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GUEST ARTICLE

Freedom or Force on the High Seas? Arms Interdiction and International Law

BY DEVON CHAFFEE[1]

The proliferation of weapons of mass destruction is a stated focal point of current U.S. national security policy, concentrating on countries such as Iraq, Iran and North Korea. But in the name of counterproliferation, some U.S. officials are advocating for a policy of interdicting[2] ships that could further contribute to global instability by eroding the international law of the sea.

Over the past four centuries, an international body of law applicable to conduct on the oceans was developed as a way to regulate competition among naval powers. Currently, international law of the sea consists of customary international law, or particular usage habitually observed by the generality of countries out of a feeling of legal obligation, and treaties which may codify aspects of customary law.[3] While the law of the sea prohibits some activities, these prohibitions do not include the transit or transfer of weapons, including weapons of mass destruction (WMD).[4] This omission, despite serious security concerns, coincides with the free oceanic transiting of WMD by the United States, United Kingdom, France, Russia, and other nuclear weapon states.

In recent years, the United States has begun pursing a policy of ocean interdiction as part of its nonproliferation strategy in a manner that would likely violate the law of the sea. These are the very laws that the United States relies upon to legitimize its own transfer and transit of missile technology and nuclear weapons and materials. While there are situations where interdiction to interrupt the transfer of certain technologies is legal under international law, recent U.S. security strategy suggests that the United States is not likely to restrict its actions to those permissible under inter-

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SOURCE: U.S. NAVY WWW.NEWS.NAVY.MIL

Italian Special Forces personnel during "Clever Sentinel 2004," a multilateral maritime interdiction training exercise led by Italy in the Mediterranean Sea. According to a U.S. Navy web site, "the exercise was part of the U.S.-launched Proliferation Security Initiative (PSI), a collaborative effort to take active measures against trafficking in WMD, their delivery systems and related materials to and from states and non-state actors of proliferation concern around the world. Five nations, including the U.S., provided assets for the exercise..."

GUEST ARTICLE

Rush to Judgment at Yucca Mountain

BY PAUL P. CRAIG[1]

The U.S. nuclear industry wants nuclear waste off its hands. It desperately wants Yucca Mountain to become the country's repository for irradiated nuclear fuel and other high-level radioactive waste. The industry fails to understand that if Yucca Mountain isn't done right, public trust in the entire industry will collapse. That includes trust in waste transport. It includes trust in the ability of the industry to build and operate reactors safely. Lack of trust has big implications for the industry's hope for new reactors. Unfortunately, the Department of Energy is rushing ahead with a defective Yucca Mountain design. Why?

For the Bush administration, the development of Yucca Mountain as the national high-level nuclear waste facility is a foregone conclu-

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national law in responding to the transit or transfer of WMD that is contrary to U.S. interest.

If the United States goes forth with an interdiction policy that is contrary to international law, it will wreak significant damage on the international law of the sea. It will thereby put in jeopardy one of the most important international legal regimes and the freedom and security that the regime assures to all countries.

The significance of the international law of the sea

The law of the sea is one of the most comprehensive and complex collections of international law in existence. In addition to being important economically and environmentally, the international law of the sea is critical to creating a more secure international environment. The underlying principle of a sea ruled by law instead of force can be traced to a pamphlet published by Publicist Hugo Grotius in 1609, arguing that the freedom of the high seas could not be the object of private or state appropriation and that the use of the high seas by one state must not infringe on availability of the seas for use by another.[5]

However, throughout the 16th, 17th, and 18th centuries, state-sanctioned piracy, known as privateering, continued to be used by predominant naval powers as a means to maintain the domination of the seas necessary for controlling and benefiting from colonized territories.[6] In the mid-1950s, as newly independent former colonies began expanding their own jurisdictions over the sea, the former colonial powers began seeking alternatives for managing the seas that would be more beneficial to their interests.[7]

Such formal agreements included the 1958 Conventions that resulted from the first United Nations Conference on the Law of the Sea, held in Geneva. These were: the Convention on the Territorial Sea and the Contiguous Zone, the Convention on the High Seas, the Convention on the Continental Shelf, the Convention on Fishing And Conservation of the Living Resources of the High Seas, and the Optional Protocol of Signature concerning the Compulsory Settlement of Disputes.[8] Over half the participating states in the Geneva negotiations were newly established developing states who had little power or experience in multilateral negotiations, many of whom chose to disregard the resulting agreements as benefiting the dominant colonial powers.[9] The United States, however, is a party to all four of the 1958 Conventions and the optional protocol.

In an effort to combine the various treaties and customary laws of the sea into a comprehensive, more universally acceptable regime, the United Nations Convention on the Law of the Sea (UNCLOS) was agreed upon in 1982. On November 16, 1994, UNCLOS came into force and currently consists of 143 States Parties.[10] Though the United States was heavily involved in the drafting process, President Ronald Reagan decided not to sign onto UNCLOS, reportedly due to certain Continental Shelf provisions.[11] The United States subsequently adopted the position that the non-seabed provision of the convention generally reflects customary international law.[12] Though UNCLOS supercedes the 1958 Geneva law of the sea conventions, it does not alter rights and obligations arising from the other agreements if they are compatible with UNCLOS.[13]

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Under Article 2 of the 1958 Convention on the High Seas, the high seas can be used by all nations for the purpose of navigation. Likewise, Article 90 of UNCLOS declares that, "Every State, whether coastal or landlocked, has the right to sail ships flying its flag on the high seas." In addition to the freedom of the high seas, countries also have the right to transit through the territorial and archipelagic waters and exclusive economic zone of a state as well as through international straits.[14]

These freedoms, which are attributed to states worldwide and based on laws that have been established through decades of practice and codified in international treaties, are invaluable to preventing armed conflict between countries, such as those that were prevalent throughout the sixteenth and seventeenth centuries. If the law of the sea were degraded, it is likely that there would be an increased number of armed confrontations over the right to use and control the sea for a variety of economic and military purposes.

Restrictions to freedom of the seas and past attempts to control arms transit

Though the law of the sea grants several freedoms, it also bars specific activities and grants states the right to intervene in such activities. Prohibited activities include piracy, slave trade, illicit traffic in narcotic drugs or psychotropic substances, and unauthorized radio or television broadcasting.[15] The prohibition of these activities has been codified by a series of multilateral treaties in addition to their codification into the law of the sea through the 1958 and the 1982 Conventions.[16] There is, however, nothing in these conventions that explicitly prohibits transit of WMD or gives states rights to interdict such transit.

UNCLOS is explicit that interdicting a ship on the high seas is not justified unless there are grounds for suspecting that it is engaged in the limited set of activities prohibited on the high seas, i.e., those named above, unless the ship is without nationality or refusing to fly its flag.[17] Similar provisions apply in international straits, and coastal states have additional authority to prevent pollution, illegal fishing, danger to other ships, or the loading and unloading of goods or persons in contravention of national laws.[18] Coastal states do not have the right to suspend innocent passage through the straits.[19]

Advocates of nuclear disarmament and nonproliferation have made the argument that transit of nuclear weapons should be barred, just as the transit of slaves and narcotics are barred, because the threat or use of nuclear weapons has now been confirmed by the International Court of Justice as illegal,[20] and transit of such weapons would thus violate Article 301 of UNCLOS, which states that:

> In exercising their rights and performing their duties under this Convention, States Parties shall refrain from any threat or use of force against the territorial integrity or political independence of any State, or in any other manner inconsistent with the principles of international law embodied in the Charter of the United Nations.

A number of states, including the United States, have actively opposed the development of norms or interpretations of international law that would inhibit the transit of WMD by the seas or air. They cite the rights and privileges established in the law of the sea to affirm their unhindered military use of the oceans. Former U.S. President Bill Clinton, for example, interpreted UNCLOS as preserving "the right of the U.S. military to use the world's oceans to meet national security requirements."[21] Some U.S. analysts support the notion that "national security" requires the free transit of U.S. submarines armed with nuclear weapons.[22]

The question of nuclear weapons transit has been a persistent concern for the United States, particularly in relation to regional Nuclear Weapon Free Zones. The United States, in reservations deposited with its ratification of the protocols of the Treaty of Tlatelolco (Nuclear Weapon Free Zone in Latin America and the Caribbean), made explicit claims to the right of transit and transport.[23] The five NPT nuclear weapons states—United States, France, United Kingdom, China, and Russia—have opposed Article 2 of the Treaty of Bangkok (South East Asian Nuclear Weapons Free Zone) because it prohibits the threat or use of nuclear weapons within the exclusive economic zone — a prohibition which could be interpreted to apply to nuclear weapons transit.[24] These countries have thus not signed the treaty's protocol.

In 2000, the UN General Assembly passed a resolution calling for a Southern Hemisphere Nuclear Weapons Free Zone (SHNWFZ), but the zone was opposed by the United States, United Kingdom, France and Monaco largely because their concerns about transit were not satisfied. Speaking on behalf of the three nuclear powers, UK Ambassador Ian Souter said:

> [The resolution's sponsors would not] allay our concerns about their seeming desire to restrict maritime rights of free passage on the high seas. Unfortunately, the sponsors refused to include in the resolution the applicable passages of the Law of the Sea Convention as well as explicit assurance that the freedom of the seas was to be unaffected by their intentions.[25]

On the other hand, the Philippines refused to sponsor the SHNWFZ resolution, arguing that the resolution should have explicitly condemned transit of nuclear weapons as illegal. Thus it appears that the sponsors of the resolution were trying to take a middle path by not

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specifically prohibiting nuclear weapons transit, but allowing for the possibility that such a prohibition might be possible without interfering with the various understandings of the law of the sea provisions protecting innocent passage and freedom of navigation.[26]

Examining the legality of nonproliferation arms interdiction

The United States is now pushing for an initiative to use interdiction of weapons as a means to stem proliferation from states of concern to the Bush administration. This new policy is contrary to the past and current U.S. policy of insisting on right to transit weapons of mass destruction. When outlining the various counterproliferation tactics available to United States to the House of Representatives on June 4, 2003, John Bolton, Under-Secretary for Arms Control and International Security in the U.S. Department of State, stated:

> Interdiction efforts are also key to a comprehensive nonproliferation strategy. Interdiction involves identifying an imminent shipment or transfer, and working to impede and turn back the shipment….
>
> …We are in the early stages of discussing with several close friends and allies the President's initiative to expand interdiction efforts related to WMD- or missile-related shipments to and from countries of proliferation concern. A robust interdiction effort requires cooperation with like-minded countries…[27]

This effort to cooperate with "like-minded countries" is known as the Proliferation Security Initiative (PSI). It includes Australia, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Norway, Poland, Portugal, Singapore, Spain, Turkey, the United Kingdom, and the United States. While meeting in Paris in September 2003, PSI countries agreed to a set of "Interdiction Principles," which included specific commitments to:

> Undertake effective measures, either alone or in concert with other states, for interdicting the transfer or transport of WMD, their delivery systems, and related materials to and from states and non-state actors of proliferation concern.[28]

The PSI countries also engaged in cooperative interdiction military exercises in September 2003 and January 2004.[29] The interception of weapons and weapons material exports would purportedly serve as a way of controlling technology and materials. Theoretically, such interceptions might also be a way of economically inhibiting the target country, North Korea (or the Democratic People's Republic of Korea, DPRK), in particular. In the case of DPRK, any shipments to be interdicted would most likely include missile technology, a valuable export of the country, fissile materials (particularly plutonium), and possibly any materials that could arguably be related to a nuclear, chemical or biological weapons program.[30]

The Bush administration seems to be considering the interdiction of ships and their cargo as a means to put pressure on a country in a way that falls short of declaring war. However, because confiscating the cargo of a ship involves the physical interference and the use or threat of use of force, such interceptions can be considered more severe and more provocative than economic sanctions. The legal implications of arms interdictions on the law of the seas depend greatly on the way the interdictions are undertaken.

Legal implications of interdictions

Blockade, an unlikely option

Because certain U.S. officials have proposed the possibility of a blockade of DPRK, it is important to briefly discuss the relevant legal implications, though it appears to be an unlikely course of action. Such a blockade has been referred to by a U.S. Department of Defense adviser as a "Cuba Lite" blockade in reference to the blockade of Russian shipments of nuclear missiles to Cuba in 1962.[31]

Given that a persuasive case has not been made that DPRK's WMD program poses a threat to the territorial integrity of the United States, a full blockade against the country, undertaken without the consent of the UN Security Council, would clearly be a violation Article 2, paragraph 5 of the UN Charter which provides:

> All Members shall refrain in their international relations from the threat or use of force against the territorial integrity or political independence of any state, or in any other manner inconsistent with the Purposes of the United Nations.

In any case, given that DPRK officials have declared that they would consider economic sanctions to amount to a declaration of war, they may not tolerate a blockade without viewing it as an act of war and thus respond accordingly.[32]

Intermittent interdictions

One alternative to a full-blown blockade would be to execute intermittent interdictions of ships suspected of carrying WMD or related materials or technology en route on the high seas or through international straits.

U.S. officials have trumpeted the October 2003 interdiction of a German vessels carrying centrifuge parts from Malaysia to Libya as a pressure tool that helped get Libya to give up its unconventional weapons program.[33] However, it is unclear how far along Libya was in its nuclear capabilities, and it is recognized that Libya had not yet attained a nuclear weapons production capability or the ability to enrich uranium. Nor have inspections found any functioning centrifuges.[34]

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Regardless of their effectiveness, any interdictions outside those explicitly allowed in existing international law of the sea would clearly violate the freedom of navigation on the high seas. Whatever the ultimate decisions of the PSI group may be, those 16 countries lack the authority to change international law affecting the rest of the 180 United Nations members without their consent.

Clearing up confusion about law of the sea

Lines have blurred in the mainstream press with regards to interdiction, giving the impression that such interdiction is within currently established international law.[35] It is important to clarify some of the nuances of the PSI's new interdiction policy in order to highlight its extraordinary significance.

Part of the international effort to put increased economic pressure on DPRK has been the crackdown on its illegal narcotics exports. In April, the Australian navy interdicted an alleged heroin shipment coming from DPRK, as it is permitted to do under Article 108 of UNCLOS.[36] Some of the U.S. and UK media, however, have used this example as a precedent for arms interdiction. In late May, the *Financial Times* reported, "U.S. policy makers are drawing up plans to apply pressure on DPRK's fragile economy by clamping down on the communist state's trade in narcotics, arms and other illicit exports."[37]

Clumping together "narcotics, arms and other illicit exports" is misleading because while there are international conventions allowing for confiscation of illicit narcotics on the high seas,[38] there are no equivalent prohibitions or confiscation norms for trade in missiles or other such arms.

In analyzing the *So San* incident, where the United States and Spain boarded a North Korean ship (the *So San*) carrying Scud missiles to Yemen but eventually allowed the ship continue, John Wolfsthal of the Carnegie Endowment of International Peace deftly pointed out that:

> Despite U.S. concern… there is nothing illegal about the sale of such missiles by DPRK. Neither DPRK nor Yemen has signed any international treaties or bilateral agreements to prohibit such trade. In fact, no international treaty banning missiles sales exists and many countries, including the United States, sell both short and long range ballistic missiles.[39]

Not only does the United States engage in the transfer of potentially destabilizing missile and missile defense technology, but it also engages in the transfer of plutonium to be used as fuel for nuclear power plants, and the deployment and transfer of nuclear weapons to other states.[40] It is unlikely that the United States would stand for similar transfers by many other countries, not the least of which includes DPRK.

There are a number of agreements controlling transfers of missiles, missile technology and nuclear technology including, among others, the Nuclear Suppliers Group (NSG), Missile Technology Control Regime (MTCR), the Australia Group and the Wassenaar Arrangement.[41] However, these regimes do not apply to transfers between states that are not voluntary members of any of these regimes. Moreover, the NSG itself is an ad hoc group, like the PSI, that has been set up outside of the framework of the NPT because the nuclear weapons states and their allies, led by the United States, prefer to exercise authority outside of more comprehensively multilateral forums where their agendas may be challenged by states with contrary interests.

In addition to not being a participant in any missile export control regimes, DPRK is not a signatory of the Chemical Weapons Convention and is no longer a member of the NPT regime, and is thus not legally bound by the requirements of these treaties. The only relevance they would have for DPRK is that they prohibit states parties to these treaties from supplying certain materials to any state, including non-parties like DPRK.

Australian Foreign Minister Alexander Downer was quoted by BBC news as admitting that there was a "very real difficulty in terms of vessels that might be going through the high seas because international law requires that those ships should not be intercepted."[42] Downer also said, "We're still working on whether there needs to be some change to international law to facilitate these types of interdictions, to stop illicit trade," without elaborating on how this change may come about.[43]

While it might be encouraging to hear Downer express concern over compliance with international law, the process of establishing international legal norms is not as simple as his statement makes it appear. In the absence of any formal multilateral treaty negotiations, it is entirely unclear how the United States and its willing coalition could possibly "change" international law of the sea to permit discriminatory arms interdiction without the participation of non-like-minded countries. If the United States wants to advance a legitimate modification of international law of the sea it should begin by ratifying the UNCLOS treaty and working within the existing multilateral treaty regime.

Bilateral agreements: The Liberia example

The United States is also pursuing intermittent interdictions by securing bilateral agreements with individual countries that permit the United States to stop and search ships registered by that country. On February 11, 2004, the United States entered into an agreement with Liberia, which will allow each country to board sea vessels registered to the other.[44]

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According to U.S. State Department spokesman Richard Boucher, the agreement allows the United States to search any Liberian vessel suspected of carrying WMD, their delivery systems or related material.[45] More than 2,000 foreign ships fly the Liberian flag, as Liberia offers a flag of convenience to a number of merchant fleets, making Liberia's shipping register the second largest in the world.[46] The United States may be seeking to establish similar bilateral agreements with other shippers.[47]

The potential effectiveness of the Liberian model is unclear. It would seem that a system of bilateral agreements could be easily circumvented by using vessels registered in countries lacking such a regime. The bilateral approach to interdiction is, however, likely to undermine the multilateral character of the UNCLOS regime, just as other bilateral agreements pursued by the Bush administration have damaged other related multilateral frameworks. The increasing preference of the Bush administration to pursue bilateral agreements as a means of circumventing, or actively undermining existing multilateral frameworks is evident in recent bilateral trade agreements and the agreements granting immunity for U.S. citizens (including soldiers) from the International Criminal Court (ICC).[48]

The bilateral trade agreements are likely motivated by hopes of circumventing the group of 21 developing countries that were able to collaborate and challenge the developed nations' agendas during the World Trade Organization (WTO) negotiations in Cancun Mexico.[49] The bilateral framework puts less powerful countries at a greater disadvantage during negotiations heavily colored by power differentials and aid needs.[50] This negotiation strategy was openly brandished by the Bush administration when it threatened to cut military aid and training to at least 35 countries who had not yet signed agreements giving U.S. citizens immunity from the ICC in July 2003.[51]

As the pursuit of bilateral agreements threatens to undermine multilateral regimes such as the WTO and ICC, bilateral agreements such as the one secured with Liberia have the potential for eroding the multilateral framework pursued through UNCLOS. The pressure of aid and power disparities is also likely to be a tool for acquiring an interception regime that puts the political agenda of the United States over the integrity of international law. For instance, at a U.S. co-sponsored conference aimed at addressing Liberia's reconstruction needs less than a week before the interdiction agreement was reportedly signed, Colin Powell pledged $200 million for humanitarian and reconstruction aid and $245 million in peacekeeping aid for Liberia.[52] It is difficult to imagine that the power levied by such timely aid promises did not affect the interdiction agreement negotiations.

Legal approaches to interdiction

Going through the UN

The European Union (EU) is also considering incorporating arms interdiction in its nonproliferation strategy, but its proposed doctrine relies on UN Security Council involvement. Both the *Basic Principles for an EU Strategy Against Proliferation of Weapons of Mass Destruction* and its corresponding Action Plan adopted by the Council of the EU on April 15, 2003, refer to the interception of WMD related shipments. The Action Plan states:

> The EU should explore a resolution in the UN Security Council to identify the spread of WMD and their means of delivery, as a threat to international peace and security. The EU should support a UN Security Council resolution requiring, when appropriate, countries to prevent shipments and overflights of materials for use in WMD.[53]

Still, the Security Council is far less inclusive then the full multilateral treaty negotiation process that established UNCLOS. It is also very unlikely that Russia or China, both permanent members of the Security Council with veto power and both refusing to join PSI, would allow a resolution supporting the discriminatory interdiction. It is similarly unlikely that any of the Security Council's permanent members, including the United States, would support a non-discriminatory ban on such shipments. Given such barriers to going through the UN, there are other means being discussed by the PSI to crack down on the transfer of weapons of mass destruction and related materials and technologies that would not violate principles of the law of the sea.

Pressure through export control and sanctions

Individual countries can establish and strengthen domestic laws prohibiting domestic companies and individuals from providing weapons technologies or materials to DPRK and other countries looking to develop WMD. Such measures when targeting specific technologies are referred to as export controls and when targeting specific countries are referred to as sanctions.

For instance, Germany has jurisdiction to prosecute the directors of a German company for trying to supply aluminum tubes to DPRK's nuclear program in violation of a German regulation as a result of the shipment that was seized in early April 2003.[54]

Working with a consortium of countries pursuing similar domestic prohibitions makes such sanctions more potent. However, it lacks the legitimacy of a more formal multilateral process, because it attempts to enforce regulations on countries that had no voice in creating them. It also perpetuates a nuclear double standard because it would not likely bind NPT nuclear weapon states that are undermining or violating their treaty obligations to cease the nuclear arms race and pursue nuclear disarmament under Article VI of the NPT.

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Regulating transit through national territory: New Zealand revisited

Countries can also attempt to prohibit the transit of certain arms and materials through their territorial seas and other areas under their jurisdiction by passing domestic legislation. The final statement of the PSI meeting in Brisbane in July 2003 suggested that the PSI group work with countries that are key coastal or transit states or states that countries would be likely to enlist in their WMD proliferation efforts, presumably so that those states would allow for or engage in interdictions in their territory.[55] Such is the strategy urged in PSI's recently issued "Interdiction Principles,"[56] and that is already being implemented in Japan with respect to DPRK shipments deemed suspect by the Japanese government.[57]

The limitation of such an effort is, of course, that state participation is purely voluntary. China, for instance, might agree to interdict some shipments of fissile materials from DPRK, but is less likely to interdict missile shipments or shipments of other technologies more tangentially related to WMD, given China's suspected cooperation with Pakistan and Saudi Arabia on such technology.[58]

Also, if the United States begins a campaign of WMD interdictions in national waters, other countries might consider barring the transit of U.S. WMD through their territory. For instance, when New Zealand made it illegal to bring nuclear powered vessels or vessels transporting nuclear weapons into their ports or internal waters, the United States argued that such legislation violated notions of sovereign immunity, and refused to confirm or deny the presence of nuclear weapons on board U.S. vessels.[59] Such a position becomes even less tenable if the United States is pushing countries to enact stronger legislation barring transit of WMD technology and materials.

U.S. military dominance and control of the seas

A *New York Times* editorial on new U.S. interdiction policies stated,

> It is encouraging to see that the Bush administration is now proposing some intriguing new ideas for reinforced international cooperation in this area. The effort is especially notable in light of the Administration's deplorable record of devaluing international approaches to arms control.[60]

The conclusion is off the mark, because this ad hoc approach would erode the law of the sea. The approach follows the current trend in U.S. policy towards dismantling norms that are important for global security but that limit its ability to exercise military dominance when it fits short-term policy goals.

The United States has moved away from multilateral nonproliferation solutions, withdrawing from the Anti-Ballistic Missile Treaty, abandoning START II contrary to its NPT obligations, failing to ratify the Comprehensive Test Ban Treaty, stalling efforts to improve the Biological Weapons Convention regime, while at the same time advocating for the use of force and other counterproliferation tactics, such as in the invasion of Iraq.[61] Increasingly there seems to be an official mentality that, due to its military might, the United States can opt out of international norms, and put military means above other means of pursuing international security.

So, while the Bush administration may be genuinely interested in stemming nuclear weapons proliferation through interdiction policies, recent history suggests that the administration is likely to pursue interdiction policies in a way that erodes restrictions on U.S. use of force on the high seas. By using bilateral agreements and small coalitions, the administration seems to be pursuing a seafaring policy that can be applied selectively with minimal reciprocity, in ways that circumvent and damage the objectives of UNCLOS.

Many lessons are to be learned about the Bush administration's approach to nonproliferation and counterproliferation policy from the invasion of Iraq. In invading Iraq, the United States failed to gain the approval of the UN Security Council, yet took action with a loose coalition of allies in violation of the UN Charter.

Similarly, the United States is working with a loose alliance on arms interdiction (the PSI) that lacks formal decision-making structures that could rein in the actions of the United States. This indicates that the United States likely would not wait for UN approval before undertaking high seas interdictions in violation of UNCLOS. Such policies would compound the damage that the U.S. invasion of Iraq did to the ability of the United Nations to be an independent and more neutral arbiter for protecting international security. The apparent nonexistence of alleged WMD in Iraq further undermines legitimacy that the United States or the PSI led by the United States may claim for interdicting DPRK vessels on the high seas.[62]

The way forward

Restricting the transit of weapons of mass destruction would be a positive development in furthering arms control and stemming proliferation, if such norms were carefully developed by the international community and applied uniformly. International law cannot, however, maintain its integrity if applied whimsically or discriminately, or if defined by a small "coalition of the willing."

Uniformity first of all means that there must be explicit provisions and enforcement based on equality before the law, at least in principle, for the powerful and the weak alike. While PSI membership may appear to be an easy way for leaders of certain countries to get back into the good graces of the Bush administration

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after disagreements over Iraq, it will likely come back to haunt them because it will contribute to the degradation of law of the sea.

Inspections and interdictions on the high seas can be designed to be compatible with and further the rule of law. Given that the International Court of Justice has declared nuclear weapons use and threats to be illegal under essentially all circumstances, it is essential to create rules regarding the presence of WMD, and especially nuclear weapons, on the high seas that apply equally to all, nuclear weapons states and non-nuclear weapons states alike.

The creation of inspection mechanisms and, if required, interdiction mechanisms for weapons of mass destruction and even missiles can and should be part of an extension of UNCLOS, for which there is some precedent. That would provide mechanisms that would be a suitable complement to the nonproliferation and complete nuclear disarmament requirements of the Nuclear Nonproliferation Treaty. Finally, the United States should ratify UNCLOS and facilitate its strengthening.

The world's seas and oceans make up about three-fourths of the earth's surface. The importance of the rules governing this expansive area should not be underestimated. If leaders of the states participating in the PSI attempt to exchange law of the sea for selective nonproliferation measures, they should realize that the trade-off could eventually restrict their own country's access to international waters.

Leaders in China are already voicing concerns that PSI interdictions could aggravate military tensions and interfere with legitimate shipping in East Asia. China's State Council released a paper regarding the PSI asserting:

> Unilateralism and double standards must be abandoned, and great importance should be attached and full play given to the role of the United Nations.[63]

The Russian government has also voiced concerns over the legality of PSI's activities when it refused to join the initiative in early February 2004.[64]

If members of the international community begin to allow the erosion of the law of the sea to suit the policy goals of the sole existing superpower, this does not bode well for global democracy and the rule of law.

1 Devon Chaffee is former Research and Advocacy Coordinator of the Nuclear Age Peace Foundation and currently a student at Georgetown University Law Center. The views here are those of the author alone and not necessarily of IEER.
2 Interdicting: intercepting ships to determine whether proscribed activities are being conducted.
3 Military and Paramilitary Activities (Nicar. v. U.S.), 1986 I.C.J. 14, 111 (June 27).
4 Transit refers to the movement of weapons or weapons materials or weapons technology through waters, such as in the case of patrolling submarines. Transfer refers to transit with the intent to give over some or all control of the weapons, materials, or technology to another party, such as through missile technology sales.
5 Malcolm N. Shaw, *International Law,* Third edition (Cambridge: Grotius Publications, 1991), p 363.
6 See "Piracy and World History: An Economic Perspective on Maritime Predation," in C.R. Pennell, ed., *Bandits at Sea,* (New York: New York University Press, 2001), pp. 90 and 94.
7 In August 1952 Chile, Ecuador, and Peru asserted sovereignty over adjacent seas up to a distance of 200 nautical miles from shore at a time when expansionist attitude were becoming increasingly predominant with the Organization of American States. See James B. Morell, *The Law of the Sea: An Historical Analysis of the 1982 Treaty and Its Rejection by the United States* (Jefferson, North Carolina: McFarland & Company, Inc., 1992), p. 5.
8 For the abstracts of these texts see United Nations, International Law Commission, *Conventions and Other Texts.* On the Web at http://www.un.org/law/ilc/convents.htm.
9 Morell, 1992, op. cit., p. 7-9.
10 See the website of the International Law of the Sea tribunal at http://www.itlos.org and the UNCLOS text at Oceans and Law of the Sea website at http://www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm.
11 The United States has, however, signed the 1994 Agreement relating to the Implementation of Part XI of the UN Convention on the Law of the Sea relating to the ownership of the seabed & environmental concerns. For the list of signatories, see http://www.un.org/Depts/los/reference_files/status2003.pdf. For information on Reagan's fears see Morell, 1992, op. cit., p. 95
12 Morell, 1992, op. cit., p. 95; Restatement (Third), Foreign Relations Law of the United States, Rules and Principles, Part 5, Introductory Note (1987).
13 See UNCLOS Article 311.
14 Transit through territorial waters is limited to innocent passage. According to the 1958 Convention on the Territorial Sea, "Passage is innocent so long as it is not prejudicial to the peace, good order or security of the coastal State." According to the 1982 Convention, the territorial sea is up to 12 nautical miles from a state's coast; an exclusive economic zone (EEZ) is up to 200 nautical miles from a state's coast; and archipelagic waters applies to states constituted wholly by a group of islands and the interconnecting waters (limited in length to 100-125 nautical miles). An

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international strait is a passage through territorial waters linking sections of the high seas.

15 Article 109(2) of UNCLOS defines unauthorized broadcasting as, "the transmission of sound radio or television broadcasts from a ship or installation on the high seas intended for reception by the general public contrary to international regulations, but excluding the transmission of distress calls." See http://www.un.org/Depts/los/convention_agreements/texts/unclos/closindx.htm.

16 These include the 1890 General Act for the Repression of the Slave Trade and the 1965 European Agreement for the Prevention of Broadcasts Transmitted from Stations Outside National Territories.

17 UNCLOS Article 110.

18 UNCLOS Article 42.

19 UNCLOS Article 45.

20 See for example, *Submission to the Select Committee on Foreign Affairs, Defence and Trade on the New Zealand Nuclear Free Zone Extension Bill,* International Association of Lawyers Against Nuclear Arms, Aotearoa New Zealand Branch (Parnell, Auckland, New Zealand, 2001) on the Web at http://www.lcnp.org/disarmament/nwfz/submission%20on%20NWF2.htm. The International Court of Justice Advisory Opinion on the Legality of the Threat or Use of Nuclear Weapons (ICJ, 1996) is on the Web at http://www.dfat.gov.au/intorgs/icj_nuc/icj_nuclear_weapons.html.

21 William J. Clinton, "The Law of the Sea Convention: Letter to the Senate", October 6, 1994, *U.S. Department. of State Dispatch,* Vol. 5, No.42, October 17,1994. On the Web at http://dosfan.lib.uic.edu/ERC/briefing/dispatch/1994/html/Dispatchv5no42.html.

22 See for example, Mark Rosen, "Nuclear-Weapon-Free-Zones," *Naval War College Review,* Vol. XLIX, No. 4 Autumn, 1996. On the web at http://www.nwc.navy.mil/press/Review/1996/autumn/free-a96.htm.

23 Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean (Treaty of Tlatelolco), U.S. Department of State, Bureau of Nonproliferation. On the Web at http://www.state.gov/t/ac/trt/4796.htm.

24 The Southeast Asia Nuclear-Weapon-Free Zone Treaty (Treaty of Bangkok) opened for signatures on December 15, 1995. On the Web at http://www.opanal.org/NWFZ/Bangkok/Bangkok-iT.htm#2. For a discussion of the opposition to the treaty, see the *Inventory of International Nonproliferation Organizations & Regimes,* by the Center for Nonproliferation Studies. On the Web at http://cns.miis.edu/pubs/inven/pdfs/seanwfz.pdf.

25 Comments on the web at: http://www.delegfrance-cd-geneve.org/chapter2/soutar_311000_l19.htm. Note, the resolution does refer to "freedom of the high seas" and the Law of the Sea Convention, but, according to the Resolution's sponsors, the three dissenting countries also wanted references to customary international law. See UN General Assembly Resolution: 55/33 I, Nuclear-weapon-free Southern Hemisphere and Adjacent Areas, passed on November 20, 2000. On the Web at http://disarmament.un.org:8080/vote.nsf/0 /1339496b47ee610a852569840053aeeb?OpenDocument&ExpandSection=5.

26 Devon Chaffee and Jim Wurst, "Strengthening Existing Nuclear Weapon Free Zones." Originally prepared for the Uppsala, Sweden Seminar on Nuclear Weapons-Free Zones, September 2000, revised April 2002. On the Web at http://www.lcnp.org/disarmament/nwfz/StrengtheningExistingNWFZ.htm.

27 Testimony before the Committee on International Relations, United States House of Representatives, June 4, 2003. On the Web at http://wwwa.house.gov/international_relations/108/bolt0604.htm.

28 "Statement of Interdiction Principles," declaration issued by the Proliferation Security Initiative (PSI), Paris, France, September 4, 2003. On the Web at http://www.state.gov/t/np/rls/fs/23764.htm.

29 "Singapore Naval Ship Joins PSI Exercise," *Kyodo News Service,* January 12, 2004.

30 R. James Woosley, "The Next Korean War," *The Moscow Times,* August 5, 2003.

31 It is worth noting that even in the case of the Soviet Union placing nuclear tipped missiles about 90 miles off the continental United States, the Kennedy Administration still felt obliged to gain approval from the Organization of American States before enacting the blockade. See: http://www.telegraph.co.uk/news/main.jhtml?xml=/news/2003/04/27/wkor27.xml and http://home.att.net/~slomansonb/CubanMissile.html. Additionally the Cuba Blockade was more proportionate to the threat posed to the United States: the USSR was placing nuclear capable missiles on Cuban soil which could reach U.S. territory; the USSR had produced nuclear warheads for these missiles; and the U.S. placed the embargo only around Cuba, not any other countries to which USSR was deploying nuclear technology nor the USSR itself. Still, in his letter to President Kennedy on October 24, 1962, Soviet Premier Nikita Khrushchev argued that the blockade was in violation of "the standards regulating navigation on the open sea, in international waters." Letter on the Web at http://www.atomicarchive.com/Docs/khrushchevletter1.shtml.

32 "N. Korea Says Blockade Means War," CBS News.com on the web at http://www.cbsnews.com/stories/2003/06/18/world/main559179.shtml.

33 Robin Wright, "Ship Incident May Have Swayed Libya," *Washington Post,* January 1, 2004. For a fact sheet on recent developments in Libya see: http://www.ceip.org/files/projects/npp/resources/Factsheets/developmentsinlibya.htm.

34 Anjali Bhattacharjee and Sammy Salama, "Libya and Nonproliferation," Center for Nonproliferation Studies, Monterey Institute, December 24, 2003. On the Web at: http://cns.miis.edu/pubs/week/031223.htm.

35 See for example, Joby Warrick, "The Gray Zone: Cargo of Mass Destruction On DPRK Freighter, a Hidden Missile Factory," *Washington Post,* August 14, 2003, p. A01; and, Andrew Ward and David Pilling, "U.S. Considers Blockade to Put Pressure on N. Korea," *Financial Times,* May 23, 2003, p. 7.

36 See: Doug Struck, "Heroin Trail Leads to North Korea; Freighter Delivered Shipment of Drugs To Australian Coast," *The Washington Post,* May 12, 2003, p. A01.

37 Ward and Pilling, 2003, op. cit.

38 See Article 17 of the UN Convention Against Illicit Traffic in Narcotic Drugs and Psychotropic Substances. On the Web at http://www.unodc.org/pdf/convention_1988_en.pdf.

39 Jon Wolfsthal, "Stopping Missiles at Their Source," Carnegie Endowment for International Peace, December 11, 2002. On the Web at http://www.ceip.org/files/nonprolif/templates/article.asp?NewsID=4076.

40 For information on U.S. plutonium transfers see U.S. Department of Energy Press Release, "Plutonium Accounting Released, New Classification Approach Proposed," February 6, 1996. On the web at http://www.fas.org/news/usa/1996/pr96009.html. The United States has deployed nuclear weapons in Belgium, Germany, Greece, Italy, the Netherlands, Turkey and the UK and has signed agreements authorizing transfer of these weapons to those states during time of war. These arrangements could violate NPT obligations of the United States not to transfer nuclear weapons and the obligations of the host states not to receive nuclear weapons. See Martin Butcher, Otfried Nassauer, Tanya Padberg and Dan Plesch, *Questions of Command and Control: NATO, Nuclear Sharing and the NPT,* PENN Research Report, 2000.1, Project on European Nuclear Non-Proliferation, March 2000, p. 23. On the Web at: http://www.bits.de/public/pdf/00-1command.pdf. Also see Otfried Nassauer, "Nuclear Sharing in NATO: Is it Legal?" in *Science for Democratic Action,* Vol. 9, No. 3, May 2001. On the Web at http://www.ieer.org/sdafiles/vol_9/9-3/nato.html.

41 For information on the MTCR see www.state.gov/t/np/rls/fs/2001/5340.htm and www.armscontrol.org/factsheets/mtcr.asp. The Australia Group's concerns chemical and biological weapons are described at www.australiagroup.net. For information on the Wassenaar Agreement see www.wassenaar.org.

42 "N. Korea Ships Face More Scrutiny," BBC, June 11, 2003. On the Web at http://news.bbc.co.uk/2/hi/asia-pacific/2980418.stm.

43 Sonni Efron and Barbara Demick, "11 nations to Discuss Blocking Shipments of Weapons Materials," *Los Angeles Times.* June 12, 2003.

44 "Liberia; Country Joins War Against Weapons of Mass Destruction, Signs Agreement With United States," Africa News, February 17, 2004.

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sion. The Department of Energy (DOE) is spending over a half-billion dollars on Yucca Mountain this year, almost all of it for getting a license application in to the Nuclear Regulatory Commission by the end of 2004. The Bush administration is committed to burying waste by 2010.

Yucca Mountain is simple in concept, but in practice involves complex geology and complex engineering. Because of its importance, the U.S. Congress established the Nuclear Waste Technical Review Board (NWTRB) to provide technical advice about Yucca Mountain to it and the Secretary of Energy. The Board's members (eleven when the Board is at full strength) are scientists and engineers with expertise relevant to Yucca Mountain. Members are appointed by the President from a list submitted by the National Academy of Science. I had the privilege of serving on the NWTRB from 1996 until January 2004.

The Board concluded, and I concur, that the present design for Yucca Mountain is deficient. Unless the design is changed, the country's high-level waste repository is likely to leak.

The DOE doesn't seem to be listening. It is continuing its usual approach, the "DAD" strategy: decide, announce, defend. Instead of drawing on the expert community or listening to the public, DOE decides internally what's to be done. Having made its decision, it announces its plan. And then it defends its decision against all criticism. The Department of Energy uses DAD often, including every time Yucca Mountain has another of its many problems. The agency is using it right now—denying the latest finding by the NWTRB that the containment canisters in its current design are likely to leak.

What's needed now is a Presidential decision instructing the DOE to slow the Yucca Mountain program and to get the science right. While that process is going on, high-level waste should be moved to dry storage containers, which can sequester it safely for many decades.

The current Yucca Mountain situation is best understood in the larger context of nuclear power. I review (1) The nuclear energy context, (2) nuclear waste history, (3) problems at Yucca Mountain, (4) what it all means, and finally, (5) what should be done.[2]

The context

In 2001, nuclear energy worldwide produced 2.5 x 10^{12} kilowatt-hours (kwh) of electricity. The top generators were the United States (31%), France (16%), and Japan (12%). France was most reliant on nuclear electricity (77%), followed by Ukraine (44%), South Korea (37%),

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45 "Pact allows U.S. search rights on thousands of ships," *Chicago Tribune,* February 14, 2004, p. 6.
46 Ibid.; "U.S., Liberia in deal to search ships for WMD," *Agence France Presse* February 13, 2004.
47 "Liberia; Country Joins War Against Weapons of Mass Destruction, Signs Agreement With United States," *Africa News,* February 17, 2004.
48 Brian Knowlton , "Failed Cancun Talks Give Impetus To Bilateral Deals," *The International Herald Tribune,* September 23, 2003. On the web at http://www.tradeobservatory.org/News/index.cfm?ID=4827.
49 Ibid.
50 For analysis on the disadvantaged position of poorer nations in bilateral trade negotiations see Mark Tran, "The cost of failure: The collapse of the trade talks in Cancun is bad news for everyone, not just the poor nations," *The Guardian,* September 15, 2003. On the Web at http://www.guardian.co.uk/wto/article/0,2763,1042578,00.html.
51 "U.S. Cuts Military Aid to Backers of International Court," *DW-World.de,* July 2, 2003. On the Web at http://www.dw-world.de/english/0,3367,1433_A_907698,00.html.
52 "U.S. Pledges $200 Million to Reconstruct Liberia," USAID Press Release, Feburary 6, 2004; "Over $500 million pledged at international reconstruction conference on Liberia," *M2 PRESSWIRE,* February 9, 2004.
53 Council of the European Union, *Action Plan for the Implementation of the BasicPrinciples for an EU Strategy against Proliferation of Weapons of Mass Destruction,* 10354/03, Brussels, June 10, 2003, page 7. On the Web at http://register.consilium.eu.int/pdf/en/03/st10/st10354en03.pdf. *Basic Principles for an EU Strategy against Proliferation of Weapons of Mass Destruction* can be found at http://register.consilium.eu.int/pdf/en/03/st10/st10352en03.pdf.
54 See "Questions Over Aluminum Tube Shipment," *New York Times,* April 27, 2003. On the Web at http://www.nytimes.com/2003/04/27/international/asia/27NUKE.html.
55 Chairman's Statement, Proliferation Security Initiative, Brisbane Meeting, July 9-10, 2003, http://www.dfat.gov.au/globalissues/psi/chair_statement_0603.html.
56 "Statement of Interdiction Principles," 2003, op. cit.
57 See Lawrence F. Kaplan, "Split Personality: The Bushies' Pyongyang Policy," *The New Republic,* July 7, 2003.
58 See Carol Giacomo, "China Links with Saudi, Pakistan a U.S. Concern," *Reuters,* February 15, 2004; and, "China warns of illegalities in U.S.-backed non-proliferation plan," *Agence France Presse,* December 4, 2003.
59 James R. Van de Velde, "'Neither Confirm nor Deny' At Sea Still Alive and Consistent With International Law," *45 Naval L. Rev. 268,* 1998.
60 "New Tools for Arms Control," *New York Times,* June 7, 2003.
61 See Nicole Deller, Arjun Makhijani, John Burroughs, eds., *Rule of Power or Rule of Law? An Assessment of U.S. Policies and Actions Regarding Security-Related Treaties* (New York: Apex Press, 2003).
62 PSI members, such as Australia, also rely heavily U.S. and UK intelligence. See "Legal Doubts over Ship Interceptions," *AAP Newsfeed,* November 26, 2003.
63 "China Warns of Illegalities in U.S.-Backed Non-Proliferation Plan," *Agence France Presse,* December 4, 2003.
64 Mark McDonald, "Russia Will Ignore U.S. and Send N-Fuel to Iran," *Deseret Morning News,* February 14, 2004.

and Germany (30%). Nuclear energy provided 21% of U.S. kilowatt-hours.[3]

The high-level nuclear waste from electricity production consists primarily of used-up reactor fuel assemblies. These assemblies are manufactured from uranium oxide isotopically enriched in uranium-235. Irradiation in reactors transmutes the uranium into other isotopes and other elements, some of which are highly radioactive. In the absence of reprocessing (which is not done commercially in the United States), used fuel assemblies must eventually be disposed of.

There are at present approximately 60,000 spent fuel assemblies in the United States, containing around 45,000 tons of spent fuel. About 95% of the assemblies are stored under water, the rest in dry casks.[4] Underwater storage (pool-storage) is expensive and vulnerable to terrorist attack. As pools fill up, in the absence of a final disposal site, utilities are increasingly planning to move the high-level waste to dry storage. The U.S. Nuclear Regulatory Commission (NRC) estimates that 52,000 metric tonnes of heavy metal (MTHM) will be stored at reactors by 2005.

The fleet of around 100 civilian U.S. reactors was originally expected to produce roughly 63,000 MTHM over their collective working lifetimes, and Yucca Mountain was sized to match this amount of waste plus about 7,000 MTHM of military waste.[5] Reactor efficiency has improved over time, and many reactors may well be relicensed. Thus the ultimate amount of waste that will eventually be produced by the existing fleet of U.S. reactors will be larger than originally projected.[6]

While the radioactivity is high, the volume of this waste is relatively modest. Sixty thousand spent fuel assemblies would cover a football field to a height of about a football player. The issues relate to the radioactivity of the material, not the volume.[7]

There is impressive international agreement that nuclear waste should be managed so that it "…affords to future generations at least the level of safety which is acceptable today," and that "…there seems to be no ethical basis for discounting of true health and environmental damage risks."[8] U.S. repository standards have been established by the Environmental Protection Agency (EPA) and call for keeping radiation levels to the exposed population below 15 millirem per year for 10,000 years. This commitment is impressive.[9] The time span far exceeds times discussed in discussions over global warming. Whether the commitment can be kept is the big question.

Some history about nuclear waste

Nuclear waste disposal was long ignored by the reactor industry. Regret over this was eloquently expressed by Alvin Weinberg, one of the fathers of the industry. Weinberg wrote:

SOURCE: DOE.WWW.OCRWM.DOE.GOV

A Yucca Mountain Project scientist tests for water movement in rock inside Yucca Mountain.

> … I paid too little attention to the waste problem. Designing and building reactors, not nuclear waste, was what turned me on… [A]s I think about what I would do differently had I to do it over again, it would be to elevate waste disposal to the very top of ORNL's [Oak Ridge National Laboratory's] agenda… I have no doubt that, if wastes had been viewed… as the highest priority on the research agenda, we could by this time [1994] have demonstrated a working high-level depository that was perceived by the public to be safe.[10]

This is an interesting perspective, but it's also possible that had the nuclear engineering community disposed of the high-level waste in those early days, they might have done the job so poorly that we'd be paying a huge environmental price today.

In any event, after various false starts the government decided to explore a range of sites throughout the country. Later the options were reduced to three sites in Texas, Washington and Utah. A combination of political pressure and high site characterization costs eventually led the Congress to instruct the DOE to characterize a single site, Yucca Mountain. That placed the DOE in a very difficult position. Since the country has but a single site, a finding that it is unsuitable after investment of huge sums of money would present an enormous political problem.

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The tensions were made even larger by the successful lobbying by the nuclear industry for laws requiring the government to take over ownership of the waste by 1998. When the government failed to accept the waste, lawsuits followed. The DOE must deal with lawsuits both by industry (which wants the waste taken off its hands) and the State of Nevada (which objects to being used as the national high-level nuclear garbage dump).

Problems at Yucca Mountain

The Yucca Mountain site has a number of features suited to a high-level waste repository. The environment is arid; population densities are low; the site has long been used for nuclear testing. Yucca Mountain consists of layers of volcanic rock (tuff) laid down approximately 12 to 13 million years ago. The underground part of the repository would be composed of a series of drifts (tunnels) located about 300 meters below the surface of Yucca Mountain and about 300 meters above the present water table. Thus, the drifts would lie in the unsaturated hydrogeologic zone.

On average, only a small fraction of the precipitation that falls on the crest of the mountain percolates down to the level where the DOE proposes to construct the drifts. However, the water that does percolate would slowly corrode the engineered materials (fuel rods plus engineered canisters and protective drip shields), and eventually transport radioactive material to the water table where it would be transported to the nearest human settlement about 20 kilometers away in the Amargosa valley, where people today are using water from this aquifer, the only existing groundwater in the area. During transport, the radioactivity will decay. If the transport processes are slow enough, doses would be small.

It turned out that characterizing Yucca Mountain was far more difficult than had been anticipated. Geological surprises kept occurring. The volcanic deposits are exceedingly inhomogeneous and hard to analyze. There are cracks through which water can flow quickly. The rock turned out to be wet. Modeling of water transport pushed the state of the art to the limit. DOE found that they could not compellingly make the case mountain alone would achieve the EPA standards.

Since DOE couldn't make the case that geology would provide adequate isolation, they added engineered barriers. This, too, proved difficult. Over the years, DOE explored a variety of approaches to engineered barriers. They began with stainless steel. When the calculations showed this material would fail, they turned to more exotic alloys. The current design calls for waste canisters made of a nickel-based alloy called alloy-22 or C-22.[11] They also added a titanium drip shield above the canisters.

The major issue is whether these metals will corrode under the DOE's design conditions. The NWTRB concluded that they may. Understanding why requires some background.

The metals proposed by DOE—alloy-22 and titanium—do not exist in nature. They are thermodynamically unstable and have only been known for about a century.[12] Metallic titanium was first prepared in 1910, and alloy-22 was developed only a few decades ago. Thus the DOE bears a special burden of proof if it wants to argue—as it does—that these materials will survive over the multi-millennial Yucca Mountain regulatory time frame.

The NWTRB examined DOE and other experimental data and theoretical analyses of alloy-22. The Board concluded that under the DOE-proposed operating conditions there are likely to be problems. Specifically, at temperatures above the boiling point of pure water, deliquescence-induced corrosion is likely. Deliquescence—the absorption of atmospheric water vapor by a solid salt to the point where the salt dissolves into a saturated solution—can raise the temperature at which liquid water can exist. Corrosion can only occur in the presence of ions, which, in this case, means in the presence of liquid water.

Deliquescence is important because it is a mechanism by which liquid water could exist on waste package surfaces during a portion of the thermal pulse, the first 1,000 to 3,000 years when temperatures would be above the boiling point of water. This can lead to the presence of liquid under conditions where liquid could not normally occur.[13]

Salts in the rock are likely to allow deliquescence, which means that liquid water (and hence ionic conduction) can exist at temperatures well above the boiling point of pure water. This means that under plausible conditions, corrosion may occur.

The NWTRB statement is unambiguous[14]:

> It is clear to the Board that all conditions (appropriate levels of temperature and relative humidity together with appropriate amounts of salt or salts present) necessary for deliquescence will be present during the thermal pulse for nearly all waste packages.

The Board concluded:

> [T]he Board believes that under conditions associated with the DOE's current high-temperature repository design, widespread corrosion of the waste packages is likely to be initiated during the thermal pulse. Once started, such corrosion is likely to propagate rapidly even after conditions necessary for initiation are no longer present. The result would be perforation caused by localized corrosion of the waste packages, with possible release of radionuclides.

Does this matter to repository performance? In the NWTRB's view, the impact could be substantial. The

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Board's report says:

> Do the Board's technical conclusions have significant effect on performance calculations for the repository system *as a whole?* Although a precise statement about whether, or how much, dose might be increased or the safety margin decreased cannot be made given the existing uncertainties, the Board believes that the implications of the Board's conclusions for repository system performance could be substantial. Therefore, it is incumbent on the DOE to demonstrate unambiguously the reliability and safety of any design concept for Yucca Mountain.

The DOE argues that titanium drip shields will help. But the drip shields are also vulnerable to corrosion. The NWTRB wrote:

> The Board believes that the DOE's position is based mostly on assumptions that could be unrealistic and overly optimistic. First, no prototype drip shield has ever been built, and the concept of a long-lasting drip shield in an underground application has never been applied elsewhere. Thus, the DOE's projections of how this structure will perform for thousands of years are speculative. The DOE assumes, for example, that the joints between drip shield segments remain leakproof during the thermal pulse despite the fact that only limited paper studies of the joints have been done. Furthermore, the DOE assumes that drip shields will not corrode to the point of leaking during the thermal pulse despite the fact that there are very little, if any, corrosion data supporting this assumption and despite the fact that titanium, the drip shield material of construction, is known to be susceptible to fluoride-based corrosion and hydrogen embrittlement, as well as to crevice corrosion in elevated-temperature, high-chloride environments.

That's where matters stand today. From a scientific point of view, DOE could respond by undertaking experiments that would check how alloy-22 performs at the higher temperatures. Or it might change the repository design by lowering the operating temperature to a region where alloy-22 will perform well (e.g., by increasing the spacing of the fuel assemblies). Both approaches would require research. As with all research, that will take time and money, and the outcomes can't be known in advance.[15]

Should DOE be able to demonstrate that alloy-22 might perform well in Yucca Mountain, the agency still faces the challenge of reliably and consistently manufacturing canisters. Each canister has corrosion-sensitive welds, and each one of the 10,000 proposed canisters must perform right.[16] DOE's Yucca Mountain program has had continuing quality-assurance problems. The DOE organization may not have the institutional capability to achieve the needed quality control.[17] I discuss this aspect in more detail below.

The one thing that makes no sense at all is to pretend these problems don't exist. But that's what DOE is doing.

Lessons to be learned

The scientific details are fascinating. Even more fascinating are the questions Yucca Mountain raises about complex institutions. The atomic industry is a vast interconnected undertaking involving industry, academia, and government. As demonstrated by Chernobyl and Three Mile Island, it's essential that the system be run with ultra-high reliability. Confidence in a nuclear reactor system requires confidence in each component of that system. High-level waste disposal is one such component. The problems DOE is having with Yucca Mountain are important in themselves. They are even more important because of their implications for the nuclear industry.

It is not enough to simply do calculations showing that canisters can provide needed isolation. Canisters must actually be built, and built properly. Reliable systems must be built to transport the waste. If one lacks confidence in the government-industry-academic complex that constitutes the nuclear industry, one is unlikely to have confidence that these challenging tasks will be done properly.

Experience with other large technical systems provides useful insights and guidelines. The Presidential inquiries into NASA's failures with the Challenger and Columbia space shuttles are relevant.[18] In both cases, the inquiries identified specific technical failures (O-ring; insulation loss). In both cases, the inquiries concluded that these specific failures had higher causes—they came about because of systemic institutional problems. NASA was a flawed organization.

The lessons from NASA are generic. They apply to the Yucca Mountain project. Research on institutions running complex technological systems has identified clear indicators of trouble. These indicators may be thought of as "formulae for failure." The indicators—six of them—are:

1) Schedule-driven programs. When keeping to schedules takes precedence over doing things right, trouble is likely. Schedule-driven programs are especially problematic when the science isn't well understood, as was the case with the shuttles and is the case with Yucca Mountain.

2) Resource constraints. Inadequate resources to do the job right are clearly an issue. Throwing money at a problem can cause a different type of problem. With too much money, managers must spend time figuring out how to keep people busy, rather than on the real issues. That's why the aerospace industry sometimes establishes "skunk works" where a few people can work unimpeded by schedules. The DOE has for

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years requested and obtained vast sums for quality assurance and to engineer detailed designs even though the basic science to support either didn't exist.

3) Fragmented organization with ineffective communication.

4) Hierarchical "top-down" organizations with one-way flow of information. Challenger and Columbia crashed because of failure of the people at the top to listen to the folk in the bowels of the organization who knew the technical details.

5) Poor design, with the flaws often obvious from the outside. An insular organizational tendency that relies on internal people rather than drawing on world-wide expertise is more likely to breed failure.

6) Institutional hubris/arrogance.

DOE's Yucca Mountain program shows all these problems. The issues are organizational. They are deeply entrenched. They stem from a combination of challenging pressures on the organization and lack of sustained top-level competent leadership. While the Yucca Mountain program has a lot of good people working for it, the overall program is far less than the sum of its parts. It's a broken system.

What should be done

It's entirely possible that a sound repository could be built at Yucca Mountain. In fact, that's my personal best judgment. However, the present design won't do the job. Further, even if a sound design were developed, DOE is at present not institutionally competent to carry it out. What's needed is for DOE to be instructed to do the job right. Doing the job right means developing the best possible design. Doing the job right includes developing the institutional capability to say "no" if a compelling case can't be made.

The right way to start is to slow down the program so as to match progress to knowledge. Even if the DOE manages to come up with a sound design for a repository at Yucca Mountain, it will be difficult for it to credibly implement that design. The highest level of quality con-

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IEER'S RESPONSE TO DR. CRAIG'S ARTICLE

Paul and I agree about the biggest problem facing the repository program: it is institutional. With the DOE in charge, there is no hope for a sound repository program. While we have no essential disagreements about the reasons for my technical judgment that Yucca Mountain would make a poor repository, Paul is technically more optimistic about the prospects for a sound repository at Yucca Mountain. If the research is done right, he thinks the technical problems can be overcome; I do not.

The following are my observations about Yucca Mountain:

- A sound repository design should involve research on engineered barriers and the geologic setting in parallel, so that the barriers are suited to the setting. Analogs of natural materials that retard radionuclide mobility can then be engineered specifically for the site. This principle was violated at Yucca Mountain. Metal in a humid, hot, oxygen-rich environment like Yucca Mountain is inherently vulnerable to corrosion. While design and laboratory experiments may reduce the corrosion rate, metal canisters in Yucca Mountain have the second law of thermodynamics working against it. That's pretty powerful opposition; overcoming it requires great precision in forecasting environmental and repository conditions for tens of thousands of years. I do not think this problem can be overcome with reasonable confidence.
- Yucca Mountain cannot meet the most reasonable standard for repositories: that peak dose be limited to a low value.
- The fact that Yucca Mountain is in a desert is both an advantage and a serious problem. The aquifer under Yucca Mountain is currently used for irrigation only 20 miles away. There is no other water. Containment failure would mean severe contamination.
- Yucca Mountain is so complex that reasonable people, armed with the same facts, will honestly disagree. This is a bad sign. Repositories should be characterizable with great confidence. A complex geologic setting, unique in some ways, is a poor location on this count alone.
- The abandonment of Safe Drinking Water standards under federal lands surrounding Yucca Mountain by the EPA is a foot in the door for similar abandonment for all kinds of other purposes. Yucca Mountain cannot meet these standards.
- A sound repository program requires an agency that does not have a vested interest in the business that creates the waste—in the DOE's case, that's making nuclear weapons and promoting nuclear power. Any agency will have a tough job on its hands doing the job right. DOE, in my view, has demonstrated that it cannot do it right. A new, independent agency that is not involved in waste creation and that will have stringent oversight is needed.

IEER has long supported geologic disposal of some kind (see SDA Vol. 7 No. 3, May 1999), within the context of an end to weapons production and a phase-out of the commercial nuclear power and, hence, the associated waste stream. So these objections are not in the context of opposing geologic disposal in general, but must be seen as specific to the site that is being developed, i.e., Yucca Mountain, and the agency, i.e. the DOE, that is in charge of the work.

—Arjun Makhijani

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trol will be required both for the manufacture and installation of the storage canisters and for the nuclear waste transportation system. DOE's continuing quality assurance problems attest to the magnitude of the difficulty.

Because of the enormous pressures from the nuclear industry, the President should simultaneously ask the nuclear industry to back down on its lawsuits so the program can become science-driven rather than schedule-driven.

The utilities need to understand that their credibility and the future of their industry is at stake. If the nuclear industry is to have a future, that future will have to be built on trust. Trust must be earned. Trust once lost is exceedingly hard to regain. In its early days after World War II the nuclear industry benefited from a huge amount of public trust. They lost it. Can public trust be regained? I don't know the answer. I do know that the worst approach is to ignore sound science. And that's what the DOE is doing at Yucca Mountain.

1 Paul Craig served on the National Research Council's Board on Radioactive Waste Management, and in 1996 was appointed by President Clinton as a Member of the Nuclear Waste Technical Review Board (from which he resigned in January 2004). Dr. Craig is a Professor of Engineering Emeritus at the University of California, Davis. He can be reached at ppcraig@ucdavis.edu. The views are those of the author alone and not necessarily of the NWTRB or of IEER.

2 Some of the material used here is based on reports of the Nuclear Waste Technical Review Board. See http://www.nwtrb.gov. Any errors arising from editing or simplification are the author's alone.

3 U.S. Energy Information Administration. On the web at http://www.eia.doe.gov.

4 U.S. Nuclear Regulatory Commission, *Information Digest* 2003 Edition, NUREG-1350, Vol. 15 (Washington, D.C., 2003). On the web at http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1350/index.html.

5 http://www.ocrwm.doe.gov/pm/pdf/pprev3hist.pdf

6 Some basic facts about nuclear spent fuel are as follows: One metric ton (sometimes denoted "tonne") equals 1000 kilograms (kg). Its content is measured in metric tons of heavy metal, where the term heavy metal refers to those metals with an atomic number of 90 (thorium) or higher. Throughout this article, metric tons, tonnes, and MTHM are used synonymously. The numbers are referenced to the amount of heavy metal in the fuel when it was loaded into the reactor. Some of this heavy metal is fissioned or burned up in the reactor in the course of power production. Typically one metric ton of uranium-235 generates about one gigawatt-year (GWyr) of electricity before it is withdrawn from the reactor. At typical burn up of 38 GWdays per metric ton, 63,000 MTHM of spent fuel (the amount of civilian high level waste presently intended for Yucca Mountain) would provide about 2000 GWyr of electricity (i.e., about 100 reactors operating for 20 years). The spent fuel is hot because of the radioactivity of the fission products in it. The amount of heat produced goes down with time as the fission products decay into stable elements (though not in a simple exponential decay because the many radionuclides in spent fuel decay at their own rates, and some decay into new radionuclides). The spent fuel from a 1,000 megawatt reactor operating for one year produces approximately 42 kilowatts (kW) of heat (or 1.37 kW/MTHM) after 10 years of storage, 0.37 kW after 100 years, and 0.07 kW after 1000 years. The volume of spent fuel is about 20 cubic meters per GWyr. The worldwide problem of spent fuel is much bigger than the United States. Total lifetime spent fuel production worldwide from the present generation of reactors will be approximately 450,000 MTHM, of which about 18% will be from the United States (not including spent fuel from reactors that might get licenses extended). [Sources: D. Bodansky, *Nuclear Energy: Principles, Practices and Prospects* (Woodbury NY, Am. Inst. Phys. 1996); and Paul P. Craig, "High Level Nuclear Waste," *Annual Review of Energy and the Environment* 24: 461-86 (1999). The latter reference lists relevant web sites and many references.]

7 Nuclear Regulatory Commission, ibid.

8 Nuclear Energy Agency of the Organisation for Economic Co-operation and Development, *The Environmental and Ethical Basis of Geological Disposal of Long-Lived Radioactive Waste: A Collective Opinion of the Radioactive Waste Management Commission of the OECD Nuclear Energy Agency* (Paris: OECD Publications, 1995). On the web at http://www.nea.fr/html/rwm/reports/1995/geodisp/collective-opinion.html.

9 The Congress instructed the EPA to seek National Research Council guidance on the regulations. The National Research Council advised that the dose should be calculated at the time of the estimated peak occurrence of contamination (National Research Council, Commission on Geosciences, Environment and

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Resources, Committee on Technical Bases for Yucca Mountain Standards, *Technical Bases for Yucca Mountain Standards* [Washington, D.C.: National Academy Press, 1995]). The present DOE computer simulations suggest the peak dose will occur several hundred thousand years in the future. The EPA rejected the National Research Council recommendations when it set the regulatory compliance time at 10,000 years. The State of Nevada claims the EPA standards are illegal. This issue is a part of a State of Nevada lawsuit that is now under consideration by the U.S. Supreme Court.

10 Alvin Weinberg, *The First Nuclear Era: The Life and Times of a Technological Fixer* (New York: American Institute of Physics Press, 1994).

11 Alloy-22 or C-22 is a nickel-based alloy with typical composition: Nickel 56%, Chromium 22%, Molybdenum 13%, Cobalt 2%, Tungsten 4%, Iron 3%.

12 The only metals that exist naturally are noble metals such as gold, and metals that are stable in a chemically reducing environment. The best example of the latter is copper, the existence of which made possible the Bronze Age. The most durable metals for chemically oxidizing environments such as Yucca Mountain are related to stainless steel. These metals, called "passivated metals," are protected by a thin layer typically a few thousand atoms thick that tends to repair itself if damaged. Passivated metals were first discovered early in the 20th century. Alloy-22, based on nickel rather than iron and hence technically not a "steel," is among the most corrosion-resistant materials known for the Yucca Mountain environment. Titanium, proposed for the drip shield, is also a passivated material. A major issue is how to extrapolate the performance of materials only a few decades old over three orders of magnitude in time to the 10,000-year Yucca Mountain regulatory time frame. In my judgment, large extrapolations should be made only if there exists a sound theoretical understanding of corrosion mechanisms and good reason to believe that all potentially important mechanisms have been identified. That's a tall order. The consensus within the materials community is that understanding of corrosion mechanisms is good enough that if certain criteria are met, temporal extrapolation over three orders of magnitude is legitimate. The main point regarding the NWTRB conclusion about the DOE's current Yucca Mountain design is that these criteria are not met in that design.

13 Salt offers a simple example familiar to many people brought up at the seashore. Salt absorbs atmospheric moisture, and can liquefy under conditions where pure water would evaporate. A classical way to over come this problem at the sea-shore is to add rice to the salt-cellar. The rice vigorously absorbs water, and keeps the salt dry enough to avoid liquefaction.

14 The following quotes are from the NWTRB, *Technical Report on Localized Corrosion,* November 25, 2003, available on the web at http://www.nwtrb.gov.

15 Present data suggest that alloy-22 will perform well at temperatures below about 100 degrees Celsius. To design a repository that would keep all the canisters below that temperature requires detailed knowledge of rock thermal conductivity. Most of the proposed repository is in the lower lithophysal region of Yucca Mountain, a region with large void inclusions (lithophyses). The lithophyses in combination with the high water saturation of the Yucca Mountain rock make thermal conductivity hard to measure. Unfortunately DOE collected very little relevant data before closing down the research program. The needed data is obtainable, but doing so will take time and resources.

16 Should it prove possible to show that alloy-22 samples won't corrode in the Yucca Mountain environment, there remain manufacturing challenges. The DOE has never actually manufactured a canister. It has never performed the welds that are required to seal canisters. This is not a trivial point. The Swedes found that welding copper — highly stable in their chemically reducing environment — is exceedingly difficult. After years of effort they are still having weld problems. A major difference between the Swedish program and the DOE's is that the Swedes believe in demonstration, while DOE prefers to rely on computer models.

17 Quality control is an issue for every aspect of the repository system. This includes the waste transport system. It also includes the above-ground facilities to receive, temporarily store, and transfer canisters.

18 See the web site of the Columbia Accident Investigation Board, http://www.caib.us/, and the *Report of the Presidential Commission on the Space Shuttle Challenger Accident,* at http://science.ksc.nasa.gov/shuttle/missions/51-l/docs/rogers-commission/table-of-contents.html.

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