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PERSPECTIVE

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Evidence-based strategies to combat scientific misinformation

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Nowhere has the impact of scientific misinformation been more profound than on the issue of climate change in the United States. Effective responses to this multifaceted problem have been slow to develop, in large part because many experts have not only underestimated its impact, but have also overlooked the underlying institutional structure, organizational power and financial roots of misinformation. Fortunately, a growing body of sophisticated research has emerged that can help us to better understand these dynamics and provide the basis for developing a coordinated set of strategies across four related areas (public inoculation, legal strategies, political mechanisms and financial transparency) to thwart large-scale misinformation campaigns before they begin, or after they have taken root.

Scientific misinformation undermines public understanding of science, erodes basic trust in research findings and stalls evidenced-based policymaking[1–3]. For example, in April 2018, Scott Pruitt (former administrator of the Environmental Protection Agency; EPA) signed a proposed rule that would sharply reduce the number of scientific studies the EPA can take into account, effectively limiting the agency's ability to regulate toxic chemicals, air pollution, carbon emissions and industries that science has already shown to have lethal impacts on human and environmental health[4,5]. This rule would, in effect, limit the amount of evidence-based information for environmental decision-making. The rule itself does not directly propagate misinformation (only the limiting of information), however, the political groundwork for such a rule was laid by a long-term and well-coordinated misinformation effort. Pruitt was joined at the announcement by Steve Milloy, a member of President Trump's EPA transition team, and perhaps the nation's most influential climate science contrarian. Milloy has a long history of working on behalf of industry-led scientific misinformation campaigns — first for tobacco companies to discredit research on the public health risks of smoking and, more recently, for fossil-fuel companies aiming to refute, confuse and obstruct acceptance of the reality of climate change[6].

Milloy declared that this new EPA rule to stamp out 'secret science' by "taxpayer-funded university researchers" is, in his words, "one of my proudest achievements. The reason this is anywhere is because of Steve Milloy"[7,8]. In another interview, Milloy explained his reasoning to *The New Yorker*. "I do have a bias. I'm all for the coal industry, the fossil fuel industry. Wealth is what makes people happy, not pristine air, which you'll never get"[9]. The new EPA rule was a long time in the making, proposed as legislation twice by Representative Lamar Smith (TX)[10]. Smith himself has been an outspoken climate science contrarian, has received more funding (US$772,347) from the oil and gas industry than any other sector[11], and is chair of the House Science Committee.

Similarly, when President Trump announced the withdrawal of the United States from the Paris Agreement, he was accompanied by Myron Ebell, the leader of the administration's EPA transition team, and an influential climate change contrarian. According to Internal Revenue Service filings, Ebell and connected think-tanks and front groups have taken in tens of millions of dollars from fossil fuel companies and wealthy family foundations such as Koch, Scaife and Mercer[12,13]. Echoing Steve Milloy (above) about the EPA rule, Ebell similarly reflected about the decades of political work that it took to get to this point. "This was a very long fight. And we have turned the corner"[12].

Many, especially climate scientists who have seen the evidence of warming first hand, wondered how we had reached this point. How had these once fringe actors, who tended to be overlooked and at times even laughed off as irrelevant bloggers, managed to embed their ideas so deeply into mainstream US politics? And how, over the course of the 1990s and 2000s, did half of the American public — and the large majority of the Republican Party and its supporters — increasingly lose trust in, and become so antagonistic towards, robust scientific facts with such dire consequences?

Recent research has shown us that the spread of scientific misinformation — at a scale and level of complexity never before witnessed — was the main culprit behind this trend, altering the nature of public debate, sowing seeds of cultural and political polarization, and making meaningful legislative action nearly impossible[13–18].

But scientific misinformation is not a modern invention. We know from the seminal work of science historians that it has been produced and deployed to confuse people throughout the ages, creating false controversy about, for example, the scientific evidence of the dangers of smoking tobacco, the causes of acid rain, the role of chlorofluorocarbons on ozone depletion and, most recently, the reality of anthropogenic climate change[19–22].

Fortunately, recent years have seen considerable progress in both the scale and complexity of research into the origins and impacts of scientific misinformation campaigns. In particular, this research has focused on identifying the elaborate institutional structures behind these campaigns and the coordination among institutional actors. In addition, it has shown there to be a patterned organizational topology in the production of misinformation that is intended to confuse the public and/or block science-based policy change. These organizations include think-tanks, philanthropic foundations, corporations, trade associations, advocacy groups, front groups, shell corporations, lobby groups and public relations firms[14].

Aiming to drive the cultural and political conversation, research has shown that this coordinated network employs a multifaceted strategy to develop and promulgate ideological viewpoints and

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policies that are favourable to political and/or industry interests[14–17]. Creating the appearance of scientific uncertainty about issues for which the solutions may threaten these interests is therefore critical to this intellectual infrastructure. The network is spear-headed by a handful of in-house and externally funded experts — often credentialed with a PhD —who discredit scientific consensus, misrepresent and draw selectively from scientific literature, and create the appearance of scientific legitimacy through their own conference presentations, questionable scientific research, white papers and web articles, thereby raising the spectre of doubt about established facts[23,24].

Public relations scholars have identified why scientific misinformation can seem to be so accurate and reliable, or even part of a legitimate 'grassroots' movement. The corporate community has, over time, integrated public relations and lobbying into its basic business strategy[25]. Between the 1970s and the 1990s, corporate public relations firms built advocacy structures to anticipate and manage perceptions of public-policy issues. These structures include public–private sector partnerships; events and sponsorships; industry benchmarking and reporting; awards/certification programmes; media training seminars; and international technology transfer systems[26].

This organizational strategy simulates a unified front to the public, creating the appearance that multiple and diverse voices are simultaneously advocating for a uniform position. This perception is reinforced via various communication channels, including academic journals, policy papers, press briefings, steering the media towards 'false-balance' coverage under the guise of presenting 'both sides' of an alleged 'scientific debate', personal attacks against prominent climate scientists and advertising to reach targeted audiences[27].

For example, this process has been revealed by research using natural language processing and automated machine learning, which has helped researchers to identify and track misinformation within massive collections of unorganized texts produced by organizations, the news media and politicians[15,16,18,28]. When these data-driven techniques are combined with network science, researchers can trace the production and diffusion of misinformation within a larger ecosystem of organizations that share complex financial and political connections, scientifically assessing the impact of these relationships.

This work has been flourishing in reaction to the startling success of climate misinformation campaigns, but it is also spurred by fellow scientists. A 2017 article in *Science*, for example, called for more research to "spotlight political interference in science-based policy development"[29]. The findings from the new research outlined above provide a number of pathways to confront large-scale misinformation campaigns. In this Perspective, we synthesize these recent social science advancements to propose a coordinated set of strategies across four interconnected areas: public inoculation, legal strategies, political mechanisms and financial transparency.

Public inoculation

It is not enough simply to communicate to the public over and again the scientific consensus on human-caused climate change[30,31]. Nor is it ultimately effective to repeatedly engage in scientific debate with industry-funded scientists (Fred Singer, for example) or political pundits, hoping to debunk their spurious findings so that the public will finally see the light. Because, paradoxically, the partisan divide on climate change grew most rapidly at the very point at which the scientific community became virtually unanimous in its conclusions about the reality and risks of anthropogenic climate change[32].

A growing body of work argues that individuals' perceptions of scientific information are deeply informed by their 'cultural cognition', or, the ways that they understand scientific information[33–35]. This line of thought suggests that individuals' preexisting ideologies and value systems can play a significant role in whether they accept or reject scientific consensus[36]. Going a step further, some argue that we have now entered an altogether new epistemological moment — the 'post-truth' era — in which the public's trust in facts and evidence more generally is eroding[37].

Researchers have begun to tease apart factors that influence the cultural cognitive process of interpreting scientific information, noting the importance of individuals' religiosity; political affiliation;[38] beliefs about the role scientists should play in policy-making;[39] beliefs about the relative independence of science from economic and political interests;[34] levels of trust in venues that disseminate science information (such as news media, government, science TV);[40] and geographical context[41]. This body of research suggests that a blunt affirmation of the scientific consensus on climate change is not alone sufficient to change the minds of skeptical publics.

One attempt to address this quandary has come from social science researchers who have integrated medical principles on preventing infection through the use of vaccines to develop and test 'attitudinal inoculation'[42,43]. In this view, public attitudes about climate change can be successfully 'inoculated' against misinformation by exposing people to a dose of refuted arguments before they hear them. Similar to how a vaccine builds antibodies to resist a virus a person might encounter, attitudinal inoculation messages warn people that misinformation is coming, and arm them with a counter-argument to resist that misinformation. Recent experimental research found that attitudinal inoculation has an effect on individuals across a political spectrum, indicating that this technique may be able to overcome some differences in cultural cognition[42,43].

To improve and expand this tactic, the public should be inoculated against the sources of scientific misinformation as well, by drawing more explicit attention to exactly who is behind these messages — that is, the financial contributions and economic motivations behind the bad-faith information they will encounter.

Inoculating the public may be an especially promising strategy for heading off misinformation campaigns before they take root, but future research on inoculation is needed to assess whether or not — and precisely how — this practice can be extended beyond experimental settings and applied more broadly to build up resistance to misinformation within large segments of the public[37]. As this body of research grows, it may investigate the following as possible avenues of inoculation. First, and perhaps most common, is for academics to work with reporters to disseminate inoculation messages via the media. This may indeed prove increasingly difficult in our fractured media landscape, and recent research has suggested that we ought to focus more attention on repairing public perceptions about scientists themselves, which may involve sidestepping the media and directly engaging with local publics towards this end[39]. Second, teachers have begun to explore inoculation-based instruction in classroom settings, with the aim to directly refute common sources of misinformation and to help young students recognize their own tendencies towards motivated reasoning[44]. Rigorous evaluation of these teaching strategies within a range of socio-political contexts can help determine whether inoculation in schools may be used as a long-term strategy against misinformation. Third, the public also take cues from elites and thought leaders, and thus working with elites on inoculation strategies might also prove useful — especially those from communities that are exposed to higher amounts of misinformation (the handful of US evangelical leaders defending climate science[45], for example).

Inoculation, however, succeeds when the patient is not already sick. In the case of climate change contrarianism, misinformation and dismissal of scientific facts are commonplace. Grappling with these broader trends of misinformation and a declining belief in truth itself, Lewandowsky, Ecker and Cook[37] propose 'technocognition', an agenda that would "design better information architectures that can build bridges between the socially-defined epistemic

islands that define the post-truth era". As one of the few proposals to holistically address broader concerns of a post-truth society, the technocognition approach would integrate both technological adaptations to prevent misinformation spread, and cognitive approaches to education and communication. We argue that an additional component of this agenda must include coordination with the following politico-legal changes that could help to stem the flow of misinformation itself.

Legal strategies

Newer research has revealed the extent to which industry actors at the centre of the climate misinformation network knowingly misled the public about the reality and risks of climate change. For example, Supran and Oreskes empirically examined climate change communications from ExxonMobil between 1977 and 2014[17]. They found that 80% of ExxonMobil's internal documents acknowledged that climate change is real and human caused, yet 81% of their public-facing materials communicated doubt. This research, when combined with recent network analysis of ExxonMobil's funding of front groups and think-tanks that spread misinformation[16], provides evidence of both the company's internal motivation and its strategic role as benefactor for a multipronged network aiming to mislead the public.

Findings such as these are playing a critical role in the slew of recent lawsuits by cities and counties in the United States and the United Kingdom, which seek to hold fossil fuel companies accountable for the impacts of climate change. These suits allege (based on internal documents) that the companies were well aware of the immense risks of using their products, yet deliberately downplayed them. This legal strategy is reminiscent of the case against the tobacco industry in the 1990s, which eventually led to a US$206 billion settlement, the largest of its kind in history. Such lawsuits may prove to be the most effective strategy for directly confronting and discouraging the spread of scientific misinformation, but they are also very costly and have a long time horizon. Yet as these lawsuits have gained more traction in the courts, they have also gained traction in the media. In turn, news coverage of these lawsuits serves to influence the court of public opinion, and perhaps to further inoculate the public about industry efforts to deliberately mislead them.

Research on the specific networks and mechanisms that create and spread climate misinformation has also buttressed legal efforts to defend climate scientists who have been personally attacked for their research. Placing these attacks within the context of this larger network of actors is a valuable tool for making legal arguments. For example, the attack on climatologist Michael Mann was led by the American Tradition Institute, which investigative journalism revealed to be a think-tank closely tied to a network of industry interests and affiliated misinformation think-tanks (such as the Heartland Institute, The John Locke Foundation and the Cooler Heads Coalition)[46]. With ad hominem attacks against climate scientists on the rise[47], continued research into the networks and mechanisms of scientific misinformation campaigns will only improve legal defense efforts for scientists who are personally and professionally threatened[48].

In addition to improving defensive efforts, research from collective behavior and social movements provides strategies for improving offensive efforts that might lead to legal change. Diani and McAdam show the value of applying network techniques to empirically grasp well-coordinated social movements[49]. Mapping out the configuration of individuals and organizations involved in climate change misinformation can help to empirically identify the most prominent and influential legal targets. Empirical and theoretical work from organizational sociology on institutional isomorphism and organizational fields can assist with this process by providing an analytic framework for understanding whether certain organizations are leading the misinformation movement, while others may be simply imitating or following their lead[50,51]. Legal reform around the issue of misinformation should address these inherently networked aspects of the creation and promulgation of such misinformation.

Political mechanisms

Any political strategy to combat scientific misinformation must confront the partisan gridlock around climate change that has been institutionalized into the US political process[15,52]. After decades of sowing the seeds of public and political polarization, the misinformation network has seen huge returns on their financial and political investments in the way of measurable impacts on political outcomes including elections, legislation, EPA rulings, vacating international agreements, party platforms and shifts in public opinion towards confusion and doubt.

One important mechanism that the network has employed to achieve this success is to attach their scientific misinformation and affiliated ideologically based arguments to real-world economic and political problems (such as energy independence, deregulation, nationalism). Through this process, scientific misinformation attains concrete utility to key actors affiliated with the larger institutions in the network (political action committees, citizen activists, social media users, elected officials, for example) whose interests are directly or indirectly threatened by actual scientific findings. We highlight here three political mechanisms for confronting this network.

First, we must deploy social science research and public vigilance to better understand when and how the political process is being manipulated. For example, according to its own internal investigation in 2018, the energy company Entergy Corporation acknowledged hiring a public relations firm that in turn contracted a company that paid 50 actors to appear at a New Orleans City Council hearing on a controversial new power plant. Clad in bright orange T-shirts printed with "Clean Energy. Good Jobs. Reliable Power", these performers were hired to create the mirage of public support for Entergy's bid to build the plant. The actors, posing as grassroots activists, signed a non-disclosure agreement, were given a financial bonus if they delivered a prewritten speech and were instructed to applaud every time someone at the meeting disparaged renewable energy[53,54].

The institutional networks spreading misinformation at large scales continue to develop sophisticated techniques like this to mimic authentic mobilization, impersonate public concern, produce spurious scientific research and steer the political process towards their interests, while at the same time disguising their funding activities[25,26,55–58]. Extant social science research has certainly provided a window into these complex political efforts, but much more is needed moving forward.

Second, a growing number of organizations are divesting their assets from firms that are involved directly or indirectly with fossil fuel extraction. Inspired, perhaps, by calls from moral leaders such as Archbishop Desmond Tutu, who suggested in 2014 that "people of conscience need to break their ties with corporations financing the injustice of climate change"[59], this movement aims to defund and publicly stigmatize the industry and its associates. At present, fossil fuel-related divestment totals more than US$6 trillion, with the largest share initiated by faith-based organizations[60]. For example, the World Council of Churches — representing 500 million Christians worldwide — has screened out investments in fossil fuel companies. Dozens of Catholic institutions, as well as Catholic banks with assets of over US$8.8 billion, have also pledged to divest their assets from fossil fuels, as have major cities including New York, which recently pledged to divest US$5 billion from 190 fossil fuel companies in its portfolio[61,62].

Third, we must target strategic efforts in geographic areas that are both particularly vulnerable to the short-term impacts of

climate change and have widespread public and political skepticism about climate change (for example, Florida and Alaska). In addition to the impact of social context discussed above (political affiliation, education) — which we believe will continue to play the leading role — we also know that personal experience with adverse biophysical events can also affect risk perceptions[63,64]. Tactics in these targeted areas might include obtaining better media coverage of local candidates' views on climate change science, inoculating these specific communities against these candidates' misinformation messages and explaining their funding sources, and pursuing strategic lawsuits tailored to address the disproportionate effects these vulnerable areas are experiencing due to climate change.

Financial transparency

Research shows that private philanthropic and industry funding enabled the large-scale proliferation of scientific misinformation[13–17,19,65]. Ideologically compatible think-tanks and advocacy groups receive the largest share of such funding, taking in hundreds of millions of dollars. Some of this funding comes directly from a few large corporations, but the large majority is provided by newly established, donor-directed foundations that shield the contributor's identity from the public (for example, DonorsTrust, Donors Capital Fund). Within the last ten years alone, giving by these donor-directed foundations to organizations dedicated to spreading misinformation about climate change has more than quadrupled, topping US$100 million[13]. Lobbying is another area where the financial resources of fossil fuels interests create a massive imbalance between proponents and opponents of climate action. From 2000 to 2016, over US$2 billion was spent on climate lobbying. The spending by fossil fuel and transportation corporations, utilities and affiliated trade associations dwarfed those of environmental organizations and renewable energy corporations by a ratio of 10:1 (ref. [65]). Weakened campaign finance laws[66], along with the growth of untraceable donor-directed philanthropy, have made it more difficult to pinpoint funding sources and amounts, and are symptomatic of the ways in which corporate and individual giving for political ends influence scientific misinformation efforts[16].

Although empirical knowledge of funding flows within these institutions and across networks has improved in recent years, it is still based on piecemeal data that is often extremely difficult to uncover, and intentionally kept hidden. Fortunately, non-partisan organizations tracking money in US politics (such as the Center for Responsive Politics, Sunlight Foundation) have become important resources for researchers in need of reliable funding data. Passing new legislation to improve funding transparency would drastically improve the availability of such data.

Better transparency may also prevent future misinformation campaigns from gaining traction in the first place. Had better transparency legislation been in place 30 years ago, it is reasonable to assume that hundreds of millions of dollars would not have been so easily, and so furtively, channelled between corporations, family foundations, think-tanks, public relations firms, super-PACS (political action committees), shell corporations and front groups dedicated to spreading scientific misinformation. Financial anonymity provides fertile ground for the development of these networks[15,16,19,67], and the cultivation of their intellectual and organizational power. Any new legislation would no doubt be vigorously opposed by many of the same actors in this network. However, the ongoing absence of such legislation only heightens the need for continued research on funding flows, which would serve to strengthen many of the strategies proposed above.

Conclusion

As science continues to be purposefully undermined at large scales, researchers and practitioners cannot afford to underestimate the economic influence, institutional complexity, strategic sophistication, financial motivation and societal impact of the networks behind these campaigns. The spread of misinformation must be understood as one important strategy within a larger movement towards post-truth politics and the rise of 'fake news'[37,68]. Any coordinated response to this epistemic shift away from facts must both counter the content of misinformation as it is produced and disseminated, and (perhaps more importantly) must also confront the institutional and political architectures that make the spread of misinformation possible in the first place. This therefore requires a dual process, and as a result, the strategies presented here do not exist in a vacuum from one another, but must be better coordinated if they are to be effective. For example, public inoculation and legal strategies depend on improved financial transparency, just as financial transparency can similarly be strengthened by legal strategies that are themselves dependent on continued research into the financial and ideological sources of misinformation. Leaders across these four strategic areas must also be better coordinated to bring together and synchronize the efforts of researchers, legal experts, political leaders and everyday citizens working to confront misinformation.

With the progress that has been made in recent years — especially sophisticated data-intensive research on the strategies, organization and funding networks behind climate misinformation — we are hopeful that the set of coordinated strategies suggested here will prove to be successful in the long-run — not only for turning the tide on the critical issue of climate change action, but also for preventing future cases of large-scale manipulation from taking root.

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Competing interests

The authors declare no competing interests.

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