

Exploring Space Science Community Engagement with Storylistening Principles

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Introduction

In this synthesis paper, I consider the ways in which the science community has engaged with narrative construction in the context of the storylistening framework and two key areas of active development in space policy: dark skies protection and space domain awareness. Having first summarised the topics under consideration, I consider three case studies of narrative representations in science. The first case study considers fictionalised representation of space debris and dark skies in the form of science fiction narratives and their dialogue with science communicators. The second case study focuses on public communication by scientists regarding light pollution in the form of journal articles, also considering reaction to their publication. Finally, the third case study discusses *Our Fragile Space*, an artistic space debris narrative designed as science communication cocreation between the artist and scientists. In each case, I evaluate to what extent the key principles of collective identities, new framings, narrative models and anticipations are represented in the dialogue as presented by the space science communities, and as interpreted by the media and public.

Dark Skies Protection and Space Domain Awareness

The issue of **dark skies protection** is not a new one. The growing ambient light around cities and towns calls into question the relative value of industrial (e.g. businesses working through the night), public safety (e.g. provision of street lighting), environmental (e.g. impact of light pollution on wildlife) and cultural concerns (e.g. difficulty of discerning the Milky Way and constellations in urban environments, impact of artificial light on astronomical observatories). *Light pollution* rose to prominence as a term in the 1970s, driven in part by the work of Riegel (1973), Walker (1973) and others advocating for astronomical dark skies, and in 1979 the UN Convention on Long-Range Transboundary Air Pollution defined artificial light at night as a pollutant within its remit. Extensive work in the decades since has demonstrated the wide range of negative impacts of artificial light at night, including risks to mental and physical health (e.g. Chepesiuk, 2009; Sánchez de Miguel et al., 2022)

While no international framework exists for regulating light pollution, increasing recognition of its impacts, together with technological advances, has led to adoption of low energy, downward-focussed technologies for street lighting, and consideration of light pollution impacts in planning and regulation decisions.

In the last few years, however, the issue of dark skies protection has faced a new challenge - and one which calls for attention from policymakers on an international level. Technological innovations have led to the creation of *satellite mega-constellations*, primarily for telecommunications (and particularly high-speed internet) applications. The previous generation of satellite communication mostly relied on signals relayed by single space vehicles in the distant geosynchronous Earth orbit (GEO). Starting in the 1990s, the geosynchronous telecom satellites were complemented by small groups of cooperative satellites, known as

constellations, in a much closer medium Earth orbit (MEO). These are used primarily for navigation purposes, with the best known being the Global Positioning Satellite (GPS) system.

The first telecommunications constellations in low Earth orbit (LEO) were also launched in the 1990s, largely to provide mobile phone services. The low power available to compact hand-held devices precluded their broadcasting reliable signals to GEO, requiring a closer satellite. To ensure that at least one such rapidly-orbiting satellite was always above the horizon required that many identical satellites were launched, with the early Iridium constellation boasting almost a hundred spacecraft. However, the rise of demand for high-speed internet, together with increasing commercialising of space access, has led to a step change in the rate of satellite construction and launching. Commercial company SpaceX launched the first satellites in its Starlink mega-constellation in 2019 and will exceed 12,000 individual spacecraft, in an orbit about half the height of the early Iridium network. Their launches each release a train of bright satellites that are later boosted into higher and more dispersed orbits. These have attracted intense attention and media interest (e.g. Pettit, 2020). Several similar mega-constellations either proposed or under construction, with projected numbers of satellites in LEO reaching several tens of thousands within the next decade (Barentine et al., 2023).

The existence of these mega-constellations enters dark sky protection debates in several ways: the impact of bright artificial sources on naked-eye-visible stellar constellations, particularly at twilight; the impact of fainter satellites on optical astronomy; and the impact of communications to and between satellites on radio astronomy. As a result, learned societies and associations in the space science area have intensified campaigns of information and lobbying regarding dark skies protection in recent years, with the International Astrophysical Union (IAU) creating its Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (CPS⁵⁹) and associated Dark and Quiet Skies Global Outreach Project in early 2022. Amongst other advocates for such dark sky protection are individual astronomers and cultural champions, both in the academic and amateur domains (see e.g. Dunnett, 2015, for an analysis of the cultural geography of light pollution in the UK).

A related concern, also rising in prominence in recent years, is the difficulty of tracking and controlling the interactions between orbiting material, particularly between active and inactive satellites or other debris generated by human activities. This field is increasingly described as **space domain awareness** (SDA), a general term which incorporates aspects of satellite tracking, space sustainability, technology development, space policy and socio-economic studies. It involves challenges of identifying, tracking, monitoring, regulating or even manipulating the build-up of human-generated space debris.

The pioneering work of Donald Kessler and collaborators in the 1970s, hypothesised a chain reaction in orbit - each collision between space craft generating debris which damaged other craft, until the entire orbit became inimical both to human life and other satellites (Kessler & Cour-Palais 1978). Several prominent incidents involving damage to active satellites or crewed spacecraft being struck by debris at orbital speeds (kilometres per second) occurred in the 2000s-2010s, raising fears of a Kessler effect event with devastating impact on an increasingly satellite dependent society (see Witze, 2018, for a historical overview). The rapid

⁵⁹ <https://cps.iau.org>

growth in satellite mega-constellations since 2019, together with issues of governance and regulation has caused further concern amongst the scientific community. The rate of collision incidents is increasing. Both the Chinese space station and Aeolus, an Earth-monitoring scientific observatory operated by the European Space Agency, for example, have been forced to execute orbital avoidance manoeuvres when Starlink satellites pass within their collision exclusion zones - the disparate safety margins required by the small, mass-produced communication satellite, and the large, one-off scientific facilities, as well as the lack of a clear order of precedence or agreed process can cause confusion and miscommunication over the need for such manoeuvres.

The need for both data acquisition and space policy development in the areas of SDA and Dark Skies has been highlighted by several governmental and government-sponsored agencies, including NASA, ESA, the UK Science and Technology Facilities Council, the UK Office for Science and Technology and the UK Space Agency. The space sciences community has responded with initiatives such as the University of Warwick's Centre for Space Domain Awareness and the Global Network on Sustainability in Space (GNOSIS⁶⁰), which brings together science and humanities academics, industry and policymakers. Crucially, while astronomers and space scientists are both stakeholders and data gatherers in these issues, their views and results must be clearly communicated in non-technical terms. These will inevitably be set against the potential societal and economic benefits of space commercialisation, and both public and governmental stakeholders are also involved. As such, technical and data-driven reports must be supplemented by narrative evidence - a form of storytelling and anticipatory modelling that is both constructed by the scientists themselves and generated in response to scientific reporting.

While narrative evidence has been considered in specific astronomy-related contexts, for example in areas such as dark skies tourism (Derrien & Stokowski, 2020) or preservation of traditional culture (Hamacher et al., 2020, Blair 2018), to date there has been little engagement of western scientists with the evaluation of narrative evidence in this field, or of how such communication has been interpreted. The storylistening technique (Dillon & Craig, 2022) provides a helpful framework for the synthesis of such narrative evidence.

Fictional, Scientific and Science-Adjacent Narratives

The storylistening framework provides a context for the interpretation and incorporation of narrative evidence in public policy and decision making. In this context narrative evidence can be interpreted broadly. From a literary and film studies perspectives, narratives are fictional or fictionalised accounts which tell stories. These may be based to a varying degree on factual information but prioritise a narrative structure, as codified, for example, by the narrative theory of equilibrium which asserts that most stories establish an equilibrium, disrupt it, recognise and resolve the disruption and finally reach a new equilibrium (Todorov 1971).

However, in media studies and related fields, the study of narratives includes the way in which information is presented, for example in the construction of news reports. More generally, elements of narrative in the form of personal stories or contextualisations of information are ubiquitous in the interactions of humans with the world around them, contributing to reporting

⁶⁰ gnosisnetwork.org

of medical, legal, cultural and even scientific issues. In each case, the current status quo must be established, a change to it considered, and the results of that change communicated to an audience.

Science communication studies ask fundamental questions about how those engaging in scientific research interact with those outside their specialisms, in areas ranging from the practical applications of medical science to the less applied areas such as quantum physics or astrophysics. One area of recent scholarship has focussed on the nature of the information transfer - whether it is unidirectional, bidirectional or involves co-creation, or alternatively whether it lies within a deficit model, a dialogue model or a participation model (see e.g. Trench 2008). Science communication, it has been argued, is often distinct from science engagement, with the former positioning scientists as separate from, or even superior to, others, while the latter recognises the importance of two-way information transfer and discussion.

Another important framing for science communication is the intent of the interaction - whether scientists present facts without imposing their own opinions (an *honest broker*, Pilke, 2007) or actively curate the evidence in order to advance their own view (acting as either as an acknowledged *subject advocate* or a more insidious *stealth advocate*, Pilke, 2015). While this view of science knowledge brokerage may be overly simplistic (e.g. Gluckman et al., 2021; Turnhout et al., 2013), an acknowledgement of the broker's intent and positioning is of crucial import in interactions between scientists, the public and policymakers. Such discussions have been further stimulated by the Covid-19 pandemic, which highlighted the need for clarity and trust in science communication.

Traditional science communication from active research scientists has been largely unidirectional, in the form of press-releases and similar publications. Indeed, a recent analysis of science communication strategy by the European Space Agency (ESA) identified 95% of its activity in 2018-2020 as corresponding to a sender-receiver deficit model, in which the audience is seen as passive or even potentially hostile (Pfleger et al 2022). This is slowly changing. There is an increased recognition of community input, with interdisciplinary workshops (e.g. Royal Astronomical Society, 2020; Walker et al., 2020; Hall et al., 2021; GNOSIS, 2022) that promote mutual exchange between scientists, industry stakeholders and policymakers.

However the majority of scientific issues are still communicated to the general public through the press-release paradigm. Here, scientists, sometimes acting in partnership with local or institutional media specialists, attempt to frame their findings in a non-quantitative manner, to engage the widest possible audience. Press releases often develop stories contextualising the work reported in the lived experience of the reader, or serve a modelling or anticipatory role connecting the reader to technical topics by analogy or extrapolation. However, such press releases are frequently not reported verbatim. As a result, the public imbibes scientific output mediated by news agencies or individual journalists. These may tailor the content or its presentation to the interests of narrower target audiences and introduce elements of framing or storytelling in *science-adjacent* narratives. Yanovitzky & Weber (2019) have positioned such news media as knowledge brokers, emphasizing their role in linking knowledge between fields and to the public, but did not consider their narrative role. Nor has the role of members of the public imbibing such narratives in building their own stories in which to contextualise the information received sufficient attention. The importance of such alternative forms of

information dissemination has been recognised in the adoption by scientific journal publishers of the commercial altmetric system⁶¹, which traces the online impact of reported research, allowing authors to monitor the narratives springing from it. As Craig & Dillon (2023) have argued, such narratives are relevant to evidence collection in the science policy field and must be analysed critically and robustly.

Formative Readings

The use of storylistening to evaluate such science and science-adjacent narratives can be explored with reference to formative readings, in the areas of fictional narratives with scientific input, purpose designed science advocacy communication and its interpretation in the media, and artistic co-creation in science communication.

Case Study 1: Fictional Narratives

Fictional narratives have featured concerns over space domain awareness since long before the field gained popular attention. James White's short story *Deadly Litter* (1964) explores a future in which the release of anthropogenic debris into space is seen as an abhorrent crime. In this narrative, a number of vessels have been lost due to debris strikes, resulting from litter ejected into space decades or even centuries before. A retired ship's captain is investigated for this crime, committed in an effort to save his own spacecraft eleven years previously. By presenting the narrative from the point of view of the investigator, White invites the reader to share his disgust at the crime and identify with those potentially threatened by space debris. The framing does not dwell on the mechanisms of space travel or its wonder, but instead roots the narrative on Earth in a more familiar police-procedural context, easing the cognitive dissonance of readers for whom space was a distant and unfamiliar setting. In building its model of a future in which space travel is routine, yet remains dangerous, *Deadly Litter* is notable for predicting the sheer mundanity of much space debris:

“There had been a time when people thought it funny that a ship could be wrecked by a few tea leaves, or a frigid, iron-hard potato peeling. But among spacemen, Gregory thought sourly, it was the sort of thing at which you died laughing.” (White, 1964).

White himself had no formal scientific training, although he became a technical clerk at an aircraft company soon after publishing *Deadly Litter*. Given its early date, written just a few years after the first human space activity, the story is limited in its anticipatory value for space debris policy today, positioning the issue as a threat only to those in space, rather than to the whole of society on the ground. It is nonetheless a striking early example of narrative model creation in this field.

More recent examples of SDA narratives can be found in the animated television series *Thunderbirds Are Go* (2015-2018), which presented an anticipatory vision of space utilisation complete with space junk clear-up efforts and considered debris production from an orbital collision (Stanway, 2022). Space clean-up was also the major theme of the manga (Japanese comic) *Planetes* (Yukimora, 1994-2004), and the anime (television animation) adaptation (Taniguchi, 2003) developed with scientific input from the Japanese space agency, JAXA. *Planetes* is a complex series which explores the framing of space from the point of view of

⁶¹ <https://www.altmetric.com/>

commercialisation, globalisation, equitable distribution of resources and exploration. Its narrative modelling of a near-future commercialised space allows the writers to anticipate concerns over space debris threats to spacecraft, and radiation damage to space travellers, amongst political and psychological issues. The narrative model of young protagonists coming of age in a congested space encourages the target audience to identify with their struggles. The series has been cited by Gärdebo and coauthors (2017) in their analysis of the role of satellites and space debris in the epistemological basis of the modern technosphere and would reward further study. However *Planetes* is unfortunately little known in the UK and has not had a significant popular culture impact.

A fictional narrative repeatedly referenced in media coverage of space domain awareness topics, is the feature film *Gravity* (Cuarón, 2013). This story follows two astronauts, stranded in space when a debris-generation chain reaction destroys the Hubble space telescope, the space shuttle, International Space Station and Chinese Tiangong space station. Cut off due to the destruction of communication satellites, the protagonists must move between space vehicles and find a way to descend safely to Earth. The film has been extensively studied in the context of its sound (Canduso, 2016) and visual design (Atkinson, 2016), its philosophical (Read, 2023) and psychological (Blothner, 2015) positioning and portrayal of technology and gender (Palmer, 2019) in space.

The framing of Cuarón's film can be read in two principal ways: with strong elements of nationalistic positioning that echo the 1960s Space Race, or as a human-against-nature survival narrative. The astronaut protagonists are Americans, working for NASA rather than representing commercial interests, while the debris-generation chain reaction is initiated by a Russian anti-satellite missile test. Space debris itself represents the film's main antagonist and human space utilisation in this film is presented as both heroic and at threat from human actors. By focussing on individuals, rather than the politics or reactions of those on Earth, Cuarón frames the story as a battle for survival against the harsh space environment. However this reading is not entirely straightforward. Carroll (2019), for example, has positioned *Gravity*, alongside *The Martian* (Scott, 2015), as a reaction against the atopia (or "non-space") and subsequent isolation that has resulted from globalisation. While national identity is certainly invoked, both through the protagonists' exchange of their respective back stories and through comments such as one astronaut noting that "*Half of North America just lost their Facebook*", collective identity is not as strong a theme in the film as individualism. Indeed, the lead protagonist spends a substantial fraction of the film alone and incommunicado.

In a science-adjacent narrative context, *Gravity* has also been subject to scrutiny regarding its technical accuracy (or lack thereof) by prominent science communicators. The extent to which *Gravity* constructs an accurate narrative model in which to contextualise the threat of space debris has been questioned by astronomers Neil deGrasse Tyson (Watercutter, 2013) and Phil Plait (Plait, 2013) and former astronauts Scott E. Parazynski (Watkins, 2013) and Garrett Reisman (Reisman, 2013) each of whom noted factual errors in the film's modelling. Perhaps most prominent of these is the plot-driven premise that everything in space occupies a very similar orbit, allowing the astronauts to travel straightforwardly between space stations, and the debris to equally damage both LEO human space activities and GEO commercial communication satellites. In fact, the relative altitudes and orbital velocities would render this scenario impossible as modelled. Nonetheless, all the commentators enjoyed the film and noted that the errors would not be apparent to non-experts, while commending the attention

to detail in other aspects of the film's portrayal of space technologies. It is interesting to note that this technical commentary also provided a platform for collection of additional relevant narrative evidence in the form of anecdote. Reisman, for instance, commented on the real threat of space debris, recalling that:

“During my first spacewalk, my partner, Rick, had to bring in a handle that was stowed on the outside of the station. When he got it inside he noticed a hole, about a millimeter in diameter, that was shot through the half-inch solid aluminum material by a piece of orbital debris. It looked like someone had taken a cocktail straw and shoved it right through the metal. He looked at me and said, “If that hit one of us...”” (Reisman, 2013).

Thus while the narrative model in *Gravity* introduced factual inaccuracies in the interests of drama, it nonetheless highlights a real and extant threat to the safety of astronauts and telecommunications-dependent systems. It also provided a model within which science communicators could clearly communicate subject-specific knowledge to the public. Unlike much science fiction (but as will be seen in later scientific narratives), the anticipatory role of *Gravity* is limited. The setting is contemporary, with no significant technological or societal extrapolations beyond the current day. The chain reaction described could happen (with certain caveats) today, rather than relying on significant extrapolation. Despite its scientific inaccuracies, the film nonetheless acts as a thought experiment, highlighting the possible consequences of a space debris generation cascade.

By comparison, popular fictional narratives addressing light pollution are relatively rare. While bright lights are often synonymous with big cities, and thus symbolise modernity, the cultural impact of losing contact with the night sky has not formed the focus of many narratives. However science fiction does provide an inverted model. Published in 1941, *Nightfall* by Isaac Asimov explores the interaction between scientific and religious communities on a hypothesised world with multiple suns. An unusual syzygy occurs every two millennia leading to eclipse of all the suns simultaneously, bringing true darkness and a revelation of the stars in its wake. The changed relationship to a sky which had hitherto been opaque leads to madness and societal collapse.

While *Nightfall* lacks physical plausibility as written (Deshmukh & Murthy (2014), the story has been cited in the context of light pollution narratives. In his introduction to an article on the health impacts of light pollution, Gilad (2016) for example juxtaposes the premise of *Nightfall* with the widely-repeated anecdote that during a power cut in 1994, alarmed residents of Los Angeles called the police to report a glowing liquid in the sky, unable to recognise the Milky Way (e.g. New York Times, 2008). Indeed Falchi et al. (2016), the authors of the research Gilad discusses, also make reference to Asimov's *Nightfall*, albeit in passing. Here *Nightfall* is being used as an inverted narrative model for Earth, comparable to the early 1940s in technology. While Asimov's original framing for his narrative in a tension between science and religion is not invoked by Gilad or Falchi et al., the underlying themes of distrust of science and the importance of a night-sky-informed cultural worldview can be seen connecting the fictional narrative with the problem it is used to illustrate. Importantly, darkness in *Nightfall*'s narrative, like light pollution in modern dark skies narratives, is a problem affecting all, with either physical or mental health impacts. The collective identity invoked here encompasses all imbibers of the story.

The manner in which *Nightfall* has been used, despite its apparent disconnect from the topic in question and from the world in which policy decisions must be made, shows the flexibility of stories in the presentation of scientific issues. This power has not been overlooked by journalists: media reports that space junk might prevent us from finding alien life (e.g. Michalitsianos, 2023) are deeply embedded in the science fiction imaginary. Recent film *Don't Look Up* (McKay, 2021) was used to frame reports of the potential impact of mega-constellations on asteroid searches (e.g. Hawkins, 2022), while Prof Alan Fitzsimmons (Queen's University, Belfast) used the narrative framings presented by the films *Don't Look Up* and *Gravity* to contextualise his commentary on space debris (Fitzsimmons, 2022).

While recognising the power of this science fictional imaginary, however, it is also important to consider the narrative structure in science and science-adjacent reporting in the absence of fictionalised content, as we will see in the next case study.

Case Study 2: Nature Astronomy Dark Skies Focus (March 2023)

An extensive body of literature exists written in the last few years by, or on behalf of, space scientists with the goal of communicating SDA and dark skies narratives. These include press releases and discursive articles from the learned societies, major observatories or individual scientists. Scientific press releases themselves are largely factual but are inevitably framed by elements of narrative describing the proliferation of satellites as a disruption to the equilibrium of our relationship with the sky, anticipating the results of inaction, and invoking collective identities amongst the audiences. The media response to each of these press releases is itself a form of narrative construction.

Here, I will consider an example of a focussed science communication effort which invoked narrative principles: the March 2023 issue of *Nature Astronomy*, a peer-reviewed science journal launched in 2017. While aimed at a more specialist audience than its public-facing parent journal *Nature*, it publishes commentary and reviews on the culture and social context of astronomy in addition to scientific research articles. The March 2023 issue of *Nature Astronomy* was presented as a Dark Skies Focus edition with an editorial (Nature Astronomy, 2023), two opinion articles (Venkatesan, 2023; Falchi et al., 2023), a 'perspective' review article (Barentine et al., 2023) and two research articles (Kruk et al., 2023; Kocifaj et al., 2023) on topics related to dark skies protection and the impact of satellite mega-constellations. While the research articles (and to a lesser extent the review) were written primarily for a technical audience, the remaining articles target a more general audience, and represent examples of narrative construction and application in science communication.

The unsigned editorial is explicit in its advocacy and call to action. Entitled "Let there be (natural) light, it invokes a collective identity that encompasses all its readers in its opening paragraph: "the extent of the problem, laid out in our Focus on dark skies, is startling and should turn us all into activists." The journal does not specify that this is uniquely the role of space scientists, although these likely dominate the readership. Instead, it positions all readers as equally affected by the matter, whatever their background, and promotes an active subject advocate stance more traditionally associated with the humanities rather than science communication. After summarising the relevant papers in the issue, the editorial ends with a reference to the recently finalised United Nations High Seas Treaty (2023) as a plausible model and template for a future orbital regulation.

The first opinion piece, by astronomer Aparna Venkatesan, is entitled “Stewardship of space as shared environment and heritage” and presents a narrative of threats to the cultural role of astronomy. In the context of a storylistening analysis, it contains a telling passage:

Space is our shared heritage and ancestor — connecting us through science, storytelling, art, origin stories and cultural traditions — and it is now at risk. Many of today’s leading space exploration corporations themselves harness the power of storytelling, depicting the colonization of space as a frontier and an escape: a modern ‘manifest destiny’. These narratives amplify conquest rather than communities, and feature only a few apex saviours with no roles for most of humanity. In contrast, the origin stories of the Big Bang theory or millennia-old sky traditions have our common heritage and belonging as the resonant centrepiece.” (Venkatesan, 2023)

There is no ambiguity in the framing of Venkatesan’s narrative here. It explicitly positions problems of SDA and dark skies protection as an attack on the shared heritage invoked by the UN Outer Space Treaty (1967) - the responsibility of, and affecting the rights of, all humanity. Venkatesan both stresses the importance of stories in shaping our understanding of our relationship with space and critiques the way they can be used to communicate ideals and assumptions that may not be recognized by casual story-imbibers.

The article is also overt in its critique of past resource utilisation on Earth. Discussing the need for legislation of space, Venkatesan questions whether the export of corporate culture to the unregulated near-Earth environment might lead to unrestrained sexism, racism or other inequalities. Here the history of western industrial society on Earth, its unmoderated exploitation of resources in unregulated contexts, and its historical record of inequality is being held up as a narratively-constructed model for the future of space, in order to argue the need for accountability and oversight.

Space scientist Fabio Falchi and collaborators contributed the second opinion article in the Focus issue: “A call for scientists to halt the spoiling of the night sky with artificial light and satellites”. The framing of this piece is passionate subject advocacy - urging scientists to take an active stance rather than act as passive information brokers. As was the case for Venkatesan, Falchi et al invoke the loss of cultural heritage as a framing for their argument:

The loss of the natural aspect of a pristine night sky for all the world, even on the summit of K2 or on the shore of Lake Titicaca or on Easter Island is an unprecedented global threat to nature and cultural heritage. (Falchi et al, 2023)

This cultural heritage framing is accompanied by a more aggressive positioning of the paper as a critique of corporate greed. The article extensively uses narrative in the form of anecdote and cultural references to build its model of the current system and anticipate the future. A key passage reads:

Let’s recall what has happened in other fields in the last decades, such as the findings related to tobacco smoke (active and passive), acid rain, climate warming, diesel emissions, asbestos, the ozone hole, silicosis, PFAS (forever chemicals), opioids, and sugar, to name only some. Every time some health or environmental issue arises and starts to be addressed in the scientific literature, the ‘machine of doubt’ is put into action

by the polluters to stop, or at least delay by years or decades, the adoption of countermeasures and rules to protect human health and the environment. The strategy is always the same. (Falchi et al., 2023)

The model under construction here is one Falchi and coauthors term “big light” in analogy to the ‘big oil’, ‘big tobacco’ and ‘big pharma’ labels used by subject advocates to argue against profit-driven corporate decision making. A story of the deliberate decision by past manufacturers to limit the lifetimes of lightbulbs is used to question how current producers of LED lighting will create new markets for their products and consider possible consequences for light pollution. The authors also identify “big space” as a model for satellite mega-constellation proliferation, characterising the issues facing dark sky protection as socio-political rather than scientific in nature. As in the quoted passage, they anticipate that attempts to regulate mega-constellations will face active resistance from those whose profits are threatened. The authors’ firm advocacy framing urges scientists to campaign for regulation rather than mitigation of the problem but falls short of detailed anticipation of the process by which this can be achieved.

The remaining articles in the Focus issue communicate more technical and quantitative insights into the impact of light pollution and satellite mega-constellations on astronomy, together with the difficulty of modelling that impact. However - as is the case for most scientific research publications - each begins and concludes with passages describing the context of the work and interpreting the quantitative results for readers. In the ‘perspective’ review article (Barentine et al 2023), this is framed as a narrative: it identifies mega-constellations as a technology disruptive of the current equilibrium, recognises and explores the impact of their unlimited expansion, and projects a possible set of consequences. Their critique of the current expansion in the final analysis is stark and - as was the case for Venkatesan - explicitly comments on the construction of narrative by mega-constellation operators:

Despite a narrative of democratizing space and delivering affordable global broadband, it is a model that prioritizes urgency, privatized benefits and short-term goals over real sustainability and the public interest. This also ignores our shared ancestry and heritage in space. (Barentine et al., 2023)

However, the narrative conflict is left unresolved, expressing hope for a more regulated future rather than anticipating of concrete solutions. Indeed, the idea of on-orbit debris removal (prominent in many SDA narratives, e.g. Alexander, 2022) is effectively dismissed as unproven and unlikely to make a big impact.

Figure 1 summarises the structural elements of narrative in this Focus issue. We find all four aspects of the storylistening framework addressed, making plain the common themes and differences between authors.

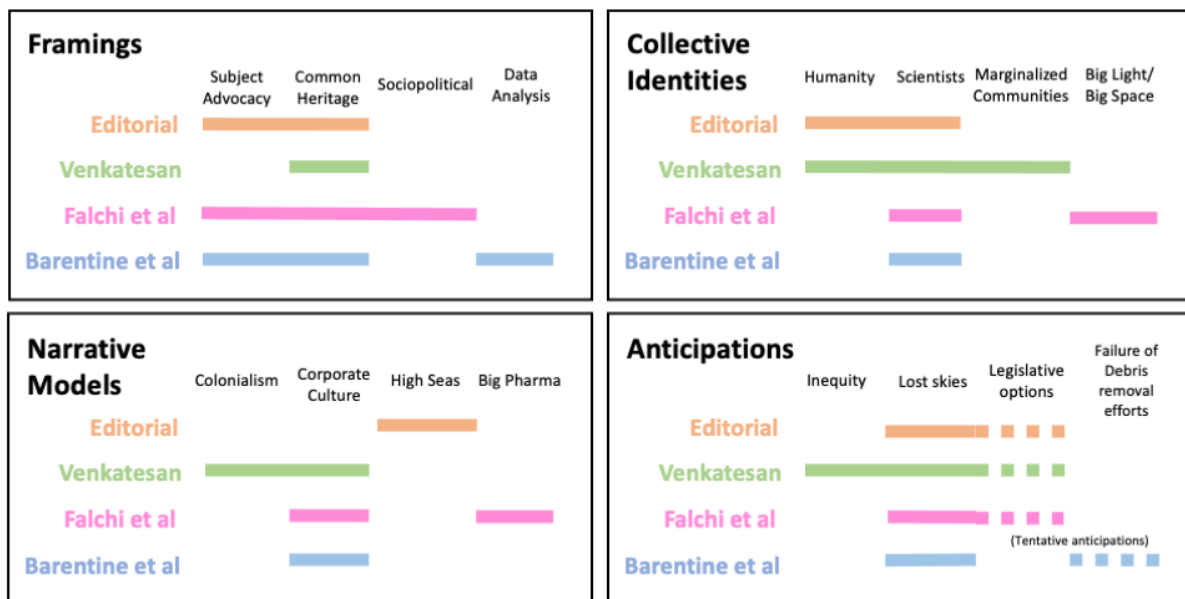


Figure 1: The different narrative elements of four articles in the March 2023 Dark Skies Focus issue of *Nature Astronomy* journal.

The Dark Skies Focus issue attracted media attention to SDA. A report distributed by the Agence France Presse (Collen 2023) appeared in publications as diverse as India Engineering News, Japan Today, ABS (Australia), Daily Sabah (Turkey), ScienceAlert (US) and Today Online (Singapore) amongst others, and in modified form in eNCA (South Africa, Suarez 2023). This report follows the narrative of the articles closely, drawing excerpts of text from each to highlight the collective identity of scientists as those sounding the alarm, the framing in terms of cultural and natural losses and the anticipation that the situation will worsen without regulation. Similar reports appeared in French language newspapers (including *Le Figaro* and *France24*), in the UK (e.g. Davis, 2023; Blakely et al 2023) and elsewhere (e.g. Singh, 2023). The Altmetric (2023, May 30) aggregator for online reports lists 96 news articles, 5 blogs, 2 public Facebook pages and 137 tweets discussing the strident Falchi et al. article on astronomical advocacy, which formed the focus of much of the reporting. While many of these represent re-tweets or repetitions, several twitter users have chosen to direct their comments to Elon Musk and Jeff Bezos, the CEOs of two of the leading space technology firms. Here we see individuals associating themselves with the collective identities invoked in the narrative, but sometimes reframing the problem as one for isolated individuals to resolve rather, than as a common problem which requires collective action.

Several news reports conflated the *Nature Astronomy* articles with a letter published in *Science* on less than two weeks earlier (Napper et al., 2023) calling for a global treaty to limit space debris. This invoked the tragedy of the commons as a framing, with reference to the High Seas Treaty as a narrative model. It had itself attracted considerable media coverage (altmetric identified 68 news outlets, 4 blogs and 85 tweets by the time of writing in May 2023, e.g. Marshall, 2023). The conflation of dark skies and SDA reports in the context of mega-constellation news narratives is inevitable, and media responses to the *Nature Astronomy* articles cannot be considered without the context of other media attention both before and after their March 2023 release. A near miss between satellites in January 2023, for example,

created a flurry of public attention regarding space debris, while press releases promising high speed satellite broadband, and near-continuous launches of naked-eye-visible and highly distinctive Starlink satellite trains have kept the mega-constellation issue literally in the public eye over much of the last two years.

As this case study demonstrates, scientific and science-adjacent reporting makes a constant use of narrative to frame and enhance its messaging. Understanding the cognitive and functional role of these narratives is essential to understanding how the public, and policymakers, perceive the information scientists provide. This is certainly true of science publications, but may also be appropriate in the context of non-text-based science communication, as we will explore next.

Case Study 3: *Our Fragile Space*

Our Fragile Space is an art installation and exhibition, created by photographer Max Alexander. Debuting in private showings at insurance brokers Lloyds of London in October 2022, to highlight the potential financial impact of space debris, and at Spaceport Cornwall for the January 2022 Virgin Space launch attempt, it was installed for public viewing in Coventry Cathedral Ruins for three weeks in May 2023, and will be taken to the next session of the UN Committee on the Peaceful Uses of Outer Space (COPUOS, May-June 2023) and to the Blue Dot Festival (July 2023), amongst other venues over the next two years. The exhibition comprises 75 photographs and illustrations together with accompanying text, exploring different aspects of space debris and near-space activity and collectively building a narrative of human space utilisation. Originally funded and developed with support from the University of Warwick's Habitability Global Research Priority fund and Centre for Space Domain Awareness, Alexander further developed the project working with a range of space scientists, industrial stakeholders and others, who are featured amongst the images. As such, this is an example of narrative co-creation which crosses interdisciplinary boundaries.

Alexander describes himself as an “editorial and commercial photographer” who “specialises in science communication through photography”⁶². Perhaps unsurprisingly then, a prominent **collective identity** invoked by the exhibition is that of the scientific community. A large number of the images in the exhibition are portrait photographs, featuring scientists including Dr Robert Massey of the Royal Astronomical Society, Prof Donald Kessler and Dr Jonathan McDowell (a prominent space debris scientist on social media). Other images feature crystal-sharp images of space-science equipment, the results of controlled experiments, such as those simulating space debris impacts, or clean-rooms for satellite construction, complete with staff in protective clothing. Importantly, however, Alexander is careful not to present the scientific community solely in the context of traditional western scientism or as entirely distinct from the self-identity of potential audiences. Scientists including Moriba Jah (University of Texas at Austin) and Mini Chakravarthini Rai (University of Lincoln) are shown in the traditional dress of their non-western background cultures, visualizing the connection between their identities as scientists and aspects of non-scientific identity. Others are shown dressed casually in jumpers, T-shirts and jeans. In the juxtaposition between the space debris context and the informal or traditional dress, Alexander constructs a collective identity for the space science

⁶² <http://www.maxalexander.com/profile/> (accessed 29th May 2023).

community that extends beyond the traditional boundaries of their discipline and reconnects with the commonality of humankind.

Alexander also contextualises the image of scientists, engineers and experiments with other imagery including anonymous portraits of a car user, a bicycle courier, a farm worker and pilots landing an aeroplane in Tenerife, all dependent on satellite navigations, as well as images of busy roads, landfill sites and financial centres. Collectively, these encompass an extensive range of aspects of modern western life and so present a construction of collective identity that extends to embrace that of the viewing public.

Based on picture selection and presentation, Alexander is clearly **framing** space debris as a problem and a danger to our modern way of life. Examples of impact damage, including a photograph taken while on the International Space Station by astronaut Tim Peake, emphasise the danger to life for those few in space. However the inclusion of images of ambulances, aeroplane flightdecks and finance hubs emphasises the more immediate risks that affect the audience directly. In images of Robert Massey (a vocal advocate for dark sky protection, Massey, 2020) positioned against the light-pollution and skyglow of London's skyscrapers at night, satellite trails above a neolithic burial chamber, and the radio interference seen by Jodrell Bank Observatory, Alexander expands his space debris framing to encompass the dark and quiet sky protection motif.

The framing of an art exhibition is unusual in that it can vary depending on the location of the installation. *Our Fragile Space* debuted at Lloyds of London, with the modernist architecture of the building providing a strong framing of space debris as an economic issue for satellite operators and, by extension, their insurers. Shown at Spaceport Cornwall it was framed by aspirations for UK space utilisation, emphasising the prominence of UK scientists and start-up companies amongst the imagery. Displayed in Coventry Cathedral Ruins (the legacy of World War II incendiary bombs, Figure 2), it is framed by evidence of humanity's inhumanity to others, wasteful destruction and conflict, and so emphasises the destructive power of space debris and the importance of cooperation to resolve the issue. Taken to the COPUOS meeting in Vienna, it is framed by the need for improved regulation and discussion of international space policy. And displayed at the Blue Dot festival, in the shadow of the Jodrell Bank Observatory's Lovell Telescope, it emphasises both the dark and quiet sky framing and the connection to the lives of the viewing public. These framings are clearly intentional on the part of the artist and demonstrate the need to consider not just the narrative evidence as presented but also its contextual setting.



Figure 2: Use of Second World War ruins at Coventry Cathedral to frame a space debris narrative in Our Fragile Space (May 2023).

Our Fragile Space is a self-guided exhibition with images viewable in any order, based on the circulation of a visitor around the photograph frames. However it is also clearly constructed as a narrative, and the intended viewing sequence of the frames is more explicit by the exhibition guide produced for the Lloyds of London premier (Alexander, 2022). This divides the images under nine subheadings of varying length, beginning with “Our Links to Space” and moving through “A Cluttered and Noisy Sky”, “The Cost of Living”, “Recognising the Threat of Space Debris”, “Eye on the Sky”, “Technology and Techniques for Removing Debris from Orbit”, “What we Leave Behind”, “Racing to the Top” and “Our Orbital Future”.

Of these, the first five sections use imagery and associated text (including guest essays) to construct a **narrative model** of our current interaction with the near-Earth environment, and its emerging impacts on the world in which we live. They present both the successful integration of satellite technology with our current society and way of life, and the threat to it as demonstrated by growing evidence of debris accumulation and impact damage, as well as cultural damage associated with dark and quiet sky losses. This is an effective use of visual images and their brief descriptions to construct a narrative model of our world and its current status that is more evocative and more easily visualised by audience than the quantitative model of facts and statistics that would form a more traditional science communication. Alexander confirmed this in his written introduction to the exhibition:

Our Fragile Space takes a human perspective, from the ground looking up, connecting the Earth to the near-space environment. I chose this everyday approach to make the issues more tangible because space debris is just up there, part of Earth's environment. (Alexander, 2022)

Thus his model building is explicitly intended to provide a framework in which visitors, and expert storylisteners, can contextualise the current SDA landscape and its possible evolution.

The final four sections of the exhibition present a more **anticipatory narrative**, which is rooted in contemporary technology development but extends towards a speculative future. Given the

photographic medium, most of the imagery here is of individuals working in this field or of current experimental technology. It captures the large and active market in start-up companies exploring space debris removal, and as such is positioned as optimistic regarding the chance of controlling space debris in the future. The short section “Racing to the Top” combines text from a satellite-specialist legal expert, Prof Joanne Wheeler, with imagery of text of the UN Outer Space Treaty and a portrait of Wheeler behind an armillary-sphere sundial, anticipating the need for regulatory and space policymaker involvement in shaping the future geometry of this field. The anticipation value in the *Our Fragile Space* narrative is relatively limited, nonetheless, since it is unable to extend more than a few years beyond our current time. Instead the anticipation is mostly implied by the absence of a clear picture of the future: by implication an absence of action will lead to continuation and worsening of the problems already presented in the modelling sections.

Perhaps unsurprisingly, the media and public response to *Our Fragile Space* has been limited by the need for informed commentators to attend the exhibition in person. The majority of reporting has been based on press releases from sponsors and involved organisations, rather than personal responses to the exhibition. Popular science magazine *New Scientist* published a short comment (Li, 2023) based on press release text, accompanied by images from the exhibition. An article appeared on the BBC News Website, quoting Alexander and the University of Warwick’s Professor Don Pollacco, also based on a press release from the university and lacking original narrative commentary (Dawkins, 2023). By contrast, local newspaper, *The Coventry Observer*, also reported from the same release but emphasised the framing invoked by the local setting, repeating the press release statement that it “*aims to enable viewers to reflect on their understanding of the skies above from the threat of the November 1940 Blitz to a fragile and threatened environment*” (Smith, 2023).

There was equally muted response on social media, with Twitter reaction limited to involved parties and a handful of tweets from *New Scientist* magazine publicising their article on the exhibition. These received a few responses from the public, mostly commenting on the tendency of humans to pollute their environment, although two readers tagged the post for the attention of Starlink CEO Elon Musk (who did not respond). These responses, while few, construct their own narrative models on the issue at hand. For example, the tweet

This will be the 'what were we thinking?' issue equivalent of the plastic lined rivers and oceans today in twenty years. What is it with humanity and waste? (Howson, 2023)

invokes a ground-based environmentalist model for space debris, and, through the use of “we” explicitly recognises the commenter’s own participation in the collective identity of those at fault. By contrast,

@elonmusk any plans to address this issue in future? You seem to be our only hope with most things that involve technology! (H, 2023)

instead positions the report within an anticipatory paradigm that requires actions from others, in this case a technology celebrity. Finally,

'Prison Earth.' It could stifle space travel in the future. Are you @neiltyson and @elonmusk. (FSM, 2023)

also takes an anticipatory approach, this time focussing on the possible consequences of inaction. As in the previous tweet, it invokes celebrity rather than recognising the commenter's own identity as amongst those affected, although the grammatical construction does not make it clear whether the individuals identified are mentioned as part of the problem, part of the solution, or simply as needing to be made aware of the issue.

This public response to *Our Fragile Space* is likely indicative of the physical restrictions of the exhibition format and the demographic of those likely to visit the exhibition to date. It demonstrates the limitations of this form of narrative construction as a tool for public communication. However, as the storylistening analysis above demonstrates, *Our Fragile Space* illustrates the potential of artist/science community co-creation to provide constructive narrative evidence that informs the space policy debate, communicating concepts and concerns without the need for quantitative and statistical evidence.

Storylistening in a Space Science Context

Here we have presented a synthesis of narrative evidence in the areas of space domain awareness and dark sky protection policy input in the context of the storylistening framework. In each case, the consideration of narrative evidence - "*the product of the expert act of both direct critical engagement with stories, and critical engagement with others' reading, viewing, or listening to stories*" (Dillon & Craig, 2022) - through storylistening techniques highlights aspects of the use of narrative in communication by space scientists. The need for attention to such narratives has also been highlighted by others.

Madden & Koprowski (2020) asserted that "*space has a narrative problem*". They urged that the construction of narrative, and in particular the narrative of loss and disaster, was essential in communicating the risks of space debris to currently-disengaged audiences. Their analysis of "*an engaging, humanizing narrative*" for space in the context of their "Without Space" science outreach project closely mirrors the storylistening framework in its emphasis on framing (to address a wide variety of publics), communicating collective identities (i.e. that all humans are affected through a range of relatable examples), modelling (as noted, "*narratives allow audiences to make sense of data in their social context*") and the effectiveness of anticipations (i.e. in the results for individuals, rather than nations, of a loss of satellite communications).

But while the storylistening framework can provide insight into scientific narratives, it may be worth considering whether it also has limitations. To take an example, in a newspaper article on space debris for The Guardian in 2022, Ian Sample presented a clear overview of the UK's SDA activities. He uses framing in the context of UK innovation, the film *Gravity* to provide a narrative model, and an anecdotal narrative of his visit to RAF Fylingdales to contextualise the nature and extent of the UK's space tracking efforts. His discussion of orbital collisions between satellites (with specific reference to the interaction between the communications mega-constellations and larger vehicles) invokes a narrative based on familiar, ground-based traffic to model less familiar orbital dynamics: "*There is no highway code in space, no accepted right of way. So it's often those with most to lose who ensure disaster is averted.*" (Sample, 2022).

Such science-adjacent reporting is clearly amenable to analysis of the framings, collective identities and models emphasised in the storylistening paradigm. However, in the area of anticipation, science and science-adjacent narratives appear to fit less straightforwardly into such analysis. As was the case in *Our Fragile Space* (Alexander, 2022), Barentine et al (2023), Falchi et al (2023) and as in *Gravity's* omission of any discussion of longer-term consequences of the debris event, Sample stops short of resolving his narrative. Instead of a clear anticipatory narrative model, he presents a discussion of the current efforts to mitigate the future space debris problem. This reports current advisory guidance on practice, and novel technologies to deorbit extant debris, without expressing a firm opinion on their likely success or failure. Such substitution of plausible or aspirational next steps in place of the firm anticipation expected of most narratives appears to be common in the case studies considered here and suggests that in scientific and science-adjacent narratives, the role of anticipation in the storylistening framework may need to be adjusted. The emphasis in scientific training on evaluating probabilities favours a more tempered discussion of possible outcomes, rather than firm predictions. Indeed Gluckman et al (2021) identified communication of “*the uncertainties, caveats, and reliability of evidence*” as one of the key roles of effective brokerage at the science-policy interface – one that overtly anticipatory narrative in space science is ill-suited to address.

This possible wariness of speculative anticipation amongst scientific communicators was articulated by Peter Calow (2023) in a letter published in response to Craig & Dillon's 2023 article “‘Storylistening’ in the science policy ecosystem”. As he notes: “*Science delivers options, not solutions*”. Calow also highlighted concerns regarding the ability of narrative to deviate from or modify the truth - a concern that echoes the debate over accurate orbital physics in *Gravity* referenced in the case study above. As has been discussed before (e.g. Schlauffer 2018), it is certainly possible for narrative constructions to present different politically-motivated interpretations even when based on the same scientific data. However, in their responding letter, Craig and Dillon noted a distinction between *storytelling* (the role of science communication) and *storylistening* (the expert act of critical engagement with the story). The latter can recognise and acknowledge the flaws and narratively-required manipulation of the former.

As this synthesis has demonstrated, despite the challenges of reconciling humanities and scientific approaches, storylistening provides a framework for the informed analysis of science narratives, allowing these, as well as the data on which they are based, to form part of a pluralistic evidence base in space policy decision making.

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