STATEMENT OF

CHRISTOPHER BOLKCOM
ANALYST IN NATIONAL DEFENSE
CONGRESSIONAL RESEARCH SERVICE

BEFORE THE

SENATE GOVERNMENTAL AFFAIRS COMMITTEE
SUBCOMMITTEE ON INTERNATIONAL SECURITY, PROLIFERATION, AND FEDERAL SERVICES.

HEARING ON CRUISE MISSILE PROLIFERATION

JUNE 11, 2002

Mr. Chairman, distinguished members of the subcommittee, thank you for the opportunity to appear before you to discuss cruise missile proliferation. As requested, I will address the following questions:

- What makes cruise missiles[1] attractive weapons to Nations of Concern or terrorist groups? What technical challenges make them an unlikely weapon for terrorist groups?

- What are the difficulties in assessing the spread of cruise missile technology?

- How aggressively are nations pursuing cruise missiles?

- What challenges does the link between cruise missiles and the aircraft industry pose to applying effective export controls?

Crosscutting Observations

Before I address these questions directly, I'd like to make three observations that cut across all four of your questions:

- First, almost all cruise missile technologies have legitimate commercial and civil applications.
- Second, because cruise missile technologies are widely found in the civil aviation industrial base, their proliferation is difficult to monitor, assess, predict, and control.
- And third, due to the previous two points, cruise missiles offer great potential for technological surprise. They can emerge quickly and unforeseen.

What features make cruise missiles and unmanned aerial vehicles an attractive weapon for nations of concern or terrorist groups?

Generally speaking, terrorists have demonstrated a preference for using cheap and easily accessible weapons and technologies. Common terrorist techniques include using truck bombs, letter bombs, suicide bombers, and hijacking commercial aircraft. If terrorists pursue cruise missiles, it will likely be because they find it easy and cost effective to do so, and because cruise missiles will offer perceived advantages over other proven terrorist weapons.

---

[1] There is no universally agreed upon definition of what constitutes a cruise missile. However, it is commonly recognized that cruise missiles are unmanned, self-propelled vehicles that sustain flight through the use of aerodynamic lift over most of their flight. Ballistic missiles (such as Scuds) are not cruise missiles. Manned aircraft are not cruise missiles. Unmanned aerial vehicles, autonomous targets and drones are not truly cruise missiles unless they carry a warhead or weapon. However, UAVs so closely resemble cruise missiles that they are often treated as such (e.g. Missile Technology Control Regime).

The main potential reason why nations of concern may pursue cruise missiles, is that they might view them as a cost effective means of "leveling the playing field" against more advanced militaries. Unable to compete against the air and naval forces of industrialized countries, nations of concern may pursue cruise missiles as the "poor man's air force" or "poor man's navy." Additionally, cruise missiles can give authoritarian regimes a higher degree of control over personnel. Disgruntled pilots can defect by flying their aircraft to neighboring countries. Cruise missiles, on the other hand, are incapable of desertion.

Cruise missiles possess many features that match observed terrorist patterns and the potential nation of concern motivations described above. These features are related to system acquisition, system employment, and logistics. Acquisition features include low acquisition cost, and multiple acquisition options. Employment features include high accuracy potential, operational flexibility, high probability of penetrating air defenses, and high pre-launch survivability. Logistical features relate to benign handling requirements and infrastructure burdens.

Low acquisition costs

Generally speaking, cruise missiles are no longer "rocket science" and are relatively inexpensive.[2] While today's most capable cruise missiles – such as the Tomahawk -- tend to cost more than $1 million per copy, many cruise missiles can be had for less than $400,000 (Otomat, AS-16, AS-17, SS-N-25, Hsiung Feng I). Some cruise missiles cost $250,000 or less (HY-2 series, AS-11). Many, if not most UAVs cost even less (e.g. Mastiff $100,000, and MQM-107 $175,000). As a point of comparison, in 1991, Russian ballistic missiles (e.g., Scud-B and SS-21) tended to sell for about $1 million each.[3] Chinese ballistic missiles have reportedly been offered for between $1 million and $2 million (the M-11 and M-9 respectively).[4]

Variety of acquisition paths

Cruise missiles can be acquired through a variety of acquisition paths. Export of relatively effective cruise missiles and UAVs (range <300km and payload <500kg) can be acquired without violating Missile Technology Control Regime (MTCR) guidelines. Once imported, access to a variety of civilian technologies and expertise could enable cruise missile upgrades or conversions.[5] Civilian and military aircraft can be converted into cruise missiles. Cruise missiles can be produced indigenously, frequently leveraging platforms and technologies found in the commercial sector. This variety of acquisition paths makes cruise missiles attractive to both terrorists and nations of concern, as it increases the likelihood of acquisition success. If one path proves fruitless, others can be pursued. (For a snapshot of the various, often overlapping cruise missile acquisition paths, see Appendix 2, a case study of Styx-class cruise missile proliferation.)

High accuracy potential

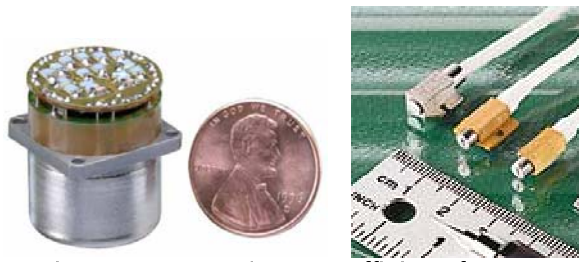
---

[2] The U.S. built the first cruise missile in 1917, and the German's launched 20,000 V1s during World War II. Adjusting for inflation, estimates price the V1 at about $3,000 in 2002 dollars.
[3] *Assessing Ballistic Missile Proliferation and Its Control*. Center for International Security and Arms Control. Stanford University. November 1991. p.27.
[4] Steven Zaloga. *World Missiles Briefing*. Teal Group Inc. Fairfax, VA. May 2001
[5] Also, some MTCR members have proven willing to export cruise missiles that arguably violate MTCR guidelines. Steven Zaloga. "The Cruise Missile Threat: Exaggerated or Premature?" *Jane's Intelligence Review.* April 1, 2000.

The advent of the Global Positioning System (GPS) has probably done more to draw attention to cruise missile proliferation than any other event. GPS -- and potentially other systems such as the Russian GLONASS -- offer cheap, effective, and passive means of correcting the drift errors inherent in the inertial navigation systems that guide cruise missiles. Today's standard GPS signals offer global accuracy of better than 10 meters.[6]

Inertial navigation systems themselves have also improved, in terms of accuracy reliability, and size. The typical inertial measurement unit (IMU), consisting of three gyroscopes, three accelerometers[7] and associated electronics weighed 25lbs in 1988. Currently, IMUs tend to weigh around 1 lb. Furthermore, fiber optic and ring laser gyros, which are more reliable and more accurate, are replacing traditional rotating mass gyroscopes. These more accurate inertial navigation systems require fewer GPS updates than less accurate systems over the same distance.

Figure 1: Modern Rotating Mass Gyro (L) and Accelerometers (R)



Precise navigation technology alone is not sufficient for accurate targeting. The target location, location of defenses, and major terrain features en route to the target must also be considered as part of the targeting solution.

The mission planning for some cruise missile applications may be easy. Delivering chemical or biological agents against cities, for example, might not require precise understanding of range, location, or terrain features. Because of their potential lethality, the effects from a very small amount of some biological agents might be felt over a very large area. Similarly, harassment, decoy, or attrition types of cruise missile attacks would not require complicated mission planning. Also, a number of UAVs are being outfitted today with communications and radar jammers. These unmanned electronic warfare (EW) platforms also would not require complicated mission planning, as U.S. communications and radar emissions would provide the required guidance. Yet, these UAVs have the potential to degrade the information dominance upon which many U.S. warfighting concepts depend.

For more complicated missions such as accurately striking point targets, today's military planners have access to, and the ability to exploit a good deal more information than the general "lat/long" of a target. Three mission-planning resources of interest to cruise missile users include maps, satellite imagery, and Geographic Information Systems (GIS).

Accurate maps, from cartographic versions to accurate digital products are readily available to most consumers. The National Oceanic and Atmospheric Administration (NOAA) for instance, sells aeronautical charts at 1:500,000 with 152-meter vertical and 610-meter horizontal contour accuracy. The U.S. Geographical Survey (USGS) provides a variety of cartographic products, including 1:24,000-scale topographic quadrangle maps, Orthophotoquads (which are distortion-

[6] On May 1, 2000, "selective availability" mode of GPS, which degraded the accuracy of GPS signals available to non-military users, was turned off.
[7] Instruments for measuring, displaying, and analyzing acceleration and vibration

free aerial photographs that are formatted and printed as standard 7.5 minute, 1:24,000-scale quadrangles), and satellite imagery maps.[8] The National Imagery and Mapping Agency (NIMA) digital maps with <20 meter vertical and <990 horizontal contour accuracy are also made available commercially, though their distribution is controlled.

Satellite imagery promises accuracy compatible with advanced navigation. Satellite pictures are currently available commercially from several countries, including China, France, India (1-meter resolution), Israel (1.8-meter), Russia (2-meter), Japan, and the United States. The U.S. Government has approved commercial sale of satellite images of up to one half meter in resolution and at least two companies sell such images via the Internet.

Figure 2: 1/2 meter Resolution Picture of Moffet Field, CA

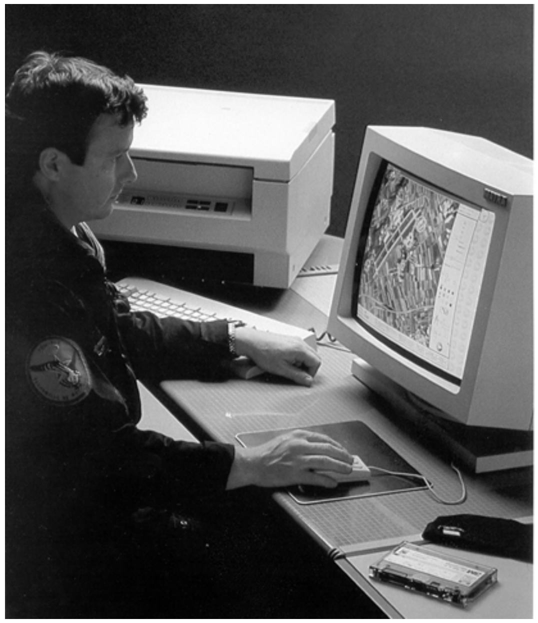
GIS, which create a computer environment for merging and exploiting different data sources, are also increasingly popular and commercially available products. For instance, *ER Mapper*, a product designed for Earth resource scientists, sells for less than $20,000. This product runs on a Sun computer workstation and can be used to integrate targeting coordinates with imagery compatible with advanced navigation systems.[9]

Cruise missile exporters include mission-planning resources as part of their sales. In their marketing literature, the French, for instance, advertise that the *Apache* cruise missile includes all required mission planning assets:

> All parameters, threats, ground relief and weather conditions are used by one workstation. Both data calculations and posting of flight plans are generated in real time on the screen. This ground equipment allows for the definition of the optimum trajectory for the missile and the carrier.[10]

[8] http://mapping.usgs.gov/www/products/1product.html
[9] http://www.ermapper.com.cn
[10] Matra Defense. *Apache* marketing brochure. 37, avenue Louis-Breguet. 78140 Velizy-Villacoublay. France

Figure 3: Apache Cruise Missile Mission Planning Workstation



In terms of accuracy and mission planning, most modern land attack cruise missiles available to or being developed by nations of concern appear capable of attacking fixed area targets from theater ranges. These include population centers, ports, airfields, military headquarters, and logistics infrastructures.

Operational Flexibility

Cruise missiles offer noteworthy operational flexibility. This may be attractive to groups or countries with limited resources. One platform may serve many different purposes. Cruise missiles can be used against a variety of targets, both on the land and sea. They can be launched from aircraft, ships, and submarines. Thus, cruise missiles can augment existing air and naval platforms or they can be shot from ground-based launchers. Ground launchers tend to be mobile and compact.

Cruise missiles can be armed with a number of different warheads, such as high explosives, submunitions, chemical and biological agents, radiological material and nuclear warheads. They can fly variable flight paths, avoiding enemy air defenses, and attacking targets from multiple and unexpected vectors. Furthermore, the amount of fuel and payload in cruise missiles is relatively interchangeable. Either range or payload can be increased on most cruise missiles. However, this is not a built-in feature of the system, and typically requires some engineering work that may incur some overall penalty in terms of missile performance.

Finally, if as discussed above, cruise missiles are obtained cheaply, they may also be acquired in bulk. Large inventories can reduce the demand for high quality or make these weapons relatively expendable.

High probability of penetrating air defenses

A cruise missile's small size tends to lend it a smaller radar signature, which makes detection by air defenses difficult. This low radar cross section (RCS) coupled with electronic countermeasures and an increasing ability to fly at low altitude gives modern cruise missiles a high probability of penetrating air defenses. Also, because a cruise missile looks more or less like a manned aircraft on a radar screen, defenders must be very certain of combat identification (CID) to avoid shooting down friendly, neutral or civilian aircraft. Verifying the identity of a "blip" on a radar screen takes time, and that time is advantageous to the attacker.

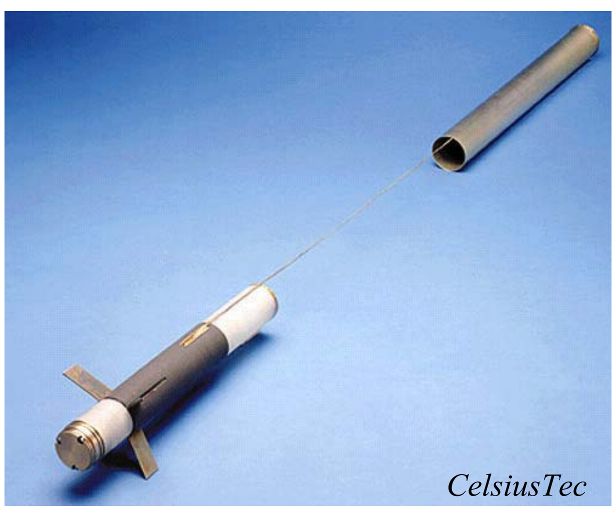
Today's low-altitude missile flight is most likely to take the form of terrain avoidance or "sea skimming." This requires some form of sensor and feedback control system to maintain the desired altitude. Some of the most readily available sensors that can be used are barometric altimeters and radar altimeters.

Barometric altimeters are simple devices that use a barometric capsule or a piezoelectric transducer to detect altitude based on the local atmospheric pressure. They are adequate to control missile flights down to about 100 meters for flights over a range of 20 to 30 km.

Radar altimeters are used to indicate the height above ground or sea. Radar altimeters can now be designed to operate down to a height of 1 to 10 meters. Such systems weigh about 2.5 kg. In practice, terrain roughness or Sea State limits the minimum safe operating altitude for low flying cruise missiles. In general, a missile would have to fly at least three times the mean crest-to-trough wave height to be reasonably certain of clearing the waves. Thus, five foot waves requires cruise missiles to fly at least 15 feet. A similar relationship would apply to overland flight.

Electronic countermeasures (ECM) such as self-protection jammers and towed radar decoys are available in size and cost commensurate with use in today's high-end cruise missiles (e.g., *Apache*). Employment of ECM could significantly increase the survivability of cruise missiles, once identified and targeted by air defenses.

Figure 4: Towed Radar Decoy Small Enough for Cruise Missile use



High pre-launch survivability

Cruise missiles, especially ground-launched cruise missiles, appear likely to enjoy greater pre-launch survivability than manned aircraft, and perhaps tactical ballistic missiles. Cruise missiles tend to project a much smaller operational footprint than manned aircraft, which require large airfields, hangars, maintenance facilities, and personnel billeting. Most modern ground launched cruise missiles are likely able to "shoot and scoot" on the same, or perhaps shorter timelines as ballistic missiles. Also, cruise missile's small size and relatively cool infra red launch signature may make them very amenable to camouflage, concealment, and deception (CCD) techniques. For example, from a distance, many cruise missile launchers are difficult to distinguish from busses, trucks, and some wheeled construction equipment. Small modifications to the cruise missile launcher – such as paint or canvas canopies, could make combat identification (CID) extremely difficult, especially if cruise missile launchers are interspersed with civilian traffic.

In Operation Enduring Freedom, the United States has demonstrated good capabilities against mobile targets compared to its "Scud hunting" track record of Operation Desert Storm 10 years ago. Yet, effectively attacking time-critical targets like ground launched cruise missiles remains a major challenge for DoD.[11] Furthermore, this class of targets appears to be much more challenging for other countries, even the relatively modern and robust militaries found among our NATO allies.

Relatively benign infrastructure and handling requirements

In addition to low acquisition costs, cruise missiles may offer a lower operations and maintenance (O&M) burden than other systems. Since there are no pilots, personnel costs for cruise missiles can be considerably less than that of manned aircraft.

The launch and mission control requirements of the average cruise missile system appear to be relatively easy to satisfy. Cruise missiles and UAVs use easily transportable "zero length" launchers (approximately the same length as the weapon), and mission control tends to be satisfied from a single small truck or van. Because weapon guidance is calculated and maintained over the course of the flight (e.g. GPS updates and terminal guidance) exact precision at launch is not critical to accurate targeting. This may facilitate fast set up and launch times. Scud missiles, on the other hand, tend to take on the order of one hour to set up and launch.

Also, because cruise missile ground launches can be achieved by relatively non-explosive means (e.g. mechanical catapult or strap-on rockets) launchers tend to require relatively little maintenance. It has been estimated that Scud TELs (transporter, erector, launcher) require overhaul after as few as three launches. Launch rails and other components need to be replaced due to metal fatigue caused by extreme temperatures.[12]

Cruise missiles powered by turbojet or reciprocating engines do not require an onerous "logistics train." These engines can be quite fuel-efficient. Ballistic missiles require both fuel and oxidant. The oxidant and fuel for a single Scud missile, by comparison, weighs 3.7 tons.

What technical challenges make them an unlikely weapon for nations of concern or terrorist groups?

---

[11] e.g. "We've got to do a much better job with time-critical targeting," said Vice Adm. John B. Nathman, commander of Naval Air Forces. *Aviation Week & Space Technology*. April 29, 2002, p.55.

[12] Joseph Bermudez. "Ballistic Missiles in the Third World: Afghanistan 1979-1992. *Jane's Intelligence Review.* February 1992.

There appear to be few technical challenges for most countries to acquire "medium-tech" cruise missiles. In a subsequent section, I will explore how many countries, even countries of modest economies, might have access to cruise missiles and many enabling technologies.

However, there are a number of more advanced cruise missile capabilities that currently appear outside the grasp of most, if not all countries of concern except through direct purchase. These capabilities include:

- Very low observable technology
- Terrain following navigation
- Ramjet propulsion
- Turbofan engines (which are very efficient and facilitate long ranges)
- High accuracy at very long ranges
- Real time targeting and battle damage assessment (BDA) required to effectively attack moving targets such as ground maneuver forces.

Also, experts debate the ease of disseminating chemical and biological agents (CBW) from cruise missiles. Some observers note that the typical cruise missile flight profile makes it a more effective delivery system than, for instance, a ballistic missile. Also, rotary-wing UAVs have become popular means of crop dusting in countries like Japan and South Korea.[13] Many claim that these unmanned helicopters could be used to spray CBW. Others disagree, saying that chemical, and especially biological agents have much more precise and delicate handling requirements than agricultural pesticides.

Figure 5: South Korean UAV. A Potential CBW Platform?

Technical challenges for terrorist organizations are less clear. The bottom line for terrorist group acquisition would likely be that cruise missiles would need to offer some capability or advantage over other delivery vehicles that are easier or cheaper to acquire. The intelligence community believes that this bottom line will remain elusive. According to a recent National Intelligence Estimate:

> "In fact, US territory is more likely to be attacked with these materials (chemical, biological, radiological, and nuclear) from non-missile delivery means – most likely from

[13] The Yamaha R-50 is an 11 foot long, UAV that has been used to spray hundreds of thousands of acres of Japanese farmland. It is GPS guided, and dispenses either dry or liquid chemicals. Unit Cost: $40,000. The Daewoo Arch 50 (S. Korea) has similar characteristics.

> terrorists – than by missiles, primarily because non-missile delivery means are less costly, easier to acquire, and more reliable and accurate. They also can be used without attribution."[14]

The Central Intelligence Agency (CIA) in recent testimony before this sub-committee echoed this opinion.[15]

What are the difficulties in assessing the spread of cruise missile technology?

In 1994, the Defense Science Board (DSB) -- DoD's premier group of scientific advisors -- made the following points regarding the proliferation of cruise missiles and their technologies:

- The cruise missile threat can be expected to evolve over time in both function and severity,
- The threat could evolve rapidly,
- It will be very difficult for the intelligence community to provide timely estimates of cruise missile and UAV threats.[16]

The DSB and others have identified several challenges to assessing the spread of cruise missiles and their technology. First, countries take great pains to keep missile design and production efforts secret. Often, countries hide missile development and production facilities, sometimes underground, to evade many U.S. surveillance techniques. The small size of cruise missiles relative to many other long-range weapons facilitates their covert development and manufacture. Aircraft manufacturing plants, as a point of comparison, tend to be very large facilities that are more difficult to hide or take underground. Iraq, Libya, North Korea, and Russia are some of the countries said to have built extensive underground military facilities.[17]

Second, countries often engage in active disinformation campaigns to intimidate neighbors and confuse those attempting to accurately assess their military intentions. A mock up of the Iraq's *Ababil* land-attack cruise missile was unveiled at an air show over a decade ago. This led many observers to conclude that Iraq was developing a long range, high payload cruise missile. Yet today, there is no open source evidence that this missile has been fielded. Was there anything more to the program than plywood models? It is doubtful that anyone outside (and perhaps even inside) the intelligence community really knows for certain.

Third, assessing the spread of cruise missiles and technology is complicated by disagreements over terms and definitions. Some defense experts call the Indian *Lakshya* air vehicle a UAV, while others say it has been tested with a warhead and is therefore a cruise missile. Some consider the Argentine *Martin Pescador* a cruise missile, while others call it an air-to-surface missile due to its rocket motor and short range. Iraq is reportedly building a solid rocket-powered tactical ballistic missile known as the *Ababil-100*. Is this the same system as the previously reported long range, turbojet-powered cruise missile? Or do two different programs merely have similar names?[18]

---

[14] Foreign Missile Developments and the Ballistic Missile Threat Through 2015. Unclassified Summary of a National Intelligence Estimate. National Intelligence Council. December 2001.
[15] Hearing of the International Security, Proliferation and Federal Services Subcommittee of the Senate Governmental Affairs Committee. March 11, 2002. Robert Walpole, Strategic and Nuclear Programs Officer, CIA.
[16] Report of the Defense Science Board Summer Study on Cruise Missile Defense. Office of the Undersecretary of Defense (A&T). January 1995. Washington, DC. p.14.
[17] See Jonathan Medalia, "Nuclear Weapons for Destroying Buried Targets." *CRS Report for Congress*. (RS20834) March 2, 2001. And Robert Burns. "Pentagon: U.S. Seeking Anti-Tunnel Nuclear Arms. *South Florida Sun-Sentinel*. March 15, 2002. P.12A.

[18] It turns out that they are, in fact, two different programs with similar names.

Fourth, the extent of today's cruise missile proliferation is difficult to assess because the technology "hides in plain sight." It is difficult to differentiate between military and civil application of many technologies that contribute to cruise missiles, such as engines, airframe materials, information technology, and GIS. There are few "tell tale" technologies that can alert export monitors of covert programs. Another complicating factor is the huge size of the commercial market for many cruise missile relevant technologies.

The commercial use of GPS, for example, is a multi-billion dollar industry that has spawned complementing and competing systems such as the Russian GLONASS, and European *Galileo* programs, as well as adjunct differential GPS systems being developed by and for the U.S. Coast Guard and Federal Aviation Administration.[19]

Accelerometers, a key navigational device, are found in the airbag deployment mechanism of almost every modern automobile. As several analysts have noted, the scope and form of information technologies that adversaries can exploit for cruise missile guidance is very broad: Iraq's import of children's video games, for instance, has become a cause for concern.[20] Similarly, it appears that many of the composite materials and structures that make surfboards both strong and lightweight could do the same for cruise missiles, as well as potentially reduce their radar signatures.

Finally, and in part due to the previous point, countries have developed, manufactured, and fielded cruise missiles in very short time spans, which makes assessment difficult and increases the likelihood of surprise. Often, they have done this by exploiting existing, and well understood aviation platforms, such as manned aircraft, UAVs, and anti-ship cruise missiles.

Leveraging manned aircraft

Historically, cruise missile builders have borrowed most heavily from aircraft technologies and techniques.[21] The Soviets borrowed heavily from existing aircraft resources in developing their first cruise missiles. The 1950s era SS-C-2b *Samlet* coastal defense missile, for example, was derived from the MiG-15 aircraft. The SS-C-2b used the MiG's fuselage with minor modifications, was powered by turbojet engines stripped from retired aircraft and shared some of the fighter's flight characteristics such as speed, range, stability, and maneuverability.

For the most part, the U.S. cruise missile development effort of the 1940s and 1950s emulated its early, WWI cruise missile R&D efforts. Engineers from both eras relied on contemporary aircraft propulsion. They adapted aircraft airframes of their time and made cruise missile-specific technological advances only in the areas of guidance and navigation. The first several U.S. post-WWII cruise missiles, for example, were built around widely used fighter aircraft jet engines and were not dissimilar to those aircraft in terms of size and performance. [22]

[19] The FAA is developing the Wide Area Augmentation System, for precise airline navigation. The Coast Guard is developing a Nationwide Differential GPS system for maritime navigation. Both concepts will use ground based radio beacons to transmit precise navigation information.

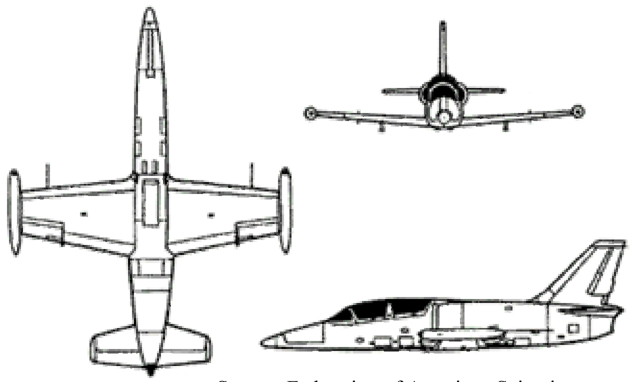
[20] The Sony Playstation 2 has 300 MHz, 128-bit processor, and a powerful graphics package. (Dennis Gormley*, Dealing with the Threat of Cruise Missiles* International Institute for Strategic Studies. Adelphi Paper 339. Oxford University Press. New York. June 2001. P.17.)

[21] In the early 1900s, experimental cruise missiles were literally unmanned aircraft. During WWI, the United States experimented with unmanned Curtiss N-9 seaplanes automatically controlled by cash register counters, and gyroscopes. British R&D focused on radio remote control of their aircraft, the *Bristol* fighter, *Sperry Avio*, *D.H.9A* and the *Wolf.*

[22] Matador, Mace, Regulus I, Regulus II, Hound Dog.

In more contemporary times, Iraq is believed to have converted manned aircraft into long-range (600km), high payload (200kg) cruise missiles. U.N. weapons inspectors reportedly suspect that Iraq is converting a Czech military training aircraft (the L-29 *Delfin*) into a long-range UAV from which it plans to disseminate biological weapons against its neighbors.[23] Norway has modified a manned aircraft, the Saab MFI-17 trainer, into a UAV.

Figure 6: L-29 *Delfin* Trainer Aircraft/Cruise Missile



Source: Federation of American Scientists

Weaponizing Unmanned Aerial Vehicles (UAVs)

Countries have converted unmanned aerial vehicles into cruise missiles. Historically, the U.S. BQM-34A *Firebee*, and *Quail* drone had a profound impact on U.S. cruise missile programs. While contemporary cruise missiles were nearly as large as fighter aircraft of that time, the 1960s era *Firebee* and *Quail* UAVs employed turbojet engines of less than one foot in diameter which allowed the design and manufacture of much smaller weapons.

Sweden converted the French CT.20 target drone into the Rb08A cruise missile, a coastal defense and anti-ship system with a 250km range. The Italian-built *Mirach* series of turbojet powered UAVs is believed to be the precursor of two Argentine cruise missile programs and the aforementioned Iraqi *Ababil* cruise missile, a system with a purported range of 500km. Many open source defense publications claim that both Iran and India have weaponized UAVs in their inventories. There also appears to be a strong connection between Israel's UAV and cruise missile programs.

[23] Biannual report to Congress by the CIA. As reported by Andrew Koch. "US, UK Intensify Air Strikes on Iraqi SAM Forces." *Jane's Defense Weekly*. September 19, 2001.

Figure 7: *Mirach* UAV/Cruise Missile on "Zero Length" Launcher

The U.S. *Predator* is the latest weaponized UAV. Designed originally to carry a variety of battlefield sensors, some *Predators* now carry *Hellfire* missiles as well. Because the *Predator* is a missile delivery platform rather than a missile itself, it is actually a more advanced class of cruise missile, the first operational uninhabited combat vehicle, or UCAV.

Building upon, or converting anti-ship cruise missiles

Anti-ship cruise missiles can serve as both evolutionary stepping-stones to a more advanced cruise missile capability and as systems that can be quickly converted directly into land attack weapons. The first generation Soviet ALCMs, GLCMs, and SLCMs, (AS-2, SS-N-1, SSC-1b) all had anti-ship capabilities, while the follow-on missiles (AS-3, SS-N-3) had both anti ship and land attack capabilities. In general, the basic design features of Soviet-era anti-ship cruise missiles suggest that these weapons are relatively easy to adapt to land attack roles. According to former Navy Secretary John Lehman, seven different Soviet anti-ship cruise missiles (SS-N-2, -3, -7, -9, -12, -19, and –22) could be converted to land-attack versions capable of striking the United States.[24]

The U.S. experience provides a more contemporary example of the conversion approach. Standoff Land Attack Missile (SLAM) was derived from off-the -shelf components, primarily from the Harpoon anti-ship cruise missile. SLAM and Harpoon share the same warhead, and sustainer and control sections. The primary difference between the two missiles is in guidance. While SLAM has the Harpoon's radar altimeter and midcourse guidance unit, it also employs technologies from other weapons systems, such as the *Walleye* video data link, and the *Maverick* imaging IR seeker. These components were coupled with a GPS receiver/processor.

The transformation of the Harpoon into the SLAM highlights some of the tradeoffs associated with the conversion approach. On the one hand, Navy engineers created a land attack cruise missile in only 18 months and at low cost. Yet, some compromises were made in missile performance. Use of existing hardware added more weight to the SLAM than more fully integrated and optimized components may have. This increased weight decreased weapon range. Off-the-shelf components required more space

[24] Arkin, Cochran et al. Nuclear Weapons Databook: Soviet Nuclear Weapons. Natural Resources Defense Council. Harper & Row Publishers. 1989. New York. P.156.

than custom-built components because they could not be integrated as efficiently. Thus, the SLAM is .64 meters longer than the Harpoon. In conjunction with the missile's increased weight, this increased length degrades the SLAM's aerodynamics since the control surfaces are optimized for the Harpoon's shorter airframe.[25]

The Harpoon to SLAM conversion began in 1988. Recent advances in the technology for precision guidance and "smart bombs," may provide cruise missile manufactures with more "off-the-shelf" conversion options today -- options that might not incur the performance penalties of past conversion strategies. The Harpoon missile again provides a case in point. Boeing is now working on a new land attack version of the Harpoon called the Harpoon Block II that incorporates an integrated INS/GPS guidance system developed for the Joint Direct Attack Munition (JDAM).

The Harpoon Block II will also use the software, mission computer and GPS antenna developed for the SLAM. Harpoon Block II is expected to perform both anti-ship and land-attack missions, and should have aerodynamic performance similar to the original Harpoon. It is not clear which countries are capable of this type of conversion today, but those that can't convert the Harpoon into "the poor man's Tomahawk," as some have called the Harpoon Block II, may be able to import the weapon. Boeing officials foresee an international market for the Harpoon Blk II of 1,100 new-build missiles, and 1,500 retrofits.[26] In May 2002 it was reported that Denmark was the first Harpoon II customer, upgrading 50 of its 100 Harpoon missiles to the land-attack capable variant.[27]

Table 1: Comparison of Harpoon and SLAM

	Harpoon	**SLAM**	**Harpoon Blk II**
Mission	Anti-ship	Land-Attack	Anti-ship/Land-attack
Range (km)	124	93	124
Payload (kg)	227	227	227
Length (m)	3.8	4.5	3.8
Diameter (m)	.34	.34	.34
Wing Span (m)	.9	.9	.9
Weight (kg)	555	620	555
Propulsion	Turbojet	Turbojet	Turbojet
Guidance			
• Midcourse	• INS, radar altimeter	• INS/GPS , radar altimeter	• Precision INS/GPS
• Terminal	• Active radar seeker	• Imaging infrared	• Anti-ship: Active Radar. Land attack: INS/GPS
• End game	• Autonomous	• Man-in-the-loop	• Autonomous

It appears that other countries have mimicked the Harpoon-to-SLAM conversion. The Israeli Gabriel II anti-ship cruise missile and the South African and Taiwanese spin-offs (Skorpioen and Hsiung Feng II respectively), appear to have land-attack capabilities. All three systems have TV terminal guidance like the SLAM and share similar airframe geometries. Many cruise missile analysts contend that all three anti-ship cruise missiles are land-attack capable.

[25] Author's conversations with industry (SAIC) and government (DARPA) aeronautical engineers. June 1995.
[26] Mark Hewish. "Anti-ship Missiles Intent on Littoral and Land Attack Roles*", q*uoting Boeing officials in *Jane's International Defense Review*. August 1998. P.45. Thomas Duffy. "Navy Says Harpoon Block II Missile Successful in First Flight." *Inside the Navy*. June 11, 2001.
[27] Thomas Dodd. "Denmark to Upgrade Harpoons." *Jane's Defense Weekly*. May 8, 2002. p. 13.

How aggressively are nations pursuing cruise missile purchases as complete systems and developing indigenous capabilities?

Despite the ambiguity and assessment challenges noted above, a survey of unclassified literature does provide some insight into today's state of cruise missile capabilities[28]:

- 81 countries today appear to have cruise missiles of some kind (See Map 1 below). In 1992, 63 countries had cruise missiles.
- Approximately 70,000 cruise missiles are operational worldwide.
- Seventy-five different types of systems are currently in service.[29]
- Over 40 additional cruise missiles are reportedly under development.

Today, the most advanced cruise missiles (e.g., long-range, reduced radar signature, high accuracy, employing terrain hugging navigation, and end-game countermeasures) tend to be in the hands of allies and like-minded countries. Our adversaries and potential adversaries tend to own cruise missiles that appear to be shorter range, have higher radar signatures, and lower accuracy. As discussed earlier, however, cruise missile capabilities can change and emerge rapidly. Partly for this reason, it is difficult to find consensus in the defense planning community regarding the future scope and pace of cruise missile proliferation.

The most rapid way a country can acquire cruise missiles is through purchase of foreign-made missiles. A review of the last 50 years indicates that cruise missile exports have not been uncommon (See Appendix 1).

Furthermore, despite fairly well established patterns of cruise missile export, observers can still be caught off guard. In 1998 for instance, many people were surprised when France -- an MTCR member – reported the sale of an accurate, long-range, potentially stealthy variant of their *Apache* cruise missile, the *Black Shahine*, to the United Arab Emirates (UAE).[30]

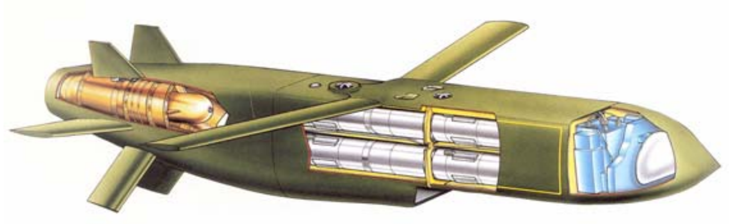
---

[28] Primary sources for the map, Tables 2-4 , Appendix 2, and estimates on cruise missile inventories and programs include publications: *Assessing Ballistic Missile Proliferation and Its Control*. Center for International Security and Arms Control. Stanford University, November 1991. Seth Carus. *Ballistic Missiles in the Third World*. CSIS. Washington, DC. Richard Betts. *Cruise Missiles: Technology, Strategy, Politics*. Brookings. Washington, DC. *Jane's Battlefield Surveillance Systems* (various years). Hooton, & Munson. Eds. Jane's Publishing Co. London. *Jane's Weapon Systems 1986-1987*. Jane's Publishing Co. London. *Jane's Air Launched Weapons*. (various years). Jane's Publishing Co. London. *Nuclear Weapons Databook.* Vol. IV Soviet Nuclear Weapons. National Resources Defense Council. Harper & Row Publishers. New York. Seth Carus. *The Prospects for Cruise Missile Proliferation in the 1990s.* CSIS. Washington, DC, 1992. Thomas Lydon. *RPV/Drones/Targets: Worldwide Market Study and Forecast*. DMS. *The Military Balance*. (various years) International Institute for Strategic Studies. London. *World Aviation Directory* (various years). McGraw Hill Publishers. New York. Michael Armitage. *Unmanned Aircraft.* Brassey's Defense Publishers. London. *Unmanned Air Vehicles After Desert Storm: Expanding World Markets for Flying Robots.* Market Intelligence Research Company. 1991. Steven Zaloga. *World Missile Briefing*. Teal Group Inc. Fairfax, VA. *Ballistic Missile Proliferation: An Emerging Threat.* System Planning Corp. Arlington, VA. 1992, *The World's Missile Dystems* (various years) General Dynamics. Pomona Division. *Aerospace Source Book* (various years) Aviation Week & Space Technology, McGraw Hill Publishers. New York.; Marketing and technical brochures on cruise missiles and technology: Aerospatiale, Alenia, Avionance S.A. Craiova, BAI Aerosystems, Boeing, Developmental Sciences Inc., E-Systems, General Atomics, Israeli Aircraft Industries, Korean Air, Aerospace Division, Lockheed Martin, Matra Bae, McDonnell, Douglas, Northrop Grumman, PT. Industry Pesawat Terbang Nusantara, Sener Ingenieria Y. Sistemas, S.A.m, Swiss Federal. Aircraft Factory, Teledyne Ryan; Databases and Web sites: http://www.cdiss.org (Master Tables), www.fas.org (Military analysis, OpFor Missiles), http://cns.miis.edu/research/missile.htm (Nuclear and missile database). Missile.Index: http://www.index.ne.jp/missile_e/

[29] The DIA reportedly estimates 130 different cruise missile types exist. Duncan Lennox. "Cruise Missiles." *Jane's Defense Weekly*. May 1, 1996.

[30] Michael Gething. "Upgrades and New Buys Boost UAE Mirage Fleet." *Jane's Defense Upgrades*. January 5, 1998

Figure 8: Apache Cruise Missile



For those concerned about cruise missile proliferation, the spread of indigenous manufacturing capabilities is arguably greater cause for concern than the sale of turnkey cruise missile systems. A country with an indigenous cruise missile manufacturing capability can be of greater concern than a country that merely has cruise missiles in its inventory for three reasons:

- Countries that make cruise missiles tend to be most able to advance the technological state of the art, making cheaper, stealthier, and more accurate cruise missiles in the future.
- Manufacturers usually can quickly and significantly increase their cruise missile inventories. They can simply run a second or third shift at the factory. They don't have to find exporters, negotiate deals, finance sales or make deliveries.
- Manufacturers are potential, if not likely, proliferants. The UAE, for instance, is unlikely to export cruise missiles anytime soon, but France, China, Russia, Sweden, South Africa, Israel, and other current manufacturers may well do so.

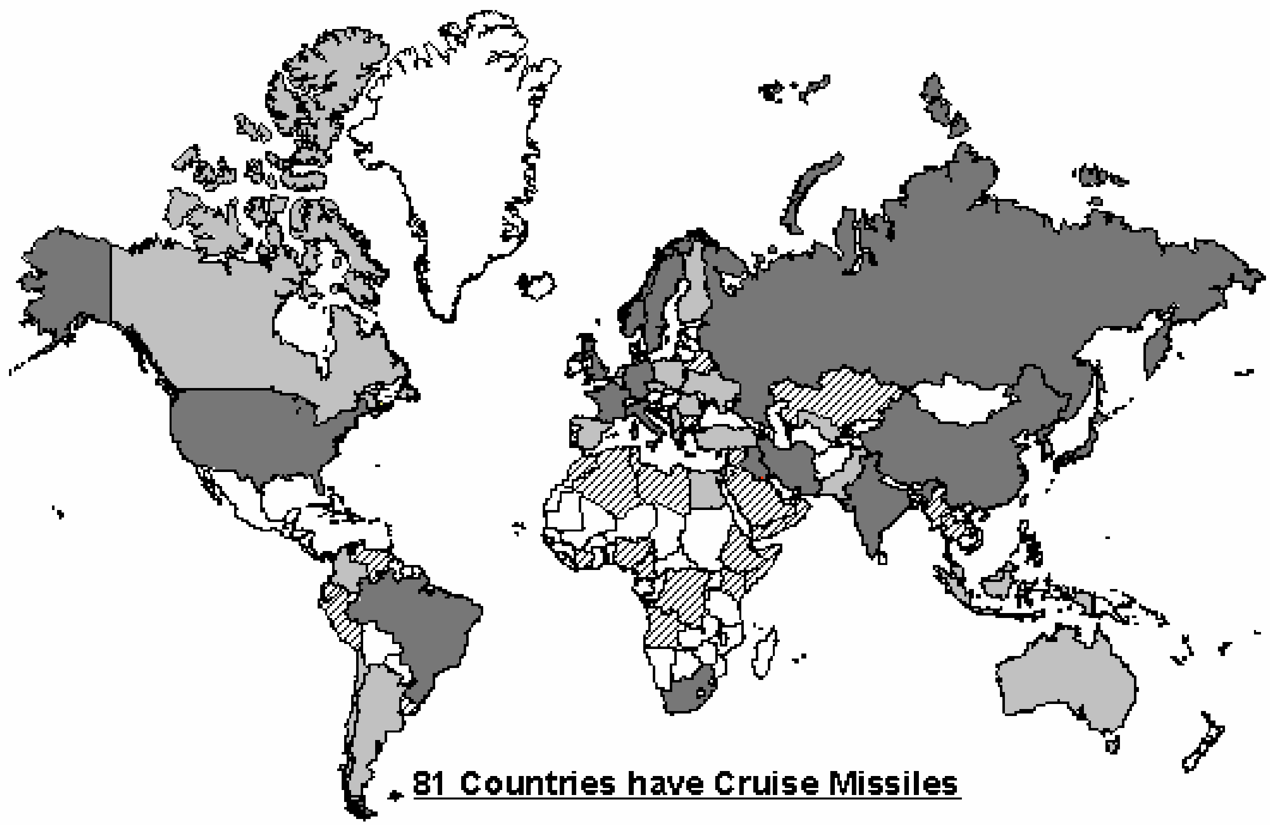
A survey of the 81 countries that have cruise missiles in their military inventories reveals that 18 countries manufacture cruise missiles domestically, and 13 of these countries also export them. These 18 countries and a simplified depiction of their supporting industrial base are summarized in Table 2 below.

Sixty-three of today's 81 cruise missile countries do not currently manufacture cruise missiles. However, 22 of these countries appear to have many capabilities that could be leveraged to create a cruise missile manufacturing capability sooner rather than later. These "threshold manufacturers" are depicted in Table 3 below.

These threshold manufacturers include a wide variety of countries and capabilities. Some, such as Argentina, have dedicated cruise missile programs, and are considered by some observers to already have a manufacturing capability today. Others, such as Canada, Australia, and the Netherlands, are industrially advanced countries that don't appear to have an indigenous cruise missile program, but clearly have the capacity to manufacture them. The exact capabilities of the remaining countries are more difficult to assess, but evidence of access to the design, engineering, and manufacturing capabilities required for cruise missiles is clear.

Using these same criteria for assessing a country's potential cruise missile manufacturing capabilities (production, cooperation and ownership), it appears that there are also at least four countries that currently do not own cruise missiles but could likely manufacture them if they desired -- Switzerland, New Zealand, Austria, and Slovakia. However, because these countries have not yet acquired cruise missiles, it is not clear that they are motivated to do so, and predicting a change in their intent is more difficult than making observations on their capabilities.

Map 1: Estimated Global Cruise Missile Capabilities



- 18 *Indigenous Manufacture* (make cruise missiles today)
- 22 *Threshold Manufacturers* (don't make cruise missiles today, but have or may soon have capability)
- 41 *Operate only* (unlikely to domestically manufacture in near future)

Table 2: Cruise Missile Manufacturers and Exporters
(listed alphabetically)

	Produce Domestically				Cooperatively Produce[31]				Own/Maintain			
18 countries	Cruise Missiles	UAVs	Combat Aircraft	Aircraft	Cruise Missiles	UAVs	Combat Aircraft	Aircraft	Cruise Missiles	UAVs	Combat Aircraft	Aircraft
Brazil	X	X	D	X	X	X	X	X	X	X	X	X
China ***E***	X	X	X	X	X	X	X	X	X	X	X	X
France ***E***	X	X	X	X	X	X	X	X	X	X	X	X
Germany ***E***	X	X		X	X	X	X	X	X	X	X	X
India	X	X	D	X	X		X	X	X	X	X	X
Iran	X	X	D	X	X				X	X	X	X
Iraq	X	X			?	X			X	X	X	X
Israel ***E***	X	X	X	X	X	X	X	X	X	X	X	X
Italy ***E***	X	X		X			X	X	X	X	X	X
Japan	X	X	X	X			X	X	X	X	X	X
N. Korea ***E***	X					X			X		X	X
Norway ***E***	X	D					X		X	X	X	X
Russia ***E***	X	X	X	X	X			X	X	X	X	X
S. Africa ***E***	X	X	X	X	X	X	X	X	X	X	X	X
Sweden ***E***	X	D	X	X	X		X	X	X	X	X	X
Taiwan ***E***	X		X	X			X	X	X	X	X	X
U. K. ***E***	X	X	X	X	X	X	X	X	X	X	X	X
U.S. ***E***	X	X	X	X		X	X	X	X	X	X	X

Key: X = Produces, cooperates, or owns, D = Under development, ? = Unclear, ***E*** = Cruise missile exporter

[31] This category includes a wide range of industrial relationships. In some instances, two countries may cooperate symbiotically in weapon system design and manufacture, where expertise and technology is shared on an equal footing, In other instances, one country may provide design expertise, while the second country manufactures the weapon under license, but gains engineering expertise in the process. A final cooperative case would be where one country simply assembles another's weapon system and little if any design or engineering expertise is transferred in the process.

Table 3: Countries that Import Cruise Missiles and are "Threshold Manufacturers" (Grouped roughly by capability)												
	Produce Domestically				Cooperatively Produce				Own/Maintain			
22 Countries	Cruise Missiles	UAVs	Combat Aircraft	Aircraft	Cruise Missiles	UAVs	Combat Aircraft	Aircraft	Cruise Missiles	UAVs	Combat Aircraft	Aircraft
Argentina	D	X		X	D	X	X	X	X	X	X	X
Australia		X				X	X	X	X	X	X	X
Canada		X		X		X	X	X	X	X	X	X
Egypt		X				X	X	X	X	X	X	X
Indonesia		X		X			X	X	X	X	X	X
Netherlands		X		X			X	X	X	X	X	X
S. Korea		X	D	X		X	X	X	X	X	X	X
Czech. Rep.		D	X	X		X		X	X	X	X	X
Spain		D		X			X	X	X		X	X
Pakistan		X		X			X	X	X	X	X	X
Malaysia		X		X				X	X	X	X	X
Belgium		X		X		X	X	X	X	X	X	X
Turkey		X		X		X	X	X	X	X	X	X
Serbia			X	X			X	X	X		X	X
Poland			X	X			X	X	X		X	X
Finland				X			X	X	X	X	X	X
Colombia				X				X	X		X	X
Ukraine				X				X	X	X	X	X
Chile				X			X	X	X	X	X	X
Romania				X			X	X	X	X	X	X
Uzbekistan				X			X	X	X		X	X
Greece				X					X		X	X
Key: X = Produces, cooperates or owns, D = Under development.												

The remaining 41 countries that operate cruise missiles today appear unlikely to become cruise missile manufacturers in the near future. These countries and a simplified portrait of their cruise missile industrial and technology bases are depicted in Table 4 below. All of the countries in this category own cruise missiles and many also own UAVs. Yet, a review of the industry in these countries indicates that not only is the ability to manufacture cruise missiles apparently lacking, but these countries don't produce UAVs, combat aircraft or civilian aircraft, which as discussed earlier, can serve as “pathways” to cruise missile manufacturing. Furthermore, with the exception of eight countries, there also does not appear to be any cooperative programs through which these countries are currently gaining cruise missile design or manufacturing expertise. Owning aircraft and combat aircraft may drive some countries to develop some technical skills, however simple. These platforms require regular maintenance and repair, which in turn require expertise, tools, and specialized equipment. A country that is able to keep its aircraft in good order with little outside help, has more potential to develop future cruise missile expertise and infrastructure, than a country that cannot.

Table 4: Countries that Import Cruise Missiles

	Produce Domestically				Cooperatively Produce				Own/Maintain			
41 Countries	Cruise Missiles	UAVs	Combat Aircraft	Aircraft	Cruise Missiles	UAVs	Combat Aircraft	Aircraft	Cruise Missiles	UAVs	Combat Aircraft	Aircraft
Singapore							X	X	X	X	X	X
Denmark							X		X		X	X
Portugal								X	X		X	X
S. Arabia								X	X	X	X	X
Morocco								D	X	X	X	X
Libya								X	X	X	X	X
Philippines								X	X		X	X
Nigeria								X	X		X	X
Algeria									X	X	X	X
Syria									X	X	X	X
Thailand									X	X	X	X
UAE									X	X	X	X
Oman									X		X	X
Peru									X		X	X
Venezuela									X		X	X
Albania									X		X	X
Angola									X		X	X
Azerbaijan									X		X	X
Bahrain									X		X	X
Bangladesh									X		X	X
Belarus									X		X	X
Bulgaria									X		X	X
Cote D’Ivoire									X		X	X

Croatia			X	X	X
Cuba			X	X	X
Ecuador			X	X	X
Eritrea			X	X	X
Kazakhstan			X	X	X
Kenya			X	X	X
Kuwait			X	X	X
Qatar			X	X	X
Somalia			X	X	X
Tunisia			X	X	X
Vietnam			X	X	X
Yemen			X	X	X
Cameroon			X	X	X
Myanmar			X	X	X
Dem. Congo			X	?	X
Brunei			X		X
Cyprus			X		X
Uruguay			X		X
Key: X = Produces, cooperates owns, D = Under development, ? = Unclear.					

What challenges does the link between cruise missiles, unmanned aerial vehicles, and the aircraft industry pose to applying effective export controls?

The ability to effectively apply export controls to cruise missiles and their technologies appears to be challenged by their link to the civil aircraft industry in three ways.

First, as discussed earlier in this testimony, differentiating between civilian and military applications of aviation technology is often difficult. Most if not all cruise missile technologies are found in the civil and commercial sector. And, apparently non-threatening civil aircraft can be converted into cruise missiles. The inherent flexibility of cruise missiles, especially in the areas of range and payload, makes agreement on system capabilities, and control of these systems difficult. The French argue, for example, that the *Apache*-class cruise missile they sold to the UAE does not fall within MTCR constraints. The U.S. Government and some independent observers disagree with the French perspective.[32]

Second, because the aircraft industry is a major segment of the U.S. economy, and exports are important to the aerospace industry, any perceived reduction in export competitiveness due to export controls would likely cause concern among both aerospace industry leaders and policy makers.

[32] Paul Beaver. "USA Angry Over French Decision to Export Apache." *Jane's Defense Weekly.* April 8, 1998.

Data provided by the Aerospace Industries Association show that over the past 35 years, for instance, the export of aerospace technology has totaled over $600 billion in sales and averaged almost 10% of all U.S. merchandise exported annually.

U.S. aerospace industry proponents point out that domestic orders for many aerospace products such as military aircraft have steadily decreased in the post Cold War timeframe. U.S. aerospace advocates argue that a reduction in domestic orders makes export success for U.S. aerospace industries more important, and impediments caused by restrictive export controls unwelcome.

As the importance of aerospace exports for U.S. companies has increased, competition for exports appears to have become more intense. European aviation and defense consolidation has matured significantly over the last 10 years, industry analysts point out, and many European aerospace products now rival U.S. products for market share. In commercial jetliner sales, for example Airbus's backlog of orders is currently larger than Boeing's, with a 51.6% share by value. Some analysts predict that Airbus's share of the overall market will continue to grow, averaging over 42% of the global market through the year 2010.[33]

Similarly, U.S. industry proponents say that in the defense aviation sector, the recently formed European Aerospace Defense and Space Company (EADS) appears to have the resources and expertise to compete with the largest U.S. defense firms. Also, due to their own decline in domestic orders, Russian aerospace companies are aggressively marketing their products abroad. Because the Warsaw Pact no longer exists, Russian aerospace exporters no longer have a "captive audience" for their products. Therefore, many argue, they are aggressively marketing their products to many countries where the United States may have previously enjoyed little competition. Also, some Russian aerospace products, like the Su-35 fighter, compare favorably to current U.S. combat aircraft, many argue, and many Russian aviation products cost less than U.S. products.[34]

Many believe that in light of the circumstances outlined above, export controls that pertain to aerospace products and technologies need to be overhauled and streamlined. In its second Interim Report, the Commission on the Future of the United States Aerospace Industry writes:

> Export controls have been and should be an important component of America's national security. The Commission believes, however, that export controls are increasingly counterproductive to our national security interests in their current form and method of implementation.[35]

The third challenge to applying effective export controls is posed by the potentially large growth in demand for unmanned systems as the technology matures and becomes applicable to an increasing number of civil and military roles. Some estimate that the market for UAVs and cruise missiles over the next eight years will exceed $25 billion.[36] Some analysts suggest unmanned systems will in the near future take on many new military roles. Companies such as Boeing and Northrop Grumman, for instance, are actively engaged today in researching and designing tomorrow's unmanned combat aerial vehicles.

The cruise missile and UAV proliferation witnessed to date has been generated by what can be described as a "niche" demand. The production and export of manned aircraft has traditionally dwarfed that of unmanned systems. How quickly and to what extent will unmanned systems proliferate in the future, as their military applications become more widespread?

---

[33] "Commercial Jet Transports: Market Overview." *World Military and Civil Aircraft Briefing*. Teal Group, Inc. Fairfax, VA. October 2001. Note: The argument over share of the commercial jetliner market is complicated. There are competing measures of market share (e.g. backlog, aircraft deliveries) and arguments can be made in favor of either company's current dominance. Airbus's competitive presence in the market, however, appears clear.

[34] For example, the Su-35 is currently competing with the F-16 for a 24 aircraft deal with Brazil. Many observers believe that the Su-35 has the upper hand in the competition. Axel Bugge. "Sukhoi said 'Sure Thing' in $700M Brazil Tender." *Moscow Times*. June 6, 2002.

[35] Commission on the Future of the United States Aerospace Industry. (Interim Report #2. March 20, 2002. Section IV "Dual Use Exports," p. 10.

[36] *World Missile Briefing.* Teal Group Inc. Fairfax VA. Figure was derived by adding forecasts for UAVs, stand-off air-to-surface, and anti-shipping missiles.

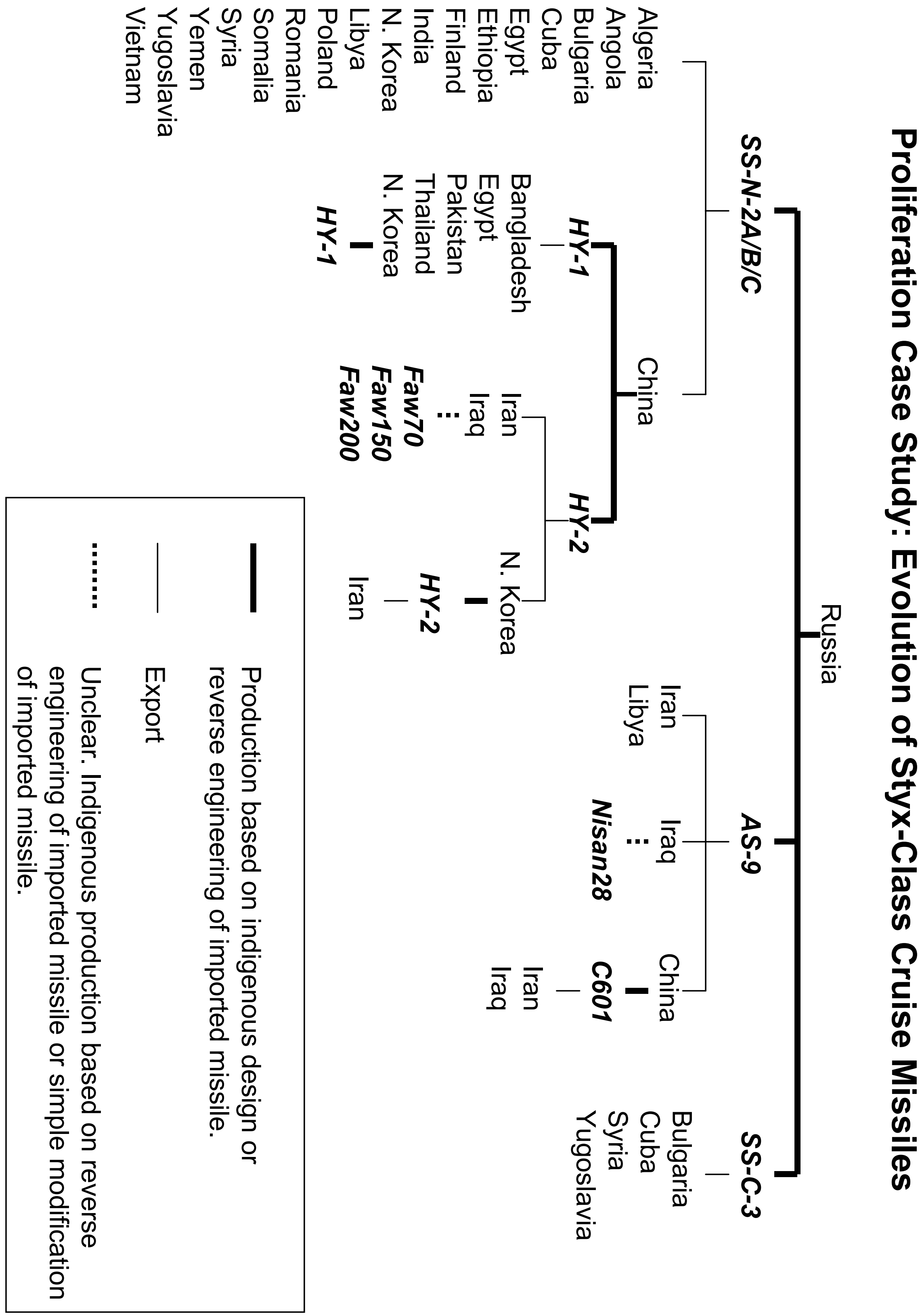
Finding a balance between national security and economic competitiveness in the area of cruise missile proliferation appears to be a complicated public policy challenge. The recently proposed export of the *Predator* UAV to Italy is an example of this challenge. On the one hand, this system (if deemed exportable under MTCR guidelines) would go to a close NATO ally, with which the United States has a long track record. It would improve Italy's surveillance capabilities, and promote interoperability with U.S. forces. The sale could help U.S. industry. On the other hand, the *Predator* is a very capable system that can be easily weaponized. Exporting this system to any country, some argue, sends the wrong message regarding cruise missile proliferation, and reduces the U.S.' leverage when attempting to deter others from exporting unmanned systems.

Appendix 1: Illustrative Cruise Missile Sales[37]

Exporter	Missile	Importer
China	FL-1/HY-1	Bangladesh, Egypt, N. Korea, Pakistan, Thailand
	HY-2	Iran, Iraq, N. Korea, Zaire
	HY-4	Iran
	C601	Iran, Iraq
	C801	Iran, Thailand
	C802	Iran
France	Apache	UAE
	Armat	Egypt, Iraq, Kuwait
	Exocet	Argentina, Bahrain, Belgium, Brazil, Brunei, Cameroon, Chile, Colombia, Ecuador, Ethiopia, Germany, Greece, India, Indonesia, Iraq, S. Korea, Kuwait, Libya, Malaysia, Morocco, Nigeria, Oman, Pakistan, Peru, Philippines, Qatar, S. Africa, Spain, Thailand, Tunisia, UAE, UK.
	SCALP	Greece
Germany	Kormoran	Italy
Israel	Gabriel I/II	Chile, Ecuador, Kenya, Singapore, S. Africa, Taiwan, Thailand
Italy	Otomat	Egypt, Iraq, Kenya, Libya, Nigeria, Peru, S. Arabia, Venezuela,
N. Korea	HY-2	Albania, Egypt, Iran, Pakistan
Norway	Penguin	Greece, Sweden, Turkey
Russia	AS-4	Iraq
	AS-5	Egypt, Iraq
	AS-9	China, Iran, Libya, Yemen
	AS-11	Iran, Iraq
	AS-12	Iraq
	Kh-41	China
	SSN-3	Syria, Yugoslavia
	SSN-2A/B	Bulgaria, Finland, India, Libya, Poland, Romania, Yugoslavia, Yemen
	SSN-2C	Algeria, Angola, Bulgaria, Cuba, Egypt, Ethiopia, Finland, India, N. Korea, Libya, Poland, Romania, Somalia, Syria, Vietnam, Yemen, Yugoslavia
	SSN-22	China, India, Iran
	SSN-25	Algeria, India, Vietnam
	SSC-2B	Bulgaria, China, Cuba, E. Germany, Egypt, N. Korea, Poland, Romania, Syria
	SSC-1B	Bulgaria, Syria
	SSC-3	Bulgaria, Cuba, Syria, Yugoslavia
Sweden	RBS15	Finland, Poland, Yugoslavia
UK	Sea Eagle	Germany, India, Oman
	Sea Skua	Germany, S. Korea, Kuwait, Turkey
US	Harpoon	Australia, Canada, Denmark, Egypt, Germany, Greece, Indonesia, Iran, Israel, Japan, S. Korea, Kuwait, Netherlands, Norway, Pakistan, Portugal, S. Arabia, Singapore, Spain, Taiwan, Thailand, Turkey, UK, Venezuela.
	Tomahawk	UK

[37] The Military Balance (Various years). International Institute for Strategic Studies. Oxford University Press. London

Appendix 2: Illustrative Export, Reverse Engineering, and Production of Russian Cruise Missiles



Source: See footnote

Appendix 3: Acronyms and Abbreviations

ALCM	Air launched cruise missile
ASCM	Anti-ship cruise missile
BDA	Battle damage assessment
CBW	Chemical and biological weapons
CCD	Camouflage, concealment, and deception
CEP	Circular error probable
CIA	Central Intelligence Agency
CID	Combat identification
DoD	Department of Defense
DSB	Defense Science Board
EADS	European Aerospace Defense and Space Co.
ECM	Electronic countermeasures
EW	Electronic warfare
GIS	Geographic information systems
GLCM	Ground launched cruise missile
GPS	Global positioning system
IMU	Inertial measurement unit
INS	Inertial Navigation System
JDAM	Joint Direct Attack Munition
LACM	Land attack cruise missile
NIMA	National Imagery and Mapping Agency
MTCR	Missile Technology Control Regime
O&M	Operations and Maintenance
RCS	Radar cross-section
R&D	Research and development
RLG	Ring laser gyro
SLAM	Stand off land attack missile.
SLCM	Sea launched cruise missile
TEL	Transporter, erector, launcher
TERCOM	Terrain contour matching
UAV	Unmanned aerial vehicle
UCAV	Uninhabited combat aerial vehicle
UN	United Nations