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Two Simple Models of Nuclear Transparency*

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ABSTRACT

The purpose of this paper is to draw attention to the concept of transparency. The paper begins by discussing the often-misunderstood nature of transparency and offers an alternative explanation as conceptualized by the authors. In addition, various subcomponents of transparency are introduced and explained. Then two simple, but useful, models are introduced in an attempt to help clarify the way in which the authors view the concept. Both models are based on analogies that draw loosely from the field of optics. The first model employs clouds and refraction whereas the second invokes lines of sight and the transmitting properties of a window. Finally, predictions based on the two models are proposed.

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* The views expressed in this paper are those of the authors and should not necessarily be ascribed to the Argonne National Laboratory, the United States Department of Energy, Det Norske Veritas AS, Los Alamos National Laboratory, or California State University, Northridge.

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Model: A simplified or idealized description or conception of a particular system, situation, or process, often in mathematical terms, that is put forward as a basis for theoretical or empirical understanding, or for calculations, predictions, etc.

-- Oxford English Dictionary (2002)

Analogies, it is true, decide nothing, but they can make one feel more at home.

--Sigmund Freud (1965)

The purpose of models is not to fit the data but to sharpen the questions.

-- Samuel Karlin (1983)

Introduction

Transparency is increasing worldwide due to globalization, democratization, and the accelerating wide-spread availability of new communication technology (e.g. Acharya, 1999; Albright, 2000; Albright, Berkhout, & Walker, 1997; Florini, 1999; Florini, 2000; Gallagher, 1999; Park, n.d.; Rosenau, 2000). The societal openness that comes with transparency can help defuse tensions and suspicion, simply because opponents learn more about each other. In the absence of malevolent intentions, extensive (mutual) worst-case military considerations can potentially be avoided. Hence, there can be real security benefits if transparency is nurtured and exploited correctly.

This is also the case in the area of nuclear arms control and non-proliferation, particularly in a setting with ever more unilateral policy decisions and political preferences. Transparency as a society-to-society confidence-building measure has strong potential for furthering nuclear arms control and associated non-proliferation goals (Maerli & Johnston, 2002). As evidenced by some national declarations of stockpiles of fissile weapons-grade material, increasingly the nuclear weapons states view a certain level of transparency as beneficial and in their national interests.

The concept of transparency, however, is poorly understood (Mitchell, 2000). In the nuclear weapons and materials context, the term "transparency" has come to mean almost any kind of data gathering and release—including invasive, adversarial on-site inspections and "national technical means" (satellite spying).[1] Indeed, it is common to talk about "verifying transparency regimes" (e.g. Benton, Glaser, Thomas, Bystrov, Skorynine, Yemelyanov, & Sinaevsky, 1999; Bieniawski & Busurin, 1999; Fetter, 1999; Finel & Lord, 2000; Mastal, Benton, & Glaser, 1999), an inherently contradictory terminology.

Transparency, at least as we view it, is not merely the acquisition of interesting data. The term "transparency" should be reserved for the deliberate, unilateral process of openness where information is allowed to flow unimpeded. The point and the measure of transparency is full and open truthfulness while being mindful that complete transparency is an abstraction that will never be fully achieved in any society. Each nation, after all, has secrets that legitimately should not be released to the world. It is, in other words, a well-calculated and balanced act, based on an appraisal of its pros and cons. Mixing international verification and intelligence gathering activities with such unilateral openness is inopportune – beyond pure semantics. Confusing transparency with other highly dissimilar concepts like verification only makes it more difficult to discuss, understand, recognize, appreciate, implement, nurture, and optimize.

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[1] There are numerous examples. Transparency regimes with verification is the general theme of the book edited Bernard I. Finel and Kristin M. (eds.) *Power and Conflict in the Age of Transparency*. (Palgrave, New York, 2000). Bieniawski and Busurin even have inspectors called "transparency monitors": Andrew Bieniawski and Yurin. Busurin, "Transparency Measures Associated with the U.S./Russian Intergovernmental HEU-to-LEU Agreement", Proceedings of the 40th Annual Meeting of the Institute of Nuclear Materials Management, Phoenix, Arizona, July 26-29, 1999, p. 3. See also Edward F. Mastal, Janie B. Benton, and Joseph W. Glaser, "Implementation of U.S. Transparency Monitoring Under the U.S./Russian HEU Purchase Agreement," Proceedings of the 40th Annual Meeting of the Institute of Nuclear Materials Management, Phoenix, Arizona, July 26-29, 1999, pp. 1-3, 6, 10; Janie Benton, Joseph Glaser, David Thomas, Alexander Bystrov, Guennadi Skorynine, Valery Yemelyanov, and Vladimir Sinaevsky, "U.S. Transparency Monitoring Under the U.S./Russian Intergovernmental HEU-LEU Agreement," Proceedings of the 40th Annual Meeting of the Institute of Nuclear Materials Management, Phoenix, Arizona , July 26-29, 1999, pp. 1-5; Steve Fetter, "A Comprehensive Transparency Regime for Warheads and Fissile Materials," *Arms Control Today*, (Jan/Feb 1999). Even one of the authors of this paper sheepishly admits to suggesting measures to "verify" transparency declarations: Morten Bremer Maerli, "Deep Seas and Deep-Seated Secrets: Naval Nuclear Fuel Stockpiles and The Need for Transparency", *Disarmament Diplomacy* 49, (2000). See also Nancy W. Gallagher, *The Politics of Verification*, (Baltimore: John Hopkins University Press, 1999), especially pp. 10 and 46.

This paper first considers the general nature of transparency as the foundation of our arguments. We then introduce two different models meant to help understand this topic in more depth. After presenting our models, we examine and discuss what they could predict. The models and their predictions should allow us to clarify the concept of transparency and the processes whereby it is used by nation states, with potential impacts and limitations. Whereas the models have the nuclear realm as a point of departure, with both Iran and North Korea as possible pertinent situations for analysis, the models may have wide applicability for inter-state interactions and dialogue within several fields and topics. The politics and problems of international environmental protection is one example.

The Nature of Transparency

Transparency has been defined as "openness" (Stiglitz, 1999) and "permitted knowledge" (CSIS, 1999). It has also been said to mean being "free from pretence or deceit", "readily understood", and "clear, frank, and obvious" (Drew, 2001; Winkler, n.d.). Others have characterized transparency as a cooperative process that (1) increases openness and builds confidence, (2) promotes mutual trust and working relationships among countries, national and international agencies, and the public, and (3) facilitates verification and monitoring measures by information exchanges (CSIS, 1999).

All of these definitions have merit, and should be further explored. In particular, we would argue that it is useful to define transparency as the process of allowing the unilateral, isotropic, unmanaged, unconditional, free-flow of information, ideas, opinions, and knowledge, and that this is an especially helpful concept for the advancement of nuclear control and the goal of non-proliferation. Operationalized in this manner, transparency not only turns into a necessary precursor for (stringent) verification and control (Lindsey, 1995), but also becomes the converse of secrecy. Secrecy means tightly controlling, managing, channeling, censoring, segregating, and tampering with information and data, or even deliberately generating misinformation or false data. Secrecy involves purposely hiding intentions, capabilities, and actions while transparency means allowing these same items to be revealed. Transparency and secrecy, however, are not either/or conditions; they represent two ends of a continuum (Florini, 2000). Thus, transparency can be used in conjunction with, and support, verification. But they are separate activities with distinct characteristics.

Whereas verification ideally will be carried out in a cooperative spirit, it is an inherently adversarial process and is best understood as an external

auditing activity. Generally, formal verification involves a set of carefully negotiated items to be monitored in accordance with rigidly fixed procedures and protocols. It is usually in the interests of the inspected state to limit the types and quantity of information obtained during such audits or inspections — behavior that is quite the opposite of transparency. The information permitted the inspectors during such activities is, moreover, constrained and they are not free to widely disseminate it, nor make use of it in any manner they wish[2] . This data control and censorship of information is likely to prevent or limit external or independent analysis.

In contrast, transparency surpasses those inspection activities mandated by treaty. Voluntarily permitting (or declining to restrict) the release of comprehensive information is working towards the truer meaning of transparency. It is the process of taking the extra steps of openness beyond expectations, treaties, or negotiated promises that is the true test of a nation state's willingness to be transparent. These extra steps could promote higher levels of trust by the global community and allow for independent assessment of compliance to treaties, agreements, and/or conditions placed on a nation-state. Based on such voluntary measures, transparency permits outsiders to accumulate data from a wide range of sources, over an extensive period of time, to build confidence that the behavior of a country or a collection of countries is consistent with international agreements, norms, declarations, and expectations.

Nuclear transparency is inherently unilateral in nature. The nation-state that controls the information decides when or if to open the data spigot, fully or partially, to let the information flow. It owns and controls the data spigot and does not need international assistance to operate it. This does not, however, mean that transparency is non-negotiable or cannot be influenced from within or outside the nation state. States, or the international community, can request or demand more openness in return for other considerations. They can always cajole, threaten, or even horse-trade for increased transparency. But no matter the incentive or disincentive offered, the nation-state in question is in charge of the information as well as any decisions regarding its potential release.

Likewise, the transparency of any nation-state will be more than just the transparency directly involving the government. The government will have

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[2] The inspected nation often continues to try to impose limitations on the information gained by inspectors or on how it is interpreted, even after it is in the inspectors' hands. This is again not at all consistent with transparency.

some degree of transparency, but the society, the general population, corporations, journalists/media, and non-government organizations (NGOs) will have their own contributions to make to transparency.

Components of Transparency

Nuclear transparency may be viewed as consisting of two major components, a self-motivated, internal component, $\mathbf{T_{self}}$, and an externally driven component, $\mathbf{T_{ext}}$. While there obviously will be overlaps and interactions between the two, T_{self} emanates from within the nation-state and is implemented primarily for domestic or internal societal reasons. External transparency (T_{ext}), in contrast, is a consequence of interactions with external agents of social or political control that result in two sub-varieties: induced transparency ($\mathbf{T_{ind}}$) and incidental transparency ($\mathbf{T_{inc}}$). An overview of the different components of transparency is given in Table 1.

Transparency		
T_{self}	T_{ext}	
	$\mathbf{T_{ind}}$	$\mathbf{T_{inc}}$

Table 1: Components of Transparency. The two major components are a self-driven component, T_{self}, and an externally driven component, T_{ext}. T_{ext} is composed of T_{ind} and T_{inc}, induced transparency and incidental transparency, respectively.

One example of T_{self} is the Freedom of Information Act (FOIA) in the United States, which grants any person (not just U.S. citizens) the right to request access to federal agency records or information. While there are limitations on the information than can be released, this process represents one way to make government more transparent. Importantly, no other nation or international entity pressured the U.S. into enacting FOIA so it is truly self-driven.

In the early 1990s, South Africa showed unprecedented levels of nuclear transparency. Inspectors of the International Atomic Energy Agency were granted permission to freely oversee the process related to the complete and total decommissioning of six nuclear devices and associated nuclear infrastructure. President de Klerk's denouncement of an indigenous nuclear weapon program in March 1993, took the world by surprise. The existence of

a clandestine South African nuclear program, operating under the constraints of an international embargo, was not publicly known. The announcement hence was self-motivated and based on domestic considerations.

Another example of T_{self} is the decision of the Russian government to reveal its closed or restricted cities (AP, 2001). Here the current Russian government is overriding information restrictions that date back to the time of the larger Soviet Union configuration. Russian authorities now have issued a list of cities, towns, and villages that are normally closed or restricted to outsiders for security reasons, thus allowing the world a view into the level of research and development activity engaged in by the Soviet government.

Another possibility would be for the nuclear-armed states to commit to declare the total quantities of fissile material they have for military purposes. The U.S. has already done this in the case of plutonium and the U.K. has declared its total stock of weapons-grade plutonium and its stockpile of HEU for use in weapons and naval reactors. It is unlikely that these declarations will be verified except with time as disarmament continues. Nevertheless, it is also unlikely that, with surplus materials and with independent estimates of their stockpiles published, countries would have a strong motivation to greatly misrepresent their stocks (International Panel on Fissile Materials, 2006).

External transparency (T_{ext}), in contrast, is a direct consequence (response) of interactions with the outside world. The 2008 Olympics is one example. While Chinese authorities are likely to expect a boost in international interest in and trade from the event, the exposure, moreover, inevitably will erode some of the current opacity characterizing this populous nation.

This external sub-component of transparency (T_{ext}) may be further subdivided into cooperatively induced transparency ($\mathbf{T_{ind}}$) and incidental transparency ($\mathbf{T_{inc}}$). The former of the two is, for instance, the type of transparency that is *voluntarily* negotiated through formal or informal international agreements and mutual cooperation that is not already intrinsically in place in the nation-state in question for domestic purposes. T_{ind} is the transparency directly and deliberately induced by other nations (not necessarily allies) or the international community as a result of encouragement, pressure, or bargaining but not based on cooperation *per se*.

Declarations on the Management of Plutonium (INFCIRC/549) are one example of T_{ind}. These IAEA guidelines, agreed to by the five NPT nuclear-weapon states plus Belgium, Germany, Japan and Switzerland, help increase transparency on the management and the holdings of civil plutonium. T_{inc}, on the other hand, is the transparency that arises as a result of external, incidental events where the international community is asked to participate in remedial activities post natural catastrophes or assists in clean-up and decontamination after a nuclear or radiological accident.

Typically, T_{ext} is of a more responsive or reactive character, while T_{self} is more proactive. T_{self} is also likely to be the most important and powerful. Self-motivated transparency – as a gradual product of norms and realism – will tend to be the broadest, the most deeply embedded, and the most holistic variant of transparency and it is thus likely to create the greatest and best sustained confidence building among external observers. This proposition is supported by what is known about the comparative impacts of intrinsic and extrinsic motivation on behavior (e.g. Hornik, Cherian, & Madansky, 1995; Utman, 1997). Also, it is preemptive given that a nation-state with a high degree of self transparency has little role or need for external transparencies (T_{ind}, or T_{inc}). Under this proposition, T_{self} is highly voluntary and more likely to be candid. As a result, there exists a stronger basis for other nations to make predictions about a state's intentions and capabilities.

Unlike the other transparencies, T_{self} tends to also be enduring and largely irreversible, short of the extreme threat of war, terrorism, or the overthrow of the government.[3] Once established, T_{self} tends to become deeply incorporated into the national psyche, institutions, politics, and infrastructure. T_{ind} and T_{inc}, on the other hand can change quickly with the international political climate because of the heavy involvement of external actors and agendas.

Key Model Concepts

Models are based on the idea that an analogy can be useful in trying to understand the real world. But the way a model accomplishes this task

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[3] In the U.S., for example, the overall transparency of the country generally decreases only during times of hot or cold war.

varies greatly depending on whom you ask, a fact demonstrated by the quotations at the beginning of this paper. To some, the true test of a model's merits is its ability to make predictions. Others, however, view a model as useful for taxonomy by helping to clarify semantics, identify issues, and assist in the organization or succinct summary of concepts. And while it is a gross generalization that certainly doesn't always hold true, the former view tends to dominate the physical sciences and the later tends to dominate in the social sciences.

Given that the authors of this paper come from a variety of academic traditions, in both the physical and social sciences, we see the merits of both viewpoints regarding the purpose of a model. Therefore, the two models presented here (although admittedly quite simple) are proposed in order to achieve three goals. First, they are intended to help organize and summarize the fundamental factors and complicated issues surrounding transparency and nuclear security. Second, they aim to allow for some interesting predictions, some of which we will discuss in this paper. Finally, it is hoped that they will help other researchers and theorists in the field to sharpen their questions and thinking for future research on the topic of transparency.

Both models use analogies based on *optical* transparency. The first model invokes clouds and refraction. The second is based on lines of sight and transmitting properties of window glass. The two models are termed the "cloud model" and the "window model", respectively. The main actors in both models are nation-states and observers. The observers attempt to understand the intentions, attitudes, behavior, and capabilities of the nation-state(s) they watch. The greater the level of transparency, the more successful and accurate the observers can be in their understanding and interpretation.

Observers can be other nation-states as well as associations of nation-states, such as the United Nations (UN) and the International Atomic Energy Agency (IAEA). Observers can also be specific government agencies, non-government organizations (NGOs), journalists/media, or individuals. These private individuals may be foreigners, or else citizens (including internal critics and dissidents) of the nation-state they are observing.

In both of our models, three-dimensional space has a somewhat non-intuitive interpretation. The location of a nation-state, or an observer in the models, does not refer to its real-world physical or geographic coordinates. Rather, location is analogous to where a given actor (i.e., nation-state or observer) belongs in an N-dimensional space of parameters, where N is very

large. These parameters specify the intrinsic character, nature, and traits of the actor. These parameters include the actor's goals, agenda, values, priorities, culture, language, attitudes, self-image, prejudices, political perspective, resources, capabilities, and other important socially defined attributes. If all these parameters could be accurately determined, the exact location of a nation-state or observer in this N-dimensional parameter space would be known. This would allow (at least in theory) for a full characterizing and understanding of all actors in the transparency process.

Some of these parameters can be determined through astute observation of social facts (such as language, political perspective and resources) while others can be validated through research. For example, Geert Hofstede has proposed (Hofstede, 1983), and research has supported (e.g. Khandelwal & Dhillon, 2004; Schimmack, Oishi, & Diener, 2005) that national cultures tend to vary on a number of dimensions. Hofstede's model originally included the dimensions of power difference, individualism/collectivism, masculinity/femininity, and uncertainty avoidance and subsequently an additional dimension called long-term/short-term orientation (Hofstede & Bond, 1984) was added. All of these dimensions may be important components in understanding where nations are oriented in the N-dimensional space, but the dimensions of power difference (the degree to which members, especially less powerful members, of the culture accept that power is distributed unevenly), individualism/collectivism (the degree to which ties between members of the group are strong or weak) and uncertainty avoidance (the level of comfort that a society has with ambiguity or uncertainty) may be particularly helpful in the context of transparency.

Throughout our analysis, the German term *eigenzüge* (literally, "self character traits") is used to refer to this set of parameters or coordinates that defines an actor and its location in N-dimensional parameter space. Thus, when two actors (nation-states or observers) are spatially adjacent in our models, this means that they are close together in N-dimensional space, i.e., they have similar *eigenzüge.* It may then be concluded that they are very similar in outlook, world-view, and intrinsic nature. Consider, for example, Australia and the United States. While geographically far apart, those two countries would be close together in our models. They have a similar history and culture, and tend to hold very similar views on nuclear, military, and security matters. Consider, for example, that Australia was among the

forerunners in congratulating and welcoming a US-India agreement of March 2006 to share nuclear technology.[4]

Further evidence of their similarities is the fact that their patterns of scoring on Hofstede's dimensions are remarkably similar. In other words, the USA and Australia share very similar *eigenzüge.* In contrast, North and South Korea — though geographically close in distance and historical culture — have very different political systems, attitudes, recent histories, and world-views.[5] Therefore, they would be relatively far apart in the N-space of the models, even though they are adjacent on the map.

Note also that the example of North and South Korea helps us understand that an actor's *eigenzüge* is not fixed for all time, i.e., a given actor is not permanently anchored to a point in N-dimensional space. The *eigenzüge* invariably change and evolve over time due to internal and external factors. For example, the "Sunshine-policy" on the Korean Peninsula, aimed at normalizing relations between North and South Korea, has seen varying levels of US support from different Presidential Administrations.

The Cloud Model of Transparency

The mental image that nation-state A has of nation-state B is likely to play an important role in any cooperation as well as determining the outcome of negotiated treaties or informal arms control measures. Nation-state A, however, can never have a complete and perfect understanding of nation-state B; it can never fully know B's *eigenzüge.* There will always be misconceptions, distortions, deliberate misinformation, prejudices, cultural differences, communication problems, historical baggage, etc. Thus, in practice, A's perception of B, which we call B', is imperfect and always somewhat off the mark with regards to the real intentions, actions, views, and capabilities of B. The goal of transparency in such a bilateral environment is to make B' as close as possible to B.

The following model for transparency is based on a simple analogy taken (loosely) from the world of physics: How light rays are distorted while traveling through an inhomogeneous, semi-turbid medium such as a cloud. The basic model, shown in Figure 1, involves two actors, nation-state A and

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[4] At the same time Australia ruled out lifting a ban on uranium exports to India while New Delhi refuses to sign the Nuclear Non-Proliferation Treaty

[5] Unfortunately comparison on Hofstede's dimensions was impossible because scores were unavailable for both nations.

nation-state B, separated by a cloud that partially obscures the view A has of B. In the model, the cloud can be thought of as an inhomogeneous and semi-turbid optical medium that hinders and refracts (deviates) rays of light passing through it from B to A. It plays the role of an absence of full transparency on the part of nation-state B.

If the relationship between the two states reflected perfect transparency, the cloud would disappear, and A would be able to see B clearly and accurately. Nation-state A would then perfectly understand B's true nature, intentions, actions, capabilities[6], and positions on a wide range of issues. In other words, A would know exactly where B was located in our (*eigenzüge*) N-dimensional space of parameters.[7]

Unfortunately, however, clouds are always present. As A peers through it in order to try to accurately locate B, A gets an incorrect idea of exactly where B sits due to the optical interference, diffraction, and scattering caused by the cloud.[8] The location where A *thinks* B is located is designated as B'.[9] B' represents an *eigenzüge* that differs from the true *eigenzüge* of B — as represented in the model by B' having a different location than B.

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[6] Nuclear capability, for example, involves the size and nature of the nuclear arsenal (including logistics, command and control, and force survivability) and of the fissile material production facilities.

[7] Figure 1 thus represents a complicated N-dimensional space of many parameters that define who the nation-state is and how it sees the world around it. A nation state and its political "position" on various issues can be characterized by where it sits in this N-dimensional space.

[8] To simplify the model, we consider only one ray coming from B and its deviation to the observer. This is not very optimal in a physical sense. In real optics, there are a large number of rays emanating from B, each of which will be diffracted and scattered differently. In the real world, observer A may actually receive two or more rays, creating a widely diffuse apparent location for B. Considering multiple rays, or even drawing them in the Figures, would create a great deal of unhelpful complexity, so we avoid doing this in the model.

[9] In optics, B' is called a "virtual image".

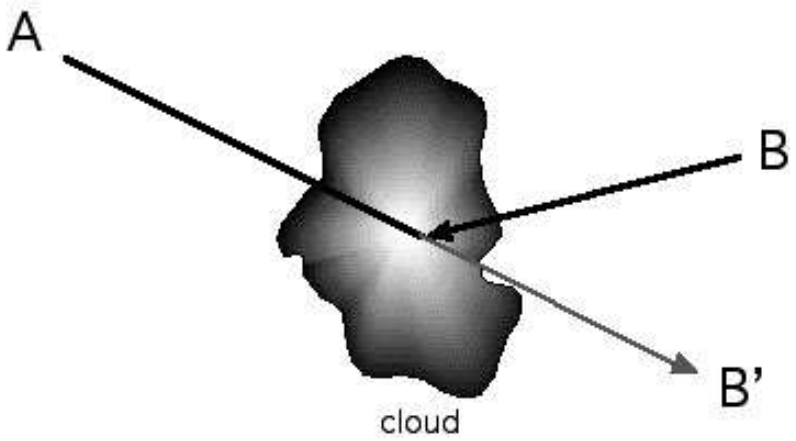

Figure 1: A ray of light leaving B and traveling right to left gets refracted (scattered) by the cloud and reaches the observer, A, in a manner that makes A think erroneously that the ray of light originated at point B'. If the cloud weren't present, A would have an accurate view of B's position by being able to sight along a more direct, undeviated ray.

In this model, when we want to consider the reverse situation of how B sees A, we need to invoke a separate cloud (the model is thus asymmetric). Thus, nation state B is largely responsible for the turbidity and inhomogeneity of the cloud through which it is observed by nation state A. Thus, while the density of the cloud in Figure 1 has contributions from $T_{self'}$ $T_{ind'}$ and $T_{inc'}$ it is T_{self} that is the most important component, as discussed above.

Although B is largely in control of the cloud in Figure 1, the cloud is not likely to remain invariant over time, even if the nation-state B seeks no changes. There are external factors (T_{ind} and T_{inc}) at work in the real world that will have an impact, such as globalization, democratization, and communications technology.

In Figure 2, we have introduced a second observer, C. This entity C has a somewhat different idea of where B is located than A does because C is looking at B from a different angle and position. While C observes B through the same cloud, the fact that C occupies a different position affects its perception of where B is located. In Figure 2, nation-state A thinks that B is located at point B', while C thinks it is located at point B". Thus, the position of the observer in this model affects the apparent position of the nation-state being observed. Each observer sees the world (and other nation-states) from its own unique perspective.

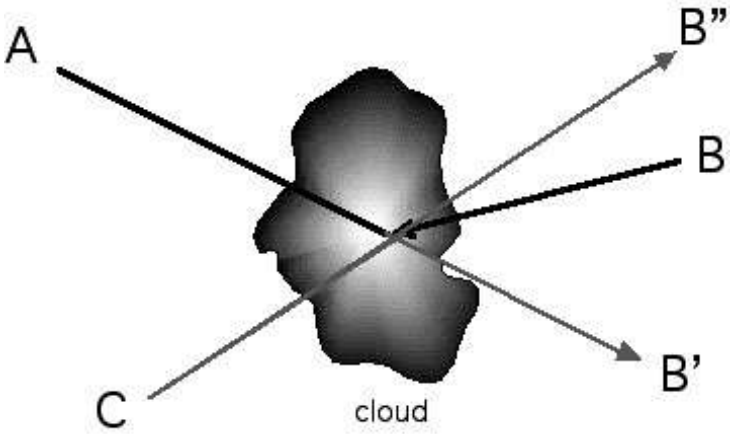

Figure 2: The ray leaving point B is partially scattered in passing through the cloud—some of it reaching point A and some information reaching point C. Even though observers A and C are looking through the same cloud, they disagree about the apparent position of point B because each has a different perspective, i.e., a different position and observation angle with respect to the cloud, causing them to sight down a different ray.

Now nation state A's vision of B may change as the observer's point of view changes, i.e., as A moves (in our N-dimensional parameter space). This is demonstrated in Figure 3. When A is at point A1, it thinks B is located at B1. When A moves to point A2, however, it thinks nation-state B is at B2. What this means is that if a nation-state changes or drifts in its political stance and world perspective, i.e., its *eigenzüge* changes, we expect it to see B differently over time.[10] Since societies often view themselves as somewhat the centre of the world, or at least that their perspective is the definition of "normal", there will be a tendency for nation-state A to think B has drifted, rather than itself.

[10] Note that the apparent position of B is not unique. Depending on the internal structure of the cloud, there may be a number of different locations that give essentially the same view of B, though most of the time; different positions for the observer yield different locations for B'.

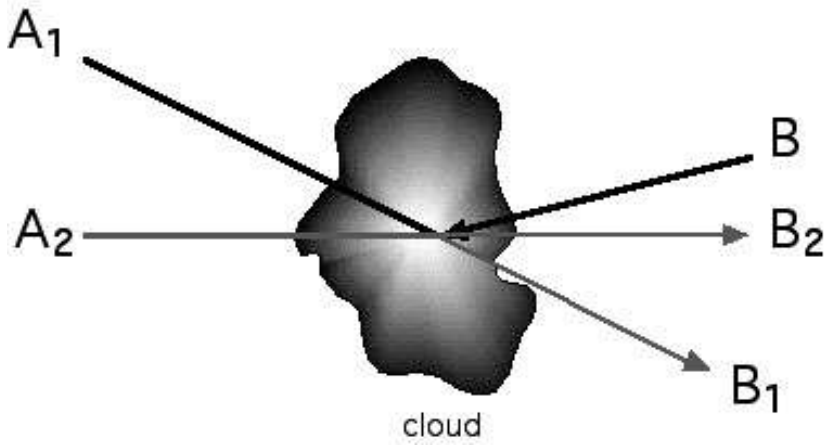

Figure 3: The position (perspective) of the observer affects where B is perceived to be positioned in variable space. When viewed from point A_1, B appears to be located at point B_1. But when viewed from point A_2, B appears to be at B_2.

Note that as the position of B slowly changes, it may be challenging for A to detect the movement if there is a thick and sizable cloud. Thus, for example, any slowly developing reforms (such as democratic or economic changes) inside a totalitarian state may be hard to identify, given a lack of transparency that exists in the first place. For example, the dismantling of the Berlin Wall was not widely expected.

Now the misperception error between the true position of nation-state B (position B in Figure 4) and where A thinks B is located (B') can be characterized by a distance, d.[11] This parameter determines how far off A is in its true understanding of B. The characteristics of the cloud, i.e., density, thickness, distortion and turbidity, determine d. With increased transparency there is a less dense cloud, so less refraction and turbidity, and thus a smaller d.

[11] The error function (distance) d is a scalar that is a function of the large number of variables comprising the N-dimensional space being represented in the Figures by spatial location.

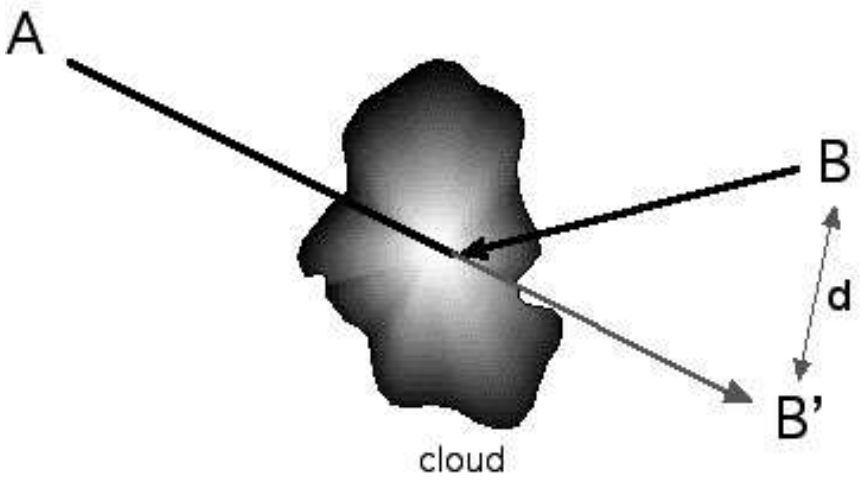

Figure 4: The distance between the true position of B and where observer A thinks B is positioned (B') tends to increase the thicker and/or denser the cloud. In the absence of the cloud, observer A would be able to correctly locate the position of B (and thus correctly understand B).

As the distance between nations, d_n, increases, it is likely that the magnitude of d will increase as well. This is due to two major causes. First, as an object moves farther from your vantage point, observing it with great detail or clarity becomes increasingly difficult. In addition, Figure 5 shows that when two nations are oriented more closely in N-dimensional space the ability of the cloud to alter A's ability to see B through refraction is hampered and thus d is decreased.

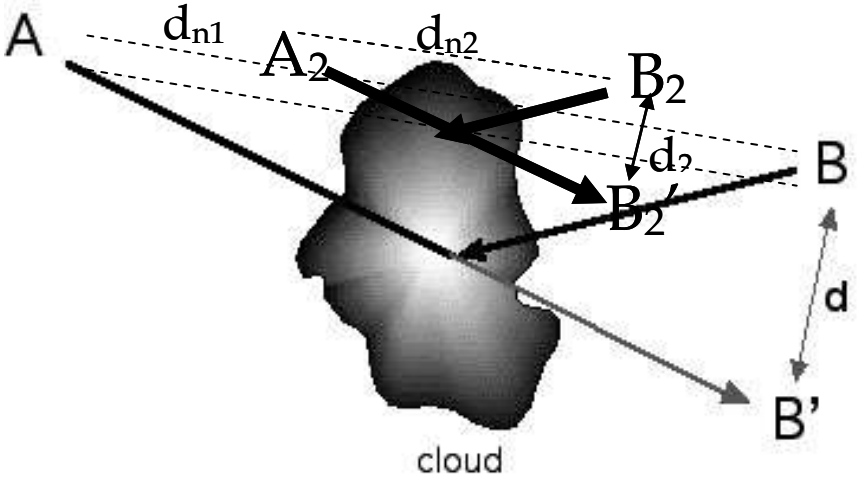

Figure 5: As A moves from position A to position A_2, bringing it closer in alignment with B, the error in its perception of the location of B decreases. i.e., d_2 is less than d.

Figure 6 demonstrates that, because of the blurring effects of the cloud, A will typically have an estimated uncertainty, or degree of confidence, in its judgment of where B is positioned. This is demonstrated by the circle drawn around B'. Most nation-states are likely to overestimate their ability to accurately understand B, and thus will underestimate the true size of the confidence region. Thus, the circle drawn around B' in Figure 6 has a radius smaller than d. If A has a good handle on the cloud thickness, turbidity, and distortion, however, it may decide on a more realistic (larger) confidence region.

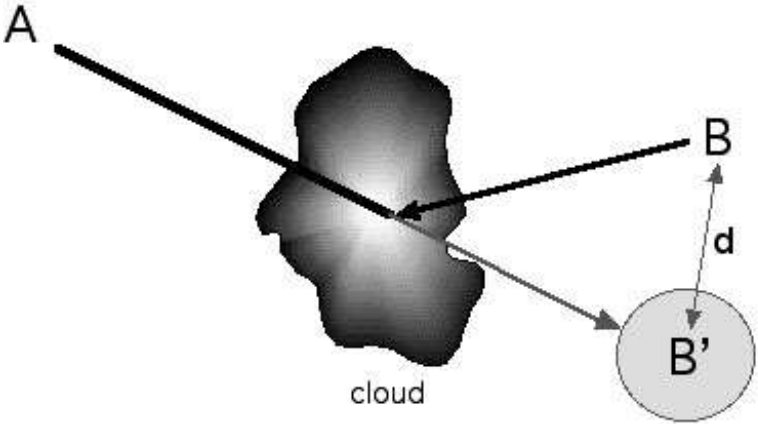

Figure 6: B', the apparent position of B, as seen by observer A with a confidence region or estimated uncertainty drawn around it.

To extend our cloud model, we add a light-bending prism as shown in Figure 7. The observer nation-state A will have its view of B slightly distorted by this (local) prism. The prism is analogous to the unconscious cultural and political biases/prejudices held by the observer nation-state that affects its view of B. The prism, moreover, may be viewed as a manifestation of deliberate efforts to maintain a specific course of action in order to harvest the broadest possible spectrum of political gains (and maintain power). For example, the Iraq war, initially justified from the presence, possible use and proliferation of weapons of mass destruction, is an obvious case in point. If risks are experienced as real, they are real as a consequence (Beck, 1992).

Beck would refer to this phenomenon as a "fabricated insecurity", upon which a state may legitimize its powers and actions (Beck, 2003). In this process, it is essential to develop stereotypical images of the enemy that can be used to integrate and further enhance culturally founded prejudices. Deliberately used to boost state military and power structures, they can become self-fulfilling prophecies. As such, they are meta-weapons that states may use to legitimize their actions in a circular manner (Beck, 2003). Effectively, through this rhetoric and heavy politicization of security issues, the control institutions and instruments of civilian society and the powerful states become mobilized and strengthened, thereby giving governments new and unprecedented room for maneuver. Though widely applied, analysis of the politics of insecurity and the reasons that groups profit from 'manufactured uncertainty' is demanding. It requires *inter alia,* a more detailed understanding of the strategies impacting the construction of collective insecurity across policy areas. One pertinent object of analysis in this regard is the problem complex associated with the threat of nuclear terrorism, where the Bush administration has been accused of "hyping" the issue (e.g. Arkin, 2006). After all, what could possibly be more mobilizing than mad actors standing ready for instance to wipe out the heart of New York City with crude nuclear weapons?

The prism, which in any case is completely "owned" by A, slightly deviates the ray of light emerging from the cloud, thus contributing to A's error in trying to locate B's position. Note that if perfect transparency were in place (no cloud), A would still be hampered in its attempts to accurately locate B due to the effects of the perception prism. If, of course, A were aware of the prism, it could be removed, or else A could factor the effects of the prism into the estimate of the location of B and its uncertainty. Sometimes, nation-state A may be aware of, or at least suspect, the existence of a prism interfering with its views. It may, nevertheless, want to maintain it for

political expediency, or because admitting it is a reality may be politically, economically, or otherwise painful.

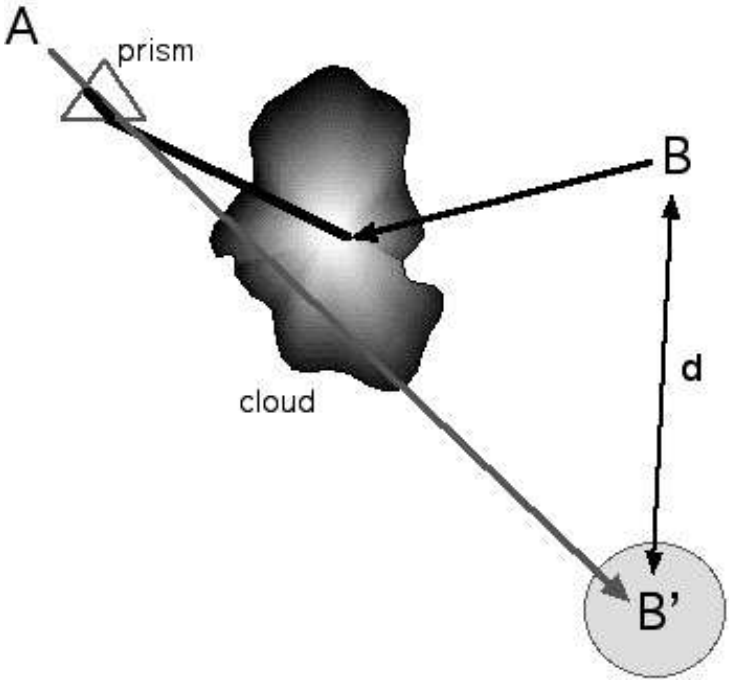

Figure 7: If observer A sees things through a light-deviating prism, this further complicates its efforts to accurately locate B. In the absence of the cloud, the prism still causes errors.

Finally, in Figure 8, we introduce a solely domestic aspect of the model, related to T_{self}. When the citizens (general population) of nation-state B view their own government, they do so from a particular perspective that is not necessarily the same as that of their government, B_{gov}. We designate the perspective (position) of the general population in the Figure as B_{pop} for "population". It is typically close to B_{gov} in our N-dimensional space, though not super-imposed exactly upon B_{gov} because the population generally has a different perspective and set of attributes (*eigenzüge*) than the official government of any nation-state. In this model, looking into the cloud from the right results in seeing a back-scattered ("reflected") image, though one still deviated by the inhomogeneities in the cloud. Thus, the citizenry of

nation-state B, when they act as observers, believe their own government is located at position B'_{gov} in the Figure, rather than the true location, B_{gov}. In general, the more dense the cloud, the greater the distance between B_{gov} and B'_{gov}.[12]

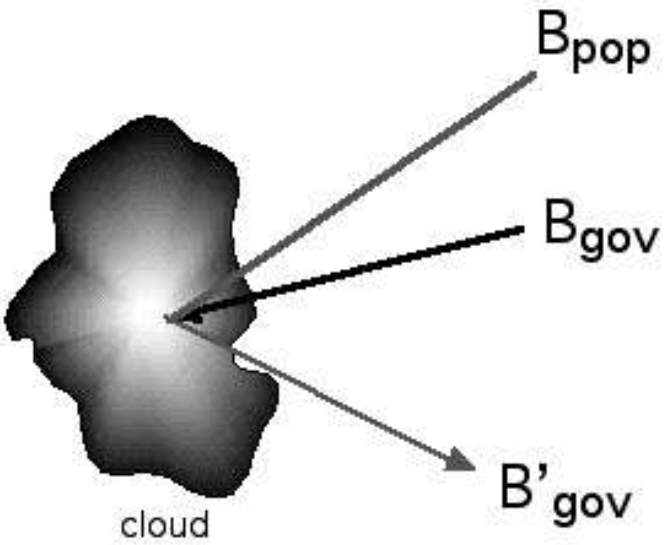

Figure 8: The population of a nation-state, Bpop, has its own estimate of where its government is located. The distance between the true position of Bgov and where these internal observers, Bpop, thinks B is positioned (B'gov) tends to increase the denser the cloud.

The Window Model of Transprency

An alternative model for transparency is based on a simple analogy used previously (Maerli & Johnston, 2002). Imagine being in charge of nation-state A and that your nation-state will be represented in the model by a house located in a neighborhood; the activities (including military, economic, political, and nuclear functions) that take place in your nation-state are represented by the activities taking place inside this home.

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[12] Note there is a bit of a problem with the physics of the model at this point. With 100% transparency, the cloud goes away and B_{pop} cannot see a back-scattered reflection of B_{gov}. We view this as a minor problem given that there never is 100% transparency.

For personal benefit, you might like your neighbors (other nation-states in the model) to know about some of the activities that take place inside your home. You might want to reassure your neighbors that these activities are wholesome, legal, ethical, responsible, safe, and the type of activities that belong in their neighborhood. You can do this by installing a window so that neighbors can look in. Apart from providing benefits to you (sunlight, views, fresh air, etc.), this form of openness allows others to look inside to get an idea of any ongoing activities and your possible intentions imbedded therein. Another possible benefit to you of such openness is that neighbors might see you fall inside your home and be able to offer assistance or summon help during an emergency. Installing the window in and of itself may also tend to make the neighbors less suspicious and hostile. Plus if you put in a window perhaps the surrounding homeowners will, too—allowing you to better understand their activities and intentions, a form of reciprocal relationship that eventually may evolve into a norm.

Note that it is your house and only you have the right to install the window. Your neighbors and the general public can cajole, bribe, or threaten you into installing that window. They can reciprocate unilaterally or negotiate mutual window installations. They can help pay for your window, or even come over to help you install the window. In the end, however, the window is on your private property and you are unilaterally in charge of deciding if it will be installed and how it will be designed and used.

You may be willing to put up with a certain loss of privacy in installing the window, but there are limits to how much windowpane transparency you will permit. Not every room or all activities inside the house are appropriate for public viewing. Intelligence-gathering activities by the neighbors, such as installing a covert listening device inside your house, or external video surveillance of your property are not acceptable, nor part of your transparency measures. That is why, for example, "national technical means" (satellite spying) should not be regarded as transparency.

Note that you as a homeowner can also choose to install your *own* video cameras (or cameras you control and can turn on or off at will) inside your house to transmit images unedited and freely (e.g., over the Internet) in order to increase the neighborhood's confidence that no improper activities are taking place inside the house. This is certainly an act that would contribute to transparency. If outsiders own, control, or operate the cameras, the video imaging should more properly be thought of as monitoring or inspection, rather than transparency. The video equipment in this case, and

the people who own, control and install it, are outsiders/intruders, and not a natural part of your home and the activities that take place therein.

It is important to recognize that your transparency does not need to be "verified". The windows are either in place and left unblocked, or they are not. Your neighbors may be concerned (especially early on) that some of your activities seen through the window are staged for purposes of misleading them. They may believe the *data* gathered from observing through the windows requires double-checking. If so, they can combine information from a wide range of different sources to gain a higher level of confidence. These additional sources can include, for example, information provided by other neighbors, data from government records, accounts contained in newspaper stories or police records, your credit ratings, etc. In an information triangulation, available data may then be used collectively to come to a general determination about your past activities and future directions.

Figure 9 shows a sketch of two external observers each watching activities (e.g., a cocktail party) taking place inside the house by looking through the picture window. Each observer could, for example, be the IAEA, a nation-state, a specific government agency, an NGO, the new media, or private citizens.

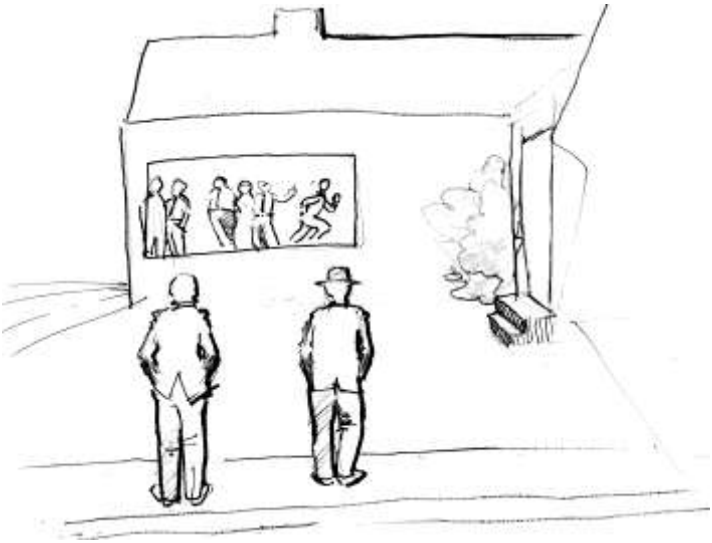

Figure 9: In this model two observers, standing on the sidewalk, watch through the window to try understanding the activities taking place inside the house (which represents the nation-state under observation). Each observer sees the activities inside the house from his own perspective, depending on his position relative to the house. In this cartoon, a cocktail party seems to be underway.

Note that the window in this model meets our understanding of transparency. The homeowner is allowing, unilaterally, the free-flow of information out of the house through the window in a relatively uncontrolled, unmanaged, unrestricted, unstaged, and (roughly) isotropic manner. Any observer strolling down the sidewalk or driving past on the street can glimpse at least some of the activities taking place inside the house. They are free to draw their own conclusions from what they observe, and they are free to share their observations and conclusions with others.

All of the potential observers in our model share a common interest in that they want to observe the activities taking place inside the house so they can better understand those activities, as well as the intentions and capabilities, of the nation-state that owns the house. Another attribute that these observers have in common is that they normally do most of their observations from outside the house, although some or all might be permitted inside on a limited, restricted, pre-arranged basis from time-to-time for "on-site visits". Only in the (hypothetical) case of *total* transparency, however, would they be allowed to wander in and out of the house at any time, for any reason, without advance notice, and with no restrictions, in order to observe the activities taking place.

In this window model, as was the case with the previous cloud model, the location of each observer (such as the front lawn of the house, the sidewalk, the street, or another yard across the street) represents their coordinates in N-dimensional space, i.e., their *eigenzüge* — who they are and how they see things. The closer an observer is to the house, the more closely his attributes, perspective, values, and world-view match that of the nation-state (the house) being watched. The position of each observer, with respect to the house being observed, also affects how much the observer can see through the window. Thus understanding the magnitude of distance on N-dimensional characteristics such as Hofstede's culture dimensions is important if only for understanding one's perspective, which will prove to be important shortly.

Note that this window model, like the cloud model, is asymmetric. When nation-state B observes the activities of nation-state A, it does so as an observer located somewhere outside the house owned by A, such as one of the two men in Figure 9. In the reverse situation where nation-state A observes the activities of the house owned by nation-state B, however, it does so not (typically) from its own house, but by standing on the front lawn, sidewalk, street, or at a more distant location (See Figure 10). The reason is that the *eigenzüge* of the nation-state (or its nuclear programs) being

observed may not be the same *eigenzüge* as that held by the observers employed by that nation-state for observing other nation-states.

To give a more concrete example, the U.S. Department of Energy (DOE) is primarily responsible for conducting U.S. nuclear activities. But other agencies, such as the Department of State, Department of Defense (DoD), Defense Threat Reduction Agency (DTRA), and U.S. intelligence agencies, take major roles in assessing the treaty compliance, arms policies, and military capabilities of other nations. The agendas, culture, perspectives, priorities, prejudices, and attitudes of DOE undoubtedly differ significantly from those of the other federal agencies, and it should not be expected that these various agencies will have the same *eigenzüge* or occupy exactly the same positions in our model. Even within DOE, the personnel who are involved in domestic nuclear safeguards and stockpile stewardship activities are not automatically the same personnel who are engaged in trying to understand the nuclear policies, behavior, and capabilities of other nations. They may thus have very different perspectives and priorities, and will be located at different locations in N-dimensional parameter space.

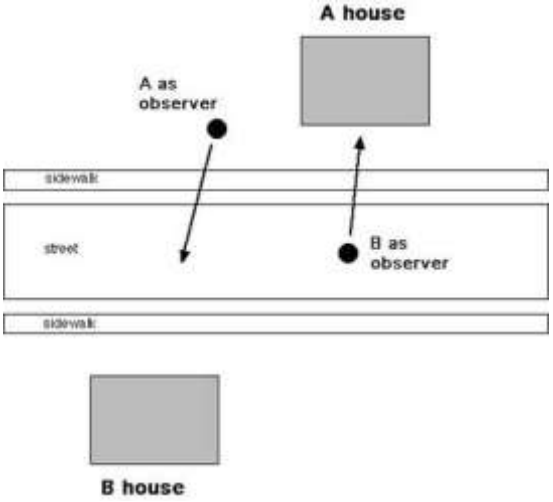

Figure 10: View from above. Nation-state A will generally occupy a different position when it is the observer vs. when it is observed. This is because the people or agencies conducting (for example) domestic nuclear activities are not automatically the same people or agencies that conduct intelligence analysis of other nation-states. In this Figure, nation-state A observes B (represented by the B house) while nation-state B observes A (represented by the A house). In this case, B as observer is closer to house A in terms of its *eigenzüge* than A as observer is to house B. What this means is that the personnel or agencies from nation-state B who are engaged in observing and analyzing (for example) the nuclear program of nation-state A have perspectives and world views closer to that of those they observe than is the case for the A observers.

Figures 11-14 demonstrate that obstacles can get in the way of an accurate view of what is going on inside the house. In Figure 11, a shrub partially obscures the observers' view of activities inside the house. The shrub is presumably deliberate since it was probably planted by the homeowner, or could at least be pruned to minimize its screening if the homeowner desired. Note that the degree to which the shrub obscures the view depends on the viewer's angle and closeness to the window, i.e., it depends on his geopolitical position relative to the nation-state that owns the house. Not all observers will be equally hampered by the shrub; some positions permit better views than others.

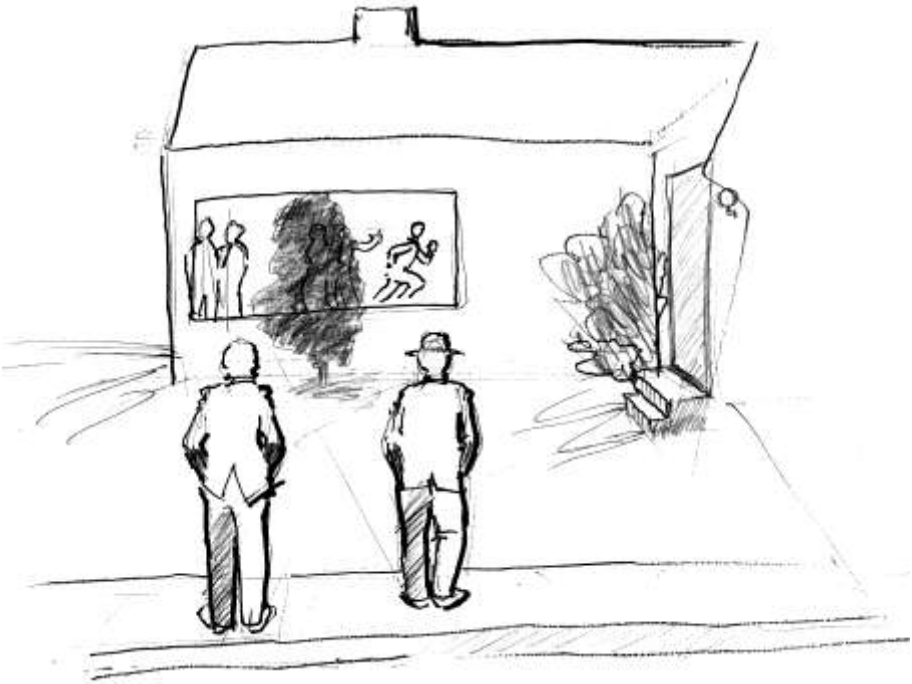

Figure 11: Deliberate obstacles can be put in the way of effective transparency, even when a window into the activities is ostensibly made available.

The analogies in the real world that interfere with transparency in the same way as the shrub in our model include such measures as national propaganda and disinformation, government control of the citizenry and journalists, military secrecy, xenophobia, persecution/prosecution of whistleblowers, harassment of dissidents, and suppression of popular movements and free speech. Like the shrub for the homeowner, these factors can all be fairly well controlled by a nation-state.

Figure 12 similarly shows that the homeowner can control the amount of information flow, even when the window is in place. In this case, Venetian blinds are used to partially reduce visibility.

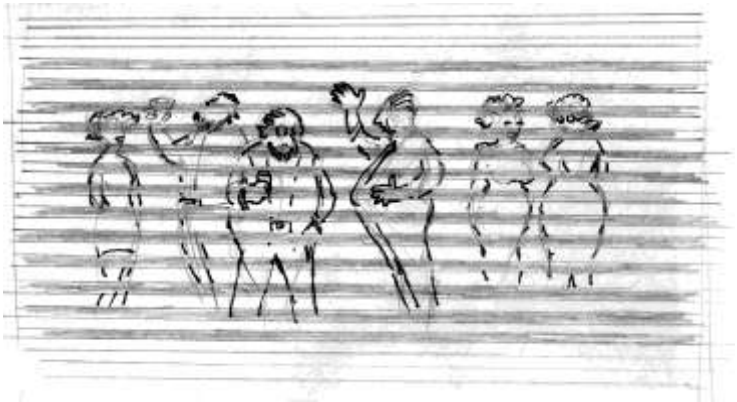

Figure 12: A nation-state can deliberately modify the amount of information made available, even when "windows" are in place. In this case, Venetian blinds are partially closed and they limit and reduce transparency, resulting in a less accurate understanding of events going on inside the house by outside observers.

Figure 13 shows that inadvertent interference with the information flow is also possible. In this Figure, a table lamp, located completely inside the house, blocks the view from certain angles. This may well be inadvertent on the part of the homeowner, as the lamp is usually intended to serve a very different and legitimate function. Indeed, it might have been placed there deliberately by the homeowner to improve the illumination so observers outside the house could better see the inside activities.

Figure 13: Transparency can be inadvertently impeded. In this case, a lamp partially blocks the view, though only for observers at certain angles.

Figure 14 shows that some barriers to effective transparency may be the observer's fault. In this Figure the observer has placed himself in front of a tree that substantially blocks his view. If he would only slightly modify his position, he would be able to observe better. Such obstacles can interfere with the efficacy of transparency, even when the nation-state being observed permits extensive transparency. It may, moreover, allow for a less exposed position on behalf of the observer, if so desired.

Figure 14: If the observer would slightly shift his position, he could see more clearly.

The position (perspective) of an observer affects what he can see. This is demonstrated in Figures 15-18. Figures 15 and 16 show that the closer the observer is able to get to the window (and thus the closer his eigenzuge to that of the nation-state he observes, the most comprehensive and accurate his view of the goings on inside the house. Figures 17 and 18 consider how movement of an observer affects what he can observe. When shifting position a given amount, the observer closest to the house will witness the greatest change in how much he can observe. Maintaining proximity is vital, not only for best possible dialogues but also for visibilities.

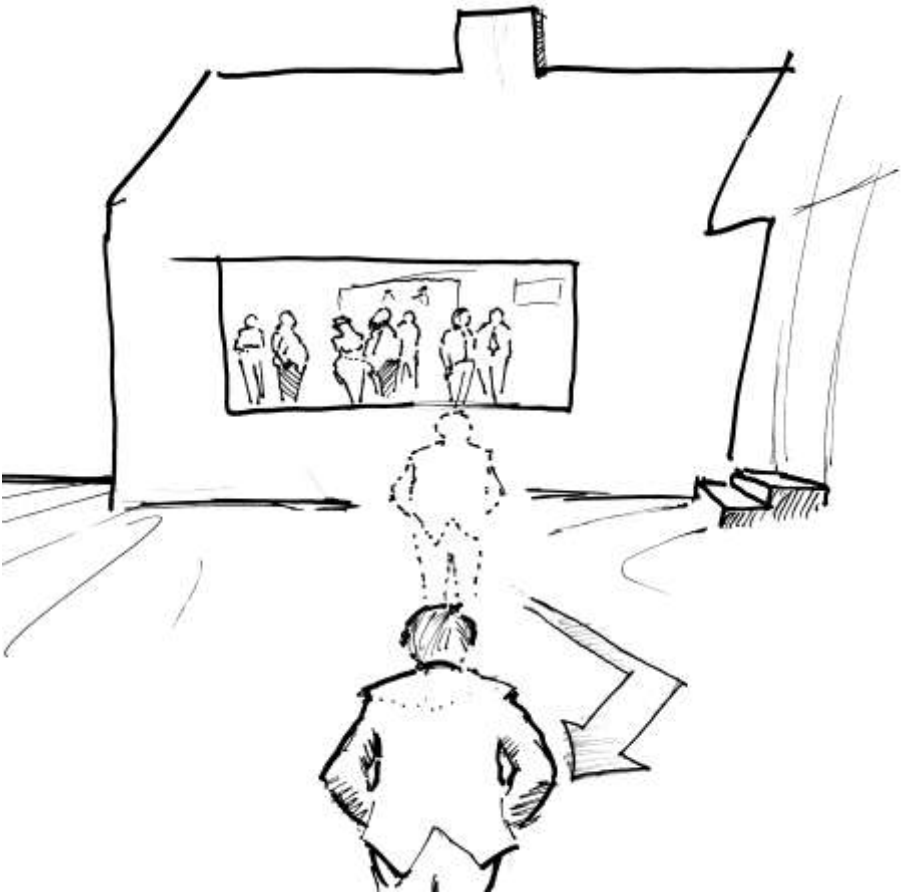

Figure 15: When an observer steps back, he can see less of what is going on inside the house. For purposes of what is going on, it is better to be closer to the house, i.e., to occupy a closer location in N-dimensional space, than to be far away from the nation-state being observed.

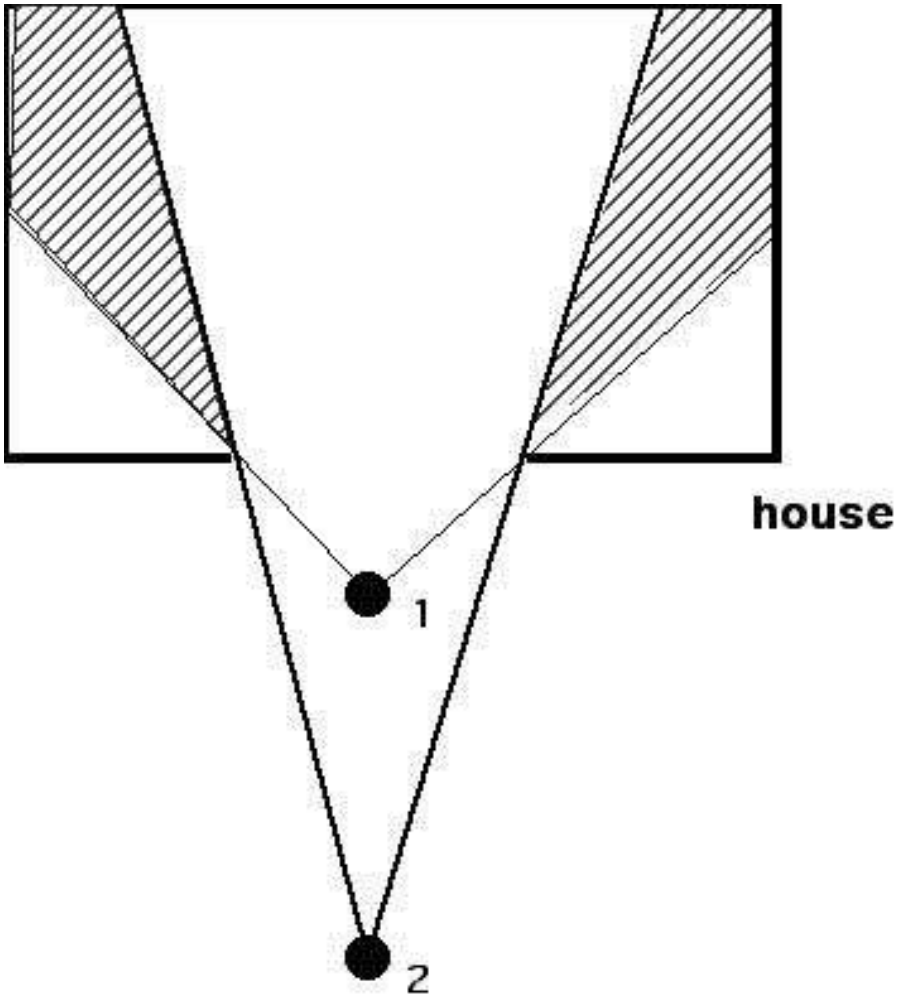

Figure 16: View from above. Because of geometry, position 1 (closest to the house) allows one to see more through the picture window than possible from position 2, which is farther away. The area inside the house that the observer can see from position 1 but not from position 2 is highlighted by diagonal lines.

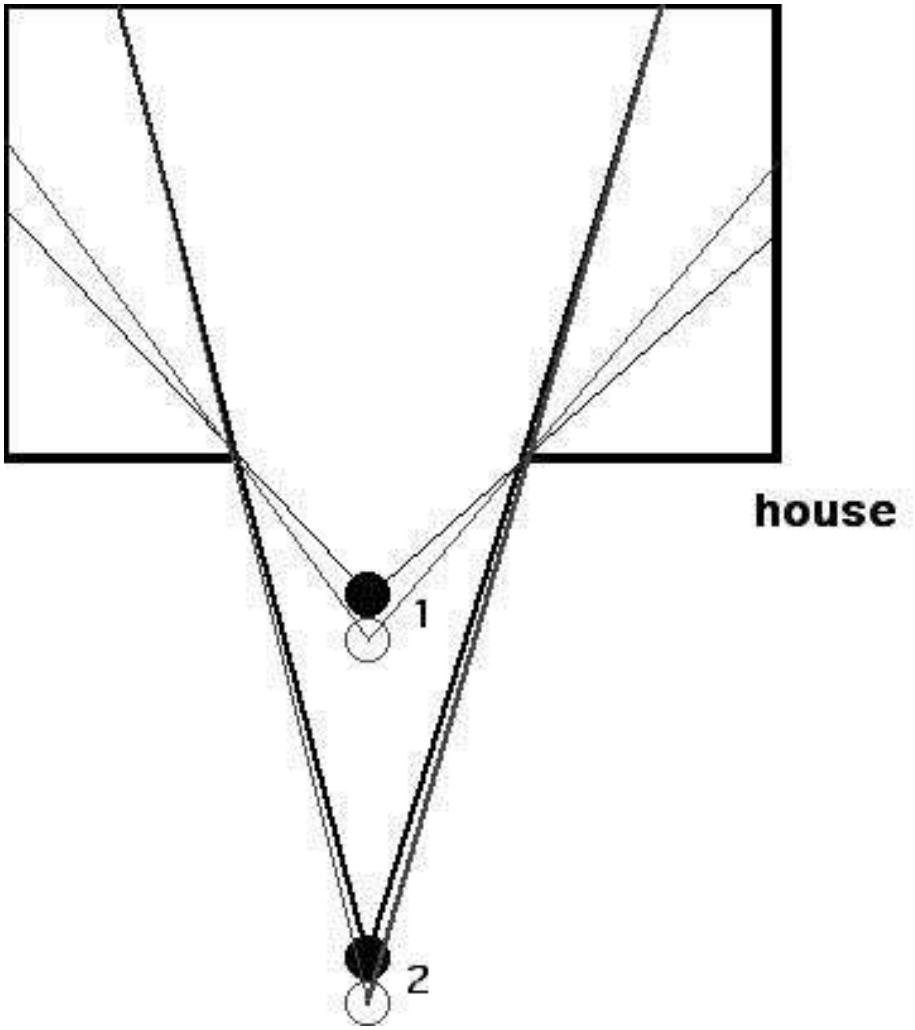

Figure 17: View from above of marginal changes. Because of geometry, stepping back from position 1, closest to the house, has a more dramatic effect on what can be seen through the picture window than stepping back the same amount from position 2. The change in the area visible inside the house is negligible for position 2, but not for position 1.

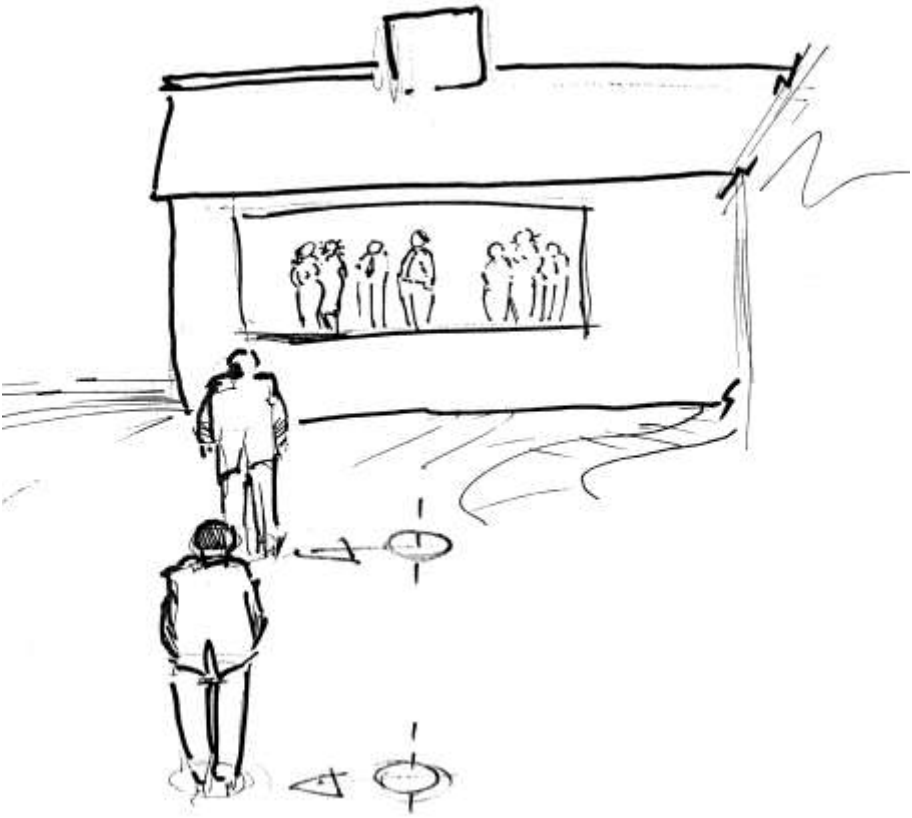

Figure 18: Here, two observers shift their geopolitical positions parallel to the nation-state being observed, rather than orthogonally as in Figure 10. Once again, because of geometry, the observer closest to the house will see the biggest change in what he can observe through the picture window.

Model Predictions

Prediction 1 (Cloud & Window Models): Each observer sees things from his own perspective. In the absence of 100% transparency on the part of nation-state B, the *eigenzüge* of observer A (that is, who she/he is and how they see the world) affects the data she/he can collect, as well as her/his perceptions, estimations, and understanding of B.

Prediction 2 (Cloud & Window Models): The *eigenzüge* of an observer and that of a nation-state are not stationary but will tend to drift or evolve over time.

Prediction 3 (Cloud & Window Models): It is only the *relative eigenzüge* of the observer with respect to the observed nation-state's *eigenzüge* that matters for transparency, not the *absolute* position of either party.

Prediction 4 (Cloud & Window Models): With increased transparency, the exact position (*eigenzüge*) of the observer becomes less critical, and his error in estimating the true position of a nation-state he observes decreases. These points can be deduced from Figures 1 (cloud model) and 9 (window model).

Prediction 5 (Cloud & Window Models): Increasing the transparency of one nation-state does not automatically increase that of another. This prediction is the result of both of our models being asymmetric: When nation-state B views nation-state A, it must peer though a completely different cloud or window than that through which A views B. There are thus really two different transparencies in a bilateral relationship, the transparency of A that affects B's view and the transparency of B that affects A's view.

Prediction 6 (Cloud & Window Models): With or without complete transparency on the part of nation-state B, A is not likely to see nation-state B accurately, if A is unaware of (or unwilling to change) its intrinsic biases and prejudices. See Figures 7 (cloud model) and 14 (window model).

Prediction 7 (Cloud Model): Intrinsic bias or prejudice on the part of an observer does not necessarily lead to an incorrect view of the nation-state being observed. Indeed, it is possible in Figure 7 for the errors introduced by the prism to fortuitously cancel (fully or partially) the errors introduced by the cloud. More often, however, prejudice or fabricated images of opponents are likely and create higher levels of distortion in the transparency process. In the absence of the cloud, the prism still causes error.

Prediction 8 (Cloud & Window Models): Observers who share with each other what they see when observing a given nation-state can obtain a more accurate view of the true intentions, actions, and capabilities of that nation-state. This is because each sees only a different partial scene (window model), and because errors can cancel each other out (cloud model). For greatest effectiveness, however, the views of each observer should ideally be "calibrated" to its unique set of *eigenzüge* and its N-dimensional distance from the observed nation-state in question.

Prediction 9 (Cloud & Window Models): International cooperation will tend to lead to a more uniform view of the intentions, actions, and capabilities of a given nation-state. In a multinational setting, there will be numerous

observers who will try to view B accurately. These observers will not ordinarily operate totally independently. The interactions and influence they have on each other will tend to cause each observer to slightly change its position, i.e., observers that cooperate will typically tend to move closer together in their *eigenzüge*. The models then tell us this means they will tend to come to see B more similarly, because they are viewing B from nearly the same perspective.

Prediction 10 (Window Model): Observers closest in N-dimensional space, i.e., having similar *eigenzüge*, to the nation-state being observed will garner the greatest amount of information from whatever transparency is permitted. See Figures 15 and 16.

Prediction 11 (Cloud and Window Models): One way to measure the true degree of transparency by a nation-state is to ascertain the extent to which the various citizens, journalists, and NGOs of that nation-state agree upon the actions, capabilities, and intentions of their government. This follows from the cloud model, and from the window model as a corollary of Prediction #10. Because they are N-dimensionally closest to the nation-state under observation, domestic observers will tend to have the most complete and accurate views. Relying instead upon the views of one or a small number of foreign, N-dimensionally distant observers to judge the degree of transparency of a given nation-state, as is done traditionally, may not be the best approach.

Prediction 12 (Window Model): A slight shift in an observer's *eigenzüge* with respect to the nation-state being observed will cause a potential dramatic change in what can be observed when the observer is similar to the nation-state, rather than dissimilar. That is, the closer in N-dimensional space that observer A is to the observed nation-state, B, the more a change in A's N-dimensional position affects his view of B. This prediction is illustrated in Figures 16 and 17.

Conclusions

In this paper, we examined the concept of nuclear transparency based on two simple physical models based loosely on optics. While being explorative and basic, we believe the models successfully achieve three goals. First, they help to summarize the concept of transparency and clarify some of its aspects that are often misunderstood. Second, the models led to multiple predictions that appear to be plausible, and potentially very useful. And third, we believe that these two models will be helpful in "sharpening the

questions and thinking" that theorists, researchers and practitioners need to ask in future work in the fields of transparency and nuclear nonproliferation. The future task for researchers and policy makers interested in reducing the level of world tension may well be to take such models and confirm or disprove their usefulness by application to specific case studies in the real world.

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