systems knowledge, namely the requisite intervention 'Mindset', 'Mechanism' and 'Principle'

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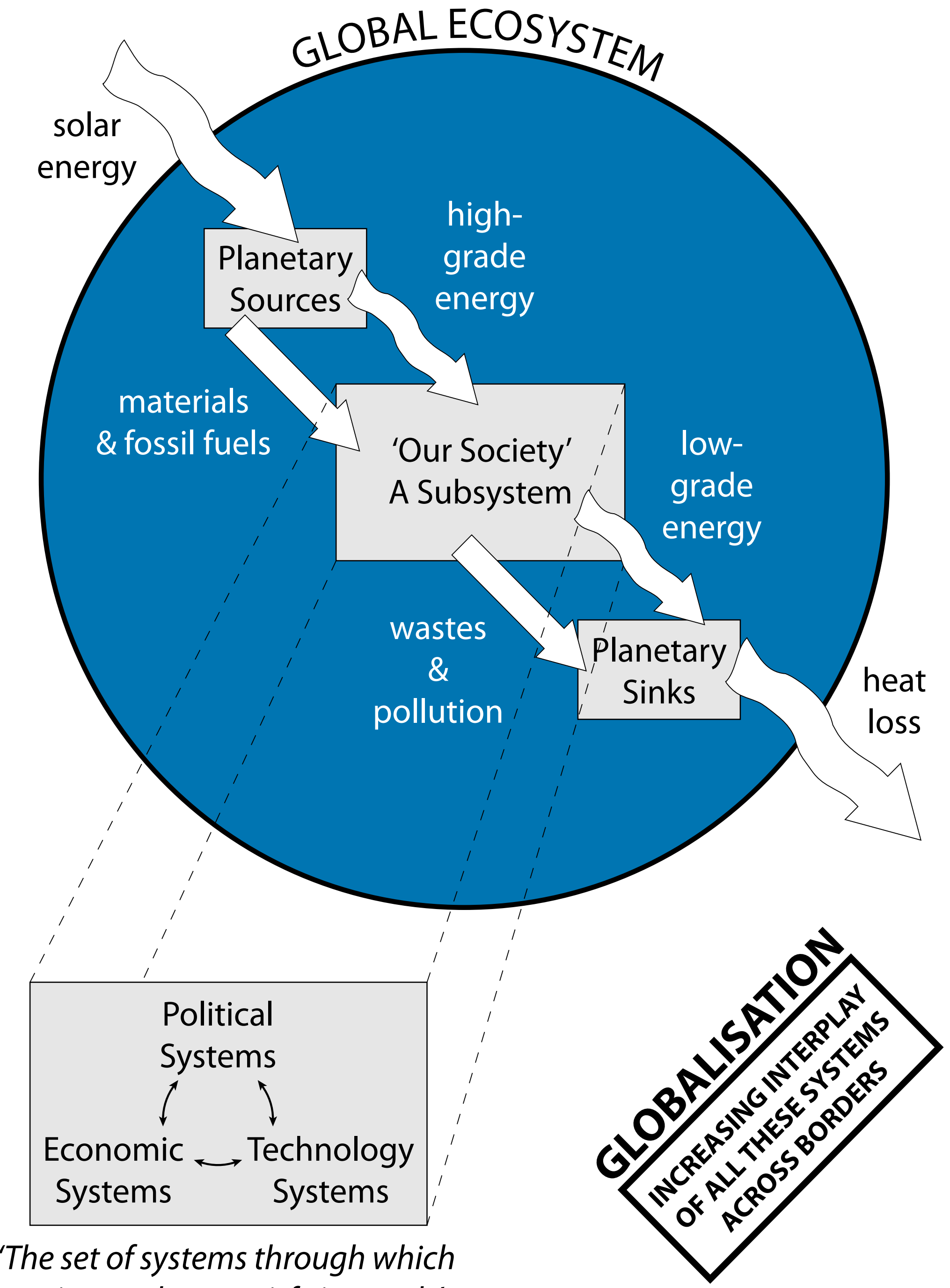
The Global System Defined



'The set of systems through which society seeks to satisfy its needs'

FIGURE 1 (opposite page) - THE GLOBAL SYSTEM
'How Everything Fits Together'
Source: Adapted from "The Limits of Growth" by Meadows, Randers and Meadows[1]

"THE BIG PICTURE"

To make the case for 'Smarter Intervention in Complex Systems' we first need a conceptual framework - a lense through which to bring the challenge into focus.

This begins with a view of how social, technological, environmental, economic and political ('STEEP') systems relate to one another.

The standard way to define the economy is as a *"system of production, distribution and consumption of goods and services"*. This is where "economic value" is created or destroyed.

However this Manifesto adopts a more holistic view of the economy, seeing it as being not just about production, distribution and consumption, but rather as *"the set of systems through which a society seeks to satisfy its needs"*. This expanded definition therefore also includes our political and technology systems.

Our society is an expression of how all of these systems interact - the resulting cultural relations and institutional arrangements. It is here that we can evaluate whether 'social value' is being created or destroyed.

In turn, our society is nested in a bigger global ecosystem that will or will not ultimately sustain it. At this level we need to concentrate our efforts on conserving and nurturing 'environmental value'.

'Globalisation' entails the increasing interaction of all these systems regardless of geography.

'Intervention' means any initiative that seeks to influence a system's behaviour. This may take many forms, including government regulation, subsidies and fiscal incentives. It may be a decision made by business or an action by civil society. Increasingly it manifests itself as algorithmic intervention - think of speed cameras, driverless trains and 'High Frequency Trading'.

What therefore is this recurrent theme, namely a 'system'?

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Systems Dynamics Introduced

WHY SYSTEMS DYNAMICS

Pioneered at MIT, 'Systems Dynamics' is an approach to understanding the behaviour of complex systems over time.

Donella Meadows was a leading proponent of systems dynamics and a key voice in what has become known as the 'sustainability movement', the international effort to reverse damaging trends in the social, technological, environmental, economic or political systems.

Her work is widely recognized as a formative influence on hundreds of other academic studies, government policy initiatives, and international agreements.

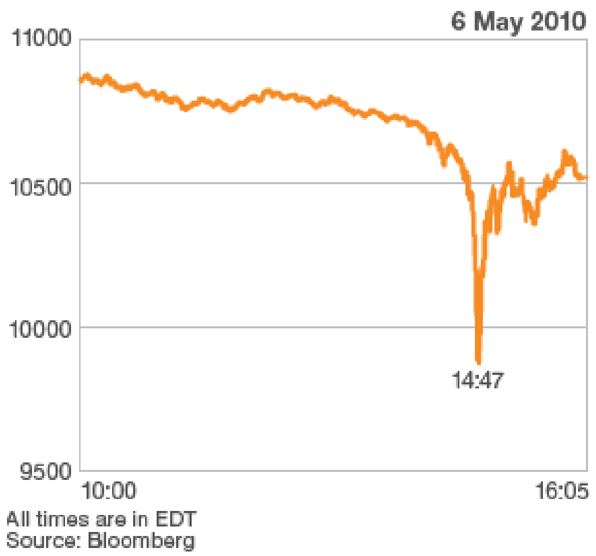
This Manifesto will draw extensively on Meadow's work (particularly her book "Thinking in Systems")[1] to set out the fundamentals of systems and their leverage points.

What follows in this section at first sight appears abstract. However consider the fact that on 6 May 2010 'The Flash Crash' wiped nearly $1,000bn off the value of US shares for a period of several minutes. Had the losses not been recovered, the Dow would have suffered one of its biggest one-day falls in history.

And that the UK government's subsequent investigation into the 'High Frequency Trading' system that caused this behaviour has recently discovered that:

> *"... in specific circumstances, a key type of mechanism can lead to significant instability in financial markets with computer based trading (CBT): self-reinforcing feedback loops (the effect of a small change looping back on itself and triggering a bigger change, which again loops back and so on) within well-intentioned management and control processes can amplify internal risks and lead to undesired interactions and outcomes.*

The Dow Jones' 15-minute crash



All times are in EDT
Source: Bloomberg

> *"The feedback loops can involve risk-management systems, and can be driven by changes in market volume or volatility, by market news, and by delays in distributing reference data."*[2]

This is the language of Systems Dynamics - one of 'feedback loops' and 'delays'.

Equipped with the 'lense' afforded by this discipline Meadows foresaw this result already back in the early 1990s stating that:

> *"...the great push to reduce information and money-transfer delays in financial markets is just asking for wild gyrations."*[3]

She observed that:

> *"The industrial society is just beginning to have and use words for systems, because it is only beginning to pay attention to and use complexity".*[4]

A fact brought home by the September 2011 edition of the Harvard Business Review whose cover story headlined with, "Embracing Complexity - You Can't Avoid It, But Your Business Can Profit From It".

Think of 'systemic risk', a term that policy-makers are just starting to grapple with as they seek to tackle the financial crisis.

To properly understand complex systems we need to look at them through the Systems Dynamics lense.

THE BASICS

With this said and using Meadows explanation (see her paper "Leverage Points - Places to Intervene in a System")[5] let us start with the basic diagram on the next page:

> *"The 'state of the system' is whatever standing 'stock' is of importance: amount of water behind the dam, amount of harvestable wood in a forest, number of people in the population, amount of money in the bank, whatever. System states are usually physical stocks, but they could be nonmaterial ones as well: self-confidence, degree of trust in public officials, perceived safety of a neighbourhood.*

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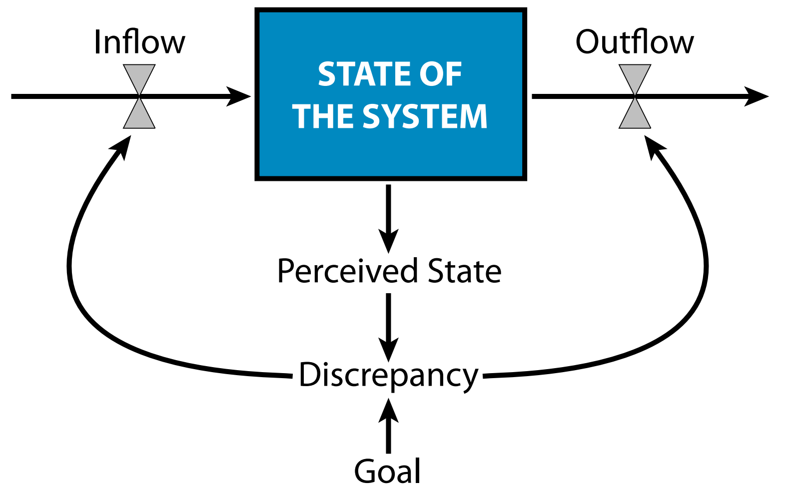
FIGURE 2 - THE IMPACT OF THE 6 MAY 2010 FLASH CRASH ON THE DOW
'Not understanding complexity and 'systems dynamics' can have potentially serious consequences'
Source: Bloomberg

FIGURE 3 - HARVARD BUSINESS REVIEW - EMBRACING COMPLEXITY
'We are just starting to wake up and pay attention to complexity and systems dynamics'
Source: Harvard Business Review

FIGURE 4 - THE FUNDAMENTALS OF A SYSTEM
'Systems consist of stocks, flows, feedback loops and goals'
Source: Adapted from "Leverage Points - Places to Intervene in a System" by Donella Meadows



"There are usually 'inflows' that increase the stock and 'outflows' that decrease it. Deposits increase the money in the bank; withdrawals decrease it. River inflow and rain raise the water behind the dam; evaporation and discharge through spillway lower it. Births and immigrations increase the population, deaths and emmigration reduce it. Political corruption decreases trust in public officials; experience of well functioning government increases it.

"In sofar as this part of the system consists of physical stocks and flows - and they are bedrock of any system - it obeys the laws of conservation and accumulation. You can understand its dynamics readily, if you can understand a bathtub with some water in it (the stock, the state of the system) and an inflowing tap and outflowing drain. If the inflow rate is higher than the outflow rate, the water gradually rises. If the outflow rate is higher than the inflow, the water gradually goes down. The sluggish response of the water level to what could be sudden twists in input and output valves is typical; it takes time for flows of water to accumulate in stocks, just as it take time for water to fill up or drain out of the tub. Policy changes take time to accumulate their effects.

"The rest of diagram shows the information that causes the flows to change, which then cause the stock to change. If you're about to take a bath, you have a desired water level in mind (your goal). You plug the drain, turn on the faucet, and watch until the water rises to your chosen level (until the discrepancy between the goal and the perceived state is zero). Then you turn the water off.

"If you start to get into the bath and discover that you've underestimated your volume and are about to produce an overflow, you can open the drain for awhile, until the water goes down to the desired level.

"Those are two negative feedback loops, or correcting ["balancing"] loops, one controlling the inflow, one controlling the outflow, either or both of which you can use to bring the water level to your goal.

"... Very simple so far. Now let's take into account that you have two taps, a hot and a cold, and that you're also adjusting for another system state: temperature. Suppose the hot inflow is connected to a boiler way down in the basement, four floors below, so it doesn't respond quickly. And you're making faces in the mirror and not paying close attention to the water level. The system begins to get complex, and realistic, and interesting."

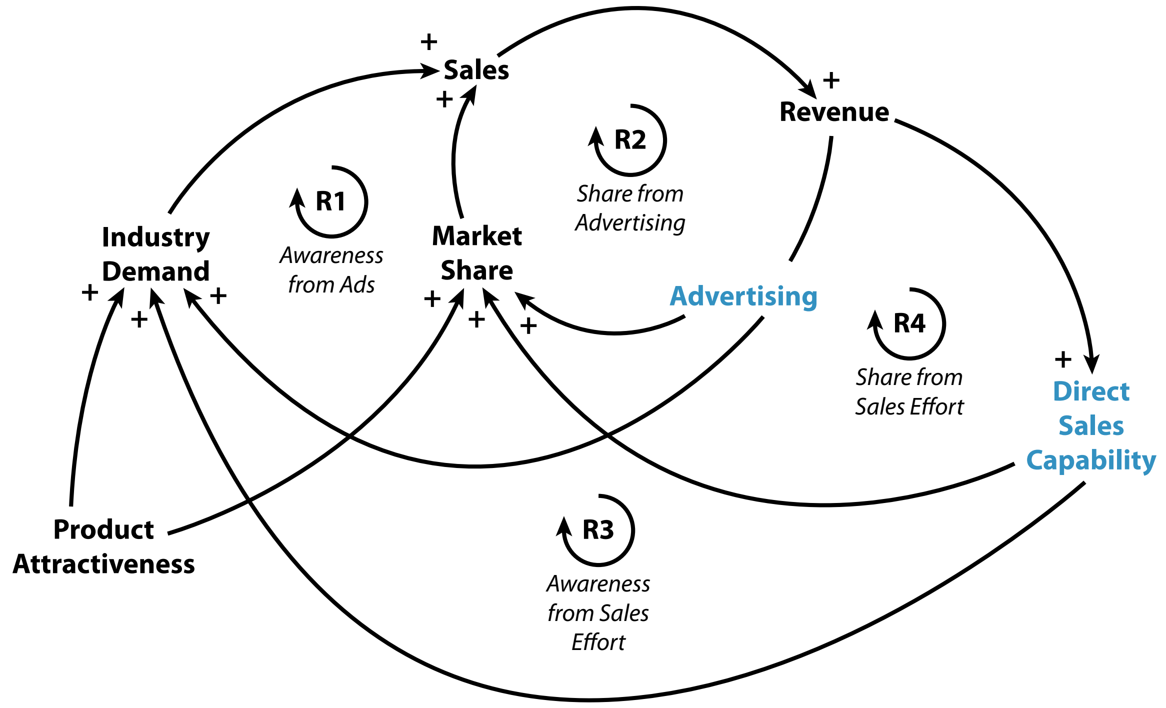
There is also a second type of feedback loop, namely a positive or 'reinforcing' one. These are self-enhancing, leading to exponential growth or to runaway collapses over time - a snowballing avalanch effect. Think of the escalating noise when a microphone comes too close to a loudspeaker.

Example of the Product Awareness System

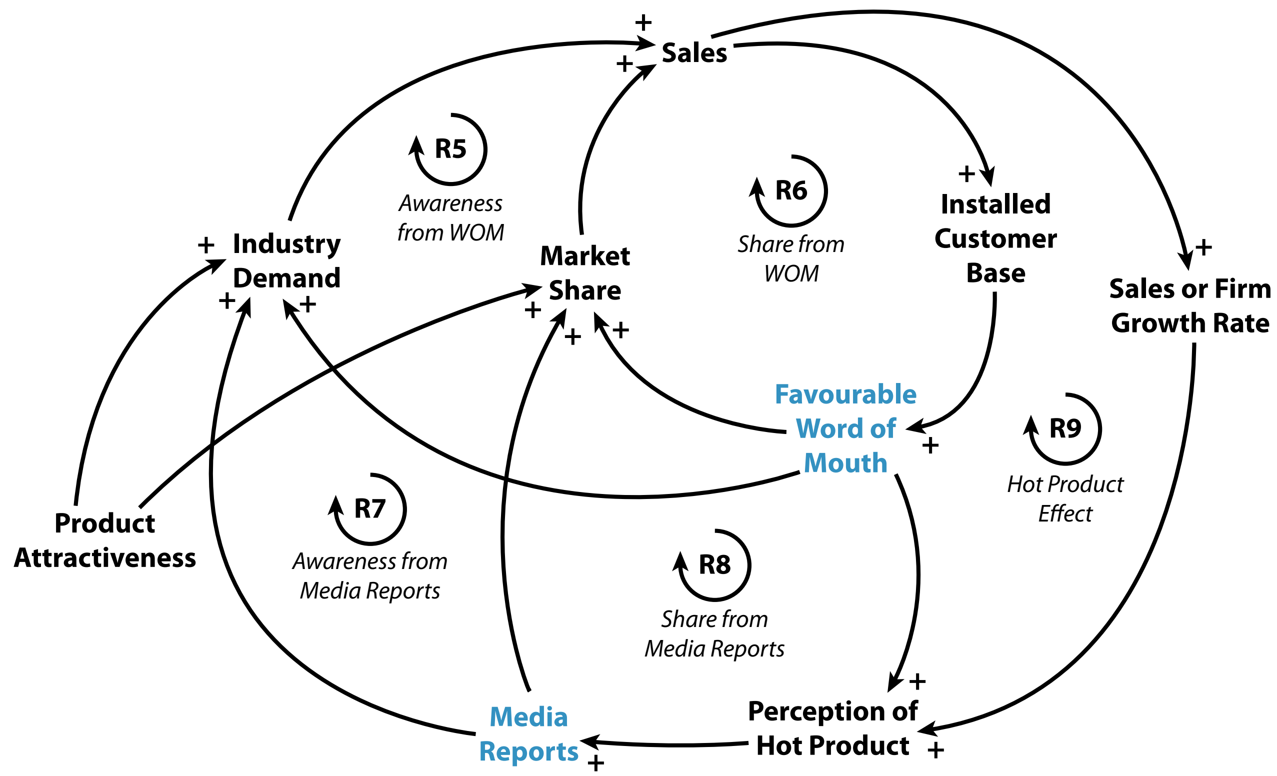
Donella Meadows' explanation gives us a clear picture of the basics of a system. Let us now bring these systems concepts more to life. Take the example of how consumers become aware of a seller's products. MIT's Professor John D. Sterman examines this system in his book "Business Dynamics". He reasons:

> *"How do potential customers become aware of a firm's products? There are 4 principal channels: advertising, direct sales effort, word of mouth, and media attention. Each of these channels creates positive feedback [loops].*
>
> *"In most firms their advertising budget ... grows roughly as the company revenue grow. Larger advertising budgets have two effects: (1) more potential consumers are made aware of the item and choose to enter the market (loop R1); (2) to the extent the advertising is effective, more of those who are aware and in the market are likely to buy the product offered by the company (R2). Similarly, the larger the revenue of the firm, the greater the sales budget. The more sales representatives, and the greater their skill and experience, the more calls they can make, the more time they can spend with customers, and the more effective their calls will be, increasing both total industry demand (R3) and the share of total demand won by the firm (R4).*
>
> *"While a firm controls its advertising and sales budgets, word of mouth and media attention are largely outside of their direct control ... As sales boost the installed base and the number of customers who have experience of the product, favourable word of mouth increases awareness, increasing total demand (R5) and also persuading more people to purchase the products of the seller (R6). A hot product or company will also attract media attention, which, if favourable, stimulates additional awareness and boosts market share still more (R7-9)."*[1]

FIGURE 5 (opposite page) - TWO VIEWS OF THE SAME SYSTEM
'One view capturing the advertising & direct sales channels, the other view the favourable word of mouth and media reports channels'
Source: Both figures adapted from "Business Dynamics" by John Sterman



These are two views of the same product awareness system
There are 4 channels to consumers - 'Advertising' & 'Direct Sales Capability' (depicted above)
And 'Favourable Word of Mouth' & 'Media Reports' (shown below)



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Leverage Points in Systems

"Numbers, the size of flows, are dead last on my list of powerful interventions. Diddling with the details, arranging the deck chairs on the Titanic. Probably 90 - no 95, no 99 percent - of our attention goes to parameters, but there's not a lot of leverage in them."[1]

Donella Meadows

Donella Meadows identifies 12 places to intervene in a system.[2] In increasing order of effectiveness they are:

(1) **NUMBERS:** Constants and parameters such as subsidies, taxes and standards

(2) **BUFFERS:** The size of stabilizing stocks relative to their flows

(3) **STOCK AND FLOW STRUCTURES:** Physical systems and their nodes of intersection

(4) **DELAYS:** The length of time relative to the rate of system changes

(5) **BALANCING FEEDBACK LOOPS:** The strength of the feedbacks relative to the impacts they are trying to correct

(6) **REINFORCING FEEDBACK LOOPS:** The strength of the gain of driving loops

(7) **INFORMATION FLOWS:** The structure of who does and does not have access to information

(8) **RULES:** Incentives, punishments, constraints

(9) **SELF ORGANIZATION:** The power to add, change or evolve system structure

(10) **GOALS:** The purpose of the system

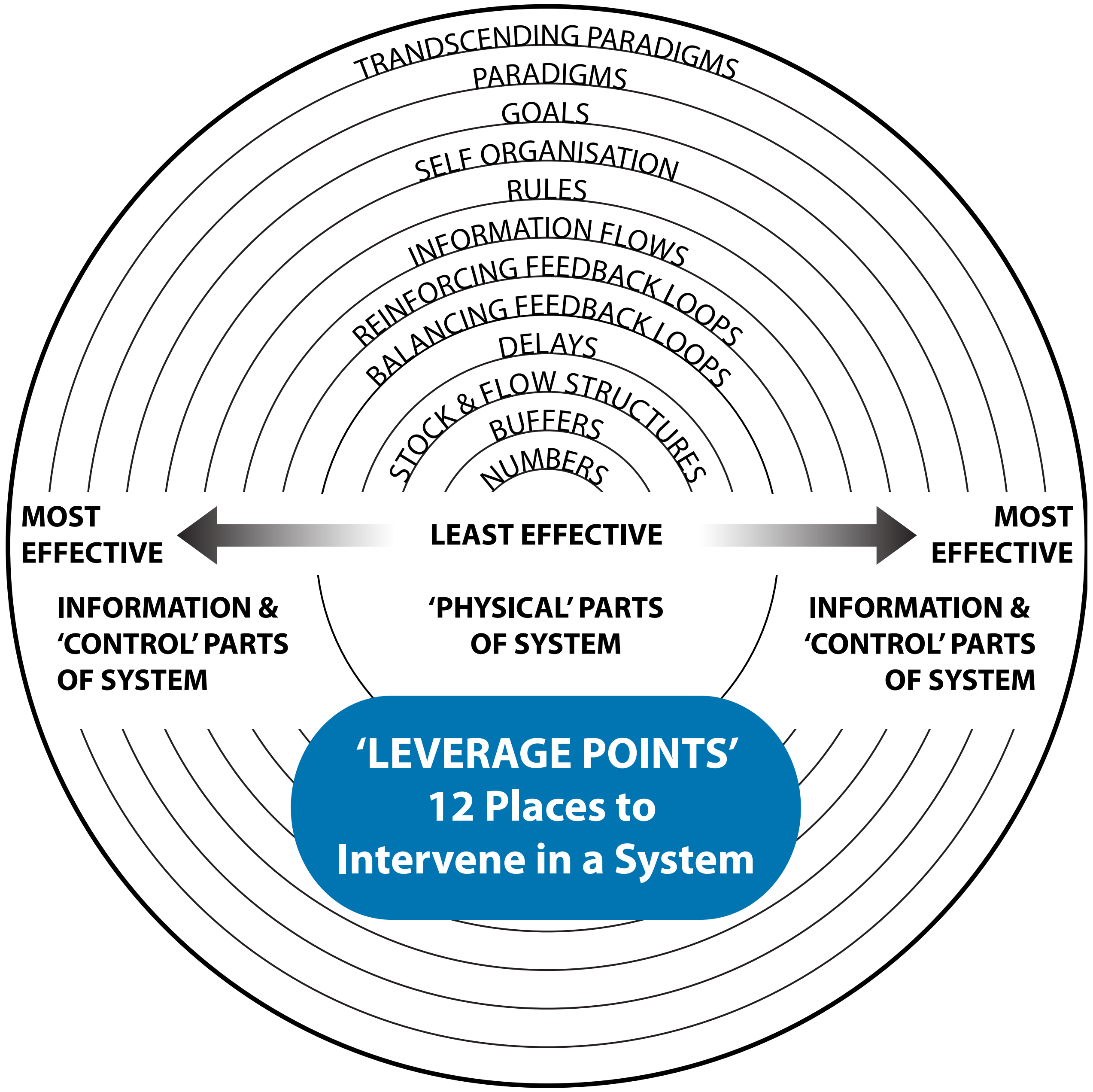
(11) **PARADIGMS:** The mindset out of which the system – its goals, structures, rules, delays, parameters – arises

(12) **TRANDSCENDING PARADIGMS:** The ability to get at a 'gut' level that no paradigm is 'true' – that every one of these paradigms is a tremendously limited understanding of reality

Figure 6 illustrates the hierarchical nature of these leverage points. How changing an outer leverage point - one higher in the list - can condition all those within it.

FIGURE 6 - TWELVE LEVERAGE POINTS IN SYSTEMS IN ORDER OF EFFECTIVENESS
"'Paradigms' are the most effective, 'buffers" and 'numbers' the least"

Source: Carré & Strauss drawn up from "Thinking in Systems" by Donella Meadows



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> *"The test of a first class mind is the ability to hold two opposing views in the head at the same time and still retain the ability to function."*
>
> F. Scott Fitzgerald on paradigms

Meadows states that:

> *"Paradigms are the sources of systems. From them, from shared social agreements about the nature of reality, come system goals and information flows, feedbacks, stocks, flows, and everything else about systems."*[3]

Change the paradigm - the mindset from which the system emanates - and everything else changes.

Meadows observes that the higher the leverage point, the more the system will resist changing it.

She is also careful to caveat this list noting that it is tentative and that there are exceptions to every item that can move it up or down in order of leverage:

> *"I offer this list to you with much humility and wanting to leave room for its evolution... [it is] distilled from decades of rigorous analysis of many different kinds of systems done by many smart people. But complex systems are, well complex. It's dangerous to generalize about them. What you read here is still work in progress; it's not a recipe for finding leverage points. Rather, it's an invitation to think more broadly about system change."*[4]

Elaborating on this she continues:

> *"I have come up with no quick or easy formulas for finding leverage points in complex and dynamic systems. Give me a few months or years and I'll figure it out. And I know from bitter experience that, because they are so counterintuitive, when I do discover a system's leverage points, hardly anyone will believe me."*[5]

Take the example of famines. Jason Pontin, editor, journalist and publisher at MIT explains:

> *"Until recently, famines were understood to be caused by failures in food supply (and therefore seemed addressable by increasing the size and reliability of the supply, potentially through new agricultural or industrial technologies. But Amartya Sen, a Nobel laureate economist, has shown that famines are political crises that catastrophically affect food distribution. (Sen was influenced by his own experiences. As a child he witnessed the Bengali famine of 1943: three million displaced farmers and poor urban dwellers died unnecessarily when wartime hoarding, price gouging, and the colonial government's price-controlled acquisitions for the British army made food too expensive. Sen demonstrated that food production was actually* ***higher*** *in the famine years.) Technology can improve crop yields or systems for storing and transporting food; better responses by nations and nongovernmental organizations to emerging famines have reduced their number and severity. But famines will still occur because there will always be bad governments."*[6]

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Smarter Intervention in Complex Systems

MANY SYSTEMS ARE "NONLINEAR"

"Why are nonlinear systems so much harder to analyze than linear ones? The essential difference is that linear systems can be broken down into parts. Then each part can be solved separately and finally recombined to get the answer. This idea allows a fantastic simplification of complex problems ... In this sense, a linear system is precisely equal to the sum of its parts. But many things in nature don't act this way. Whenever parts of a system interfere, or cooperate, or compete, there are nonlinear interactions going on. Most of everyday life is nonlinear, and the principle of superposition fails spectacularly."[5]

Steven Strogatz

GETTING TO GRIPS WITH 'COMPLEXITY'

Before employing Meadow's 12 leverage points, we first need to get a better handle on 'complexity'. Only then will we have a better shot at achieving smarter intervention in complex systems.

Meadows draws attention to the fact although people deeply involved in a system often know intuitively where to find leverage points, more often than not they push the change in the wrong direction.

She observes that this is because "complex" systems are inherently unpredictable. 'Nonlinearities' in their architecture can flip them from one mode of behaviour to another. Take as an example, an economic system flipping from boom to bust.

Meadows explains that:

> *"A 'linear' relationship between two elements in a system can be drawn on a graph with a straight line. It's a relationship with constant proportions. If I put 10 pounds of fertilizer on my field, my yield will go up 2 bushels. If I put on 20 pounds, my yield will go up by 4 bushels. If I put on 30 pounds, I'll get an increase in 6 bushels.*
>
> *"A 'nonlinear' relationship is one in which the cause does not produce a proportional effect. The relationship between cause and effect can only be drawn with curves and wiggles, not with a straight line. If I put 100 pounds of fertilizer on, my yield will go up by 10 bushels; if I put on 200, my yield will not go up at all; if I put on 300, my yield will go down. Why? I've damaged my soil with 'too much of a good thing'."*[1]

Meadows also provides the example of traffic flows:

> *"As the flow of traffic on a highway increases, car speed is affected only slightly over a large range of car density. Eventually, however, small further increases in density produce a rapid drop-off in speed. And when the number of cars on the highway builds up to a certain point, it can result in a traffic jam, and car speed drops to zero."*[2]

Software can behave in complex nonlinear ways. It is made up of lots of different 'if-then-else' branches in the code and feedback loops. As stocks of data are processed changing combinations of these branches and feedback loops come to dominate the system at different moments. This can lead to unpredictable results. That is why even after exhaustive testing software for any significant undertaking is never entirely bug free.

A good illustration of nonlinearity is the 'Logistic Map' - one of the most famous equations in the science of dynamical systems.[3]

The equation states that:

$$x_t+1=Rx_t(1-x_t)$$

The specifics of the equation are unimportant. What matters is that the components of the equation (x, 1, R, etc.) are readily comprehensible, but the resulting behaviour of the equation is not. It produces erratic, chaotic and unpredictable behaviour - see Figure 7.

Put differently, the system's behaviour is greater than the sum of its parts - it is 'emergent'. To date no comprehensive explanatory theory for complex systems exists.

Melanie Mitchell, Professor of Computer Science at Portland State University, explains:

> *"The mathematician Steven Strogatz has termed this goal the quest for a "calculus of complexity". The analogy is apt in some ways: Newton, Liebniz and others were searching for a general theory of motion that could explain and predict the dynamics of any object or group of objects subject to physical force, whether it be earthly or celestial. Before Newton's time, there were individual pieces of such a theory (e.g. the notions of 'infinitesimal', 'derivative', 'integral', etc. existed) but no one had figured out how all these pieces fit together to produce a completely general theory that explained a huge range of phenomena that were previously not unified. Similarly, today, we have many different pieces of theory related to complex systems, but no one has yet determined how to put them all together to create something more general and unifying."*[4]

Nevertheless, this has not prevented Strogatz from offering up a top-level framework for classifying systems on the basis of their dynamics - see Figure 8.

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"You think that because you understand 'one' that you must therefore understand 'two' because one and one makes two. But you forget that you must also understand 'and'"[6]

Meadows recounting
a Sufi teaching story

A NEW INTERVENTION "MINDSET"

In the absence of a 'calculus of complexity' enabling us to perfectly 'predict-and-control' reality we need some other mechanism for effectively deploying Meadows' twelve leverage points in a complex nonlinear systems environment - for using her 'heuristics' (i.e. 'rules of thumb') as a point of departure for systems intervention.

Tim Harford offers some insights in his book "Adapt - Why Success Always Starts With Failure".

He sets out three 'Palchinsky principles',[7] named after the Russian engineer who formulated them:

(1) **VARIATION:** Seek out new ideas and try new things

(2) **SURVIVABILITY:** When trying something new, do it on a scale where failure is survivable

(3) **SELECTION:** Seek out feedback and learn from your mistakes as you go along

There is an important role for prediction in this approach - some 'attempt at foresight' - but with Meadows major caveat that:[8]

(A) **MODELS:** All our predictions are "models" of the world. None of these models is the real world.

(B) **CONGRUENCE:** Our models may well have a strong congruence with the world and often do.

(C) **LIMITATIONS:** However conversely our models also fall short of representing the world fully.

This led statistician George Box to proclaim 30 years ago:

"All models are wrong, but some are useful"[9]

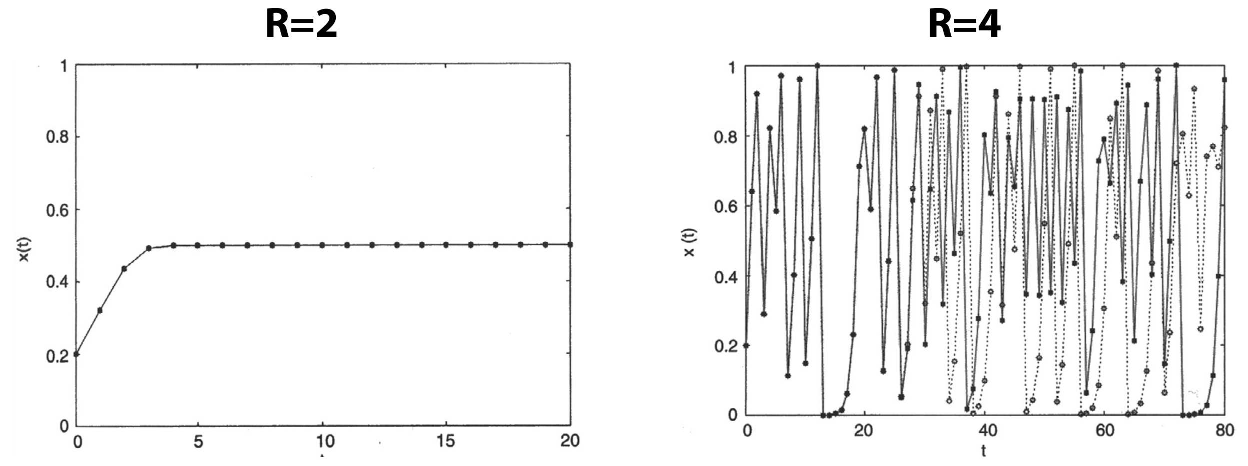
It is when we couple 'prediction' with the illusion of perfect 'control' - that they are reality - that we run into problems.

As Meadows puts it:

"Systems can't be controlled, but they can be designed and redesigned. We can't surge forward with certainty into a world of no surprises, but we can expect surprises and learn from them and even profit from them. We can't impose our will on a system. We can listen to what the system tells us, and discover how its properties and our values can work together to bring forth something much better than can ever be produced by our will alone."[10]

FIGURE 7 - THE LOGISTIC MAP
"An illustration of how complex nonlinear behaviour can result from a very simple starting point"

Source: Melanie Mitchell, "Complexity"



Melanie Mitchell elaborates on the 'complex nonlinear behaviour' of 'The Logistic Map':

"The logistic map is an extremely simple equation and is completely deterministic: every xt maps onto one and only one value of xt+1. And yet the chaotic trajectories obtained from this map, at certain values of R, look very random - enough so that the logistic map has been used as a basis for generating pseudo-random numbers on a computer. Thus apparent randomness can arise from very simple deterministic systems."[11]

It is a simple illustration of how 'complex' systems confound our expectations about the relationship between action and response - between input and output / cause and effect.

Change the value of 'R' in the logistic map from '2' to '4' and the system's behaviour changes radically - it flips to a new behavioural pattern (in fact this happens somewhere between R=3.4 and R=3.5). This system is complex, nonlinear, unpredictable.

A fuller simulation of its dynamics can be viewed at:

http://en.wikipedia.org/wiki/Logistic_map

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FIGURE 8 - A FRAMEWORK FOR CLASSIFYING SYSTEMS
'One axis tells us the number of variables needed to characterize the state of the system. The other axis tells us whether the system is linear or nonlinear.'

Source: Steven H. Strogatz, "Nonlinear Dynamics and Chaos"

Steven Strogatz proposes a framework for classifying systems:

> *"Admittedly, some aspects of the picture are debatable. You might think that some topics should be added, or placed differently, or even that more axes are needed - the point is to think about classifying systems on the basis of their dynamics.*
>
> *... You'll notice that the framework also contains a region forbiddingly marked 'The frontier'. It's like in those old maps of the world, where the mapmakers wrote ,'Here be dragons' on the unexplored parts of the globe. These topics are not completely unexplored of course, but it is fair to say that they lie at the limits of current understanding. The problems are very hard, because they are both large and nonlinear. The resulting behaviour is typically complicated in **both space and time**, as in the motion of a turbulent fluid or the patterns of electrical activity in a fibrillating heart."*[12]

Note that systems such as 'economics' and 'ecosystems' fall beyond this frontier.

Number of variables →

← Nonlinearity

	n = 1	n = 2	n ≥ 3	n >> 1	Continuum
Linear	***Growth, decay, or equilibrium*** Exponential growth RC circuit Radioactive decay	***Oscillations*** Linear oscillator Mass and spring RLC circuit 2-body problem (Kepler, Newton)	Civil engineering, structures Electrical engineering	***Collective phenomena*** Coupled harmonic oscillators Solid-state physics Molecular dynamics Equilibrium statistical mechanics	***Waves and patterns*** Elasticity Wave equations Electromagnetism (Maxwell) Quantum mechanics (Schödinger, Heisenberg, Dirac) Heat and diffusion Acoustics Viscous fluids
Nonlinear	Fixed points Bifurcations Overdamped systems, relaxational dynamics Logistic equation for single species	Pendulum Anharmonic oscillators Limit cycles Biological oscillators (neurons, heart cells) Predator-prey cycles Nonlinear electronics (van der Pol, Josephson)	***Chaos*** Strange attractors (Lorenz) 3-body problem (Poincaré) Chemical kinetics Iterated maps (Feigenbaum) Fractals (Mandelbrot) Forced nonlinear oscillators (Levinson, Smale) Practical uses of chaos Quantum chaos ?	**The frontier** Coupled nonlinear oscillators Lasers, nonlinear optics Nonequilibrium statistical mechanics Nonlinear solid-state physics (semiconductors) Josephson arrays Heart cell synchronization Neural networks Immune system Ecosystems Economics	***Spatio-temporal complexity*** Nonlinear waves (shocks, solitons) Plasmas Earthquakes General relativity (Einstein) Quantum field theory Reaction-diffusion, biological and chemical waves Fibrillation Epilepsy Turbulent fluids (Navier-Stokes) Life

> *"I can live with doubt, and uncertainty, and not knowing. I think it's much more interesting to live not knowing than to have answers which might be wrong."*
>
> Richard Feynman

In other words, we need to embrace a far more 'iterative' approach to problem solving if we are to learn to 'dance' with increasingly complex systems in the 21^{st} Century.

This means taking small steps, predicting, but monitoring reality constantly and being willing to change the course as we find out more about where it is leading.

We have to abandon the illusion of 'predict-and-control' and adopt a new 'trial-and-error' approach.

It is a different approach to problem solving.

Meadows again:

> *"The trick, as with all the behavioural possibilities of complex systems, is to recognize what structures contain which latent behaviors, and what conditions release those behaviors - and, where possible, to arrange the structure and conditions to reduce the probability of destructive behaviors and to encourage the possibility of beneficial ones."*[13]

In other words, try to coax the system into providing the solution - try to 'evolve' the solution, not 'determine' it.

Frame the question. Provide the right tools for it to yield the answer. Try to release beneficial system behaviours. Correctly structured, a system will arrive at the solution.

Put simply, we need a fundamentally new paradigm for problem solving. We need to adopt a new 'Complex Systems' mindset based on three tenets:

(1) **EMBRACE UNCERTAINTY**

(2) **USE 'TRIAL-AND-ERROR'**

(3) **PROVIDE TOOLS**

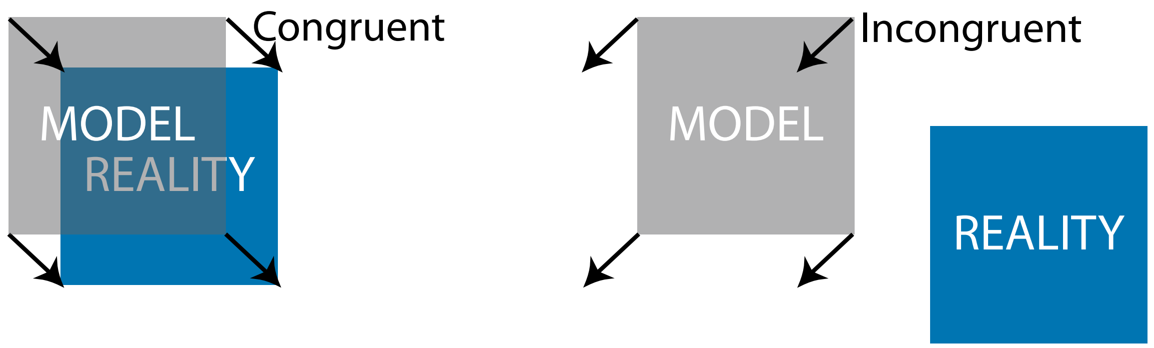
Recall that changing the 'paradigm' is the second most effective place to intervene in a system - point eleven in Meadows' twelve point list. For this is the mindset out of which the entire system arises and the basis for regulating it.

It has concrete implications. For example, individuals and organisations are held liable in courts of law for system behaviours based on the presumption that they can 'predict-and-control' these complex nonlinear systems. This can result in multi-million euro fines for those accused and found guilty. Think of the litigation surrounding counterfeit items.

Similarly, Information Society Service Providers (ISSPs) may use probabilistic techniques, such as 'rankings', to try and help consumers with foresight in a complex retail environment. They are not providing assurances that these are perfect predictions. Yet we are seeing lawsuits against ISSPs based on claims to the latter.

FIGURE 9 - UNDERSTANDING MODELS
'Models often have a strong congruence with reality but not always'

Source: Carré & Strauss drawn up from "Thinking in Systems" by Donella Meadows[14]



Everything we think we know about the world is a model. Our models have a strong congruence with the world.

... BUT NOT ALWAYS which is why we encounter surprises. For our models fall far short of representing the real world fully. Think of the recent failure to understand 'risk modeling' in finance.

Author Robert Pirsig captures the importance of prevailing paradigms when he states:

> *"If a factory is torn down but the rationality which produced it is left standing, then that rationality will simply produce another factory. If a revolution destroys a government, but the systematic patterns of thought that produced that government are left intact, then those patterns of thought will repeat themselves... There's so much talk about the system. And so little understanding."*[15]

The longer we cling to a 19^{th} Century reductionist view of a clockwork Newtonian universe that is ticking along a perfectly predictable path, the more

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trouble we are going to get into - be that in our environmental, economic, political and social systems or our system of globalisation.

Disciplines such as physics have already had to undergo this change in mindset - albeit that they began 100 years ago.

It was in Parc Leopold adjacent to the European Parliament that Einstein and Bohr debated this change in mindset at the famous Solvay Physics Conference of 1927.

Playing out at the beginning of the 20th Century and known as the 'Einstein-Bohr debates', the arguments centred over whether the universe evolves in an arbitrary or deterministic way.

Einstein argued that *"God does not play dice"*, Bohr the opposite, on one occassion answering, *"Einstein, stop telling God what to do"*.

Today's prevailing scientific consensus is that 'God' (i.e. nature) does play dice - perfect prediction *à la* Laplace is impossible.

And they act in this knowledge daily.

Chris Pollard, Member of the Royal College of Veterinary Surgeons, cites the example of administering anaesthetics:

> *"With anaesthetic drugs we know what they can do, what side effects they may have in certain situations, which situations they may be most effective in. However, for the most part, the most elusive element is determining exactly how they really work. We do not control the physiological system. We do not dictate what happens. We try to dance with the system. We add inputs to the system. We monitor. We make adjustments. But we do not have the final say over what happens. It's a nonlinear way of dealing with the system. Not a linear one. I can look at two identical cases. Treat them exactly the same and have two different results."*[16]

This approach fits with Strogatz's framework for classifying systems. Recall that he places 'life' beyond the 'frontier' of current understanding in figure 8.

Indeed the entire modern 'scientific method' is a constant process of falsification - of 'trial-and-error'.

The social sciences mindset needs to catch up with the natural sciences mindset.

It is a case of C.P. Snow's 'Two Cultures'. In his book "The Two Cultures and the Scientific Revolution", Snow contends that the breakdown of communication between the 'Two Cultures' of modern society – the sciences and the humanities – is a major hindrance to solving the world's problems.

As Meadows puts it, our challenge is one of:

> *"Linear minds in a nonlinear world"*[17]

FIGURE 10 - A CENTURY AGO PHYSICISTS WERE ALREADY CHANGING THEIR MINDSET
'The prevailing scientific consensus is that perfect prediction turns out to be impossible'

Source: Institut International de Physique de Solvay, Parc Leopold

Note:

1) For those interested, the physicist Stephen Hawking expands on the debate at:

http://www.hawking.org.uk/index.php/lectures/64

2) The picture above was taken on the steps of what is today the Lycée Emile Jacqmain in Parc Leopold, Brussels

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A NEW INTERVENTION 'MECHANISM'

How then do interventionists put this new 'Complex Systems' mindset into concrete action in a system?

Here it is instructive to draw on the work of John Boyd, a military strategist, US Airforce fighter pilot and Colonel. Boyd helped design and champion the F-16 fighter jet.

He formulated the 'OODA Loop'[18] to enable fighter pilots to quickly assess and adapt to complex and rapidly changing environments - ones that cannot be controlled. In which poor decision-making can be a matter of life and death. Today the loop is written into US Air Force doctrine.

Taken at its simplest level, Boyd contends that to prevail up in the air a fighter pilot needs to be more effective than his opponent at continually cycling through four processes:

(1) **OBSERVE:** Gather sensory inputs from the environment - 'monitor' and 'intelligence gather'.

"Radio chatter informs me that there is an unidentified aircraft in my airspace."

(2) **ORIENT:** Make sense of this observational data by creating a mental picture - a 'model' - of the situational reality.

"....The aircraft is not yet in range but it would already be useful to try to predict the likely identity of the pilot, his nationality, level of training, etc.

... Now that the aircraft is in radar contact the speed, size, and manoeuvrability of the enemy plane has become available. I have some real information to go on and unfolding circumstances can take priority over my earlier predictions.

... The aircraft's intentions appear hostile."

(3) **DECIDE:** Use this new 'knowledge' as the basis for decisions.

"... Time for evasive action.

... I am going to get into the sun so that my opponent cannot get a clear visual on me."

(4) **ACT:** Translate this into action.

"... Pull back on the joystick and let my aircraft climb."

Back to the process of 'observation':

"Is the other plane reacting to my change of altitude?"

Then to 'orient':

"Is he reacting characteristically - predictably - or perhaps instead acting like a noncombatant?

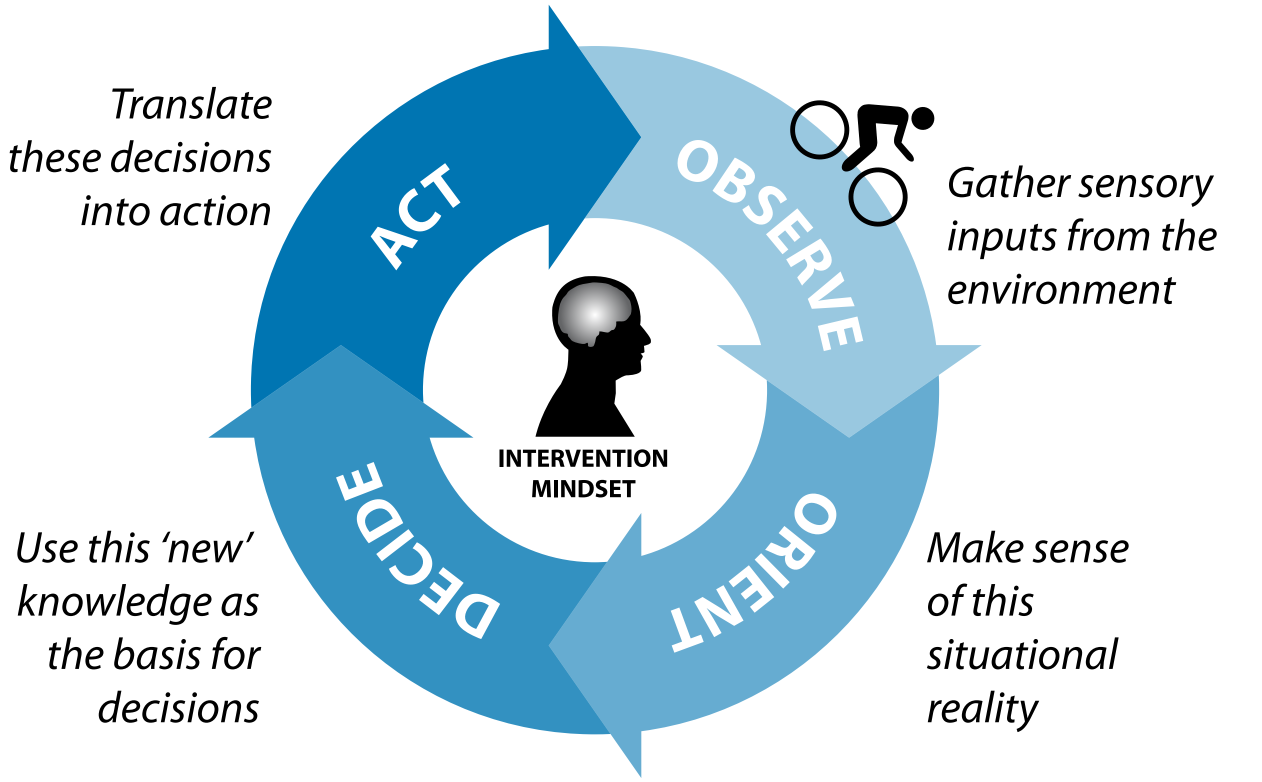
Is his plane exhibiting better-than-expected performance?

Do I need to revisit my assumptions?

Are they congruent with the complex reality that I am observing?"

FIGURE 11 - CYCLE THE "OODA LOOP"
'A practical intervention mechanism for complex nonlinear systems'

Source: Carré & Strauss expanding on John Boyd's concept of the OODA Loop



And so the cycle continues.

We find similar decision making loops in other disciplines. For example, the 'Sense-Model-Plan-Act' Loop in the field of Artificial Intelligence.

Indeed in software development it is akin to 'Agile Programming'. Agile Programming is a methodology for quickly and effectively cycling through software development. It supersedes an earlier linear design approach called the 'Waterfall Model'.

Importantly the 3 Palchinsky Principles of 'Variation', 'Survivability' and 'Selection' can

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FIGURE 12 (opposite page) - THE SIMPLIFIED 'INTERVENTION MIX' IN 2D
'Interaction can emanate from average people, experts or computers and can be configured in different forms, either in the form of individuals or of wisdom of crowds'

Source: Carré & Strauss - the human decision making components of this diagram are assembled principally from Len Fisher's explanation in "The Perfect Swarm"[19]

be integrated into the OODA Loop.

As we cycle through the loop we can seek out new ideas and try new things (Variation).

Providing we cycle through the loop iteratively, then when we do attempt something new we can act on a scale where failure is survivable (Survivability).

And as we act the OODA Loop is designed to seek out feedback and learn from our mistakes as we go along (Selection).

In other words the OODA Loop is a practical 'trial-and-error' mechanism for dancing with a complex systems.

Therefore if we wish to optimise systems intervention in for example, the consumption system, we need to know how to cycle most effectively through the OODA Loop.

'INTERVENTION AGENTS' & 'THE INTERVENTION MIX'

To successfully address this question we need to examine the strengths and weaknesses of those that have the potential to cycle through the loop, namely the 'Intervention Agents'. Then we can decide 'who' should intervene.

Should individuals be the interventionist?

The 'wisdom of the crowd'?

Experts or non-experts?

Computer algorithms?

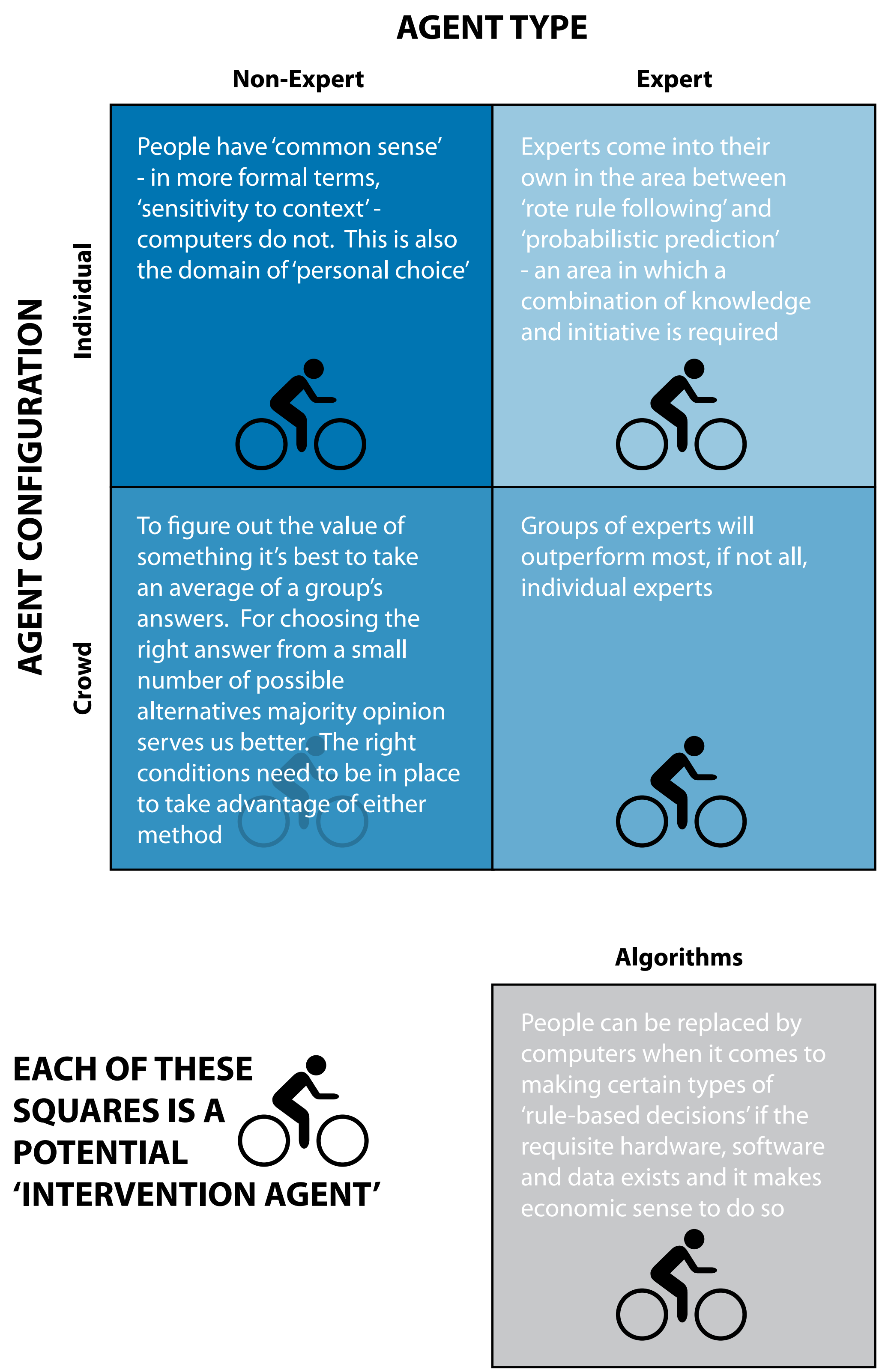
A combination of all the above - an 'Intervention Mix'?

In fact we live with intervention mixes everyday. Think of when you apply the brakes whilst driving your car. It is your foot pressing the brake pedal, but it is also the car's anti-lock braking system at work - a computer. It is the combination of these two agents that brings a fast moving car to a smooth stop at the traffic lights. A mix of man and machine.

Again these are not abstract issues.

At this very moment we are trying to determine how far we can automate High Frequency Trading? Can we leave the software algorithms to their own devices or do we need human intervention to avoid events such as the May2010 Flash Crash?

Similarly a debate ensues over whether



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PAGE'S THEOREM ON 'STATE ESTIMATION'

collective error = average individual error - prediction diversity

"The calculations are slightly tricky because statisticians use squared values of errors. But the message is simple ... the theorem shows that our collective error as a group has to be smaller than our average individual error because of the diversity of answers. The crowd performs better than most of the people in it."[20]

Len Fisher, "The Perfect Swarm"

CONDORCET'S JURY THEOREM ON MAJORITY OPINION

"The theorem in its simplest form says that if each member of a group has a better than 50:50 chance of getting the right answer to a question that has just two possible answers, then the chance of a majority verdict being correct rapidly becomes closer to 100 percent as the size of the group increases. Even if each individual has only a 60 percent chance of being right, the chance of the majority being right goes up to 80 percent for a group of 17 and to 90 percent for a group of forty-five."[22]

Len Fisher, "The Perfect Swarm"

ISSPs can completely automate counterfeit items off of their platforms?

As we will see, no intervention agent is the panacea - expert, 'wisdom of crowds' or computer algorithm. Each has its strengths and weaknesses depending on the specific circumstance. For example, we are all too familiar with the 'madness of crowds' and with 'mob mentality' in certain situations.

THE 'WISDOM OF CROWDS'

What follows on the 'wisdom of crowds' versus that of 'experts' is in large part drawn from the explanation provided by Len Fisher, a Physicist at the University of Bristol, in his book "The Perfect Swarm - The Science of Complexity in Everyday Life".[21]

"For problems that involve figuring out the value of something (like a compass bearing or the classic case of the number of beans in a jar) the best way to tackle the problem is to [employ group decision making and to] take an average of all the answers. Scientists call these 'state estimation' problems. For problems that involve choosing the right answer from among a small number of possible alternatives, a group's majority opinion serves us better. To take the best advantage of either, we need to fulfil just three conditions:

(1) **DIVERSITY:** *"The people in the group must be willing and able to think for themselves and reach diverse, independent conclusions.*

(2) **VERIFICATION:** *"The question must have a definite answer that can ultimately be checked against reality.*

(3) **ALIGNMENT:** *"Everyone in the group must be answering the same question. (This may seem obvious, but it is often possible for people to interpret the same question in very different ways.)*

"When these 3 conditions are fulfilled, the mathematics of complexity leads to three astounding conclusions:

(1) **STATE ESTIMATION:** *"When answering a state estimation question, the group as a whole will always outperform most of its individual members."*[23] University of Michigan complexity theorist, Scott Page, proves this with his theorem that demonstrates that *"our collective error as a group has to be smaller than our average individual error because of the diversity of our answers"*.[24] As Page puts it, *"being different is as important as being good."*[25]

(2) **MAJORITY OPINION:** *"If most of the group members are moderately well-informed about the facts surrounding a question to which there are several possible answers (but only one correct one), the majority opinion is almost always bound to be right. If each member of a group of one hundred people has a 60 percent chance of getting the right answer, for example, then a rigorous mathematical formulation [Condorcet's Jury Theorem] proves that the answer of the majority has a better than 99 percent chance of being the correct one.*

(3) **VALIDITY:** *"Even when only a few people in the group are well-informed, this is usually sufficient for the majority opinion to be the right one."*[26]

'EXPERTS' AND 'GROUPS OF EXPERTS'

Fisher cautions that, *"There is just one caveat, which is to remember that Page's theorem proves only that the group outperforms 'most' of its members when it comes to state estimation problems. It does not necessarily outperform 'all' of them. If there is an identifiable expert in the group, it may be that they will do better than the group average ... That's not to say that experts always do better than the average."*

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FIGURE 13 (opposite page) - THE RISE OF THE MACHINES
'Algorithmic trading has rapidly taken off'

Source: Aite Group diagrams reproduced by The Economist, February 25th 2012

"A collection of experts can also outperform most, if not, all of the individual experts. Page gives the example of a group of football journalists forecasting the top dozen picks in the 2005 NHL draft. Not one of them performed nearly as well as the average of all of them ...

"According to Michael Mauboussin, a Professor of Finance at Columbia Business School, experts come into their own in the area between rote rule following and probabilistic prediction - an area in which a combination of knowledge and initiative is required."[27]

That is why we continue to have experts in policymaking, experts in software development, experts in the enforcement of trademark rights etc.

"When we don't have an expert available, we must fall back on the diversity of the group."[28]

COMPUTERS VERSUS 'COMMON SENSE'

Fisher observes that, *"Experts are also being replaced in many areas by computer algorithms when it comes to making 'rule-based' decisions"*.[29] An algorithm is a series of steps that transforms an input into an output - in other words, a 'definite procedure' or a 'recipe'.[30]

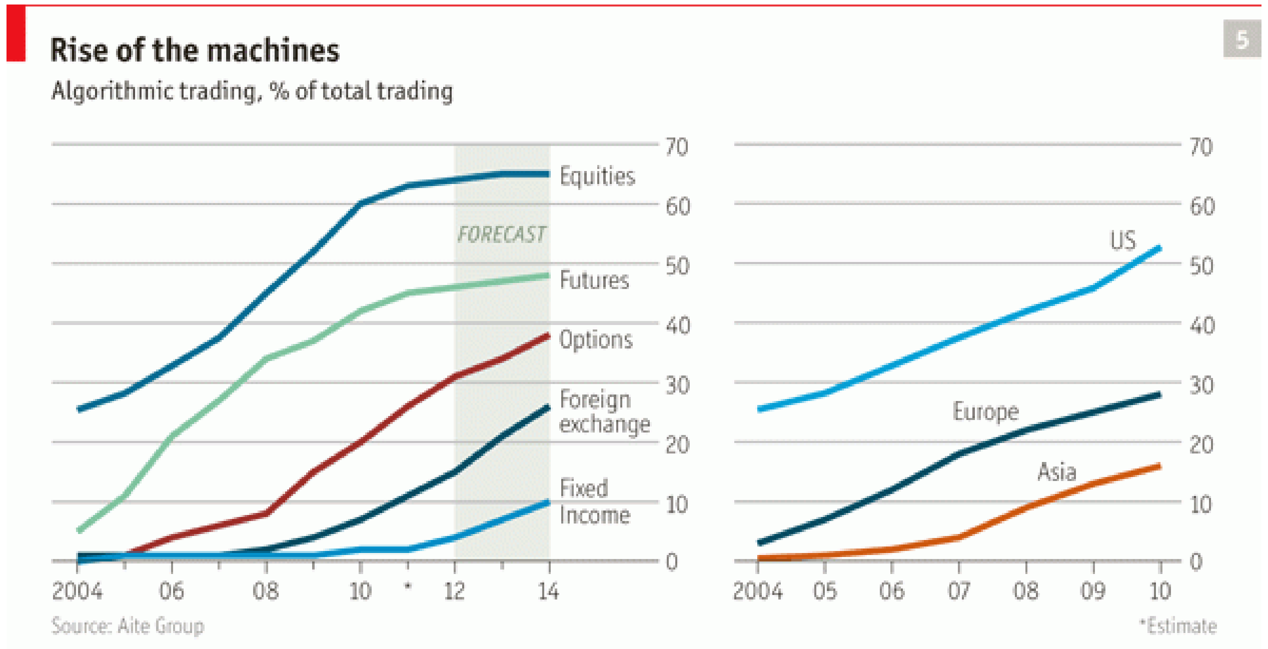
Back to Melanie Mitchell who notes that:

> *"Computer controlled vehicles can now drive by themselves across rugged desert terrain. Computer programs can beat human doctors at diagnosing certain diseases, human mathematicians at solving complex equations, and human grand masters at chess. These are only a few examples of a surge of recent successes in artificial intelligence (AI) that have brought a new sense of optimism in the field."*[31]

But she also draws attention to the fact that despite this optimism we need to remain grounded and not get ahead of ourselves:

> *"There are a few 'human-level' things computers still can't do, such as understand human language, describe the content of a photograph, and more generally use common sense... Marvin Minsky, a founder in the field of artificial intelligence, concisely described this paradox of AI as, 'Easy things are hard.' Computers can do many things that we humans consider to require high level intelligence, but at the same time they are unable to perform tasks that any three-year-old child could do with ease."*[32]

We frequently experience the fact that computers lack 'common sense', or more formally in computer science terms, 'sensitivity to context'.[33]



Duncan Watts, Principal Research Scientist at Yahoo, provides a definition of 'common sense' in his book "Everything Is Obvious* - *Once You Know The Answer":

> *"Roughly speaking, it is the loosely organized set of facts, observations, experiences, insights, and pieces of received wisdom that each of us accumulates over a lifetime, in the course of encountering, dealing with, and learning from, everyday situations."*[34]

He states that:

> *"It is largely for this reason, in fact, that commonsense knowledge has proven so hard to replicate in computers - because, in contrast with theoretical knowledge, it requires a relatively large number of rules to deal with even a small number of special cases."*[35]

Mitchell again:

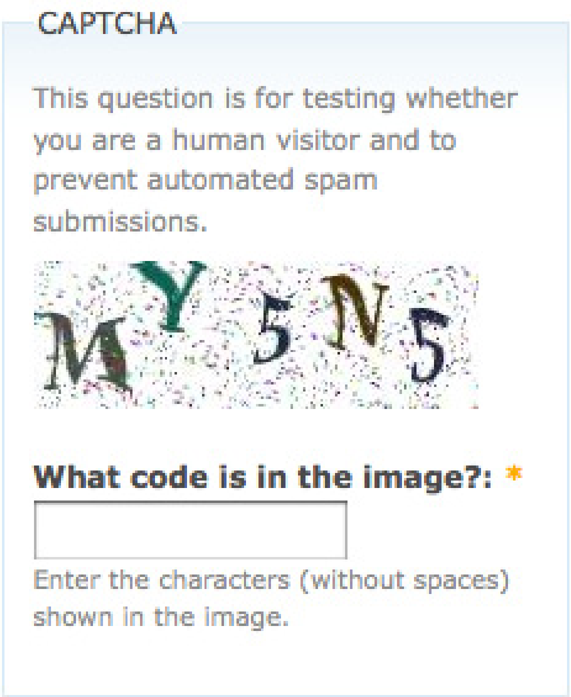
> *"My computer supposedly has a state-of-the-art spam filter, but sometimes it can't figure out that a message with a 'word' such as* **V!a&®@** *is likely to be spam."*[36]

Most people however see V!a&®@ for what it is instantly. That is why most spam filters draw extensively on pooling information feedback from real users. If 1,000 people click on the 'This is Spam' button when they encounter V!a&®@ then the computer can catalogue it as likely to be spam.

FIGURE 14 (below) - THE LIMITS OF COMPUTATION
'Computers are unable to perform some tasks that humans find trivial'

Source: Drupal.org

This lack of sensitivity to context is also the reason why web users are on occasion asked to retype a code - see Figure 14 below. This code cannot be read by a computer because it lacks the common sense - the intuition - to tell that it says **MY5N5**. The aim in this 'CAPTCHA' code example is to prevent automated programmes (i.e. spam in this instance) from requesting access to some piece of information - it is just for human consumption - those "agents" that can discern the text.



It is for this reason, as well as for legal, ethical and moral considerations, that military drones are remote controlled and are not fully autonomous. At least for now humans still make the decision to fire.

Johann Borenstein, head of the Mobile Robotics Lab at the University of Michigan observes that:

> *"Robots don't have common sense and won't have common sense in the next 50 years, or however long one might want to guess."*[37]

Consequently he believes that human skills will remain critical in battle far into the future.

And there are additional limits to computing power, namely:

(1) **THEORETICAL LIMITATIONS:** In the 1930s Kurt Gödel and Alan Turing quashed the hope of the unlimited power of mathematics and computing. Gödel proved that mathematics is either inconsistent or incomplete. Building on this discovery Turing proved that the answer to the *'Entscheidungsproblem'* ('decision problem') is 'no' - i.e. not every mathematical statement has a definite procedure that can decide its truth or falsity. He demonstrated this fact via the *'Halting problem'*. In short, there are certain classes of problem that cannot be computed.[39] Moreover even when problems can be computed it may be very time consuming to do so. For instance, to date no efficient algorithm is known for an important class of problems known as *'NP-complete'*. These search problems include scheduling, map colouring, protein folding, theorem proving, packing, puzzles, the travelling salesman and many more such problems. In fact the Clay Mathematics Institute classifies the NP-complete problem as one of the seven most important questions to be answered this century and is offering $1,000,000 dollars to the first person that does so.

THE 'NP-COMPLETE' PROBLEM

"If it is easy to check that a solution to a problem is correct, is it also easy to solve the problem? This is the essence of the P vs NP question. Typical of the NP problems is that of the Hamiltonian Path Problem: given N cities to visit, how can one do this without visiting a city twice? If you give me a solution, I can easily check that it is correct. But I cannot so easily find a solution."[38]

Clay Mathematics Institute

(2) **HARDWARE AND SOFTWARE LIMITATIONS:** Theoretical limitations aside, there are hardware and software limitations to consider. Yes, computer processing power is increasing exponentially and becoming less and less expensive (a process encapsulated by Moore's Law). However as virtual reality pioneer Jaron Lanier notes in his book "You Are Not A Gadget", *"software development doesn't necessarily speed up in sync with improvements in hardware. It often instead slows down as computers get bigger because there are more opportunities for errors in bigger programs. Development becomes slower and more conservative when there is more at stake, and that is what is happening."*[40]

(3) **DATA LIMITATIONS:** Eric Schmidt, Executive Chairman of Google, points out that, *"From the dawn of civilization until 2003, humankind generated five exabytes of data. Now we produce five exabytes every two days... and the pace is accelerating"*.[41] As a result there is a lot excitement surrounding the promise of what is being termed, 'Big Data' - the ability to cycle the OODA loop in unprecedented ways in almost every walk of life due to advances in technology. Nevertheless there are significant challenges to be addressed, not least those pertaining to privacy. Simon Szykman, Chief Information Officer of the US Commerce Department, has outlined his top nine Big Data challenges.[42] These are: data acquisition; storage; processing; data transport and dissemination; data management and curation; archiving; security; workforce with specialized skills, and; the cost of all of the above.

(4) **ECONOMIC LIMITATIONS:** Sometimes it simply makes no financial sense to try to develop complex software algorithms to solve a problem that a human can solve instantly and effortlessly. Lanier notes that until recently, computers couldn't even recognize a person's smile.[43]

As a result, leading artificial intelligence researchers, such as Professor Hans Moravec from the Robotics Institute at Carnegie Mellon University, acknowledge that *"Computers have far to go to match human strengths"*.[44]

Lanier recalls that *"Before the crash, bankers believed in supposedly intelligent algorithms that could calculate credit risks before making bad loans."*[45]

Indeed Lanier is careful to draw the distinction between ideal and real computers.[46]

Nevertheless this is not to say that "common sense" approaches do not have their own shortcomings.

Watts identifies three limitations in common sense reasoning:[47]

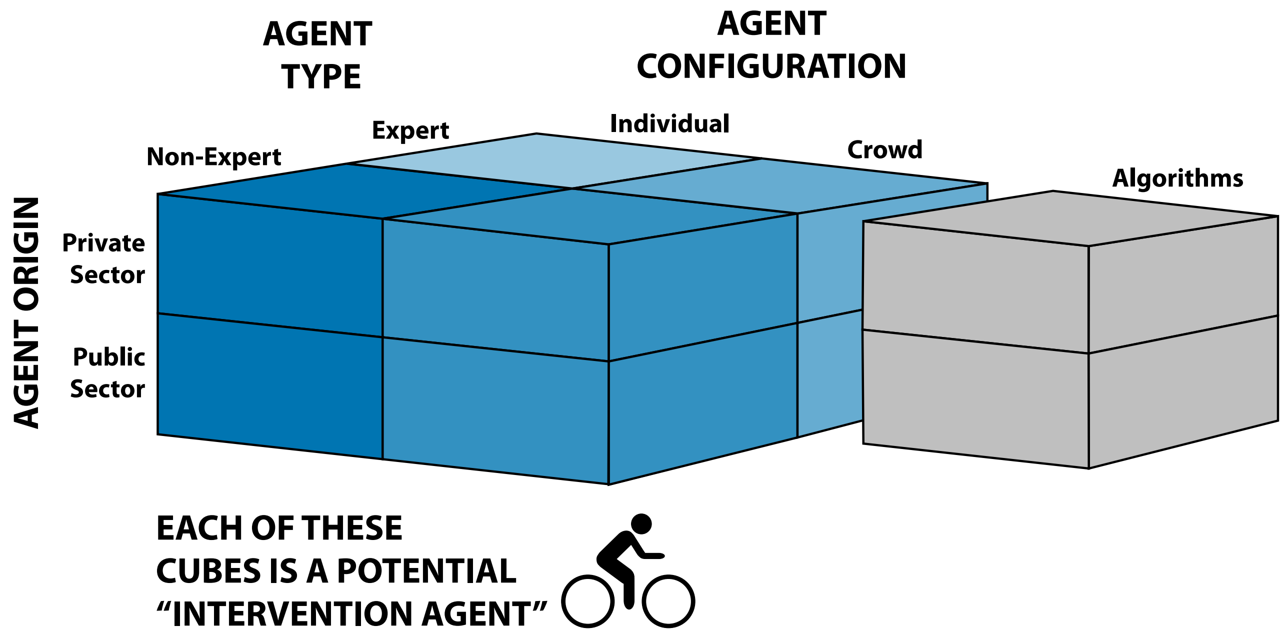
(1) **INDIVIDUAL BEHAVIOUR:** Our mental models systematically fall short of capturing the complexity of what drives individual behaviour.

(2) **COLLECTIVE BEHAVIOUR:** Our mental models of collective behaviour fail to take account of the fact that collective behaviour is greater than the sum of its parts.

(3) **LEARNING FROM HISTORY:** We learn less from the past than we think we do and this misperception in turn skews our perception of the future.

FIGURE 15 - THE FULL 'INTERVENTION MIX' IN 3D
'As well as there being different intervention types and configurations, intervention can also originate from the private and public sectors'

Source: Carré & Strauss



Watts concludes that:[48]

> *"Commonsense reasoning, therefore, does not suffer from a single overriding limitation but rather from a combination of limitations, all of which reinforce and even disguise one another. The net result is that common sense is wonderful at **making sense** of the world, but not necessarily at understanding it."*

PUBLIC VERSUS PRIVATE SECTOR INTERVENTION

We have covered the strengths and weaknesses of the various 'Intervention Agents'. We now need to introduce the third dimension to the 'Intervention Mix', namely the division between public and private sector intervention.

For both sectors can deploy all of these agents. Think of general elections and referendums ('wisdom of crowds'), expert committees and groups of 'wise men' ('groups of experts'), as well as representatives elected to political office (often 'non-experts') and online tax forms or speed cameras ('computer algorithms').

Taken to its logical conclusion we can and should extend this approach to include other sectors, such as civil society (i.e. NGOs, Trade Unions, Think Tanks, Academia, Media, Citizens, etc.). However for the sake of time and simplicity we will stick here to just two sectors.

So can we delineate between whether we need:

(A) Public sector intervention

(B) Private sector intervention

(C) A mix of public and private sector intervention

To even begin to make this call we need to return to the OODA Loop and ask:

> *"Knowing the strengths and weaknesses of the intervention agents that we have at our disposal - the various types and configurations ...*
>
> *And aware that we can deploy either public or private sector intervention or both ...*
>
> *How do we use intervention agents to cycle most effectively through the OODA Loop?"*

And we need to frame this question in the context of a specific issue.

A generic debate over the merits of more or less government intervention - often in the form of regulations, subsidies or fiscal incentives - will serve no purpose.

There is no 'off-the-shelf' answer.

So let us "try" to answer this question when we seek to intervene in a specific system:

> *"How do we use intervention agents to cycle most effectively through the OODA Loop?"*

A NEW "INTERVENTION PRINCIPLE"

And when answering this question let us 'try' to invoke a new 'Intervention Principle' to guide us:

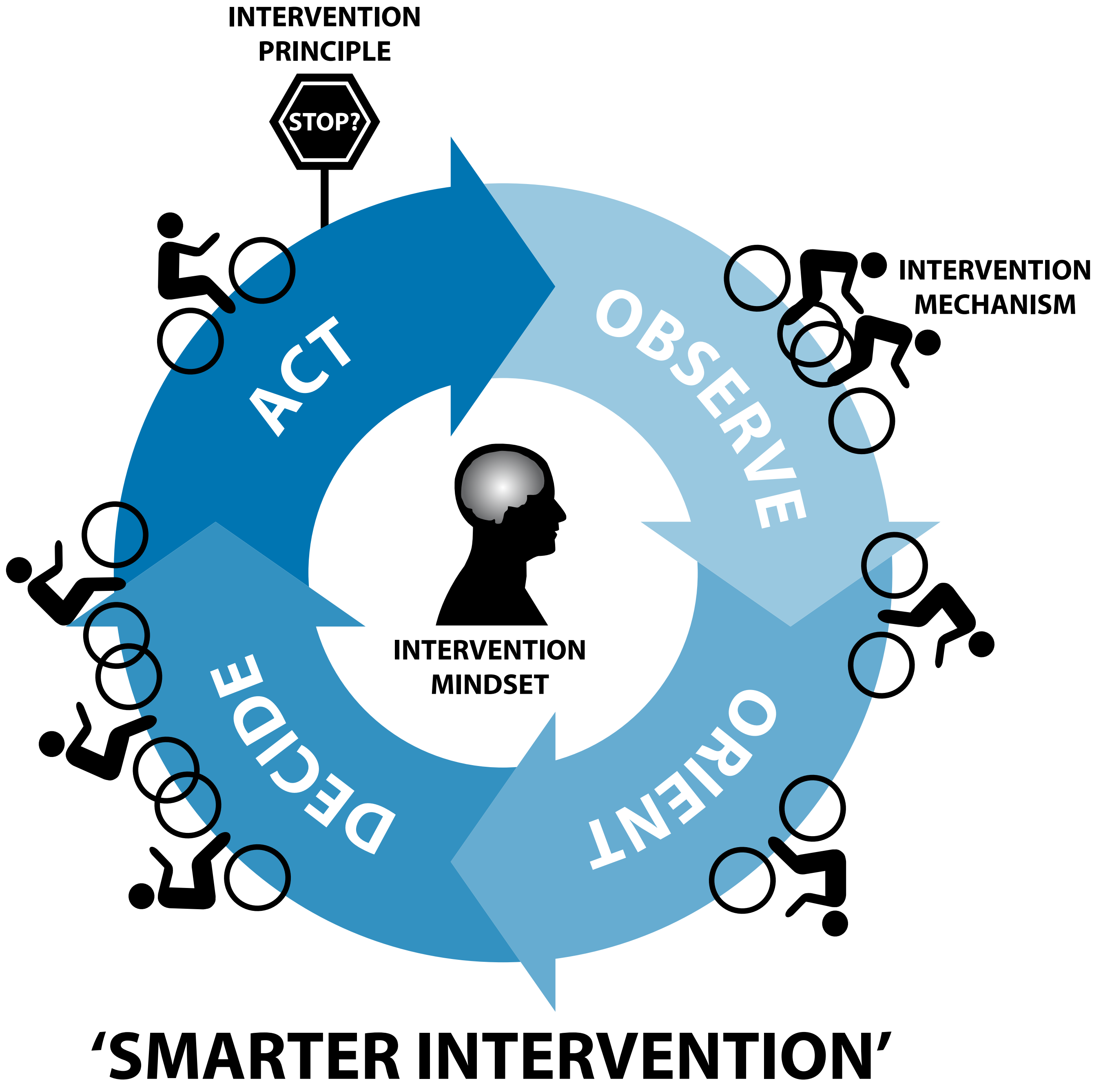
> *"An intervention agent is to intervene only if, and in so far as, it is reasonably foreseeable that the objectives of the proposed intervention cannot better be achieved by the system running itself or in default of this by another agent"*[49]

The objective should be as little intervention as possible. Referring back to Donella Meadows:

> *"Aid and encourage the forces and structures that help the system run itself. Notice how many of those forces and structures are at the bottom of the hierarchy. Don't be an unthinking intervenor and destroy the system's own self-maintenance capabilities. Before you charge in to make things better, pay attention to the value of what's already there."*[50]

FIGURE 16 - SMARTER INTERVENTION
'A new intervention mindset, mechanism & principle - in short a new paradigm for intervention'

Source: Carré & Strauss



As she points out:

> *"Any system, biological, economic or social that gets so encrusted that it cannot self-evolve, a system that systematically scorns experimentation and wipes out the raw material of innovation, is doomed over the long term on this highly variable planet."*[51]

For:

> *"The ability to self-organize is the strongest form of system resilience. A system that can evolve can survive almost any change, by changing itself."*[52]

Note the Intervention Principle's holistic approach to intervention. It applies to any 'Intervention Agent', regardless of its type, configuration or the sector from which it originates.

Also observe that the Intervention Agent has to be able to make a 'Reasonable' case for why they are intervening. Why are they not leaving the system to self-organise - to run itself? And if intervention must take place why not defer to the actions of another Intervention Agent?

The principle employs the word 'Foreseeable' because we have some pointers to help us to intervene - we have the OODA Loop and we know the strengths and weaknesses of the various Intervention Agents, their different types and configurations - but nothing is certain in a complex nonlinear systems world.

Finally, when we do intervene we need to take into consideration:

(1) **TEMPO:** Can the Intervention Agent cycle through the OODA Loop at the right tempo? Intervening too fast or too slow can be detrimental, leading to oscillations in the system's behaviour. To paraphrase the words of Donella Meadows, intervention needs to fit with *"the beat of the system"*.[53]

(2) **ACCOUNTABILITY:** What will ensure that the Intervention Agent can be held accountable as it cycles through the OODA Loop? Will it always be possible to hold Agents accountable in systems whose behaviours are greater than the sum of their parts? This has significant implications for our current liability regimes.

(3) **CONSISTENCY:** How do we avoid 'silo approaches' to intervention whereby one Intervention Agent's action undermines those of another? Instead all of these actions need to reinforce one another. They need to act in concert with each other - to 'interface' successfully with one another. In other words, the various Intervention Agents need to cycle around the loop as a team.

(4) **BIAS:** Mary Cummings, Director of the MIT Humans and Automation Lab, draws our attention to the phenomenon of 'automation bias'.[54] She defines this as the tendency to trust an automated system, in spite of evidence that the system is unreliable, or wrong in a particular case.

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Conclusion

"The future is already here - it's just not very evenly distributed."

William Gibson

'FAST FORWARD TO THE FUTURE'

When one looks at many of the different predictions that are being made about the future - be they right or wrong - 'Smarter Intervention in Complex Systems' will become an ever greater imperative.

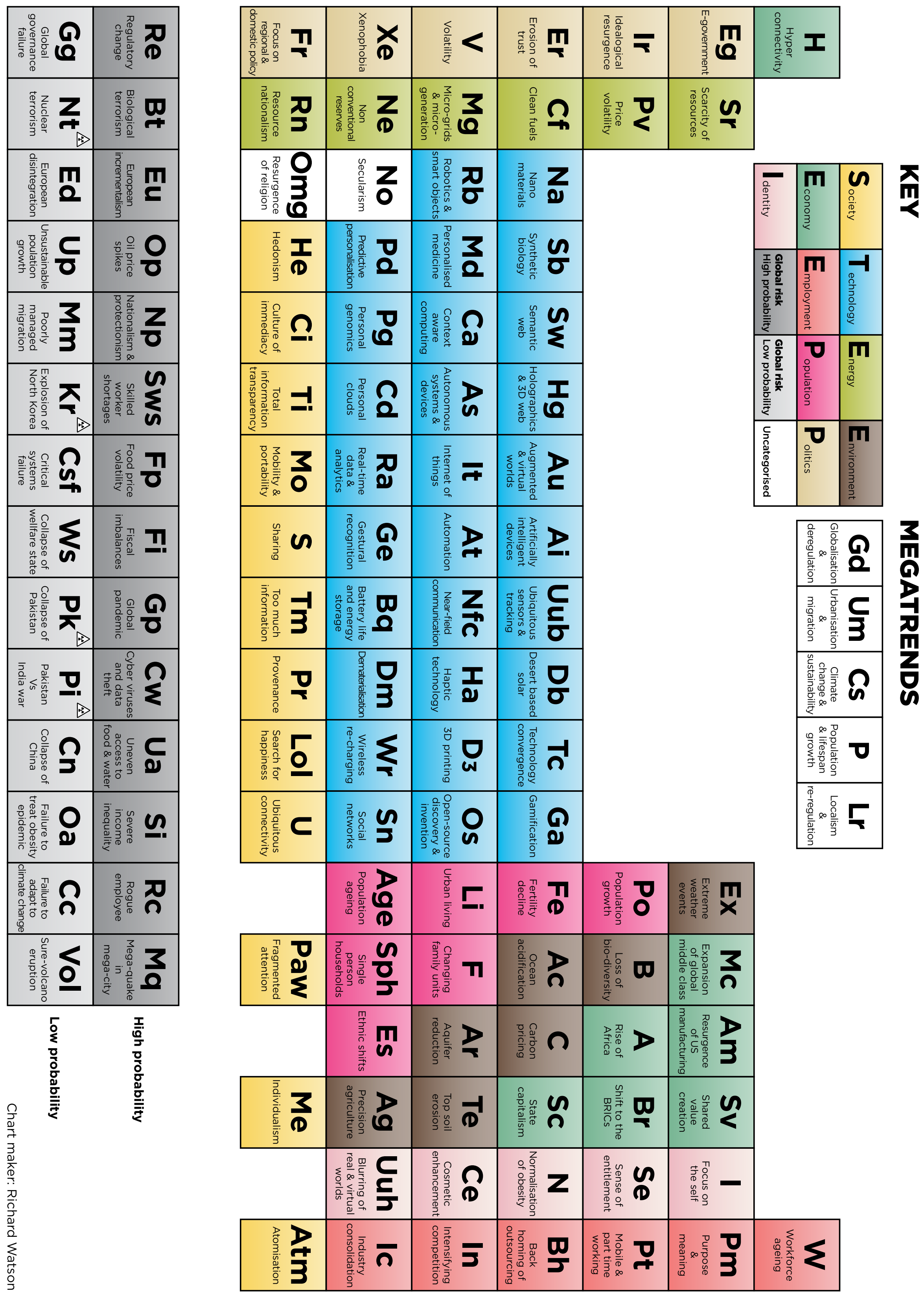
These are but a few of the exciting advances that are likely to be grounded in complex nonlinear systems: augmented reality and virtual worlds, gestural recognition, holographics and the 3D web, 3D printing, nano materials, real time data and analytics, robotics and smart objects, the semantic web, synthetic biology, ubiquitous sensors and trackers, and quantum computing. As a result the ability to cycle the 'Observe-Orient-Decide-Act' loop effectively will be a critical success factor. Doing so will involve varying configurations of experts, non-experts, crowds and individuals. This in turn means correctly employing all of these intervention agents - playing to their strengths, whilst mitigating their weaknesses - ensuring the right tempo, accountability and consistency, as well as avoiding automation bias. Invoking these agents when necessary, but leaving the system be when it is not.

And increasingly many of these innovations are going to challenge our preconceptions of what constitutes:

(1) **COMPUTATION:** How far are we going to be able to programme our environment? After all 'computation' is not only done by silicon based computers. It is widespread in the natural world. For instance, we find it taking place in cells, tissues, plants and the immune system. Consider this statement by the US geneticist and 'biohacker', Craig Venter, in May 2010: *"We're here today to announce the first synthetic cell, a cell*

FIGURE 17 (opposite page) - TABLE OF TRENDS & TECHNOLOGIES FOR THE WORLD IN 2020
'One futurist's recommended set of ideas to watch'

Source: Richard Watson[1]



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'OTHER IDEAS TO WATCH'

"Avatar assistants; Biomimicry; Clean coal; Comfort eating; Contextual deficit; Diminishing use of email; Decline of voice communication; Electrification of transport; Facial recognition on mobile phones; Gene hacking; Holographic telepresence; Increasing complexity; Local living; Mobile money; Peak water; Peer-to-peer lending/giving; Quantum computing; Reverse migration; Self-tracking; Smart infrastructure; Slow education; Shift from products to experiences; Ultra-efficient solar; Value redefinition; Voluntary simplicity."[2]

Richard Watson

made by starting with the digital code in the computer, building the chromosome from four bottles of chemicals, assembling that chromosome in yeast, transplanting it into a recipient bacterial cell and transforming that cell into a new bacterial species. So this is the first self-replicating species that we've had on the planet whose parent is a computer. It also is the first species to have its own website encoded in its genetic code."[3] Venter has likened the advance to making new software for the cell. He believes that "*If we can really get cells to do the production that we want, they could help wean us off oil and reverse some of the damage to the environment by capturing carbon dioxide."*[4]

(2) **MORALITY:** To what extent, are we going to be able encode morality into our algorithms? Or are we still going to need to mix human intervention into the OODA loop to guarantee ethical decisions and actions - ones instilled with empathy and compassion? As military forces around the world increasingly deploy drones they are having to grapple with this issue. Can or should armed robots be given fully autonomous capabilities in combat? Various approaches have been proposed, such as Ronald Arkin's 'Ethical Governor'.[5] Arkin is a roboticist at the Georgia Institute of Technology and he suggests a 2-step decision procedure before pulling the trigger- i.e. an algorithm. However a report coauthored by Human Rights Watch and Harvard Law School contends that, *"fully autonomous weapons would be incapable of meeting international humanitarian law standards, including the rules of distinction, proportionality, and military necessity. These robots would lack human qualities, such as the ability to relate to other humans and to apply human judgement that are necessary to comply*

FIGURE 18 (opposite page) - CRAIG VENTER'S SYNTHETIC CELL
'The synthetic cell looks identical to the 'wild type' and extends our concept of 'computation"

Source: BBC Online News sourcing the picture from Science, 20 May 2010

FIGURE 19 (above) - 'MORALS AND THE MACHINE'
'Do humans need to remain in the OODA Loop to ensure ethical decision making?'

Source: The Economist, June 2^{nd}-8^{th} 2012

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"We are made wise not by the recollection of our past, but by the responsibility of our future."

George Bernard Shaw

with the law."[6] As a result, Steve Goose, Director, Arms Division, Human Rights Watch, argues that, *"... you must have meaningful human control over key battlefield decisions of who lives and who dies. That should not be left up to the weapons system itself".*[7] In other words, when it comes to the question of armed drones, then humans need to remain in the OODA loop. An 'Intervention Mix' is required.

(3) **HUMANITY:** Rapid advances in technologies, such as prosthetics, are increasingly blurring the line between man and machine. Take the example of Nigel Ackland and his "bebionic3" prosthetic hand. It operates by responding to Nigel's muscle twitches. He configures its functionality - grips, thresholds and radio frequency - by using software that runs on Microsoft Windows. Nigel states that, *"Having a bebionic hand is like being human again, psychologically I wouldn't be without it. I can hold the phone, shake hands and wash my left hand normally, which I haven't been able to for five years!"*[8] Ray Kurzweil, Director of Engineering at Google, argues that this convergence between man and machine is passing through six epochs culminating in a "Technological Singularity" - a moment when "humans transcend biology".[9] Critics such Stephen Pinker, Psychology Professor at Harvard University, counter that *"There is not the slightest reason to believe in a coming singularity. The fact that you can visualize a future in your imagination is not evidence that it is likely or even possible. Look at domed cities, jet-pack commuting, underwater cities, mile-high buildings, and nuclear-powered automobiles - all staples of futuristic fantasies when I was a child that have never arrived. Sheer processing power is not a pixie dust that magically solves all your problems."*[10]

So are we are entering a brave new world or one full of exciting technological promise?

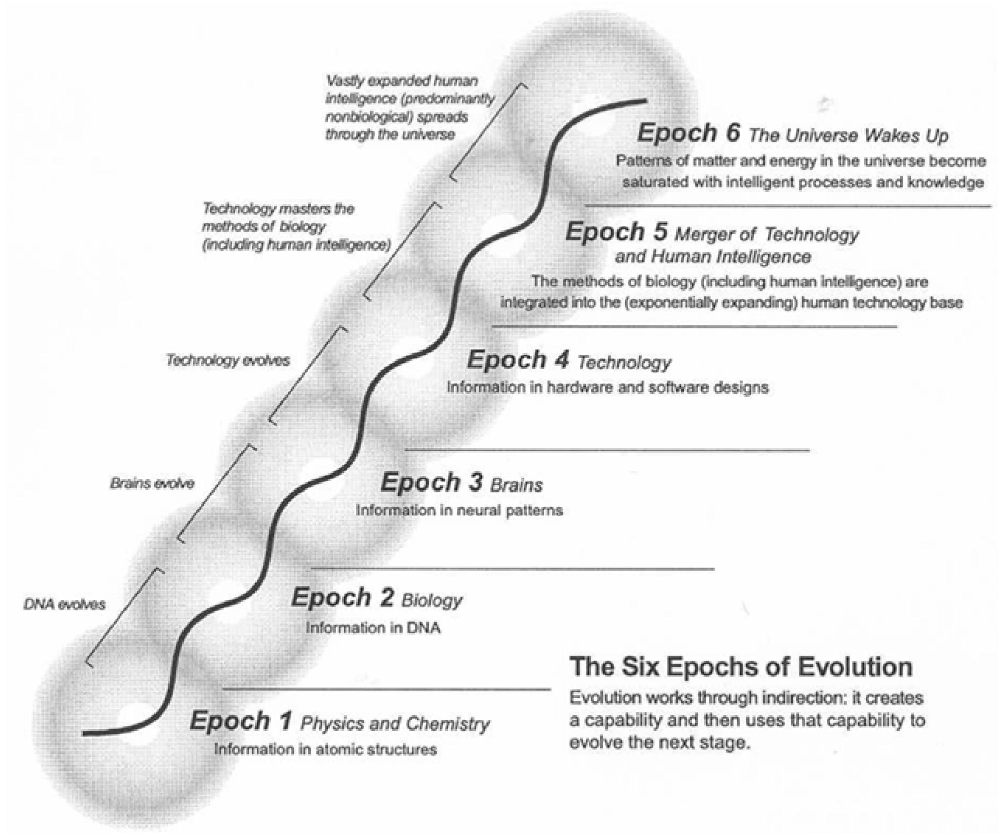
Much will depend on how successful we are in pursuing "Smarter Intervention in Complex Systems".

Adopting a new intervention mindset, mechanism and principle will improve our chances of building and securing a sustainable future.

FIGURES 20 and 21 - 'THE INCREASING CONVERGENCE OF MAN AND MACHINE'

'Nigel Ackland using his 'bebionic3' prosthetic hand made by RSLSteeper (below). Ray Kurweil's controversial vision of 'The Singularity' (bottom)'

Sources: YouTube video of Nigel Ackland, RSLSteeper technical information manual for bebionic3, and "The Singularity" by Ray Kurzweil



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[54] Mary Cummings idea of "Automation Bias" is examined by Peter Asaro in "Modeling the Moral User", IEEE Technology and Society Magazine, p. 22

CONCLUSION - "FAST FORWARD TO THE FUTURE"

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