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CHARTING A PATH THROUGH THE SPACE ARMS CONTROL VERIFICATION CHALLENGE

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Summary

Many U.S. policymakers are deeply skeptical that a space arms control agreement can be effectively verified. But is verification truly as impossible as it is made out to be? This paper provides a framework to chart the interrelationship among a treaty's terms, verification technology, and the level of trust among parties. We should be under no illusion that effective verification will be easy, but by breaking the overall challenge into its enabling components, the problem can be addressed with more concrete and feasible steps than initially imagined. While rising tensions between the key parties needed to negotiate an impactful agreement could stall meaningful space arms control discussions for years to come, if there is an opening, this paper finds verification can be a surmountable obstacle given new technologies and several other factors at work.

Introduction

Arms control aimed at limiting weapons and threatening behaviors in space has faced myriad obstacles through the decades, and one of the most persistent hurdles has been that of verification. Given the difficulties in monitoring what is happening in orbit, the question is frequently asked: how will we verify that the other side is following through on their commitments, that they will not cheat on the agreement? Many U.S. policymakers and diplomats are deeply skeptical of verification for space arms control, arguing that it is impossible to define a space weapon, let alone to identify such a weapon in orbit and credibly attribute who deployed it.

But is verification truly as impossible as it is made out to be? Looking back through the details of historical efforts to negotiate arms control for space, verification challenges have often taken the blame when other political and strategic challenges played a more significant role in stalling or derailing the negotiations. This study indicates that verification can be a surmountable obstacle thanks to developments in modern technologies, new stakeholders, and more robust information-sharing processes related to space, as well as new approaches for defining the systems and behaviors that could be limited in space arms control.

> ***"Verification has long been the nemesis of arms control."***
>
> —William C. Potter[1]

This paper, without passing judgment on whether arms control is the solution to current space security challenges, provides a framework that could help ensure that verification challenges are not used as a convenient excuse for giving up on space arms control as an option. The framework encompasses several factors that will need to be considered to achieve an effectively verifiable space arms control agreement, including treaty prerequisites, the treaty's core limits and constraints, the treaty's verification provisions, and consultative measures. Technology and trust play central roles in the framework, as they each facilitate verification differently.

The analysis uses the framework to assess four successful arms control treaty negotiations. These cases demonstrate the interplay of the key factors and lay the groundwork for discussion on how the framework could be applied to future space arms control efforts. In particular, the challenge of space arms control verification could be addressed through a combination of:

1. Taking advantage of breakthroughs in key technologies relevant to verification of space activities.

2. Leveraging non-governmental Space Situational Awareness (SSA) data providers to build broader trust and redundancy around space verification information.

3. Focusing arms control efforts on identifying dangerous *behaviors* instead of identifying and counting dangerous *systems*.

These options, plus the framework's assistance with navigating them, indicate there is hope for verification, and therefore the possibility of space arms control sometime in the future.

Verifying Arms Control and Why It is Tough for Space

This section connects verification to current U.S. policy, defines verification and compliance, and explores the many difficulties that can get in the way of effectively determining if a treaty party is complying with an agreement. The discussion also touches upon the political and diplomatic dimensions of verification and compliance and describes several verification challenges specific to space arms control.

Verification is defined as the process of gathering and analyzing information to make a judgment about treaty participants' compliance or noncompliance with the terms of an agreement.[2] V*erification of compliance* is a term of art that implicitly refers to legally binding treaties.[*] When a treaty participant (also referred to as a treaty party) meets its treaty commitments, it is assessed to be "in compliance." Verification regimes aim to collect and analyze information on whether all parties remain in compliance or whether they have violated the core limits and constraints of the treaty.[3]

Effective Verification

The 2020 U.S. National Space Policy says the Department of State will "[l]ead the consideration of proposals and concepts for arms control measures if they are equitable, effectively verifiable, and enhance the national security of the United States and its allies."[4] It is important to recognize that U.S. policy does not set perfect or foolproof verification as the standard. In past arms control treaties, the United States has accepted effective verification to

[*]The term "monitoring" frequently refers to nonlegally binding international confidence-building measures. Officials use the terms "confirming" and "assessing" to connote non-legally binding, voluntary, best practices, guidelines, standards, and norms of behavior. Nevertheless, these terms are often used interchangeably. (Discussion with U.S. Department of State official, July 15, 2021.)

mean verification adequate to provide the United States the ability, in a timely manner, to detect noncompliance that might alter the relative strategic position of the United States.[5] This highlights that while effective verification focuses on identifying irregularities that could constitute violations, it does not have to be designed necessarily to quickly discover every single incidence of noncompliance.[6] Moreover, monitoring and verifying compliance is primarily technical in nature while determination of noncompliance is fundamentally political. When purposeful noncompliance is uncovered, its significance is weighed on a scale that considers the cheating's political and military significance and effect on the strategic balance.[7]

Many obstacles can get in the way of effective verification, even in the absence of intentional cheating. This is partially because not all noncompliance is purposeful. Noncompliance can be due to ambiguity in language, treaty loopholes and omissions, operational implementation challenges and mistakes, and genuine misunderstanding about the agreement terms. In some cases, a party to a treaty may lack the capacity to fully comply due to resource constraints, bureaucratic ineptitude, or lack of technical ability.[9]

> ***"Many concerns relating to compliance involve matters of interpretation."***
>
> —U.S. Department of State[8]

Challenges such as these often make it impractical to determine noncompliance quickly. And oftentimes, depending on the treaty, exacting and immediate compliance is neither necessary nor feasible.[10] For these reasons, the United States characterizes noncompliance across a spectrum of risk from "in compliance" to "compliance concern" to "violation" to "material breach," (as shown in Figure 1).[11] The U.S. Department of State notes "…it may take significant time to assess whether the actions or activities that gave rise to concerns constitute violations or simply represent differences in implementation approaches or some other permissible activity."[12]

Even when it appears there is a clear case of cheating, reaction to the suspected cheating can be far from quick. For example, the United States first raised Intermediate-Range Nuclear Forces (INF) Treaty compliance concerns with Russia in May 2013, assessed Russia was in violation in July 2014, and declared Russia in material breach in December 2018.[13] On August 2, 2019, the United States formally withdrew from the INF Treaty—five years after first assessing Russia to be in violation.[14] More recently, in January 2023, the United States assessed the Russian Federation to be in violation of the "Treaty between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms" (New START Treaty).[15] However, at the time of this writing, the United States assesses there is still a chance to bring Russia back into compliance, that there is not a strategic imbalance between the United States and Russia,

Figure 1: Compliance spectrum of risk.

and that Russia's treaty violations do not currently threaten U.S. national security.[16] The INF and New START cases clearly demonstrate that treaty verification processes can occur over extended periods.[17]

Space Arms Control, Verification, and the Problem of Dual-Use Satellites

While some arms control treaty provisions that constrain space activities already exist in various agreements, a set of verification issues have routinely been deployed over the decades to argue against further space arms control. The verification challenges are real, but the historical record shows other political priorities and contextual factors may matter more when it comes to space arms control.

> ***"Unfortunately, there are no pragmatic or proven proposals for how to conduct verification of weapons in outer space."***
>
> — U.S. Ambassador Bruce Turner, March 30, 2023.[18]

For example, several nuclear arms control agreements have helped preserve stability in the space domain. Treaties have prohibited activities such as the detonation of nuclear weapons in space, the placement of weapons of mass destruction in space, interference with national technical means (NTM) of verifying arms control treaties, and the testing and deployment of ballistic missile inceptors in space.† However, efforts to achieve broader, dedicated space arms control agreements have consistently failed and blame for the failures has often been placed on verification difficulties.[19,‡]

In 1978, the United States and the Soviet Union began formal negotiations on anti-satellite (ASAT) weapon limitations. The talks focused on limiting the development and the use of ASATs but stalled when both sides agreed they needed more time to study various issues.[20] Along with broader tensions in U.S.-Soviet relations, the talks stalled because of several unique-to-space verification issues. Since this experience, arms control practitioners and scholars have identified and deemed several space arms control challenges as supposedly insurmountable.

One major challenge is that no agreement exists on the definition of a space weapon, with ASATs considered one type of space weapon.[21] The resulting ambiguity on what counts as a space weapon makes verifying compliance with any limits on them very doubtful.[22] The primary obstacle to a clear-cut definition is that many space systems have dual uses; i.e., they can be used for military purposes and civilian purposes. Dual-use satellites may possibly be used as a cover for space-based weapons.[23] Taking the dual-use problem to its logical extreme, some argue that

† With the exception of the removal of the prohibition on deploying ballistic missile interceptors in space with the U.S. withdrawal from the Anti-Ballistic Missile (ABM) Treaty in 2002, the treaties prohibiting nuclear detonations in space and placing WMD in space are still in effect. In addition, subsequent nuclear arms control treaties from the 1980s to today carried over the prohibition on interference with NTM.

‡ More recently, the United States has consistently described the draft "Prevention of the Placement of Weapons in Outer Space Treaty" (PPWT), proposed by China and Russia since 2008, as "fundamentally flawed" for four key reasons: (1) the draft PPWT or any other proposal like it are inherently unverifiable, (2) given the dual-use nature of many space systems, it is impossible to define a "weapon in space," (3) it fails to address concerns about a potential stockpiling and breakout capabilities, and 4) verification of compliance cannot be achieved. U.S. Mission Geneva, "U.S. Remarks for Conference on Disarmament Subsidiary Body – Prevention of an Arms Race in Outer Space," (March 22, 2022). htttps://Geneva.usmission.gov/2022/03/cd-prevention-of-an-arms-race-in-space/

any maneuverable satellite has the residual ability to be used as an anti-satellite weapon if it is maneuvered to collide destructively with another satellite.[§] Hence, the reasoning goes, compliance monitors will have great difficulty, if not an impossible task, in distinguishing a benign satellite from a weaponized satellite.[24] For example, during the 1978 to 1979 ASAT negotiations, the Soviets wanted to count the space shuttle (which did not fly for the first time until 1981) as a space weapon due to its robotic arm, its maneuverability, and its ability to return space objects to the ground in its payload bay. The United States categorically rejected this idea, but until negotiations were cut off following the Soviet invasion of Afghanistan in December 1979, negotiators continued to discuss useful, verifiable limits and constraints. For example, the U.S. position on the problem of any maneuverable satellite having the inherent capability to collide with another satellite was that treaty limits would only be placed on distinguishable, dedicated, space-based ASAT weapons.[25] Other suggested constraints included forbidding any country's satellite from touching or changing the orbit of another country's satellite. The Carter administration also considered mutual constraints on terrestrial-based ASATs.[26]

U.S. interests changed with the incoming Reagan administration. The administration's new priority was missile defense, including space-based missile defense envisioned in the Strategic Defense Initiative (SDI). Although Reagan was not initially against restarting ASAT arms control talks in the early 1980s, the administration's concern was that space-based ASATs could not be distinguished from space-based missile interceptors. At the end of the day, the United States did not want this problem to risk the possibility that ASAT arms control could result in limitations on space-based missile interceptors.[27] This became the key reason the Reagan administration rejected constraints on ASATs. Even so, the United States did not want this reason to be publicized and instead asserted verification challenges were the key obstacle to making any progress in ASAT arms control.[28] Throughout the 1990s and 2000s, such verification concerns and fears of limiting missile defenses in space played a significant role in shaping U.S. views on space arms control.

This history shows that while the space arms control verification challenge is serious, it is not immutable and is not always the true primary obstacle in negotiations. *Political and contextual conditions—such as the deterioration in U.S.-Soviet relations—not verification, caused the failure of space arms control during the Cold War*. Under different conditions there may be better outcomes regardless of the enduring difficulty of verification.

A Verification Framework

While there is a need for more study of space arms control verification, a framework for developing and assessing verification regimes could help practitioners and scholars navigate the complexities of the issue.

After the Cold War, studies on arms control in general were widely seen as superfluous.[29] As a result, the number of studies focused specifically on verification drastically declined, from over 400 articles and books published on the topic between 1977 and 1985 to relatively few in the last couple decades.[30] Several recent papers on arms

[§] Such a scenario could be used as pretext to deflect attempts to reach agreement to limit deployment of dedicated space-to-space anti-satellite weapons, whether such a possibility is really the issue or not.

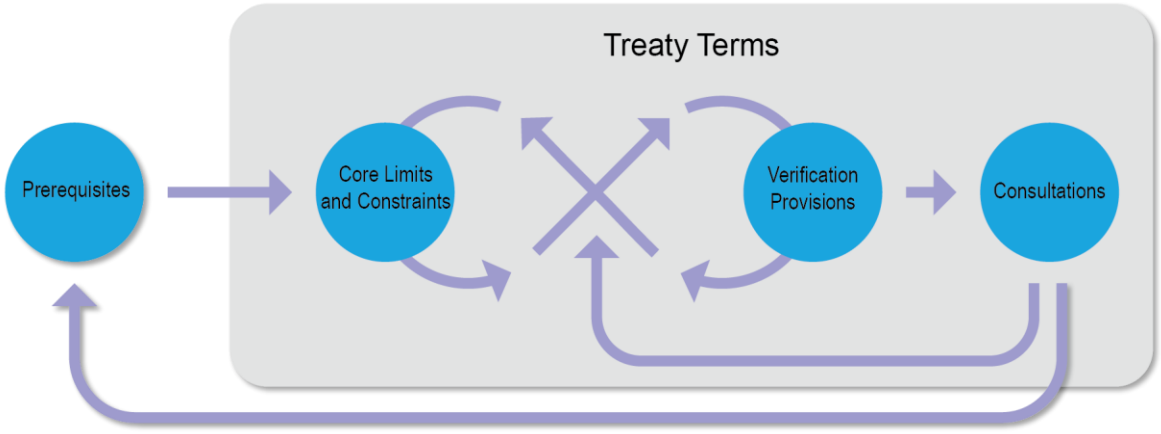

Figure 2: Arms control verification framework.

control have directly and indirectly considered space arms control verification issues and signal an uptick in interest on the topic, but the last few decades have overall seen relatively little scholarship directed specifically at the complexities of verifying a space arms control agreement.[31] Ideally, the verification framework offered below will inform future U.S. space arms control efforts. At a minimum, hopefully the proffered framework will spur more interest in space arms control issues.

As illustrated in Figure 2, the proposed verification framework consists of four major segments. Each segment is comprised of a variety of factors and each segment interrelates to the other segments as described below. Three of these segments comprise the Treaty Terms, which are implicitly and explicitly worked into the text of the treaty and must be developed in tandem. But first, the prospective treaty parties need to clear a series of prerequisites in order to even get to the negotiating table.

Prerequisites

Before negotiations can start and before verification becomes a key issue for the United States, several prerequisite conditions must be addressed. First, potential negotiating partners must recognize a confluence of interests and be willing to talk. A confluence of interests does not, however, imply uniformity of interests. The presence of arms control negotiations and agreements also does not indicate that cooperation has superseded competition in a relationship or that disagreements over contentious issues cease.[32] States may have divergent interests and significantly different motivations for arms control, but a treaty becomes possible when two or more countries' interests converge closely enough in an area that they agree to formal talks.

National leaders also will need to decide the principal purpose of a treaty. Arms control practitioners, scholars, and proponents have described several common purposes for arms control. According to the literature, arms control can improve strategic stability, curtail the scope and

Table 1: Prerequisites	
Overarching Purpose	◆ Advantage ◆ Disarmament ◆ Stability
U.S. Domestic Political	◆ Senate ◆ Interagency ◆ Public
Negotiating Partner(s)	◆ Confluence of interest ◆ Bilateral ◆ Multilateral

violence of war, shape and limit areas of competition, and help prevent unnecessary and costly arms races.[33] States may even use arms control negotiations to advance their own competitive agendas while trying to reduce the risks that come with strategic competition.[34] The eminent scholar, Robert Jervis, argued that the overarching purpose of arms control is to make war less likely.[35] These rationales collectively emphasize that limits on weapons, technologies, and behaviors are the means to an end and the limits should not be mistaken as an end in themselves.[36]

The arms control scholar John Mauer has placed the various rationales in three broad categories: advantage, disarmament, and stability.[37] Understanding the United States' primary rationale for a notional space arms control treaty using these categories helps clarify potential negotiating priorities, areas for compromise, and openings for flexibility within some boundaries. The *advantage* rationale views arms control as a way for status quo powers to maintain their own capabilities while preventing dangerous countries, for example North Korea and Iran, from acquiring threatening technologies and weapons. The *disarmament* rationale perceives arms control primarily as a means to moderate the pressure to build more arms from each country's domestic, hawkish interest groups. Ultimately disarmament proponents aim to reduce or eliminate different kinds of weapons.[**] The *stability* rationale considers the primary aim of arms control to be creating or reinforcing strategic stability by mitigating mutual fears of surprise attack, reducing the risk of inadvertent conflict escalation, creating crisis communication methods, and spawning norms of behavior.[38] The various arms control rationales are not mutually exclusive, and may blend together. Past arms control agreements have managed to serve multiple purposes.[39]

Next, U.S. policymakers must evaluate the U.S. domestic political context and judge if it is plausible for a treaty proposal to garner sufficient political support among key stakeholders, interest groups, politicians, the media, and the public. The domestic political context will also help set the bar for effective verification and what, if any, verification provisions must be included in the treaty terms, highlighting the fact that verification is as much a political issue as a technical issue. Domestic political actors such as senators or interagency stakeholders may press for near-perfect verification or set a less stringent verification standard depending on the treaty objectives and the level of threat that they perceive from the other countries participating in the negotiation.[40]

In addition, at some point negotiating partners will need to consider how many countries to include in the formal talks to develop a treaty. Bilateral negotiations are sometimes the most straightforward path, with other countries acceding to a treaty and its verification provisions after it has been hammered out bilaterally or among a narrow group of key parties. Having more than two treaty parties could complicate the path to agreement.

This paper does not attempt to suggest how the variety of prerequisite conditions can be met in the future since the focus of this paper is on the verification challenge. However, the outcomes of the prerequisites stage will inform the treaty terms.

[**]For example, on December 25, 2023, Pope Francis said the weapons industry was fueling the conflicts around the globe. Nicole Winfield, "Pope Francis denounces the weapons industry as he makes a Christmas appeal for peace in the world." Associated Press, (December 25, 2023). https://apnews.com/world-news/pope-francis-0000018ca11fd7a5a79da55feff40000

Most importantly, the treaty's overarching purpose will drive the treaty's core limits and constraints, which will, in turn, define what needs to be verified.[41]

A Feedback Loop: Core Limits and Constraints vs. Verification Provisions

Once the prerequisites are met, substantive negotiations may begin. Figure 3 represents a zoomed in view of the framework to illustrate the interaction and feedback that occurs during negotiations over core limits, constraints, and verification provisions. As Figure 3 notes, the treaty's limits and constraints may include quantitative, qualitative, or behavioral limitations. *Quantitative* limits refer to treaty parties agreeing to cap, reduce, or eliminate a specific number of weapons, warheads, delivery systems and so forth. *Qualitative* limits refer to restriction or prohibition on certain characteristics of weapons systems, such as limits on a missile's range. *Behavioral* limitations bound when, where, and how a capability may be used, such as limiting nuclear weapon testing or prohibiting interference with NTM of verification.

The treaty terms define what specific capabilities and behaviors need to be verified, in turn setting the requirements for what kinds of verification methods can be used. There are many ways to categorize verification regimes, such as the commonly used distinction between unilateral, cooperative, multilateral, and open verification explored, among others, by Ambassador Roger Harrison.[42] While those categories include differences in *who* conducts verification, this paper focuses more simply on *how* the verification data are collected— "intrusively" versus "nonintrusively"—as the foundation for the framework and explained below.

Importantly, even if each party has unique verification requirements, each party will have to accept reciprocal verification methods in the treaty's verification provisions. For example, if one party assesses intrusive on-site inspections are needed to

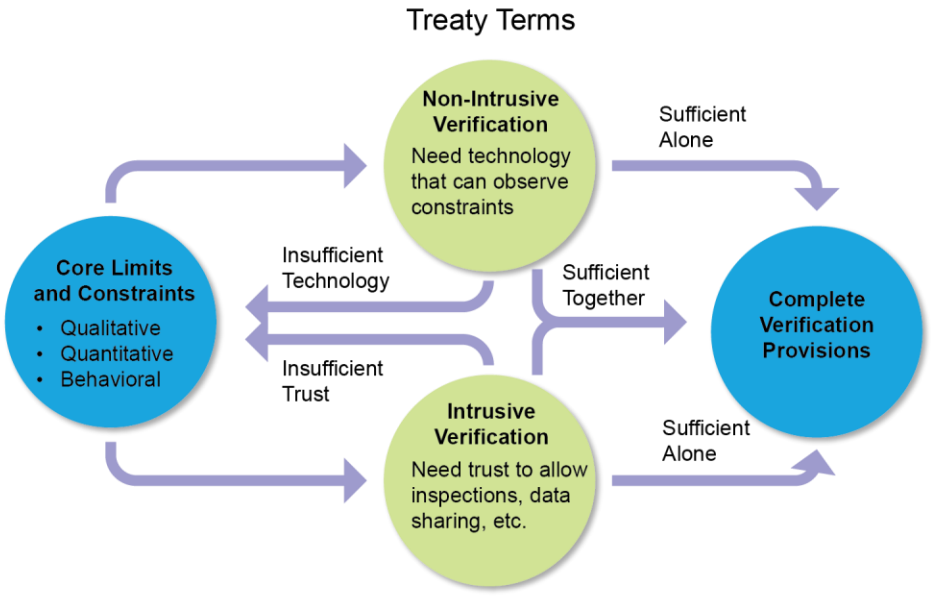

Figure 3: Treaty terms including verification provisions.

effectively verify compliance with treaty limits, that party will have to agree to the other party conducting on-site inspections as well. If this is a concern, it can be avoided if compliance with proposed limits can be verified with nonintrusive verification methods.

Nonintrusive Verification

Nonintrusive verification methods involve states using technology to unilaterally verify treaty compliance without having direct on-site access. When treaty terms do not include specific verification provisions, nonintrusive verification is assumed. Several arms control treaties have relied completely on nonintrusive verification of all treaty limits and restraints.[43] When the arms control treaty's terms focus on quantitative limits, counting accurately becomes the essence of compliance verification. NTM that can remotely distinguish the treaty-restricted items may be sufficient for effective verification. Prohibitions on interference with NTM have appeared in the provisions of numerous arms control treaties, indicating mutual recognition of the importance of technology to nonintrusive arms control treaty verification. Although most such protections are purposely ambiguous in phrasing, noninterference treaty provisions legitimize the use of satellite reconnaissance for treaty verification and provide a measure of confidence to treaty parties that such satellites will not be interfered with unless the antagonist is willing to risk undermining the treaty and potentially signal a crisis in the relationship.

However, relying completely on nonintrusive technology is not always sufficient or feasible, depending on specific treaty limits and the given state of technology. For example, treaty terms limiting weapon stockpiles, production, testing, and other activities that may be concealed underground, in buildings, or otherwise hidden may not be verifiable using only remote sensing technologies.[44] In such cases, effective verification has depended on agreement on reciprocal, intrusive verification methods.

Intrusive Verification

A treaty's terms may include (and be shaped by) any intrusive verification provisions each party finds necessary to verify compliance. Intrusive verification provisions, however, bring more attention to the role of trust.[45]

Trust can be a tricky term to define, with multiple potential meanings in an arms control context. In fact, some may argue that two negotiating parties who "trust" each other would not need verification regimes at all because they would each believe the other party will fulfill the treaty terms without supervision or a need to provide evidence. *For this assessment, the "trust" factor applies narrowly to the willingness of states to allow others to conduct verification via intrusive methods.* Agreement to mutual, intrusive verification methods relies on at least a baseline level of trust among treaty parties because each party must be sufficiently satisfied that the other party will not cause damage to their national security with the inspection.[46] Each party to the proposed treaty will weigh the benefits of the mutual limits under negotiation in the core treaty terms against the risk that vulnerabilities or important national security secrets could inadvertently be exposed during intrusive verification inspections.[47] In a more trusting environment, treaty parties may agree on a mutually intrusive verification regime if they each judge the risk to be acceptable. On the other hand, less "verification trust" between parties makes agreement on intrusive verification less likely and thereby narrows the range of mutually acceptable treaty limits.[48] In other words, if the treaty terms can only be verified by intrusive methods and treaty parties do not trust each other enough to allow such intrusion, then negotiators have to go back to the drawing board and adjust the treaty terms, as demonstrated by the feedback loop in Figure 3.

An alternative in a low-trust environment is establishing an international organization (IO) in the

treaty terms for the purpose of verifying treaty compliance. If perceived as sufficiently trustworthy or neutral by all parties, such a multilateral verification regime could allow for intrusive verification inspections using international inspectors. Such an IO's findings would be more generally accepted, authoritative, and harder to dispute. The Nuclear Non-Proliferation Treaty and its verification by the International Atomic Energy Agency is an exemplar of this approach.[49] Reaching agreement on how to organize, fund, and manage such an IO is another complex political and diplomatic hurdle and may be unlikely today. But if interests align enough, a verification regime designed in this way provides another potential pathway to overcome mutual distrust among treaty parties.

A Symbiosis of Nonintrusive and Intrusive Verification

In reality, both nonintrusive and intrusive methods are often used simultaneously. When nonintrusive verification means are not sufficient to effectively verify a treaty's terms, a common U.S. approach for effectively verifying compliance has been to use nonintrusive and intrusive verification techniques together, as depicted in Figure 3. The benefit of the combination approach is greater than the sum of its parts as nonintrusive and intrusive verification practices inform and complement each other, giving greater confidence to compliance judgments.[50]

Regardless, if a combination of nonintrusive and intrusive verification methods is not sufficient to verify the core treaty limits and constraints, reaching agreement will require more negotiations as represented by the arrows leading back to the Core Limits and Constraints component of Figure 3. To avoid failure, negotiators will need to propose alternative treaty terms that can be effectively verified.

Consultative Mechanisms

Treaty development and implementation does not necessarily stop at the official treaty signing ceremony. Many treaties nowadays are not just words on a piece of paper frozen at the time they are written. They are living documents that create continuing relationships and discussion over long periods of time. For example, treaties may include provisions to help resolve verification and compliance issues as they arise.[51] As shown in Figure 2, the arms control verification framework's fourth major segment represents formal consultative mechanisms. Formally established consultative mechanisms significantly improve the durability of arms control agreements and establish a continuing dialogue among treaty parties on the issue at stake.[52] Furthermore, consultative mechanisms provide a regular forum for parties to discuss new issues—such as technological advancements like new weapon systems or unexpected geopolitical shifts like the collapse of the Soviet Union—that may have a bearing on the treaty's provisions.[53] Consultative bodies may agree to additional treaty verification measures, protocols, amendments, and annexes which are often signed by the head of state and do not require additional ratification.[54]

Preferably, the discussions enabled by a treaty's consultative mechanisms provide each party assurance that the other party is not cheating or intentionally violating the treaty. However, risks increase if regular consultations among the treaty parties fail to resolve compliance concerns, potentially indicating noncompliance is purposeful and signaling a treaty violation or material breach is at hand.[55] For example, in October 2022, Russia failed to comply with the New START Treaty obligation to convene a session of the Bilateral Consultative Commission (BCC) within the proper timeline, contributing to the U.S. Department of

State's judgment that Russia is not in compliance with New START.[56]

Table 2: Consultations
◆ Resolve ambiguities in treaty terms ◆ Resolve unexpected issues ◆ Raise and resolve compliance concerns ◆ Develop additional verification measures ◆ Facilitate treaty implementation

Sometimes arms control treaties do not include explicit consultative mechanisms or establish inadequate consultative mechanisms in the verification provisions, leaving compliance and implementation concerns to be addressed on an ad hoc basis. In such cases, practical compliance issues can be more difficult to resolve and verification challenges may mount, ultimately sparking diplomatic conflict and weakening a treaty's usefulness and durability.[57] On the other hand, several arms control treaties have endured for decades without establishing formal consultative mechanisms.

Finally, treaty parties have a spectrum of options if direct consultations do not resolve compliance concerns. Parties have options ranging from doing nothing in the hope the other party will come back into compliance to asking for third-party arbitration to formally withdrawing from a treaty. In fact, procedures for withdrawing from a treaty are often included in the treaty terms, thereby providing parties the flexibility to formally leave a treaty when the treaty is no longer in their interests. Of course, parties have the option to abruptly terminate or abrogate the treaty when there is great risk to national security or time of war.

Applying the Framework to Past Arms Control Treaties

By applying the verification framework to historical examples, this analysis explains how verification challenges have been overcome in the past. These cases demonstrate how the strategic context and technology can change, making verification possible where it had previously been judged impossible. The prerequisite conditions are assumed to have been met in each case, so they are not examined in-depth here. The analysis draws primarily from four successful arms control efforts and their resulting treaties: the 1963 Limited Test Ban Treaty (LTBT), the 1972 Anti-Ballistic Missile (ABM) Treaty and Interim Agreement, collectively referred to as the Strategic Arms Limitation Treaty (SALT I); and the 1987 Intermediate-Range Nuclear Forces (INF) Treaty. Each negotiation took years of stalemate and back-and-forth negotiations before a change in the key verification factors resulted in a treaty. This section provides the basic background of the four treaties and analyzes each treaty to discern which of the key factors shifted markedly, resulting in a treaty that the United States judged effectively verifiable.

The Limited Test Ban Treaty (LTBT)

The LTBT entered into force on October 10, 1963 after ratification by the three original states: the United States, the United Kingdom, and the Soviet Union. The treaty has unlimited duration and over a hundred other countries have since signed, ratified, or acceded to it. The LTBT prohibits nuclear weapons tests or explosions in the atmosphere, in outer space, and underwater as well as banning any kind of nuclear explosion that would release radioactive debris outside the borders of the country conducting the explosion. The treaty does not include any verification provisions, implicitly

making effective verification dependent upon a unilateral verification regime and technology to enable nonintrusive verification. The treaty does not contain any formal consultative mechanisms to address verification and compliance issues.

It took eight years between the first proposals and the adoption of the LTBT in 1963. For most of this time, the Soviet Union and Western powers disagreed over verification issues even though they recognized a common interest in limiting nuclear testing. They disagreed on the number of intrusive, on-site inspections, which the United States and others saw as necessary for any ban on underground nuclear testing because those could be mistaken for earthquakes given the technology available for remote verification at the time. The impasse was clear in 1961 when the United States and the United Kingdom wanted 20 on-site inspections per year and the Soviet Union only wanted to allow three.[58] In the language of this paper's verification framework, negotiations stalled at this point due to insufficient technology to rely solely on nonintrusive verification technologies and insufficient trust to allow for adequate intrusive verification methods.

There was a breakthrough in discussions following observation of the negative effects of the summer 1962 Starfish Prime nuclear detonation in space and the October 1962 Cuban Missile Crisis.[59] Soviet Premier Nikita Khrushchev gave a speech on July 2, 1963 calling for an agreement that only outlawed tests in the atmosphere, in outer space, and underwater, which were "environments where both sides agreed their existing verification systems could adequately police a ban."[60] The decision was made to set aside the underground nuclear testing issue, narrowing the treaty objectives and terms to what could be verified without on-site inspections. After Khrushchev indicated willingness to focus on banning the more easily verifiable types of nuclear tests, the final negotiations between the United States, Soviet Union, and United Kingdom took only 10 days to produce a treaty.

Improvements in technology enabled verification of nuclear testing in space, and this further allowed negotiators to break out of the feedback loop between constraints and verification provisions. A conference of experts in 1958 concluded that existing technology could not verify nuclear tests over 50-kilometer altitudes.[61] The United States later overcame this limitation with the deployment of the Vela Hotel satellite series—a program initiated in 1959 and first launched in October 1963, immediately after the LTBT came into force—which could detect nuclear explosions in space and was the first space-based technological capability to verify compliance with arms control agreements.[62] The Soviet Union also made significant space capability advances that affected their stance on arms control and verification. In July 1962, the Soviets completed their first successful test of the Zenit-2 photoreconnaissance satellite, resulting in the first usable photographs of U.S. sites and having a significant impact on Khrushchev's attitude towards the value of space-based reconnaissance.[63]

In the LTBT case, applying the verification framework highlights that the verification challenge was overcome by shaping treaty terms around what could be effectively verified using nonintrusive means. Technological advancements made detecting nuclear detonations in space possible, enabling the agreement even though it was more narrow than the all-encompassing test ban goals sought when negotiations started. As a result of political and diplomatic priorities after the Cuban Missile Crisis and both a change in core treaty terms and new technical capabilities, the LTBT was signed by the United States, USSR, and United Kingdom only a month after Khrushchev's speech,

a rapid turnaround from the years of gridlock.[††] The treaty's lack of a formal consultative mechanism has not affected its durability over the decades.

The Anti-Ballistic Missile Treaty and the Interim Agreement (SALT I)

Despite the promise of détente between the United States and Soviet Union in the early 1970s, distrust was still high. However, improving technology for nonintrusive verification led to increasingly ambitious arms control agreements as reflected in the ABM Treaty and Interim Agreement (i.e., SALT I).

In 1967, President Lyndon Johnson began calls for strategic arms limitation talks with the Soviet Union. While the two countries were developing advanced nuclear delivery and defense technologies, the aim was to limit both offensive and defensive strategic systems so that the U.S.-Soviet relationship could stabilize, the arms race could be restrained, and Johnson could pursue his domestic political agenda. The SALT I talks formally began in November 1969 and concluded in May 1972 with the signing of the ABM Treaty and the Interim Agreement. The ABM Treaty limited each country to two ground-based ABM deployment sites (later reduced to one) with a maximum of 100 interceptor missiles and 100 launchers at each site. The ABM Treaty also limited qualitative improvements of ABM technology, including a ban on development or deployment of interceptor missiles with more than one independently guided warhead and a ban on developing, testing, or deploying mobile or sea-, air-, or space-based ABM systems or components. Both sides were evidently confident in their ability to detect noncompliance with this ban on space-based ballistic missile defense systems or components. The accompanying Interim Agreement on offensive systems set limits on the number of intercontinental ballistic missile launchers and submarine-launched ballistic missile launchers each side could possess, with the intention of renegotiating the agreement within five years.[64]

Overlaying the verification framework on these cases shows how improvements in verification technology played a significant role in SALT I because new, space-based NTM expanded the range of objects and activities that could be distinguished and therefore monitored without intrusive on-site inspections. By 1968, U.S. policymakers had enough confidence in their space-based NTM that they were willing to begin negotiating an agreement that did not require intrusive on-site inspections.[65] NTM were seen by both the Soviet Union and the United States as so valuable for nonintrusive treaty verification—thereby valuable for nuclear stability—that both the ABM Treaty and the Interim Agreement included verification provisions, albeit minimal ones. Both treaties specified that "for the purpose of providing assurance of compliance," both parties would use the NTM at their disposal, would not interfere with the other's NTM used for verification, and not use deliberate concealment measures which impede verification by NTM.[66] These treaty verification provisions, legitimized space-based, nonintrusive verification means for the first time.

The ABM Treaty also established a Standing Consultative Commission (SCC) that was chartered to, among other topics, consider issues related to treaty ambiguities, verification and compliance concerns, changes in the strategic situation, and potential treaty amendments.[67] The SCC met at least two times per year in Geneva, Switzerland, or at

[††]The LTBT is still in force. As of this writing, the Comprehensive Test Ban Treaty (CTBT) has not entered force. The CTBT has not been signed by North Korea, India, or Pakistan; has been signed but not ratified by the United States and China; and as of November 2023, Russia has revoked its ratification. https://www.armscontrol.org/act/2023-11/news/russia-deratifies-nuclear-test-ban-treaty.

another agreed location, and provided a critical venue for communication between the United States and the Soviet Union even when other diplomatic channels were closed.[68] The Interim Agreement, Article VI, set the ABM Treaty's Standing Consultative Commission as its consultative mechanism.[69]

The 1987 Intermediate-Range Nuclear Forces (INF) Treaty

Preliminary discussions to limit U.S. and Soviet intermediate (500 km to 5,500 km) range missiles began in late 1980 with formal talks starting on September 23, 1981. The United States proposed to eliminate its nuclear-armed Pershing II ballistic missiles and Ground Launched Cruise Missiles (GLCMs) if the Soviet Union would dismantle *all* its nuclear SS-20, SS-4, and SS-5 ballistic missiles. This was referred to as the "Zero Option." The U.S. position was that any INF agreement must:

- Provide for equality both in limits and rights between the United States and the Soviet Union.
- Be strictly bilateral and thus exclude British and French systems.
- Limit such American and Soviet systems on a global basis.
- Not adversely affect NATO's conventional defense capability.
- Be effectively verifiable.[70]

Applying the verification framework helps identify several factors that contributed to the INF Treaty being judged effectively verifiable by the United States and the importance of a baseline level of trust being necessary to enable intrusive inspections. Nonintrusive, technology-enabled means of verification were necessary but not sufficient for the tasks of verifying the complete elimination of entire missile classes and addressing the problem of monitoring Soviet mobile missiles. Effectively verifying compliance required on-site baseline inspections to confirm the initial data update; short notice inspections, and closeout site inspections to confirm elimination of INF systems. The right to on-the-spot monitoring of the entrances and exits to relevant facilities was also required to verify compliance.[71]

On November 23, 1983, the Soviets walked out of the talks over fundamental disagreements with the U.S. proposal and formal talks did not resume until March 1985. However, throughout 1985 and 1986, disagreements about the terms of the treaty narrowed significantly. In March 1987, the United States offered a draft INF Treaty which reflected the agreement reached by President Reagan and General Secretary Gorbachev at a summit meeting in Reykjavik, Iceland in October 1986.

The Reykjavik summit was a landmark meeting in that it demonstrated an increasing trust between Gorbachev and Reagan.[72] The Soviet counteroffer to the U.S. draft treaty surprisingly showed that the Soviets agreed in principle to some of the provisions of the U.S.-proposed verification regime, including on-site inspection of INF missile inventories and facilities, on-site observation of destruction of INF missiles, and data exchanges. Negotiations identified intrusive verification mechanisms for which there was enough trust to cooperate.

On December 8, 1987, Reagan and Gorbachev signed the INF Treaty and it entered into force on June 1, 1988. The U.S. Department of State notes: "At the time of its signature, the Treaty's verification regime was the most detailed and stringent in the history of nuclear arms control, designed both to eliminate all declared INF systems entirely within three years of the Treaty's entry into force and to ensure compliance with the total ban on possession and use of these missiles."[73] The presence of a

minimum level of trust between the United States and the Soviet Union (and later Russia) enabled these mutually intrusive verification methods which, in turn, enabled agreement on a combination approach to verification and more comprehensive core treaty limits.

The INF Treaty also established a consultative mechanism within the verification provisions. The INF Treaty's Special Verification Commission (SVC) was to assemble if either party requested a meeting and served as a forum to discuss and resolve implementation and compliance issues.[74] The SVC met over 30 times between 1987 and 2017, before Russia's material breach of the treaty's terms and the United States' withdrawal from the treaty. Although the INF Treaty is no longer in effect, the INF case shows how effective verification of the ambitious terms of the treaty (i.e., the "Zero Option") was only possible with highly intrusive on-site inspections. A sufficient amount of mutual trust was instrumental in enabling the parties to agree to reciprocal intrusive verification methods unlike any that had ever been agreed upon previously.

Table 3 summarizes how each of the treaties discussed fits within the lens of the core limits and constraints, verification provisions, and consultative mechanisms segments of the verification framework proposed in this paper.

Applying the Framework to Future Space Arms Control

The verification framework offered herein informs the variety of ways in which the space arms control verification challenge may be overcome in the future, even if trust remains low among the United States, China, and Russia. The discussion below shows how the framework can be laid over today's strategic context and help chart a path through the space arms control verification challenge.

In applying the framework, analysts should recognize how the outcomes of the prerequisites stage will inform the treaty terms, the verification provisions, and the consultative mechanisms. Assuming the prerequisites are set at some point in the future—including deciding the primary purpose of the notional treaty—U.S. negotiators will need to determine core treaty limits and constraints. In turn, the core limits and constraints will drive what needs to be verified. For example, proposals that focus on placing limits and constraints on the most significant threatening behaviors or offensive space weapon systems that can be distinguished open the

Table 3: Application of Verification Framework to Historical Treaties

Treaty	Core Limits/Constraints	Verification Provisions	Consultative Mechanisms
1963 LTBT	Behavioral, limited to more observable behaviors	Nonintrusive, including using space-based NTM (Implicit)	No formal mechanism
1972 ABM/SALT I	Quantitative and Qualitative for missiles and missile defense	Nonintrusive (Implicit), protections on space-based NTM (Explicit)	Standing Consultative Commission
1987 INF	Quantitative and Qualitative, "Zero-Option"	Combination nonintrusive (Implicit) and intrusive (Explicit)	Special Verification Commission

door to a verifiable agreement. In contrast, trying to negotiate limits and constraints on theoretical edge cases posed potentially by, for example, any maneuverable satellite, will bear little fruit since such terms cannot be monitored confidently.

The analysis below does not include proposals for specific limits on numbers of space weapons, their capabilities, or behavioral restraints, instead focusing on ways to generalize and mitigate the verification challenge using nonintrusive or intrusive verification methods or both. If nonintrusive methods will be relied upon alone, verification will require suitable technology be on hand to distinguish a benign satellite from a weaponized satellite, or benign behavior from threatening behavior. If verification of compliance with core limits and constraints requires elements of an intrusive verification regime, a baseline of trust will be necessary.

The Distinguishability Dilemma

While distinguishability remains the root problem to effective verification of a future space arms control agreement, several developments point to promising solutions. As noted previously, the terms of many past arms control agreements included placing limits on the number of capabilities each side can possess or field while using technologically enabled, nonintrusive verification methods. Effectively verifying a future space arms control treaty that replicates this approach would depend on having NTM that can distinguish the capabilities in question and enable them to be characterized and counted in a sufficiently accurate and timely manner. The ubiquitous presence of dual-use satellites in orbit and the lack of a definition of a space weapon poses an enormous challenge. However, several new technologies, emerging partnerships, and innovative ways to approach the indistinguishability problem suggest the problem is not intractable. Nonintrusive verification of a future space arms control treaty may be more viable than ever.

Although there is still room for improvement in potential space arms control verification technologies, in recent years the United States has acquired significant capability improvements that have apparently reduced the problem of distinction and could make verification more feasible. Military systems such as the Geosynchronous Space Situational Awareness Program (GSSAP), which achieved initial operational capability (IOC) in 2015, and Space Fence, which achieved IOC in 2020, improve the timeliness and accuracy of space situational awareness (SSA) data.[75] In addition, the United States is acquiring several other new, highly capable space surveillance systems.[76] According to the U.S. Space Force (USSF), the nascent Silent Barker space surveillance capability "enables indications and warnings of threats" against high-value U.S. systems and will "provide capabilities to search, detect, and track objects from space for timely threat detection."[77] Similarly, USSF Space Systems Command states the Deep Space Advanced Radar Capability (DARC) will have the ability to identify adversarial threats to civil and military satellites. Moreover, a Space Systems Command official said, "Building out a global DARC system, while working with our closest allies, ensures the ability to detect, track, identify, and *characterize* (i.e., distinguish) objects in geosynchronous orbit to protect and defend our most valued space assets against adversarial action" (emphasis added).[78] The first DARC radar should be operational by 2026.[79] It is reasonable to assume that the "threats" talked about in these statements which need to be defended against are implicitly *identifiable* adversary space weapon systems.

Frequently, over the last few years, U.S. senior leaders and organizations have stated explicitly they have observed Russian space-based weapons in orbit, implying that the United States has the capability, to some degree, to distinguish weapons in space and discern threatening behaviors. For example, in July 2020, a U.S. Space Command

statement outright described a Russian satellite and accompanying subsatellites as an orbital ASAT weapon.[80] A day later, a senior U.S. Department of State official publicly stated, "Russia has already tested projectile-firing satellite weapons in orbit not just once, but now twice."[81] These and several other similar statements made in the last few years indicate that, in at least some conditions, senior leaders feel comfortable identifying certain space objects as dedicated space weapons.

The growing number of space surveillance data sources should also help, especially if the new data sources contribute to monitoring behavioral constraints, rather than being used to count difficult-to-discern satellite subsystems and weapon capabilities. For example, U.S. Space Command is actively integrating more DOD sensors into its space surveillance mission, including collecting data from the Army-Navy Transportable Radar Surveillance-2, Sea-Based X-Band Radar, and Aegis radar platforms.[82] Several U.S. allies also are improving their SSA capabilities, including Australia, the European Union, Japan, the UK, the United Arab Emirates, and others.

U.S. commercial and nongovernmental SSA providers are another potential source of significant amounts of space surveillance data that could contribute toward effectively verifying compliance with a future treaty. In 2020, Brian Weeden, then director of program planning at the Secure World Foundation, predicted that commercial capabilities to maintain a space object catalog and provide close approach warnings could exceed that of the U.S. military in the next five years.[83] U.S. Space Command now has SSA data sharing agreements with 170 partners from the commercial sector, academia, and foreign and intergovernmental agencies.[84] One startup company, True Anomaly, suggests its "Jackal" satellites will have the capability to identify nefarious spacecraft on-orbit and can discern if they carry space weapons.[85]

The distinguishability challenge may also be mitigated somewhat by reimagining the problem. With regard to dual-use technologies in general, arms control scholars have suggested reformulating the concept of distinguishability by characterizing it around four attributes:

1. A technology's physical properties (which is likely the sole measure observers usually use to judge distinguishability).

2. The technology's development pathway (i.e., any distinct design and production process differences between dual-use technologies intended for civil or military uses).

3. Doctrine and deployment decisions surrounding a particular dual-use technology which creates patterns of observable behavior for civil and military uses.

4. The speed of conversion from civil uses to military uses.[86]

Assessment of these four attributes holistically by the intelligence community broadens the distinguishability problem beyond the focus on a satellite's physical characteristics.

Artificial Intelligence (AI) also will be a factor in arms control verification. AI will enable reliable data from multiple sources to be analyzed quickly for verification purposes. AI should help with pattern recognition, baselining normal behaviors, quickly spotting irregularities, and triggering greater attention when needed.[87]

New technologies, the availability of more data, and the promise of AI suggest distinguishing weapons or treaty forbidden behaviors in space will be possible. A future space arms control agreement that focuses on placing quantitative, qualitative, or behavioral limits on threatening capabilities using only nonintrusive verification methods should not

be ruled out, even when trust is low among treaty parties.

If sufficient trust exists in the future to enable intrusive verification methods, such as in the combination approach, effectively verifying compliance with qualitative and quantitative numerical treaty limits—as well as behavioral constraints—would be even more plausible. Agreement on intrusive verification methods also would broaden the types of treaty terms that can be verified, and perhaps lessen reliance purely on technology for verification. For example, at the most optimistic end of the trust spectrum, significant trust could enable verification provisions that include on-site inspections of satellite manufacturing and space launch facilities, on-location monitoring, data sharing, prohibitions on some encrypted telemetry, and other forms of compliance assessment. Perhaps a future space arms control treaty could allow for on-orbit proximity operations to verify compliance by inspecting satellites—another potential contribution from the commercial space sector—with agreed upon notifications and procedures incorporated into the treaty's verification provisions.

Conclusion

There are many challenges facing arms control in space, not the least of them being the rising tensions between the key parties needed to negotiate an impactful agreement. A lack of political will or a failure to meet any of the prerequisites for arms control could stall meaningful space arms control discussions for years to come. However, if there is an opening, this paper has shown that verification should not be considered an insurmountable barrier to space arms control. Verification is doable, and changing conditions in technology and the variety of stakeholders are making it more feasible in the future.

This study also found that there are gaps in the current literature regarding verification challenges associated with space arms control. This is less than ideal given the increasing risk of instability in space, growing threats to U.S. space capabilities, and the growing importance of space to everyday life. While acknowledging the significant contributions of several contemporary arms control scholars, hopefully the proffered verification framework will stimulate renewed interest in this complex topic.

We should be under no illusion that effective verification will be easy. But neither should it be assumed that it is an impossibility. Ultimately, the interrelationship among a treaty's terms, the availability of adequate verification technology, and the trust sufficient to enable intrusive verification, if required, is key to reaching an agreement that is effectively verifiable. Before and during negotiations, parallel efforts to improve technology, to raise the level of trust among parties, and to explore alternative treaty terms can provide opportunities for progress and arms control breakthroughs. By breaking the overall challenge into its enabling components, it is clear that the problem, while complex and difficult, can be addressed with more concrete and feasible steps than initially imagined. The policy condition requiring the United States to be able to effectively verify a space arms control agreement before such an agreement can be accepted does not have to be a showstopper.

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