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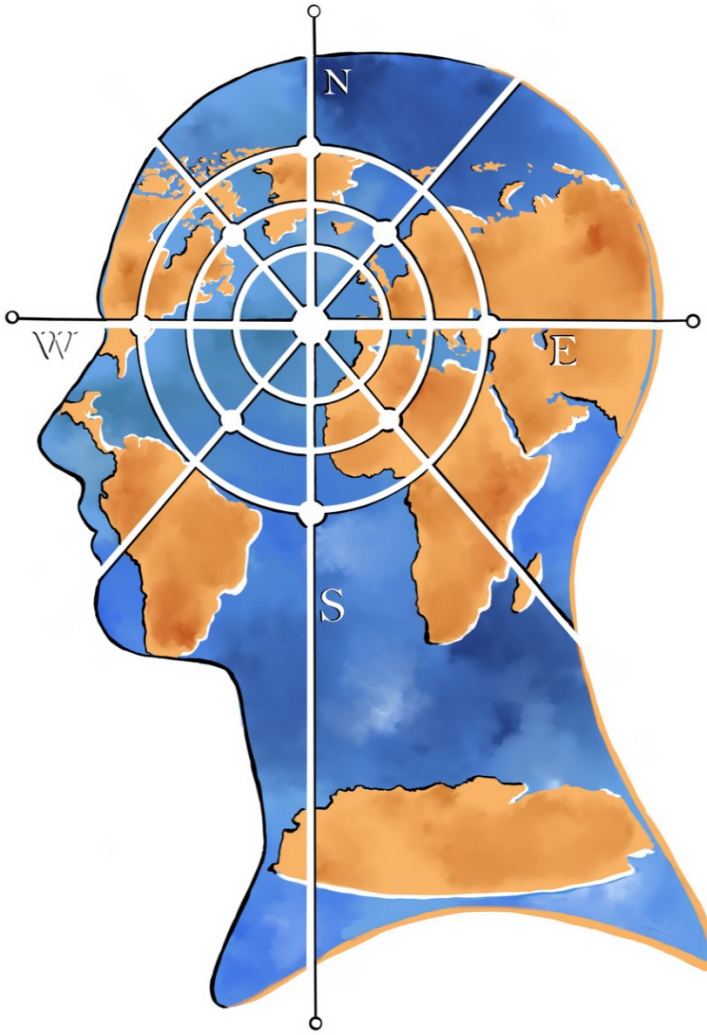

Research Institute for European and American Studies – RIEAS
School of Law and Government, Dublin City University
International Centre for Policing & Security, University of South Wales

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Under the editorial direction of the

School of Law and Government, Dublin City University

and the **International Centre for Policing & Security, University of South Wales**

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The *Journal of European and American Intelligence Studies* (*JEAIS*, formerly the *Journal of Mediterranean and Balkan Intelligence* —*JMBI*) is published by the Research Institute for European and American Studies (RIEAS) under the editorial direction of the Department of Security and Intelligence Studies at Coastal Carolina University. It is an international academic-led scholarly publication that focuses on the field of intelligence and related areas of study and practice, such as terrorism and counterterrorism, domestic and international security, geopolitics, and international relations. The journal's rationale is driven by the global nature of security challenges, where we are called more than ever to communicate and work collaboratively to solve our common problems. Thus, the *JEAIS* aspires to promote an international dialogue between diverse perspectives and experiences, based on original research on the broader European and American practice and study of intelligence. The *JEAIS* is an all-inclusive academic platform that allows accomplished and emerging scholars and practitioners from both the public and private sectors to share their knowledge, ideas and approach to intelligence studies. By crafting each journal issue through a rigorous and highly selective screening process of potential contributors, and an exhaustive review process, the *JEAIS* adheres to its mission, which is three-fold: (a) to provide an equal opportunity for academics and practitioners of intelligence to discuss and challenge established and emerging ideas; (b) to address existent knowledge gaps by advancing new knowledge; and (c) to shape the evolution of intelligence scholarship beyond traditional communities of research.

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Contents

Editor's Note

Joseph Fitsanakis

Professor, Department of Intelligence and Security Studies, Coastal Carolina University

Welcome to Volume 9, Issue 1, of the *Journal of European and American Intelligence Studies* (*JEAIS*). This issue brings together a diverse and timely collection of articles examining intelligence analysis, intelligence cooperation, democratic accountability, professional education, and organizational adaptation under conditions of uncertainty. The value of this volume lies not only in the breadth of its subject matter, but also in the way its contributions illuminate the increasingly interdisciplinary character of intelligence studies. The collection of articles in this volume move across theory, method, policy, education, and applied sectoral analysis—demonstrating that intelligence cannot be understood narrowly as a state function or professional practice alone. Rather, it is a field shaped by—among other things—analytical rigor, institutional trust, ethical contestation, geopolitical realignment, and the capacity of organizations to adapt under pressure. Taken together, the contributions speak to a central concern in contemporary intelligence studies: how intelligence institutions, analysts, educators, and partner organizations can remain effective when political, technological, strategic, and ethical environments are increasingly fluid.

The issue opens with Yakov Ben-Haim's "Dilemmas of Robustness, Opportuneness and Informativeness: Implications for Intelligence Analysis", a theoretically rich contribution that applies info-gap decision theory to the work of intelligence analysts. Ben-Haim examines the tension between the informativeness of intelligence assertions and their reliability, showing how claims that provide greater decision advantage may also become more vulnerable to uncertainty. The article further develops the concept of "opportuneness", emphasizing that uncertainty may not only threaten judgments but also create possibilities for sharper and more useful intelligence assessments. A hypothetical example concerning the possibility of a Chinese invasion of Taiwan demonstrates the operational relevance of these concepts.

Minas Lyristis's "Intelligence Sharing in a Multipolar Middle East: The European Union-Saudi-China Triangle" shifts attention to the geopolitical consequences of Saudi Arabia's increasingly autonomous foreign policy. As Riyadh deepens ties with China and recalibrates relations with Iran, Western intelligence services face new dilemmas in

managing sensitive cooperation with a partner no longer easily understood through traditional alliance categories. The article calls for more flexible models of intelligence sharing that preserve source protection while recognizing the multipolar realities of Gulf security.

Methodological innovation is at the center of Charalampos 'Bobby' Paraskevopoulos's "Whistleblowing Across Time: A Hybrid Methodology for Comparative Case Analysis in Intelligence Studies." The article proposes a framework that integrates established academic methods with Structured Analytical Techniques from intelligence practice. By treating bias and error management as core elements of research design rather than afterthoughts, the article offers a replicable model for studying contested intelligence phenomena under conditions of secrecy, uncertainty, and politicization.

Jonathan Smith's "Academic Centers as Drivers of Student Professionalization in Intelligence Education" examines the growing role of academic centers in intelligence education. Drawing on a cross-national dataset, the article compares US-based centers, which tend to emphasize experiential learning and entry-level career preparation, with non-US centers, which more often prioritize research, policy engagement, and communities of practice. The result is an important contribution to understanding how institutional structures shape professional identity formation in intelligence studies.

Eirini-Anna Lagonika and Stella Lagonika's "The Impact of Geopolitical Security, Energy-Security Intelligence, and Financial Performance on the LNG Shipping Sector" extends the scope of our issue into organizational and energy-security intelligence. Using panel data from 2016 to 2024, the authors examine how organizational intelligence affects the financial performance of LNG shipping firms during periods marked by pandemic disruption, war, and energy crisis. Their findings suggest that firms with stronger intelligence capacities are better positioned to adapt and compete during geopolitical volatility.

The issue concludes with Paraskevopoulos's "The Snowden Shockwave: Intelligence Leaks, Democratic Resilience, and the Limits of Reform," which revisits the political, legal, and security consequences of the 2013 Snowden disclosures. The article argues that the scale and downstream effects of the leaks place them closer to strategic betrayal than principled whistleblowing, while also acknowledging their role in accelerating global debates over privacy and surveillance. Its findings underscore the persistent structural tension between intelligence imperatives and democratic accountability.

Across these articles, a common theme emerges: intelligence is not merely a function of information collection or analytic tradecraft, but a field shaped by uncertainty, institutional trust, political legitimacy, professional formation, and strategic adaptation. This issue invites readers to consider how intelligence studies can better connect theory and practice while remaining attentive to the ethical and institutional pressures that define the field.

Dilemmas of Robustness, Opportuneness and Informativeness: Implications for Intelligence Analysis

Yakov Ben-Haim

Faculty of Mechanical Engineering, Technion - Israel Institute of Technology, Haifa, Israel

Abstract

Intelligence analysts support decision makers by using evidence to formulate assertions that are informative and reliable. We identify generic conditions in which informativeness trades off against reliability: Informativeness improves as reliability deteriorates, subject to a condition on scalability of informativeness. We use info-gap decision theory to assess this trade off, thus assessing utility for decision makers of intelligence assertions. We assess reliability of an assertion with the concept of robustness to uncertainty as developed in info-gap decision theory. Robustness responds to the pernicious side of uncertainty, but surprise can be favorable and uncertainty can be propitious. An assertion has great opportuneness from uncertainty if small increments of evidence can dramatically improve informativeness of the assertion. We identify generic conditions in which informativeness trades off against opportuneness. We show that robustness and opportuneness both improve or both worsen as informativeness changes. We develop these ideas generically and discuss an example, demonstrating relevance to intelligence analysis. The example considers whether, and when, the People's Republic of China will invade the Republic of China (Taiwan). The formulation is hypothetical and qualitative, and demonstrates the evaluation and interpretation of the robustness and opportuneness concepts, and their use in choosing reliable and promising intelligence assertions.

1. Introduction

Intelligence analysts use evidence to formulate assertions that are both informative and reliable. An assertion is informative if it provides the analyst's customer with timely and relevant insight. However, deep uncertainty surrounds the formulation of assertions in intelligence assessment. An assertion is reliable if it is robust to this uncertainty. We develop a methodology, based on info-gap decision theory, for both managing and exploiting this uncertainty in intelligence analysis. We explore trade-offs and 'trade-ons' confronting the analyst. The analysis is demonstrated in a hypothetical example considering the possible invasion of Taiwan by the People's Republic of China.

An assertion is very informative if it entails a precise and detailed description or prediction. An assertion is very uninformative if it is very vague or imprecise. For example, consider the following pair of descriptive assertions:

> A1: WW II occurred sometime between 1900 and 2000.
> A1': WW II occurred sometime between 1930 and 1950.

Assertion A1 is less informative than assertion A1'. Similarly, consider the following pair of predictive assertions, where we refer to the People's Republic of China as `China' and the Republic of China as `Taiwan':

> A2: China will invade Taiwan within 6 years.
> A2': China will invade Taiwan within 6 months.

Assertion A2 is less informative than assertion A2'.

Sections 2—4 gradually develop a generic theoretical framework for choosing between available options when facing deep uncertainty. This framework is then applied, in section 5, to a hypothetical and qualitative analysis of the robustness against pernicious uncertainty in choosing between assertions A2 and A2'. Section 6 applies the framework to the analysis of the opportuneness from propitious uncertainty in the same decision. Together these examples illustrate the generic methodology for decision support in protecting against adverse surprises and in exploiting favorable surprises.

The informativeness of assertions is usually a matter of degree, and the previous examples are discrete points on a continuum of informativeness. The intelligence analyst must decide which assertion, on this continuum, will be transmitted to the intelligence customer. The relevance of the assertion is one criterion: vacuous assertions, and assertions with endless detail, are not relevant to the customer.

However, within the domain of relevant assertions, the impact of error or uncertainty in the evidence is important in choosing the assertion for transmission. An uncertain assertion has limited usefulness for policy makers. For instance, 16th century Spain was far more powerful than England, but Spain's king hesitated to attack England because of the uncertain impact on

numerous collateral Spanish interests (Sims[1]). Likewise, Kovacs[2] emphasizes that intelligence "is a practical and service-oriented occupation whose sole *raison d'etre* is to facilitate military and political action and decision making." Kovacs stresses the difference between intelligence and the domains of history and political science, whose goal is the pursuit of 'truth' (Kovacs' quote marks). In this sense, intelligence is similar to engineering in its distinction from basic science: engineering supports the implementation and realization of plans and designs, rather than the discovery of laws of nature. Similarly, Hershkovitz[3] stresses the role of intelligence analysis in "sense-making" for policy decision makers: identifying uncertainties (and reducing them when possible) in support of situational awareness and decision making. Friedman[4] uses the approach of subjective probability to support assessment and decision-making when facing uncertainty in international politics. One focus of this paper is on evaluating and managing the adverse impact of uncertainty.

Much attention has been given to various trade-offs inherent in decision-making under uncertainty. Friedman[5] for instance discusses the trade-off between the risk inherent in a given option, and the quality of the outcome to be achieved. Friedman discusses the use of subjective probability in assessing risks in foreign policy decisions, where less risky alternatives may be preferred, even if their anticipated outcomes are less promising. Likewise, Kovacs[6] discusses 4 "inner tensions and [...] trade-offs" in imagery intelligence. While uncertainty hovers over these trade-offs, it is not the core issue in Kovacs' treatment. Rather, the tensions arise for logistical or organizational reasons. Kovacs[7] writes that "Sometimes, intelligence of great import and potential impact may prove the hardest to use [...]. In particular this means that much centrally-collected intelligence is difficult to utilize at the tactical level." The present paper explores two different trade-offs, elaborated subsequently, that are inherent in decision-making under uncertainty.

A given assertion, based on the current body of evidence, has a particular level of informativeness. The assertion may require modification as evidence accumulates or changes. This may alter the informativeness of the assertion. Future evidence is unknown at any given point in this process, so future informativeness is uncertain. The concept of robustness responds to this uncertainty. For any required value of informativeness, the *robustness* (to uncertainty in future evidence) of an assertion is the greatest level of uncertainty at which the informativeness of that assertion is guaranteed to be no worse than the required value. That is, while the assertion may change in response to new evidence, the robustness of the assertion is the greatest level of uncertainty up to which the informativeness of the revised assertion is guaranteed to be no worse than the required value.

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[1] Jennifer E. Sims, *Decision Advantage: Intelligence in International Politics from the Spanish Armada to Cyberwar*, (New York: Oxford University Press, 2022), pp.51-2.

[2] Amos Kovacs, "Using Intelligence", *Intelligence and National Security,* vol 12, no. 4, (1997), p.145.

[3] Shay Hershkovitz, *Future of National Intelligence: How Emerging Technologies Reshape Intelligence Communities,* (Lanham, Maryland: Rowman & Littlefield, 2022) pp.14, 39.

[4] Jeffery A. Friedman, Jeffrey A., 2019, *War and Chance: Assessing Uncertainty in International Politics,* (Oxford: Oxford University Press, 2019) pp.2, 93.

[5] Friedman, *War and Chance,* pp.2, 4, 29.

[6] Kovacs, 1997.

[7] Kovacs, 1997, p.162.

Our first claim is that an assertion that is very robust to uncertainty has low informativeness; equivalently, high informativeness implies low robustness to uncertainty. More precisely, if assertion B is more informative than assertion B', then B' is more robust to uncertainty than B, subject to a specific condition on the scalability of informativeness. Robustness to uncertainty trades off against informativeness. This claim is stated and proven as proposition 1 in section 4.1.

A statement is *reliable* if it is robust to uncertainty in the evidence. A statement is *useful* if it is informative. We would like a useful statement to be reliable. However, our first claim indicates the contrary. This presents the analyst with a dilemma: the more informative (and useful) an assertion is, the less is it robust to uncertainty in the evidence supporting that assertion. Thus, the more useful an assertion, the less reliable it is. The analyst must manage the dilemma by assessing and balancing this trade-off. This paper provides a methodology for doing so by robustly protecting against adverse uncertainty while striving to achieve an essential or critical level of informativeness. This approach is called robust-satisficing.

This trade-off between informativeness and robustness does not hold if we compare assertions A1 and A2' because their domains of reference are different. A2' is more informative than A2, but not more informative than A1. Subsequently, when comparing the informativeness of two assertions we will presume that they apply to the same domain. This idea is formulated more precisely in section 4.

We have considered the uncertainty in future evidence as pernicious in the sense that this unknown evidence may weaken the informativeness of an assertion. However, unknown future evidence may be propitious in the sense that it enhances the informativeness of an assertion. We now consider the implications of propitious uncertainty. We will refer to the unknown extent or level of uncertainty as the "horizon of uncertainty".

An assertion is very opportune to uncertainty if a small change in the evidence can enhance the informativeness of the assertion. For any aspired level of informativeness, the opportuneness of an assertion is the lowest horizon of uncertainty at which there is an increment of evidence that alters the informativeness of that assertion so that the informativeness is no worse than that aspired value. The opportuneness is large if this opportune horizon of uncertainty is small. That is, the opportuneness is large if enhancement of informativeness is possible even when facing only low uncertainty in the evidence. Opportuneness is different from the robustness of an assertion discussed above. For any required value of informativeness, the robustness of an assertion is the greatest horizon of uncertainty at which the informativeness of that assertion is guaranteed to be no worse than that required value. The robustness is large if the robust horizon of uncertainty is large.

Our second claim is that an assertion that is very opportune to uncertainty has low informativeness, or, equivalently, high informativeness implies low (poor) opportuneness from uncertainty. More precisely, if assertion C is more informative than assertion C', then C' is more opportune to uncertainty than C, subject to a specific condition on the scalability of informativeness. Opportuneness to uncertainty trades off against informativeness, which again presents the analyst with a dilemma: the more informative (and useful) an assertion is, the less

it is opportune to the potential for new evidence. This claim is stated and proven as proposition 2 in section 4.2. The analyst must manage this dilemma between informativeness and opportuneness by assessing and balancing the trade-off. This paper develops a methodology based on the idea of exploiting uncertainty to facilitate a wonderful outcome. This approach is called opportune windfalling.

An immediate implication of the two propositions is that robustness and opportuneness are sympathetic as informativeness changes. That is, as informativeness improves (from one assertion to another), the robustness will worsen (first proposition) and the opportuneness will also worsen (second proposition). This is discussed further in section 4.2.

Sections 2 and 3 present simple examples that provide preliminary insight into the info-gap concepts of robustness to uncertainty, opportuneness from uncertainty, and their trade-offs against informativeness. Section 4 presents and discusses two generic results. Sections 5 and 6 present deeper examples illustrating these propositions and the methodologies for evaluating robustness and opportuneness based on verbal qualitative analysis. Section 7 is a concluding discussion.

2. Mathematical Metaphors: Simple Examples with a Single Estimate

Some intelligence assertions are quantitative—the number of tanks, or the size of the military budget—while some are qualitative—tanks crews are poorly trained, or the military budget is efficiently allocated. Analysis of the trade-off between informativeness and robustness, and between informativeness and opportuneness, employ different tools for quantitative and qualitative assertions. In this and the following section we illustrate the quantitative analysis of info-gap robustness with several simple examples. These examples explore trade-offs and implications for analysts, and offer insight into subtler and more difficult qualitative analysis explored later. The math is a metaphor for qualitative analysis.

Info-gap theory is a non-probabilistic methodology for decision-making when facing deep uncertainty. Info-gap theory is conceptually distinct from statistics, but there are parallels between these methodologies discussed extensively elsewhere (Ben-Haim and Elishakoff[8]; Ben-Haim[9]).

Example 1: Robustness and informativeness.

Consider two assertions about the size of a domain containing an object, or the duration of past or future events, such as assertions A1 and A1', or A2 and A2' in section 1. Let s denote the real scalar quantity of interest, such as the size or duration, and let $\tilde{s}$ denote the best available estimate of s, also a real scalar quantity. The value of $\tilde{s}$ is uncertain and may vary by $\pm w$ or

[8] Yakov Ben-Haim and Isaac Elishakoff, *Convex Models of Uncertainty in Applied Mechanics,* (Amsterdam: Elsevier Science Publishers, 1990).

[9] Yakov Ben-Haim, "A non-probabilistic concept of reliability", *Structural Safety,* (1994) 14:227-245. Yakov Ben-Haim, 2004, "Uncertainty, probability and information-gaps", *Reliability Engineering and System Safety,* 85: 249-266. Yakov Ben-Haim, *Info-Gap Decision Theory: Decisions Under Severe Uncertainty,* 2nd edition, (London: Academic Press, 2006), p.18.

more; w is a known positive value. No worst case (maximum error) is known. The uncertainty in the estimate is quantified by the non-probabilistic and epistemically minimalistic info-gap model of uncertainty in eq. (9) of appendix A. The informativeness of such assertions increases as the size or duration, s, decreases.

The future informativeness may be worse (greater) than the estimated informativeness, $\tilde{s}$. Assertion B1 is that the largest value of s is s_*, while assertion B1' is that the largest value is s_*' which is less than s_*; both values exceed $\tilde{s}$. That is, the analyst asserts:

$$\text{B1}: \quad s \le s_* \qquad (1)$$

$$\text{B1}': \quad s \le s_*' \qquad (2)$$

where: $$\tilde{s} < s_*' < s_* \qquad (3)$$

B1' is more informative than B1 but both are less informative than the current estimate.

For any critical value of the estimate, s_c, such as $\tilde{s}$, s_* or s_*', consider the assertion that the informativeness is no worse than s_c, namely: $s \le s_c$. The robustness to uncertainty in future evidence, of this assertion, is the greatest horizon of uncertainty in the estimate, up to which the assertion is satisfied for all realizations of the informativeness at that horizon of uncertainty. The robustness function, denoted $\hat{h}(s_c)$, is formulated precisely and derived in appendix A and shown schematically in Fig. 1.

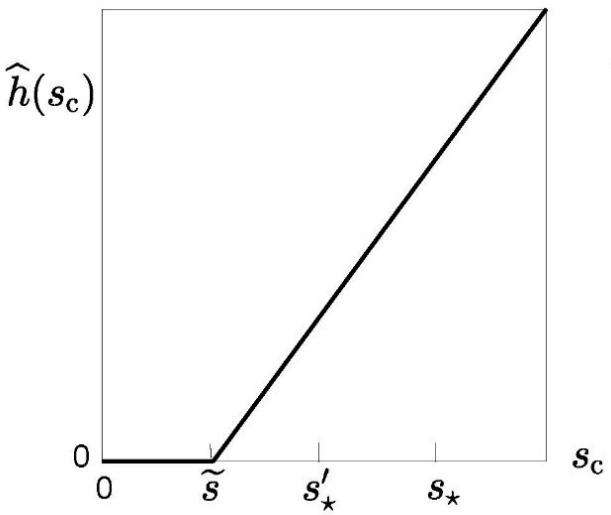

***Fig. 1**: Schematic robustness curve*. Robustness improves as critical informativeness deteriorates: robustness trades off against informativeness.

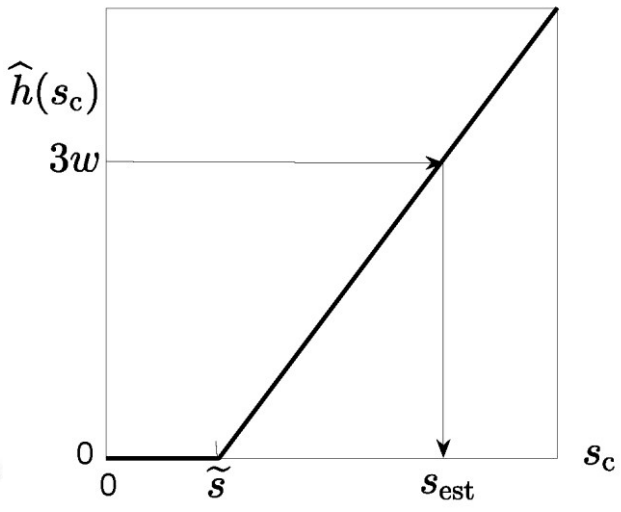

***Fig. 2**: Schematic robustness curve.* Shows estimated informativeness at robustness of 3w. Identifies a value of informativeness whose robustness is 3 times the error estimate, which may be considered a reliable estimate. This estimate is informative if it is small enough to be useful.

Large robustness to uncertainty is preferred over low robustness, and large informativeness is preferred over low informativeness. Recall that small s implies large informativeness. Fig. 1 shows that the robustness *improves* ($\hat{h}(s_c)$ increases) as the critical informativeness *deteriorates* (s_c increases): robustness trades off against informativeness. One sees that B1' is less robust than B1 because $\hat{h}(s_*') < \hat{h}(s_\star)$. However, B1' is more informative than B1 because $s_*' < s_\star$. The positive slope of the robustness curve expresses the trade-off between robustness and informativeness. Furthermore, a steeper slope implies a stronger trade-off. When robustness is adopted as a proxy for reliability, we see that informativeness trades off against reliability, which illustrates our first claim.

This provides decision-support for the analyst who must provide an informative and reliable estimate of the size or duration s, or decide that no such estimate is available. The best available estimate is $\tilde{s}$ but the robustness of this estimate is zero as seen in Fig.1, so $\tilde{s}$ is not at all reliable. The correct value may exceed $\tilde{s}$ by w or more, and a worst case (maximal s) is not known. However, a value of s exceeding the estimate by 2 or 3 times the error estimate, w, may be considered a reliable estimate. This estimate is informative if it is small enough to be useful. For instance, the analyst may consider the value of s_c whose robustness is $3w$ to be reliable. This estimate, s_{est}, is shown in Fig. 2. The analyst must then decide if s_{est} is small enough to be useful to the intelligence customer; it not, then the analyst reports the unavailability of a useful and reliable estimate.

Example 2: Opportuneness and informativeness.

Continue example 1 by considering the opportuneness from uncertainty in future evidence underlying the estimated informativeness.

Recall that a small value of s—which is an estimated duration or size—implies great informativeness. Let s_w be a wonderfully small value of s and suppose that the current estimate of s exceeds s_w. That is, the current estimate, $\tilde{s}$, is that the size or time is greater (worse, less informative) than s_w. In other words, the current estimate implies that the following assertion is considered to be true:

$$\mathrm{B}: \quad s > s_w \qquad (4)$$

The opportuneness from uncertainty in future evidence, of the assertion that the informativeness is greater (worse) than the wonderfully informative value s_w, is the lowest horizon of uncertainty at which the assertion is violated (and hence negated) for at least one realization of the informativeness. Equivalently, the opportuneness of assertion B is the lowest horizon of

uncertainty at which there is an s that violates the inequality in eq.(4), causing one to accept that the informativeness is indeed no greater than s_w.

Consider the following 2 assertions:

$$\text{B2}: \quad s \le s_\times \qquad (5)$$

$$\text{B2}': \quad s \le s_\times' \qquad (6)$$

where:

$$s_\times' < s_\times < \tilde{s} \qquad (7)$$

Assertion B2 is that the largest value of s is $s_\times$, while B2' asserts that the largest value is $s_\times'$, both of which are less than $\tilde{s}$. Eq.(7) implies that B2' is more informative than B2 and both are more informative than the current estimate, $\tilde{s}$.

A small value of the opportuneness function implies that a wonderfully small value of s is possible at that horizon of uncertainty. Hence a small value of the opportuneness function is better than a large value, unlike the robustness function for which bigger is better. For any value of the estimate, s_w such as $\tilde{s}$, $s_\times$ or $s_\times'$, consider the assertion that the informativeness is no larger (no worse) than s_w, namely, that $s \le s_w$ which means that assertion B in eq.(4) is wrong. The opportuneness is the lowest horizon of uncertainty at which assertion B is negated for at least one realization of the informativeness. The opportuneness function, denoted $\hat{\beta}(s_w)$, is defined formally and derived in appendix A.

The opportuneness function is shown schematically in Fig. 3. One sees that the opportuneness *improves* ($\hat{\beta}(s_w)$ decreases) as the windfall informativeness, s_w, *deteriorates* (s_w increases). That is, B2 is more opportune to uncertainty than B2' because $\hat{\beta}(s_\times) < \hat{\beta}(s_\times')$. However, B2' is more informative than B2 because $s_\times' < s_\times$ The negative slope of the opportuneness curve expresses the trade-off between opportuneness and informativeness. Furthermore, a steeper slope implies a stronger trade-off. When info-gap opportuneness is adopted to assess the opportuneness of an assertion, we see that informativeness trades off against opportuneness, which illustrates our second claim.

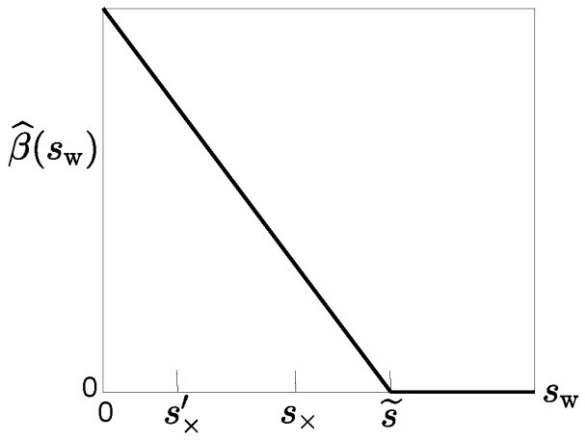

***Fig. 3**: Schematic opportuneness curve.* Shows that opportuneness deteriorates (takes larger values) as windfall informativeness improves (gets smaller): opportuneness trades off against informativeness.

The opportuneness function provides a decision support tool for the intelligence analyst that is complementary to the robustness function. The estimated informativeness is $\tilde{s}$. However, this estimate is uncertain and may err by $\pm w$ or more. This uncertainty is propitious because it opens the possibility that the actual informativeness may be better (more informative) than $\tilde{s}$, like s_x and s_x'. Suppose that the opportuneness of s_x is 1, that is, $\hat{\beta}(s_x) = 1$. This means that the estimate need err by only one unit of the error estimate, w, in order for s_x to be possible. Thus s_x is a plausible value for the informativeness, and the analyst may report this to the customer as a favorable possibility.

Our discussion of the robustness function, $\hat{h}(s_c)$, in example 1 and the opportuneness function, $\hat{\beta}(s_w)$, in example 2 illustrates that robustness and opportuneness both improve or both worsen as the estimated informativeness changes. Thus we say that opportuneness and robustness are sympathetic with respect to change in estimated informativeness. Recall that robustness improves as $\hat{h}(s_c)$ increases, and opportuneness improves as $\hat{\beta}(s_w)$ decreases. In Fig. 3 we see that the opportuneness function shifts to the right as the evidence-based estimate, $\tilde{s}$, increases, and shifts to the left as $\tilde{s}$ decreases. Thus, a change in the evidence that causes an increase in $\tilde{s}$ causes a worsening of the opportuneness, while a decrease in $\tilde{s}$ improves the opportuneness. The situation is the same for the robustness function as seen in Fig. 1. The robustness function shifts to the right as $\tilde{s}$ increases, and shifts to the left as $\tilde{s}$ decreases. Thus the robustness decreases (gets worse) as $\tilde{s}$ increases, and the robustness increases (improves) as $\tilde{s}$ decreases. That is, opportuneness and robustness both improve or both worsen as evidence alters the estimated informativeness. In short, robustness and opportuneness are sympathetic.

3. Mathematical Metaphors: Simple Example with Multiple Estimates

Example 3: Conflicting evidence.

We now consider a situation in which the intelligence analyst confronts conflicting evidence, accompanied by uncertainty. The different estimates of s now reflect fundamental dispute among the sources, so linear combination would overlook this legitimate dispute. We illustrate the dilemmas of robustness, opportuneness and informativeness arising from a particular relation between different bodies of uncertain and conflicting evidence.

The first body of evidence, E, implies an estimated scalar value of informativeness $\tilde{s}$, which may err by $\pm w$ or more. The second body of evidence, E', implies a less informative estimate, $\tilde{s}'$, whose estimated error, $\pm w'$, is also lower. Thus E' is less informative but more reliable than E. These parameters are related as:

$$w' < w, \quad \tilde{s}' > \tilde{s} \qquad (8)$$

We use the same formulations of robustness, opportuneness and info-gap uncertainty as employed in examples 1 and 2.

The analyst faces the same trade-offs between informativeness and robustness, and between informativeness and opportuneness, that were illustrated in the previous examples. In addition, the analyst confronts the fundamental conflict between the two bodies of evidence that are represented, respectively, by $(\tilde{s}, w)$ and $(\tilde{s}', w')$. These bodies of evidence support different best-estimates of s, and the first body supports a more informative but also more uncertain estimate.

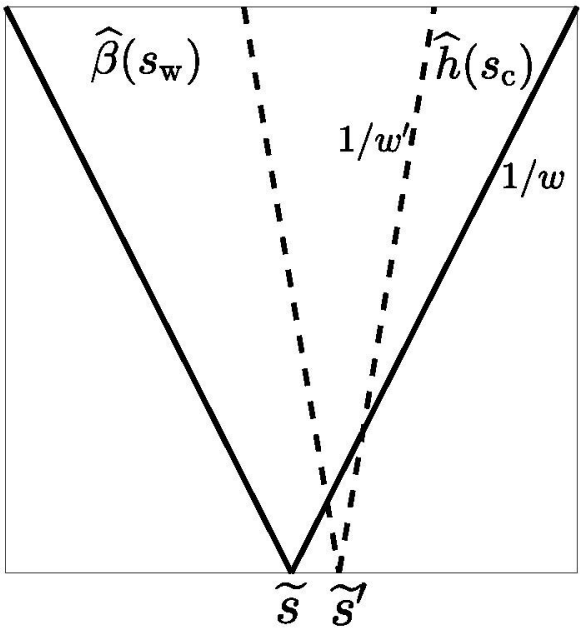

Fig. 4*: Schematic robustness and opportuneness curves with different estimated informativeness and error.* Robustness and opportuneness curves for different prior information. Robustness and opportuneness reflect distinct approaches to management of uncertain and conflicting evidence. Robust-satisficing protects against pernicious uncertainty. Opportune windfalling exploits propitious uncertainty.

Fig. 4 shows robustness curves (positive slopes) and opportuneness curves (negative slopes) for estimated informativenesses and uncertainty weights of eq.(8). The solid curves are for $(\tilde{s}, w)$ and the dashed curves are for $(\tilde{s}', w')$. The robustness curves have positive slopes of $1/w$ and $1/w'$, and the opportuneness curves have negative slopes with the corresponding values.

Consider the robustness curves in Fig. 4. Neither body of evidence supports an estimate of less than $\tilde{s}$, so a value less than $\tilde{s}$ could not responsibly be transmitted to the customer. This is expressed by the robustness being zero for any estimate less than $\tilde{s}$.

But neither body of evidence can be rejected or ignored; they conflict, but each has its own validity. The evidence supporting $(\tilde{s}', w')$ indicates zero robustness for estimates less than $\tilde{s}'$, so validity of this evidence rejects adopting an estimate less than $\tilde{s}'$. Only estimates exceeding $\tilde{s}'$ have positive robustness to uncertainty. The challenge is to assess robustness to uncertainty for estimates exceeding $\tilde{s}'$, in light of the conflicting bodies of evidence. This assessment underlies the robust-satisficing analyst's choice of the estimate that will be transmitted to the customer.

The positive slopes of the robustness curves express the trade-off between informativeness (small s) and immunity to uncertainty (large $\hat{h}(s_c)$). Let s_x denote the value of s_c at which the robustness curves cross one another. We now demonstrate the use of the robustness curves in choosing the estimate of s for reliable transmission to the customer.

- The two bodies of evidence agree on the robustness to uncertainty of s_x as an estimate of s. If that robustness is large enough in the judgment of the analyst, then s_x could reliably be transmitted to the customer.
- If the robustness of s_x is not large enough to justify its adoption, then the cautious analyst would tend to assess robustness of greater values of s_c according to the solid curve $(\tilde{s}, w)$, whose robustness is lower than of the other body of evidence $(\tilde{s}', w')$. The analyst would select a value of s_c whose robustness is large enough to justify transmission.
- If the robustness of s_x is very large, then the analyst can use the dashed robustness curve to choose a more informative (smaller) estimate whose robustness is large enough to justify transmission.

The conflict between the two bodies of evidence has been resolved by treating both prior estimates, $\tilde{s}$ and $\tilde{s}'$, as uncertain, and basing the analyst's decision on a conservative or cautious assessment of robustness to that uncertainty.

Now consider the opportuneness curves (negative slopes) in Fig. 4 from the perspective of the opportune windfalling analyst for whom uncertainty in unknown future evidence entails the possibility of better-than-anticipated informativeness.

The opportuneness function, $\hat{\beta}(s_w)$, expresses the lowest horizon of uncertainty at which it is possible that future evidence would justify the estimate s_w. Thus a small value of $\hat{\beta}(s_w)$ is more opportune than a large value.

The opportune windfalling analyst seeks to exploit the uncertainty of unknown future evidence to identify a wonderfully small (highly informative) estimate of s that could occur. This is different from the robust-satisficing analyst who seeks an acceptably large (less informative) estimate that is relatively immune to future uncertainty. The opportune windfalling analyst is optimistic or perhaps even adventurous, as distinct from the cautious or conservative robust-satisficing analyst. The opportune windfalling analyst will use the decreasing solid opportuneness curve, which indicates greater opportuneness for wonderfully small estimates of s, rather than the dashed opportuneness curve.

In summary, the robustness and opportuneness curves in Fig. 4 reflect two distinct approaches to management of uncertain and conflicting evidence. The robust-satisficing approach attempts to protect against pernicious uncertainty, while the opportune windfalling approach attempts to exploit propitious uncertainty. The info-gap analysis highlights the differences and provides a methodology for each approach.

4. Generic Results

We consider assertions whose information can be expressed on a scale. That scale may be quantitative (e.g. from 6 to 18 months, or from 5 to 15 km), or the scale may be qualitative (e.g. the level of proficiency is well known, moderately known, or poorly known). The informativeness of the assertion decreases as one moves up the scale; we refer to this as monotonic informativeness. Not all assertions can be expressed on a scale and not all scales are monotonically informative. Our discussion is limited to assertions that are scalable and monotonically informative. For instance, the informativeness of assertion A1 in section 1 is 100 years and the informativeness of A1' is 20 years; the informativeness of A2 and A2' are 6 years and 6 months, respectively.

Assertions contain diverse information. For instance, A1 in section 1 asserts the occurrence of World War II, that it may have begun as early as 1900, and that it occurred sometime during the subsequent century. All of these elements may be uncertain, but we will consider assertions in which only a single component of information is uncertain. Thus, the generic form of assertions in our subsequent development is:

B: The uncertain entity of interest is no greater than s.

B': The uncertain entity of interest is no greater than s'.

where s and s' are the same information element, s' is less (better) than s implying that B' is more informative than B, and all of the other information in B and B' is the same. Assertions of this form are scalable on the same scale and monotonically informative.

Recall that the informativeness, s, may be quantitative (a number such as 6 km) or qualitative (a verbal expression such as 'soon'). In either case the informativeness is scaled from high to low: 1 km is more informative than 6 km, and 'soon' is more informative than 'sometime'. If s' is more informative than s, then we denote this as $s' \prec s$.

This section presents two propositions, one relating robustness and informativeness, and the other relating opportuneness and informativeness.

4.1. First Claim: Robustness Trades Off Against Informativeness

For any required value of informativeness, the robustness (to uncertainty in future evidence) of an assertion is the greatest horizon of uncertainty at which the informativeness of that assertion is guaranteed to be no worse than the required value.

Proposition 1. Robustness to uncertainty trades off against informativeness when considering assertions that are scalable on the same scale and monotonically informative.

Proof of proposition 1. Consider two assertions on the same monotonically informative scale, B and B', where B' is more informative than B. The informativeness of B is s and the informativeness of B' is s', where s' is less (better) than s. That is, $s' \prec s$. These assertions are of the form:

B: The uncertain entity of interest is no greater than s.

B': The uncertain entity of interest is no greater than s'.

Any evidence that refutes B asserts that the informativeness exceeds s. Hence this evidence also refutes B' because B and B' are on the same scale and s' is less than s.

Some evidence that refutes B' asserts that the informativeness exceeds s' but is less than s. This evidence does not refute B.

We conclude that B' is more vulnerable to uncertain evidence than B. Equivalently, B is more robust to uncertain evidence. However, B is less informative than B'. Hence robustness increases as informativeness decreases.

4.2. Second Claim: Opportuneness Trades Off Against Informativeness

The opportuneness function assesses the possibility of a wonderful value of informativeness, as distinct from the robustness function that assesses the certainty of an acceptable or required value. For any aspired value of informativeness, the opportuneness (from uncertainty in future evidence) of an assertion is the lowest horizon of uncertainty at which some realization of the evidence modifies the assertion so that its informativeness is no worse than the aspired value.

Proposition 2 Opportuneness from uncertainty trades off against informativeness when considering assertions that are scalable on the same scale and monotonically informative.

Proof of proposition 2. Consider an assertion, B, whose monotonic informativeness is $\tilde{s}$. Let s and s' be two other levels of informativeness where s is better (smaller, more ambitious) than s' which is better (smaller, more ambitious) than $\tilde{s}$. Thus $s \prec s' \prec \tilde{s}$.

Any evidence that alters B so that its informativeness is better (less) than s also makes its informativeness better than s'.

Some evidence that alters B so that its informativeness is better (less) than s' does not make its informativeness better (less) than s.

Thus, the lowest horizon of uncertainty at which there is evidence that can alter B so its informativeness is better than s' is lower than the lowest horizon of uncertainty at which there is evidence that can alter B so its informativeness is better than s.

Equivalently, a greater horizon of uncertainty is required to enable s than is required to enable s'. That is, the opportuneness for s' is better (a lower horizon of uncertainty is required) than for s. The aspiration for s is more ambitious than the aspiration for s'. Thus, the opportuneness improves as the aspired informativeness gets less ambitious. We have demonstrated that opportuneness from uncertainty trades off against informativeness.

4.3. Discussion of the Propositions

Consider an assertion that is revised over time as new evidence comes in. The informativeness of the assertion may increase as a result. In that case, proposition 1 shows that the robustness to uncertainty in future evidence decreases over time, subject to the condition of monotonic scalability. This is suggestive of the paradox of certainty: one who knows a lot (possessing a highly informative assertion) may tend to ignore the need to obtain new knowledge (Sims[10]). If the informativeness of one's assertion has improved as a result of new evidence, one may tend to ignore the down-side trade-off that the robustness to uncertainty has gotten worse.

Conversely, the informativeness of an assertion may decrease due to new evidence. Proposition 1 then implies that the robustness to uncertainty will increase over time. Large robustness to uncertain future evidence is desirable, but this may augment the analyst's preference for low informativeness.

In both cases the analyst's task is to combine the assessment of robustness with judgment of necessary informativeness in order to identify relevant and reliable assertions for transmission to the customer.

Propositions 1 and 2 imply that robustness and opportuneness are correlated as informativeness changes. That is, as informativeness increases (from one assertion to another) the robustness will worsen (proposition 1) and the opportuneness will also worsen (proposition 2). More explicitly, consider two assertions on the same topic, A and A', where A and A' are scalable on the same monotonically informative scale and A' is more informative than A. Assertion A is more robust to uncertainty than assertion A', and A is also more opportune from uncertainty than A'. One enhances (or worsens) both robustness and opportuneness by the same transition from one assertion to another.

However, correlation, or sympathy rather than antagonism, between robustness and opportuneness is not universal. Many applications—in fields different from the subject of this study—show antagonism between robustness and opportuneness of an assertion, decision, or action (Ben-Haim[11]). In the present application, the sympathy between robustness and

[10] Sims, *Decision Advantage,* p.97.
[11] Ben-Haim, 2006, *Info-Gap Decision Theory.*

opportuneness is a result of the specific relation between informativeness, robustness and opportuneness, and subject to the condition of monotonically scalable informativeness.

The correlated response of robustness and opportuneness to change in informativeness relaxes the analyst's need to study both attributes because improving one necessarily improves the other; one needn't 'buy' robustness to uncertainty by 'selling' opportuneness from uncertainty. Nonetheless, both attributes are important and simultaneous improvement of both does not mean that the improvement is at the same rate, as informativeness decreases.

5. Will China Invade Taiwan? Robustness Analysis

We now demonstrate the qualitative procedure for evaluating the robustness against uncertainty in future evidence. The next section demonstrates the evaluation of opportuneness.

We return to the pair of predictive assertions discussed earlier, repeated here for convenience:

A2: China will invade Taiwan within 6 years.

A2': China will invade Taiwan within 6 months.

A2 and A2' are scalable on the same monotonically informative scale. A2' is more informative than A2, but A2' is also less robust to uncertainty in the evidence as asserted by proposition 1. But questions remain: how robust is A2', and how much less robust than A2? Can A2', or even A2, be confidently transmitted to the intelligence customer? A2' and A2 are points on a continuum of assertions, so perhaps some other assertion on the continuum should be transmitted. We demonstrate a qualitative assessment of robustness because mathematical assessment is infeasible in cases such as this. Our goal is to illustrate the methodology by which the analyst can assess robustness and can choose the assertion to transmit. The analysis here is hypothetical and demonstrative, not a realistic assessment of the actual situation.

We begin with a concise (and by no means comprehensive) summary of relevant evidence (Hou[12]; Sacks[13]).

China maintains that Taiwan is an integral part of its sovereign domain, while also asserting that it prefers peaceful unification. In contrast, China has extended its powers over Hong Kong, eroding Hong Kong's autonomous administrative status and contravening the 1997 agreement transferring Hong Kong to China. China has developed substantial military capabilities that would facilitate an invasion of Taiwan, including ballistic missiles, advanced military aircraft, and a sizeable navy. China has engaged in extensive military exercises around Taiwan.

[12] Philip Hou, 2023, "China won't invade Taiwan—For now", *The Diplomat,* https://thediplomat.com/2023/12/china-wont-invade-taiwan-for-now. Accessed 22.1.2024.

[13] David Sacks, "Why China would struggle to invade Taiwan, Council on Foreign Relations", January 10, 2024. https:// www.cfr.org/article/why-china-would-struggle-invade-taiwan. Accessed 22.1.2024.

However, invading Taiwan would be challenging. The shallow water surrounding Taiwan would keep China's fleet far from the Taiwanese coast, requiring slow movement of forces and equipment to the island, making them highly vulnerable. China has not engaged in a major war for many decades, and has engaged in extensive peaceful investments in many countries around the world in recent years.

Taiwan maintains its legitimacy as an autonomous, democratic, and Western-oriented polity, though it has made no formal declaration of independence. Since 1991, Taiwan has recognized the jurisdiction of China over the Chinese mainland and supports the status quo. Some Taiwanese political parties support an eventual unification with China, while others seek the formal international recognition of Taiwan. Taiwan has extensive and sophisticated defensive military power for repelling an invasion. Taiwan has high mountains, impeding invasion and facilitating guerilla warfare. Taiwanese capital Taipei would necessarily be a major target for Chinese invasion, requiring difficult urban warfare.

Our qualitative assessment of robustness is based on six conceptual proxies for the idea of robustness to uncertainty (Ben-Haim and Demertzis[14]; Ben-Haim[15]). The robustness is large if the assertion is strong in all or most of the following six attributes. It has low robustness if it is weak in all or most of them.

1. *Resilience:* rapid recovery of critical functions. Failures and short-falls are likely, so one should build recovery capability to make one's solutions robust against adverse surprise.
2. *Redundancy:* multiple alternative solutions. "Two is better than one [...] and the three-fold strand will not quickly break" said Solomon (*Ecclesiastes,* 4: 9-12). Robustness to surprise can be achieved by having alternative solutions at hand.
3. *Flexibility* (sometimes called agility): rapid modification of tools and methods. Agility, as opposed to stodginess, is often useful in recovering from surprise. A physical or organizational system, or a policy, or a decision procedure is robust to surprise if it can be modified in real time, on the fly.
4. *Adaptiveness:* adjust goals and methods in the mid- to long-term. Be willing to adjust as your knowledge changes. The thought process for managing deep uncertainty is rarely a once-through procedure. We often have to re-evaluate and revise assessments and decisions. The emphasis is on the longer time range, as distinct from on-the-spot flexibility.
5. *Margin of safety* (sometimes called preponderance): excess of the benefits (and deficiency of the drawbacks) beyond what is actually required. A margin of safety is

[14] Yakov Ben-Haim and Maria Demertzis, "Decision making in times of Knightian uncertainty: An info-gap perspective", *Economics,* The Open-Access, Open Assessment e-journal, Special Issue Radical Uncertainty and Its Implications for Economics. (2016) No. 2016-23: 1-29. url: http://www.economics-ejournal.org/economics/journalarticles/2016-23.

[15] Yakov Ben-Haim, *The Dilemmas of* Wonderland: *Decisions in the Age of Innovation,* (Oxford: University of Oxford Press, 2018).

not a maximum (or minimum); it is a buffer between adequacy and failure, a predominance in number, quality, or importance of relevant attributes.

6. *Comprehensiveness:* interdisciplinary system-wide coherence. The outcome of one's decisions can be impacted by technology, organizational structure and capabilities, cultural attitudes and beliefs, historical context, economic constraints and opportunities, and other factors. Robust decisions will address the multi-faceted nature of the problem at hand.

We assess the robustness of A2' which asserts that China will invade Taiwan within 6 months. The assertion explicitly refers to Chinese intentions, but Chinese capabilities are implicit. Without capability, the intention is vacuous. Our analysis will focus on capabilities. We assess the robustness of the assertion by examining the six proxies. The strength of each proxy is assessed qualitatively as low, moderate, or high.

Resilience. Chinese invasion of Taiwan would require well-coordinated combined-arms action: naval power, infantry, air power, artillery, and intelligence. Resilience is the ability to recover effective aggressive action if elements of this combined action falter. On the one hand, China has a large and diverse military, with significant modern technological capability. However, that military has not been honed in combat, so its resilience has not been demonstrated in practice. Nonetheless, long training and high motivation suggest at least *moderate* resilience.

Redundancy. China's military is substantially larger than any other military in the world, though not all Chinese units possess the same level of professionalism. Nonetheless, the size encompasses *high* redundancy of units.

Flexibility. Chinese society has shown diverse tendencies regarding initiative. Some elements in the economic sector have shown great initiative and flexibility in responding to international markets. On the other hand, Chinese society is traditionally very hierarchical with strong submissiveness to authority. While discipline is essential in military operations, it conflicts with flexibility in response to rapidly changing or surprising circumstances. Chinese military flexibility, especially at the tactical level, is at best moderate, and more plausibly *low.*

Adaptiveness. Operational goals and methods are the province of staff officers and high-level field officers. Strategic goals and methods are the responsibility of senior political leaders. These elite cadres are likely to have high professionalism and to show *high* adaptiveness.

Margin of safety or preponderance. The Chinese military is vastly larger than that of Taiwan. The same is true of their respective populations. Levels of military professionalism are likely similar in the two countries. The margin of safety of a Chinese invasion is *high.*

Comprehensiveness. A Chinese invasion of Taiwan would entail military challenges, domestic political factors, and multilateral international tensions or even confrontations. A Chinese

invasion would weaken Chinese attempts to establish world leadership through cooperative investment and infrastructure development in many countries. A Chinese invasion could terminate attempts to strengthen cooperative relations with the United States. A Chinese invasion would likely raise Russia's standing in the world. These international factors could enhance the military challenges and may even incite adverse domestic reaction. The comprehensiveness of the invasion is at best moderate, and more plausibly low.

In summary, the strengths of the six proxies have been assessed as: moderate, high, low, high, high, low. If we conceptually "average" these six assessments we could say that the overall robustness to uncertainty is between moderate and high. Confidence in assertion A2' that China will invade Taiwan in the next 6 months is not high, but it is greater than moderate. The analyst may transmit the 6-month prediction with confidence between moderate and high.

6. Will China Invade Taiwan? Opportuneness Analysis

We now demonstrate the qualitative assessment of opportuneness from uncertainty of the predictive assertion A2' whose robustness was considered in section 5.

Opportuneness is the conceptual complement of robustness, and the mind-set of the opportune windfaller is fundamentally different from the mind-set of the robust satisficer. The opportune windfaller views uncertainty as the potential for favorable surprise, and tries to exploit this propitious uncertainty to achieve an outcome that is better than anticipated. In contrast, the robust satisficer views uncertainty as a threat and tries to protect against pernicious uncertainty by achieving an outcome that is no worse than a critical requirement. Robustness against pernicious uncertainty is large if most or all of the proxies discussed earlier hold strongly. Opportuneness from uncertainty is large if at least one of the following proxies holds strongly.

1. *Uncertainty is great.* The vast unknown entails possibilities for wonderful outcomes. Possible rewards are unknown or even unimaginable, and great reward is possible. Severe risks seem avoidable or do not appear immediate.
2. *Past experience has limited relevance.* The situation under consideration is new or the context is unfamiliar. The "rules of the game" are different and some of the 'players' are unfamiliar or totally unknown.
3. *The situation is changing rapidly.* It is unclear if things are improving or getting worse. Anticipation or foresight is limited. Opportunities must be exploited quickly or they may pass.

We assess the opportuneness of A2' which asserts that China will invade Taiwan within 6 months. As before, we focus on Chinese capabilities. We assess the opportuneness of the assertion by examining the three proxies, each of which is assessed qualitatively as low, moderate, or high based on the contextual knowledge summarized in section 5.

Military capabilities are intended to achieve tactical, operational, or strategic goals by the threat or use of force. Degradation of those capabilities is an inherent possibility. A wonderful outcome is one in which the goals that are achieved are wonderfully better than anticipated, or the degradation is wonderfully less than anticipated. The employment—by threat or use—of military capabilities is highly opportune if a wonderful outcome is plausible in light of the ambient uncertainties. We now consider the three proxies.

Uncertainty is great. The relevant uncertainties, from the Chinese perspective, relate to three issues. (1) Taiwanese defensive military capabilities in comparison to Chinese offensive capabilities, (2) Taiwanese resolve in repulsing Chinese invasion, and (3) international support of Taiwanese independence in response to Chinese invasion.

Taiwanese defensive capabilities are large. Chinese persistence can surely overcome them, though the cost in military personnel and equipment would be large.

Taiwanese resolve is generally strong. Some elements of the Taiwanese population support unification with the mainland, but those elements may be subdued or silent when confronted with military invasion rather than diplomatic overtures.

International support for Chinese invasion will be mixed. Western democracies—the United States and the European Union primarily—will surely support Taiwan. However, that support will most likely be diplomatic and provision of military supplies rather than direct military engagement. Other countries with whom China has developed positive relations through investment and infrastructure development may be more supportive of China's claim to sovereignty over Taiwan. However, these countries may restrain further relations with China due to apprehension of potential Chinese aggression.

Overall, the uncertainties regarding Chinese opportunities are not highly favorable; at best this proxy is *moderate.*

Past experience has limited relevance. The China-Taiwan conflict is not new and is highly familiar. China has been threatening Taiwan for decades, but has not employed actual kinetic military aggression. Taiwanese leaders and most of the public have shown resolve and persistence in responding to Chinese threats. The opportuneness of past experience is *low.*

The situation is changing rapidly. This is clearly not the case. China-Taiwan relations have been frozen in a state of pending war for decades. The opportuneness of this proxy is *low.*

In summary, the strength of the three proxies for opportuneness are moderate, low, and low. Clearly Chinese invasion of Taiwan does not entail serious potential for wonderful windfall outcomes. The opportuneness of assertion A2' is low.

Combining the conclusions of this and the previous section we see that assertion A2' is fairly robust against adverse uncertainty, but not particularly opportune to favorable surprise. More explicitly, the (hypothetical) assessment is that the military capability of China is plausibly sufficient to support invasion of Taiwan in the next six months, but this would be challenging to Chinese forces and surprises that are favorable to China are not plausible.

7. Concluding Discussion

Intelligence analysts formulate assertions that are informative, reliable, and relevant to their customers, such as "This will happen soon" or "That occurred within a radius of 2 km". More generally, we have considered assertions that can be expressed on a scale that may be quantitative (e.g. a duration in months, or a size in kilometers) or qualitative (e.g. short, moderate, or long time frame). The assertions are monotonically informative in the sense that the informativeness increases as one moves down the scale (e.g., 1 km is more informative than 2 km; short time frame is more informative than long time frame). Some assertions are not scalable, and even if they are, not all scales are monotonically informative. We only considered assertions that are scalable and monotonically informative.

Analysts employ evidence and understanding to formulate assertions that are informative and reliable. Proposition 1 identifies generic conditions in which scalable and monotonic informativeness of an assertion trades off against its reliability: Informativeness improves as reliability deteriorates. This presents a dilemma in formulating assertions, because both informativeness and reliability are desirable. Our first focus has been on developing an analytic methodology for assessing this trade-off and managing this dilemma.

We use the concept of robustness to uncertainty as developed in info-gap decision theory to assess the reliability of an assertion. The robustness is large if the informativeness remains above a specified required level even if the evidence changes substantially. The robustness of an assertion is low if even small changes in the evidence can cause the informativeness to fall below the required level. Info-gap robustness provides a methodology for evaluating the reliability of an assertion, or for identifying the most informative assertion that has acceptable reliability.

Robustness responds to the adverse or pernicious side of uncertainty, but uncertainty can be favorable and propitious. An assertion has great opportuneness from uncertainty in future evidence if a small increment of evidence can dramatically improve the informativeness of the assertion. Proposition 2 identifies generic conditions in which scalable and monotonic informativeness of an assertion trades off against its opportuneness: The informativeness gets worse as its opportuneness from uncertain future evidence improves. This presents a different dilemma, because both informativeness and opportuneness from uncertainty are desirable attributes of an assertion. Our second focus has been on developing an analytic methodology for assessing and managing this dilemma. The concept of opportuneness from uncertainty, as developed in info-gap decision theory, is used to assess the opportuneness of an assertion.

Propositions 1 and 2 imply that robustness and opportuneness are sympathetic: they both improve or both get worse as the informativeness of an assertion changes. Robustness against pernicious uncertainty will usually engage the analyst more than opportuneness from propitious uncertainty. Nonetheless, by enhancing robustness one also enhances opportuneness, though not necessarily to the same degree (perhaps more, perhaps less).

We illustrate the trade-offs between informativeness and robustness, and between informativeness and opportuneness, with an example demonstrating the relevance to intelligence analysis. The example considers assertions about the time frame for a Chinese invasion of Taiwan. The example is hypothetical and qualitative, and not intended as a realistic assessment of the actual situation. The example illustrates the evaluation and interpretation of the concepts of robustness and opportuneness, and demonstrates how the info-gap methodology is used in choosing reliable and promising intelligence assertions.

We have explored three properties of assertions: informativeness, robustness to uncertainty in the evidence, and opportuneness from uncertainty in the evidence. We have said nothing about the truth of the assertion. For instance, the assertion that WW II occurred between 1920 and 1922 is far more informative than assertion A1' in section 1, but this assertion is false. The robustness (of an assertion) to uncertain future evidence can be viewed as a tentative proxy for the truth of that assertion. An assertion whose informativeness would not change despite the accumulation of vast evidence may tentatively be viewed as true. But truth is elusive. Large robustness supports the validity of the assertion but does not prove its truth.

The opportuneness (of an assertion) from uncertain future evidence is not a truth-proxy like the robustness. Intelligence analysts may therefore tend to focus more on robustness than on opportuneness. However, the opportuneness of an assertion is an indication of the utility of new evidence. An assertion that is very opportune to new evidence is an assertion whose informativeness could substantially improve with small increments in evidence. Opportuneness motivates the search for new evidence, and can indicate directions in which to search.

Appendix: A Derivation of Quantitative Robustness and Opportuneness Functions for Section 2

In this appendix we derive the robustness and opportuneness functions for the examples in section 2.

The scalar estimate of s, and the corresponding informativeness, will perhaps change as evidence accumulates. The future informativeness is uncertain as expressed by the following info-gap model based on the current estimate of s:

$$U(h)=\left\{s:\quad \left|\frac{s-\tilde{s}}{w}\right|\le h\right\},\quad h\ge 0 \qquad (9)$$

where w is a known positive value.

The robustness to uncertainty is the greatest horizon of uncertainty at which the informativeness is guaranteed to be no worse (no larger) than s_c. That is, the robustness is the greatest horizon of uncertainty at which the following requirement is guaranteed:

$$s \le s_c \qquad (10)$$

The robustness function is defined:

$$\hat{h}(s_c) = \max\left\{h: \quad \left(\max_{s \in U(h)} s\right) \le s_c\right\} \qquad (11)$$

The inner maximum in eq.(11) is $\tilde{s} + wh$ from which one readily finds the following expression for the robustness:

$$\hat{h}(s_c) = \frac{s_c - \tilde{s}}{w} \qquad (12)$$

or zero if this is negative.

The opportuneness from uncertainty is the lowest horizon of uncertainty at which it is possible for the informativeness to be at least as good as s_w. That is, the opportuneness is the lowest horizon of uncertainty at which the following aspiration is possible:

$$s \le s_w \qquad (13)$$

The opportuneness function is defined:

$$\hat{\beta}(s_w) = \min\left\{h: \left(\min_{s \in U(h)} s\right) \le s_w\right\} \qquad (14)$$

The inner minimum in eq.(14) is $\tilde{s} - wh$ from which one readily finds the following expression for the opportuneness:

$$\hat{\beta}(s_w) = \frac{\tilde{s} - s_w}{w} \qquad (15)$$

or zero if this is negative.

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