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Technological Expectations and Global Politics: Three Waves of Enthusiasm in NonGovernmental Remote Sensing

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ABSTRACT

Media, industry, and academia frequently depict the commercialization of satellite imagery as geospatial revolution with transformational effects on global politics. In doing so, they follow an understanding that isolates technology from politics. While this division is still prevalent in international relations, recent scholarship has promoted the intricate relationship of technology with politics as socio-material. Adding to this literature, I draw on the sociology of expectations to propose an alternative reading of nongovernmental remote sensing. For this purpose, the notion of technopolitical barriers is introduced to trace controversies about technological expectations of satellite imagery. Based on expert interviews and document analysis, I identify three waves of enthusiasm, which are characterized by particularly salient expectations and techno-political barriers. The first wave is fueled by an enthusiasm about the general benefits of visual transparency as opposed to Cold War secrecy. The second wave turns toward nongovernmental imagery intelligence for human security. In the third wave, satellite imagery joins multiple data streams to support political and business decisions. Taken together, the three-wave model distorts the linear understanding of a revolutionary development but reveals the political and controversial nature of the ongoing commercialization of satellite imagery. As a part of this, nongovernmental remote sensing has experienced a focus shift from visual transparency toward geospatial big data. Moreover, the three-wave model highlights the persistence of expectations and techno-political barriers in the nongovernmental sector with important implications for policy-making and the global impact of commercial satellite imagery.

1. Introduction

The commercialization of satellite imagery has been met with mixed reactions from great enthusiasm to critical reservation. Most perspectives, however, agree on the transformational character of emerging nongovernmental remote sensing that opens up commercial satellite imagery to a variety of nonstate actors including NGOs, universities, think tanks, and the media: The commercialization of satellite imagery has an impact on global politics across a variety of domains from humanitarian action, human rights, environmental politics, and international security. In other words, the scope of this development is understood as nothing short of a geospatial revolution because "[g]eospatial information influences nearly everything. Seamless layers of satellites, surveillance, and location-based technologies create a worldwide geographic knowledge base vital to solving myriad social and environmental problems in the interconnected global community" [1–4]. Optimists take satellite imagery as a ready-to-use solution to revolutionize the economy "[n]o matter your industry or goal" [5] and altogether "how we see the world" [6]. A more pessimist follower of the revolution thesis would add terrorism, military interventions, and global surveillance of citizens to the list of applications.

This understanding of technology as revolutionary contains two central flaws: First, the revolution terminology offers an empirically sanitized and misleading account of the commercialization of satellite imagery that disregards the temporal context and alteration of technological expectations. Second, the geospatial revolution ascribes technology a linear force of changing social order. As a result, it obscures the politics of the commercialization of satellite imagery and ignores the ongoing controversies, which are characterized by various actors, interests, expectations, and practices.

Drawing on insights from the sociology of expectations, I pursue two objectives in this article: First, to distort the linear vision of commercial satellite imagery as a neutral agent of global change. Focusing on technological expectations in their historical context, I

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propose an alternative reading of the commercialization of Earth observation in the United States, which captures the techno-political controversies in three more or less distinct waves of enthusiasm. As such, this does not constitute another history of commercial remote sensing but rather a reconstruction of future expectations over time. Second, this approach complements a growing literature in International Relations (IR) that deals with the mutual relationship between governance and technological projects. More specifically, it adds the sociology of expectations to the theoretical debate on techno-political visions. In doing so, it offers a theoretical starting point for empirically grounded discussions on the role of emerging technologies in (future) world politics.

The following section briefly reviews how IR scholarship deals with the difficult question of future impacts of technologies. Next, I outline the central claims of the sociology of expectations and lay out my analytical approach. The main part of the article presents the three waves of enthusiasm that characterize the commercialization of satellite imagery. Finally, I discuss several insights from the empirical findings and conclude with a brief summary, limitations of the chosen approach, and policy implications.

1.1. Technological futures in IR

The different answers to how IR copes with potentially transformational technologies can be organized with respect to their conceptions of technology and how they deal with the futurity problem of speculative effects. With this in mind, I identify three modes of technological futures related to the respective technology understandings in IR scholarship: instrumental, deterministic, and socio-material. Although a large share of mainstream IR theorizing is attuned to technological developments, it stops short of conceptual engagement with technology which often renders it a residual variable that is exogenous to politics [7–9]. There are two notions of technology which have dominated much common sense and IR thinking, i.e. an instrumentalist and a deterministic version [10–16]. Both notions arguably come with a specific understanding of technological futures that is rarely discussed. In addition, I insert a socio-material understanding of technology as a third option, which has recently gained popularity in IR and more prominently considers the future as a concept. Almost by definition, such categorizations do not do justice to the breadth and nuances of the research cited as representatives of either category. Sometimes, it contains traces of all of the above. However, it is useful to briefly spell out these broader figures of thought to situate the analysis and introduce differing conceptions of technological futures implicit in IR.

(1) Instrumentalism knows no fixed technological futures but takes technologies as neutral means that are subject to the values and intentions of human agents. They are tools indifferent to the ends they are used to and can easily be transferred across political, temporal, and cultural contexts without losing their specific functionality [11]. The instrumentalist views on technology cuts across theoretical divides in IR and security studies [12]. In this sense, regardless of the rhetoric of revolutions in military affairs (RMAs) or network-centric warfare, it is politics and strategy that dictate technology and not vice versa [17]: In this line of thinking, it becomes strategically justifiable to, at once, tolerate nuclear weapons or lethal drones in the hands of some actors and condemn it in those of others [18,19]. Instrumentalists are firmly rooted in the present because technology has no stand-alone effect on the fundamental rules of war, political regime, society, or governance. In this sense, Colin Gray [20] argues that Clausewitz's credo of war as the continuation of politics still applies no matter the technological means of warfare. Yet another textbook case of the instrumental notion of technology is put forward by James Rosenau [21] who contends that information technologies are initially free of value. Value is only determined in their use: "the neutrality of information technologies is permissive because it enables the democrat as well as the authoritarian to use information in whatever way he or she sees fit." In short, the use of neutral technologies does not predetermine future outcomes of global politics.

(2) Determinist notions of technology in IR scholarship often come down to an extrapolation of pessimism or optimism about the future trajectory of technological development [14]. No matter the goals or values of human agents, determinists attribute "an autonomous cultural force to technology that overrides all traditional or competing values" [11,22–24]. In contrast to instrumentalism, technology is not a mere tool but has a significant impact on its own on the organization of global politics [8,15]. In structure-oriented IR theories, technologies affect the distribution of power [25] or reduce transaction costs to facilitate international cooperation [26]. Using determinist arguments, nuclear weapons or lethal drones are attributed uniform effects on politics regardless of who possesses them. Similarly, the dawning development of lethal autonomous weapons inspires the Campaign to Stop Killer Robots—a consortium of various NGOs—to lobby governments for their immediate ban. Coinciding with the first meeting of the Convention on Conventional Weapons (CCW) Group of Governmental Experts on lethal autonomous weapons systems, the Campaign released the video of a fatalistic vision [27]: Private companies offer autonomous swarms of micro drones for sale which can kill human beings following a predefined set of characteristics such as age, uniform, or ethnicity.[1] The only escape from technologically determinist futures, then, is "a return to tradition or simplicity" that forsakes technological development [11].

(3) More recently, socio-material understandings of technology are proliferating in IR which criticize both instrumental and determinist accounts for their unitary conceptions of technology. Drawing on work in science and technology studies, they highlight the inextricable relationship between politics and their material environment. Two approaches stand out in this literature: Some scholars draw on actor-network theory (ANT) [28] to empirically trace socio-material relations and examine how humans and technologies co-constitute governance practices [29–31]. However, the strong focus on immanence and contingency renders the future an overly elusive concept. Such studies frequently reconstruct bygone controversies and then-anticipated futures during technology development. On the other hand, the notion of sociotechnical imaginaries [32,33] more decidedly engages with the co-productive relationship between politics and technology in technological futures but hitherto found a limited resonance in IR scholarship – with a few exceptions [34,35]. Sheila Jasanoff [36] defines sociotechnical imaginaries "as collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of,

[1] How technology slips away from human control is a recurring theme in other cultural products such as Isaac Asimov's *I, Robot* (1950), Stanley Kubrick's *Dr. Strangelove* (1964) or the Wachowskis' *The Matrix* (1999).

advances in science and technology." In this sense, socio-technical imaginaries cast a wide net that includes visions of alternative modes of governance, social order, and technological infrastructures [37].

Similar to ANT and socio-technical imaginaries, this article follows a socio-material understanding of technology. Instrumentalism cannot capture the force of materiality, whereas determinism comes close to a submission to technology. In light of the focused research objectives to reconstruct techno-political expectations of nongovernmental remote sensing in their historical context, the article adds the sociology of expectations to the IR literature on technological futures. It is situated between ANT's micro focus on tracing socio-material relations and the macro view of socio-technical imaginaries. The following section outlines the foundations of the sociology of expectations and the analytical framework that builds on them.

2. Sociology of expectations: coping with technological futures

2.1. Central claims

The essence of the sociology of expectations can be sketched out in four central claims. First, expectations are collective. In contrast to psychological interests in individual beliefs, the sociology of expectations is concerned with the practices, objects, and articulations that more or less publicly enact the future [37]. In doing so, it takes the future as an analytical object that groups of people create and shape in the present [38]. Second, expectations are performative. Multiple authors have shown how technological visions and expectations shape the ways societies deal with controversial technologies [32], affect research trajectories and policy, or guide the development of specific devices [31,39]. Expectations define actor roles, frame the prospects of technologies, and co-shape the space of potential actions and strategies [40,41]. Third, expectations are dynamic. Technological expectations vary over time in response to changing attention, resources, and optimism [42]. Actors use differing expectations in controversies about the future of technologies which has made the hype-disappointment cycle for emerging technologies all too familiar [41]. The position of actors toward the knowledge field of the technology is an important determinant of the hype of expectations [37,38]. In this sense, social scientists are often particularly prone to overestimate and extrapolate the impact of emerging technologies. Finally, expectations are material. They are no mere imaginaries of the mind but enacted in present material practices [42,43]. This collapsing of the matter-meaning distinction is well known in ANT and new materialism [44–47]. In this way, the future is not wide open to human will, but there are affordances and constraints offered by technologies – they lock in particular usages and path dependencies. Studying the virtual effects of objects and technologies directs the researcher's attention to practices of involved actors because they become visible when in use [43,48]. For example, the development of computer-based climate models or pilot projects of military weaponry reveal particular socio-material assumptions and expectations about the future.

2.2. Analytical approach: reconstructing expectations of nongovernmental remote sensing

The analytical approach departs from "traditional" hypothesis testing but deliberately includes empirical data at an early stage to guide theorizing and further analysis [49–51]. More specifically, I draw on interviews with satellite imagery analysts and industry experts. Initial analysis of these interviews questions the linear narrative of a geospatial revolution but rather points toward a series of excessive expectations and barriers shifting over time. Contrary to the enthusiasm of the geospatial revolution narrative, actors close to the use, production, and marketing of the technology identify economic, legal, political, and technical barriers to the straightforward success story of commercial satellite imagery. Additional document analysis corroborates these observations. Based on this tension between expectations and techno-political barriers, the analysis develops an alternative narrative of the commercialization of satellite imagery. The conceptual categories expectations and techno-political barriers are integrated into an analytical template for an in-depth content analysis of interview transcripts and related documents including legal regulations, academic publications, news articles, and company reports (Fig. 1). This approach allows for a systematic analysis that is responsive to the various empirical data at hand.

Within the analytical template, technological expectations are defined as "real-time representations of future technological situations and capabilities" [41]. Such representations are not only limited to what actors are saying but also include their actions and specific artifacts. At the same time, fears and concerns play a corresponding role in the shaping of expectations [41]. Importantly, although individual promises and concerns constitute the building blocks of expectations, not until they are shared among a wider network, they take full effect [40]. Then, expectations justify statements and actions, legitimate investments, attract new resources, and structure the relationships among actors and things [40–42]. This provides a series of indicators for the analysis including but not limited to trends in financial investment, R&D policies, pilot projects of satellite imagery applications, research

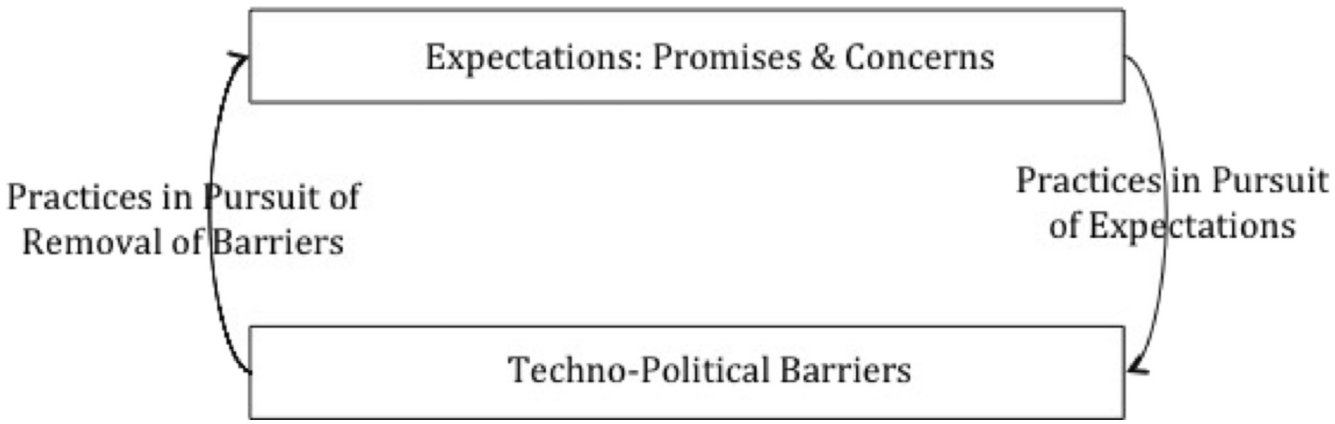

Fig. 1. Analytical template – expectation-barrier cycle.

activities, a changing industrial landscape as well as economic forecasts, and the use of particular jargon including talk of "revolution" or "breakthrough" in interviews and other documents [38,41]. Of course, public utterances on the promises of technology need to be adequately interpreted given the increasingly competitive and strategic character of technological innovation that encourages exaggeration in the competition for funding and attention [41].

The notion of techno-political barriers highlights the controversies and politics in the making of expectations and visions. For this purpose, it builds on the idea that disappointment is inherent to overblown expectations – especially in early stages of technological development [41,42]. Moving beyond the passive state of disappointment, barriers challenge expectations and denote a source of action as they stand in the way of realizing technological visions. Once a network of visionaries encounters a techno-political barrier, whether and how it can be bypassed or removed becomes subject to political controversy involving economic, technical, and normative resources. In this sense, barriers are not a "reality check" of expectations that assume a division of hypothetical vision and realistic fundamentals [41,43,52]. Rather, contesting expectations are enrolled in the settling of controversies over techno-political barriers. For example, when legal regulations, economic interests, or security concerns stand in the way of technological promises, a number of actors engage in a controversy whether and how to overcome those barriers. In doing so, they modify and readjust the expectations.

In a second step, I compare the emerging different periods as denoted by particularly salient expectations and techno-political barriers. This leads to empirical insights into how expectations concerning commercial satellite imagery have shifted over time, who are the drivers of the geospatial revolution narrative, and how were particular controversies settled and to what effects. Moreover, it serves the further theoretical development of the notion of techno-political barriers as a useful tool to examine the hype surrounding technological innovation in global politics.

As noted previously, initial data collection started with expert interviews on the early commercialization of satellite imagery. Going further, the analysis draws on a variety of data types by following the principle of theoretical sampling. With this in mind, I select further interview partners and supplementary documents such as legal texts, academic articles, R&D strategies, investment and foresight reports, press releases, and news archives guided by the analytical template and in light of the conceptual development of an expectation-focused narrative [50,51]. In total, 14 interviews with US-based experts and 54 additional documents are included in the analysis. Interview transcripts and additional material are analyzed using qualitative data analysis software Atlas.ti (version 8.1.0). Using the analytical template, the interview data are coded for specific utterances, practices, and artifacts related to expectations and techno-political barriers as part of the commercialization of satellite imagery. At the same time, an additional set of codes is assigned to signify the specific temporal reference. In doing so, one single code can, for example, denote economic barriers to the practice of nongovernmental remote sensing across documents and is concurrently tied to various historical contexts. This way, empirical data linked to economic barriers can be examined across time to identify and analyze relevant developments and changes. In an interpretive process, the resulting codes are then repeatedly rearranged and condensed to arrive at more definitive substantial and temporal representations until theoretical saturation is achieved. This ensures that the analysis captures collective expectations in their dynamic and temporal contexts. The interviews concentrate on satellite imagery experts who have closely followed and in parts actively driven forward the commercialization of satellite imagery in the US since the mid-1980s. Eight interviewees are expert satellite imagery analysts at NGOs or think tanks covering human rights, security, humanitarian and environmental issues. Most of them have been involved in this work since the early beginnings of the commercialization and provide extensive information about changing practices and expectations of nongovernmental remote sensing. Similarly, the remaining six experts have been or are actively involved in the political and commercial developments of Earth observation in the US. I focus on the US because, arguably, it hosts the most mature commercial Earth observation industry. By international comparison, this has facilitated the emergence of a great number of NGOs, think tanks and universities that make use of satellite imagery.

3. Three waves of enthusiasm

This section outlines three waves of enthusiasm as an alternative to the narrative of a unitary geospatial revolution. In light of the research objectives, I decided against choosing major events of the commercialization to classify distinct periods. This would neglect the politics, alteration and persistence of expectations over time and uphold the illusion of closure represented by specific policy decisions or technological achievements. In contrast, the image of the wave illustrates the lasting overlap of rationales across time periods. However, each wave is characterized by particularly salient expectations concerning the impact of commercial satellite imagery on global politics and corresponding techno-political barriers. Following these characteristics, the times around 2003 and 2013 have emerged out of the data analysis as rough points of orientation.

3.1. First wave

3.1.1. The visual transparency paradigm

The first wave of enthusiasm is characterized by expectations of a growing visual transparency and as a reaction to the Cold War-induced secrecy. Although proponents of the commercialization of remote sensing in the US government prevailed, nongovernmental actors initially remain skeptical about their unrestricted access to the data. Moreover, previously sensitive sites such as military installations become an early focus of nongovernmental remote sensing. Finally seeing what is hidden, prohibited and illegal – as it is reserved for intelligence imaging systems – drives the enthusiasm of nonprofit and commercial actors alike. The commercialization of satellite imagery is projected to be a swift endeavor that revolutionizes global politics and various industries. On this hope, multiple satellite imagery companies form in the early 1990s although it takes until the end of that decade for the first sub-meter capable satellite to arrive in orbit. Early on, the developments in terms of spatial resolution from Landsat to SPOT to IKONOS play a central role in the enthusiasm and techno-political controversies.[2] The launch of IKONOS (from Greek εικόνα for image) in 1999 by Space Imaging and the exuberance about the image quality represent the importance of sheer visuality in the early years of the commercialization.

Business and civil society actors expect a quick proliferation of technology applications driven by economic benefits and international competition [53–55]. Moreover, they envision visual transparency to become an important tool to publicly show remaining nuclear stockpiles, military equipment or logging roads for the first time. Also critical social scientists who take non-governmental Earth observation as complicit in reproducing global inequality,

[2] See also Presidential Directive/NSC-37 from May 11, 1978.

gendered power relations, illusory objectivism and hegemonic discourse apply similar economic and technical expectations to present their normative concerns [56,57]. Overall, the expected impact on global politics remains quite vague but it is building on the shared understanding that visual transparency is a significant driver. For example, a satellite image of Area 51 is believed to have political importance despite the fact that the location is already known. Given the focus on the visual product itself, the practice of satellite imagery analysis does not feature prominently in the early discourse: self-taught skills suffice as the emphasis is on acquiring and publicly showing satellite imagery of classified or restricted areas. Accordingly, there is an expectation that media organizations like newspapers and TV producers – as particularly visual businesses – would introduce satellite imagery as a regular part of the news gathering process.[3] The idea suggests that newspapers and TV stations would utilize satellite imagery not to report the news but make the news. While this has indeed happened in certain places [58], there is a widespread disillusionment that even by now this has not come to pass on a regular basis – despite early efforts in that direction on the part of the satellite industry.

3.1.2. Piercing holes into governmental secrecy

The visual transparency-secrecy dichotomy also plays a major role in the controversies about techno-political barriers during the first wave of enthusiasm. Security, legal and economic issues become increasingly entangled in the commercialization of satellite imagery [59]. This entanglement already becomes apparent in debates about the UN Principles Relating to Remote Sensing of the Earth from Outer Space of 1986, which regulate applications in natural resource management, land use and environmental protection. Especially developing countries without active remote sensing capabilities raise concerns regarding their national sovereignty and data access when foreign systems sense their territory. However, the US and European nations prevail with their position which is informed by political but also commercial interests so that no prior permission is needed to observe another nation's territory as long as the sensed state has equal access to the data on reasonable cost terms [60].

In the aftermath of the Cold War, US technology companies Lockheed and Raytheon voice their interest in further monetizing the high-end spacecrafts and ground stations they have developed for the US government. They are supported by some lawmakers who argue that the reason for secrecy vanished with the collapse of the Soviet Union and the public should benefit from the huge investment made in previous decades [61,62]. Moreover, there is a perception of a growing international pressure from European, Russian and Indian markets threatening the technological leadership in Earth observation the US has since the 1960s [63].[4] However, the intelligence community in particular remains reluctant to giving up its dominant position over satellite imagery – even after the 1992 Land Remote Sensing Act that formally introduces licensing procedures for commercial satellite imagery providers [62].

The expectations of a geospatial revolution on either side shape controversies about techno-political barriers whose repercussions can be felt until today. From the beginning there are controversies about the adequate maximum spatial resolution of commercial satellite imagery. Following a similar logic, the 1997 Kyl-Bingaman amendment bans US companies from selling satellite imagery of Israel that is more detailed than from other commercial sources. Effectively, both restrictions aim to control the visual transparency by limiting what can be seen on commercial satellite imagery. Moreover, the shutter control policy has been codified in the Presidential Decision Directive/NSC-23 that sets the licensing requirements for US remote sensing operators in 1994. It addresses concerns about potential threats to US national security and foreign policy objectives emanating from the release of commercial satellite images. It allows for cabinet-level decisions to prohibit the collection and dissemination of US commercial satellite imagery.

Although shutter control has never been formally implemented,[5] it provokes an extensive controversy in the first wave of enthusiasm, which serves as a good indicator for then-held expectations. In light of the resistance of the intelligence and military community, proponents of the commercialization expect First Amendment issues to arise if the US government restricts access to satellite imagery. Acting on this expectation, they use the anticipated legal barrier as a platform to influence policy. The Radio and Television News Director's Association forms a “Satellite Imaging Task Force” to work on the regulatory implications of transferring satellite technology from the intelligence into the commercial domain. Effectively, they preempt a legal controversy by issuing statements and lobbying policy makers [61]. Also academics pick up this issue and voice their concern about the remaining power of the US government to influence imagery collection [55,57,64]. In 1999, the first public commercial satellite imagery by IKONOS makes the front page of the New York Times. In reference to the free speech controversy, Space Imaging chooses to release a picture of downtown Washington, DC depicting the Washington Monument, Constitution Avenue and the US Department of Commerce, which is in charge of licensing commercial satellite operators. Following the legal controversy, practitioners continue to test the politically acceptable limits of their operations by ordering imagery of particularly sensitive sites such as Area 51. Although the commercial imagery provider Space Imaging has to walk a fine line, it eventually sells the imagery of the secret military complex to the Federation of American Scientists – and the US government does not intervene – setting an early precedent in the controversy about visual transparency.

3.2. Second wave

3.2.1. Embedding imagery: non-governmental intelligence practices

The second wave of enthusiasm turns the idea of visual transparency into non-governmental imagery intelligence. Simply showing an overhead image of Area 51 or Russian ICBM sites does not suffice anymore. The release of GoogleEarth in 2005 at the latest naturalizes the view from above. From then on, it becomes increasingly important to integrate the imagery into contextual knowledge, to create added value beyond visual transparency. This wave acknowledges that “satellite images by themselves in some cases can be misleading or if not misleading then just ambiguous” (Interview with satellite imagery analyst, 2017, Washington, D.C.). As a result, remote sensing is increasingly recognized as a verification tool to corroborate other information sources. For this purpose, non-state actors in parts undergo the same learning experience as intelligence agencies since the 1960s and imitate or

[3] The Office of Technology Assessment issued a technical memorandum to weigh the feasibility of a media-owned satellite called Mediasat. Among other things, it identified high costs, image interpretability and national security concerns as likely barriers to such plans [85].

[4] See the Memorandum to the President by then-National Security Advisor Samuel R. Berger from March 3, 1994.

[5] In the run-up to the war in Afghanistan in 2001, the National Imagery and Mapping Agency (NIMA, now the National Geospatial-Intelligence Agency (NGA)) purchased all available IKONOS imagery with exclusive rights to deny others access; this was called “checkbook shutter control.”

seek the help of (former) security professionals. As a result, human rights NGOs adapt the methods, language and reporting style of intelligence agencies. This turn to intelligence practices, or professionalization, raises the expectations of the benefits of commercial satellite imagery for a range of human security issues such as human rights, non-proliferation, food security and arms control.

In 2003, the Committee for Human Rights in North Korea (HRNK) publishes its first study that combines the testimony of North Korean refugees with satellite imagery to expose North Korea's political prison camp system [65]. The refugees actively collaborated with imagery analysts to identify structures and produce evidence to counter the North Korean government that still denies the existence of such camps. Only a few years later, the American Association for the Advancement of Science (AAAS) establishes the Geospatial Technologies and Human Rights Program. Essentially, NGOs are encouraged to approach AAAS with a specific problem, which can be addressed with satellite imagery. AAAS then purchases images, collects additional information and produces a technical report that the NGOs use for their own research and advocacy. Other think tanks and NGOs produce similar reports about various human security issues and military programs in India, Iran, Israel, North Korea Pakistan, Russia, Sudan and elsewhere.[6] Arguably one of the most-cited cases is the Satellite Sentinel Project (SSP). A consortium of civil society actors supported by DigitalGlobe and private funding from George Clooney utilizes satellite imagery and a network of on-the-ground sources to monitor the security situation in Sudan and South Sudan. In this sense, they produce non-governmental intelligence products that bring together multiple sources. At the time, SSP is unique in its aspiration to release near real-time information in order to not only document but deter further violence. Two notable aspects unite the examples above. First, disillusionment has grown among non-governmental analysts concerning the extent of their political impact. The turn to intelligence practices challanges the myth of satellite imagery as impactful by virtue of the impartial truth of visuality but reveals it as demanding and norm-laden knowledge practice liable to human and technical error [66]. Second, the examples are mostly pilot projects that showcase the theoretical possibilities of non-governmental intelligence work. At the same time, though, their specific setup highlights remaining techno-political barriers by temporarily suspending them.

3.2.2. Temporarily eliminating techno-political barriers

The pilot projects of the second wave briefly override skill and economic barriers of the NGO sector by temporarily outsourcing imagery analysis and cooperating with commercial satellite imagery providers or third-party funders. They also point to related controversies that stretch into the future pertaining to the methods and ethics of imagery analysis as well as the exclusion of other global actors because of economic restraints.

During the second wave, NGOs are lacking the awareness, experience and analytical skills to exploit satellite imagery and even less integrate it in their routine day-to-day operations. Awareness of the benefits and limits of commercial satellite imagery in the NGO sector is building only slowly. In fact, it can often be traced back to particular encounters with certain pioneers and satellite imagery enthusiasts. In larger organizations, it also requires a certain amount of in-house advocacy to free resources and explore the capabilities of Earth observation. One interviewee associates the advent of commercial satellite imagery with the puppy effect: The immediate exuberance at first sight vanishes once they realize how much work it is to effectively extract added value. Put simply, while pilot projects and GoogleEarth help to create some awareness, good analysts are not made from just looking at imagery but require specialized training. AAAS solves this problem for NGOs by providing them with written satellite imagery analyses. Similarly, HRNK, 38North and the SSP rely on external expertise from DigitalGlobe and professional imagery analysts. By definition, pilot projects provide only a temporal fix and controversies about satellite imagery analysis have emerged concerning appropriate methodologies and ethical behavior. The second wave of enthusiasm produces a number of self-educated analysts. As a part of that, fears of wrong or misleading reports by amateur analysts spur efforts at AAAS and the Harvard Humanitarian Initiative to educate the non-governmental sector by way of imagery interpretation guides and workshops. Similarly, ethical issues of what and when information can be released gain traction in response to the increasing speed that new commercial satellite imagery becomes available. Because in contrast to intelligence agencies, NGOs are presented with a diametrically opposed incentive structure to produce publicity, beat others to the punch and avoid “nothing to report”-analyses when they have spent a couple of thousand dollars on imagery.

In fact, economic constraints severely limit the uptake of commercial satellite imagery by non-governmental actors. While archival imagery might be more affordable, location and time-sensitive intelligence work often requires the tasking of commercial satellites. But the imagery pricing remains prohibitively expensive especially for smaller NGOs. The situation is a reflection of the difficulties of the commercial satellite industry to find markets and sustainable business models. Of course, it was no secret to the industry that space-related projects often are expensive, but “none of those problems turned out to be as easy as we thought” admits one satellite imagery expert. While the US market starts out with a number of companies planning to sell very high-resolution satellite imagery, it is reduced to two competitors in 2006 and effectively one in 2013 after the merger of DigitalGlobe and GeoEye. The market seems smaller than expected and, on top of that, heavily dominated by the US government as by far largest customer [67]. As a result, it exercises significant power over what is being imaged – and what is not. This does not amount to outright political interference but according to various interviewees even an informal request of the largest customer can go a long way. While another large share of revenue can be attributed to the defense, intelligence, oil, gas, mining and agriculture sector. In light of the limited financial resources of NGOs, there is hardly any commercial interest in long-term business relations rendering it a low-priority area for most imagery providers. The pilot projects in imagery intelligence of the second wave are emblematic of the expectations of non-governmental imagery intelligence to promote human security. At the same time they foreground essential controversies concerning the necessary analytical capabilities and economic commitment. As a result, while showcasing the potential of commercial satellite imagery to the nonprofit sector, remaining techno-political barriers prevent normalization at scale.

3.3. Third wave

3.3.1. Democratization of data? Machine learning and predictive analytics

More recently, expectations of the third wave of enthusiasm push further and intensify the trend towards context-based intelligence. The third wave moves away from case-specific, stand-alone satellite imagery analysis. Instead, it attempts to harness multiple

[6] For example, “Crisis in Darfur” (Google Earth and USHMM), “Eyes on Darfur” (Amnesty International); see also www.38north.org, www.isis-online.org.

global datasets, including satellite imagery, using machine learning, crowdsourcing and other techniques.[7] As a result, the trend continues to pay less attention to visual transparency and individual images. To a greater degree, expectations are tied to data-driven answers to problems of global scale. The central technical expectation of the third wave is an abundance of data. The growing imagery archives of commercial providers, new global market entries, and numerous announcements about future satellite constellations raise expectations of an increasing quantity and affordability of satellite data. Analytics and value-added services are envisioned to drive the growth in the industry rather than mere satellite imagery sales [68,69]. The focus on data quantity has also made spatial resolution and immediate visuality fade from the spotlight to some degree. Instead, temporal resolution, i.e. the imaging frequency of one location, as well as the value of thermal infrared and radar imagery catch the attention of non-governmental actors. While those capabilities are often even more obscure to the eye of laypeople, it is possible to extract additional information.[8] As a result, many non-state actors are excited about the possibilities of combining visible-spectrum satellite imagery with other bands and data sources: "most people don't want the raw data, they simply want an answer" (Interview with satellite imagery expert 2017, Washington, D.C.). Expecting a flood of data, non-governmental satellite imagery analysts envision to increasingly turn to machine learning and computer-assisted imagery interpretation. They are in a process of figuring out what "machines are going to be able to do well […] and what does this leave the humans to do like adding additional pieces of information" (Interview with satellite imagery expert, 2017, Washington, D.C.). Up until now, some analysts have become oddly familiar with certain deserts as they are combing through imagery in search for military equipment or refugee encampments. These and similar time-consuming tasks are expected to be performed by automated change detection and feature extraction software. The human analyst then is alerted if something happened in a previously defined area of interest and only has to review a small share of the imagery stream [70–72].

Relatedly, the expected combination of vast amounts of imagery with other data sets also leads to a shift in the projected political impact. There is a tendency away from reactively analyzing past situations towards more proactive uses: When remote sensing turns from verification into a prediction tool, this reverses the relationship of satellite imaging and on-the-ground action. The rationale of and interest in predictive analytics is straightforward and well-known, for example, in governmental remote sensing applications for national security purposes. Hitherto, once a non-governmental actor has analyzed the satellite imagery, the harm is done and political consequences depend on political will and diplomacy. Predictive analytics are envisioned to help "getting left of bang," as one interviewee put it, which means avoiding harm and empower people on the ground to prevent an unfavorable situation. According to this shift towards big data exploitation and prediction, non-governmental actors are expected to ask different questions and expand the area of application to detailed environmental monitoring, the promotion of the UN sustainable development goals (SDG) and even business issues such as supply-chain monitoring. All in all, though, this is still congruent with the belief that more knowledge, more data and more transparency – in the right hands – eventually make for a better and safer world.

[7] The combination of multiple geospatial technologies and data streams has been called the "GEOINT revolution" [3].

[8] For example, thermal infrared imagery can pinpoint heat signatures while radar imagery that works with an active signal reflected from the Earth's surface works at night and during cloud cover.

3.3.2. NGO dependence on commercial providers

While there already are a few examples of how non-governmental actors employ machine learning and predictive analytics [73,74], the overarching controversy of the third wave concerns coping with the inflow of large amounts of data. Both NGOs and satellite imagery providers face techno-political barriers how to analytically and economically deal with geospatial big data [34]. While analytical skills of NGOs already play an important role in the second wave, technology adoption is further complicated when expectations about the use of machine learning call for the expertise of computer and data scientists. Arguably, this might be a more pressing problem for human rights and security groups than for often science-heavy environmentalists and conservationists. Moreover, project-based funding structures discourage long-term capacity building, coordination and technical exchange among NGOs to retain unique selling points that are attractive to donors. Taken together, non-governmental actors, at once, expect significant benefits from geospatial big data and difficulties to make it consistently work for their mission. Outsourcing those technical tasks to commercial actors is controversial. It requires a large amount of trust from NGOs who often depend on being perceived as objective and impartial. While non-governmental imagery intelligence with its arrows and captions remains rather easily comprehensible, it becomes all the more opaque with complex algorithms that crunch data from various sources. In short, NGOs might be more interested in an answer than an image. But their credibility rests on transparent methodologies which could be compromised when those methods are not only difficult to understand but also proprietary.

Commercial imagery providers, too, struggle with the abundance of data. Similar to DigitalGlobe in the high-resolution imagery sector, Planet has emerged as the prime provider of moderate-resolution satellite imagery after taking over RapidEye and Google's Terra-Bella (formerly Skybox). Thus, backed by government contracts and venture capital, the industry pushes the technology absent an existing demand anticipating that it will be beneficial and, not least, profitable. This expectation is encapsulated in the peculiar notion to "democratize access to data" [75]. Surely, the industry-wide trend towards smaller and cheaper satellites has enabled large-scale projects such as Planet's constellation to image the Earth's landmass on a daily basis and promises an abundance of data. As of yet, though, the democratization terminology is somewhat misleading. The remaining high prices, government involvement and technical difficulties pose significant access barriers for (non-)governmental actors both in the Global North and South [76,77]. First and foremost, it is an industry euphemism that highlights the exuberance and enthusiasm underlying the commercialization of satellite imagery. Moreover, most interviewees expect data and services for NGOs to remain a sporadic by-product of large defense and commercial contracts – although imagery providers show varying interest in the non-governmental sector as a customer. Again, similar to the nonprofit sector, commercial imagery providers themselves are still figuring out business models to monetize the steady flow of data. Nobody has found "the canonical 'killer app' for commercial imagery" [78].

4. A techno-political project in the making

The empirical analysis of the changing expectations of the commercialization of satellite imagery draws a different picture than the unitary narrative of a geospatial revolution. By comparing the individual waves, this section further elaborates on the central findings and teases out a number of additional observations.

First, the commercialization of satellite imagery is an ongoing political process. The shifting expectations and varying enthusiasm across time contradict determinist understandings of a geospatial

revolution. Instead, the commercialization is a techno-political project in the making. With this in mind, it is important to emphasize that expectations of the technological development of commercial satellite imagery neither follow a linear path nor match common practices. Instead, expectations frequently outpace realities on the ground. Many independent analysts and NGOs still operate according to the rationales of the first and second wave. Only a smaller share has managed to integrate machine learning and big data analytics into their work. Moreover, the concept of techno-political barriers reveals the politically contested nature of Earth observation technologies. The US government and especially the intelligence community have struggled to permit the transfer of satellite imagery from the secret into the open domain. Still, legal restrictions, national security concerns and burdensome licensing regulations remind commercial and non-profit actors of the Cold War roots of satellite technology. Similarly, the imagery providers that have come out on top after a series of mergers remain heavily dependent on the security and economic expectations of key government actors and venture capitalists.

Second, and rather ironically, the commercialization of satellite imagery promotes a gradual shift away from visuality. The first wave of enthusiasm celebrates satellite imagery as a boon for visual transparency. Afterward, it is increasingly put in a broader context of additional information going from what I have called non-governmental imagery intelligence towards more complex imagery exploitation and big data analytics.[9] Needless to say, only because visual transparency was more salient in the past does not mean it has become irrelevant. However, clearly the focus has shifted. The changing purpose and expected political impact of commercial satellite imagery substantiates this shift: Early adopters used satellite imagery to publicly expose the locations of secret facilities united by a shared belief in the benefits of visual transparency as a public good. Second wave non-government actors produce imagery intelligence in their human security missions. In doing so, they turn satellite imagery into a verification tool by combining it with relevant context information. The abundance of satellite data in the third wave further abstracts the visual dimension of satellite imagery and joins it with other big data to support decision-making across myriad domains.

Third, the defense and intelligence sector remains an important driver of expectations of satellite imagery, albeit this is not prominently acknowledged outside of industry circles. Although the intelligence community regularly quarrels with easing restrictions on commercial remote sensing technology, it is the premier customer of its imagery and can arguably tip the scales in techno-political controversies. Unsurprisingly, companies and public programs, such as the EU Copernicus project, rather emphasize the benefits of their data products for environmental research, humanitarian causes and sustainable development. In contrast, the analysis has highlighted the multiple roles of government actors as regulator, client and even as role model for non-governmental imagery intelligence. In this sense, the government occupies an ambiguous position: Joanne Gabrynowicz [79] identifies a pattern where overwhelming military funding has repeatedly streamlined the US remote sensing industry to serve particular mission needs and, thereby, selects a few winners that take over industrial competitors which ultimately stifles technological innovation. As was shown in the analysis, all too often this makes non-governmental uses of commercial satellite imagery a by-product of a government-backed technology push. At the same time, however, the US government is the major customer and as such the guarantor of the domestic satellite imagery industry and enables non-governmental access to it.

Fourth, social scientists, too, influence and foster technological expectations of commercial satellite imagery. A large share of academic publications refer to prominent pilot projects of non-governmental applications of Earth observation to fathom the politics of satellite imagery [76,77,80–82]. Extrapolating from pilot projects to political effects, however, can be misleading if it renders them common practices and overestimates their prevalence and significance. Considering the performativity of technological expectations, we risk to become, deliberately or not, complicit in nurturing overly enthusiastic or alarming visions of non-governmental remote sensing [37]; and in doing so, miss other legitimate targets of critique. I would argue that a direct engagement with the everyday practices of people involved in the technological development and operations, e.g. by means of interviews, participant observation and similar ethnographic approaches, helps to mitigate that risk. Because the closeness to or material experience of the technological practices more immediately expose the contingencies, failures and techno-political barriers [38]. Relying on desk research only, on the other hand, makes it more difficult to evaluate exuberant descriptions of the technology in company press releases, NGO reports and journalistic publications. Having said that, it is still important to early on caution against potential effects of technological developments. Once technological practices are locked in they become difficult to change.

Lastly, the empirical analysis reinforces the theoretical proposition that techno-political barriers are inherently intertwined with technological expectations. Surely, analyzing the performative expectations, imaginaries and visions of actors provides useful insights into the development of emerging technologies [41]. Going further, the notion of techno-political barriers builds on this and takes the disappointment of those expectations as another data point. For instance, the controversies surrounding shutter control, economic and analytical constraints of NGOs or the influx of geospatial big data show them as important sources of action and carriers of differing expectations. Moreover, including techno-political barriers in the sociology of expectations serves as a reminder of the political and messy nature of socio-technical visions. As such, they figure as a useful conceptual antidote to falling into the trap of unreflected technological expectations.

5. Conclusion

In this paper I have challenged the linear technological vision that depicts the commercialization of satellite imagery as the source of a geospatial revolution that will “create important new opportunities for the public at large” [4]. Drawing on the sociology of expectations, I have identified three waves of enthusiasm, which are characterized by particularly salient technological expectations and techno-political barriers. They distort determinist ideas of a linear development but reveal the political nature of the ongoing commercialization of satellite imagery in the US.

The first wave of enthusiasm expects a quick (global) proliferation of commercial satellite imagery that would be picked up by NGOs, companies and news organizations. Arguably, the decades-long, classified nature of satellite imagery foregrounds the visual dimension of transparency in revealing secret or restricted locations often for the first time. In this context, techno-political barriers concentrate on legal and regulatory concerns about the allowable spatial resolution of satellite imagery and its national security

[9] Interestingly, this finding resembles the development of the government-run Landsat program, which provides low-resolution satellite imagery to the science community since the 1970s. As Ray Williamson [54] writes: “Throughout the history of the Landsat system, the value-added industry has been the primary interface between the data producer and the ultimate user of information generated from remotely sensed data.”

implications. Above all, satellite imagery is conceived as a means for visual transparency and delivering a variety of rather unspecific benefits for mankind. The second wave is more focused on human security benefits. After the initial enthusiasm, NGOs recognize the challenges involved in professional satellite imagery analysis. Mirroring lessons learnt in the intelligence agency they turn it into a verification tool that works best in connection with additional information sources. As this predominantly requires expensive high-resolution imagery, concerns about economic resources join a lack of analytical expertise as central techno-political barriers of non-governmental actors. A number of pilot projects such as the SSP and AAAS address these barriers at the time. The third wave of enthusiasm completes the major shift from visual transparency to dataism. Individual satellite images increasingly fade from the spotlight. Machine learning and artificial intelligence are expected to exploit the abundance of data from large-scale satellite constellations. In doing so, NGOs return to rather general expectations about the overall benefits when satellite imagery is analyzed in concert with multiple other data streams. Despite the grandiose promise of "democratization of data" from the industry, analytical and economic barriers are more pressing for NGOs and other non-governmental actors in light of the abundance of imagery. Throughout, the defense and intelligence sector has been an anchor customer of the commercial satellite imagery industry and an important driver of the waves of enthusiasm. Given the regulatory and financial dependence of imagery providers on the government, changed mission needs have repercussions not only for the further commercialization of satellite imagery but also for the practices of non-governmental actors. In the same vein, non-governmental Earth observation often figures as a by-product of commercial operations as they do not promise sufficient financial returns.

The sociology of expectations has informed the analytical approach and conceptualizes expectations as collective, performative, dynamic and material. In this sense, practices, actor relations and artifacts inform the enthusiasm about the commercialization of satellite imagery. As such, the approach features a socio-material understanding of technology similar to ANT and socio-technical imaginaries both of which are increasingly adopted in IR scholarship [29,31,34,35,83,84]. However, the sociology of expectations more decidedly turns to the future as an analytical object. This is particularly useful considering the growing academic interest in the entanglement of technology and global politics in general and in discussions about the political impact of emerging technologies in particular. With this in view, I have introduced the notion of techno-political barriers in order to analytically cope with various forms of technology optimism, disappointment and dystopian presentiments.

In terms of limitations of the paper, the extensive time period covered forced a focus on particularly salient issues in the three waves, which left others unidentified. For example, expectations and efforts of some NGOs and international organizations especially since the second wave to establish satellite imagery as legal evidence could not be discussed – although they by and large match the then retrospective and verifying understanding of satellite imagery. Another limitation comes from the importance of expert interviews in the analysis. As all interviews were conducted in 2017, informants recapitulated expectations they had in some cases decades ago. This involves the risk of manipulating then-held beliefs of the future to match present realities. As a way to mitigate that I have opted for a greater amount of complementary material to cover the early years of commercialization.

Overall, the research findings point towards a more cautious approach in evaluating the revolutionary force of commercial satellite imagery. More specifically, the three-waves model makes clear that all rationales *and* techno-political barriers outlined above are still momentous for particular non-profit and commercial actors. Bearing this in mind is relevant when devising suitable policy regulations and new funding streams. Project-based funding remains a persistent problem for many non-governmental actors despite significant decreases in imagery pricing. Project durations of a couple of months incentivize the short-term hiring of rather expensive, external geospatial analysts and complicate the build-up of sustainable in-house capabilities. Especially in light of the expected relevance of computer-assisted analytical practices, providing dedicated, lasting support in the form of funding and training would go a long way to assist non-governmental actors to learn, consolidate and share innovative uses of commercial satellite imagery.

Declaration of interest

None.

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Appendix A. Supplementary data

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