Year: 2023

Do Eyes in the Sky Ensure Peace on the Ground? The Uncertain Contributions of Remote Sensing to Ceasefire Compliance

Sticher, Valerie ; Verjee, Aly

DOI: https://doi.org/10.1093/isr/viad039

Originally published at:
Sticher, Valerie; Verjee, Aly (2023). Do Eyes in the Sky Ensure Peace on the Ground? The Uncertain Contributions of Remote Sensing to Ceasefire Compliance. International Studies Review, 25(3):1-30.
DOI: https://doi.org/10.1093/isr/viad039

International Studies Review (2023), viad039

ANALYTICAL ESSAY

Do Eyes in the Sky Ensure Peace on the Ground? The Uncertain Contributions of Remote Sensing to Ceasefire Compliance

Valerie Sticher
Johns Hopkins University, USA

AND

Aly Verjee
University of Gothenburg, Sweden

In many conflicts, international ceasefire monitors are deployed to mitigate future violence. Increasingly, such monitors use satellite imagery, uncrewed aerial vehicles, and other camera-equipped assets to supplement, and sometimes substitute, human monitoring efforts to document ceasefire violations. To date, we know little about when and how such technology contributes to ceasefire compliance, with scholars offering diverging assessments of the effects. Integrating scholarship on the use of remote sensing in ceasefire monitoring with theories on the causal processes underlying ceasefire monitoring, this analytical essay offers a framework to assess the contribution of remote sensing to ceasefire compliance and illustrates the empirical application of this framework by examining the most technologically advanced ceasefire monitoring mission yet deployed, the Special Monitoring Mission in Ukraine. Focusing on the period prior to the Russian invasion of 2022, our research finds that while the mission's observational power was expanded, remote sensing technologies ultimately had little effect on modifying conflict party behavior or compliance. While in this case remote sensing technology minimally increased compliance, the study contributes to debates on the use of technology as a conflict management tool, and provides an assessment framework for scholars and for policymakers considering adopting technology in other monitoring contexts.

En muchos conflictos, se despliegan supervisores internacionales de alto el fuego con el fin de mitigar la violencia futura. Estos supervisores utilizan, cada vez con más frecuencia, imágenes satelitales, vehículos aéreos no tripulados y otros dispositivos equipados con cámaras para complementar, y a veces sustituir, los esfuerzos humanos en materia de vigilancia que se llevan a cabo para documentar las violaciones del alto el fuego. Hasta la fecha, sabemos poco sobre cuándo y cómo contribuye dicha tecnología al cumplimiento del alto el fuego, y los académicos ofrecen evaluaciones divergentes de sus efectos. Este ensayo analítico ofrece, mediante la inte-

Sticher, Valerie, and Aly Verjee. (2023) Do Eyes in the Sky Ensure Peace on the Ground? The Uncertain Contributions of Remote Sensing to Ceasefire Compliance. *International Studies Review*, https://doi.org/10.1093/isr/viad039

gración de la bibliografía sobre el uso de la teledetección en la vigilancia del alto el fuego con las teorías sobre los procesos causales subyacentes a la vigilancia del alto el fuego, un marco para evaluar la contribución de la teledetección al cumplimiento del alto el fuego e ilustra la aplicación empírica de este marco mediante el examen de la misión de vigilancia de alto el fuego más avanzada tecnológicamente que ha sido desplegada hasta la fecha, la Misión Especial de Observación en Ucrania. Nuestra investigación se centra en el período anterior a la invasión rusa de 2022, y concluye que, si bien el poder de observación de la misión se fue expandiendo, las tecnologías de teledetección tuvieron, al final, un efecto escaso en la modificación del comportamiento o en el cumplimiento de las partes en conflicto. Si bien en este caso, la tecnología de teledetección aumentó mínimamente el cumplimiento, el estudio contribuye a los debates sobre el uso de la tecnología como herramienta de gestión de conflictos, y proporciona un marco de evaluación para académicos y formuladores de políticas que consideren adoptar estas tecnologías en otros contextos de supervisión.

Dans nombre de conflits, des observateurs du cessez-le-feu international sont déployés pour atténuer les risques de nouvelles violences. Ces observateurs ont de plus en plus recours aux images satellites, aux véhicules aériens sans pilote et à d'autres actifs dotés de caméras pour renforcer les efforts de surveillance humaine, et parfois s'y substituer, dans la documentation des violations de cessez-le-feu. À ce jour, nous en savons peu sur quand et comment ces technologies contribuent au respect du cessez-le-feu, les chercheurs proposant différentes évaluations des effets. En intégrant la recherche sur l'utilisation des capteurs à distance dans l'observation d'un cessez-le-feu aux théories sur les processus causaux sous-jacents à cette observation, cet article analytique propose un cadre pour évaluer la contribution des capteurs à distance au respect du cessez-le-feu. Il illustre aussi l'application empirique de ce cadre en examinant la mission d'observation d'un cessez-le-feu la plus avancée sur le plan technologique déployée à ce jour, la mission spéciale d'observation en Ukraine. En se concentrant sur la période précédant l'invasion russe en 2022, notre travail de recherche conclut que bien que le pouvoir d'observation de la mission se soit élargi, les technologies de capteur à distance n'ont finalement eu que peu d'effet sur la modification du comportement ou du respect des parties au conflit. Bien que dans ce cas, la technologie de capteur à distance ait quelque peu augmenté le respect, l'étude contribue aux débats sur l'utilisation de la technologie en tant qu'outil de gestion des conflits. Elle fournit également un cadre d'évaluation pour les chercheurs et les législateurs qui envisagent d'adopter cette technologie dans d'autres contextes d'observation.

Keywords: ceasefires, remote sensing, Ukraine

Until the Russian invasion of February 2022, the Organization for Security and Co-operation in Europe (OSCE)'s Special Monitoring Mission to Ukraine (SMM) was widely seen as the ceasefire monitoring mission to emulate. The SMM was often admired for its "pioneer" use of remote sensing technologies, including satellite imagery, camera-equipped uncrewed aerial vehicles (UAVs), and stationary cameras to monitor eastern Ukraine's troubled ceasefire from 2014 to 2022 (Peško 2017; Kemp 2018; Dorn and Giardullo 2020a, 32). Beyond Ukraine, the use of remote sensing in ceasefire monitoring is increasing (Lute 2014; Giardullo, Dorn, and Stodilka 2020; UNDPPA 2020; Buchanan, Clayton, and Ramsbotham 2021; Grand-Clément 2022; Hug and Mason 2022). However, even as the remote sensing of monitoring armed conflicts becomes more common, as part of a wider trend toward technological adoption and adaptation in conflict and conflict resolution, little is known about the impact of these technologies on ceasefires. In particular, it is unclear whether the use of remote sensing by ceasefire monitoring missions improves ceasefire compliance, the raison d'être for most missions. Some scholars emphasize the benefits of remote sensors, arguing that—even if challenges persist—they allow a mission to collect previously unimaginable information, and verify information that would otherwise be unproven (e.g., Giardullo, Dorn, and Stodilka 2020; Dorn and Giardullo 2020b). Others question the significance of data collected through remote sensors, arguing that their effects largely depend on parties' political will to adhere to a ceasefire (Buchanan, Clayton, and Ramsbotham 2021; Hug and Mason 2022, 4; United Nations Institute for Disarmament Research 2022, 22). Skeptics suggest that the use of such technologies may inadvertently risk reinforcing the status quo (Richmond and Visoka 2021) or even undermine important ceasefire monitoring functions (see Conciliation Resources 2020; UNDPPA 2020; Buchanan, Clayton, and Ramsbotham 2021, 6, 21).

We believe that these divergent assessments result from a lack of integration of remote sensing research with the wider ceasefire literature, particularly of studies examining the causal processes underlying ceasefire monitoring. In this analytical essay, we propose a theoretical framework to assess when and how remote sensing technology can contribute to ceasefire compliance, and then demonstrate its application in an empirical case study. Building on existing ceasefire literature, in particular Fortna (2003, 2004), we identify three possible pathways through which remote sensing can contribute to compliance. First, remote sensing can reduce third-party uncertainties about the perpetrators and circumstances of a violation, enabling third-party actors to impose costs for violations. Second, conflict parties' acceptance and non-interference with remote sensing systems can signal intent, thereby reducing uncertainties about opponents' actions and intent. Third, by allowing monitoring missions to gather and verify information that can be shared with conflict parties, remote sensing can enable the respective chains of command to intervene in the case of non-strategic ceasefire violations and help mitigate conflict escalation.

We then apply our framework empirically, tracing the three pathways in the case of the OSCE SMM in Ukraine, the most technologically advanced ceasefire monitoring mission deployed to date (Conciliation Resources 2020). The Ukraine case study serves two purposes: first, it illustrates how to assess the contributions of remote sensing to ceasefire compliance empirically, and second, it provides the first systematic assessment of the effectiveness of remote sensing technology in this specific case. We find that, despite enabling the SMM to gather and verify useful information that increased its situational understanding, the effects of remote sensing on ceasefire compliance in eastern Ukraine were limited because of the way in which information was shared and acted upon, as well as the political context inhabited by, and which shaped, the monitoring mission. The insights generated by this essay rebut the techno-optimist narrative that technology is a panacea, but also reject the notion that the successful use of technology in peacemaking is solely dependent on the political will of the conflict parties. Instead, we argue that different mechanisms are circumstantially contingent. We offer a framework to evaluate these circumstances, thus highlighting important considerations for those seeking to design effective ceasefire monitoring missions.

We proceed as follows. In the first section, we provide an overview of existing research, showing how the literature on the role of remote sensing in ceasefire monitoring tends to be disconnected from the wider ceasefire literature. In the second section, we address this issue by proposing three theoretical pathways for when and how remote sensing technology *can* contribute to ceasefire compliance, before assessing these pathways in our empirical case in the third section. We discuss our findings in the fourth section, in which we also show how the effects of remote sensing on compliance may differ from the effects on *non-compliance*. We highlight implications of our research in the concluding remarks.

Ceasefire Monitoring and the Role of Technology

A growing number of studies either assess the effects of ceasefire monitoring on ceasefire compliance or detail the benefits and challenges of using remote sensing technology for monitoring, but there are few efforts to connect the two. As a result, we fail to understand when and how remote sensing affects ceasefire compliance and non-compliance.

The Role of Ceasefire Monitoring

Ceasefires range widely in terms of scope and purpose, but their shared declared objective is to suspend or terminate conflict violence (Clayton et al. 2019). Research shows that ceasefire monitoring missions *tend* to increase the expected duration of such violence suspension in both inter- (Fortna 2003, 2004) and intrastate conflicts (Clayton and Sticher 2021), although much depends on their implementation (see Kolås 2011; Verjee 2019b).

Fortna proposes three main mechanisms through which ceasefire provisions—including ceasefire monitoring missions—may affect ceasefire compliance: by altering the incentives to comply, by reducing belligerents' uncertainties about actions and intentions, and by controlling accidents (Fortna 2003, 2004).

The first mechanism, altering incentives, refers to a strategy to increase the costs conflict parties endure when violating a ceasefire. High costs make it less attractive to deliberately violate an agreement (Fortna 2004, 21–22; see also Pinaud 2021, 475). Measures to increase costs in the context of civil conflicts primarily relate to third-party audience costs (Fortna 2003, 342–43; Clayton and Sticher 2021, 635). However, even if conflict parties have an incentive to comply with a ceasefire, they may find it challenging to credibly communicate this intention, and they may doubt the good faith of their opponent(s) (see Fearon 1995; Walter 2009). These issues of communication and trust can impede successful cooperation. Parties may overcome these impediments by accepting measures that make cheating more costly (Fearon 1997).

A second mechanism through which ceasefire provisions can make ceasefires more effective and more durable therefore lies in reducing uncertainties about actions and intentions (Fortna 2004, 22–23). By accepting compliance mechanisms that make it harder and more costly to cheat, conflict parties can signal their seriousness about compliance (Fortna 2003, 344; Clayton and Sticher 2021, 639). However, such signaling should be viewed in context. Third-party pressure can make it costly not to sign an agreement, which may lead conflict parties to accept agreement provisions despite a lack of intention to honor these provisions or to only partially comply.

A third mechanism for how ceasefire provisions may increase compliance is by preventing accidents from spiraling out of control (Fortna 2004, 23–24). Monitoring missions may provide information about general compliance or verify allegations of violations, allowing actors to distinguish between aggressive moves, accidents, and legitimate acts, and within the category of aggressive acts, better determine the significance and magnitude of such violations.

In general, conflict parties are thought more likely to trust information provided by an impartial third party rather than by parties to a conflict (Fortna 2003, 343–44). However, in many civil conflicts—particularly those where actors share not only territory but also a history of formerly aligned forces—conflict actors may understand conflict dynamics much better than third-party actors (Verjee 2019b, 5). They often have existing networks—independent of third parties—which may more rapidly and accurately convey information between the parties, as well as serve to deliberately conceal information from third parties. This may severely limit the ability of monitoring missions to convey novel and relevant information to the conflict parties (Hirblinger et al. 2023).

Beyond information provision and affecting costs, ceasefire monitoring missions may provide a forum for conflict actors to build working relations and discuss incidents (Fortna 2003, 344–45; see also Brickhill 2018; Åkebo 2019, 474; Pinaud 2021, 477–78). Such an exchange—together with any information deemed credible—may help reduce uncertainties about the actions and intention of the opponent, as well as prevent accidents from escalating out of control (Fortna 2003, 343–45).

Yet, even if monitoring missions succeed in reducing uncertainties, such reductions may not ensure a ceasefire holds. Even in the presence of unambiguous information—e.g., who committed what type of ceasefire violation—third parties may not be willing or able to act upon the information to alter the incentives of conflict parties. Similarly, uncertainties about the actions and intent of the opponent(s) may not be the definitive obstacles to ceasefire compliance. If a conflict party prioritizes a military objective rather than a political settlement, it may use any justification to escalate violence, regardless of information about an opponent's intent (see Clayton and Sticher 2021; Sticher and Vuković 2021). Put differently, monitoring may facilitate ceasefire compliance if parties are already inclined to comply, but it cannot substitute for a lack of political will among conflict parties (see also Palik 2021).

Given the frequent absence of the political will of conflict parties, even well-designed and well-executed ceasefire monitoring can be ineffectual, and risk contributing to freezing conflicts (Åkebo 2016). Cyprus, for example, hosts one of the longest running ceasefire monitoring missions anywhere; some argue this has contributed to a comfortable status quo where the dispute is perpetuated (Mahieu 2007). Further, flawed ceasefire monitoring can be worse than ineffectual and exacerbate conflict situations. Deficient monitoring can serve as tacit approval for conflict parties to continue their activities (Kolås 2011).

Perhaps even worse, bias in ceasefire monitoring toward a particular party or selectivity in monitors' activities can discredit the ceasefire agreement as a whole. Inaccurate or superficial monitoring—even when unintended—can distort understanding of a conflict's dynamics and evolution. Delayed investigations and reporting on ceasefire violations may put monitors in a position of constant catch-up, and interruptions to monitoring could also lead to distorted assessments of the conflict. Subjugating credible monitoring to other interests, such as those of mediators who would prefer to control the timing of the release of information until the moment they determine it is "appropriate," may be justifiable but also risks monitors' credibility, particularly when mediators and monitors are closely interlinked, as in Sri Lanka (Chounet-Cambas 2011) or South Sudan (Verjee 2019a). Ceasefire monitoring can also be largely performative, with its findings calibrated in the interests of balancing attributions of responsibilities, or even be ignored by those to whom monitors ostensibly report (Verjee 2019a).

Debate about the Role of Remote Sensing Technology

Much of the scholarly literature on remote sensing technology and armed conflicts focuses on how states use reconnaissance satellites or UAVs for espionage, defensive military operations, and warfare (Harris 2006; Lee and Steele 2014; Kindervater 2016; Boyle 2020; Early and Gartzke 2021). Meanwhile, an emerging body of literature specifically investigates how remote sensing affects ceasefire monitoring. While research on this topic is still limited, several case studies point to the benefits, challenges, and risks of using such tools. However, none of these studies directly relate their assessments to the ceasefire mechanisms described above, which limits our understanding of *when* and *how* technology affects ceasefire compliance.

Potential Benefits

Several studies argue that the use of stationary cameras, UAVs, satellite imagery, and other remote sensors allows missions to expand their presence geographically and temporally. Without the use of remote sensing technology, it may be impossible for human monitors to cover vast conflict areas systematically. A particular challenge is to cover remote areas or areas where access is limited by the conflict (see Giardullo, Dorn, and Stodilka 2020; Dorn and Giardullo 2020b; Buchanan, Clayton, and Ramsbotham 2021; Hug and Mason 2022). Remote sensors, such as camera-equipped UAVs, allow missions to contemplate a geographically and temporally more substantive, even 24-hour presence, despite limited staff or movement restrictions on those staff (Hug and Mason 2022). Nighttime coverage may be particularly crucial as, in some conflicts, many violations occur after dark and thus preclude eyewitness monitoring. Some argue that such increased presence in and of itself can be desirable, as it increases deterrence (Kemp 2018, 117; Hug and Mason 2022, 3).

Another potential benefit to ceasefire monitoring is technology's ability to mitigate the very real risks to human monitors of car accidents, landmines, and hostile action, by reducing the frequency of their movements and exposure to hazards (Witmer 2015). Like in peacekeeping and other peace interventions, foreign publics, states, and their militaries (with whom international monitors are often connected) are sensitive to the risks their seconded monitors face (Van Der Meulen and Soeters 2005). As Feaver and Gelpi (2011) point out, even when the general public may tolerate casualties, militaries and governments are often more risk averse. Although expectations of zero casualties in modern conflict may be unrealistic, even with the availability of advanced technology (Ben-Ari 2005), most monitoring missions are anxious about incurring casualties, especially among unarmed (and ostensibly) civilian monitors. The line between risk mitigation and limitation and risk aversion, however, is fine. Risk aversion may alter the way in which monitoring occurs and in which understanding of incidents arises. At the same time, remote sensing technology may alter perceptions of acceptable risk, by giving missions the option to pursue some form of monitoring without or with limited human presence, rather than having to choose between deploying human monitors and no monitoring at all.

The quality and speed of information gathered through remote sensing promises additional benefits. Certain types of information (e.g., the number of vehicles in a convoy) tend to be more accurate if captured on camera, rather than from witness statements. Such information may also be more trusted, although in an age of deep fakes, trust in the system itself may be an important pre-requirement (Grand-Clément 2022, 31–32; Hug and Mason 2022). Collected data can serve as documentary evidence or may be used to support allegations others contest (Dorn and Giardullo 2020b, 3; Hug and Mason 2022). Imagery evidence—such as video feeds collected by UAVs—can provide more realistic information about conflict zone conditions. Graphic images may increase public pressure to act and mobilize third-party action (Giardullo, Dorn, and Stodilka 2020, 132). The speed at which information is gathered can be as important, particularly in crisis situations (Buchanan, Clayton, and Ramsbotham 2021, 21), although the detection, investigation, and analysis of conflict incidents depend considerably on the time that has elapsed since an incident (Witmer 2015). Other related arguments are that remote sensing can increase transparency, as it facilitates information sharing with the public, and that it can lead to a more comprehensive understanding of the conflict situation (Giardullo, Dorn, and Stodilka 2020, 136; Buchanan, Clayton, and Ramsbotham 2021, 21–22).

Challenges and Risks

Scholars also highlight several challenges that arise with the use of remote sensing and point to risks that may outweigh the benefits offered by these technologies.

One challenge relates to the analysis of the gathered data. Remote sensing allows missions to collect a wealth of data, but the analysis of such data risks creating new bottlenecks (see Dorn and Giardullo 2020b; Buchanan, Clayton, and Ramsbotham 2021, 21). Having more data may not mean that all of that data have significance; as one former monitor noted, "we spent a lot of time looking at pictures of forests."[1] Some data, such as radar satellite or thermal images, can only be analyzed by specialists (Grand-Clément 2022, 31). However, even if some data are easier to interpret, such as video streams from stationary cameras, analysis requires considerable human resources and contextual understanding. Cameras may not get tired and can work more than 9 to 5, but alone, they are unlikely to provide context. The impact of more and more data may in some cases be meaningless if data cannot be processed systematically and quickly. Machine learning may eventually mitigate this problem, for example, by pre-selecting relevant images for human analysts to review (Grand-Clément 2022, 51). However, for the foreseeable future, the analysis of data collected by remote sensors remains a considerable challenge.

Another challenge relates to costs: one motivation for missions to adapt remote sensors is to save money that might otherwise be spent on human monitors. Yet, many of the remote sensing tools in use are expensive and require expertise to be operated and maintained (Kemp 2018; Giardullo, Dorn, and Stodilka 2020, 123; Grand-Clément 2022, 30; Hug and Mason 2022, 116).

By complementing, and in some cases substituting, activities of human monitors, remote sensing may also affect the interactions between conflict parties and third parties. Ceasefires are often used as measures to build confidence, and joint monitoring activities may provide important moments of trust and relationship building across conflict party lines (Brickhill 2018) or with civil society (Pinaud 2021). Using remote sensing instead of (more) human monitors may take ownership away from conflict parties, and reduce these opportunities for confidence building (Conciliation Resources 2020; Buchanan, Clayton, and Ramsbotham 2021, 21; UNDPPA 2020). In addition, data gathered by remote sensing may privilege the recording and measurement of certain types of ceasefire violations but play little role in measuring less dramatically visible forms of violence against civilians, including gender-based violence. Since gender-based violence is already often underreported in most conflicts (Alcorn 2014; Fernández-Fontelo et al. 2019), the increased use of remote sensing technology may only exacerbate this tendency.

Finally, some question the use of more and more data, particularly in cases where conflict parties lack the will to move toward a lasting settlement. They argue that it is hard to see how data collected through remote sensing may make a difference if there is no political process to address the issues conflict parties contest (see Hug and Mason 2022).

Three Pathways to Contribute to Ceasefire Compliance

Despite a general understanding of the potential benefits, challenges, and risks of remote technology in ceasefire monitoring, the lack of integration between the literature on technology and the literature on the causal processes underlying ceasefire monitoring makes it difficult to identify the conditions under which technology may enhance ceasefire compliance. In this section, we build on the causal mechanisms first introduced by Fortna (2003, 2004) to develop three separate pathways through which the use of remote sensing technology in ceasefire monitoring can *in theory* contribute to ceasefire compliance. Our aim is to better understand and

[1] Interview with former SMM monitor, January 27, 2022, online.

assess the potential causal relationship between the use of remote sensing technology in ceasefire monitoring and improved ceasefire compliance, as a framework to assess the role of remote sensing technology in any specific case. Our mechanisms revolve around the role played by information provision, as remote sensing is generally used for the purpose of data collection and verification (as compared to, for example, establishing trust or working relations). We focus on the use of remote sensing technology by ceasefire monitoring missions rather than by the conflict parties, recognizing that such use by the latter can also affect compliance. Finally, we deliberately focus on the promotion of ceasefire *compliance*, acknowledging that remote sensing can also have non-compliance effects, as discussed toward the end of this essay.

We use the term compliance to refer to the extent to which conflict parties adhere to the terms and uphold the spirit of a ceasefire arrangement. Compliance is not binary and is better thought of as existing on a dynamic spectrum (Jancsics, Espinosa, and Carlos 2022). Consequently, compliance does not indicate a total absence of ceasefire violations—violations occur in almost all ceasefire arrangements (Bara, Clayton, and Aas Rustad 2021)—but relates to the intent, types, and significance of ceasefire violations that occur and subsequent responses by the parties. Our mechanisms contribute to compliance if they prevent or lower the risk of significant violations; lower escalation risks following a ceasefire violation; or lower the risk of ceasefire breakdown following escalatory dynamics. We take an inclusive approach to defining ceasefire violations, encompassing both violent and non-violent acts that contravene the terms of a ceasefire agreement.[2] Violations vary in severity and come in different types, including those authorized or implicitly sanctioned by the conflict party leadership for military advantage (strategic violations); those ordered as retaliation against an opponent (retaliatory violations); those that occur against the orders and will of leaders (spoiling violations); those driven primarily by local dynamics (localized violations) (Sticher 2022); and those motivated by the presence of monitors in a conflict theater (third-party signaling violations) (Verjee 2023). As we specify in our pathways below, different mechanisms are effective in dealing with different types of violations. Finally, rather than setting an arbitrary numerical threshold of ceasefire violations or battle-related deaths to determine the breakdown of a ceasefire and the resumption of full-fledged hostilities, we view a ceasefire as operative as long as conflict parties continue to indicate an intent to abide by the agreement.

Pathway 1: Reducing Uncertainties of Third Parties

The first causal mechanism introduced by Fortna focuses on altering incentives (Fortna 2004, 21–22). Ceasefire monitoring missions and other third-party actors, such as regional and international organizations or external state actors to whom monitoring missions may be accountable, can alter the incentives of ceasefire compliance by imposing costs for violations (see discussion above). However, third parties need high confidence about the perpetrator(s) and circumstances of a violation, if they are to consider any response. Without convincing information, third parties are unlikely to impose costs on violators. This suggests that even though information in and of itself does not alter incentives, it plays an important role in enabling third-party actors to impose costs.

Remote sensing increases the observational power of missions, consequently reducing uncertainties and enabling the imposition of costs for violations. We define observational power as referring to two main aspects. First, remote monitoring expands a mission's temporal and geographical reach, allowing it to monitor other-

[2] An example of a violent ceasefire violation is the killing of an opponent during a declared ceasefire; a non-violent violation might entail the movement of heavy weaponry into a zone prohibited by the ceasefire arrangement.

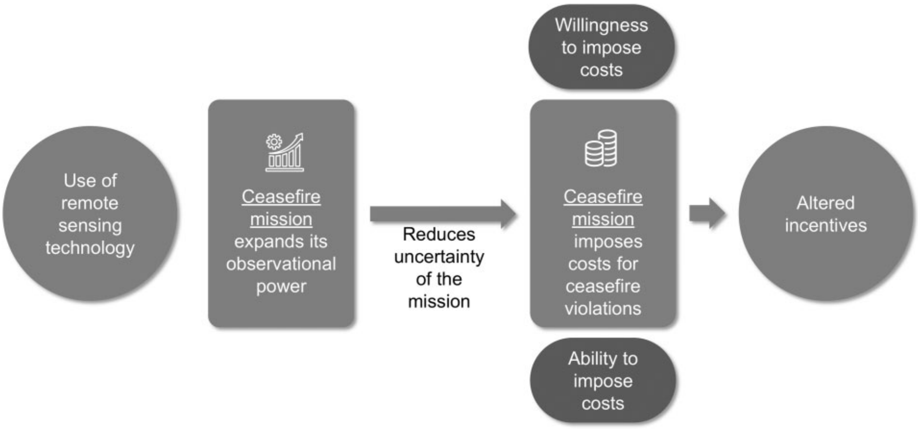


Figure 1. Pathway 1a (altering incentives): ceasefire mission imposes costs

wise inaccessible situations, such as violence at nighttime and areas unreachable by human monitors due to limited resources, restrictions posed by the conflict parties, or security concerns (Giardullo, Dorn, and Stodilka 2020; Dorn and Giardullo 2020b; Buchanan, Clayton, and Ramsbotham 2021; Hug and Mason 2022). Even if operational considerations and limited information processing capabilities constrain a mission's ability to systematically observe and assess all conflict events at night or in isolated locations, remote sensing still considerably enlarges a mission's reach, and thus reduces uncertainties related to violations that occur in these circumstances.

Second, the use of remote sensing produces imagery that is more difficult to dispute than witness statements. Such evidence may improve third-party confidence about the nature and perpetration of a violation, especially when it complements reports from human monitors.

Based on the information they gather and verify, monitoring missions may impose costs for violations directly, or they may provide information to other third-party actors who can impose such costs. However, even if third-party actors are confident about who committed a violation, they may not be willing or able to impose costs on the violators. There are different reasons for this: third-party actors may not deem the incident serious enough to impose costs on the violating party or they may fear setting a precedent. They may have concerns about antagonizing the conflict parties and escalating the conflict, or fear being perceived as biased. They may have concerns about signaling to the non-violating party that it can take advantage of costs imposed on the violator, or they may be constrained in their mandate, which is often the case for regional and international organizations whose member states may have a direct or indirect stake in the conflict. Our first possible pathway is thus strongly conditioned by the general willingness and ability of third-party actors to impose costs for ceasefire violations.

To recap, a first pathway by which remote sensing can increase compliance is to reduce uncertainties about the perpetrators and circumstances of a ceasefire violation, thereby enabling third-party actors to *alter incentives* for violations. We depict this causal mechanism, showing how the mission may impose costs directly (figure 1) or may share information with other third-party actors who then impose costs (figure 2).

The circles in figures 1 and 2 represent trigger and outcome, the rectangles represent activities by a specific entity (ceasefire mission or third-party actors), and the arrows represent causality. The main conditions enabling this mechanism—the willingness and ability of monitoring missions or linked third parties to impose costs—

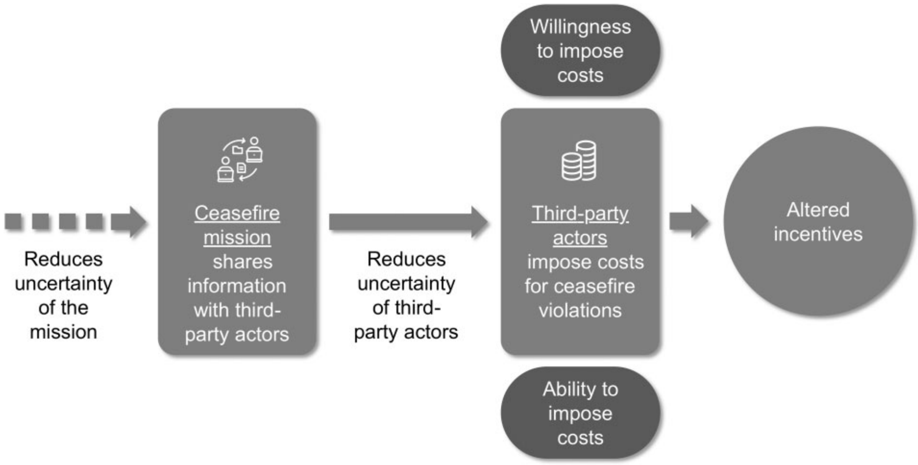


Figure 2. Pathway 1b (altering incentives, continued from pathway 1a): third parties impose costs

are indicated in dark ovals. This mechanism primarily works for strategic violations and third-party signaling violations, as it alters the incentives of conflict party leaders to authorize or tolerate violations. It is less likely to reduce the occurrence of spoiling or localized violations, as costs tend to be imposed on the conflict party leadership and not the actors committing the violation on the ground.

Pathways 2 and 3: Reducing Uncertainties of Conflict Parties

The two other causal mechanisms relate to uncertainties among the conflict parties. Conflict parties may seek to mitigate an opponent's uncertainties about their intent through costly signals, or they may use third-party information to reduce their own uncertainties about an opponent's actions and intent.

Signaling Intent

Uncertainties about an opponent's actions and intent can greatly impede cooperation (Walter 2009). One way conflict parties may signal their intent is by accepting compliance mechanisms (see also Fearon 1997; Fortna 2003, 344; Gartzke and Lupu 2012; Schultz 2012), as discussed above.

As noted in pathway 1, remote sensing increases the observational power of a ceasefire monitoring mission, allowing it to surveil situations it could not previously monitor and facilitating its evidence collection. A key form of remote sensing, the use of satellite images, is a relatively non-intrusive form of monitoring (Diehl 2002). However, other forms of remote sensing, in particular UAVs, are highly intrusive. Unless imposed by the UN Security Council, the state actor must consent to the use of such technology and may reconsider or impose conditions on their use over time. Consent may also need to be sought from non-state actor(s), especially if a monitoring mission forms part of a larger peace process.

There might be important reasons for states not to consent to more intrusive remote sensing systems, such as sensitivities around sovereignty (Boyle 2020, 414). A rejection of such measures should, therefore, not automatically be read as a sign of devious intent. Voluntary acceptance of the deployment of remote sensing technologies, meanwhile, can signal some willingness to accept strong compliance measures.

Beyond nominal acceptance, allowing ceasefire monitoring missions to freely operate remote sensing systems can provide an even more important signal of intent.

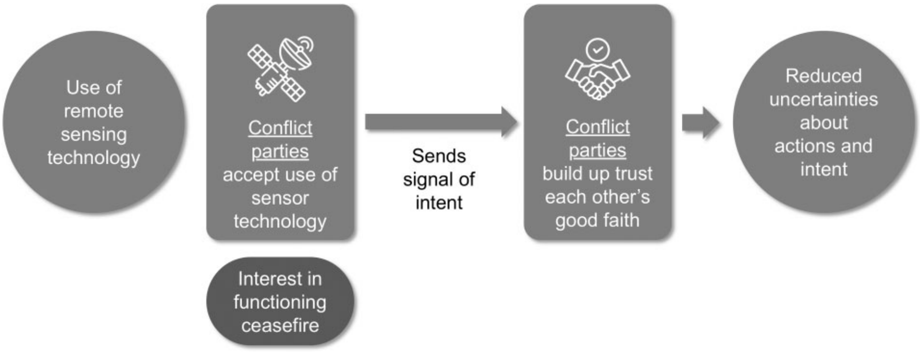


Figure 3. Pathway 2 (reducing uncertainties)

Tolerance of resistance by ceasefire monitoring missions is arguably much higher when technologies are involved compared to human monitors. For example, the jamming or downing of a UAV will cause much less political fallout than a physical attack on human monitors. This suggests that actors that are not content with constant surveillance may interfere with remote sensing systems, without paying a large political price.

By accepting the use of remote monitoring technology—not just in name but also in practice—parties can therefore signal their intent, which may lead to more trust in the good faith of the opponent. This, in turn, reduces misunderstandings and facilitates cooperation, which could increase compliance (Fortna 2003, 343–44; Clayton and Sticher 2021, 636–37). Conflict party leaders may be less likely to authorize or tolerate violations by their subordinates if they perceive the benefits of potential cooperation (reducing strategic and localized violations), and less likely to retaliate if they believe the opponent is acting in good faith (reducing retaliatory violations).

However, this pathway requires the conflict party leadership to have a basic interest in a functioning ceasefire: signaling helps with reducing uncertainties, but when actions simply confirm that there is no intent to comply, there is no reason to assume that this would improve compliance—it may instead further entrench mistrust. Furthermore, while acceptance and non-interference with remote sensing systems may help conflict parties signal intent, this arguably only affects ceasefire compliance if uncertainties about intent are a salient obstacle to cooperation.

Thus, a second mechanism by which remote sensing may increase ceasefire compliance is by allowing conflict parties to signal their intent. Figure 3 depicts this pathway in an ideal-typical way. Since acceptance and non-interference are on a spectrum and may shift over time, and the intrusiveness of remote sensing varies, these factors also condition the potential signaling effect.

Containing Escalatory Dynamics

The third mechanism concerns the prevention of escalatory dynamics. Localized incidents or spoiling behavior may lead to retaliation or trigger the breakdown of a ceasefire. Ceasefire monitoring and verification can reduce the risk of involuntary escalation, and by extension, the risk of a ceasefire breakdown, by providing timely and trustworthy information about the circumstances of an alleged violation (Fortna 2004, 23–24). As discussed earlier, the ability of a ceasefire monitoring mission to provide useful information is considerably limited in intrastate wars, as conflict actors often possess much more intimate knowledge of the conflict situation and may hold or obtain information that is not easily accessed by third-party actors.

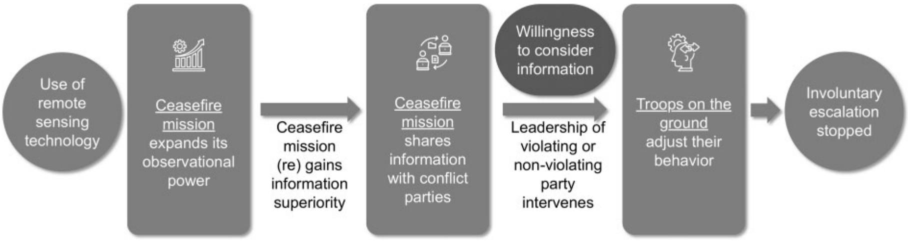


Figure 4. Pathway 3 (containing involuntary escalation)

As remote sensing increases the observational power of a ceasefire monitoring mission, it can help missions close some of this gap. It provides missions with the means to gather information in remote areas and in the hours of darkness, possibly allowing a mission to detect violations more systematically and more quickly than a conflict party's leadership—at least in cases where violations did not occur as a result of orders from the chain of command (Hirblinger et al. 2023). While the narrative context necessary for the interpretation of such information may be lacking, a mission may still be able to provide conflict party leaders with novel and timely evidence. This can help a monitoring mission regain a superior information function, as originally conceived by Fortna (2003, 2004).

A third pathway through which remote sensing may contribute to ceasefire compliance is, therefore, by enhancing a ceasefire monitoring mission's ability to provide useful information to the conflict parties about conflict events. To affect compliance, conflict actors need to be willing to consider such information when deciding their reaction to an incident (even if they may not acknowledge this publicly).

A mission may share information with the violating party, asking it to intervene in an ongoing or repeated ceasefire violation. If their personnel or affiliates are involved in a ceasefire violation, then the violating party's command may order a cessation or remediative action. We expect this primarily to work for localized and spoiling violations, that is, for types of violations that were not authorized or implicitly sanctioned by the conflict party leadership.

A mission may also share information about a ceasefire violation with the leadership of the non-violating party.[3] Provided a violation was likely an accident or resulted from spoiling behavior, leaders may be less inclined to retaliate and may ask commanders on the ground to respond moderately, thus lowering the risk of escalation. This third pathway through which remote sensing can contribute to ceasefire compliance is depicted in figure 4.

To summarize, we argue that there are three main possibilities for remote sensing to theoretically improve ceasefire compliance: by enabling third parties to alter incentives, by signaling intent through acceptance and non-interference with remote sensing systems, and by mitigating the risk of involuntary conflict escalation through information provision. We now turn to the case study to demonstrate how to trace these pathways empirically, including the factors that condition these pathways.

The OSCE SMM to Ukraine

The SMM, an unarmed civilian mission, focused on monitoring the security situation between the Ukrainian armed forces and Russian-backed separatist forces in eastern Ukraine until its monitors were withdrawn shortly after the expansion of the war in 2022. Since beginning work in March 2014, the SMM faced high expectations to help resolve the conflict while operating in a politicized and hostile context. The

[3]Remote sensing may also provide information about the likely abrogation of a ceasefire by one of the conflict parties, which we discuss below given the Russian escalation in February 2022.

sheer number of incidents to observe, and perceived risks to monitors, incentivized the adoption of technology as part of broader trends in peace interventions to avoid risk (Van Der Meulen and Soeters 2005; Oksamytna 2018).

The selection of the SMM as a case study was motivated by its more widespread use of remote sensing technology than any previous mission, providing a unique opportunity to examine the various applications of this technology. Assessed contemporarily, Ukraine may seem an exceptionally difficult case for the effective deployment of remote sensing technology, opening our case selection to potential critique. However, the purpose of our empirical study is not to provide a general assessment of the effectiveness of remote sensing on ceasefire compliance, but to demonstrate how we may study its effectiveness in any case, by applying the framework introduced above. In addition, our case study offers the first systematic assessment of the effectiveness of remote sensing in strengthening ceasefire compliance in eastern Ukraine, which did vary over time, suggesting that the case offers its own contextual nuances. While the focus of our analysis is the period before February 2022, we also consider what the Russian invasion reveals about the effectiveness of remote sensing technology for ceasefire monitoring. We do not consider operational issues (unless they relate to our three pathways) and particularly focus on the post-2015 period, when remote sensing technology was more widely introduced at the SMM.[4]

Brief Background and Empirical Approach

The SMM was deployed in March 2014 as the security situation in Ukraine worsened following Russia's annexation of Crimea in February. Hostilities between the Ukraine army and Russian-backed separatist forces in eastern Ukraine broke out shortly after. When, about 5 months later, a ceasefire was agreed, the OSCE was tasked to monitor the arrangement (Neukirch 2015, 193). As no amended mandate for the SMM could be agreed upon due to the OSCE's requirements for unanimous decisions, the original broad mandate remained unchanged throughout the mission's duration. Although the SMM's mandate was national, the majority of monitoring activity focused on the so-called line of contact, which, after the summer of 2015 and until early 2022, was a fairly static 420-km-long line dividing the Ukrainian government-controlled areas of the Donbas from those under separatist control (Neukirch 2016).

The SMM employed four main types of remote sensors (see Giardullo, Dorn, and Stodilka 2020):

1. **UAVs mounted with cameras** (optical and thermal infrared): these can be further divided into three categories. Mini-UAVs fly at low altitude for up to 30 minutes, have a range of 2–5 km, and can be launched from unpaved surfaces, which made it the most commonly used type of UAV by monitoring teams. Mid-range UAVs have a longer range of between 15 and 50 km, and higher resolution cameras, but need paved surfaces to launch, which was often difficult given the infrastructure around the contact line. Long-range UAVs fly at higher altitude, for longer distances, with greater endurance, and can also fly at night; this allowed the mission to cover much vaster areas, but these had to be flown by specialized operators rather than typical monitors.
2. **Fixed stationary cameras** (optical and thermal infrared): these were placed in hot spots and other designated areas around the contact line. At its

[4]For operational challenges related to the introduction of remote sensing technology, see OSCE Conflict Prevention Centre (2021).

peak, the SMM had as many as 28 cameras in 23 locations, which allowed the mission to monitor specific areas around the clock.

3. **Access to high-resolution satellite images:** Satellite images were acquired upon request from the European Union Satellite Centre. The mission also had access to Digital Globe imagery. These images allowed the mission to compare developments on the ground over time, with regard to, for example, the movement of forward positions, construction of trenches, or the state of critical infrastructure (Conciliation Resources 2020).
4. **Fixed, passive acoustic sensors**: these were used to count and identify the direction of fire; however, the use of these sensors was not as systematic or successful as the use of other sensor technologies (Giardullo, Dorn, and Stodilka 2020, 128).

As OSCE procurement documents show, in 2016 the SMM spent over €800,000 on the purchase of 22 UAVs, over €5 million on satellite surveillance systems and another €300,000 on two UAVs in 2017, more than €26.3 million on UAVs in 2018, and €670,000 on video monitoring systems in 2020.[5] The procurement of remote sensing technology was therefore a considerable portion of the mission's annual budget.[6] The use of these various sensors was designed to complement the activities of human monitors.

In the following sub-sections, we trace when and how these sensors helped alter incentives (pathway 1), contributed to the signaling of intent (pathway 2), and helped contain escalatory dynamics (pathway 3) in the Ukraine case. For each pathway, we develop a set of guiding questions that address the specific causal argument. We then assess these questions, drawing on three main sources. First, we used daily, spot, and thematic monitoring reports and lessons learned produced by the SMM, to gather basic data about the mission and track what types of ceasefire violations were recorded by what means. Second, we consulted secondary readings to search for possible insights regarding our guiding questions for assessment. Third, we conducted thirteen in-depth expert interviews with monitors and officials of the SMM, the OSCE, and the Trilateral Contact Group (TCG)[7] that served during the 2014–2022 period of study. We anonymized our sources to protect the identity of the interlocutors. Interlocutors were identified through our personal networks, through cold contacts, and via snowballing techniques. This allowed us to reach experts that served in different positions and offered a variety of perspectives, with each expert being able to speak to a sub-set of our questions. We ensured that we collected several perspectives on each question and triangulated information wherever possible. Some guiding questions are more difficult to answer, as, for example, when they touch on the matter of signaling intent. In these cases, we use the available data to make an informed assessment while highlighting the methodological challenges faced by our assessments.

Pathway 1: Altering Incentives

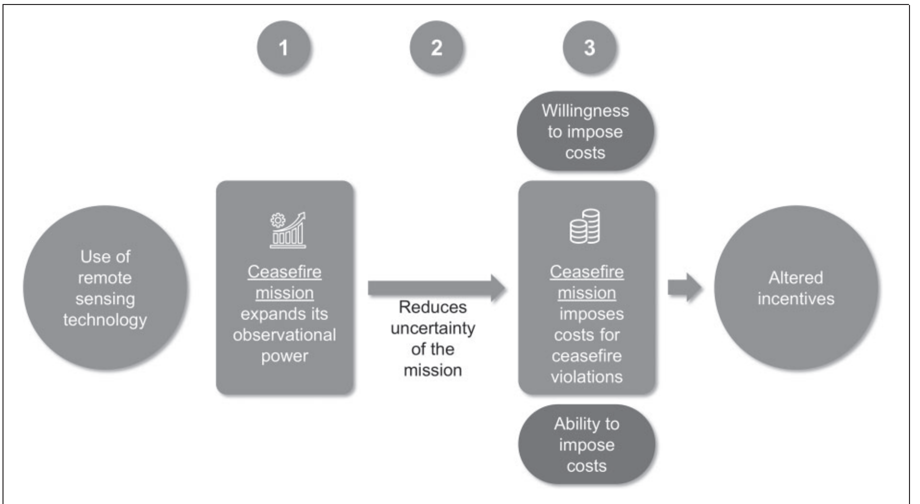
To understand when and how remote sensing may have increased compliance by enabling third parties to alter incentives, we trace how the SMM collected and shared

[5]See OSCE, "Contract Awards 2016," https://procurement.osce.org/resources/document/contract-awards-2016-0; OSCE, "Contract Awards 2017," https://procurement.osce.org/resources/document/contract-awards-2017-1; OSCE, "Contract Awards 2018," https://procurement.osce.org/resources/document/contract-awards-2018-0; and OSCE, "Contract Awards for 2020," https://procurement.osce.org/resources/document/contract-awards-2020.

[6]In 2020–2021, the SMM's annual budget was €108.9 million. See OSCE, "Annual Report 2020," https://www.osce.org/files/f/documents/e/e/485321_0.pdf (2021), 75.

[7]The TCG was established in 2014 as a diplomatic forum to work toward the implementation of the Minsk agreements.

Table 1. Questions to empirically assess pathway 1a



Q1	To what extent was the mission able to expand its observational power through remote sensing (expanding geographical and temporal reach or gathering documentary evidence)?
Q2	How and to what extent did the expansion of observational power reduce the mission's uncertainties about the origins and circumstances of alleged violations?
Q3	To what extent was the ceasefire mission able and willing to impose costs for ceasefire violations?

information about ceasefire compliance, and the degree to which the monitoring mission and other third-party actors imposed costs for ceasefire violations.

Assessment Pathway 1a (Mission Imposes Costs)

Table 1 lists questions for our empirical assessment of pathway 1a in which the mission directly imposes costs for ceasefire violations. The table represents the causal mechanism, with the numbered boxes and arrows corresponding to the numbered questions.

The use of remote sensing technology affected information collection dramatically. The geography of the 2014–2022 conflict made remote sensing technology particularly suitable, as the conflict parties were usually clearly separated, and most ceasefire violations occurred in the vicinity of the contact line.[8]

From a quantitative perspective, remote sensing allowed the mission to track the vast number of violations that occurred. From operating only one UAV system in 2015 (Neukirch 2016, 232), the SMM quickly expanded its use of UAV and other remote sensing technology, recording more than 100,000 violations by remote sensing in both 2018 and 2019, more than 40,000 in 2020, and more than 30,000 in 2021.[9] These volumes of incidents would have been impossible to record by human monitors alone.[10] While this volume of violations is undoubtedly large, its size is partly an artifact of the methodology used by the mission, which decided to count single acts as a violation, rather than clustering related acts by conflict event.[11]

[8]Interview with former SMM monitor, February 16, 2022, online.

[9]Figures calculated by the authors based on OSCE data. See OSCE, "2019 Trends and Observations," https://www.osce.org/files/f/documents/1/e/444745.pdf and OSCE, "2020 Trends and Observations," https://www.osce.org/files/f/documents/e/8/476809.pdf.

[10]Not every recorded incident may represent a unique occurrence, as the same incident might be reported by SMM monitoring teams on both sides of the line of contact, and also be recorded by remote sensing. However, the mission tried to triangulate information to avoid duplication in official reports.

Remote sensing technology expanded the observational reach of the mission both geographically and temporally, allowing it to gather and verify information about violations that it might not have otherwise seen. Most incidents recorded by remote sensing technology were not witnessed by SMM monitors directly, particularly after a 2017 incident in which a mission staffer, Joseph Stone, was killed when his vehicle hit a landmine. Subsequent restrictions on monitor movement implemented as a reaction to Stone's death prevented human patrols from leaving paved surfaces. After this event, remote sensing technology became increasingly important to the SMM's data collection, given that ceasefire violations readily occurred away from paved roads. Concerning the temporal scope of the conflict, a majority of recorded violations took place at nighttime, when monitors were not allowed to circulate.[12] Arguably, many of these more distant and nighttime violations would not have been recorded, or only with limited details, had it not been for the use of remote sensing technology.

UAVs and satellite images became the prime tools for the mission to identify weapons placed in violation of the withdrawal lines set out in the Minsk II agreement.[13] Up to 75 percent of these incidents were recorded by technological means.[14] Over time, the parties became apt at camouflaging their heavy weapons systems, but the mission also became better at locating these assets through its remote sensing systems, for example, by looking for tracks in the dirt.[15]

Since the mission was required to give advance notice before flying UAVs, in some cases, conflict parties could adjust their behavior to avoid being caught in a violation. However, after initially being set at 24 hours, the notification period was later shortened to under an hour—not long enough for the parties to move large weapons systems outside the disengagement area, for example.[16]

Beyond broadening its geographical and temporal reach, remote sensing also expanded the observational power of the mission by increasing its ability to gather documentary evidence. Imagery collected through remote sensing allowed the mission to analyze otherwise unavailable or hence uncertain details collected by other means. For example, video footage of stationary cameras often helped estimate the direction of artillery fire. The mission could compare before and after satellite and UAV images, enabling it to identify changes on the battlefield, such as new trenches or changes in forward positions. Aerial footage further helped monitor the state of critical infrastructure, such as water or chemical treatment plants, and precisely locate landmines.[17]

Although all the information collected was processed to some degree, processing happened differently. Some information gathered by sensors, such as footage of mini-UAVs and sometimes mid-range UAVs, was analyzed by monitors on the ground. Monitors summarized their findings and forwarded relevant data to the mission headquarters in Kyiv. Other information, such as the footage of long-range UAVs and stationary cameras, was only analyzed at headquarters. In the case of satellite imagery, most requested images arrived pre-analyzed at the mission.[18]

[11]For example, every artillery round fired was counted as a separate violation. In contrast, in, for example, South Sudan, an entire battle was counted as a single ceasefire violation. These differing methodologies make a cross-context comparison of the number of ceasefire violations difficult.

[12]See footnote 9.

[13]The Package of Measures for the Implementation of the Minsk Agreements—commonly known as Minsk II—was negotiated between Ukraine, Russia, and the OSCE in the context of the TCG. Together with two earlier documents, it became known as the Minsk Process. See OSCE Conflict Prevention Centre (2021, 26–27).

[14]See footnote 9.

[15]Interview with former SMM team leader, February 10, 2022, online. Interview with former SMM monitor, February 22, 2022, online.

[16]Interview with former SMM monitor, January 22, 2022, online.

[17]Interview with former senior SMM official, March 24, 2022, online. Interview with former SMM monitors, February 2, 2022 and February 22, 2022, online.

The data collected through remote sensing technology increased the mission's situational awareness and provided information on hostile activity around the contact line. In a conflict context characterized by a high level of distrust, and widespread problems related to mis- and disinformation, "hard facts" in the form of imagery evidence were perceived as particularly important. As one monitor put it, "70–80 percent of what we were hearing [by talking to people on the ground] was fake news."[19] Remote sensing gave the OSCE SMM a tool to directly observe and to triangulate narrative information gathered by other means. Staff on the ground and in Kyiv reported that the use of remote sensing enhanced their understanding of individual incidents as well as conflict dynamics more broadly.[20]

However, this reduction in uncertainties did not translate into costs imposed for ceasefire violations. Responding to a conflict that involved two OSCE member states—Ukraine and, if not officially, then effectively in practice, Russia—meant that the mission operated in a difficult political context. Not only did the mission lack an explicit mandate to attribute blame, let alone impose costs on violators; it was also dependent on unanimous consent among member states to regularly extend the mission.[21] The threat of non-extension meant that the mission was careful not to greatly antagonize either side, while still seeking to report the situation on the ground accurately.[22]

The mission tried to address this conundrum through aggregated reports that were made public. Based on all verified information gathered by the monitors and through technological means, it produced reports 6 days a week and ad hoc spot reports focusing on specific incidents, publishing both types of reports online—an uncommonly frequent level of public reporting for an international monitoring mission.[23] The mission did not attribute blame in these reports, but details were often included that allowed informed observers to deduce the culprit(s).[24] Nevertheless, the lack of attribution by the mission (and the organization to which it reported, the OSCE) meant that there were no real consequences for the parties, even when presented with evidence of a ceasefire violation.

Despite a lack of direct costs, there is some anecdotal evidence that the mere presence of a mission with eyes in the skies affected compliance. In one account, separatists retreated from incursions into the disengagement zone because they appeared concerned that UAVs would record their movement.[25] As one former senior SMM official put it, "even the noise of UAVs" sometimes helped calm the situation.[26] Within certain limits, both sides were interested in being seen as compliant, blaming the other for any aggression. Conversely, there are also examples where the presence of remote sensing technology appeared to increase, rather than deter, ceasefire violations. For example, after the parties agreed in the Minsk process on an additional disengagement zone, and cameras were installed, both sides started to move into that area and fighting intensified.[27] This may be explained by the desire of some actors on the ground to, at times, make a statement or attract attention

[18] Interview with former senior SMM official, March 24, 2022, online. Interview with former SMM team leader, February 10, 2022, online.

[19] Interview with former SMM monitor, February 22, 2022, online.

[20] Interviews with former SMM monitors (January 22, 2022, January 27, 2022, February 2, 2022, and February 22, 2022); former SMM team leader (February 10, 2022); and former senior SMM officials (March 24, 2022, May 18, 2022, and July 4, 2022); all online.

[21] Interview with former senior SMM official, July 4, 2022.

[22] Interview with OSCE staff in Vienna, February 22, 2022, online. Interview with former SMM monitor, February 23, 2022, online.

[23] Interview with former senior SMM official, May 18, 2022, online.

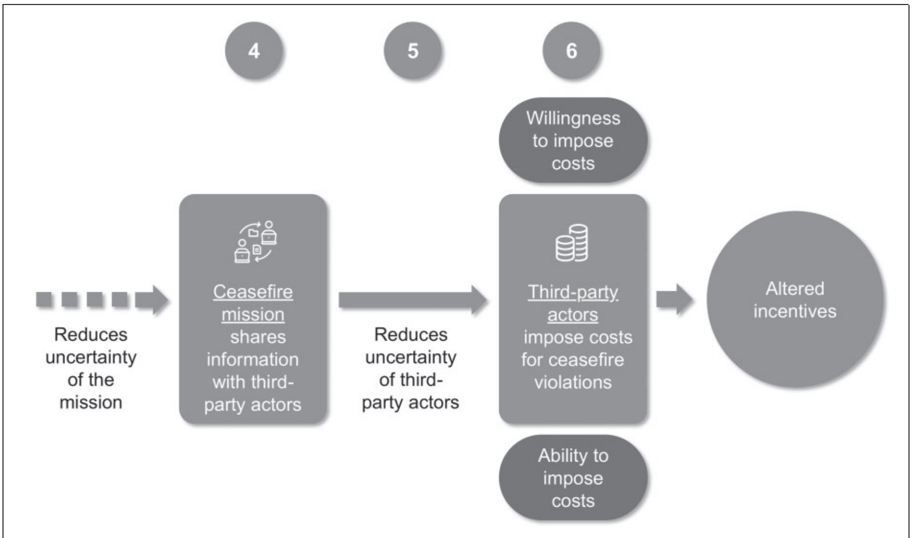
[24] Interviews with former senior SMM officials, March 24, 2022 and July 4, 2022, both online; see also Dorn and Giardullo (2020b, 7).

[25] Interview with former SMM monitor, February 2, 2022, online.

[26] Interview with former senior SMM official, March 24, 2022, online.

[27] See footnote 26.

Table 2. Questions to empirically assess pathway 1b, in addition to Q1 and Q2 in table 1



Q4	To what extent was information gathered through remote sensing shared with other third parties?
Q5	To what extent did this information reduce third parties' uncertainties about the origins and circumstances of an alleged violation?
Q6	To what extent were these third parties able and willing to impose costs for ceasefire violations?

to a specific situation. In such cases, remote sensors ensured that "every violation counted" (and was literally counted).[28]

Assessment Pathway 1b (Third Party Actors Impose Costs)

Even if a mission is unwilling or unable to impose direct costs for ceasefire violations—as was the case with the SMM—information gathered through remote sensing may still alter incentives if a mission shares such information with other third-party actors who then impose costs. Table 2 lists the questions we identify as needing to be addressed, in addition to Q1 and Q2 discussed above, to assess pathway 1b.

In addition to publicly available reports, the SMM also produced more detailed, more analytical weekly reports, shared only with OSCE member states in Vienna. These reports sometimes included supporting evidence gathered by remote sensing, such as UAV images. A series of thematic reports were published, some of which were made public, and which also sometimes relied on information gathered by remote sensing. OSCE headquarters cleared and edited these reports. In general, the mission appeared more reluctant to publish details than was headquarters.[29] The chief monitor and his deputies regularly briefed the OSCE Permanent Council, noting trends and concerns based on the official reports. As noted above, public reports did not attribute blame. Confidential reports and briefings rarely attributed blame, even in clear-cut cases of culpability. Some officials did however highlight those points that made it easy for attentive observers to infer culpability.[30]

The mission lacked institutional arrangements to share more sensitive information, including with members of the Normandy Four mediation format or with the

[28]Interview with OSCE headquarters staff, February 22, 2022, online.
[29]Interview with former senior OSCE official, April 28, 2022, online.
[30]Interview with senior SMM official, March 24, 2022, online.

TCG. However, the coordinator of the TCG working group on security had access to all SMM information by virtue of also being the mission's chief monitor. Moreover, members of the SMM and OSCE headquarters often shared such information on an ad hoc basis via their personal networks.[31]

Despite these limitations, the information gathered by the SMM—enhanced by its use of remote sensing—provided the most comprehensive observations about conflict events in eastern Ukraine. Indeed, it was the only entity allowed to collect data on both sides of the conflict (International Crisis Group 2022). Members of the UN Security Council, OSCE member states and even humanitarian actors frequently referred to information included in the SMM reports in their public statements. Contributing states often highlighted specific violations and—in contrast to the official OSCE reports—did attribute blame.

This did not, however, have concrete consequences for the conflict parties, aside from reputational costs, and even here, such costs were limited. This was due to a de facto policy that western OSCE states only focused on violations committed by the separatists, while Russia only raised those committed by Ukrainian forces.[32] In response to violations, any condemnation of the parties by their allies would have been more effective in altering the incentives of the conflict parties (see also comments on private information sharing in pathway three, below).

In short, as one former monitor noted, being presented with the photographic facts of a violation was "embarrassing for them back in Vienna [OSCE headquarters]. But did it change anything for the parties on the ground? No."[33] That said, while violations were persistent, many were relatively minor. Third-party actors may have stepped up to impose genuine costs for conflict actors in the context of large-scale violations,[34] and many interlocutors saw the main value of the mission as preventing a major escalation through an international presence on the ground and in the skies.

Pathway 2: Signaling Intent

The second possible pathway by which remote sensing technology can potentially improve ceasefire compliance is through the signaling of intent. In table 3, we list the questions that speak to the activities and causal arguments of this second pathway.

OSCE members—including Ukraine and Russia—voluntarily agreed to the use of remote sensing technology, pursuant to the Minsk II Agreement. Minsk II called for "effective monitoring and verification of the ceasefire regime and the withdrawal of heavy weapons by the OSCE from day 1 of the withdrawal, using all technical equipment necessary, including satellites, drones, radar equipment, etc."[35] Senior representatives of the Russian-backed separatists in Luhansk and Donetsk also initialed Minsk II (OSCE Conflict Prevention Centre 2021, 26).

Formal consent to remote sensing was thus enshrined in the ceasefire agreement. Moreover, at the early stages of the SMM's operation, both Russian and Ukrainian representatives to the OSCE called for the strengthening of the mission's remote sensing technology capacities.[36]

[31] See footnote 30.

[32] Interviews with former senior OSCE official, April 28, 2022, and former senior TCG official, March 29, 2022, both online.

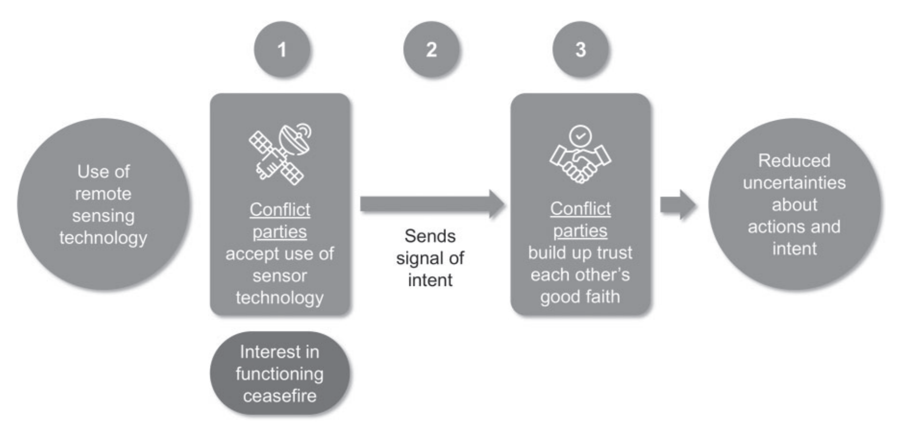
[33] Interview with former SMM monitor, February 16, 2022, online.

[34] An extreme example is the imposition of sanctions against Russia following its full-scale invasion in Ukraine, which we briefly discuss below. A counterexample is the refusal of Russia to condemn separatists for shooting down Malaysian Airlines flight MH17 in July 2014.

[35] OSCE. 2015. Package of Measures for the Implementation of the Minsk Agreements. https://www.osce.org/files/f/documents/5/b/140221.pdf.

[36] OSCE. 2015. Decision No. 1162 Extension of the Mandate of the OSCE SMM to Ukraine.

Table 3. Question to empirically assess pathway 2



Q1	To what extent did the parties accept the use of remote sensing technology, both nominally and in practice? Did the parties have a general interest in a functioning ceasefire?
Q2	To what extent did the parties' acceptance of remote sensing technology signal intent?
Q3	To what extent did parties build trust in the other's good faith?

However, despite formal consent to remote sensing, acceptance found resistance on the ground. Further, resistance seems to have increased over time. In part, this was due to the improvement of the technical capacity of the conflict parties to jam or otherwise interfere with SMM-deployed technology. Over the years, the mission lost more than thirty UAVs, including at least nine (more valuable) long-range UAVs.[37] OSCE staff reported that the risk of UAVs being shot down was a serious impediment to monitoring. Various reasons were given as to why UAVs were shot down, including indiscipline and boredom by troops along the contact line, failure of military commanders to notify their forward positions of planned SMM UAV flights, fear that the opponent was using a "UAV flight window" by the SMM to fly their own UAVs, and resistance to being monitored.[38] Jamming was an even more persistent problem and appeared a more systematically intentional act of resistance to monitoring.[39] In 2021 alone, the SMM recorded 2,386 instances of signal interference, compared with only 851 freedom of movement restrictions (OSCE 2022). Finally, while less frequent, there were also reports of damage to stationary cameras.[40]

We find no convincing evidence that the acceptance of remote sensing technology was interpreted as a signal of good faith by either of the conflict parties. Throughout the conflict's history, actors on both sides appeared convinced of their opponent's malintent. They used evidence gathered by remote sensing to blame the other side and consistently attempted to ensure that the opponent did not gain from any interaction.[41] Many interlocutors felt that the leadership of the parties was not fully committed to the ceasefire (see also OSCE Conflict Prevention Centre

[37]Between October 2014 and March 2019, the SMM lost 29 UAVs. See OSCE Conflict Prevention Centre (2021, 50). At least two more UAVs were lost in 2021.

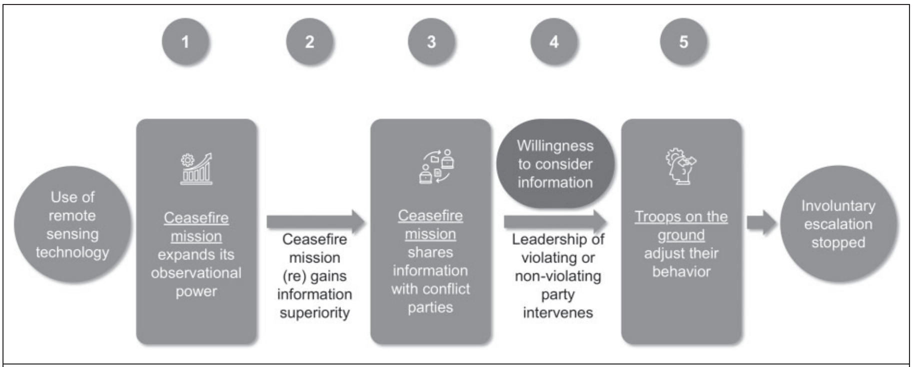
[38]Interviews with former SMM monitors (January 25, 2022, January 27, 2022, February 2, 2022, February 16, 2022, and February 23, 2022) and former SMM team leader (February 10, 2022); all online. See also Grand-Clément (2022, 27).

[39]Interview with former SMM monitor, January 27, 2022, online.

[40]For example, OSCE. 2021. "OSCE SMM Spot Report 17/2021: SMM camera at the Oktiabr mine near non-government-controlled Donetsk city damaged by gunfire," https://www.osce.org/special-monitoring-mission-to-ukraine/491635.

[41]Interview with former TCG official, March 29, 2022, online.

Table 4. Question to empirically assess pathway 3



Q1	To what extent was the mission able to expand its observational power through remote sensing (expanding geographical and temporal reach or gathering documentary evidence)?
Q2	To what extent did this allow the mission to (re)gain information superiority?
Q3	To what extent did the mission share this information with the leadership of the violating or non-violating conflict party?
Q4	Were leaders of either the violating or non-violating party willing to consider this information and intervene to correct behavior or moderate responses?
Q5	To what extent did troops on the ground adjust their behavior?

2021; International Crisis Group 2022, 30), indicating that a key condition for the functioning of pathway 2 was not consistently present in the Ukraine case. We stop our assessment of pathway 2 here, as there is no reason to assume that—in the absence of signaling of good intent—the (only nominal) acceptance of remote sensing technology had any positive effect on trust building between the conflict parties.

Pathway 3: Containing Escalatory Dynamics

Finally, to understand if remote monitoring contributed to compliance by helping to contain escalatory dynamics, we assess how remote sensing allowed the SMM to provide novel information to the conflict parties and to what extent they adjusted their behavior in response to such information (see questions, table 4).

As discussed in detail in pathway 1, there is strong evidence that the use of remote sensing technology expanded the mission's observational power, in terms of both geographical and temporal reach, and in allowing it to gather documentary evidence that seems harder to dispute than witness statements.

This in turn allowed the mission to gain information superiority, albeit only partially. For while generally the conflict parties well knew what was going on in their areas of control, some activities took place without the knowledge of the chain of command. Some types of activities, such as the movement of heavy weaponry into the disengagement zone, were unlikely to happen without the knowledge of the military command. However, the conflict in eastern Ukraine also experienced persistent low-scale violations, many of which were not directly ordered by the respective military leadership.[42] In non-government-controlled areas, in particular, indiscipline among rank and file was persistent. On both sides, some individuals appeared more strongly ideologically motivated, and low and mid-level commanders often tried to make an impression by engaging in violence when they arrived at a new position.[43] In addition to initiatives taken by forward positions, there were also

[42]Interviews with former SMM monitors, January 25, 2022 and February 22, 2022; with former SMM team leader, February 10, 2022; all online.

incidents that occurred in response to (real or perceived) violations by the other side. In these situations, the SMM sometimes had an information advantage over the chain of command, thanks in part to its eyes in the sky.

In terms of sharing such information with the conflict parties and interventions this prompted, our assessment is mixed. In contrast to many ceasefire architectures that have a joint commission with representatives from relevant conflict parties, the SMM did not have a joint ceasefire committee or other mechanisms institutionalizing information sharing among conflict party leaderships.[44] Nonetheless, we identified several channels through which information was shared.

One such channel was the Joint Centre for Control and Coordination (JCCC) on ceasefire and stabilization of the demarcation line. A joint initiative between Ukrainian and Russian armed forces was established in September 2014; the entity was separate from the SMM, but the SMM placed liaison officers at the JCCC. The JCCC was never fully functional, and Russia withdrew in December 2017 citing impediments to the work of its personnel.[45] Nonetheless, the JCCC (and after its dissolution, personal networks established through the JCCC) allowed members of the SMM to share information with military commanders on both sides. Monitoring teams would, for example, report on what they observed with UAVs and ask commanders of the violating party to intervene. At this local level, information sharing was informal and did not involve any documentary evidence, any sensitive military information, or any information about the opponent.[46] There is anecdotal evidence of some incidents, such as persistent shelling, being stopped in response to such information.[47] However, it was often unclear whether violence ended of its own accord or whether the termination was due to an intervention by the chain of command. The effectiveness of this channel depended not least on the personal relationships of mission members with military commanders, which in the non-government-controlled areas were often helped by the fact that liaison officers were Russian speakers.[48]

Another channel through which information was shared with conflict parties was the TCG, a forum established in 2014 to work toward the implementation of the Minsk agreements (see Hess Sargsyan 2019). The TCG held biweekly meetings between representatives of all parties, including the armed formations. Beyond official SMM reports, no information about specific incidents was shared with the parties involved in these meetings.[49] The most relevant working group in terms of discussing ceasefire violations—the working group for security—discussed violation patterns rather than individual incidents, in an effort to address the inadequacies of the Minsk agreements.

There is little indication that information shared through this second channel enabled commanders to respond to individual incidents, and therefore contain escalatory dynamics on the ground. Information tended to be used by the conflict parties to blame each other, and meetings were often characterized by quarrels over format and participation,[50] and over whom to blame for the violence, rather than working toward genuine cooperation.[51] The work of the TCG did, however, allow members of the mission to establish personal relationships on all sides, which were

[43] Interview with former SMM team leader, February 10, 2022, online.

[44] Interviews with former senior SMM officials (March 24, 2022 and July 4, 2022); both online.

[45] For a critical account of the JCCC, see Kemp (2018, 119–21).

[46] Interviews with former SMM team leader, February 10, 2022; and former SMM monitor, February 16, 2022; both online.

[47] Interview with former SMM team leader, February 10, 2022; and former SMM monitor, February 16, 2022; both online.

[48] Interview with former SMM monitor, February 16, 2022, online.

[49] Some former monitors noted concerns that the SMM's capabilities might be seen as espionage if imagery collected from remote sensing technology was disclosed; others had concerns that the sharing of such data might provide one side or another with a military advantage (if it was possible to subsequently geolocate an image, for example).

[50] Interviews with former senior SMM officials, March 24, 2022 and July 4, 2022; both online.

sometimes called upon when an escalation of violence threatened. In some cases, this appeared to lead to interventions by the military leadership of the violating party to calm the situation, for example, if it threatened to cause damage to critical infrastructure.[52]

The third main channel we identified was at the OSCE headquarters. Based on information produced by the SMM, the OSCE Secretary-General (SG) would sometimes launch additional investigations and, if information on the circumstances and culpability was clear, follow up with the leaders of the violating conflict party. The OSCE SG also shared such information with Moscow and Washington, using images collected by remote sensing as documentary evidence. These interventions appeared to trigger follow-up actions with the conflict party leadership, with some notable changes in behavior. However, this channel was primarily used to stop ceasefire violations that targeted the SMM, such as sophisticated jamming of long-range UAVs or harassment of monitors. It therefore primarily served to reduce third-party signaling violations; the effects on other types of ceasefire violations were much less clear.[53]

While there is some evidence of informal information sharing with the violating party of specific incidents, there are few examples of the SMM sharing information (beyond publicly available reports) with the non-violating party to moderate its response.

In all three channels, it is not clear to what extent commanders receiving information were genuinely unaware of events, or whether sharing of information made it more difficult to deny knowledge—most likely, it was a mix of both.[54] However, in terms of shaping the response on the ground, it appeared less important whether relevant counterparts already knew the information, and more important whether intervening served the interests of the leadership. We discuss the possible implications of these observed dynamics below.

Discussion

The OSCE SMM in Ukraine was a pioneer in the use of remote sensing technology for ceasefire monitoring purposes. Yet, as our assessment shows, this had a limited impact on ceasefire compliance.

For pathway 1—enabling the mission or third-party actors to alter incentives by reducing their uncertainties about ceasefire violations—our assessment is mixed. There is clear evidence for the shared part of the pathway, namely, that remote sensing expanded the observational power of the mission, and that this reduced uncertainty about the origins and circumstances of alleged ceasefire violations. However, we find no evidence that reduced uncertainties enabled the ceasefire mission to impose costs for ceasefire violations: even when violations were clear, a limited mandate and the politics of subordination to a consensus-based member state organization left the mission with little means to alter incentives. Third-party actors, who could have stepped in, were not willing to or did not have the leverage to meaningfully alter the incentives. In particular, supporters of the conflict parties—Moscow for the separatists and Western states for Ukraine—refrained from publicly condemning violations by their allies. Basic conditions for this pathway to function—for either a strong mission mandate that enables the mission to impose costs for confirmed violations (pathway 1a) or the willingness and ability of third-party actors to do so (pathway 1b)—were, therefore, absent.

[51] Interviews with former senior TCG official, March 29, 2022; former senior SMM official, March 24, 2022; and former SMM monitor, February 16, 2022; all online. See also OSCE Conflict Prevention Centre (2021, 29).

[52] Interview with former senior SMM official, March 24, 2022, online.

[53] Interview with former senior OSCE official, April 28, 2022, online.

[54] Interview with former senior OSCE official, April 28, 2022; and former SMM team leader, February 10, 2022; both online.

The second pathway—reducing uncertainties by accepting intrusive monitoring technology—is entirely absent in the Ukraine case. Without genuine interest in cooperation, there was very little "good faith" that the parties could signal. Instead, the conflict parties saw the ceasefire as an instrument to keep violence at a low level, while retaining the possibility to turn up the heat when political tensions were rising. While technology was nominally accepted, interference was a daily challenge, and there was little intent on both sides to make the ceasefire work.

We do find some evidence for a functioning pathway 3, namely, that sharing of information with conflict parties in some cases triggered the chain of command to intervene, helping contain escalatory dynamics. However, information was apparently only shared with the violating party, suggesting that this pathway was primarily used to stop ongoing or repeated ceasefire violations of a violating party rather than trying to mitigate escalatory responses.

Information sharing happened primarily through personal networks, and a more institutionalized mechanism at the leadership level—for example, in the form of a joint ceasefire commission—could have strengthened this pathway.

From the information we obtained, it was not possible to identify in which cases leaders or commanders on the ground were aware of reported violations, and awareness did not appear to make a difference in terms of triggering a response. This prompts us to refine pathway 3, distinguishing between two possibilities by which private information sharing with conflict party leaders and commanders of the violating party can lead to interventions on the ground. The first, theorized above, remains: through the use of remote sensing, a monitoring mission may possess timely and relevant information not available to leaders or commanders on the ground. Sharing such novel information can enable them to intervene, if it is in their interest to do so. The second relates to plausible deniability. It borrows from the "caught red-handed" mechanism outlined by Nutt and Pauly (2021) which explains how private information sharing with a violating party can incentivize them to act in order to save face. By privately sharing information about a ceasefire violation with relevant counterparts, a mission can demonstrate that it understands events and who is able to intervene. This may incentivize leaders or commanders to intervene if they want to be seen as cooperating. This second version of pathway 3 does not require that information is novel, but that it is accurate and discovered in time to intervene. Remote sensing can help with both aspects of accuracy and timeliness.

It is important to note that the anecdotal examples we found for pathway 3 all referred to incidents where it was of benefit for the commanders to intervene, be it to avoid damage on their side or for reputational reasons. There is no indication that this mechanism was effective when activities were ordered through the chain of command or reflective of political tensions in Minsk.[55] This is in line with the theoretical assumptions, but it does limit the usefulness of this mechanism in contexts where violations are primarily a political tool, as was the case in Ukraine.

More generally, even though we do find some evidence that the use of technology contributed to ceasefire compliance, these effects were marginal compared to those of other formal political dimensions. Whenever political tensions were high, violations went up. Conversely, when the parties reached interim measures to contain violence (a "ceasefire in a ceasefire"), violence decreased, only to pick up again in the absence of sustained progress on political disputes (Conciliation Resources 2020; UNDPPA 2020; International Crisis Group 2022). This pattern, the OSCE observed, "suggested that the sides could adhere to the ceasefire when they had the political will to do so" (OSCE Conflict Prevention Centre 2021, 30). The use of technology clearly cannot replace political will, but it can address certain types of violations under certain conditions, which may go a long way to avoid involuntary escalation.

[55]Interviews with former senior SMM official, March 24, 2022; and former SMM team leader, February 10, 2022; both online. This observation was also made at various policy workshops, e.g., Conciliation Resources (2020) and UNDPPA (2020).

Russia's Expanded War

In February 2022, Russian attacks on Ukraine expanded the conflict beyond its eastern regions, setting off the largest European war since the Second World War. The ceasefire in the east and the political decisions that mandated the SMM were effectively nullified by the Russian invasion, the SMM shortly after suspended monitoring, and its mandate was not extended. The invasion may strongly suggest that the SMM's use of remote sensing (and, indeed, the mission as a whole) was ineffective. We call for a more nuanced reading of the situation: the effectiveness of remote sensing should not be measured by the outcome alone, but by its effects while deployed. In other words, it is possible for remote sensing to make a contribution, but still not be able to prevent conflict escalation or a full-scale resumption of hostilities.

Rather than judging the effectiveness of the SMM by its inability to prevent a wider war, we should ask: how would the SMM have affected ceasefire compliance without remote sensing technology? As we have shown, without remote sensing technology, the observational power of the mission would not have comparably expanded, but this did not result in significant costs for the conflict parties (pathway 1). The knowledge that violations were observed and documented may have affected conflict party behavior, and more serious violations may have occurred had remote sensing technology not been used. However, this did not change the wider decision to turn to a full-scale war in Ukraine. Russia's military action was so apparent that third-party remote sensing to observe and document what happened and who bore responsibility largely confirmed what was already widely known.[56]

Regarding positive signaling (pathway 2), we have argued that acceptance of remote sensing was primarily nominal, with good faith absent. With remote sensing not contributing to such positive signaling, trust and cooperation would likely have been comparably low had the SMM not used remote sensing technology. And while a lack of trust and cooperation can presage a ceasefire breakdown, in this case, the resumption of full-fledged hostilities was triggered by Russia's decision to attack Ukraine, suggesting that an effective acceptance of the signaling of good faith in eastern Ukraine would not have changed the events of February 2022 and subsequently.

Finally, in relation to escalatory dynamics (pathway 3), relying on conventional forms of monitoring would have run into familiar monitoring problems of the timeliness, novelty, and definitiveness of information. Although the mission did continue to produce novel information by conventional means, plausible deniability would have been easier for conflict parties to achieve when confronted with violation allegations lacking remote sensing evidence. This suggests that more violations at a local level would have been seen, with a higher risk of involuntary escalation, had remote sensing technology not been used. However, as discussed earlier, the mechanism was not effective when actions were ordered by the chain of command; the same logic applies to the wider war ordered by Moscow.

In sum, the empirical analysis suggests that remote sensing had a limited effect on ceasefire compliance in eastern Ukraine but was ineffective in preventing the ceasefire's breakdown following the Russian invasion.

Although it extends beyond the scope of our analysis, it is important to note that remote sensing—and in particular the use of satellite imagery—did shape the trajectory of the conflict that followed. When in 2022, Russia amassed troops and materiel at the Ukrainian border, video evidence of the mobilization circulated rapidly, but its sheer size only became apparent with the help of satellite images. Reconnaissance satellites helped Ukraine and its allies gain a clear sense of the location, type, and amount of equipment and personnel Russia stationed at the border. And even though the decision to invade took many by surprise, as many analysts had viewed the mobilization as a costly bluff, the evidence provided by satellite imagery allowed

[56]However, satellite images helped with near real-time damage assessment (Sticher, Wegner, and Pfeifle 2023).

Ukraine and its allies to prepare, denying Russia the benefits of strategic surprise. At this stage, the contribution of remote sensing used by ceasefire monitors was of lesser relevance, as the same or better information was provided by reconnaissance and even commercial satellite providers and analyzed worldwide. This suggests that there is an important temporal dimension to the value of remote sensing in contributing to ceasefire compliance; once mobilization begins, the prospects of ceasefire compliance no longer depend on the capabilities of monitors.

Effects on Non-Compliance

Our pathways deliberately focus on the potential effects of remote sensing on *improving* conflict parties' compliance with a ceasefire. Yet in our assessment of the three pathways, we also note some dynamics through which remote sensing can potentially contribute to non-compliance. One example relates to the lowering of the threshold of resistance. As discussed above, conflict parties face much less serious consequences if they interfere with remote sensing technology compared to attacking human monitors. This creates a new category of violations and enlarges the range of responses at the hands of combatants. In eastern Ukraine, this had a diversionary effect: every time a UAV was jammed or shot at by one of the conflict parties, there was a lot of noise without much consequence, shifting the focus away from the deeper issues at stake.

Another example where remote sensing appeared to contribute to non-compliance relates to the quantification of ceasefire violations. We noted that in some cases violations apparently increased when remote sensing was introduced, possibly as a way for actors on the ground to attract attention. Conflict parties also gained important new information through the public SMM reports, as they could observe the disjuncture between documented evidence of violations, and the lack of consequences for those violations. This may have been interpreted as "carte blanche" to commit future violations.[57]

A third example arising from our case study is the tactical use of opportunities created by a mission's use of remote sensing technology. Since the conflict parties had advance notice of SMM UAV flights, they were sometimes able to take advantage of SMM flights to operate their own UAVs, in violation of the ceasefire agreement.[58] These shadow flights may not have occurred had ceasefire monitors not deployed their own UAVs. Consequently, the mere presence of third-party remote sensing technology in a conflict theater can change the military opportunities for the conflict parties.

As these preliminary discussions suggest, the effects of remote sensing on non-compliance are not necessarily the converse of the effects on compliance: they take place through additional causal pathways and are conditioned by other factors. Devising and assessing these potential pathways is an intriguing avenue for future research.

Conclusion

Remote sensing technology provides an effective way for third-party actors to gather, verify, and share information around ceasefire compliance and violations. This increases the situational awareness of a mission, reduces uncertainties about the circumstances and origins of a violation, and helps third-party actors gain accurate and timely information about violations. Most assessments of the use of remote sensing technology in ceasefire monitoring stop here.

[57]Interview with former senior TCG official, March 29, 2022, online.

[58]Interviews with former SMM monitors, January 25, 2022, February 2, 2022, and February 23, 2022; and former SMM team leader, February 10, 2022; all online.

Yet, as our essay shows, to understand whether and how remote sensing improves ceasefire compliance, we need to go further and assess how the information provided through the use of this technology affects conflict parties' incentives, uncertainties, and actions. Building on Fortna (2003, 2004), we identified three pathways through which remote sensing can theoretically improve compliance: by enabling third-party actors to alter incentives, by helping parties signal intent, and by enabling conflict party leaders to contain involuntary escalation. We then applied our framework empirically, tracing the three pathways in the case of the SMM in Ukraine. While we only find limited effects on compliance in this case, our analysis illustrates how the effects of remote sensing technology may be assessed more generally and furthers our understanding of the conditions under which each pathway is effective.

As our discussions show, the ways in which remote sensing can contribute to ceasefire compliance are not inherent to the technology or its specific features—they depend on how information gathered through remote sensing is shared and acted upon, and on the wider context. By identifying different causal mechanisms and how they function in different circumstances and for different types of violations, we nuance the debate about the role of technology in conflict resolution, showing that the effects of technology neither replace political will nor entirely depend upon it. This highlights important considerations for policymakers considering the use of remote sensing technology as part of a ceasefire monitoring mission. While techno-optimism is prevalent as conflicts and conflict resolution become more sophisticated, our causal mechanisms encourage thinking beyond the immediate benefits or challenges of remote sensing technology for the mission itself, to assess *how* and *for what* technology may make a difference in a specific conflict context.

Importantly, each pathway has its own set of conditions, and understanding the most promising pathway in a given context helps allocate resources and efforts most effectively. For example, in the absence of a genuine interest in a functioning ceasefire by the conflict parties, missions may invest heavily in institutionalizing information sharing with third-party actors, if these are willing and able to impose costs for violations. Conversely, when there is limited willingness or ability of third-party actors to impose costs, but a genuine interest by the conflict party leadership to tackle ceasefire violations, missions should prioritize information sharing with conflict parties on the ground and up the chain of command. This is particularly relevant in contexts of high distrust between the parties, or where a conflict party struggles with indiscipline and spoiling behavior within its own ranks.

With the general trend of peacemaking adopting technology increasing, the use of remote sensing in ceasefire monitoring is likely to become more common. While wider political considerations remain paramount, better understanding the underlying causal mechanisms by which compliance—and non-compliance—is realized by remote sensing technology is both theoretically and practically necessary. Without such understanding by those who negotiate, design, and implement such missions, the adoption of remote sensing in future monitoring contexts may seem attractive but risks unproductive or even adverse consequences.

Acknowledgments

The authors are listed in alphabetical order to reflect their equal contributions to this article. They are very grateful to the monitors and officials of the OSCE Special Monitoring Mission to Ukraine, the OSCE Secretariat, and the Trilateral Contact Group, who were willing to share their insights during in-depth interviews. They thank Jan Bachmann, Govinda Clayton, participants at the 2022 PRIS conference at the Swedish Defence University, former personnel of the

OSCE Special Monitoring Mission to Ukraine, and two anonymous reviewers who provided feedback on earlier versions of the text.

References

Åkebo, Malin. 2016. *Ceasefire Agreements and Peace Processes. A Comparative Study. Routledge Studies in Peace and Conflict Resolution.* London: Routledge.

———. 2019. "'Coexistence Ceasefire' in Mindanao." *Peace & Change* 44 (4): 468–96.

Alcorn, Ted. 2014. "Responding to Sexual Violence in Armed Conflict." *The Lancet* 383 (9934): 2034–37.

Bara, Corinne, Govinda Clayton, and Siri Aas Rustad. 2021. "Understanding Ceasefires." *International Peacekeeping* 28 (3): 329–40.

Ben-Ari, Eyal. 2005. "Epilogue: A 'Good' Military Death." *Armed Forces & Society* 31 (4): 651–64.

Boyle, Michael J. 2020. *The Drone Age: How Drone Technology Will Change War and Peace.* New York: Oxford University Press.

Brickhill, Jeremy. 2018. *Mediating Security Arrangements in Peace Processes: Critical Perspectives from the Field. CSS Mediation Resources.* Zurich: Center for Security Studies, ETH Zurich.

Buchanan, Cate, Govinda Clayton, and Alexander Ramsbotham. 2021. "Ceasefire Monitoring: Developments and Complexities." In *Accord Spotlight.* London: Conciliation Resources.

Chounet-Cambas, Luc. 2011. *Negotiating Ceasefires: Dilemmas & Options for Mediators. Mediation Practice Series.* Geneva: Centre for Humanitarian Dialogue.

Clayton, Govinda, Simon Mason, Valerie Sticher, and Claudia Wiehler. 2019. "Ceasefires in Intra-State Peace Processes." *CSS Analyses in Security Policy, No. 252.*

Clayton, Govinda, and Valerie Sticher. 2021. "The Logic of Ceasefires in Civil War." *International Studies Quarterly* 65 (3): 633–46.

Conciliation Resources. 2020. "Ceasefire Support and Monitoring Architecture." *Accord/PSRP Ceasefire Joint Analysis Workshop Series (Online).*

Diehl, Paul F. 2002. "The Political Implications of Using New Technologies in Peace Operations." *International Peacekeeping* 9 (3): 1–24.

Dorn, A. Walter, and Cono Giardullo. 2020a. "Technology Investments Paying Off in Peace Operations." *Analysis. Security and Human Rights Monitor.* Last accessed June 1, 2023. https://www.shrmonitor.org/technology-investments-paying-off-in-peace-operations/.

———. 2020b. "Analysis for Peace: The Evolving Data Tools of UN and OSCE Field Operations." *Security and Human Rights* 31 (1-4): 90–101.

Early, Bryan R., and Erik Gartzke. 2021. "Spying from Space: Reconnaissance Satellites and Interstate Disputes." *Journal of Conflict Resolution* 65 (9): 1551–75.

Fearon, James D. 1995. "Rationalist Explanations for War." *International Organization* 49 (3): 379–414.

———. 1997. "Signaling Foreign Policy Interests: Tying Hands Versus Sinking Costs." *Journal of Conflict Resolution* 41 (1): 68–90.

Feaver, Peter, and Christopher Gelpi. 2011. *Choosing Your Battles: American Civil-Military Relations and the Use of Force.* Princeton, NJ: Princeton University Press.

Fernández-Fontelo, Amanda, Alejandra Cabaña, Harry Joe, Pedro Puig, and David Moriña. 2019. "Untangling Serially Dependent Underreported Count Data for Gender-Based Violence." *Statistics in Medicine* 38 (22): 4404–22.

Fortna, Virginia Page. 2003. "Scraps of Paper? Agreements and the Durability of Peace." *International Organization* 57 (2): 337–72.

———. 2004. *Peace Time: Cease-Fire Agreements and the Durability of Peace.* Princeton, NJ: Princeton University Press.

Gartzke, Erik, and Yonatan Lupu. 2012. "Still Looking for Audience Costs." *Security Studies* 21 (3): 391–97.

Giardullo, Cono, Walter Dorn, and Danielle Stodilka. 2020. "Technological Innovation in the OSCE: The Special Monitoring Mission in Ukraine." In *OSCE Yearbook 2019*, edited by, IFSH. 119–37. Baden-Baden: Nomos.

Grand-Clément, Sarah. 2022. *Exploring the Use of Technology for Remote Ceasefire Monitoring and Verification.* Geneva: UNIDIR.

Harris, Chad. 2006. "The Omniscient Eye: Satellite Imagery, 'Battlespace Awareness,' and the Structures of the Imperial Gaze." *Surveillance and Society* 4 (1–2): 101–22.

Hess Sargsyan, Anna. 2019. "Unpacking Complexity in the Ukraine Peace Process." *CSS Analyses in Security Policy, No. 243.*

Hirblinger, Andreas T., Martin Wählisch, Kate Keator, Chris Mcnaboe, Allard Duursma, John Karlsrud,

and Valerie Sticher et al. 2023. “Forum: Making Peace with Un-Certainty: Reflections on the Role of Digital Technology in Peace Processes beyond the Data Hype.” *International Studies Perspectives* ekad004. https://doi.org/10.1093/isp/ekad004.
Hug, Alexander. 2020. “Ceasefire Monitoring and Verification and the Use of Technology: Insights from Ukraine 2014–2022.” *CSS Mediation Resources*.
Hug, Alexander, and Simon Mason. 2022. *Ceasefire Monitoring and Verification Technology. CSS Policy Perspectives*. Zurich: Center for Security Studies, ETH Zurich.
International Crisis Group. 2022. “Conflict in Ukraine’s Donbas: A Visual Explainer.” *Visual Explainer*. Last accessed June 1, 2023. https://www.crisisgroup.org/content/conflict-ukraines-donbas-visual-explainer.
Jancsics, David, Salvador Espinosa, and Jonathan Carlos. 2022. “Organizational Noncompliance: An Interdisciplinary Review of Social and Organizational Factors.” *Management Review Quarterly*. https://doi.org/10.1007/s11301-022-00274-9.
Kemp, Walter. 2018. “Civilians in a War Zone: The OSCE in Eastern Ukraine.” In *OSCE Yearbook 2017*, 113–23. Baden-Baden: Nomos.
Kindervater, Katharine Hall. 2016. “The Emergence of Lethal Surveillance: Watching and Killing in the History of Drone Technology.” *Security Dialogue* 47 (3): 223–38.
Kolås, Åshild. 2011. “Naga Militancy and Violent Politics in the Shadow of Ceasefire.” *Journal of Peace Research* 48 (6): 781–92.
Lee, Ricky, and Sarah Steele. 2014. “Military Use of Satellite Communications, Remote Sensing, and Global Positioning Systems in the War on Terror.” *Journal of Air Law and Commerce* 79 (1): 69–112.
Lute, Jane H. 2014. “Final Report of the Expert Panel on Technology and Innovation in UN Peacekeeping.” Last accessed June 1, 2023. https://peacekeeping.un.org/sites/default/files/performance-peacekeeping_expert-panel-on-technology-and-innovation_report_2015.pdf.
Mahieu, Sylvie. 2007. “When Should Mediators Interrupt a Civil War? The Best Timing for a Ceasefire.” *International Negotiation* 12 (2): 207–28.
Neukirch, Claus. 2015. “The Special Monitoring Mission to Ukraine: Operational Challenges and New Horizons.” In *OSCE Yearbook 2014*, 183–97. Baden-Baden: Nomos.
———. 2016. “The Special Monitoring Mission to Ukraine in Its Second Year: Ongoing OSCE Conflict Management in Ukraine.” In *OSCE Yearbook 2015*, 229–39. Baden-Baden: Nomos.
Nutt, Cullen G., and Reid B.C. Pauly. 2021. “Caught Red-Handed: How States Wield Proof to Coerce Wrongdoers.” *International Security* 46 (2): 7–50.
Oksamytna, Kseniya. 2018. “Policy Entrepreneurship by International Bureaucracies: The Evolution of Public Information in UN Peacekeeping.” *International Peacekeeping* 25 (1): 79–104.
OSCE Conflict Prevention Centre. 2021. “A Peaceful Presence: The First Five Years of the OSCE Special Monitoring Mission to Ukraine.” Last accessed June 1, 2023. https://www.osce.org/secretariat/491220.
OSCE. 2022. “2021 Trends and observations from the Special Monitoring Mission to Ukraine.” Last accessed June 1, 2023. https://www.osce.org/special-monitoring-mission-to-ukraine/511327.
Palik, Júlia. 2021. “Watchdogs of Pause: The Challenges of Ceasefire Monitoring in Yemen.” *International Peacekeeping* 28 (3): 444–69.
Peško, Marcel. 2017. “The OSCE’s Engagement in Response to the Crisis in Ukraine: Meeting New Challenges with New Solutions.” In *OSCE Yearbook 2016*, 23–32. Baden-Baden.
Pinaud, Margaux. 2021. “Home-Grown Peace: Civil Society Roles in Preliminary Ceasefire Monitoring.” *International Peacekeeping* 28 (3): 470–95.
Richmond, Oliver P., and Gëzim Visoka. 2021. “Peace-Making: New Technologies Are No Panacea.” *Nature* 590 (7846): 389.
Schultz, Kenneth A. 2012. “Why We Needed Audience Costs and What We Need Now.” *Security Studies* 21 (3): 369–75.
Sticher, Valerie. 2022. “Ceasefire Violations: Why They Occur and How They Relate to Strategic Decision-Making Processes.” *International Studies Review* 24 (4): viac046.
Sticher, Valerie, and Siniša Vuković. 2021. “Bargaining in Intrastate Conflicts: The Shifting Role of Ceasefires.” *Journal of Peace Research*. 58 (6): 1284–99.
Sticher, Valerie, Jan D. Wegner, and Birke Pfeifle. 2023. “Toward the Remote Monitoring of Armed Conflicts.” *PNAS Nexus* 2 (6): pgad181.
UNDPPA. 2020. “Remote Monitoring and Sensing of Peace and Ceasefire Agreement Implementation.” Workshop on Artificial Intelligence and Mediation (Online).
United Nations Institute for Disarmament Research. 2022. “Virtual Launch of the Technology and Ceasefires Publication: Exploring the Use of Technology for Remote Ceasefire Monitoring and Verifica-

tion." Last accessed June 1, 2023. https://unidir.org/events/virtual-launch-technology-and-ceasefires-publication-exploring-use-technology-remote.

Van Der Meulen, Jan, and Joseph Soeters. 2005. "Considering Casualties: Risk and Loss during Peacekeeping and Warmaking." *Armed Forces & Society* 31 (4): 483–86.

Verjee, Aly. 2019a. "Ceasefire Monitoring in South Sudan 2014–2019: 'A Very Ugly Mission'." In *PeaceWorks 150*. Washington, DC: United States Institute of Peace.

———. 2019b. *Monitoring Ceasefires is Getting Harder: Greater Innovation is Required. Oslo Forum Peacewriter Prize 2019*. Geneva: Centre for Humanitarian Dialogue.

———, 2023. "Signaling Violence: Ceasefire Monitors and the Production of Ceasefire Noncompliance." *Unpublished manuscript*. Sweden: School of Global Studies, University of Gothenburg.

Walter, Barbara F. 2009. "Bargaining Failures and Civil War." *Annual Review of Political Science* 12 (1): 243–61.

Witmer, Frank D. W. 2015. "Remote Sensing of Violent Conflict: Eyes from Above." *International Journal of Remote Sensing* 36 (9): 2326–52.

Sticher, Valerie, and Aly Verjee. (2023) Do Eyes in the Sky Ensure Peace on the Ground? The Uncertain Contributions of Remote Sensing to Ceasefire Compliance. *International Studies Review*, https://doi.org/10.1093/isr/viad039