Appendix A: Selected Bibliography of Campaign Analyses

Year	Author	Title	Publication
1954	Wohlstetter, Hoffman, Lutz, and Rowen	Selection and Use of Strategic Air Bases	RAND
1973	Davis and Shilling	All You Ever Wanted to Know About MIRV and ICBM Calculations but Were Not Cleared to Ask	*Journal of Conflict Resolution*
1976	Steinbruner and Garwin	Strategic Vulnerability: the Balance between Prudence and Paranoia	*International Security*
1981	Epstein	Soviet Vulnerabilities in Iran and the RDF Deterrent	*International Security*
1984	Posen	Measuring the European Conventional Balance: Coping with Complexity in Threat Assessment	*International Security*
1987	Epstein	*Strategy and Force Planning: The Case of the Persian Gulf*	Brookings
1988	Posen	Is NATO Decisively Outnumbered?	*International Security*
1988	Mearsheimer	Numbers, Strategy, and the European Balance	*International Security*
1988	Epstein	Dynamic Analysis and the Conventional Balance in Europe	*International Security*
1988	May, Bing, Steinbruner	Strategic Arsenals After START: the Implications of Deep Cuts	
1989	Mearsheimer	Assessing the Conventional Balance: The 3:1 rule and its Critics	*International Security*
1989	Salman, Sullivan, and Van Evera	Analysis or Propaganda? Measuring American Strategic Nuclear Capability, 1969-88	*Nuclear Arguments*
1990	McCue	*U-Boats in the Bay of Biscay: An Essay in Operations Analysis*	NDU Press
1994	Masaki	The Korean Question: Assessing the Military Balance	*Security Studies*
1996	Biddle	Victory Misunderstood: What the Gulf War Tells Us About the Future of Conflict	*International Security*
1998	O'Hanlon	Stopping a North Korean Invasion: Why Defending South Korea is Easier than the Pentagon Thinks	*International Security*
2001	Greenhill	Mission Impossible? Preventing Deadly Conflict in the African Great Lakes Region	*Security Studies*
2003	O'Hanlon	Estimating Casualties in a War to Overthrow Saddam	*Orbis*
2004	Glosny	Strangulation from the Sea? A PRC Submarine Blockade of Taiwan	*International Security*

2004	Kuperman	*The Limits of Humanitarian Intervention: Genocide in Rwanda*	Brookings
2005	Armstrong and Powell	A Stochastic Salvo Model Analysis of the Battle of the Coral Sea	*Military Operations Research*
2006	Lieber and Press	The End of MAD? The Nuclear Dimension of U.S. Primacy	*International Security*
2007	Raas and Long	Osirak Redux? Assessing Israeli Capabilities to Destroy Iranian Nuclear Facilities	*International Security*
2007	Bjoern	African Adventure?: Assessing the European Union's Military Intervention in Chad and the Central African Republic	MIT Security Studies
2008	Talmadge	Closing Time: Assessing the Iranian Threat to the Strait of Hormuz	*International Security*
2010	Gholz and Press	Protecting "The Prize": Oil and the US National Interest	*Security Studies*
2011	Bennett and Lind	The Collapse of North Korea: Military Missions and Requirements	*International Security*
2011	Shifrinson and Priebe	A Crude Threat: The Limits of an Iranian Missile Campaign Against Saudi Arabian Oil	*International Security*
2012	Bell	Can Britain Defend the Falklands?	*Defence Studies*
2014	Haggerty	Safe Havens in Syria: Missions and Requirements for an Air Campaign	MIT Masters Thesis
2014	Anderson	Peacekeepers Fighting a Counterinsurgency Campaign: A Net Assessment of the African Union Mission in Somalia	*Studies in Conflict & Terrorism*
2015	Armstrong and Sodergren	Refighting Pickett's Charge: Mathematical Modeling of the Civil War Battlefield	*Social Science Quarterly*
2016	Heginbotham et al.	*The US-China military scorecard*	RAND
2016	Glaser and Fetter	Should the United States Reject MAD? Damage Limitation and Nuclear Strategy toward China	*International Security*
2016	Biddle and Oelrich	Future Warfare in the Western Pacific: Chinese Antiaccess/Area Denial, U.S. AirSea Battle, and Command of the Commons in East Asia	*International Security*
2016	MacKay, Price, and Wood	Weighing the Fog of War: Illustrating the Power of Bayesian Methods for Historical Analysis through the Battle of the Dogger Bank	*Historical Methods*
2017	Talmadge	Would China Go Nuclear? Assessing the Risk of Chinese Nuclear Escalation in a Conventional War with the United States	*International Security*

2020	Fagan, Horwood, MacKay, Price, Richards, and Wood	Bootstrapping the Battle of Britain	*Journal of Military History*
2020	Wu	Living with Uncertainty: Modeling China's Nuclear Survivability	*International Security*

Appendix B: Selecting Input Distributions

Our proposed approach to handling uncertainty requires researchers to select a distribution for the inputs, decide on its parameters, and to model the correlation between different inputs. Guidance for parameter assignment can be found in Step 4, and we provide guidance for distribution selection and correlation here. Although implementing Monte Carlo once distributions are selected is a computational task, substantial qualitative research (e.g. analysis of historical campaigns, consultations with experts), should inform distribution selection. Many statistical distributions are available for researchers to use. The choice of distribution can affect the outcome, both by producing the incorrect variance for the outcome measure, but also potentially by introducing statistical bias, though most of the simulation literature focuses on variance.[1] As with constructing the model, no universal rules exist for selecting the appropriate distribution.[2] That said, there is some general guidance on which distributions are appropriate in which circumstances. Researchers can draw on their substantive knowledge and conduct research (e.g. examining historical campaigns or consulting experts) to decide on distributions, or they could conduct an additional form of sensitivity analysis, comparing the results from using different distributions.[3]

The distribution that encodes the least information about a variable is a *uniform* distribution. If researchers can specify upper and lower bounds on a variable but have no other information about which values within that range are more likely than any other, then a uniform distribution is the appropriate choice. For instance, in their sensitivity analysis, Press and Lieber examine a range of nuclear weapon reliability and accuracy, plugging in values from uniform distributions.[4]

Researchers conducting campaign analysis often have an estimate of a most likely value, in addition to the upper and lower bounds of model variables. When researchers have a sense of these three values only, the simulations literature suggests using a *triangular* distribution, with a maximum value at the most likely value suggested by the expert, and probability decreasing linearly (and potentially asymmetrically) to 0 at each of the extremes.[5]

[1]See Eunhye Song and Barry L Nelson, "Input Model Risk," in, *Advances in Modeling and Simulation* (Springer, 2017), pp. 63–80, pp. 68-69

[2]Alan R Washburn and Moshe Kress, *Combat Modeling*, vol. 139 (Springer, 2009), p. 9.

[3]Bahar Biller and Barry L Nelson, "Answers to the Top Ten Input Modeling Questions," in, *Proceedings of the Winter Simulation Conference*, vol. 1 (IEEE, 2002), pp. 35–40, doi:10.1109/WSC.2002.1172865; Song and Nelson, "Input Model Risk."

[4]Keir A Lieber and Daryl G Press, "The End of MAD? The Nuclear Dimension of US Primacy," *International Security*, Vol. 30, No. 4 (2006), pp. 7–44, doi:10.1162/isec.2006.30.4.7.

[5]Biller and Nelson, "Answers to the Top Ten Input Modeling Questions.". Several R packages and Python's numpy library provide functions for sampling from a triangular distribution.

The parameters of a normal distribution are more difficult to set qualitatively and normal distributions are symmetrical and unbounded, but is a defensible choice for many variables. The mean of a set of independent variables, regardless of their distributions, is asymptotically normally distributed, making it a valid choice for some types of variables, such as the total time for an operation, given independent components that make up the total time. More concretely, firing errors are usually normally distributed, making normal distributions valuable for modeling weapon accuracy.

Other distributions have attractive statistical properties but have parameters that are difficult to extract in the research process. Log-normal or beta distributions are useful distributions for continuous outcomes that are positive and continuous (log-normal) or between 0 and 1 (beta). Setting the parameters for these will often involve data that may not be available. The number of independent events or arrivals in a time period are distributed as a Poisson distribution, but the "rate" parameter can be difficult to estimate qualitatively.[6] Finally, some specific problems have distributions that have been characterized in the operations research or military modeling literatures. Research in search theory, for instance, shows that the probability of finding an object, $P(S)$, if searching effort is randomly allocated within the search area, is an exponential distribution $P(S) = 1 - e^{(-\text{effort/area})}$.[7]

Researchers must also decide how to model the dependence between different inputs. A known pitfall in the combat modeling literature, which relies heavily on statistical distributions, is the assumption that all inputs are independently distributed.[8] A researcher might believe that if one variable takes a high value, a second variable is also likely to take a high value. For instance (as we discuss further in the replication section), the probability that the United States would detect one type of Chinese nuclear facility could be correlated to some degree with the probability of detecting another type of nuclear facility. The simplest way to impose correlation is to use perfect correlation for all values: the detection probabilities for all targets might be identical within a single run. Often, though, researchers would not like to assume perfect correlation. If researchers are using normal distributions, they can set a level of covariance between them and draw from a multivariate normal.[9]

[6] This is nothing to say of events often being correlated, which makes the Poisson distribution inappropriate.

[7] Bernard Osgood Koopman, "Search and Screening," *OEG Rep.*

[8] Washburn and Kress, *Combat Modeling*.

[9] Textbooks on Bayesian hierarchical modeling also have useful guidance on creating joint distributions.