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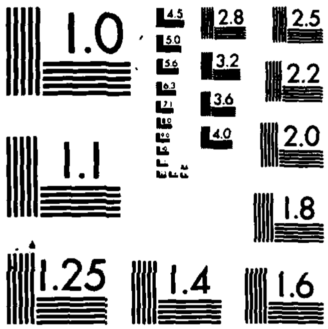

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MONITORING BOMBERS AND CRUISE MISSILES
FOR THE PURPOSES OF ARMS CONTROL

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February 20, 1985

P-7065

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INTRODUCTION

To date, arms control agreements have dealt with only a fraction of the air-breathing system threat--namely, "heavy" bombers. The SALT II Treaty defined heavy bombers either by aircraft type--currently B-52s and B-1s for the United States and Tupolev-95 (Bear) and Myasishchev (Bison) types for the Soviet Union--or by their ability to carry cruise missiles with a range in excess of 600 km. Future bomber types are included if they can carry out the mission of a heavy bomber. Cruise missile carriers (CMCs) were counted separately under the 1,320 MIRVed missile/CMC subceiling, whereas other heavy bombers counted against the 2,400 (or 2,250) total launcher limit. Until December 31, 1981, the protocol to the SALT II Treaty banned the deployment of ground-launched or sea-launched cruise missiles.[1] However, such deployments are now a moot issue, since the United States has deployed ground-launched cruise missiles in Europe and is reported to have deployed Tomahawk cruise missiles aboard U.S. attack submarines.[2] Except for SALT II, qualitative and quantitative limits do not exist for bombers and cruise missiles. In particular, intermediate-range aircraft (for example, FB-111s and Backfires) and dual-capable, theater-based aircraft are not limited under any existing arms control agreement.

This paper discusses the extent to which bomber/cruise missile characteristics and activities can be monitored by national technical means (NTM). Particular attention is paid to those characteristics and activities relevant to arms control. National technical means--which refers to various technical means by which monitoring data can be gathered, usually involving satellite reconnaissance--are not the sole means for monitoring, though they may be the most dependable.

Monitoring involves collecting and evaluating intelligence data in an effort to identify and count different aircraft types, and to determine their characteristics. Monitoring an opponent's forces should be distinguished from the process of verifying whether the opponent's

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[1] *SALT II Agreement*, U.S. Department of State, Selected Document No. 12B.

[2] "Cruise Missiles Deployed on Attack Submarines," *Washington Post*, June 28, 1984, p. A-17.

actions violate particular treaty provisions. The former is essentially a technical process, the latter a legal judgement. Verification relies on data provided by one's monitoring capabilities; however, since these data often lead to equivocal assessments, careful judgement is required before one can verify treaty compliance. In particular, one must account for an opponent's ability to evade detection should he choose to deliberately violate a treaty. In other words, monitoring has more to do with detecting, identifying, and measuring, whereas verification involves judging treaty compliance.[3]

Whether a treaty is "adequately" verifiable involves still broader political and military judgements. To assess whether compliance can be adequately verified we must understand the risks that potential violations pose to our national security, as well as our ability to counter any noncompliance. These risks must be weighed against the political and military advantages derived from the treaty. Judgements concerning adequate verification are influenced by past experience with the other party, the present political climate, and by one's view of the other party's intentions. Furthermore, adequate verification should not be viewed as an absolute condition since the overall benefits derived from a treaty may compensate for any weakness in our ability to verify compliance. This is particularly true if those provisions that are difficult to verify involve low risk.[4]

It is beyond the scope of the present discussion to determine whether arms control treaties involving bombers and cruise missiles can be adequately verified. What will be discussed, however, is the confidence one might have in monitoring bombers and cruise missiles. The following arguments are based on elementary technical considerations as well as a familiarity with past arms control agreements.

Monitoring confidence is judged as either high, medium, or low, depending on how difficult it is to obtain the requisite information via national technical means. High confidence reflects an optimistic

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[3]*Verification: The Critical Element of Arms Control,* U.S. Arms Control and Disarmament Agency, Publication No. 85, March 1976.

[4]Howard Stoertz, "Monitoring a Nuclear Freeze," and Steve Meyer, "Verification and Risk in Arms Control," *International Security,* Vol. 8, No. 4 (Spring 1984).

assessment of monitoring capability, while low confidence implies that NTM alone probably cannot provide sufficient data to assess treaty compliance reliably. In some cases, this difficulty reflects physical constraints on one's ability to make observations. More often, however, it reflects the ease with which an opponent (that is, the Soviet Union) could deliberately conceal that which one is trying to observe. Concluding that deliberate concealment is relatively easy does not imply that concealment would, in fact, take place. However, given the Soviets' penchant for secrecy, allegations that they have deliberately concealed activities in the past, and a cautious estimate of one's monitoring capabilities, it is reasonable to assume that if certain activities can be concealed, they will be difficult to observe. In assessing monitoring confidence, human intelligence sources are not taken into account. Furthermore, no credit is given for fortuitous events, such as information obtained from a defector. National technical means are assumed to be the sole source of intelligence data.

Monitoring data can be observed directly, derived, or inferred. Counting aircraft inventories is an example of direct observation. Derived quantities are calculated using certain assumptions; for instance, a bomber's payload can be derived from a knowledge of the aircraft's range, along with assumptions about its structural design. Inferred data arises when observed activity might be plausibly linked to the characteristic one wishes to determine; for example, the capability to carry nuclear weapons might be inferred from the aircraft's alert status. Typically, U.S. aircraft designated for nuclear missions are placed on quick-reaction alert to enhance their survivability. Whether this corresponds to Soviet practice is another matter, which points to the weakness of inferred characteristics.

Characteristics that can be observed directly are more desirable from the standpoint of verification, since they are more reliable. Consequently, it behooves the United States to construct arms control agreements using direct observables to the extent possible since this reduces verification ambiguities. Furthermore, direct observables are more important if one chooses to respond to a treaty violation since evidence based on them has more influence on public and international opinion.

In general, bans are easier to monitor than treaties involving numerical limits, since one reliable counterexample suffices to verify noncompliance. The confidence with which numerical limits can be monitored depends on the counting accuracy. Quantitative limits (for example, aircraft numbers, dimensions, and the like) are easier to monitor than qualitative limits (for example, guidance accuracies or a bomber's electronic countermeasure capability) since quantitative limits usually involve direct observables. Deployment is usually easier to monitor than production, since the former involves direct observation. For the same reason, testing and deployment are easier to monitor than research and development. Large, fixed objects are easier to monitor than small, mobile ones for the simple reason that the latter are easier to conceal. Similarly, platforms that perform a single function (for example, strategic nuclear bombers) are easier to monitor than dual-capable platforms (for example--fighter-bombers capable of delivering either nuclear or conventional ordnance, or radars capable of operating in an air defense mode and an ABM mode), provided that one wishes to distinguish between different types of dual-capable platforms. Few direct observables seem to exist that distinguish between dual-capable platforms. "Concealment," whether intentional or not, occurs by virtue of their identical appearance.[5]

These qualitative points concerning monitoring are applicable to arms control in general. The remaining sections of this paper consider, in greater detail, their relevance to monitoring bombers and cruise missiles.

BOMBERS

This section gives examples of bomber characteristics relevant for arms control, along with the confidence with which they can be monitored. In particular, it discusses counting specific aircraft types, and determining aircraft range, payload, and the capability for delivering nuclear weapons. Monitoring bombers presents problems because aircraft are versatile platforms. Basically, it is hard to distinguish between the nuclear missions one wishes to constrain and

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[5]Howard Stoertz, op. cit., footnote 4, p. 95.

missions left unconstrained (antisubmarine warfare, reconnaissance, in-flight refueling, transport, and so on). The ability to carry weapons, either internally or externally, is the only fundamental characteristic that distinguishes bombers (including cruise missile carriers) from other types of aircraft.

Identifying and Counting Aircraft

The SALT II Agreement used functionally related observable differences (FRODs) to determine which aircraft types were counted as heavy bombers. FRODs were defined as those observable differences that indicate whether the airplane in question "can perform the mission of a heavy bomber." Examples of FRODs were never given, since those details were left to the Standing Consultative Commission. Bomb bay doors might be one example.

The drawback with FRODs is that they are few in number and not necessarily reliable. For example, the lack of bomb bay doors does not preclude external weapon carriage, nor is it clear how long it would take to install bomb bay doors. This is especially true for Soviet nonstrike aircraft, since they use the same airframe as Soviet bombers. (The Soviet Union has about 75 Tu-142 reconnaissance and antisubmarine warfare aircraft--Bear versions D, E, and F--and approximately 113 Tu-95 bombers--Bear versions A, B, and C.[6]) Furthermore, bomb bay doors are difficult to observe in the first place, since satellite photoreconnaissance occurs from an overhead perspective. Identifying bomb bay doors might require intercepting the bombers outside Soviet airspace, which implies that we would observe only those planes the Soviets want us to see. Thus, whereas in principle FRODs allow one to distinguish aircraft types with high confidence, in practice they are of more modest utility.

Monitoring the ability to carry weapons externally might be equally difficult, since pylons (external structures to which weapons are attached) are hard to observe from an overhead perspective. Moreover, pylons can carry a variety of objects (for example, external fuel tanks, or electronic countermeasure pods) that are not necessarily related to

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[6] *Jane's All The World's Aircraft: 1983-84,* ed. J.W.R. Taylor, Jane's Publishing Co., Ltd., London, 1983, pp. 234-240.

weapon carriage. Hence, the ability to carry weapons externally can only be inferred if pylons are observed. Even if pylons are not observed, this does not prove that a plane cannot carry weapons externally. External hard points are the critical feature for this capability. Hard points are specific locations on the fuselage or wings that are structurally reinforced to handle heavy weights. It is at these points that pylons are attached. Consequently, for monitoring purposes, the absence of pylons should not be relied upon to disprove the capability to carry weapons externally. Hard points may be difficult to observe.

If reliable FRODs do not exist, externally observable differences (EODs) often allow one to distinguish between aircraft types. Though EODs can be detected with high confidence, they do not unequivocally indicate whether an aircraft can perform bombing missions. Examples of EODs are differences in aircraft dimensions, landing gear housings, external radomes and miscellaneous "blisters" (bulges in the fuselage), and "strakelets" (small, aerodynamic fins).

Though the United States apparently could distinguish Bison tankers from Bison bombers using EODs, the Soviets were required to give their 31 Bison tankers FRODs within six months after the SALT II Agreement was signed to confirm that these aircraft could not perform bombing missions. Apparently, the United States was not convinced that these tankers could not easily be converted into bombers.[7] Depending on how extensive the modifications must be before an aircraft can perform bombing missions, EODs can be used to identify bombers with moderate to low confidence.

Once a given aircraft type has been identified, the total inventory can be counted with reasonably high confidence. Witness the fact that 31 Bison aircraft were singled out as tankers in SALT II. (The total Bison force was about 74 planes in 1979.[8]) One can surmise that aircraft counts are accurate to within several planes, at least for aircraft no longer in production. The uncertainty arises because the planes cannot all be observed simultaneously. For aircraft still in

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[7] *SALT II Agreement*, op. cit., footnote 1, Article II-3, pp. 12-13.
[8] *Jane's All the World's Aircraft: 1980-1981*, p. 203.

production, greater uncertainties arise because the inventory is increasing at an uncertain rate.

Identifying and counting cruise missile carriers (CMCs) is obviously important for arms control. The SALT II Treaty separated CMCs from heavy bombers and counted them as MIRVed launch platforms under the 1,320 MIRVed missile/CMC subceiling. In the treaty, only EODs were required to distinguish B-52G air-launched cruise missile (ALCM) carriers from non-ALCM carriers.[9] FRODS were required for CMCs other than existing heavy bomber types.[10]

CMCs can be distinguished from other bombers or transport aircraft with, at best, modest confidence. Cruise missiles carried internally are hard to detect. Special doors for dispensing ALCMs, for example, from transport aircraft, would provide a FROD for monitoring purposes. However, without such a FROD, the confidence with which one could identify these CMCs would probably be low.[11] Cruise missiles carried under the wings can be monitored with high confidence, provided that the aircraft is observed fully loaded. If they are carried under the fuselage, observation becomes more difficult. If the CMC is not fully loaded, the capability for external carriage must be inferred by observing pylons or hard points.

In summary, total aircraft inventories can probably be counted with high confidence. The real problem for monitoring lies in determining which aircraft types can perform bombing missions. This problem is exacerbated by the Soviet tendency to use bomber airframes for their nonstrike aircraft. The confidence with which one can identify designated bombers is high. Determining that nonstrike aircraft cannot perform bombing missions can be accomplished with moderate to low confidence, depending on how extensively the aircraft must be modified. However, high monitoring confidence might not be required for adequate verification, since nonstrike aircraft presumably are required for other vital military missions. Hence the probability that they might be converted seems low.

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[9] *Jane's All the World's Aircraft: 1983-1984*, op. cit., footnote 6, pp. 234-240.

[10] *SALT II Agreement*, op. cit., footnote 1, Article II-3, Fourth Agreed Statement.

[11] *Aviation Week and Space Technology*, September 5, 1977, p. 17.

Aircraft Range

Aircraft range can be used to distinguish between heavy bombers, medium bombers, and fighter-bombers. Aircraft that can deliver payloads over intercontinental distances are categorized as heavy bombers, since they constitute a "strategic" threat. A plane's takeoff gross weight roughly correlates with aircraft range, which explains why strategic bombers are called "heavy"; however, relying on takeoff gross weight alone can be misleading. Typically, the aircraft range that defines "intercontinental" falls between 8,000 km and 10,000 km. The variation results from differences in the launch points and the proximity of recovery bases. One might also consider one-way missions. (In SALT II, intercontinental ballistic missiles were defined as those land-based missiles with a range greater than 5,500 km.)

A plane's actual range depends on numerous mission-related details--for example, the payload weight, whether the plane refuels in flight, whether the route is direct (for example, a circuitous route might be required to avoid local air defenses), the range of standoff weapons, and requirements for low-altitude flight and supersonic dash. Because mission ranges vary so widely, this measure should not be used to distinguish heavy bombers. For the purposes of arms control, the unrefueled cruising range (or ferry range) provides a better measure, since its value is intrinsic to the plane.

The unrefueled cruising range is the distance a plane can fly at optimal altitude (high altitudes) without refueling. It can be derived from the Breguet range equation with the following four inputs: (1) the plane's optimal cruising velocity, (2) the lift-to-drag ratio (a measure of the plane's aerodynamic efficiency), (3) the specific fuel consumption (a measure of the engine efficiency), and (4) the fraction of the takeoff gross weight devoted to fuel.[12] The unrefueled cruising range can be determined, at best, with moderate confidence, since most of these inputs are derived or inferred from direct observations. To give just one example of the first input: a plane's optimal cruising speed can be roughly determined from the sweep angle on swept-wing aircraft.

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[12] P.G. Hill and C.R. Peterson, *Mechanics and Thermodynamics of Propulsion*, Addison-Wesley Publ. Co., Reading, Mass., 1965, p. 145.

The problem for arms control is to decide which bombers can fly intercontinental distances. Since the cruising range is extended by thirty to forty percent with one in-flight refueling, one must account for refueling capability. This was the essence of the Backfire debate during SALT II. According to the Military Balance, 1983-84, the unrefueled cruising range of the Backfire is 8,000 km.[13] If this is correct, the plane has marginal intercontinental capability. However, since early versions of the Backfire were observed with a refueling probe, the plane potentially had an intercontinental capability, regardless of whether intercontinental missions were intended. Verifying that this refueling capability was removed, as required by the SALT II Treaty, became central to the debate. Although one can probably observe that refueling probes have been removed, they are the least important indicator of refueling capability. The internal plumbing and controls are more crucial, since they take longer to install. However, the presence of this equipment cannot be detected with much confidence.

Lest one jump to the conclusion that in-flight refueling cannot be adequately verified, one should bear in mind that almost any aircraft can be converted for refueling within several weeks. During the Falklands War, the British gave Nimrod early-warning aircraft an in-flight refueling capability within seventeen days.[14] Including designated tankers in arms control agreements would help account for an opponent's ability to conduct intercontinental strikes; however the British again demonstrated that other aircraft can be quickly converted into tankers. During the Falklands War, C-130 transports and Vulcan bombers were converted into tankers within six to seven weeks.[15]

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[13] *The Military Balance: 1983-84,* The International Institute for Strategic Studies, London, 1983, p. 121.

[14] *Jane's All the World's Aircraft: 1983-84,* op. cit. footnote 6, p. 269.

[15] *Jane's All the World's Aircraft: 1982-83,* p. 260, and Ray Braybyook, *Battle for the Falklands: Airforces,* Osprey Publ., London, 1983, pp. 17-18.

Thus, NTM can probably measure a bomber's unrefueled cruising range with moderate confidence and identify the capability for in-flight refueling with high confidence, provided that external refueling probes are visible. If the Soviets deployed a refueling capability covertly, it would be hard to detect. Whether one can verify in-flight refueling adequately depends on the likelihood that such covert deployments will occur. One should remember that, in any event, aircraft can be converted within several weeks.

Bomber Payload

The best measure of a bomber's offensive potential is the payload that can be delivered over a given distance. This is analogous to ballistic missile throwweight. Payload is hard to estimate because it is a sensitive function of aircraft range. For example, reducing a bomber's range by ten percent by offloading fuel increases the payload that can be delivered over this distance by approximately fifty percent. Alternatively, if one holds the range constant, but the plane refuels once in-flight, the payload could increase by around three hundred percent, in principle. Thus, it is misleading to specify the mission payload without specifying the mission range and whether the plane is refueled in-flight.

Nevertheless, nominal range-payload values can probably be derived with moderate confidence if one estimates the plane's structural and aerodynamic characteristics. This monitoring capability may not provide adequate verification, since people will invariably disagree on the assumed mission characteristics. This occurred during the Backfire debate in SALT II. Different range-payload estimates for the Backfire were derived by assuming recovery bases in Cuba, one-way missions, and/or high-altitude (i.e., maximum range) flight profiles under the assumption that low-altitude penetration is less critical against U.S. air defenses.

Nuclear Capability

Including dual-capable fighter-bombers in the arms control process, especially those based in the European theater, remains a thorny issue. Neither the Soviet Union nor the United States is eager to have arms control agreements aimed at nuclear forces constraining their conventional forces. Consequently, one must distinguish which dual-capable aircraft are, in fact, nuclear-capable. This is difficult (some say impossible) essentially because nuclear warheads weigh about the same as conventional munitions. (Nuclear warheads typically weigh between 200 kg and 1,000 kg, depending on the type and yield.) Consequently, any fighter-bomber that can deliver conventional munitions most likely can deliver nuclear weapons as well. This problem does not arise with heavy or medium bombers, despite their conventional roles, because there are fewer aircraft and the majority are designated specifically for nuclear missions.

To identify those fighter-bombers that are nuclear-capable, one might attempt to detect special communication, command, and control (C^3) links associated with nuclear release, determine whether the planes are hardened for operation in a nuclear environment, or determine whether they have the enduring alert capability usually associated with designated U.S. nuclear strike aircraft. Since nuclear capability can only be inferred from such indicators--and the evidence for these characteristics or activities is likely to be equivocal--I conclude that one can identify nuclear capable fighter-bombers with low confidence.

Conclusions

This section has illustrated the confidence with which one can monitor bomber characteristics by examining four examples: (1) identifying and counting aircraft types, (2) determining bomber range, (3) determining bomber payload, and (4) determining whether a bomber is nuclear-capable. In principle, aircraft types (bombers, cruise missile carriers, nonstrike aircraft and so forth) can be identified by functionally related observable differences (FRODs). In practice, however, unambiguous FRODs are rare. As a result, aircraft types are typically identified on the basis of externally observable differences

(EODs). Since EODs are not necessarily functionally related to the mission, aircraft that can perform bombing missions can be identified with, at best, moderate confidence. Once identified, aircraft types can be counted with reasonably high confidence. Range-payload characteristics can be determined with moderate confidence, since they can be derived from externally observable features. The capability for in-flight refueling can be identified with high confidence, provided that external refueling probes are observed. Without this FROD, monitoring confidence drops to a low level. Finally, one can probably identify nuclear-capable bombers with moderate confidence, except for nuclear-capable fighter-bombers, which can only be identified with low confidence.

Whether this monitoring ability is sufficient to adequately verify arms control treaties depends on numerous political and military factors. Several military considerations that might be important are discussed briefly in the last section of this paper.

CRUISE MISSILES

Cruise missiles are more difficult to monitor. Their small size (at least for modern long-range cruise missiles like the Tomahawk and the current U.S. Air Force ALCM) makes them difficult to count whether or not deliberate concealment is practiced. If one thinks of a cruise missile as an additional warhead, then counting cruise missile inventories should be compared to counting total warhead inventories--a task that I assume cannot be accomplished by NTM alone. Counting CMCs as MIRVed launchers in SALT II is consistent with this perspective, since cruise missiles become analogous to ballistic missile reentry vehicles. However, cruise missiles are more often thought of as launchers, since they fly substantial distances under their own power. This perspective leads to a greater desire for monitoring capability, since arms control agreements (such as SALT II) frequently use launchers as a metric.

Cruise Missile Numbers, Type, and Range

Cruise missile inventories can be inferred by multiplying the number of launchers by the number of cruise missiles each launcher can carry. Summing over all launcher types provides an estimate of the total stockpile. Actually, these estimates measure the carrying capacity of the force, rather than the number of weapons deployed. Alternatively, one could estimate cruise missile inventories by monitoring production rates. This approach suffers from the difficulties in monitoring the production of small items, not to mention from opportunities for concealment (discussed later). Consequently, the confidence with which one can measure cruise missile inventories is probably low.

As with dual-capable fighter-bombers, nuclear cruise missiles are virtually impossible to separate from their conventionally armed counterparts. Schemes to detect the radioactive decay from a nuclear warhead (as the Swedes did with the Soviet submarine that ran aground on October 27, 1981) might detect nuclear cruise missiles; however, the short detection range for radioactivity and obvious countermeasures, such as shielding the warheads, limit the utility of this approach.

Range is more difficult to monitor for cruise missiles than for bombers. The factors in the Breguet range equation are harder to measure, since cruise missiles are small and easy to conceal. A rough estimate might be derived from the missile's volume. (It has been suggested that tactical cruise missiles be defined as missiles with volume less than one-half cubic meter.[16]) One can estimate cruise missile volume with high confidence if one can see the missile. However, this approach suffers from the ease with which cruise missiles can be concealed. Also, there is a problem with older cruise missile types, since they tend to be large for their range. Observing flight tests would be a third way to verify cruise missile range. Observing cruise missile test flights is not a trivial proposition (as will be discussed later), since they have low "observables"--that is, optical, infrared, and radar signatures. Furthermore, the point is often made

[16]Kosta Tsipis, "Cruise Missiles," *Scientific American,* February 1977.

that cruise missiles need not be tested to full range to ensure their reliability and accuracy. In short, if deliberate concealment does not take place, cruise missile range can probably be estimated with moderate confidence. With concealment, monitoring confidence becomes rather low. One can at least be thankful that questions relating to in-flight refueling don't arise.

Thus, monitoring cruise missile numbers, type (conventional or nuclear), and range, with high confidence, is hard to accomplish using NTM. Deliberate concealment would reduce the level of confidence considerably.

Other Monitoring Schemes

Table 1 summarizes the confidence levels associated with other monitoring approaches. Two arms control regimes are considered--bans and aggregate limits. Each observable is examined for its applicability to cruise missiles in general and to those armed with nuclear warheads. For cases designated with moderate-low confidence, the moderate level pertains to situations in which no concealment occurs, otherwise low confidence is more appropriate. The following sections provide more detailed discussions of each observable. As mentioned earlier, monitoring bans is easier than monitoring limits, since it only requires the detection of one counterexample, whereas accurate counting is necessary for monitoring limits.

Flight Tests: Cruise missile flight tests are probably difficult to detect. Unlike ballistic missiles, cruise missiles fly close to the earth, where detection (especially by radar) is difficult. Moreover, they don't need to be tested to their full range as ballistic missiles do--though, given the difficulty detecting the test, it hardly matters what the range is. Telemetry, another signature that makes ballistic missile tests observable, could be difficult to detect, since the transmitter would need only enough power to reach a nearby aircraft that follows the cruise missile during its flight. On the other hand, ballistic missile telemetry must be sent back from 1000 km above the earth. Thus, a ban on testing cruise missiles with ranges in excess of 600 km could probably not be monitored with high confidence.

Table 1

CONFIDENCE ASSOCIATED WITH MONITORING SCHEMES
FOR LONG-RANGE CRUISE MISSILES

OBSERVABLE	BAN		LIMIT	
	all	n-only	all	n-only
1. Flight test	moderate-low	low	low	low
2. Radar Mapping	low	low	low	low
3. Production	moderate-low	low	low	low
4. Launchers				
a. Bombers (ALCM)	moderate-low	low	moderate-low	low
b. Submarines (SLCM)	moderate-low	low	moderate-low	low
c. Surface Ships (SLCM)	low	low	low	low
d. GLCM	moderate-low	low	moderate-low	low
5. Associated Equipment or Operational Procedures	low	low	low	low
COOPERATIVE				
6. External	moderate	moderate	moderate	moderate
7. Internal	high	high	high	high

Bans which only apply to flight tests for nuclear cruise missiles cannot be monitored with confidence. The payload has little to do with flight testing, except that conventional cruise missiles would need to be tested with greater terminal accuracies. Cruise missile limits cannot be monitored using flight tests, since testing is tenuously related to the number of systems deployed.

In any event, since the United States has tested cruise missiles beyond 600 km, this approach will probably not attract much enthusiasm from the Soviets.

Radar Mapping: Modern cruise missiles usually require accurate maps to provide precision guidance. Monitoring the development of these maps might be another approach to cruise missile arms control. For example, terrain contour matching (TERCOM) guidance requires accurate radar maps of selected portions of an opponent's territory. If TERCOM maps required active radar sounding, one could monitor this activity with high confidence. This is not the case, however, since terrain altitude data obtained from surveys or stereophotography can be transformed into synthetic TERCOM maps.[17] Moreover, other guidance technologies exist that do not require active mapping techniques.

In general, guidance technologies are difficult to monitor, since their development is primarily a research activity. Evidence from flight tests often give the first indication of new or improved guidance systems. It is impossible to ban mapping techniques that apply only to nuclear cruise missiles, since they use the same guidance system as conventional cruise missiles (except for the terminal fix, which must be more accurate for conventional cruise missiles). Numerical limits cannot be monitored via the guidance technology, since no relationship exists between the two.

Production: Bans on cruise missile production would probably be difficult to monitor simply because the weapons are so small. Manufacturing could take place separately, with final weapon assembly done covertly. The separate parts would be hard to distinguish from parts for drones and other small aircraft. Certainly, the nuclear warheads would be produced separately, making a ban solely on the production of nuclear cruise missiles impossible to monitor. Production limits would be even more difficult to monitor than bans on production, simply because it is harder to determine absolute production levels than to detect production activity when there is supposed to be none.

Launchers: Monitoring cruise missile deployments by observing their launch platforms poses fewer problems for NTM. However, since many launch platforms serve dual purposes, it may be hard to distinguish

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[17] John C. Toomay, "Technical Characteristics," in *Cruise Missiles: Technology, Strategy, Politics*, ed. R.K. Betts, The Brookings Institution, Washington, D.C., 1981, p. 39.

cruise missile launchers according to a unique functionally related observable difference. Nevertheless, verifying a ban by monitoring cruise missile launchers might be moderately reliable.

As discussed earlier, bombers carrying ALCMs can usually be distinguished using externally observable differences. Since the Tomahawk submarine-launched cruise missile (SLCM) can be launched from torpedo tubes, monitoring a SLCM ban by observing launch tubes, aboard either submarines or surface ships, would be difficult. However, if launch tubes designed specifically for SLCMs (for example, vertical tubes) were deployed, a ban might be effectively monitored. This is less true for surface ships since it is too easy to conceal SLCM launchers below deck. A ban on ground-launched cruise missile (GLCM) launchers might be successfully monitored, since current GLCM launchers look sufficiently different from other military vehicles. However, a concerted effort to deploy GLCMs deceptively, on otherwise innocuous-looking trucks, would be very difficult to detect.

Monitoring a ban on nuclear cruise missiles via their launchers would be difficult to accomplish, since there would probably be few observable differences between conventional and nuclear launchers. Certain activities might arouse suspicion if they were observed at cruise missile sites--for example special handling and storage procedures associated with radioactive warheads--but one could only infer the existence of nuclear cruise missiles from such activities. Consequently, one could not monitor a ban with much confidence. For the same reason, limits which apply only to nuclear cruise missiles would be difficult to monitor.

Thus, one can probably monitor limits on total cruise missile deployments with moderate confidence, provided that one can distinguish the launch vehicles. However, deliberate efforts to conceal cruise missile launchers would lead to low monitoring confidence.

Associated Equipment and Procedures: If special equipment or operating procedures are essential to cruise missile storage, handling, or launching, one might detect the presence of related activities or vehicles instead of the cruise missiles themselves. One obvious example is the cruise missile launcher, which has been discussed separately because of its monitoring importance. Another example is detection of special handling procedures associated with nuclear warheads, though radiation safety and special security precautions are associated with other nuclear missions as well. It is difficult to invent other examples because the equipment associated with cruise missiles is physically small and probably indistinguishable from countless other pieces of military equipment. Since one can only infer cruise missile activity by identifying associated equipment, this monitoring technique is probably of low reliability.

Cooperative Arrangements: Stepping beyond the realm of NTM, it is useful to ask how confident one could be with cooperative monitoring arrangements which allowed for a large number of on-site on-demand inspections. Without spelling out the detailed procedures for such inspections, one can distinguish two cases: external inspection, which means that one is allowed to inspect questionable locations or launch platforms but is not allowed to board any aircraft, submarine, or surface ship, or to enter any sensitive facility; and internal inspection, which describes a situation in which one can enter any suspected cruise missile site.

External inspection does not necessarily help much since cruise missiles can easily be stored out of sight. Radioactive detectors might help locate nuclear warheads at certain sites. However it would probably be difficult to distinguish cruise missile warheads from other nuclear warheads stored at the same site. External inspection might give one a better view of possible production facilities, launchers, or associated equipment; though it is not clear that one could gain decisive information about cruise missile activity (nuclear or otherwise).

Obviously, internal inspection allows one to monitor a great deal. Cruise missile bans could easily be monitored; however, cruise missile limits could not be monitored with high confidence unless each party was allowed a large number of on-site inspections. It should be equally obvious that internal inspection is a complete nonstarter politically. Covert operations are the only source of internal inspections, and they can hardly be called cooperative.

Conclusions

The picture that evolves is rather gloomy. At best, NTM can monitor cruise missile characteristics and activities with moderate levels of confidence. Any effort to deliberately conceal cruise missiles reduces this confidence to a low level. In general, bans can be monitored with greater confidence than limits, though the summary in Table 1 is hardly reassuring.

ADEQUATE VERIFICATION

Despite the fact that monitoring air-breathing systems with high confidence appears to be very difficult, this does not necessarily imply that arms control agreements cannot be adequately verified. Certainly, as one's monitoring confidence diminishes, the prospects for adequate verification dwindle. However, broader political and military considerations must be included before judgement can be passed. This section briefly addresses several military factors that might influence judgements on adequate verification--namely, the effect of air-breathing systems on crisis stability and the role cruise missiles might play in our strategic force posture.

Crisis instability refers to a situation in which both sides believe a decisive advantage can be gained by striking first against the other side's forces. Air-breathing systems are not particularly destabilizing, since they make poor first strike weapons because of their long flight times--about ten hours for intercontinental missions and two to three hours for theater missions. Thus, if detected, bombers and cruise missiles give adequate time for an opponent to launch his forces before they are attacked. This conclusion holds even for supersonic cruise missiles. If cruise missiles or bombers could sneak under early-warning radars, attacking without warning, the situation would be very different.

A related scenario, the "decapitation" strike, arises if Soviet cruise missiles attack Washington, D.C., from submarines. The point to keep in mind here is that SLCMs do not pose a new threat, since SLBMs can also be used for decapitation strikes, especially if they are launched on a depressed trajectory. If SLCMs are launched one hundred nautical miles from shore, they will reach Washington D.C. in approximately fifteen minutes (the nominal flight time for SLBMs, if they are not on a depressed trajectory). If such a threat developed, it would be relatively easy to enforce a 100 nm keep-out zone around Washington, D.C., or other vital coastal cities using antisubmarine warfare. Again, this conclusion rests on the assumption that SLCMs cannot evade early-warning radars or other detectors. Thus, the recent Soviet threat to deploy SLCMs within striking range of Washington, D.C. is a political move intended to counter NATO INF deployments, rather than a significant military threat.[18]

In sum, air-breathing systems do not contribute to crisis instability to the same degree as highly accurate MIRVed ICBMs. To the extent that air-breathing systems pose a lesser threat to the United States, concern with potential treaty violations might be reduced. For example, surreptitious aircraft deployments would not enhance Soviet ability to strike first successfully. Nor would any offensive advantage necessarily arise if the Soviets covertly deployed nuclear cruise missiles among indistinguishable conventional systems. In fact, insofar as deployments (overt or covert) on either side contribute to a secure reserve, confidence in a successful first strike diminishes, thus enhancing deterrence as well as crisis stability.

To appreciate the role of cruise missiles in our strategic force posture, we should consider the following three missions: the role of cruise missiles as a secure strategic reserve force, their ability to saturate air defenses, and the role of conventional cruise missiles in theater and strategic warfare. The requirements for adequate verification depend, in part, on likely missions for Soviet cruise missiles. Moreover, the enthusiasm with which the U.S. military will embrace arms control constraints on cruise missiles depends on the military utility of these forces.

The merits of cruise missiles as an addition to our strategic reserve are debatable.[19] On the positive side, their mobility, ease of

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[18]"Soviet Subs Off U.S. Bear Cruise Missiles," *Washington Times*, January 27, 1984, p. 1.

[19]Bruce Bennett and James Foster, "Strategic Retaliation Against the Soviet Homeland," in *Cruise Missiles: Technology, Strategy, Politics*, ed. Richard Betts, The Brookings Institution, Washington, D.C., 1981.

concealment, and large deployments make them difficult to target (this is also why they are hard to monitor). This enhances their prelaunch survivability, thus providing a larger force with which to retaliate. Since cruise missiles are capable of striking hard targets (for example, missile silos and hardened C^3 posts) and a wide range of other military targets, their role need not be confined to countervalue retaliation alone. On the negative side, if circumstances allow cruise missiles to be located and attacked before they disperse, they are relatively easy to destroy. Several other factors combine to make them less attractive than other reserve forces (SLBMs and penetrating bombers)--namely, the problem of penetrating Soviet air defenses (especially terminal defenses) though bombers suffer similar problems, poor cruise missile effectiveness against mobile targets, and a relatively inflexible retargeting capability.

Cruise missiles might provide a cost-effective means for saturating local air defenses, if deployed in large numbers, since they are relatively inexpensive. Such deployments could significantly influence the dynamics of the offense/defense competition in a situation with unconstrained strategic defenses.

The proliferation of conventionally armed cruise missiles will affect theater, if not strategic, warfare. Theater missions will feel the impact first, since conventional cruise missiles have shorter ranges (approximately 700 nautical miles for current-generation U.S. conventional cruise missiles).[20] In the European theater, cruise missiles might enhance conventional deterrence/defense by providing viable "deep strike" options against Soviet or Warsaw Pact targets. With increasingly accurate guidance systems and specialized conventional warheads, conventional cruise missiles might perform certain missions previously relegated to nuclear weapons--for example, limited nuclear options or demonstrations of resolve.

Whether conventional cruise missiles are useful for reducing the likelihood of nuclear war depends on the scenario. For theater missions, conventional cruise missiles may reduce the likelihood of conventional conflict by strengthening conventional deterrence. Furthermore, if deterrence fails, the likelihood that nuclear weapons

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[20] John C. Toomay, op. cit., p. 46.

will be used diminishes if effective conventional weapons exist. Obviously, a detailed analysis is required to determine whether cruise missiles do, in fact, enhance one's conventional options.

As a means to accomplish strategic missions, conventional cruise missiles appear less attractive. For example, though limited strategic strikes might appear less escalatory with conventional warheads, this is probably illusory, since it requires that escalation depend more on the warhead used than on the target struck. Furthermore, one's opponent may not wait until the weapon detonates before retaliating, in which case it hardly matters whether the warhead is conventional or nuclear. In fact, the greater willingness to use conventional weapons for strategic strikes might lead to nuclear war more quickly.

Insofar as cruise missiles become a new strategic reserve force, or can be used to saturate local air defenses, or will be an effective conventional weapon for theater warfare, they will likely be deployed in large numbers. Consequently, arms control ceilings for cruise missiles will probably be high. Although this may seem discouraging to some, it has the virtue that adequate verification becomes easier to accomplish, simply because small violations tend to be less significant. Therefore, high aggregate ceilings may be adequately verifiable despite our modest ability to monitor deployments.

In sum, although monitoring bomber/cruise missile characteristics and activities with high confidence appears to be difficult, the possibilities for adequate verification may not be hopeless.

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