Appendix to Wu Riqiang, "Living with Uncertainty: Modeling China's Nuclear Survivability," *International Security*, Vol. 44, No. 4, (Spring 2020).

1 Additional Figures for the Three scenarios

Figure 1. China's nuclear retaliatory capability against the European part of the Soviet territory in 1984.

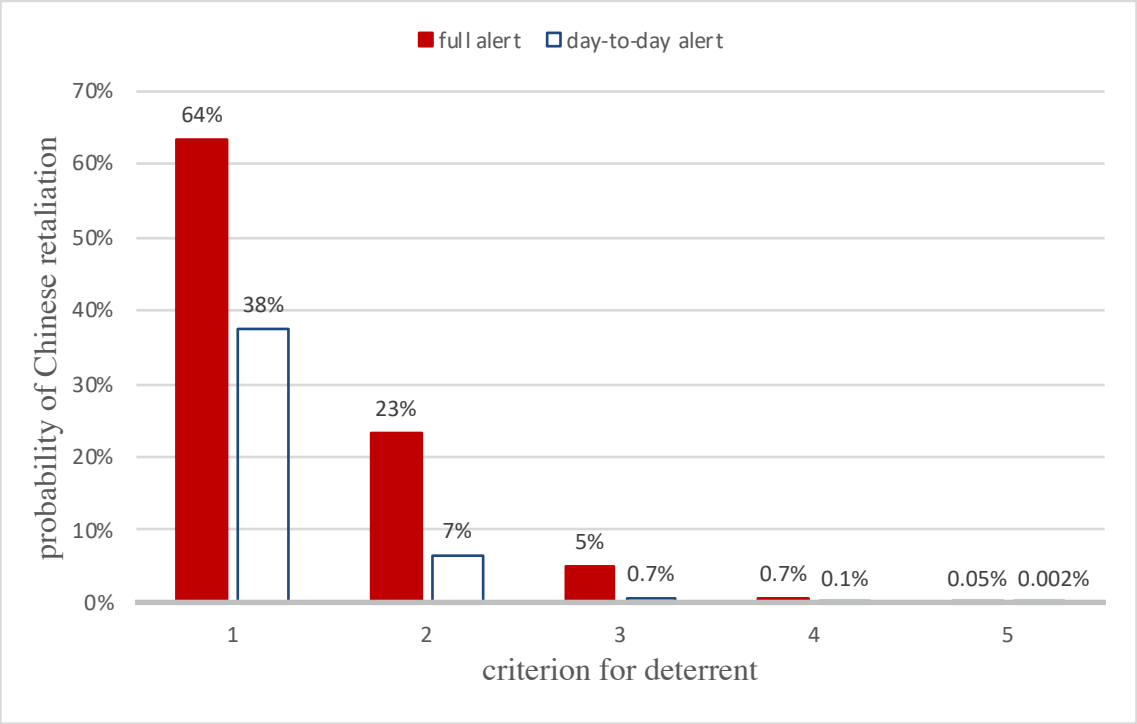


Figure 2. China's nuclear retaliatory capability against the continental United States in 2000

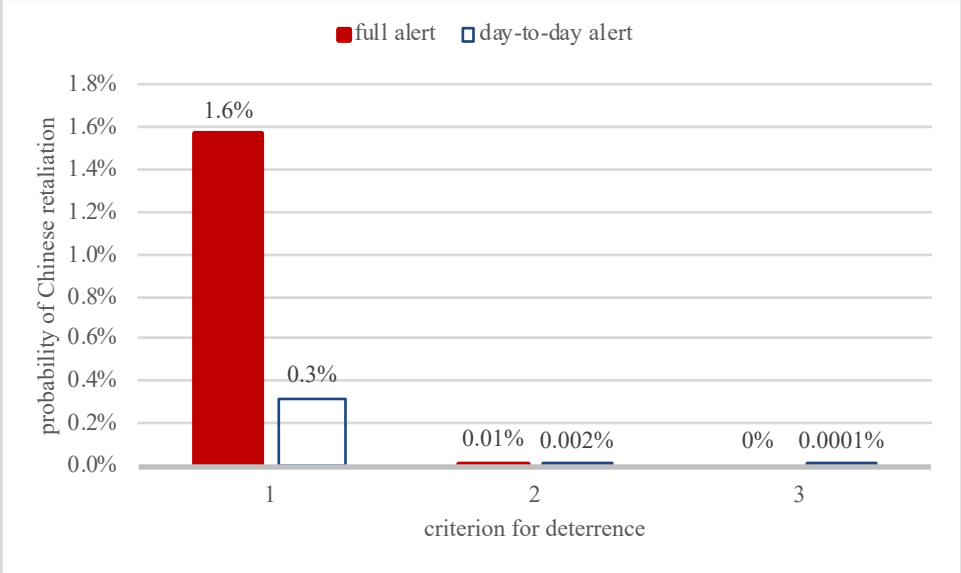
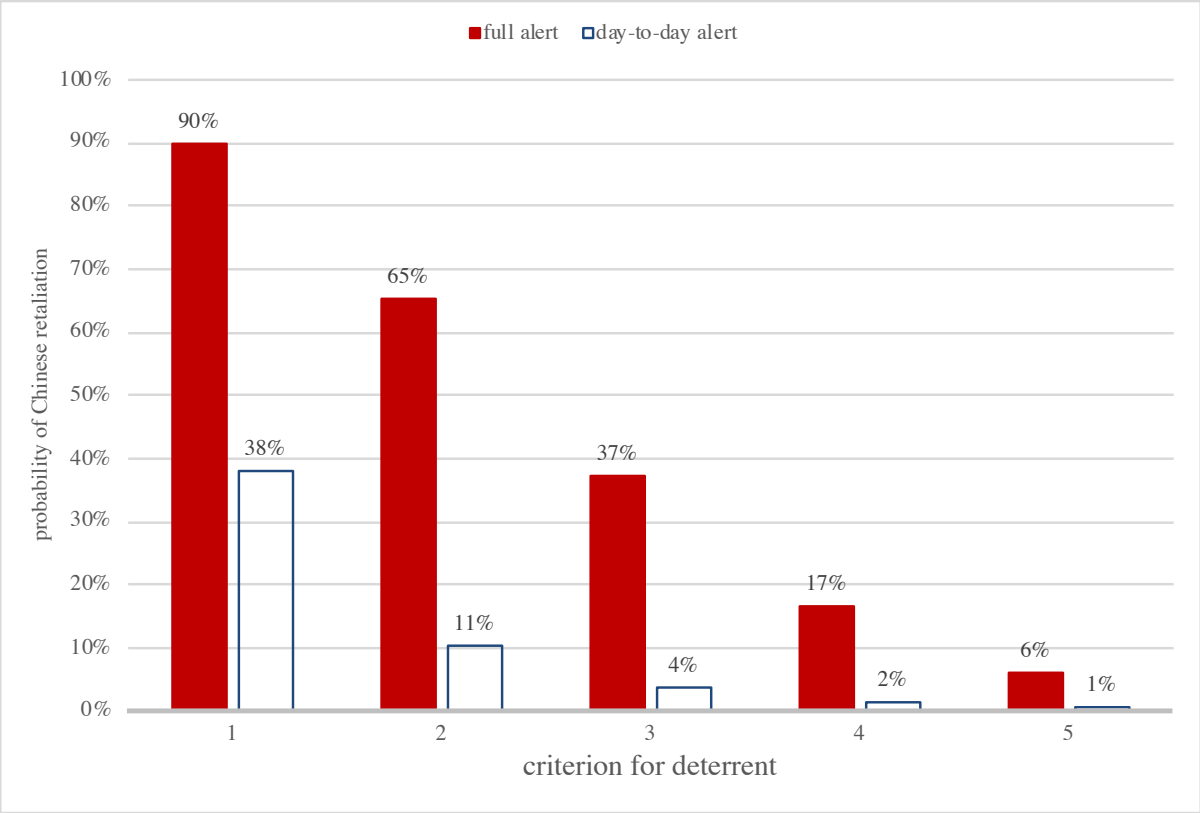


Figure 3. China's nuclear retaliatory capability against the continental United States in 2010



2 Formulas and Parameters Used in the Model

For a missile dispersed to its forward site, the probability of successful retaliation could be calculated as:

$$P_{disperse}=P_{forsite}P_{pad}P_{move}P_{launch}P_{reliable}(1-P_{dis}P_{inter})^4$$

where: $P_{disperse}$—the probability of successful retaliation for a dispersed missile;

$P_{forsite}$ —the probability a forward site survives;

P_{pad} — the probability at least one launch pad survives;

P_{move} —the probability a missile survives during movement;

P_{launch} —the probability a missile survives during launch preparation;

$P_{reliable}$ —the reliability of Chinese missiles;

P_{dis} —the probability of target discrimination of BMD system, assuming four interceptors are used against one missile;

P_{inter} —the probability BMD successfully intercepts identified warheads (i.e. the reliability of the interceptors).

For a missile kept in its technical site, if the technical site and the warhead base survive, then the probability of successful retaliation could be calculated as:

$$P_{dealert}=P_{pad}(1.2P_{move})P_{launch}P_{reliable}(1-P_{dis}P_{inter})^4$$

For a technical site, if the warhead base survives, the probability of successful retaliation can be calculated as:

$$P_{tech}= P_{techsite}[1-(1-P_{dealert})^{Nd}]$$

where: $P_{techsite}$ — the probability the technical site survives;

Nd—the number of de-alerted missiles in a technical site.

For a silo-based missile, if the warhead base survives, the probability of successful retaliation can be calculated as:

$$P_{silomissile}=P_{silo}P_{reliable}(1-P_{dis}P_{inter})^4$$

where: P_{silo} —the probability the silo survives;

For all the nuclear missiles kept in the silos and technical sites, the probability of successful retaliation could be calculated as:

$$P_{warhead}= P_{warheadbase}[1-(1- P_{silomissile})^{Ns}(1- P_{tech})^{Nt}]$$

where: $P_{warheadbase}$ —the probability of the warhead base survives;

Ns—the number of silo-based ICBMs;

Nt—the number of technical sites.

All in all, the probability of Chinese nuclear retaliation:

$$P_{ret}=1-(1-P_{warhead})(1-P_{disperse})^{Nf}$$

where: Nf—the number of missiles dispersed to forward sites.

The kill probability of missile silos can be calculated as: [1]

$$SSKP=1-0.5\text{^}(LR/CEP)^2$$

$$LR=2.62(Y/H)^{1/3}$$

where, $SSKP$ = single-shot kill probability

LR = lethal radius, nautical mile

CEP = circular error probable, nautical mile

H = target hardness, pounds per square inch

Y = yield of warhead, MT

[1.] Lynn Etheridge Davis and Warner R. Schilling, "All You Ever Wanted to Know about MIRV and ICBM Calculations but Were Not Cleared to Ask," *Journal of Conflict Resolution*, Vol. 17, No. 2 (June 1973), pp. 207–242, doi.org/10.1177%2F002200277301700203.

The values of different detection probabilities are shown in table A.1.

Table A.1. Detection Probabilities of Chinese Nuclear Forces

Targets	China-Soviet Union 1984	China-United States 2000/2010	China- United States 2025
Silos/warhead base	90%	99.9%	99.9%
Launch site	—	60%	65% (DF-31A/G) 0 (DF-41)
Forward site	60%	70%	75%
Technical site	70%	80%	85%
Moving liquid-propellant missile	50%	—	—
Moving solid-propellant missile	--	50%	50% (DF-31A) 25% (DF-41)
Launch preparation (liquid mobile missile)	50%	—	—
Launch preparation (solid mobile missile)	—	20%	20% (DF-31A) 10% (DF-41)
SSBN	—	—	97%

The kill probabilities of the UGFs used in the model are shown in table A.2.

Table A.2 Kill Probabilities of Chinese Underground Facilities

Scenarios	Kill Probability
China-Soviet Union, 1984	70%
China- United States, 2000/2010	80%
China- United States, 2025	80%

The hardness of DF-5 silos is shown in table A.3.

Table A.3. Hardness of Chinese DF-5 Silos

Scenarios	Hardness (pounds per square inch)
China-Soviet 1984	900
China-U.S. 2000/2010/2025	2000

The kill probabilities of both moving missile TELs and mobile missiles under launch preparation were assumed to be 100 percent. Both are soft targets. In regard to moving TELs, the offense could use several warheads to cover the entire possible target area. The U.S. intelligence assigned a vulnerability number (VN) of 11Q9 to Soviet road mobile missiles. Assuming the same number for Chinese mobile missiles, for a 455 kiloton warhead (Trident II D5), the corresponding damage radius would be 5,765 meter (with a height of burst of 2,110 meter).[2] With a speed of 45 kilometers per hour, a TEL could move as far as 15 kilometers for 20 minutes (the flight time of U.S. SLBMs or Soviet MRBMs/IRBMs). Therefore, seven to nine warheads would be required to barrage the potential target area. However, given the fact that Chinese TELs lack off-road mobility, the number of warheads required against a mobile TEL could be reduced to three.

It takes several hours to launch a Chinese liquid-propellant mobile missile – much longer than the flight time of an offensive missile. As for solid missiles, the preparation time is at the

[2.] Matthew G. McKinzie et al., *The U.S. Nuclear War Plan: A Time for Change* (New York: Natural Resources Defense Council, 2001), p. 54. See also *Mathematical Background and Programming Aids for the Physical Vulnerability System for Nuclear Weapons* (Washington, D.C.: U.S. Defense Intelligence Agency, May 24, 1978).

level of tens of minutes – comparable to the flight time of an offensive missile. From China's conservative perspective, it is assumed that the missiles under launch preparation would be destroyed once detected.

The performance of U.S. BMD is shown in table A.4.

Table A.4. The performance of U.S. BMD

	2010	2025
Reliability of interceptors	50%	90%
Target discrimination probability	10%	30%

3 China's Retaliatory Capability Against the Adversaries' Whole Territory

This section discusses China's retaliatory capability against the whole territory of the Soviet Union and the United States, including eastern part of Soviet Union, Hawaii, Alaska and Guam.

China's nuclear capabilities that could target Soviet and U.S. territory are listed in table A.5. In 1984, the total number of the DF-2s and DF-3s were 50 and 60 respectively. Their possible deployment areas include Northeast China (Tonghua), Eastern China (Liangxiwang), Southwest China (Jianshui) and Northwest China (Liuqingkou).[3] Because of the range limit, only those DF-2s deployed in Northeast China and DF-3s deployed in Northeast and Northwest China could hold Soviet territory at risk. Therefore, it is assumed that 12 DF-2s (one brigade) and 24 DF-3s (two brigades) could be used in retaliation against the Soviet Union.

[3.] U.S. National Photographic Interpretation Center, *Section I: Chinese Missile Support Bases and Launch Sites* (Langley, Va.: Central Intelligence Agency, 1980), https://www.cia.gov/library/readingroom/docs/CIA-RDP81T00034R000100450001-7.pdf.

Table A.5. China's Nuclear Forces

Missile Type	Range (kilometers)	Number of Missiles		
		1984	2000	2010
DF-2	1250	12 (1)/50	—	—
DF-3	2800	24 (2)/60	—	—
DF-4	4750	4 (1)	20 (2)	10 (1)
DF-5	13000	2	20	20
DF-31	7200	—	—	12 (1)
DF-31A	11200	—	—	24 (2)

SOURCE: *The Military Balance, 1984*, p. 91; *The Military Balance, 2000*, p. 194; and *The Military Balance, 2010*, p. 399, all published by the Institute for International Strategic Studies; John Wilson Lewis and Hua Di, "China's Ballistic Missile Programs: Technologies, Strategies, Goals," *International Security*, Vol. 17, No. 2 (Fall 1992), pp. 5–40, doi.org/10.2307/2539167; and Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China, 2010*, p. 66.
NOTE: The numbers of missile brigades are in parentheses. The brigade numbers in 1984 are the author's estimate.

The calculation reveals that in two scenarios (China-Soviet Union in 1984 and China-United States in 2010), if fully alerted, China's retaliation would be closed to assured. But if the criterion for deterrence is raised to more than three, then China's deterrence still cannot be assured. In other scenarios/alert status, China's retaliation is still far less than assured, as shown in figure A.4, A.5, and A.6.

Figure A.4. China's Retaliatory Capability against the Whole Soviet Territory in 1984

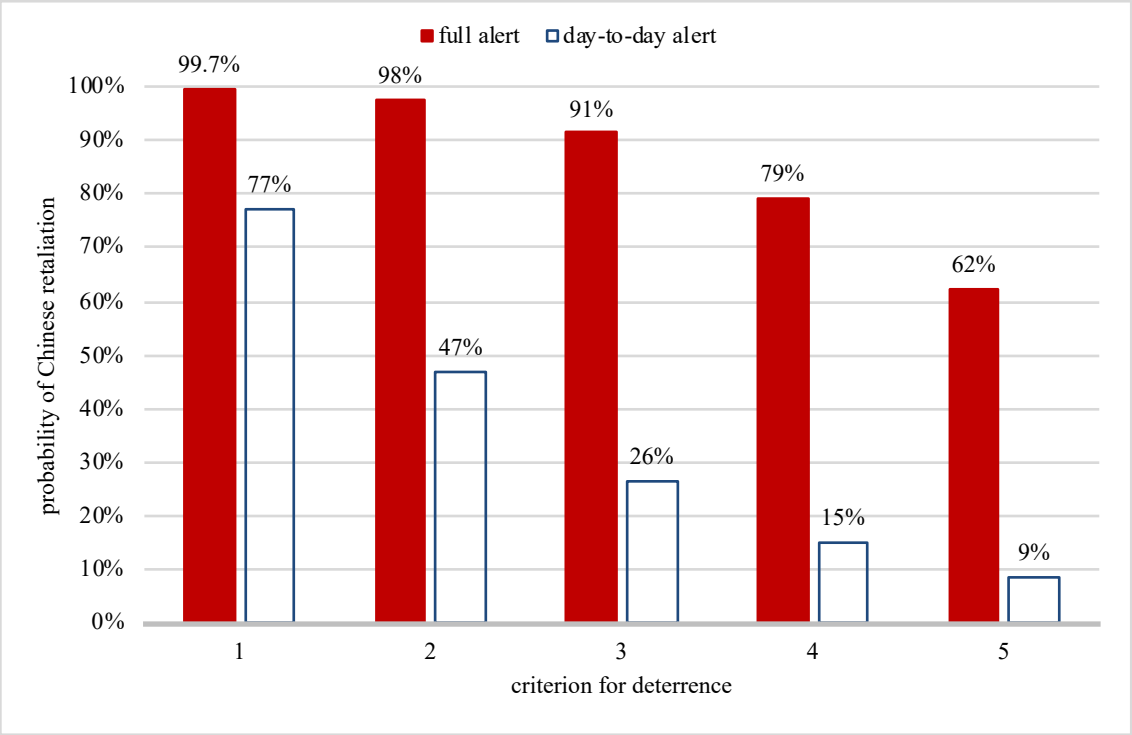


Figure A.5. China's Retaliatory Capability against the Whole U.S. Territory in 2000

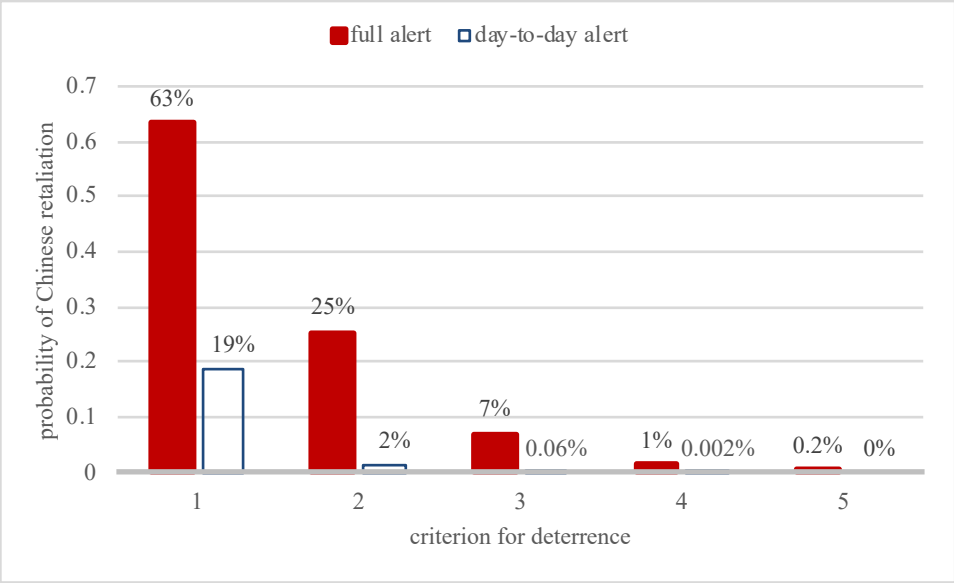
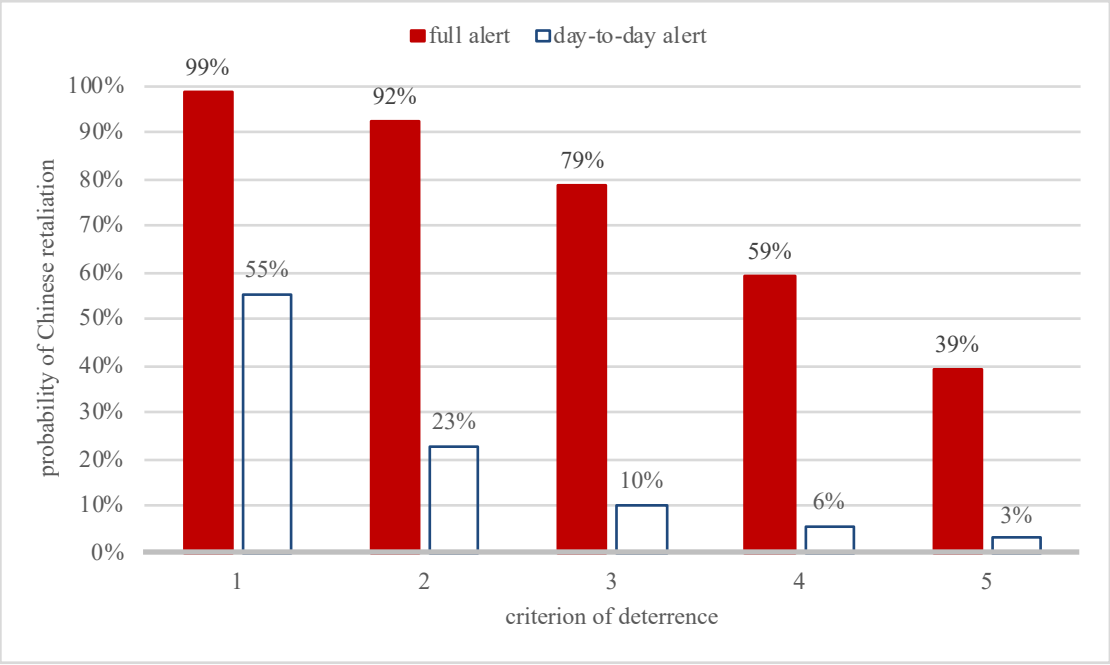



Figure A.6. China's Retaliatory Capability against the Whole U.S. Territory in 2010