# Analyzing Misinformation Through The Lens of Systems Thinking

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## Abstract

Recently, there has been an alarming rise in the presence of false information online, which may be spread knowingly with malintent ("disinformation") or naively without knowing ("misinformation"). The spread of both these types of false information disintegrates public trust on the information ecology and can have deleterious effect on society (e.g., when wrong health information is adopted or when polarization and hostility increases due to incorrect news about others). Various interventions have been tried (e.g., enhancing digital literacy) with mixed results. Current analytical methods are not well suited for studying such complex adaptive systems as they fail to capture the interactions and interdependencies between the various parts of the system. In this paper, we propose the use of system thinking for modeling misinformation (for convenience and simplicity of exposition, we refer to all false information as misinformation regardless of the intent). We demonstrate the use of system thinking tools such as causal loop diagrams and stock-and-flow models for modeling misinformation. To the best of our limited knowledge, this is the first of its kind of research regarding viewing misinformation from the perspective of system thinking.

## 1 Introduction

How can we solve the problem of misinformation and disinformation in an effective manner? Why do our problems persist despite the best efforts, and why do our solutions to the pressing 21st century challenges in turn often perpetuate these problem even further. These questions motivate us to view the rising issue of misinformation from the perspective of systems thinking. System thinking can translate a problem, such as prevalent misinformation, into a set of feedback loops that represent reinforcing and balancing processes, rather than the traditional linear thinking of cause and effect. It posits that events and trends observed in a system is inherent to its internal structure, which is defined by the relationships between its elements and which gives rise to its purpose (John, 2000). Applying the lens of systems thinking will contribute in improving truth and trust issues; by enabling us to focus on the interconnections of this complex problem. It will allow us identify root causes and anticipate long term consequences and unanticipated side effects of solutions under consideration.

There is a plethora of information on online media in this era. Recently, there has been an alarming rise in the presence of false information online, which may be spread knowingly with malintent ("disinformation") or naively without knowing ("misinformation"). In this paper, we refer to all kinds of false information online as misinformation for convenience and ease of exposition even though technically misinformation is different from disinformation in that there is a definite intention in the latter to harm and deceive unlike the former case. However, for the purpose of the paper, we will misinformation to be synonymous and inclusive of disinformation. The spread of both these types of false information disintegrates public trust on the information ecology and enables an infodemic that strains the ability of people to find relevant authentic information from the Internet.

Unfortunately the problem of taming the infodemic and countering misinformation is far from easy. This is because the modern information ecology—comprising billions of humans who use information sources managed by public and private owners and influenced by various regulations and policies using new media such as the Internet, social media, and mobile phone apps—is a complex adaptive social system. Such systems are well



*Proceedings of the 2020 Truth and Trust Online (TTO 2020)*, pages 55–63,
Virtual, October 16-17, 2020.

known to be counterintuitive due to the presence of various intertwined feedback loops that interact nonlinearly. This results in an overall system in which causes and their effect are linked together indirectly through circuitous paths, distant in time and space, which makes the job of analyzing the efficacy of an intervention difficult and error-prone (Forrester, 1971). Despite efforts to regulate misinformation through legislation, legal warnings to corporations, and innovations in Artificial Intelligence (AI) to track and label cases of misinformation, authorities have failed to overcome the challenges posed by misinformation (M.West, 2017).

Systems thinking is ideally suited to such complex adaptive systems. Systems thinking has been defined as "the ability to understand the systemic interconnections in such a way as to achieve a desired purpose" (Stroh, 2015b). Systems thinking is a highly-developed discipline with many schools of thought (including system dynamics, complexity theory, general systems theory, human system dynamics, etc. (Stroh, 2015b) (Arnold and Wade, 2015)) and highly-developed qualitative and quantitative tools (Kim, 1995) (some of which we discuss in the next section) (Stroh, 2015b)).

The following four key distinctive thinking patterns are said to distinguish systems thinking from conventional thinking (Richardson, 2011): *firstly*, the ability to think dynamically (e.g., using graphs over time); *secondly*, to think causally through feedback loops; *thirdly*, to think of stocks and flows (i.e., accumulation and transfer); and *finally*, to think more deeply about endogenous influences (where the system itself is the cause of the observed problems). System thinking can also be understood by contrasting it with open-loop based conventional thinking (see Table 1), which fails to take into account that social systems are more properly modeled as *multi-loop nonlinear* feedback systems and in such systems hardly anything is ever influenced linearly in just one direction (Forrester, 1971) and in nonlinear systems, "*the act of playing the game has a way of changing the rules*" .

Systems thinking can allow us to rigorously analyze the anticipated outcomes of interventions designed to mitigate misinformation. A pioneer of the system thinking, Jay Forrester, describes the discipline as "take the knowledge we already have about details in the world around us and to show why our social and physical systems behave the way they do" (Meadows, 1999). Unfortunately, frequently various solutions to the problem of misinformation exacerbate the problem—the cure being worse than the disease. As said by Lewis Thomas, "If you want to fix something you are first obliged to understand... the whole system." He further said even when one is anxious to solve any problem of significant complexity, it is inappropriate to intervene naively and have 'much hope of helping' (Stroh, 2015a). Motivated by this viewpoint, this paper builds on selected concepts discussed in misinformation literature via the lens of systems thinking so that we can understand misinformation fully and bring sustainable and lasting improvements while avoiding common pitfalls.

## 2 Primer on System Thinking

Systems thinking had its genesis during the development of the intellectual discipline of system dynamics, which emerged in 1950 at MIT, USA. It describes the bigger picture, so sustainable solutions can be implemented with fewer resources. In terms of looking at interconnected causes of complex problems, addressing the underlying problems, not symptoms, controlling the solution of the dynamic problem by changing system's behaviour, thinking about the endogenous variables operating in feedback loops, discouraging policies that intend to foresee long term success based on quick short-term fixes and focusing on improving the relationship among parts by coordinated changes over a long period system thinking differs from the conventional linear thinking (Stroh, 2015a).

### 2.1 System Thinking Tools

Since the genesis of system thinking at MIT [as systems dynamics] in the 1950s, the system thinking community has developed versatile set of qualitative and quantitative tools such as causal loop diagrams, graphical functions diagrams using stock and flow models. These system thinking tools have been widely applied in various sectors such as healthcare, education, and management to gain insights into effective policy-making and to study the behavior of complex systems. We discuss causal loop diagrams and stock and flow models next.

#### 2.1.1 Causal Loop Diagrams

Causal Loop Diagrams (CLD) present non-linear cause and effect relationship in a simplified illus-

Table 1: Conventional vs. Systems Thinking [Credit: (Yaqoob et al., 2018); Details: (Senge, 2006)(Stroh, 2015b)]

| | ***Conventional Thinking*** | ***Systems Thinking*** |
|---|---|---|
| *Model of thinking* | Linear, causal, open-looped, immediate feedback | Nonlinear, multi-causal, close-looped with delayed feedback |
| *Determining a problem's cause* | Obvious and easy to trace | Indirect and non-obvious |
| *Cause of problems* | External to the system | Internal (System-as-a-cause thinking) |
| *How to optimize?* | By optimizing the parts | By optimizing relationships among the parts |
| *Where to intervene?* | Aggressive use of "obvious" solutions | Careful change applied at the "leverage points" |
| *How to resolve problems?* | Cure the symptoms | Fix the systemic causes |

tration of a collection of feedback loops. They are comprised of elements and the causal links between these elements along with the associated polarity of this link. Polarity can either be "same" (represented by "S") which indicates that the two elements move in the same direction or "opposite" (represented by "O") which indicates that the two elements move in opposite directions. As a clarifying example we present a simplified causal loop diagram of population. Here the elements consist of births, deaths, and population. Births are linked to population and move in the same direction (more births means more population). Deaths are linked to population and move in the opposite direction (more deaths means less population). A feedback loop is a closed circular connection between an action and a result whose consequences feed again in the loop and affect the further actions and results (Lane and Sterman, 2011). Feedback loops that amplify change are called "*reinforcing loops*" and are labelled with an R, whereas causal loops that stabilize change are called "*balancing loops*" and are labelled with a B. Figure 1 presents this CLD.

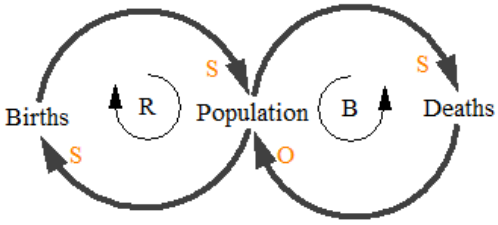


Figure 1: Population Causal Loop Diagram

#### 2.1.2 Stock and Flow Models

Stock and flow models allow for the simulation of systems once its basic structure is mapped out through a CLD. In generating a CLD, systems thinking practitioners must simply map out the direction of change, whereas in stock and flow models they must extend their understanding of the system to further quantify the magnitude or rate of this change. Stocks represents the elements that accumulate over time, such as water in a bathtub, data in a hard drive, or the number of shares on a social media website. Flows represent the change over time of these elements such as the flow of water from a faucet, downloads of data onto a hard drive, or upload of videos to a social media website. In Figure 2, the population CLD (cf. Figure 1) is converted into a stock and flow diagram. It can be observed that some elements of the CLD are converted into flows, some into stocks, whereas other elements need to be added to quantitatively complete the model.

In the following example, it is shown that birth rate and population affect the births (inflows) and population and life expectancy affect the deaths (outflows). With the increase in inflows stock accumulates and with the increase in outflows stock diminishes. Any element can not affect the stock directly, stock only increases or decreases with the inflows and outflows, but stock can affect different elements and elements can also affect the inflows and outflows, which, in turn increase or decrease the stock.

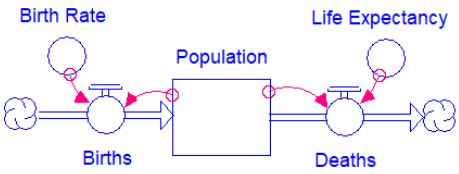


Figure 2: Population Stock and Flow Model

### 2.2 System Archetypes

A key insight in system thinking is that system behavior stems from the system's structure. Over time, theorists have studied various systemic structures and have catalogued a library of system archetypes of how systems behave (or misbehave). System archetypes are useful to understand patterns of behaviour that arise in different system.

System archetypes can be used diagnostically and prospectively: *diagnostically*, they are useful to gain insights into the behavioural structure of a system, and *prospectively*, they can help foresee unintended consequences (Braun, 2002). CLDs with specific structures give rise to predictable behaviour can be understood as specific archetypes even if the underlying content or field differs. Once an archetype is identified insights from disparate disciplines that also exhibit that archetype can be transferred. System archetype models are valuable for different organizations' stakeholders as it gives them a nuanced understanding of the root causes, problem symptoms and the reasons which are preventing them to move towards fundamental solutions in dealing with misinformation.

### 2.3 Principle of Leverage

The influential system thinker Donella Meadows defines leverage point as a place in a complex interconnected system where minimal change can produce long-lasting positive change. To address the underlying problem, leverage points must be sought out, and attention should be devoted towards those *high-leverage* points that can produce significant positive change in the long run without being neutralized by the systems (Yaqoob et al., 2018). System dynamic research shows that these policy intervention points are not where we mostly expect and if recognized they are likely to treat by intuition which leads us to the wrong direction and worsens the problem, as Forrester explained, due to the counter-intuitive nature of complex systems (Forrester, 1971). In her study on leverage points and where to intervene, Meadows states that we can produce the most substantial changes by changing the system's paradigm, goals, and rules (Meadows, 1999). Thus it is important to study the incentives and constraints of various actors involved in sharing information and judiciously use these in the plan of interventions.

## 3 Applying Systems Thinking to Misinformation

System thinking is well suited for the study of misinformation system through (1) the use of graphs of behaviour over time to study the dynamic behavior of the system; (2) the modeling of the interactions of the various subsystems using feedback loops for the causal understanding of the problem and by using stock and flows models to understand accumulation and transfers. By using these tools, we can utilize "system-as-cause" thinking to understand how problematic behavior such as misinformation emerges from the systemic structure itself in the larger information ecosystem.

We now apply systems thinking tools described above to misinformation. Using causal relationships as discussed in misinformation literature, we develop causal loop diagrams of system archetypes that are critical in governing the behaviour of the system of misinformation. We describe these archetypes through the use of brief case studies. We further combine these archetypes into a single CLD which provides a more holistic and interconnected view of misinformation. Lastly, we quantitatively model future possible trends, that would be the output of this single CLD using a stock and flow diagrams.

### 3.1 System Archetypes in Misinformation

#### 3.1.1 Fixes that Fail

The "Fixes that Fail" archetype describes how a quick fix reduces the problem symptom in the short run, while the unintended consequences of this fix further exacerbates the problem in the long run; and thus the fix may cause more harm than good. It can help the organizations to reflect on their underlying structure of quick fixes and anticipate the long term consequences. This archetype is illustrated in Figure 3 and depicts the unintended consequence due to the quick fix of warning labels on misinformation such as warnings from fact-checking organisations against true news.

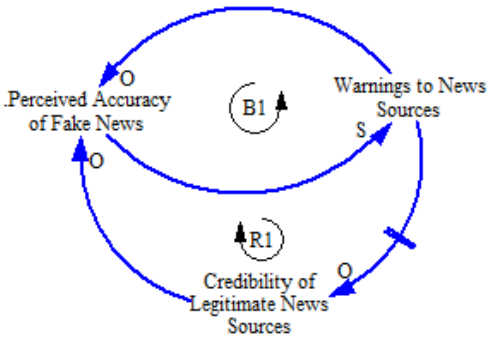


Figure 3: Fixes that Fail

In the short run, the quick fix succeeds to lessen the problem as individuals were able to differentiate between misleading news and accurate

news pointed out by fact-checking organisations as shown in the balancing feedback loop B1. On the other hand, Freeze et al. (2020) expound that the false warnings to credible news sources such as wrong labelling of informative news as inaccurate, reinforces the problem in the long run by damaging the credibility of legitimate news sources as shown in the reinforcing feedback loop, denoted by R1. People no more perceive credible news sources as legitimate after the fix introduced because people consider warnings to news sources as a label they start believing on other invalid sources or remain in doubt. Thus, a quick, obvious solution, in turn, exacerbates the problem in the future.

For instance, in the 2016 U.S. election, sharing of misleading news via social media became a common feature of communication, so fact-checking organizations came into action. Due to the elites' pressure to shape opinions of people, these organisations targeted valid and invalid news both, which affected the credibility of legitimate news sources in the long run because of biased and inefficient warnings (Freeze et al., 2020).

While giving warnings to sources to reduce the spread of fake news, fact-checking organisations should map out any potential unintended consequences of their warnings.

### 3.1.2 Shifting the Burden

The "Shifting the Burden" archetype suggests that symptomatic solutions temporarily alleviate the symptoms of the problem, thereby reducing the perceived need to implement a fundamental solution. It differs with the fixes that fail behaviour situation as problem symptom deteriorates not because of the fix but in spite of the fixes. Thus, this archetype behaviour draws attention to the underlying gap between the mounting pressure in the short-term and long term fundamental solutions.

We have sketched in the archetype how the use of AI technology helps detect deep fakes by authenticating content based on the findings of Westerlund (2019). However, researchers at The Brookings Institution's Artificial Intelligence and Emerging Technology put forth that using AI as defensive approach also widens opportunities of innovation in deepfake generation as detection methods are similar to the creation of deepfake, so inadvertently produce side effect while improving the deepfakes (Engler, 2019). As shown in the following archetype, using AI to fight with deepfakes, in turn, lessens the pressure to implement the fundamental solution such as funding for ethical and digital literacy. The organisations trap in the reinforcing loop, which is called as a 'vicious circle that can cause healthy growth or runaway destruction' by Meadows (Meadows, 2008). It is represented by R1 in the figure. It happens when organizations treat symptoms and obvious causes and do not think about the side effects of their proposed solutions.

For example, the technological advancement to track fake videos not only accelerated the invention of AI-enabled tools that help in the detection method but also give rise to apps which increased the misinformation and against ethics such as Deep Video Portraits, Deep Nudes, Grover, an AI developed by the University of Washington, first became an expert in generating fake news- so that it could detect it (Marr, 2019).

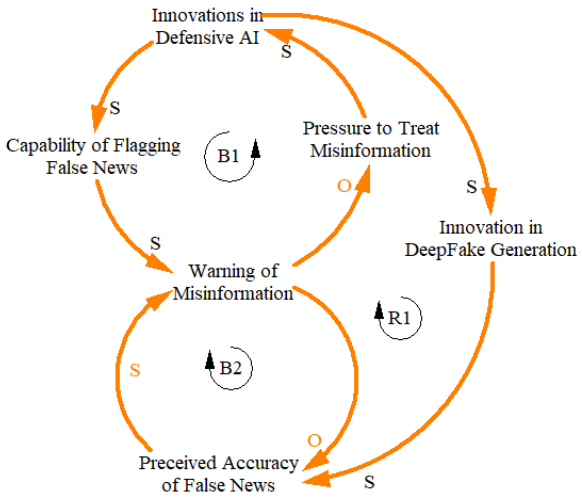


Figure 4: Shifting the burden

### 3.1.3 Success to the Successful

The "Success to the Successful" archetype exhibits that performance gap between two projects is because of frequently devoting resources to one project though both projects are equally capable. It gives insights to identify potential competency traps by tracing the history of the success gap.

As shown in Figure 5, devoting resources for using AI as a solution to track misleading content leads to innovation in AI; but on the other side, we find that tracking of misinformation by using AI occurs at the cost of reducing resources for teaching and developing the ethics needing to contribute in improving ethical decision making around mis-

information. This archetype portrays that success or failure is due to starting conditions; thus, it help managers discover internal performance gaps causes. Türegün sheds light on the causal relationship between ethical awareness and ethical decision making and expounds how ethical awareness improves ethical decision making in the long run (Türegün, 2018).

Organisations devoting most of the resources for technological solutions to detect misleading content should calibrate the opportunity cost of using tech-based solutions instead of other alternatives.

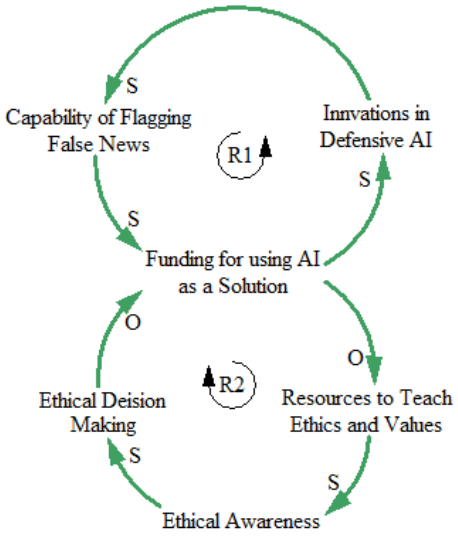


Figure 5: Success to the Successful

### 3.2 A Holistic Misinformation CLD

In the previous sections we have presented concepts related to misinformation as well known and studied system archetypes. We take this further to combine selected archetypes into a single causal loop diagram (see Figure 6) that describes the interaction between the different system archetypes.

In our discussion on the "Fixes that Fail" archetype, we saw how labelling of news, especially the incorrect labelling of news perceived as correct, may lead to increased skepticism of credible news. Warnings of misinformation, especially at a large scale, will be defined by innovations and the defensive use of AI. However, the "Shifting the Burden" archetype describes how improvements in AI for capturing fake news leads to innovations in generating more convincing fake news, as innovative technology that is developed to recognize false news may also be used to create it.

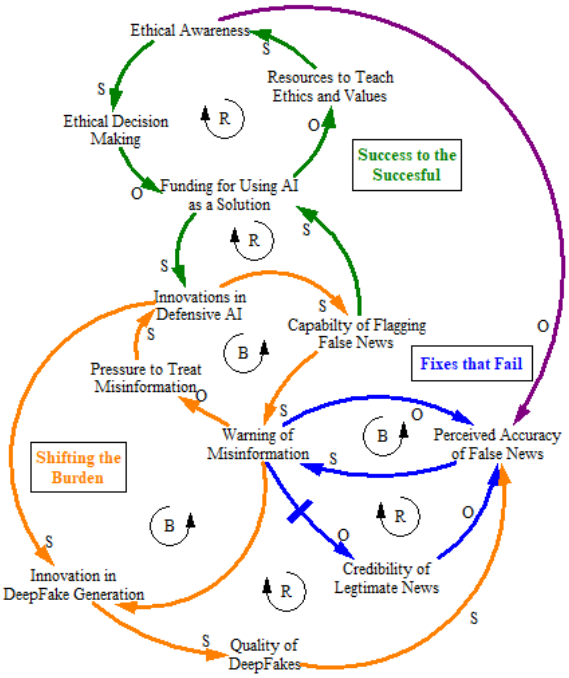


Figure 6: Causal Map of Misinformation

Lastly, the "Success to the Successful" archetype describes how investments in the technological solutions to misinformation, leads to diversion of resources from other possible solutions such as developing an ethical base for sifting and sharing misinformation without verification.

We find that the actions used to combat misinformation have the following unintended consequences:

- Funding technological solutions diverts funds from long term solutions such as funding for ethical and digital literacy.
- Innovations in defensive AI for detecting false news develops the same technology that creates the same false news
- Warnings of false news leads to skepticism of credible news sources

### 3.3 Simulating Possible Futures in Misinformation

The use of CLDs provide insights into the direction of change and the causal interaction between key variables. For instance we see that increased innovation in fake news generation will increase the Quality of fake news, and similarly a decrease in innovation in fake news generation will decrease the quality of fake news. The use of simulation allows researchers to explore possible future

scenarios. A case study of simulating the CLD discussed in the previous section is presented by using, simulation software, Stella, to illustrate this approach.

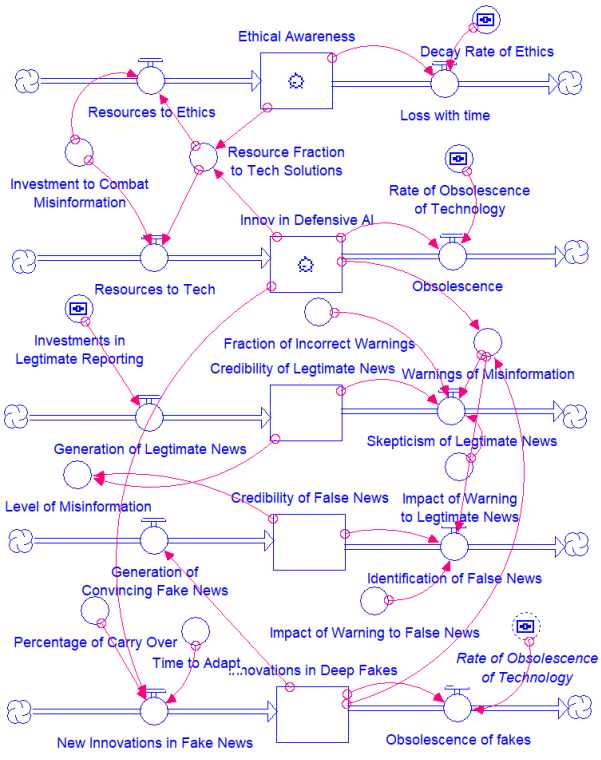


Figure 7: Stock Flow Diagram of Misinformation

### 3.3.1 Model Results

In this section we present selected results from the simulation of the stock and flow model illustrated in Figure 7. The absolute value of the selected indicators are not presented in the graphs, as their values relative to other indicators, as well as the dynamic trends that they exhibit, are of interest. Moreover, further work can include sensitivity analysis which is beyond the scope of this introductory paper.

The "Success to the Successful" archetype is illustrated in Figure 8, which presents predicted resource allocations. We see that due to the initial difference in starting conditions technology based solutions receive the majority of funds and developments and innovations in AI for detecting fakes see a spikes. However, due to the longer decay rate of gains in ethics as compared to the faster obsolescence rate of technology, the stock of "Ethical Awareness" around the initially new topic of misinformation is slowly able to grow over the years, and maintain its growth as it captures funds from the technology based solutions.

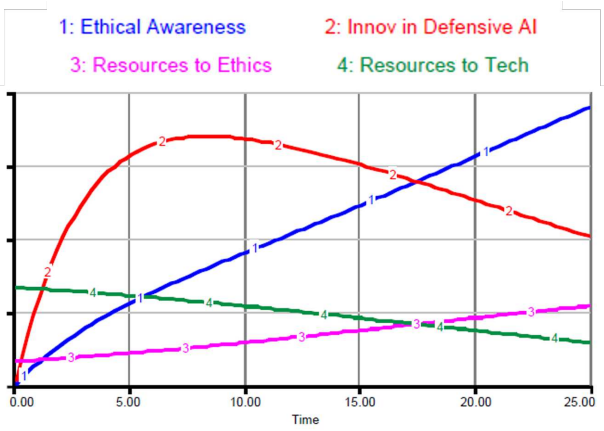


Figure 8: Resource Allocation

Figure 9 shows how early innovations in defensive AI are followed by innovations in deep fakes with some delay. The result of this is that although warnings for misinformation increases due to an initial large relative gap between the technical stock of false news sensing and generation capability, warnings for fakes fall over the years as this gap is considerably narrowed, reducing the capacity for detection of false news.

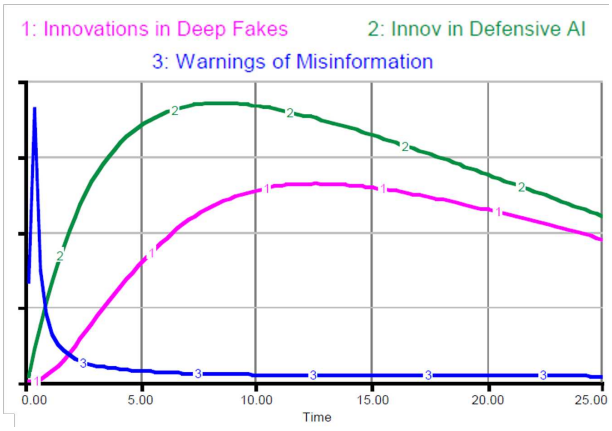


Figure 9: Effects of Innovations in Technology

Lastly, Figure 10 presents a surprising finding of this model. Although, legitimate news presently have more credibility, low investments in credible news sources coupled with burgeoning field of AI which supports the development of fake news, the credibility of false news may in fact over take the credibility of legitimate news. Factors that cause this are discussed qualitatively in previous sections, and are results of undesirable feedback effects of the efforts to curb false news. This result is surprising since constant investments are made into both technology and ethics based innovations throughout the considered time period. This high-

lights the importance for using a systems-based approach to vet new solutions to tackle false news from a holistic systems standpoint and potentially uncover counter intuitive effects such as these. Lastly, we see that only after witnessing a sustained period of growth does the level of misinformation begin to fall near the end of the simulation period.

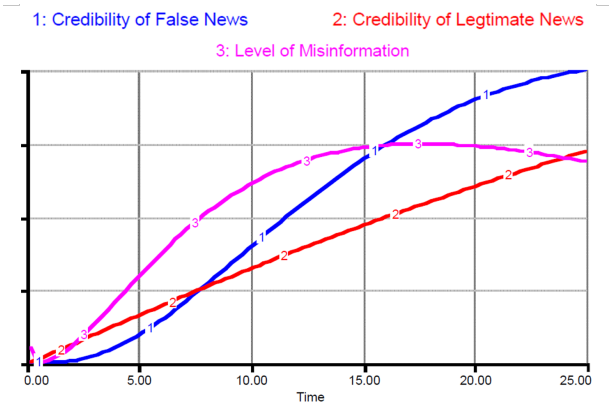


Figure 10: Possible Future of the Levels of Misinformation

## 4 Conclusions

Misinformation is the scourge of the modern information ecology. Attempts to mitigate misinformation have to address the formidable complexity of the interactions of various actors having different interests, points of view, and incentives. In this work, we have shown the feasibility of system thinking tools by proving some toy models of the proliferation of false information online ("misinformation"). Our purpose was not to develop the most valid model (which is a complex undertaking, best taken by a large multidisciplinary team), but to show the plausibility and viability of this under-utilized approach for the purpose of obtaining a big picture understanding of the misinformation ecosystem and compare different interventions. We have discussed how naive interventions in such complex adaptive systems can have counterproductive results and there is a crucial need to meticulously examine the unanticipated effects of these interventions. We propose that future policies and actions should not only rely on traditional linear thinking approach but also use system thinking tools to thoroughly understand the dynamics within the misinformation system and its interconnections with other systems.

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