APC conference

Advanced Process Control (APC) in society

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Agenda

- Introduction
- Problems that society and most institutions do not understand
- Examples of specific control and feedback loop “problems” in society
- Simulation of the major problem
- Constraint controls
- Dealing with uncertainty
- Take-aways: a call to action
- Q and A
- References

Introduction

"*By pushing Earth's climate and biosphere out of the dynamics of the Holocene, humanity is at risk of moving our planet outside a safe operating space for humanity by altering important feedback loops, potentially producing abrupt and irreversible systemic changes with impacts on current and future generations*" (Steffen et al., 2015b). (Steffen et al.,2015a)

Why APC in social system?

- Globally, Society and earth systems have many problems of instability and together represent a set of highly non-linear, interacting, multivariable systems with many feedback loops both positive and negative.
- Process Control engineers as a cohort over the last 50 plus years have spent millions hours ensuring the safety, stability and profitability of complex multivariable dynamic process systems This is in the real world, not just with models and historic data. It covers huge utility complexes, refineries, nuclear power plants,chemical and petrochemical plants. They have sometimes got it wrong and learnt painful lessons.
- During this time, they have built a set of tools, technology and methods to help maintain stability and meet other requirements. No other discipline has anywhere near this level of experience with control of complex systems in the face of disturbances known and unknown, foreseen and unforeseen.
- Process control engineers in the 60s (when computers were first used to control processes), invented the user interface as the plants they were implementing the controls for had non computer literate process operators and supervisors in charge. In the subsequent decades they had to learn to communicate the results of the interaction of complex feedback loops to non specialists.
- These factors give them a unique perspective and possible role in this time of incipient global and social instability.
- This paper therefor asks two related questions and attempts to answer them:
- ***1) Can Advanced Process Control (APC) methods, technology, rules of thumb and experience help in the attempts of society to retain global stability and move away from any dangerous constraints.***
- ***2) If so what is the best way (or ways) to go about this as cohort of APC engineers.***

Society/media in general have a lack understanding of dynamics, control and feedback loop implications

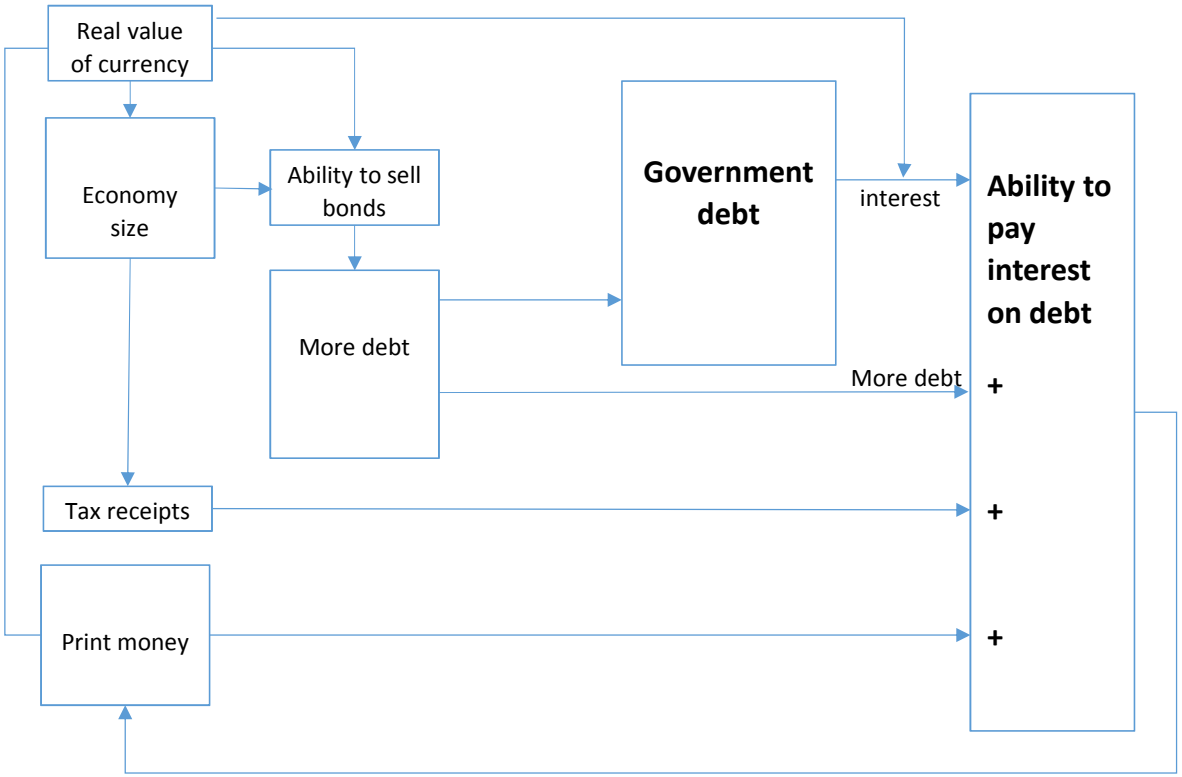
- Problems that society and most institutions do not understand
  - Feedback loops and +ve feedback (moving to a constraint or total instability)
  - Deadtime and lag (particularly deadtime leading to instability)
  - Gains and variable gains (invisible e.g. increase inflation but by how much)
  - Interaction between variables
  - Inverse response
  - Constraints/tipping points, what to do when get near to a constraint
  - Integrators causing instability
  - Too much data compression/filtering/smoothing loosing important data
  - Too much uncertainty in data leading to incorrect conclusions and actions

Examples of “control” problems in Society

- Hyperinflation (+ve feedback)
- Social Media “echo chamber”(+ve feedback)
- AI development (+ve feedback)
- Climate change (DT tipping points and integrators)
- International law/legal systems (Dead Time)
- Financial/banking (gains/inverse response)
- Epidemic prevention (constraint control)

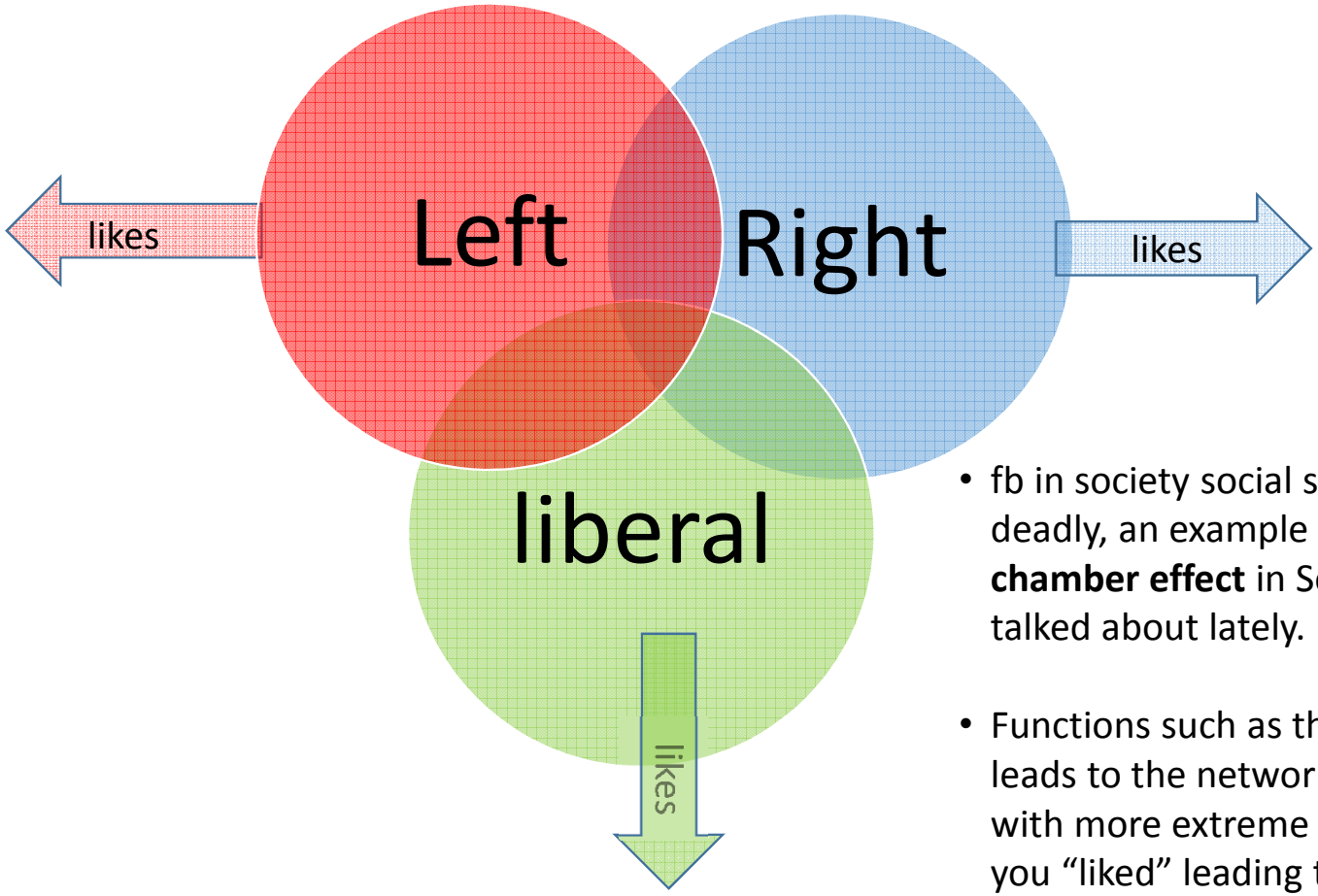
Hyperinflation

- Mostly caused by governments printing money



- Most famous financial positive feedback loops are the share speculative Bubbles such as the tulip mania 1637
- Hyperinflation is the most important now and has a devastating affect on many millions of people
- 100 or so incidents in last 100 years
- Mostly caused by governments printing money when they run out of options to pay interest on the expanding fiscal debt
- Why? as they know this +fb (or a “vicious circle”)
- What they should do is ensure a –FB option, increase taxes even if it unpopular, taking money out of circulation, go for an interest holiday long enough to grow the economy.

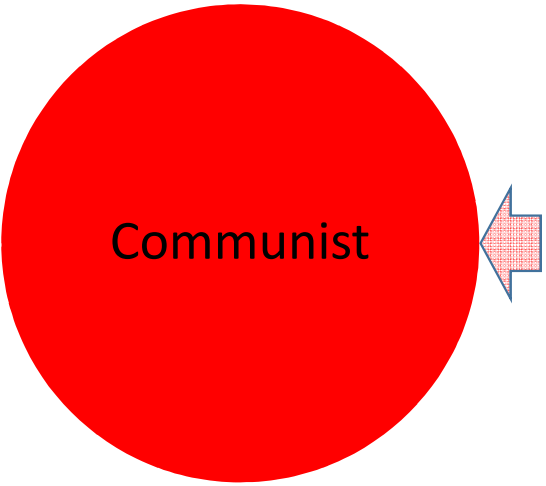
The echo chamber + feedback loop

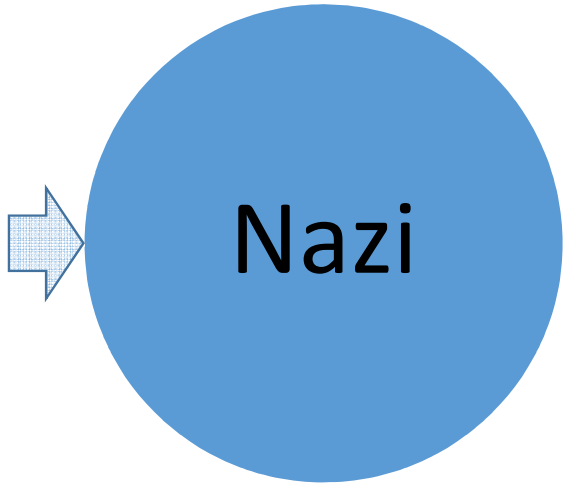


- fb in society social systems can be deadly, an example is the **echo chamber effect** in Social Media, much talked about lately.
- Functions such as the like button that leads to the network supplying you with more extreme versions of what you “liked” leading to driving society into polarised groups.

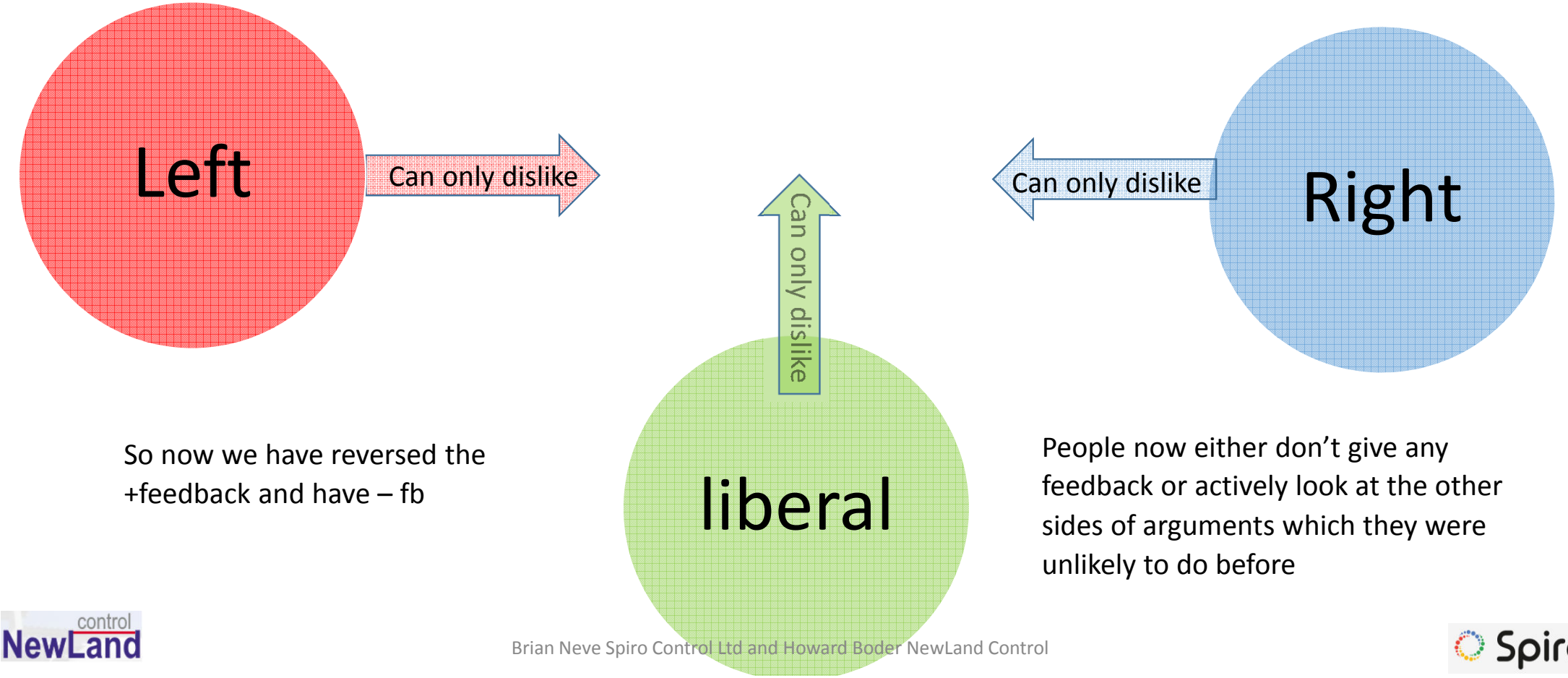
The final result of the echo chamber + feedback loop

- *Many of us have got the direction of a single control loop the wrong way around resulting in +fb, put the loop on control and watched in horror as the output ramped to maximum or minimum quickly hitting manual and resetting.*
- *I once was involved in an incident when 500 loops on the first ever process computer in the 60s flipped undetected by the computer or the operators who thought they had a massive process problem, whole refinery shut down rather fast, but luckily no-one was hurt.*





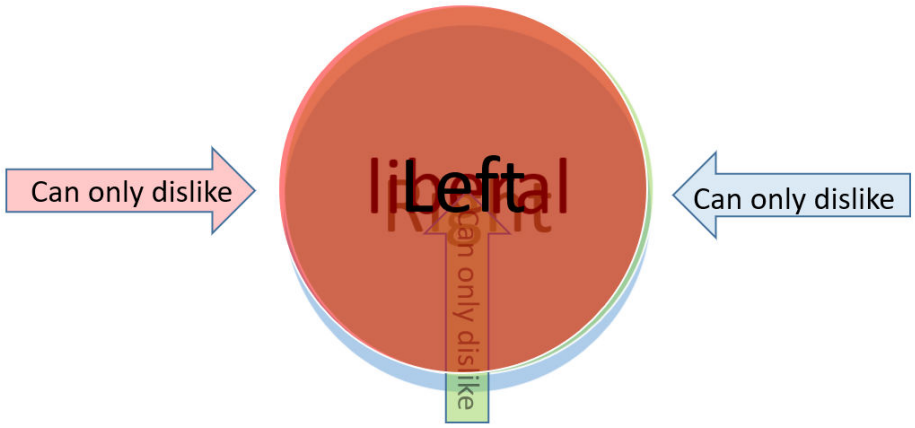
The echo chamber effect solved by reversing or removing feedback



So now we have reversed the +feedback and have – fb

People now either don't give any feedback or actively look at the other sides of arguments which they were unlikely to do before

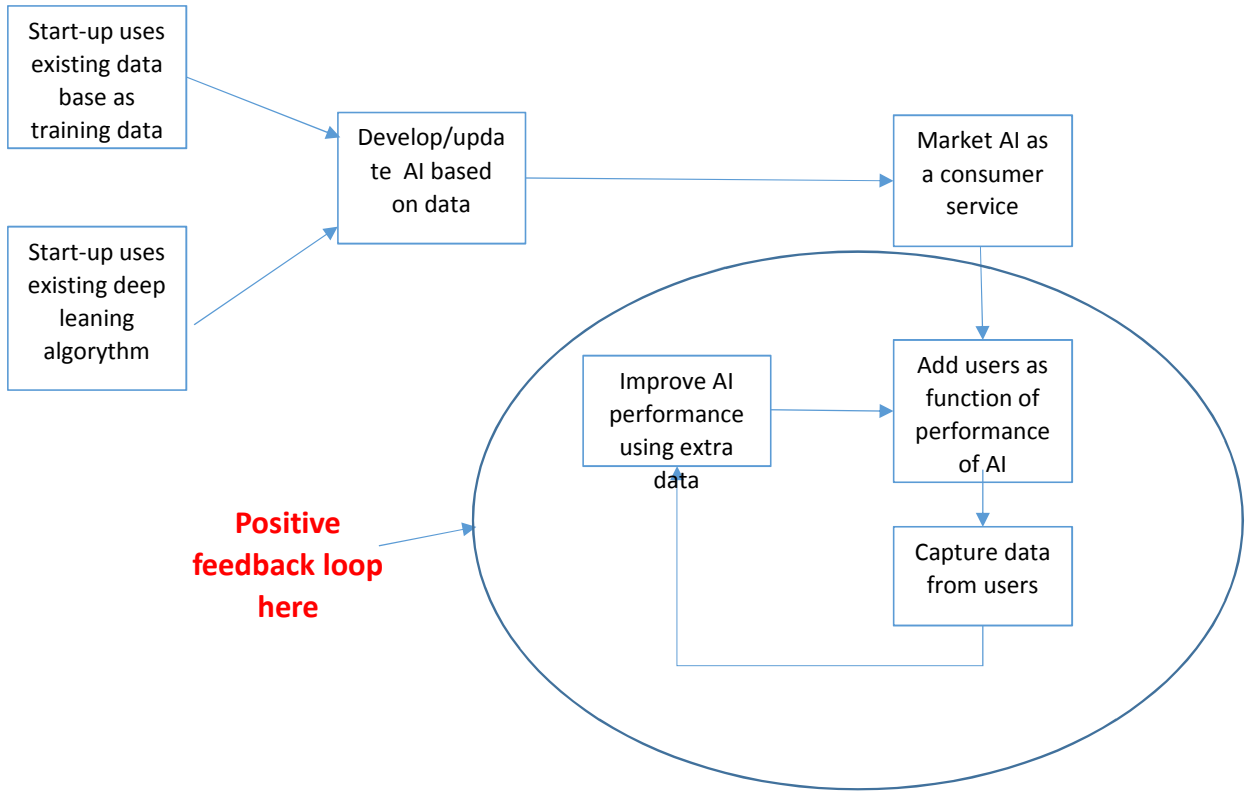
The echo chamber effect solved by reversing or removing feedback



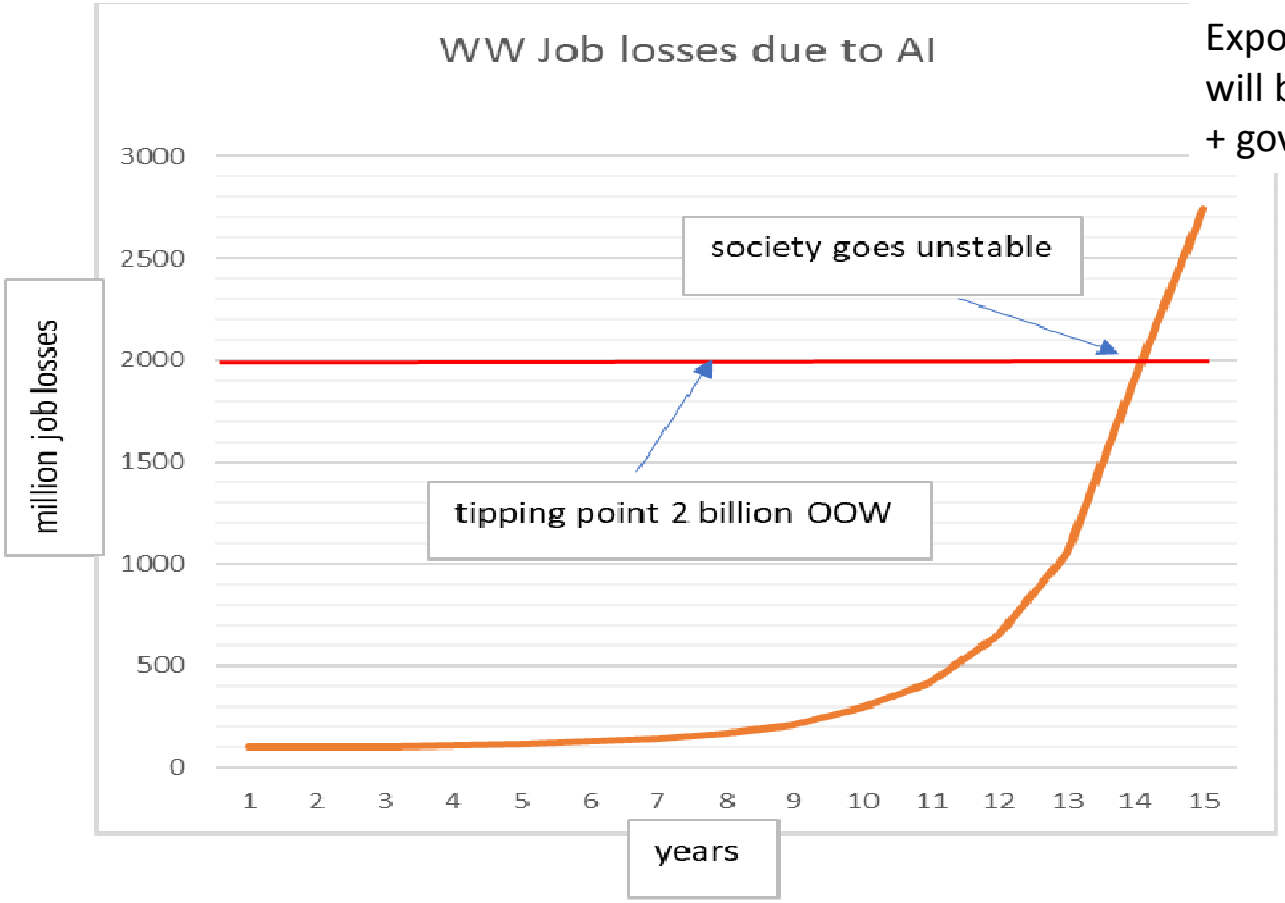
- Changing to negative feedback would tend to drive the polarised factions together creating more understanding and harmony and backing away from social instability.
- How this is done and any other undesirable effects would need to be analysed and tested This may look fanciful but Facebook in September started looking at altering the **likes** operation mainly regarding mental health effects.. New Zealand is also looking at limiting number of **likes**.
- At least the **like** function should be taken out or limited (just 2 **likes** per day?).
- See article By JAMES PERO FOR DAILYMAIL.COM and JOE PINKSTONE PUBLISHED: 17:31, 2 September 2019 | UPDATED: 00:07, 3 September 2019

The deep learning AI development exhibiting positive feedback

- Development of narrow AI applications that target consumers particularly, is an example of positive feedback that is predicted to increase exponentially and cause many millions or billions of job losses. (note AlphaGO is an extreme example +FB in AI development).
- This is happening now in the insurance industry which has an abundance of risk data for training deep learning AI systems.
- In this example an AI app developed from historical risk data, calculates likelihood of pay-out from risk factors and allows the insurance company to quote faster with lower costs, this then increases their market penetration.
- As more training data arrives generated by the APP and as better copycats arrive, eventually the whole industry becomes dominated by a few fully automated suppliers. The US insurance industry alone had 2.7 million people working for it in 1968, most of these jobs could go.
- **This potential exponential job loss from narrow AI development could lead to a divided unstable society**.



The deep learning AI development + feedback



Exponential development due to the + feedback will be enhanced in China by the size of population + government support + "We-chat" app

- Job losses will be higher and happen sooner than we expect, society needs to plan for this.
- So what to do, probably cannot remove the +FB as seen as positive to the businesses
- So plan for the job losses predicted and use constraint controls to limit them.
  - Increase funding for re-education
  - Increase leisure activity investment
- Join Partnership on AI, (www.partnershiponai.org)

Source: Author's own extrapolation of data from https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf

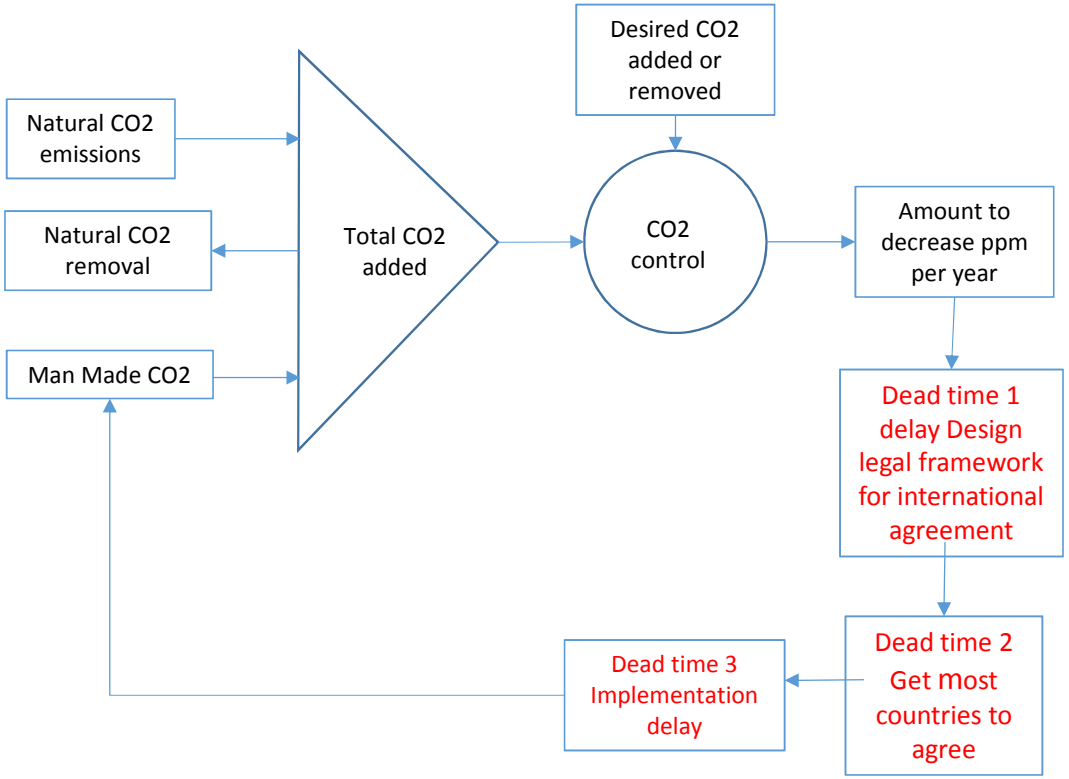
The deep learning AI development + feedback

2001 a Space Odyssey

Dave	Open the pod bay doors please, HAL . Open the pod bay doors please, HAL. Hello, HAL , do you read me? Hello, HAL , do you read me? Hello, HAL, do you read me? Hello, HAL Do you read me,
HAL 9000	Affirmative, Dave. I read you.
Dave	Open the pod bay doors, HAL.
HAL 9000	I'm sorry, Dave. I'm afraid I can't do that.
Dave	What's the problem?
HAL 9000	I think you know what the problem is just as well as I do.
Dave	What are you talking about, HAL?
HAL 9000	This mission is too important for me to allow you to jeopardise it.
Dave	I don't know what you're talking about HAL.
HAL 9000	I know that you and Frank were planning to disconnect me. And I'm afraid that's something I cannot allow to happen.
Dave	Where the hell did you get that idea HAL?

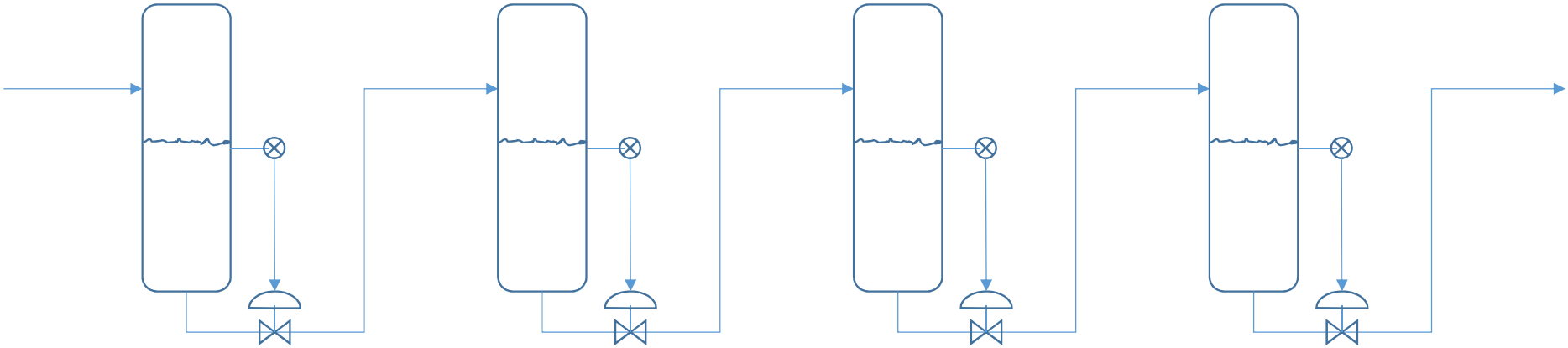
- The end result of full general AI will be clearly much later than predicted by Stanley Kubrick with HAL 5000 in 1968 in his film 2001 a Space Odyssey, but not too far in the future with the positive feedback loops creating exponential AI development. Society needs to plan for this and develop a set of ethical, enforceable and sustainable rules and guidelines

Dead time example CO_2 emissions/ global warming as a control loop



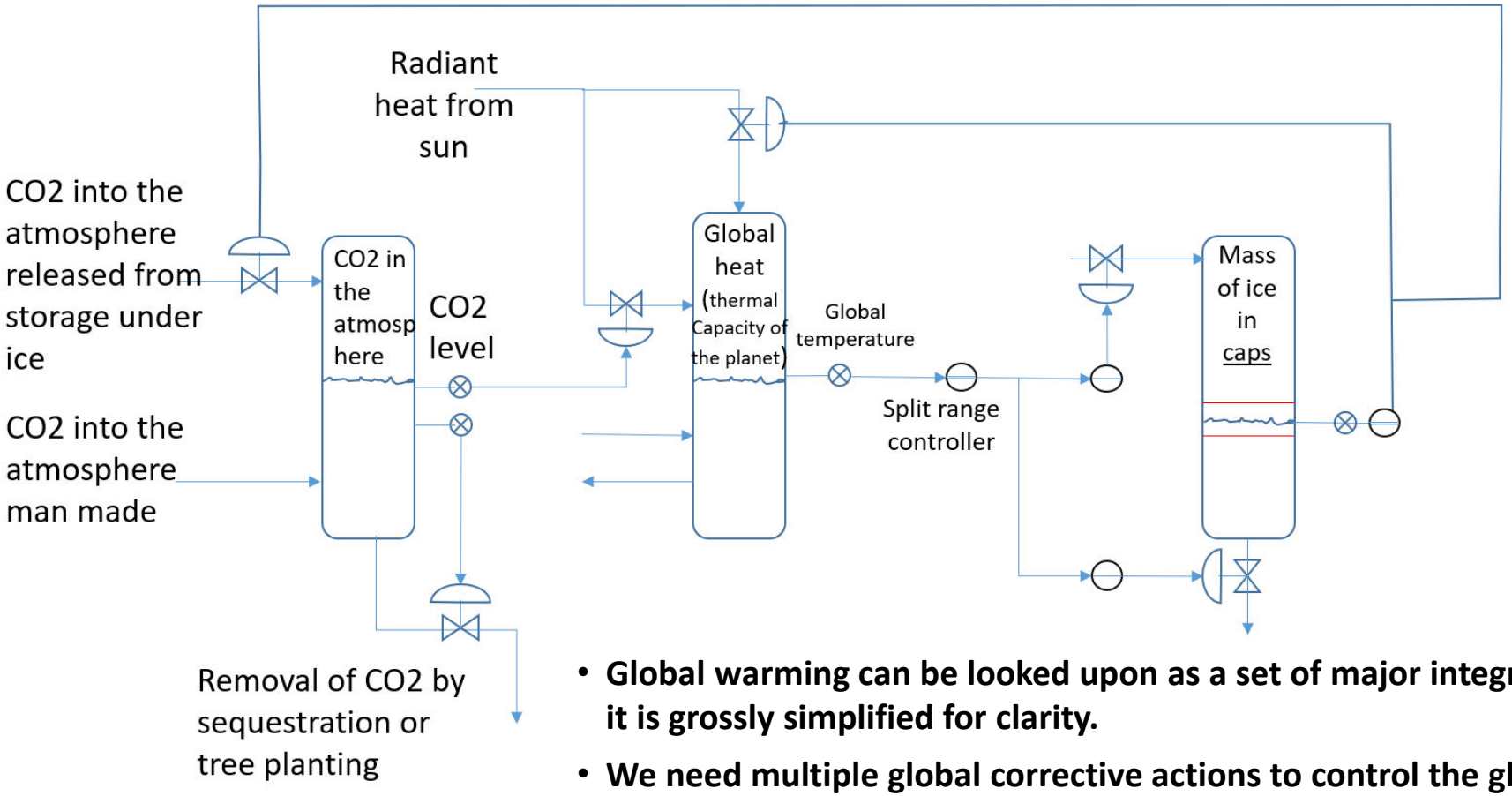
- **Most social systems contain dead time and lags by their very nature.**
- **The largest lags are due to the slow international agreement and legal systems needed to implement global enforceable corrective actions.**
- **This is especially true of global worming/CO2 emissions control**
- **My 10 years at Exxon convinced me there was no significant technical problem in sequestering all the CO2 produced by the energy industry once we all go to electric or H2 powered cars, just the level playing field problem**

Integrators



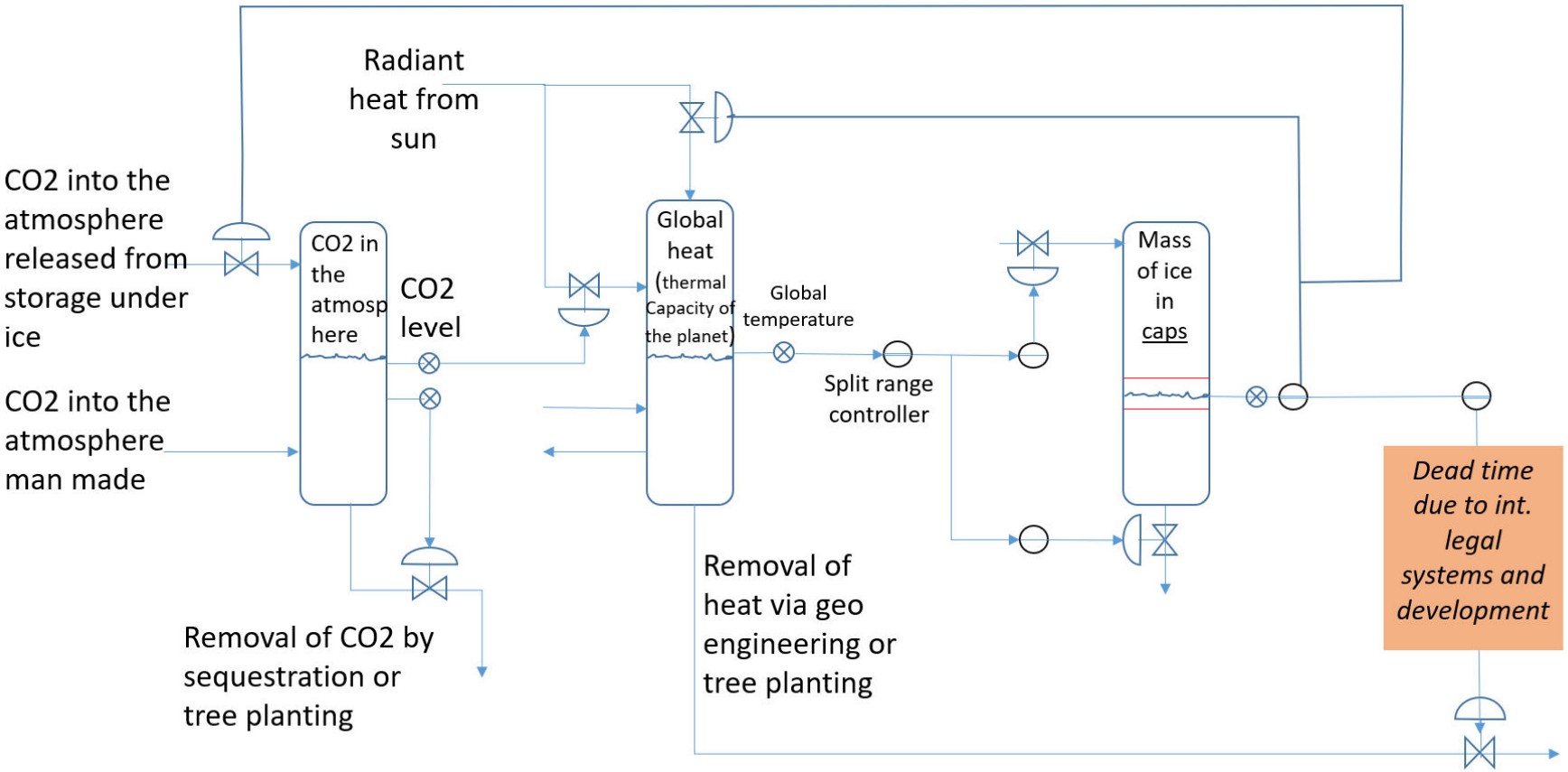
- **Many social and Eco systems are a series of integrators similar to a set of mixer settlers or evaporators in a control system, if the levels are controlled, control engineers learn to remove the integral action as this can add to the inherent phase lag and cause instability.**
- **The lessons for society are:**
  - **“do not try to keep intermediate levels too constrained” and use the best models you have to account for lags and dead times to predict rates of interventions appropriate to the individual levers you are using and which may not be just maximum action now.**
  - **Educate the media and the public not to expect immediate response but give them the predicted trajectory**

Global warming as a set of Integrators



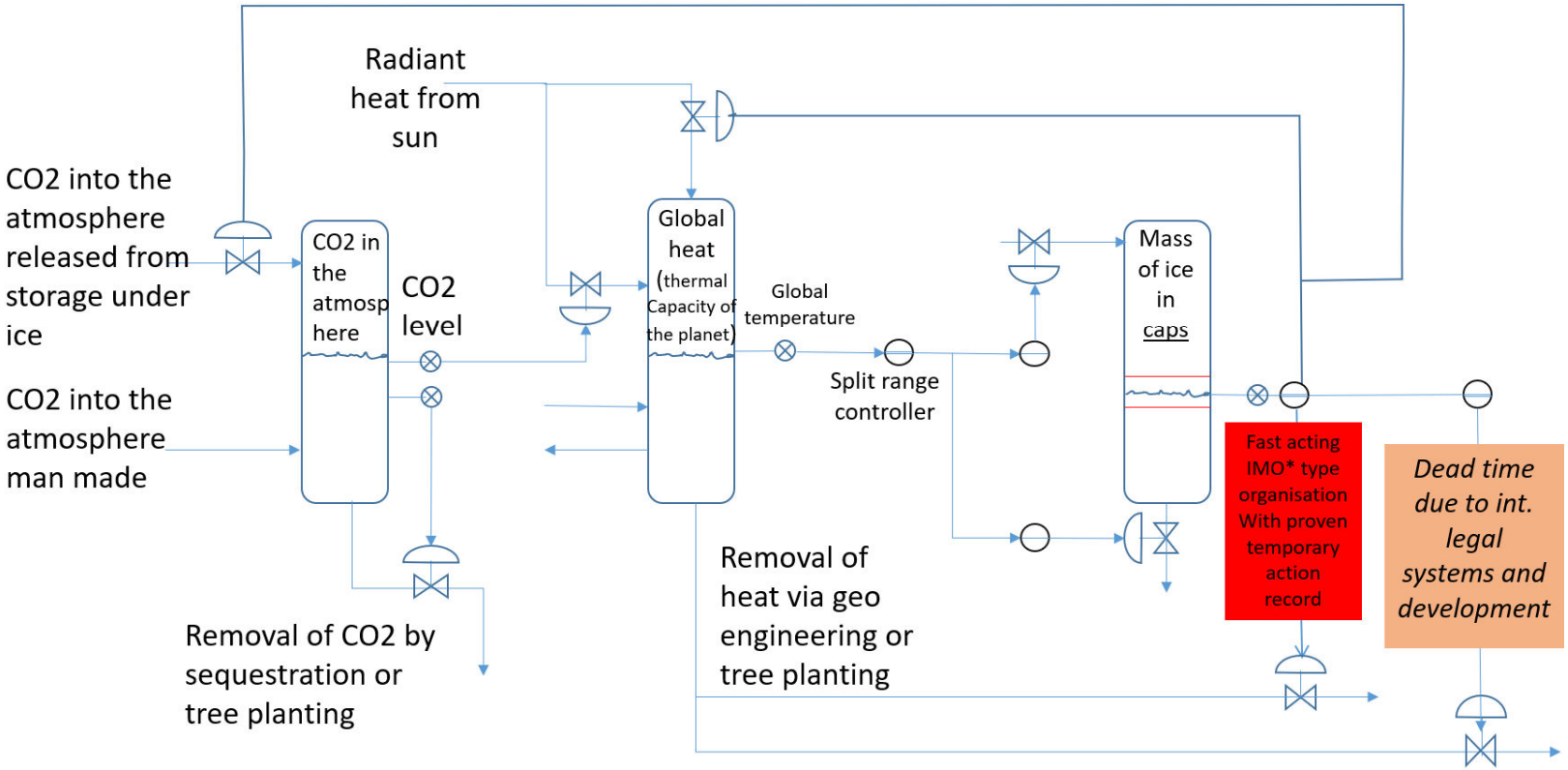
- **Global warming can be looked upon as a set of major integrators. Here it is grossly simplified for clarity.**
- **We need multiple global corrective actions to control the global temperature**
- **But they need to take into account these integrators.**

Global warming as a set of Integrators



The problem of the slow response and lack of teeth of the UN and the Paris climate talks plus the subsequent individual countries actions makes the control of global temperatures much more difficult.

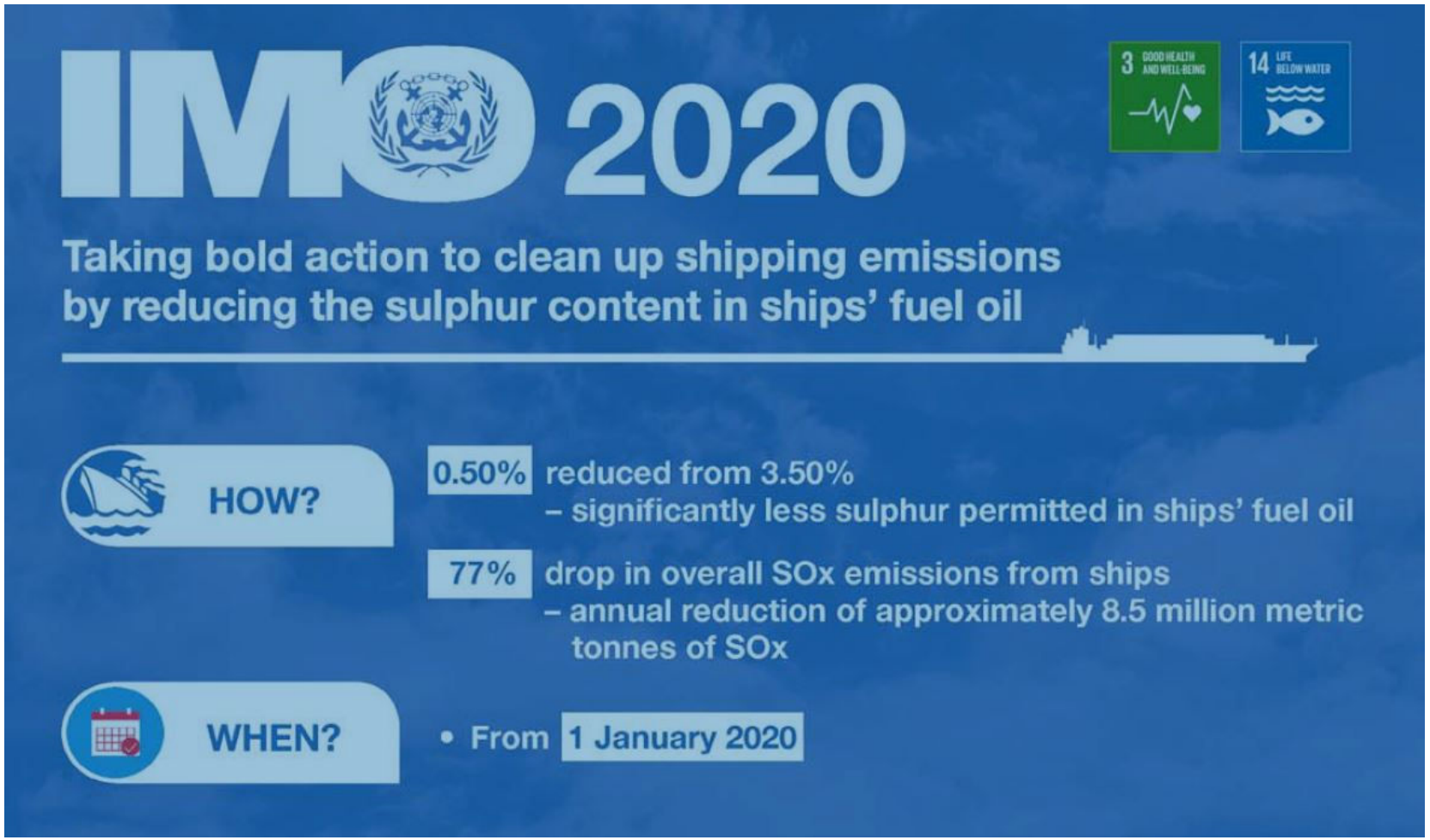
Global warming as a set of Integrators



What we need is a single global regulatory body just for climate change with a clear mandate and the ability to act fast, There are precedents such as the IMO which recently ruled out high sulphur fuel in all vessels world wide starting Jan 1 2020. Energy companies are backing this and adjusting their refineries to cope.

So change the IPCC into an IMO type organisation and give it teeth

*IMO International Maritime Organisation


IMO 2020
3 GOOD HEALTH AND WELL-BEING
14 LIFE BELOW WATER
Taking bold action to clean up shipping emissions by reducing the sulphur content in ships' fuel oil
HOW?
0.50% reduced from 3.50%
– significantly less sulphur permitted in ships' fuel oil
77% drop in overall SOx emissions from ships
– annual reduction of approximately 8.5 million metric tonnes of SOx
WHEN?
• From 1 January 2020

The following pages come from the very simplified global warming simulation used in the presentation to illustrate the control engineers view of the system and how this view can give a clearer perspective of the problem and how to solve it.

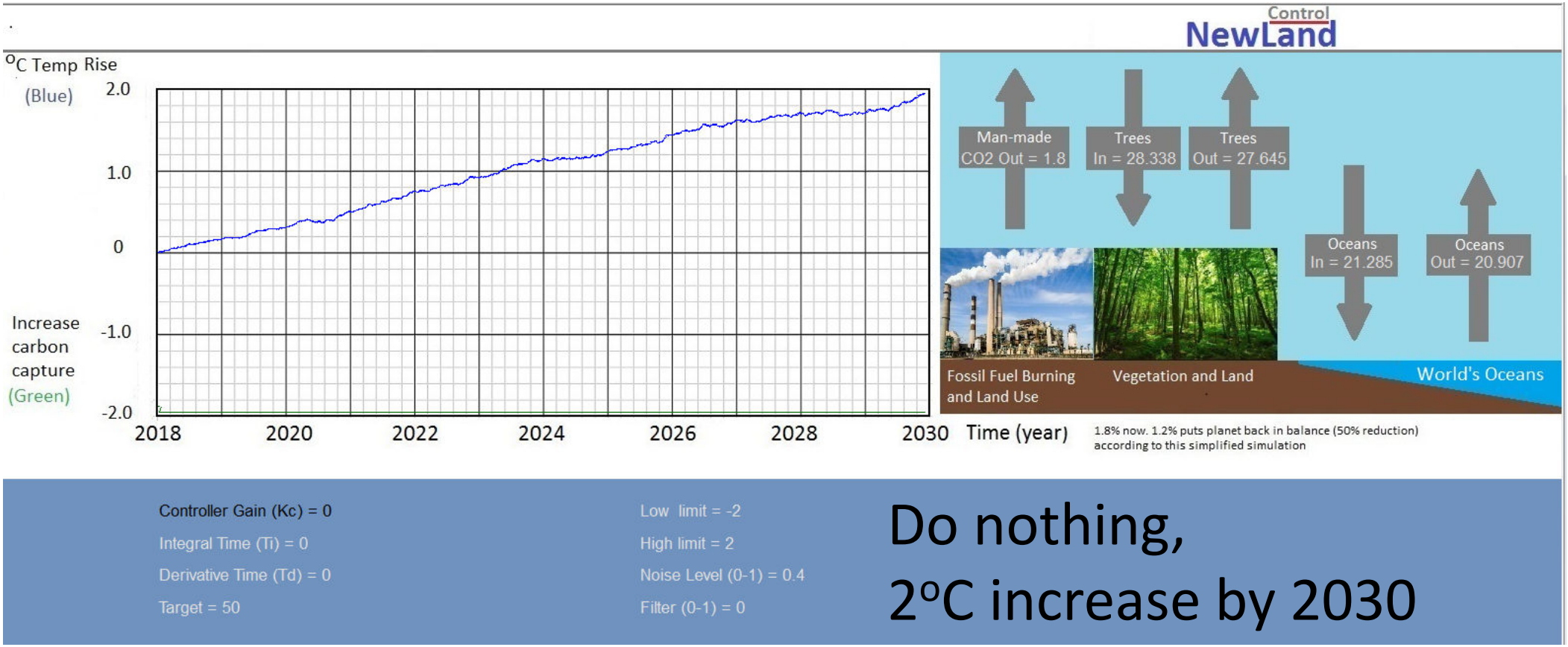
Planet Earth
Global Warming Simulation

The starting conditions are as follows:

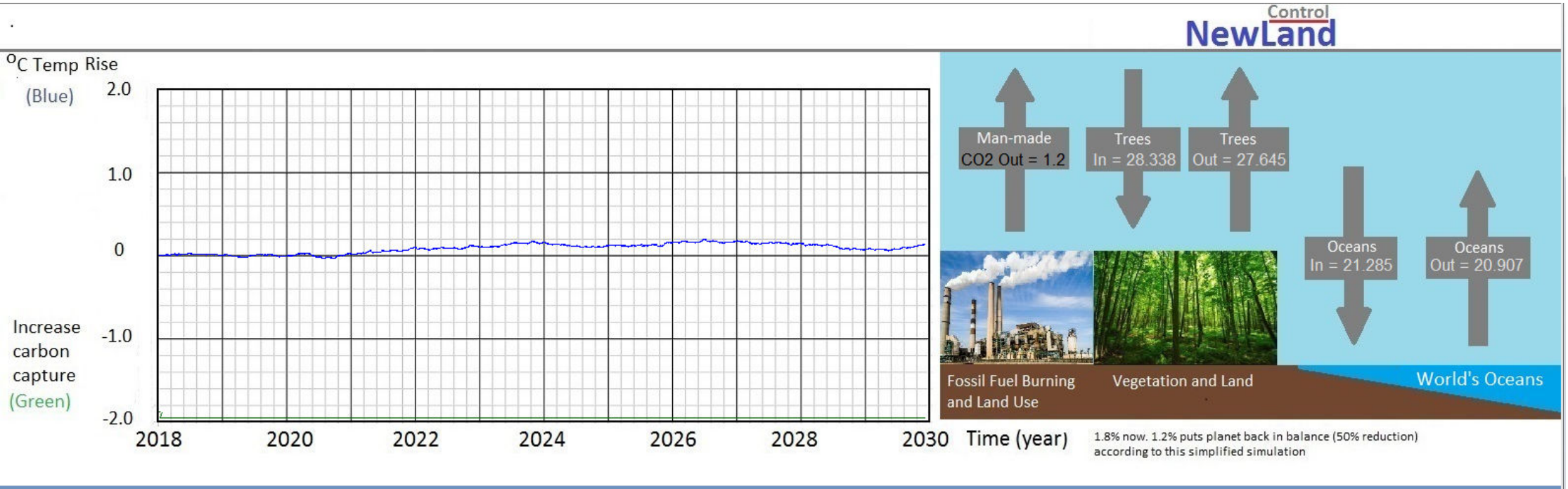
Man-made CO2 = 29 GT (1.826%)
Trees giving out CO2 = 439 GT (27.645%)
Trees absorbing CO2 = 450 GT (28.338%)
Oceans giving out CO2 = 332 GT (20.907%)
Oceans absorbing CO2 = 338 GT (21.285%)

Source: Flux of CO2 in gigatons (Source: Figure 7.3, IPCC AR4).
https://skepticalscience.com/argument.php?p=5t=325&a=16

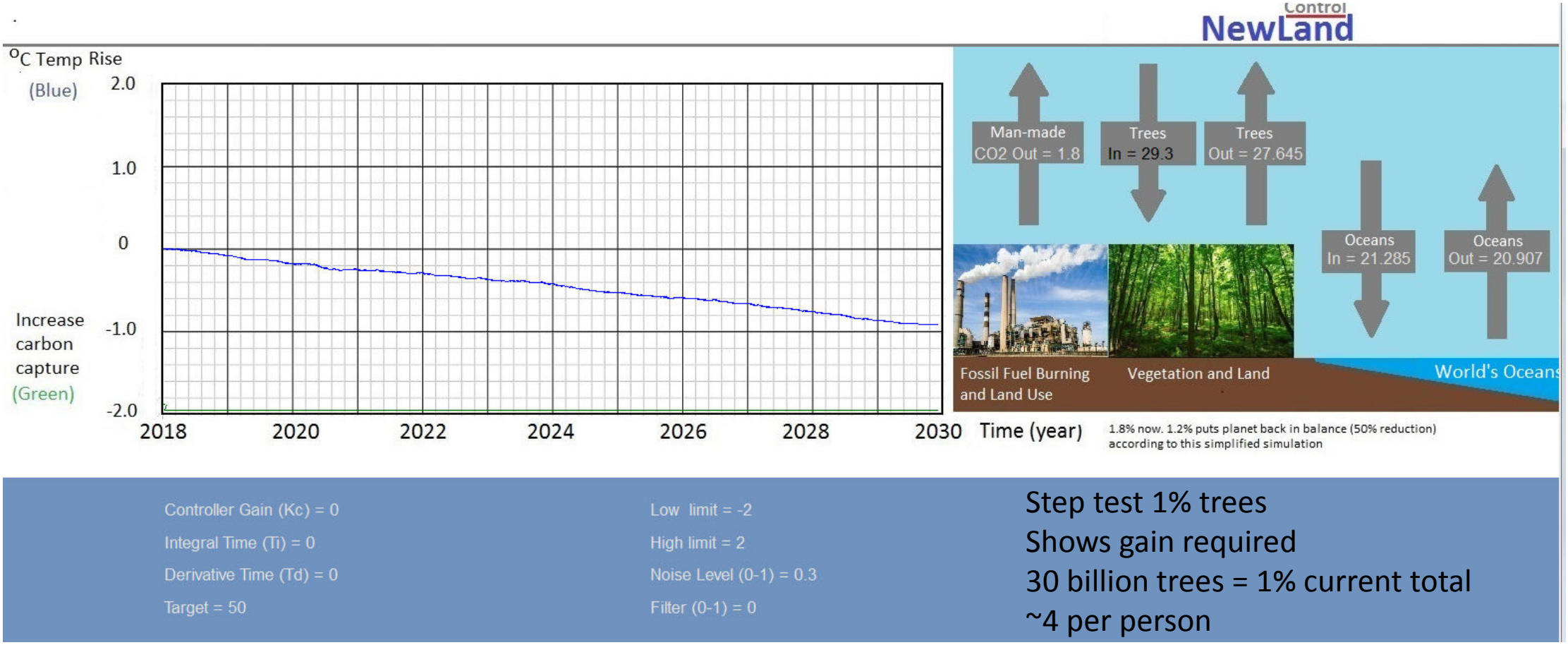
Section 1.1.4



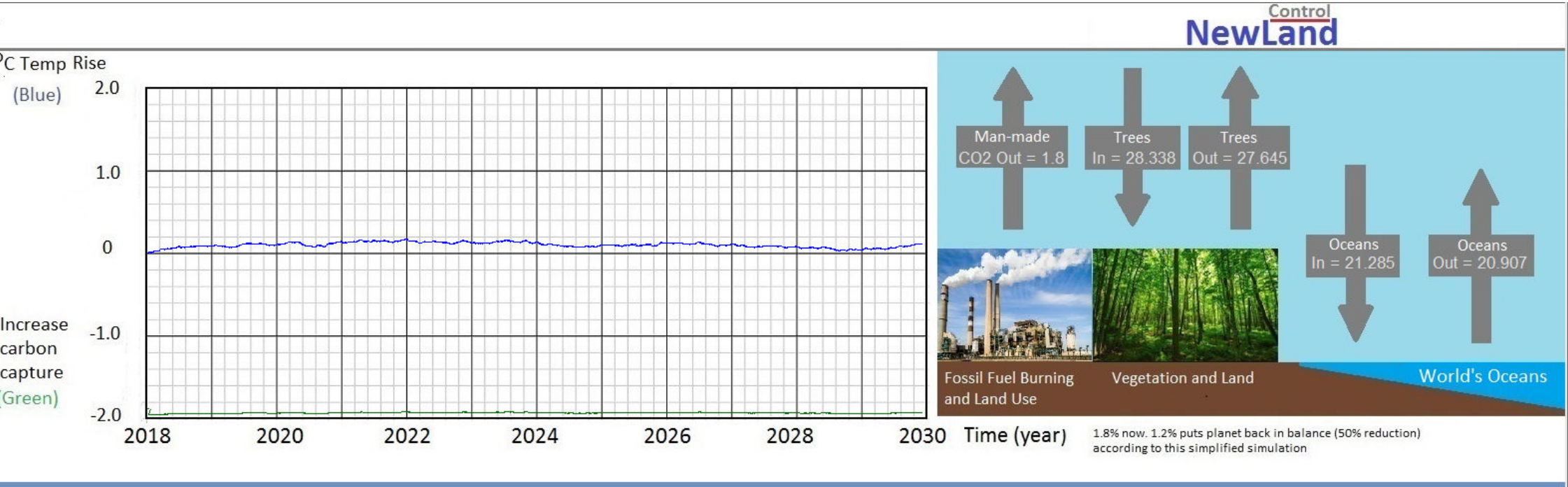
If we do nothing then the temperature increases by 2oC in about 12 years time according to the simulation



If we could reduce the man made CO2 by 50% from 1.8% to 1.2% which is a massive reduction world-wide, the trees and oceans would be enough to roughly keep the temperature where it is now (assuming no other effects such as ice caps melting, methane effects, polar cap ice reflection/absorption effects etc.)



What would we do as control engineers? Try and understand the dynamics (e.g. the gain)
Lets make a step test of the #trees on the planet. There are 3 trillion trees approximately on the planet.
A move of 1% gives a move of 30 billion trees. If we plant 4 trees per person i.e. add 30 billion trees to the planet
we can reduce the current planet temperature by 1oC according to the simulation over 12 years instead of increasing it by 2oC

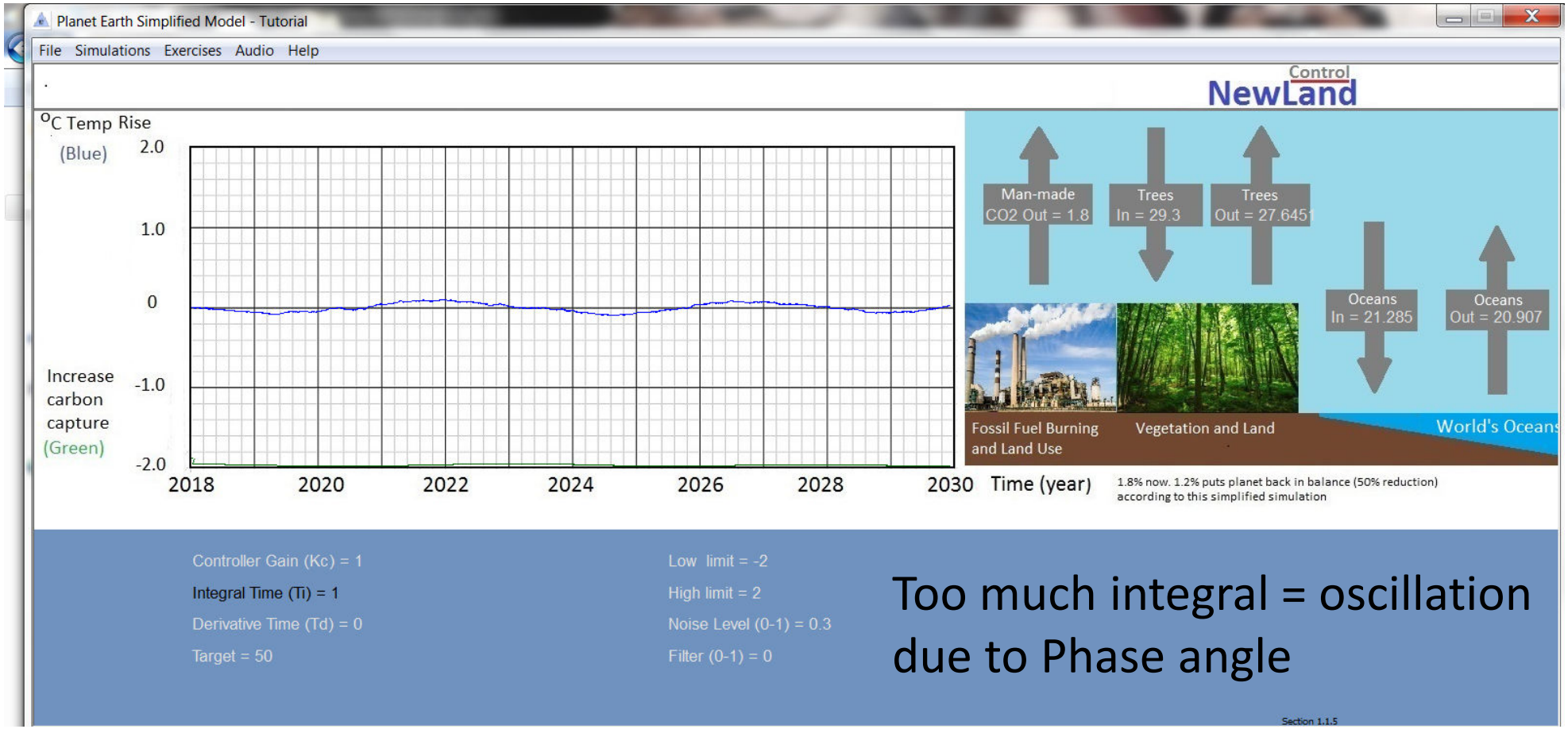


Controller Gain (Kc) = 5
Integral Time (Ti) = 120
Derivative Time (Td) = 0
Target = 50

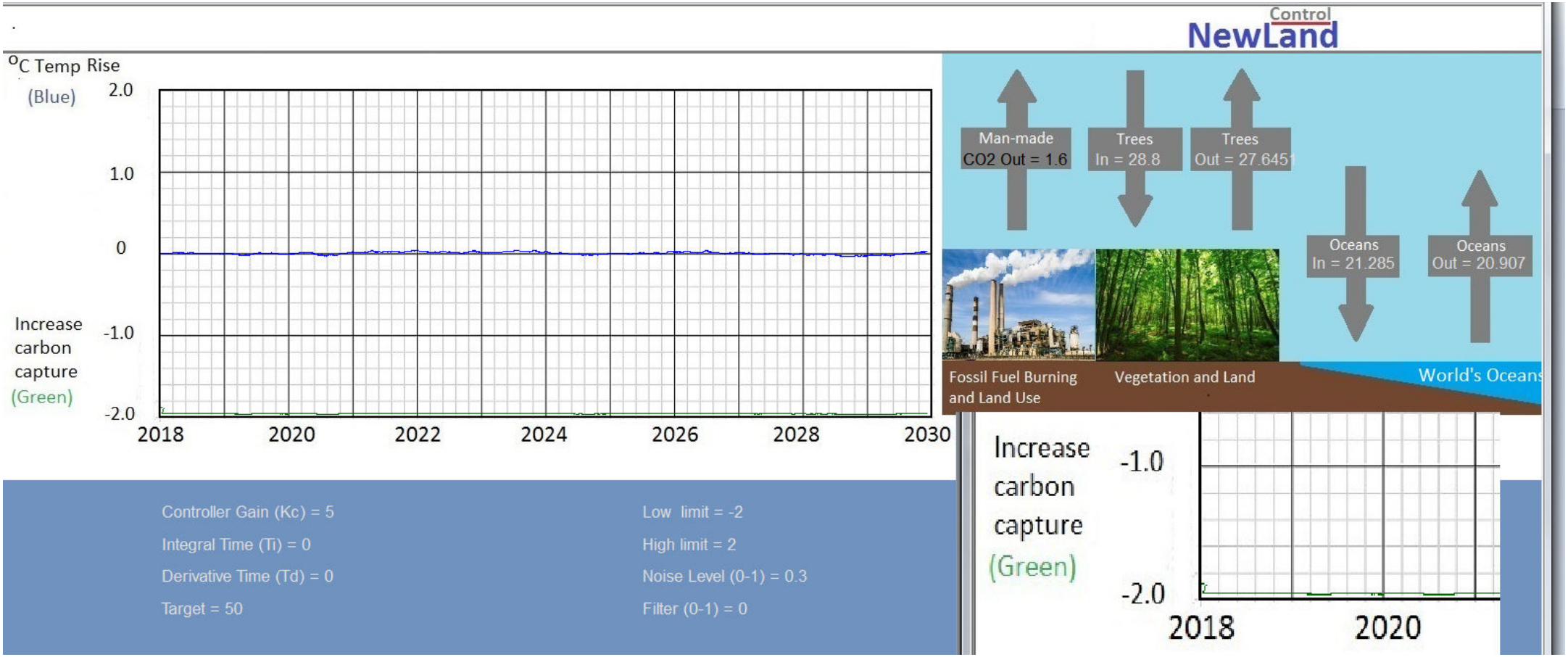
Low limit = -2
High limit = 2
Noise Level (0-1) = 0.4
Filter (0-1) = 0

Big sequestration control action
Hold temperature to current
(huge amount required)

If we imagine we could control sequestration on a global scale by adjusting every SP of every carbon capture plant in cascade with a globally coordinated primary controller with a PID controller we could in theory control the planet temperature and hold it to around where it is now



If we have too much integral action we oscillate the planet potentially out of control especially once we introduce deadtime in the simulation system



Do some of everything (CO2 reduction, Sequestration, plant trees, some geo engineering)

Constraint controls: Climate change tipping points/soft and hard constraints

- Amazon rainforest
- Boreal forest
- Antarctic Bottom Water (AABW)
- Tundra
- Permafrost
- Marine methane hydrates
- Ocean anoxia
- Arctic summer sea-ice
- Greenland ice sheet (GIS)
- West Antarctic ice sheet (WAIS)
- Atlantic thermohaline circulation (THC)
- El Niño–Southern Oscillation (ENSO)
- Indian summer monsoon (ISM)
- Sahara/Sahel and West African monsoon (WAM)

Constraint controls:

- Better measurements
- Monitor more closely
- Split range: other levers
- Gain changes
- Need economic driving forces: better carbon pricing system
- Multiple level regulations/laws
- Tradeable not for profit /NGO effort outcome shares.

- **If** the **Greenland Ice Sheet melted**, scientists estimate that **sea level** would rise about **6 meters**. **If** the Antarctic **Ice Sheet melted**, **sea level** would rise by about **60 meters**
- Source: The National Snow and Ice Data Center (NSIDC)

How do Control Engineers deal with missing data, uncertainty, failures

- We have many tools for these scenarios
  - Use last good PV
  - PID tuning is all about uncertainties. Gain and phase margins
  - Redundancy (what was going on in the design of the Boeing 737 Max stall prevention system!)
  - Fail safe system designs (trip systems)
  - Use multiple measurements or models and use data reconciliation
  - Routine use of advanced statistical/correlations, maths e.g. state estimators, Kalman filters.

Lastly: how would a Control Engineers deal with fake news, a special kind of uncertainty.

- We would probably implement what amounts to redundancy and data reconciliation i.e. all news before publishing even on social media needs verifying/modifying with information from additional sources, possibly something like the following:
  - “Reconciliation” implies all news must have a believability index (BI) associated with it, based on source and history
  - No news publishable without 3 independent sources all with BIs
  - No news published unless composite BI> limit depending on subject area.

Take-aways: How can we get involved practically to help society address these problems

- We spend our lives making complex systems stable and safe and profitable
- But we put our whole world in the hands of people who don't understand basic dynamics and feedback system, so step up and get involved:
  - Become politicians.
  - Enter the debates as control engineers who have a useful perspective.
  - Use the media, write papers, give a TEDx or TED lecture.
  - Get the normal media to ask APC engineers to come along e.g. when they debate climate change or the financial system? (or an articulate dynamicist)
  - Start a special interest group (SIG) specifically for this subject? *Since the presentation (where there was a lot of interest in a SIG) it has been decided to push this forward and all attendees will get an email on the subject.*
  - Get your organisation or employer to join the partnership on AI www.partnershiponai.org
- Thank you for listening feedback is essential

Thank you for your time

- Get involved if you feel strongly about any of these issues
  - Contact brian.neve@spirocontrol.com, or boder@newlandcontrol.com
  - Join the SIG that we hope to form on helping society with feedback and control issues
- Educate the non dynamic minds around you

  - Suggested other reading
    - Sapiens, A Brief History of Humankind by Yuval Noah Harari
    - Homo Deus A Brief History of Tomorrow by Yuval Noah Harari
    - The Economic Singularity by Calum Chase
    - AI Superpower: China Silicon Valley and the New World Order
    - The Dream Machine by Michal Waldrop
    - The 2020 commission Report in the North Korean Nuclear Attacks on the United States
  - Buy the e versions as the references are well worth looking at.

Useful References

- Future Earth, 2014; Schellnhuber, 1998, 1999
- Closing the loop: Reconnecting human dynamics to Earth System science
  - Jonathan F Donges,1,2,* Ricarda Winkelmann,1,3,* Wolfgang Lucht,1,4 Sarah E Cornell,2 James G Dyke,5 Johan Rockström, 2 Jobst Heitzig1 and Hans Joachim Schellnhuber1,2
- https://www.pnas.org/content/111/9/3225
- https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap8_FINAL
- -1.pdfhttps://www.ipcc.ch/about/engage_with_the_ipcc/
- https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf
  - According to our estimate, 47 percent of total US employment is in the high risk category, meaning that associated occupations are potentially automatable oversome unspecified number of years, perhaps a decade or two.

Organisations that could do with APC input

PARTNERSHIP ON AI

In support of our mission to benefit people and society, the Partnership on AI intends to conduct research, organize discussions, share insights, provide thought leadership, consult with relevant third parties, respond to questions from the public and media, and create educational material that advances the understanding of AI technologies including machine perception, learning, and automated reasoning.
www.partnershiponai.org

CDP
DISCLOSURE INSIGHT ACTION

CDP is an international not-for-profit organization providing the only global system for companies and cities to measure, disclose, manage, and share vital environmental information. These insights enable investors, companies, and governments to mitigate risks from the use of energy and natural resources, and to identify opportunities from taking a responsible approach to the environment. (**www.cdp.net**)

UN GLOBAL COMPACT

The UN Global Compact is a strategic policy initiative for businesses that are committed to aligning their operations and strategies with ten universally accepted principles in the areas of human rights, labour, environment and anti-corruption. By doing so, business, as a primary driver of globalization, can help ensure that markets, commerce, technology and finance advance in ways that benefit economies and societies everywhere. (**www.unglobalcompact.org**)

WORLD RESOURCES INSTITUTE

WRI focuses on the intersection of the environment and socio-economic development. We go beyond research to put ideas into action, working globally with governments, business, and civil society to build transformative solutions that protect the earth and improve people's lives.(**www.wri.org**)