APPLES TO APPLES, FIGHTERS TO SUBMARINES: COMPARATIVE ANALYSIS OF CONVENTIONAL CAPABILITY-BASED SIGNALING CAPACITY THROUGH TECHNOLOGICALLY WEIGHTED STATE ARSENAL INDEXING

by Lee Habib Roberts

Under publication review by Journal of Military Studies

Last revised: November 29, 2021

Abstract: In this paper, I propose a new contribution to the field of comparative analysis of state conventional military capabilities. First, I review other scholars' perspectives on the merits of comparing capabilities, arguing that the most accessible insights lie in the signals sent by state arsenals rather than in predicting conflict outcomes judging from state armament. Second, I present the conventional firepower potential indexing (CFPI) method and demonstrate that coding for tactical role and degree of technological sophistication enables previously unfeasible estimative comparisons of deterrent signaling value. Third and last, I apply CFPI scoring to the conventional arsenals of the United States and the four prospective adversary states named in that country's most recent National Defense Strategy (China, Russia, North Korea, and Iran), deriving conclusions that would be more difficult without accessible comparative analysis.

Biographical information: Lee Habib Roberts is a U.S. Army Strategic Intelligence Officer and a political science doctoral student at George Mason University. He is a graduate of the United States Military Academy at West Point and holds master's degrees in international security and strategic intelligence from George Mason University and the National Intelligence University respectively. Findings, views, and opinions in this article are strictly his own and should not be construed as representing the official position of the United States Army, the Department of Defense, or any element of the U.S. Government.

Apples to Apples, Fighters to Submarines: Comparative Analysis of Conventional Capability-Based Signaling Capacity through Technologically Weighted State Arsenal Indexing

Introduction

In May of 2018, then-President of Ukraine Petro Poroshenko made a remarkable assertion. During an address commemorating the end of World War II, he congratulated his Ministry of Defense on the Ukrainian military becoming one of the ten most powerful in Europe. (Kuzmenko 2018) Although most listeners would not register this as unusual, military analysts and security scholars were likely intrigued by the claim: how could Poroshenko make this declaration with any confidence when the elements of military power are so extensive and varied as to defy authoritative comparison?

Investigative journalist Oleksiy Kuzmenko reveals that Poroshenko cited rankings from a commercial and self-styled entertainment site called *Global Firepower Index* (*GFI)* run by an entrepreneur whose other ventures include a wedding dress customization site. Kuzmenko's reporting revealed several things to be true about *GFI*: (1) its opaque methods yield questionable conclusions; (2) it lacks credibility with serious analysts; and yet (3) it is widely cited by relatively reputable journalistic outlets including *Newsweek* and *Forbes*.

While shoddy work by a staff eager to inject some high notes into a leader's remarks might be to blame, the episode raises a genuine issue: given the importance of military strength (however conceived) to the international distribution of power, the lack of accessible, rigorous methods for comparing military capabilities suggests that journalists and government staff may continue citing commercial sources purporting to perform such analysis even if they lack credibility.

In this paper, I propose a new contribution to the field of comparative analysis of state conventional military capabilities. First, I review other scholars' perspectives on the merits of comparing capabilities, arguing that the most accessible insights lie in the signals sent by state arsenals rather than in predicting conflict outcomes judging from state armament. Second, I present the conventional firepower potential indexing (CFPI) method and demonstrate that coding for tactical role and degree of technological sophistication enables previously unfeasible estimative comparisons of deterrent signaling value. Third and last, I apply CFPI scoring to the conventional arsenals of the United States and the four states named in that country's most recent National Defense Strategy (China, Russia, North Korea, and Iran), deriving conclusions that would be more difficult without accessible comparative analysis.

Why Compare Capabilities?

In this section, I review selected perspectives on merits and challenges inherent in making comparisons between state capabilities. Noting that capability analysis—particularly arsenal analysis—alone is unreliable in predicting conflict outcome, I posit that the prevalent use for major military hardware is to contribute to strategic signaling rather than to prosecute conflict. I then highlight extant methods for arsenal analysis and derive principles for a signaling value-focused approach.

Conflict Outcome Prediction versus Signaling Value Interpretation

While it seems intuitive to apply comparative arsenal analysis to conflict outcome prediction, compelling scholarship indicates materiel-focused analysis is unreliable. Carroll and Kenkel find that capability-based conflict outcome prediction performs only one percent better than a coin flip, while their own substantially improved method fares only 20% better. (Carroll and Kenkel 2019) Biddle demonstrates convincingly that insight into conflict outcome comes from states' employment of their forces during combat, an approach that to have predictive value would require reliable estimates of how a state's military *would* act during prospective conflict. (Biddle 2004)

These lessons run into an empirical challenge: most states do not use their arsenals for interstate conflict. Sarkees and Wayman's exhaustive examination of interstate conflicts reveals that in the 60 years following World War II, fewer than 60 state governments—less than a third of the 188 accorded undisputed sovereign status by the United Nations—engaged in interstate armed conflict. In the preceding 60 years, over 120 distinct states engaged in such conflict over substantially longer durations. (Sarkees and Wayman 2010) The modern era sees most states purchasing and retaining conventional weapons that spend the vast majority—or entirety—of their existences unused in combat.

It is not clear that most states could employ their arsenals in any sustained way even if they were to commit to interstate conflict. An International Peace Institute survey of United Nations Peacekeeping Operations (UNPKO) suggests most states struggle to project and sustain even small fractions of their militaries over short distances for more than a few weeks. (Coleman and Williams 2017) Nor is this challenge limited to the generally smaller and more developing pool that typically participates in UNPKO; a study by RAND concluded that the United Kingdom, France, and Germany—developed states with some prevalence of premier conventional armaments—would each be hard-pressed to marshal, deploy, and sustain a single brigade of combat power *within Europe* for more than a month without the undertaking becoming the main effort of their respective militaries and eclipsing any capacity for other contingencies. (Shurkin 2017)

Given that the majority of state-owned military hardware never sees combat and that most states struggle to employ their arsenals, continuing, widespread procurement of combat systems without addressing logistical deficiencies suggests a major aim of acquiring weaponry is merely having it. Scholars identify weapon possession as the capability dimension of conventional strategic signaling capacity, where credibility (reputational willingness to employ weapons for strategic aims) and communication (explicit statements from one state to others) constitute the other two dimensions. (Haffa 2018; Morgan 2012; Gerson 2009)

The premise that conventional weapons contribute to a state's strategic signaling capacity yields an avenue for comparative analysis. Where most weapons are never employed in conflict, all weapons (save those successfully concealed) contribute to signaling. The relative signaling contribution of a weapon is a less complicated phenomenon to estimate than its prospective combat use, an activity that entails innumerable factors. With this in mind, I survey selected methods of arsenal computation to derive lessons for signaling capacity estimation and identify precursor techniques for the CFPI method.

Adapting Arsenal Computation Methods for Signaling Value

Representing an impressive recent innovation in comparative arsenal analysis, the *Distribution of Military Capabilities* (*r*DMC) dataset uses data from the International Institute for Strategic Studies' (IISS) *The Military Balance* to code military technology distribution among 173 countries from 1970 to 2014. (Gannon 2021) While no public resource currently matches *r*DMC's depiction of the prevalence of *types* of technology in state arsenals throughout this period, *r*DMC makes no distinction between systems within each technology type on the basis of sophistication or effectiveness. Analysts can use *r*DMC to see which states have—for example—air defense missile systems, their quantities, and how distribution over time changes. However, aging, relatively incapable systems code identically to advanced systems that cost far more and arguably contribute to more compelling strategic signals. While this criticism is simple, an accessible, informative solution to the comparison problem is another matter. The ensuing paragraphs explore computational methods that attempt quality-based distinctions between weapons.

A majority of extant analytic methods attempting quality distinctions between conventional weapons purport to project their performance under certain combat conditions. The archetype of these is the venerable Lanchester set of models, which—despite being re-validated by RAND as highly informative for engagement modeling—undercuts its feasibility by assuming large-scale engagements involving simultaneously firing masses of weapons. (Lanchester 1916; Darilek et al. 2001) Innovations in this tradition modifying Lanchester's concepts for guided weapons and modern defenses similarly attempt attritive results rather than inherent comparative value for the systems themselves, attracting criticism for unwieldiness. (Hughes 1995; Armstrong 2013; Lucas and McGunnigle 2003)

Three techniques that distinguish themselves from the Lanchester and related conflict outcome methods are: (1) the summation technique in the United States' Naval Postgraduate School's aggregated firepower score (AFS) method; (2) Dubois et al.'s algebraic incorporation of combat power *potential* in their *Concise Theory of Combat Power*; and (3) the coefficient weighting technique in the United States Army Concepts Analysis Agency's Weapon Effectiveness Index (WEI) method. (U.S. Naval Postgraduate School 2000; Dubois, Hughes, and Low 1997; U.S. Army Concepts Analysis Agency 1991)

The AFS method also attempts engagement outcome prediction, but approaches it distinctly from Lanchester and other attritive tools. While Lanchester and salvo models attempt to project casualties and survivors by matching weapon systems on each side of an engagement, AFS adopts the straightforward but elegant solution of coding values to different types of equipment, multiplying these by their quantity, and then adding them to the scores of other systems to aggregate a score for all equipment arrayed in a given engagement. (Naval Postgraduate School 2000) While arguably far too reductive for predicting the outcome of an activity as complex as combat, AFS provides an obvious precursor technique for a comparative method for estimating inherent signaling value for weapon systems rather than predicting their combat performance.

In their theory, Dubois, Hughes, and Low express the potential firepower inherent in any weapon system as part of a comprehensive combat power concept. (Dubois, Hughes, and Low 1997) Isolating a facet of combat power that consists solely of the inherent potential firepower of a weapon system offers a proxy for signaling; the capability-based signaling value of a weapon logically resides in its *potential* for employment, potential being a property that does not require actual use to manifest.

Finally, the WEI method piloted by the now-defunct U. S. Army Concepts Analysis Agency differentiated between degrees of technological sophistication among weapons of the same tactical role with weighted coefficients. (U.S. Army Concepts Analysis Agency 1991) A major limitation of WEI was the need for recurrent re-evaluation by panels of experts with divergent views on the indexed systems' effectiveness in combat, one of the shortcomings that that Ben-Haim partly mitigates by adding robustness. (Ben-Haim 2018) Avoiding the complex task of engagement outcome prediction by focusing on signaling value contribution means a weighted coefficient concept can be used without constant re-evaluation for effectiveness.

The next section of this paper incorporates WEI's weighting concept, AFS' role-sensitive summation approach, and Dubois et al.'s expression of potential into processes to compute relative signaling capacity contribution by conventional systems.

The Conventional Firepower Potential Indexing (CFPI) Method

This section describes the CFPI Method's computational processes. First, I algebraically derive the CFPI's processes from the precursor techniques. Second, I illustrate CFPI's accounting for tactical roles and technological sophistication of weapons using a comparative example (China and Russia air-focused CFPI in 2021). Third, I note constraints and unexplored possibilities of CFPI-informed analysis.

Deriving an Expression for Conventional Firepower Potential

The CFPI method uses conventional firepower potential as a proxy for capability-based strategic signaling capacity. The following computational processes are intended only to abstractly score capability contributing to signaling. See *Constraints, Trade-offs, and Possibilities* at the conclusion of this section of the paper for a summary of the distinctions between using indexed approximations of capability for signaling value versus engagement outcome projection, something that CFPI never attempts to do.

The firepower potential of a set of conventional weapons is the sum of the products of each system's role, technological sophistication, and quantity. In this approach, CFPI builds on the precursor techniques of AFS, DuBois et al.'s algebraic expression of combat power, and the WEI method's weighted coefficient approach. These techniques are expressed as follows:

$$\mathrm{FPI} = \left(\sum_{i=1}^{n} \mathrm{X_i}\right)\mathrm{S_i} \qquad \vec{P} = f\,[\,\alpha N, \vec{u}\,] \qquad WEI = c_f F + c_m M + c_s S$$

The AFS expression yields the total firepower assessed for weapons of type i assigned a relative firepower score of S_i and present in quantity X. Dubois et al. conceive of combat power, P, as a vectored quantity that exists as a function of potential combat power (u) and realizing actions (αN). A helpful simplification of WEI expresses a weapon's score as the sum of the firepower (F), mobility (M), and survivability (S) scores assigned to all weapons of a particular type once modified by a coefficient intended to compare specific models with a base model. (Krondak et al. 2007)

Eliminating the aim of predicting combat effectiveness or engagement outcomes means that only certain elements of these concepts apply to an index of strategic signaling value. Combining applicable concepts of the three methods means that CFPI score—an approximation of the *potential* firepower inherent in the technology considering no other factors or actions—for a certain number of weapon systems of the same type and technological sophistication is expressed:

$$U_{\mathrm{oe}} = \alpha_{\mathrm{oe}} (\Sigma t_{\mathrm{h}})$$

U is potential firepower, o is a domain marker (air, land, or naval), and e designates the type of system (e.g., destroyer, main battle tank). The numeric score in the index is the product of α, the weighted value attributes for the system (see *Tactical Roles and Generational Tiers*), and the sum of the quantities of all systems of that type and technological tier, or t_{h}. Where there are multiple technological tiers among the same weapon type, these are accounted for by separate summation as follows:

$$U_{\mathrm{oe}} = \alpha_{\mathrm{oe}} (\Sigma t_{\mathrm{h1}} + \Sigma t_{\mathrm{h2}})$$

This expresses CFPI score for a group of one weapon type drawn from two generational tiers of sophistication h_1 and h_2. CFPI divides the global pool of major conventional weapons into five such groupings across the three conventional domains of air, land, and sea. Score focused on a single domain is expressed:

$$U_{\mathrm{o}} = U_{\mathrm{oe1}} + U_{\mathrm{oe2}} + \ldots$$

This expression uses as many terms as necessary to account for all types of weapon categorized as belonging to the domain. To make this concrete, the following expresses the CFPI score of a state's major conventional weapons focused on the air domain:

$$U_{\mathrm{a}} = U_{\mathrm{ai}} + U_{\mathrm{am}} + U_{\mathrm{ag}} + U_{\mathrm{ad}}$$

The a subscript represents the air domain, while other subscripts represent weapon systems whose firepower potential focuses on that domain: i for air superiority fighters (interceptors); *m* for multirole fighters; *g* for ground attack aircraft; and *d* for air defense missile systems. The total CFPI for a state arsenal incorporates the firepower potential-possessing (and therefore signal value-contributing) systems focused on all three domains, expressed:

$$U_p = U_a + U_l + U_n$$

The subscript *p* denotes conventional firepower across all domains, making U_p the overall notation for a state's CFPI score. The other subscripts correspond to domains: *a* for air; *l* for land; and *n* for naval ("naval" used in place of "sea" for precision because of the inclusion of naval aviation systems that resemble fixed-wing systems categorized as air-focused).

The preceding paragraphs algebraically express the process of indexing a state's conventional arsenal into firepower potential scores. To enumerate these algebraic expressions, we must compute a value for the coefficient α. The next subsection details enumeration of α with proxy values for tactical role and relative technological sophistication of each system in the CFPI.

Tactical Roles and Generational Tiers

CFPI derives a relative, unitless value for each system type's intended tactical role and a generational tier coefficient for technological sophistication. The overall coefficient applied to each system quantity is expressed:

$$\alpha_{thoe} = G_h r_{oe}$$

The subscript t_h denotes technological sophistication of degree *h*. *G* is the constant multiplier associated with degree *h*. The variable *r* represents the conventional firepower potential—unmodified by technological sophistication—for all systems *e* in domain *o*. Numeric values for *r* and *G* permit numeric CFPI scores.

To estimate *r*-values for a given weapon type weapon, CFPI first computes a "raw" firepower potential and then weights this for the system's *advertised* versatility in releasing its munitions and ostensibly engaging other systems. For brevity, I refer to these three factors as the normalized yield ratio, release versatility, and engagement versatility. The following paragraphs derive each of these and concretely illustrate the process with the multirole fighter weapon type.

"Raw" firepower potential is the product of absolute values of a system's single-engagement explosive yield, index munition range, and operational range (or two-hour travel range in the case of naval vessels) with all ranges expressed in hundreds of kilometers and the process removing all units. In every system's case, this product is multiplied by a scaling constant of 0.036 and rounded to the nearest whole number solely to achieve a more intuitive scale across the CFPI. In the following expression—not reflecting these last two scaling steps—*m* represents the index munition (a munition commonly employed by the index system of this weapon type).

$$Raw\ FP_{oe} = |\,Engagement\ yield_{moe}\,| * |\,Range\ in\ 100s\ of\ km_{moe}\,| * |\,Operational\ range\ in\ 100s\ km_{oe}\,|$$

For engagement explosive yield, CFPI uses estimated energy yield in megacalorie (Mcal) TNT equivalence of the index munition's explosive mass assuming it behaves consistent with tritonal explosive's properties (a mixture of 80% trinitrotoluene and 20% aluminum commonly employed in modern munitions and releasing approximately 18% more energy than a comparable mass of TNT). (U.S. Department of Energy 2002) This assumption uses the U.S. National Institute for Standards and Technology's TNT equivalence convention of one gram of TNT releasing 4.184 kilojoules or one kilocalorie; one kilogram of tritonal explosive would yield approximately 1.18 megacalories. (U.S. Department of Commerce 2008) This in turn is multiplied by aimed releases of the index munition by the index system in the space of a single minute.

$$Engagement\ yield_{moe} = Tritonal\ mass\ equivalent\ in\ kg * 1.18\ \text{Mcal} * Aimed\ releases\ in\ 1\ minute$$

The following steps compute the *r*-value for multirole fighter aircraft. CFPI uses the American F-16C as an index system for multirole fighter jets and the GBU-12 precision air-to-ground bomb as the index munition.

$$Engagement\ yield_{\text{GBU-12}} = 87\ \text{kg} * 1.18\ \text{Mcal} * 1\ \text{release} = 102.66\ \text{kg-Mcal-release}$$

Next, we multiply the engagement explosive yield by the index munition range and the index system range. Multiplying this product by the scaling coefficient of 0.036 and rounding provides the normalized yield ratio, the computed firepower potential precursor of tactical role value.

$$Raw\ FP_{am} = |\,Engagement\ yield_{\text{GBU-12}}\,| * |\,Range\ in\ 100s\ km_{\text{GBU-12}}\,| * |\,Range\ in\ 100s\ km_{\text{F-16C}}\,|$$

$$Raw\ FP_{am} = 102.66 * 0.25 * 8.6 = 220.72$$

$$Normalized\ yield_{am} = 0.036 * Raw\ FP_{am} = 0.036 * 220.72 = 7.95 \approx 8$$

The last step in deriving role value for a weapon system type is to apply ordinal weight for release versatility and engagement versatility. Release versatility expresses the index system's advertised adaptiveness to target behavior when releasing the index munition, while engagement versatility accounts for two factors: (1) whether the index system is ordinarily intended to engage in one or multiple domains; and (2) whether the index system is ordinarily configured to engage the systems designed to neutralize it. Table 1 offers a rubric for determining release and engagement versatility.

Tab. 1: CFPI Release and Engagement Versatility Rubric

Value	Release Versatility	Engagement Versatility
3	Index system releases systems of release versatility 2 that release the index munition, giving the index system multiple levels of release articulation and adaptiveness to target behavior	Index system is ordinarily intended to engage systems in multiple domains and is ordinarily configured to engage those systems purpose-built to target the index system
2	Index system can maneuver leading up to and during index munition release allowing a larger window of adaptation to target behavior	Index system is ordinarily intended to engage systems in multiple domains or is ordinarily configured to engage those systems purpose-built to target the index system
1	Index system must be motionless to release the index munition; the index system cannot make dynamic adaptations to target behavior immediately leading up to or upon release of the index munition	Index system is ordinarily intended to engage systems in only one domain and is not ordinarily configured to engage those systems purpose-built to target the index system

Remembering that CFPI's tactical role value for a weapon system type is the product of normalized yield, release versatility, and engagement versatility, the tactical role value of multirole fighters thus computes:

$r_{am} = \textit{Normalized yield}_{am} * \textit{Release versatility}_{am} * \textit{Engagement versatility}_{am} = 8 * 2 * 2 = 32$

Table 2 contains the weapon types, index systems and munitions, normalized yields, versatilities, and *r*-values of the CFPI method, which does not consider operational readiness, ammunition availability, environmental effects, crew proficiency, or any other factors. Where possible, index systems selected are examples of the middle (or "competitive") generational tier. CFPI uses index systems in a markedly different way from the WEI precursor, which compared every single other scored system to the index system. Instead, CFPI's index systems set the tactical role value for all systems of one type. Since CFPI scores are only abstract representations of relative capability-based contributions to signaling (rather than to performance), specific technical differences between same-type, same technological generation systems are superfluous.

To enumerate $G_h r_{oe}$ (setting the value of the coefficient α_{thoe} and enabling calculation of numeric CFPI scores), the CFPI method employs five different weighted degrees of relative technological sophistication: obsolete; aging; competitive; advanced; and cutting-edge. These correspond to the four-tier technological grading employed by the U.S. Army's *Worldwide Equipment Guide* (*WEG*) as of 2021 with several modifications noted in Table 3. An important difference is that the *WEG*'s tier numbers decrease as sophistication increases, with tier 1 most sophisticated and tier 4 least sophisticated. CFPI's tiers increase directly with degree of sophistication for two reasons: (1) although the *WEG* was useful in designing CFPI, the two need not be perpetually linked; and (2) rather than recalibrating tiers in an inverse tier-number scale, CFPI can add new systems to appropriate existing tiers or create new tiers as generations of technology emerge.

Like the *WEG* tiers, CFPI tiers correspond roughly to introduction dates of weapon systems exhibiting newer technological characteristics. Using weighted coefficients for sophistication and representing capability-based contribution to strategic signaling value rather than conflict outcome precludes the need to compare or adjust systems toe-to-toe. CFPI thus understands state possession of any system of a particular role in a particular tier the world over to contribute the same capability-based element to strategic signaling, enabling comparative analysis across the global system of arsenals. I next flesh out an example of such comparison through CFPI scores for the air-focused components of Chinese and Russian arsenals in 2021.

Tab. 2: Weapon System Role Values

Domain	Role	Index System	Index Munition	Normal Yield Ratio	Versatility		*r*-Value
					Release	Engagement	
Air	Air Superiority Fighter	F-16A/B Blk 15/20 (USA)	AIM-120	6	2	2	24
	Multirole Fighter	F-16C/D Blk 52+ (USA)	GBU-12	8	2	2	32
	Ground Attack Aircraft	A-10C (USA)	GBU-12	12	2	1	24
	Air Defense (Missile)	MIM-104C (USA)	PAC-2	24	1	1	24
Land	Main Battle Tank	M1A2SEP (USA)	M830A1	2	2	2	8
	Armored Fighting Vehicle	M2A3 (USA)	M792	1	2	2	4
	Self-Propelled Cannon Artillery	M109A6 (USA)	M483A1 DPICM	2	1	1	2
	Towed Cannon Artillery	M119A1 (USA)	M915 DPICM	1	1	1	1
	Rocket Artillery	M270A1 (USA)	M26A2 DPICM	3	1	1	3
	Rotary Wing Attack	AH-64A (USA)	AGM-114N	4	2	2	16
	Multirole Armed Rotary Wing	MH-60A (USA)	7.62x51mm NATO	1	2	2	4
	Air Defense (Gun)	ZSU-23-4 (RUS)	23x152B BZT	1	1	1	1
	Surface-to-Surface Missile	DF-16 (PRC)	DF-16 Conventional	24	1	1	24
Naval	Aircraft Carrier	America-Class (USA)	AGM-154C via AV-8B	400	3	3	3,600
	Ship-Based Armed Rotary Wing	MH-60S (USA)	AGM-114B	3	2	1	6
	Ship-Based Armed Fixed Wing	AV-8B (USA)	AGM-154C	8	2	2	32
	Ground-Based Armed Maritime Fixed Wing	P-8A (USA)	Mk-46 Mod 5	12	2	1	24
	Cruiser	Ticonderoga-Class (USA)	RGM-109E	75	2	3	450
	Destroyer	Arleigh Burke (flt. II) (USA)	RGM-109E	50	2	3	300
	Frigate	Grigorovich (RUS)	P-800	35	2	2	140
	Corvette	Type 056A (PRC)	YJ-83K	15	2	2	60
	Missile Boat / Fast Attack Craft	Type 022 (PRC)	YJ-83K	12	2	1	24
	Tactical Submarine (Nuclear-Powered)	Los Angeles-Class (flt. III) (USA)	RGM-109E	50	2	3	300
	Tactical Submarine (Non-nuclear-powered)	Kilo-Class (Improved) (RUS)	53-65M	15	2	2	60
	Ground-Based Anti-Ship Missile	YJ-62 (PRC)	YJ-62	30	1	1	30

Reference: U.S. Army Worldwide Equipment Guide

Tab. 3: WEG-CFPI Technological Tier Conversion and Coefficient Weighting

WEG Tier	**CFPI Tier**	**Descriptor**	***G*-value**	**Adjustments (Additions)**
1(+)*	4	Cutting-edge	6	System introduction establishes new generation; long-range missile systems of *WEG* tier 1
1	3	Advanced	4	Long-range missile systems of *WEG* tier 2
2	2	Competitive	3	Long-range missile systems of *WEG* tier 3; short-range missile systems of *WEG* tier 1; wheeled armored fighting vehicles of *WEG* tier 1; towed anti-aircraft systems of *WEG* tier 1
3	1	Aging	1	Long-range missile systems of *WEG* tier 4; short-range missile systems of *WEG* tier 2; wheeled armored fighting vehicles of *WEG* tier 2; towed anti-aircraft systems of *WEG* tier 2
4	1	Aging	1	Short-range missile systems of *WEG* tier 3; wheeled armored fighting vehicles of *WEG* tier 3; towed anti-aircraft systems of *WEG* tier 3
4(-)*	0	Obsolete	0	Short-range missile systems of *WEG* tier 4; wheeled armored fighting vehicles of *WEG* tier 4; towed anti-aircraft systems of *WEG* tier 4; systems of *WEG* tier 4 operated in a quantity less than 1% of their lifetime production run

Reference: U.S. Army Worldwide Equipment Guide

*Denotes an equivalent tier that does not labeled as such in the *WEG*

Example – CFPI Scoring of Chinese and Russian Air-focused Systems, 2021

In this brief demonstration, the computational procedures from the previous section generate index scores for the conventional weapon systems of the People's Republic of China and the Russian Federation in the air domain as of 2021. Beginning with the expression for overall CFPI score, I expand to express score within a single domain (air), and expand and compute CFPI score for a single system type (multirole fighters). I then illustrate how even one domain's CFPI score for two states allows comparative capability-based signaling analysis that previously would not have been possible. The expression for total CFPI score is:

$$U_p = U_a + U_l + U_n$$

Focusing on the air domain:

$$U_a = U_{ai} + U_{am} + U_{ag} + U_{ad}$$

Multirole fighters specifically:

$$U_{am} = (G_0(\Sigma t_{0am}) + G_1(\Sigma t_{1am}) + G_2(\Sigma t_{2am}) + G_3(\Sigma t_{3am}) + G_4(\Sigma t_{4am}))\ r_{am}$$

The above results from expanding the expression for a single system type to include systems at each of the five generational tiers of the CFPI. Tables 4 and 5 list multirole fighter inventories of China and Russia in the year 2021 per the International Institute for Strategic Studies' *The Military Balance*, an annual resource that estimates weapon quantities in the arsenals of over 170 states. Note that the data—lists of platforms and quantities—are incomprehensible to readers lacking expertise in the designations of these weapons, and even those readers with some familiarity may lack a command of the variants of each fighter.

Tab. 4: Chinese Multirole Fighters, 2021

Platform	Quantity
J-10A/S	307
J-10B/C	175
J-11/B/BS	202
J-16	150
J-20/A	24
Su-27/B/C	32
Su-30M2/MKK/MKI/SM	97
Su-35/BM/S	24

Source: International Institute for Strategic Studies

Tab. 5: Russian Multirole Fighters, 2021

Platform	Quantity
MiG-29SM	16
MiG-31BM	107
Su-27/B/C	48
Su-27ML/SM/SM3	71
Su30M2/MKK/MKI/SM	132
Su-35/BM/S	94

Source: International Institute for Strategic Studies

Faced with the raw data, an analyst unfamiliar with each platform designation would be limited to unhelpful techniques like simply comparing the number of multirole fighters in each inventory (an unfortunately common practice). At this point, it is only apparent that China's 2021 arsenal contained more multirole fighters and that there is some model overlap between the two states. To avoid such underwhelming conclusions, analysts can either abandon the pursuit or commit considerable effort to gaining familiarity with the seemingly endless nomenclatures of conventional weapons. A downside to the latter approach is that the ensuing analysis risks being incomprehensible to its intended audience.

In order to make comparisons that do not encounter granular barriers to entry, we can score the systems using CFPI. Table 6 lists a selection of multirole fighters currently coded in the CFPI method found in the arsenals of the United States, China, Russia, North Korea, and Iran with generational tiers resulting from *WEG* conversion (table 3).

Tab. 6: Multirole Fighters by CFPI Tier

Platform	CFPI Tier
EF-2000	2
F/A-18 A/B	2
F/A-18 C/D	3
F-15E	3
F-16C/D	2
F-35/A/I	4
FC-20	2
J-10A	2
J-10B/C	3
J-11/B/BS	2
J-16	3
J-20	4
J-6	1
JAS 39A/B	1
JAS 39C/D	2
JAS 39E	3
JF-17/A/B	2
MiG-29SM	2
MiG-31BM	2
Mirage 2000/E	2
Mirage F1	1
Rafale B F3/C F3/B F3-R/C F3-R	3
Rafale B/C/DH/DM/EH/EM (F2)	2
Su-27/B/C	1
Su-27ML/SM/SM3	2
Su-30	2
Su-30M2/MKK/MKI/SM	3
Su-35/BM/S	3

Reference: U.S. Army Worldwide Equipment Guide

Using the table above, we can compute values representing the conventional capability-based signaling afforded Russia and China by each state's multirole fighters in the year 2021. Tables 7 and 8 demonstrate this.

Tab. 7: Chinese Multirole Fighter CFPI Score, 2021

Platform	**Quantity**	*t*	***G***	***r***	**CFPI**
J-10A/S	307	2	3	32	29,472
J-10B/C	175	3	4	32	22,400
J-11/B/BS	202	2	3	32	19,392
J-16	150	3	4	32	19,200
J-20/A	24	4	6	32	4,608
Su-27/B/C	32	1	1	32	1,024
Su-30M2/MKK/MKI/SM	97	3	4	32	12,416
Su-35/BM/S	24	3	4	32	3,072
				U_{am}	**111,584**

Quantity Source: International Institute for Strategic Studies

Tab. 8: Russian Multirole Fighter CFPI Score, 2021

Platform	**Quantity**	*t*	***G***	***r***	**CFPI**
MiG-29SM	16	2	3	32	1,536
MiG-31BM	107	2	3	32	10,272
Su-27/B/C	48	1	1	32	1,536
Su-27ML/SM/SM3	71	2	3	32	6,816
Su30M2/MKK/MKI/SM	132	3	4	32	16,896
Su-35/BM/S	94	3	4	32	12,032
				U_{am}	**49,088**

Quantity Source: International Institute for Strategic Studies

Having followed the CFPI scoring steps, some more helpful conclusions follow. We could already observe that Russia's inventory of multirole fighters was considerably smaller than China's, but we can additionally observe that it is only marginally less technologically sophisticated. The difference between the capability contribution of multirole fighters to the signaling value of each state's arsenal is then roughly proportional to the numerical difference, a conclusion that we could not make with any real confidence before scoring. Table 9 lists data and scores for the entire air-focused components of Chinese and Russian conventional arsenals in the year 2021.

Tab. 9: Comparison of Air-focused CFPI Scores, Russia and China, 2021

	CFPI Score	
System Type	**Russia**	**China**
Air Superiority Fighter (U_{ai})	3,984	19,248
Multirole Fighter (U_{am})	49,088	111,584
Ground Attack Aircraft (U_{ag})	38,328	27,744
Air Defense Missile System (U_{ad})	138,480	111,072
Total (U_a)	229,880	269,648

Underlying Quantity Source: International Institute for Strategic Studies

The data suggest instructive conclusions concerning the two states' capability basis for air-focused conventional signaling. China's airpower arsenal exhibits two principal repositories of firepower potential: multirole fighters and air defense missiles. This suggests a relatively even prioritization of deterrence through unambiguously defensive systems (air defense) and through systems whose offensive potential for power projection lends them an ambiguous quality. Russia, on the other hand, has a clear center of gravity for its air-focused firepower potential: air defense missile systems. Restricting our consideration for the moment to air-focused CFPI scores, the data do not suggest a robust Russian airpower projection signal relative to that inherent in China's inventory.

Constraints, Trade-offs, and Possibilities

This paper's method aims to enhance the pursuit of capability-based balance of power analysis by enabling estimative comparisons of conventional strategic signaling value of state arsenals, with distinct constraints and possibilities. These include: (1) the abstract nature of indexes; (2) the inability to consider unconventional capabilities or systems not listed; (3) the impossibility of using CFPI scoring to predict conflict outcomes with any confidence; and (4) the possibilities of using CFPI scoring to enhance other avenues of defense analysis.

I simply cannot claim that CFPI enables any sort of precise measurement of the aggregate quality of state conventional weapon systems; it only improves incrementally on the current paradigm of comparative analysis, which is characterized by a practical inability to make quality-based comparisons between weapons outside methods intended to project their effectiveness in combat with questionable conclusions. Just as gross domestic product (GDP) provides an accessible overall metric but fails to capture nuances beyond an economy's size and easily masks sector-specific weaknesses or strengths, CFPI enables analysts without granular conventional weaponry knowledge to discern only the broad contours of capability-based signaling capacity for balance of power analysis.

By its very nature, CFPI is unable to capture signaling contributions of military systems that are not conventionally armed. These include nuclear platforms (aircraft, submarines, and missile systems primarily intended for nuclear weapons delivery are excluded from CFPI tables), logistical systems that could contribute to strategic signals (particularly large-scale airlift or sealift systems), and mobility systems (e.g., mine warfare vessels, bridging vehicles). While these blind spots are understandable given the method's firepower potential focus and the observation at this paper's outset that most states procure far more combat hardware than their relatively weak logistical systems can support, they are blind spots nonetheless and analyses using CFPI should appropriately caveat or avoid broad ascriptions of intent or capability.

CFPI absolutely cannot on its own support conflict outcome prediction with any degree of confidence, and even with multiple tools conflict outcome prediction is a fraught pursuit. It may seem ironic that, having noted the criticism that has befallen techniques like aggregated firepower score and WEI/WUV, I root CFPI's tactical role value computation in reductive approximations of explosive yields by index systems releasing index munitions under wholly theoretical conditions. However, I do not propose—and strongly caution against—applying normalized munition yields from CFPI *r*-values toward engagement outcome prediction. CFPI projects neither damage nor survivability prospects, and in fact does not incorporate engagement modeling at all beyond an initial proxy for the capability component of "capability-based" signaling capacity. There are simply too many other factors—possibly an unknowable number—that contribute to combat power potential.

These caveats notwithstanding, I believe CFPI solves real problems facing would-be military balance of power analysts. Accepting the premise that most of the world's conventional weaponry serves a signaling contribution role most of the time, CFPI scoring represents an accessible proxy for this signaling in the conventional arena. CFPI can also combine with other concepts to make well-worn avenues of defense analysis more informative.

Assuming that when states purchase weapons they are usually purchasing the capability-based component of conventional signaling capacity, more meaningful analysis of procurement spending becomes possible. Even when procurement spending is disaggregated from total defense spending—a constantly cited figure that typically lacks information to be useful—the inability to make comparisons between state arsenals impedes a full appreciation of procurement analysis.

While the applications in this paper focus on CFPI scoring for comparative analysis between states in the same year, CFPI also enables analysis of state arsenals over multiple years. This may simply describe and compare change over time or support procurement analyses. The change in a state's CFPI score is expressed:

$$\Delta U_{\mathrm{p}} = U_{\mathrm{p(y)}} — U_{\mathrm{p(y-1)}}$$

In this straightforward, recursive expression, change in CFPI score is the difference in CFPI score between the year of analysis *y* and the previous year *y-1*. This is not yet suitable for linking procurement spending to ΔU_{p} since procurement is not instantaneous. Embracing the approximate natures of proxy values and indexes, a staggered recursive value of CFPI change across several years over the expenditure of previous years compensates for lag. A 2018 RAND study found an average of 3 years between intermediate design, production, and fielding milestones in the U.S. acquisition system roughly analogous to those of purchase agreement and inventory receipt for states importing weapons. (Light et al. 2018) Using this, a staggered recursive expression for CFPI score change over procurement spending and across time would be:

$$\eta_{U\mathrm{p}} = \frac{\Delta U_{\mathrm{p(y)}} + \Delta U_{\mathrm{p(y-1)}} + \Delta U_{\mathrm{p(y-2)}}}{x_{(y-1)} + x_{(y-2)} + x_{(y-3)}}$$

Analysis employing this expression requires longitudinal CFPI scores and procurement spending data, and probably cannot work for states that indigenously produce their weapons (particularly with substantial research and development). Within these constraints is an avenue for comparative proxy analysis of conventional weaponry procurement by arms-importing states. The merits of adopting one proxy measurement over another is debatable—and any inferences to intent would require additional evidence and analysis—but it seems difficult to refute the observation that states updating their inventories with more competitive systems, at lower expense, and over shorter periods of time are procuring more efficiently compared to other states.

Using CFPI Scoring to Gain Insight into the U.S. National Defense Strategy

The United States released the most recent version of its statutorily-mandated National Defense Strategy (NDS) in 2018. The thesis statement reads:

> *Long-term strategic competitions with **China** and **Russia** are the principal priorities for the Department, and require both increased and sustained investment, because of the magnitude of the threats they pose to U.S. security and prosperity today, and the potential for those threats to grow in the future. Concurrently, the Department will sustain its efforts to deter and counter rogue regimes such as **North Korea** and **Iran**, defeat terrorist threats to the United States, and consolidate our gains in Iraq and Afghanistan while moving to a more resource-sustainable approach.* (U.S. Department of Defense 2018)

Does a comparative analysis of the approximate signaling value of the Chinese, Russia, North Korean, and Iranian conventional arsenals offer insight into the "magnitudes of the threats" or "potential for those threats to grow"? What do apparent conventional postures of each state suggest for "increased and sustained investment"? In this section, I use CFPI scoring to examine the premises and conclusions of the NDS in ways that would be difficult or misleading without structured comparative analysis of capacity-based conventional strategic signals.

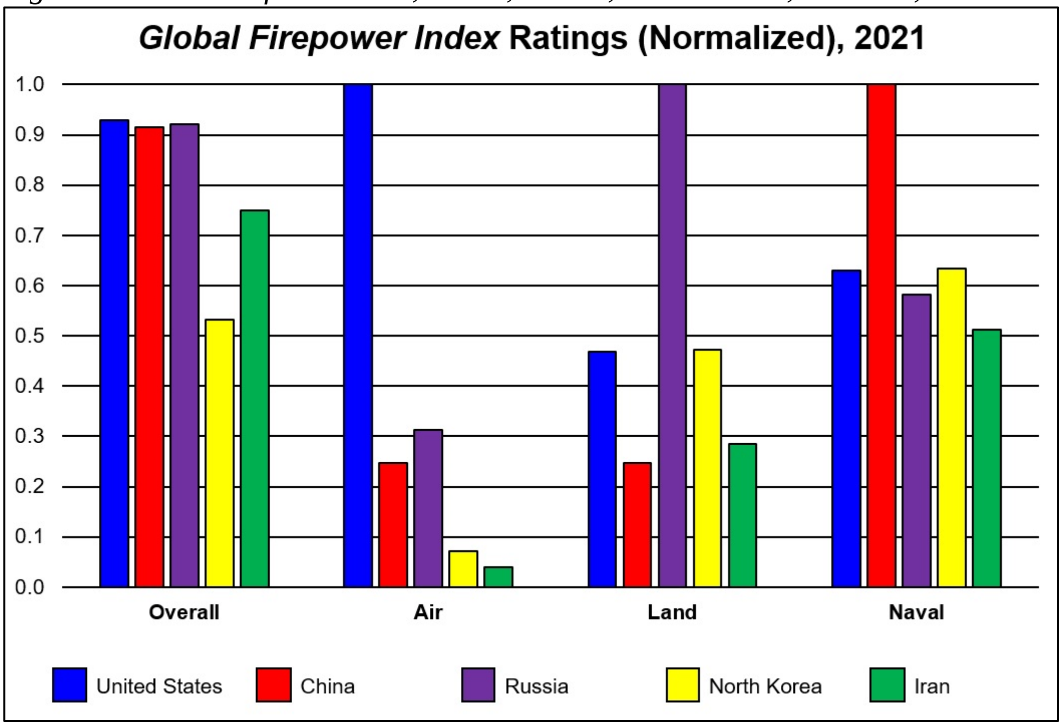
Before presenting CFPI results, I visit *GFI*'s ranking of the five countries' capabilities to highlight how a number of academic, professional, and journalistic settings troublingly cite *GFI* as premises for strategic arguments. I next present CFPI scoring for the five states: overall; by domain; by technological tier; and by extra-regional deterrence suitability. Finally, I translate this into three main conclusions: (1) of the prospective adversary states, only China appears eventually capable of a truly competitive conventional posture; (2) the conventional advantage of the United States heavily incentivizes all four states to pursue unconventional capabilities including nuclear armament, cyber, and disinformation; and (3) the investment called for can only do so much to further extend a long conventional posture lead and may be better allocated to countermeasures against unconventional state threats.

GFI – Cited by Journalists, Professionals, and Even Scholars

The *Global Firepower Index* enjoys widespread citation by journalists and governments despite the opacity of its methodology. The next few paragraphs examine *GFI*'s ratings for the states mentioned in the NDS while reviewing a sampling of ostensibly serious journalistic, professional, and academic settings glossing over the non-rigorous nature of *GFI* to cite these rankings. I further illustrate the problem raised in the introduction, namely that a dearth of accessible methods for comparative analysis exacerbates tendencies of would-be analysts to cite sources like *GFI*.

GFI purports to rank states by overall "military strength," "airpower," "land forces," and "naval forces." (Global Firepower 2021) Figure 1 is a normalized depiction of these rankings where each state's score is depicted as a percentage of the highest score awarded by the site in each category.

Fig. 1 – GFI Scores for the U.S., China, Russia, North Korea, and Iran, 2021



Source: Global Firepower

Site rankings put the United States first overall, with Russia a close second and China a close third. As *GFI* does not publish its methods, readers must wonder how the individual domain rankings generate overall rankings. Rankings for "Airpower," "Land Forces," and "Naval Forces" simply entail counting military aircraft, main battle tanks, and naval vessels respectively. Despite this approach, there is no identifiable relationship between the domain ratings and the overall ratings. GFI puts North Korea ahead of Iran in all three domains, but ranks Iran ahead of North Korea overall. Incidentally, *GFI* ranks North Korea ahead of the United States in "Land Forces" and "Naval Forces."

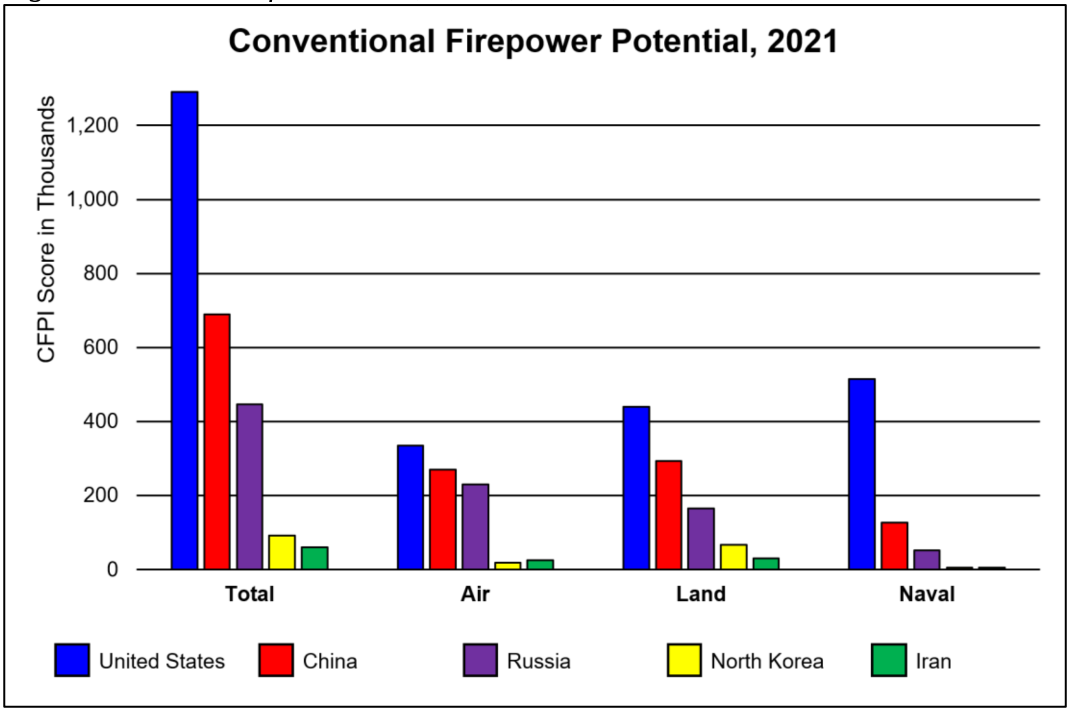
These questionable conclusions do not completely dissuade citation of *GFI*'s analysis in journalistic, professional, and even academic settings. *Business Insider* cited *GFI*'s 2018 rankings to report on the NDS, depicting Russia and China as close behind the United States. (Woody 2018) The Association of the United States Army (AUSA), the principal professional organization for current and former American soldiers and officers, cited *GFI* in asserting that the United States trails Russia and China in land power. (Association of the United States Army 2019) The instructional materials for "America's Weapon Systems," a short-form course at the College of William and Mary, cites *GFI* to state that "Russia overwhelmingly leads" in the arena of conventional land systems. (Hickok 2018)

Oleksiy Kuzmenko's reporting indicates serious security scholars and defense analysts either have not heard of *GFI* or do not take it seriously. Nevertheless, *GFI* and the malleable narratives implied by its rankings still proliferate through citations in settings assumed to be reliable. Widespread use of *GFI*'s rankings offers a prestige boost—or perhaps raises alarm—for Russia and Iran. *GFI* has consistently ranked Iran's military ahead of Israel's, a fact noticed by both states' journalistic communities. (Winston 2019; Iran International 2019) While this paper does not score Israel's arsenal, the next subsection paints a starkly different landscape for Russia and Iran than does *GFI* and advances more transparently informed conclusions.

CFPI Scoring of the U.S. and Prospective Adversaries Identified in the NDS

I focus on depicting comparative results of CFPI scoring for the United States, China, Russia, North Korea, and Iran using arsenal data from the 2021 edition of the IISS' *The Military Balance*. Figure 2 depicts overall and domain-specific scores for the five states, while Table 10 lists each state's score derived from each the 25 system types.

Fig. 2: CFPI Scores for the U.S., China, Russia, North Korea, and Iran, 2021



Underlying quantity source: International Institute for Strategic Studies

It is immediately apparent that CFPI suggests a dramatically different set of capabilities contributing to conventional strategic signals compared to the popular *GFI* portrayal. The core of this difference is the United States' greater concentration of systems—particularly naval—that CFPI accords higher role scores and technological tiers. Figure 3 depicts technological composition of each state's arsenal in system counts (with no tactical role weighting). Figure 4 shows the derivation of each state's score from systems of each degree of sophistication. Figures 3 and 4 demonstrate why simply counting platforms muddies insights into arsenal composition. Finally, figure 5 scores only conventional firepower potential for systems suited to extra-regional projection and thus extended deterrent signals. These include extended flight-capable fixed-wing aircraft, blue-water naval vessels, and ship-based naval aviation (see table 10).

Tab. 10: Comparison of Conventional Firepower Potential Index Scores, U.S., China, Russia, North Korea, and Iran, 2021

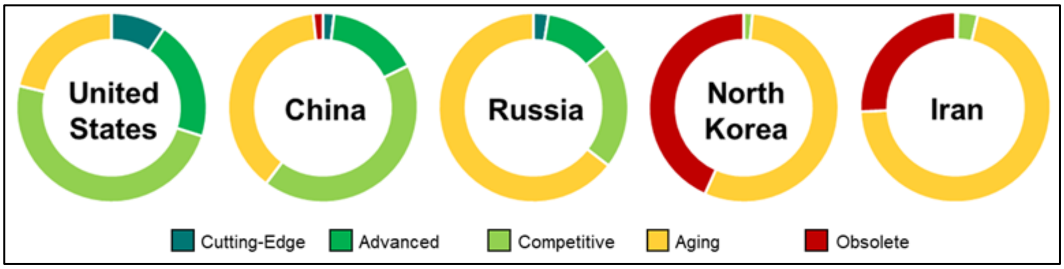
	CFPI Score				
System Type[†]	**United States**	**China**	**Russia**	**North Korea**	**Iran**
Air Superiority Fighter	44,424	19,248	3,984	7,776	3,912
Multirole Fighter	193,280	111,584	49,088	0	3,200
Ground Attack Aircraft	20,880	27,744	38,328	2,736	2,256
Air Defense Missile System*	76,680	111,072	138,480	8,880	15,408
Air Domain Subtotal	**335,264**	**269,648**	**229,880**	**19,392**	**24,776**
Main Battle Tank*	49,448	110,400	48,560	33,160	10,760
Armored Fighting Vehicle*	279,300	114,428	70,040	7,112	3,700
Self-Propelled Cannon Artillery*	6,876	10,840	7,742	8,596	584
Towed Cannon Artillery*	6,201	1,288	3,825	2,150	1,840
Rocket Artillery*	5,760	10,110	4,656	9,435	828
Rotary Wing Attack*	57,024	15,872	15,840	0	800
Multirole Rotary Wing*	30,844	7,288	2,964	1,144	424
Air Defense Gun System*	0	1,446	210	2,750	572
Surface-to-Surface Missile*	5,136	22,200	11,664	2,496	11,520
Land Domain Subtotal	**440,589**	**293,872**	**165,501**	**66,843**	**31,028**
Aircraft Carrier	212,400	14,400	3,600	0	0
Ship-Based Rotary Wing*	20,448	1,062	864	0	78
Ship-Based Fixed Wing	113,120	4,352	3,360	0	0
Shore-Based Maritime Fixed Wing*	10,152	4,776	1,728	0	72
Cruiser	35,100	1,800	2,700	0	0
Destroyer	64,800	31,200	3,600	0	0
Frigate	11,760	17,640	5,880	280	420
Corvette*	0	13,200	11,580	0	60
Missile Boat / Fast Attack Craft*	720	4,896	0	840	1,536
Tactical Submarine – Nuclear-Powered	46,800	6,300	9,900	0	0
Tactical Submarine – Non-Nuclear Powered*	0	9,120	2,160	3,600	960
Shore-based Anti-ship Missile*	0	17,310	5,880	540	1,620
Naval Domain Subtotal	**515,300**	**126,056**	**51,252**	**5,260**	**4,746**
Total 2021 CFPI Score	**1,291,153**	**689,576**	**446,633**	**91,495**	**60,550**

Underlying quantity source: International Institute for Strategic Studies

†Systems are classified according to international convention reflected in IISS' *The Military Balance*. This sometimes means systems are evaluated as types different from the retaining state's label (e.g. large "corvettes" may be scored as frigates).

*Indicates systems excluded from extra-regional projection CFPI score (see figure 5)

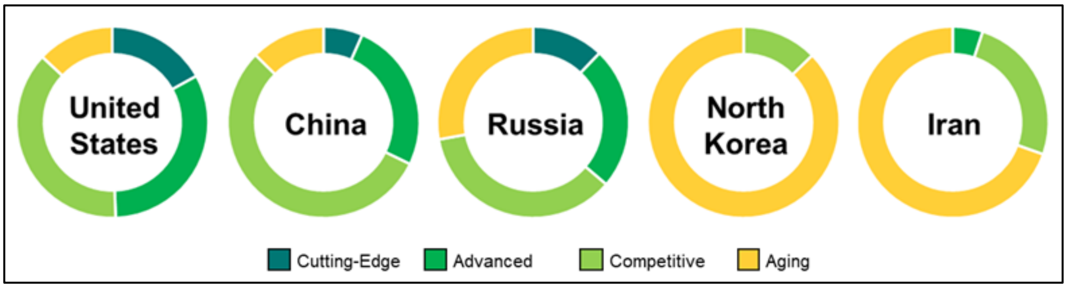
*Fig. 3: Technological Composition of U.S., China, Russia, North Korea, and Iran Conventional Arsenals (Excluding AFVs), 2021**



Quantity Source: International Institute of Strategic Studies

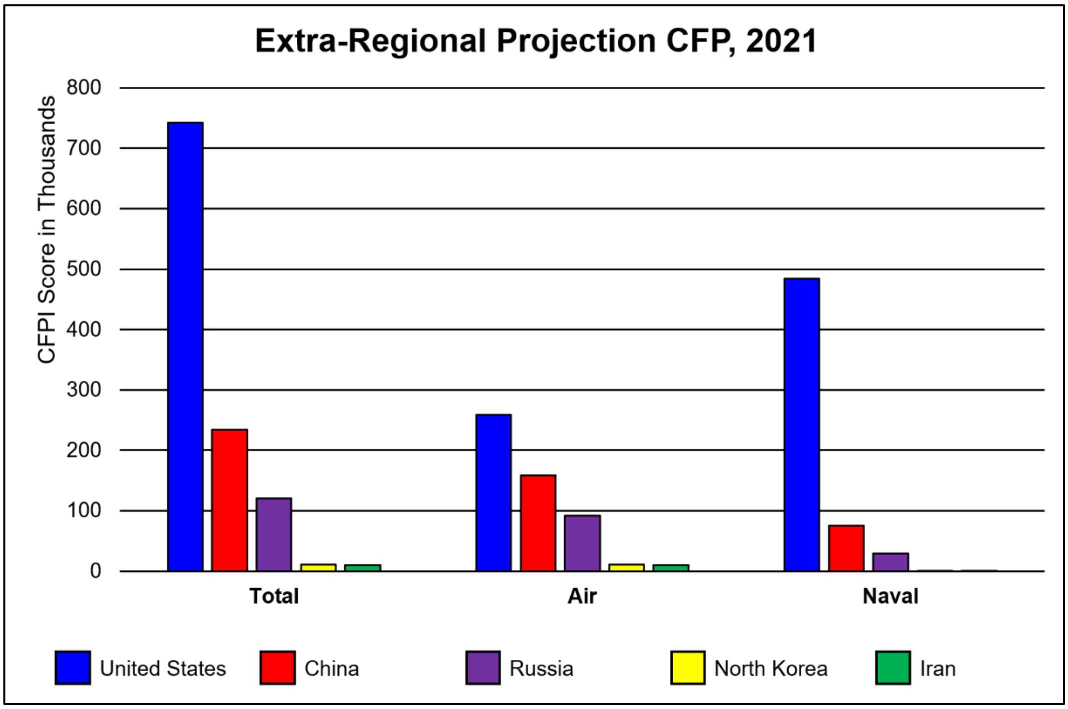
*All five states have large, mostly aging inventories of armored fighting vehicles (AFVs)—armored, armed vehicles other than main battle tanks—that would inject misleading noise into this depiction, which counts but does not weight systems. Figure 4 takes AFVs into account.

Fig. 4: Technological Composition of U.S., Russia, China, North Korea, and Iran Conventional Arsenals by Sources of CFPI Score, 2021



Underlying quantity source: International Institute for Strategic Studies

Fig. 5: CFPI Scores for Extra-Regional Projection Platforms for the U.S., China, Russia, North Korea, and Iran, 2021*



Underlying quantity source: International Institute for Strategic Studies

* “Extra-regional projection platforms” includes the set of systems in the CFPI excluding all land systems, air defense systems, and short-range or coastal naval platforms (corvettes, missile boats, non-nuclear-powered tactical submarines, and anti-ship missiles). See list in table 10.

CFPI-Facilitated Analytic Conclusions of the NDS' Threats and Investments

The data of the preceding charts enables us to revisit the 2018 U.S. NDS thesis. Rather than embarking on an in-depth analysis of each chart—the aim of this paper is to contribute the CFPI method and illustrate possibilities, not a deep-dive into the NDS' outlook—I briefly distill insights into the magnitude and nature of the cited threats and prospective investments.

CFPI scoring combined with readily available macroeconomic data suggests that only China can realistically contemplate future conventional parity with the United States. The yawning gap in conventional posture incentivizes the other states to pursue unconventional advantages. For North Korea and Iran, nuclear arms represent an attractive insurance policy. Russia, already possessing nuclear arms and with its legacy ability to advance a prestige narrative by showcasing some premier capabilities, is nonetheless also incentivized to exploit capabilities in the difficult-to-attribute realms of offensive cyber and disinformation operations. (Lilly and Cheravitch 2020; Cunningham 2020)

While the United States is free to pour resources into politically popular and technically straightforward efforts to further bolster conventional advantage, the reality is that America's arsenal uniquely postures it to send robust extra-regional extended conventional deterrent signals. This means that "increased and sustained" investment in conventional capabilities—while necessary if the U.S. prioritizes a conventional posture edge over China—probably crosses a point of diminishing returns given the extant capability gaps and the astronomical price tags of advanced air and naval systems. The most lucrative avenue for the U.S. to keep China's capability-based posture in check may be to devote resources to arming allies in the region; note Australia's abandonment of longtime strategic ambiguity in agreeing to receive nuclear-powered submarines from the United States implicitly to balance China. (Pei 2021)

Setting aside the largely diplomatic challenges of managing nuclearization by North Korea and Iran, CFPI scoring suggests that, dollar for dollar, more promising applications for "increased and sustained" investment lie in counter-cyber and counter-disinformation measures. An irregular warfare annex to the 2018 NDS particularly noted Russia's proclivity toward and proficiency with disinformation and cyber operations, which suggests that at least some within the Pentagon share this perspective. (U.S. Department of Defense 2020)

This all confines the scope of the CFPI scoring-informed analysis to threats cited by the NDS. Other voices argue climate change and pandemics represent risk sources that would benefit from some share of U.S. spending otherwise pouring into extending already wide conventional advantages. If comparative arsenal analysis represented a great enough challenge to justify the writing of this paper, devising a framework for fiscal value judgments across completely disparate realms of policy justifies authorship of multiple libraries of books.

Conclusion

This paper set out to identify a problem and propose some degree of solution. Conceiving the problem as the existence of extensive obstacles to meaningful, accessible comparative conventional arsenal analysis and the proclivity of journalists and governments to cite non-credible sources in the absence of credible ones, the solution is adopting a clear if reductive framework with modest goals to enable comparative conventional armament posture analysis. By avoiding conflict outcome prediction and focusing on the capability component of conventional strategic signals suggested by arsenal compositions, I believe this CFPI contributes some new methodological good to the field. I look forward to exploring and improving the method by employing it in more systemic and longitudinal analyses.

References

Aggregated Combat Models. Monterey, CA: U.S. Naval Postgraduate School Operations Research Department, February 2000.

Armstrong, Michael J. "The Salvo Combat Model with Area Fire." *Naval Research Logistics*, vol. 60, iss. 8 (December 2013), pp. 652-660.

Association of the United States Army. "U.S. Army Ranks No. 3 In Global Land Power Evaluation." August 13, 2019. https://www.ausa.org/news/us-army-ranks-no-3-global-land-power-evaluation.

Ben-Haim, Yakov. "WEI/WUV for Assessing Force Effectiveness: Managing Uncertainty with Info-Gap Theory." *Military Operations Research*, vol. 23, no. 4 (2018), pp. 37-50.

Biddle, Stephen. *Military Power: Explaining Victory and Defeat in Modern Battle.* Princeton, NJ: Princeton University Press, 2004.

Carroll, Robert J. and Brenton Kenkel. "Prediction, Proxies, and Power." *American Journal of Political Science*, vol. 63, iss. 63 (July 2019), pp. 577-593.

Coleman, Katharina P. and Paul D. Williams. *Logistics Partnerships in Peace Operations*. New York: International Peace Institute, June 2017.

Cunningham, Conor. *A Russian Federation Information Warfare Primer*. The Henry M. Jackson School of International Studies, University of Washington. November 12, 2020. https://jsis.washington.edu/news/a-russian-federation-information-warfare-primer/.

Darilek, Richard E., Walter L. Perry, Jerome Bracken, John Gordon IV, and Brian Nichiporuk. *Measures of Effectiveness for the Information-Age Army*. Arlington, VA: RAND, 2001.

Dubois, Edmond, Wayne P. Hughes, and Lawrence J. Low. *A Concise Theory of Combat Power*. Monterey, CA: Naval Postgraduate School Institute for Joint Warfare Analysis, 1997.

Gannon, J Andres. 2021. "Planes, Trains, and Armored Mobiles: Introducing a Dataset of the Global Distribution of Military Capabilities (rDMC)" Working Paper. https://militarycapabilities.com

Gerson, Michael S. "Conventional Deterrence in the Second Nuclear Age." *Parameters*, vol. 39, no. 3 (Autumn 2009), pp. 32-48.

Global Firepower Index. Interactive database. http://www.globalfirepower.com.

Haffa, Robert P., Jr. "The Future of Conventional Deterrence: Strategies for Great Power Competition." *Strategic Studies Quarterly*, vol. 12, no. 4 (Winter 2018), pp. 94-115.

Hickok, John. *America's Weapon Systems: Our Safety Net*. The College of William and Mary in Virginia. 2018. https://www.wm.edu/offices/auxiliary/osher/course-info/classnotes/hickokweaponssystems.pdf

Hughes, Wayne P., Jr. "A Salvo Model of Warships in Missile Combat Used to Evaluate Their Staying Power." *Naval Research Logistics*, vol. 42, iss. 2 (March 1995), pp. 267-289.

Krondak, William J., Rick Cunningham, Oren Hunsaker, Daniel Derendinger "Unit Combat Power (and Beyond)." Paper presented at the 24th International Symposium on Military Operations Research, Cranfield, UK, August 2007.

Kuzmenko, Oleksiy. "Ukrainian President Cites Clickbait Ranking in National Address." *Bellingcat*, June 29, 2018. https://www.bellingcat.com/news/uk-and-europe/2018/06/29/ukrainian-president-cites-clickbait-ranking-national-address/.

Lanchester, Frederick W. *Aircraft in Warfare: The Dawn of the Fourth Arm*. London: Constable & Company, 1916.

Light, Thomas, Robert S. Leonard, Meagan L. Smith, Akilah Wallace, and Mark V. Arena. *Benchmarking Schedules for Major Defense Acquisition Programs*. Santa Monica, CA: RAND, 2018.

"Latest Military Strength Ranking: Iran at 14, Israel at 17." *Iran International*, August 12, 2019. https://old.iranintl.com/en/world/latest-military-strength-ranking-iran-14-israel-17.

Lilly, Bilyana, and Joe Cheravitch. "The Past, Present, and Future of Russia's Cyber Strategy and Forces." in *20/20 Vision – The Next Decade: Proceedings of the 12th International Conference on Cyber Conflict*. Tallinn, Estonia: NATO Cooperative Cyber Defence, 2020, pp. 129-155.

Lucas, Thomas W. and John E. McGunnigle, "When is Model Complexity Too Much? Illustrating the Benefits of Simple Models with Hughes' Salvo Equations." *Naval Research Logistics*, vol. 50, iss. 3 (April 2003), pp. 197-217.

Morgan, Patrick M. "The State of Deterrence in International Politics Today." *Contemporary Security Policy*, vol. 33, iss. 1 (April 2012), pp. 85-107.

Pei, Minxin. "China Can't Win an Arms Race With the U.S." *Bloomberg*, September 22, 2021. https://www.bloomberg.com/opinion/articles/2021-09-22/australia-sub-deal-shows-china-will-lose-arms-race-with-u-s.

Sarkees, Meredith Reid, and Frank Wayman, eds. *Resort to War, 1816-2007*. Washington, DC: Sage Publishing, 2010.

Shurkin, Michael. *The Abilities of the British, French, and German Armies to Generate and Sustain Armored Brigades in the Baltics*. Arlington, VA: RAND, 2017.

The Military Balance. Washington, DC: International Institute for Strategic Studies, 2021.

U.S. Army Concepts Analysis Agency. 1991. *FY 1991 Annual Report*.

U.S. Army Training and Doctrine Command. *Worldwide Equipment Guide*. Interactive database. https://odin.tradoc.army.mil/WEG.

U.S. Department of Commerce. National Institute of Standards and Technology. *Guide for the Use of the International System of Units*, by Ambler Thompson and Barry Taylor. NIST SI 811. 2008.

U.S. Department of Defense. *Summary of the 2018 National Defense Strategy of the United States of America*. 2018.

U.S. Department of Defense. *Summary of the Irregular Warfare Annex to the National Defense Strategy*. 2020.

U.S. Department of Energy. Lawrence Livermore National Laboratory. *Estimating Equivalency of Explosives through a Thermochemical Approach*, by J.L. Maienschein. UCRL-JC-147683. 2002.

Winston, Alex. "Israel Drops a Slot in 2019 Military Strength Ranking, still behind Iran." *The Jerusalem Post*, August 12, 2019. https://www.jpost.com/israel-news/israel-falls-to-17th-place-in-global-military-index-598306.

Woody, Christopher. "These are the 25 Most Powerful Militaries in the World in 2018." *Business Insider*, November 22, 2018. https://www.businessinsider.com/most-powerful-militaries-in-the-world-ranked-2018-11.