Mike Moore, Editor, *Bulletin of the Atomic Scientists*
6042 S. Kimbark, Chicago IL 60637

16 July 1991, revised 9 August 1991

Lessons from Iraq

To the Editor:

Press reports about Iraq's nuclear bomb program reflect disturbing confusions apparently traceable to official briefers. Their misinformation suggests some mixture of ignorance, mendacity, and wish either to underplay or to exaggerate the threat.

For example, in discussing how much highly enriched uranium (HEU) can make how many bombs, some officials have apparently assumed that one bomb needs one critical mass of a "bare" sphere of uranium metal (*i.e.*, with no neutron reflector) at normal density (~18.8 g/cm^3). That critical mass is 49 kg of the fissile isotope ^{235}U if it's 93.5% of the total uranium, a common high-enrichment level. But in a bomb, the HEU would be neither bare nor at normal density. At normal density, just a neutron reflector can readily reduce critical mass from 49 kg to <20 kg ^{235}U; a thick beryllium reflector, to <10 kg. In addition, uniform compression of the core and reflector further reduces critical mass as the square of density, *i.e.*, by at least severalfold.[1] That's why the official U.S. "trigger quantity" of ^{235}U in 20+%-enriched uranium is only 5 kg, not ~50 kg. Some government briefers thus understated the number of potential bombs by about tenfold, leaving the false impression that Iraq's known inventory of 12.3 kg of French 93.5% ^{235}U and ~33 kg of Soviet 80%[2] ^{235}U -- ignoring whatever uranium it enriched by itself -- was hardly enough for one bomb, when in fact it could have made many.

Worse, our government's nuclear experts are apparently thinking more about how *they* would make bombs than about how Iraq could. The U.S. assumed Saddam Hussein wouldn't use calutron technology because it's old and inefficient; but he did use it because it's readily available, it can (as he proved) be built on a large scale without detection[3], it can probably be all homemade, and it works. Indeed, he is rumored at least to have intended to boost the calutrons' bomb-material output severalfold by pre-enrichment with an even easier-to-hide chemical process.

In the opposite error, some journalists were apparently told that Iraqi HEU bombs wouldn't be deliverable because they'd require a 1945 Hiroshima-style gun-type assembly mechanism as big and heavy as a piece of a naval gunbarrel. Secretary Cheney even stated, absurdly, that an Iraqi bomb would need an 18-wheeler to carry it. But in fact, implosive assembly, which makes far more efficient and portable bombs, works about as well[4]

---

[1] J. Foster Jr., *Encyc. Americana* 20:251 (1970), states that military implosion bombs achieve core densities "several times" normal. Note, however, that plutonium cores are smaller than the corresponding uranium-235 cores and can therefore be compressed more with similar high-explosive lenses: imploding, for illustration, an incompressible solid spherical shell yields pressure inversely proportional to the fourth power of radius. See A.B. Lovins, "Thorium cycles and proliferation," *Bull. atom. Scient.* 35(2):16-22 (1989) at 17.

[2] Critical mass is only ~8% higher with 80% than with 93.5% ^{235}U, so the total inventory would be equivalent to ~43 kg of 93.5% ^{235}U, or more than eight times the 5-kg U.S. "trigger quantity." (This would rise to ~45 kg 93.5%-^{235}U-equivalent if the ~4.5 kg of 36% ^{235}U were also counted, since its critical mass is ~1.9x that of 93.5% ^{235}U.) Any of these uranium inventories would be bomb-usable, with hazards acceptable to such a ruthless government, even if lightly irradiated. Since Iraq has admitted illegally separating gram quantities of plutonium from spent fuel, it evidently has a pilot reprocessing capability too, so even heavy irradiation cannot prevent ultimate recovery of both uranium and plutonium from the spent fuel. However, like reprocessing, actual metal fabrication into bomb-core components would lose some material, depending on skill in metal-forming and scrap recovery.

[3] Iraq wasn't even known to be considering calutrons, let alone using them. Although their infrared signature could probably be detected during actual production, they could also be disguised as a civilian metallurgical or electrochemical plant.

[4] The main exception is that mentioned in footnote 1.

1739 SNOWMASS CREEK ROAD, SNOWMASS, COLORADO 81654-9199
(303) 927 3851 FAX (303) 927 4178

with ^{235}U as with ^{239}Pu, and is commercially available in highly sophisticated civilian form virtually identical to the military version. Indeed, in skilled hands this approach is capable of extremely large -- even arbitrarily large -- fission yields.

These examples suggest a dangerous pattern of sloppy thinking. Supposing that whatever the Soviets had found out might as well be published is just the fallacy that put the details of calutrons, and for that matter reprocessing and bomb design, irretrievably into open literature. Supposing that of the 20-odd known routes to bombs, Iraq would choose the most sophisticated and efficient (*e.g.*, centrifuges[5] or lasers for enrichment) fails to put oneself in the shoes of pragmatists working with different resources and constraints. The same mentality still leads many who should know better to claim that proliferators wouldn't make bombs out of high-burnup plutonium because it's not the ideal material -- even though it's widely and innocently available and makes fully functional bombs.[6] Of course cabinetmakers prefer rosewood, but pine will do.

Other troubling lessons can be drawn too. Neither national intelligence services nor the IAEA detected most of Iraq's probably multi-billion-dollar, at-least-four-routes bomb program.[7] Despite intense international scrutiny, Iraq, recent Chair of the NPT Review Conference, got away with these flagrant violations of the NPT as well as of other critical treaty obligations, and was ultimately exposed only by a wartime defector. Even skilled, unannounced, on-the-ground inspections of undeclared sites are winkling out further details of the bomb program only with difficulty and with no assurance of completeness. This abject breakdown of international safeguards should surprise nobody: after all, the IAEA's previous head long asserted the impossibility of concealing a military within a civilian nuclear program, before it turned out that this had once been precisely his responsibility in his own country. But many anxious to rely on the IAEA fig-leaf still have not drawn the appropriate conclusions.

Among these is that no NPT signatory can be objectively confirmed not to be making bombs unless *all* flows of nuclear materials can be confidently and precisely tracked, down to and including natural uranium and thorium. Knowledge and technology are no longer reliable bars to turning these "safe" materials into bombs.[8] Bernard Baruch was right -- except that, as he foresaw, technical progress has virtually erased the line between "safe" and "dangerous" nuclear activities. This makes nonproliferation incompatible in principle with the commercial nuclear programs that now provide proliferators not only with do-it-yourself bomb kits, but also with an innocent-looking civilian "cover."[9]

AMORY B. LOVINS
Director of Research

---

[5]However, an Associated Press story in 9 August 1991 newspapers further states that a surprise U.N. inspection in early August found an unacknowledged factory originally intended to start turning out uranium-enrichment centrifuges, at the rate of 200 per year, at the end of 1991; so apparently Iraq didn't mean to stick to unsophisticated methods after all. AP therefore reports "administration officials" as stating that "Iraq was a year or two away from producing enough [homemade] nuclear [material]...for a bomb, not five or 10 years as U.S. intelligence believed." This revelation confirms the need for skepticism about some analysts' postulation of key gaps in Iraq's technical capabilities needed for making bombs. The same people would probably have said, as many did, that Iraq wasn't capable of enriching uranium or extracting plutonium either. One lesson of this whole affair is that a renegade government with billions of dollars and no inhibitions can overcome many obstacles.

[6]A.B. Lovins, "Nuclear Weapons and Power-Reactor Plutonium," *Nature* 283:817 (1980), 284:190 (1980).

[7]*I.e.*, three kinds of enrichment plus plutonium production.

[8]A disturbing possibility is that Iraq might have gotten its centrifuge plans from Pakistan, which earlier stole some from Holland. If so, might not Iraq also have gotten Pakistani help in designing and manufacturing bombs? And if so, might not Iraq, even today, be arbitrarily close to having one or more bombs?

[9]A.B. & L.H. Lovins, *Energy/War: Breaking the Nuclear Link*, Harper & Row/Colophon, New York, 1981, summarized in A.B. & L.H. Lovins & L. Ross, "Nuclear Power and Nuclear Bombs," *Foreign Affairs* 58:1136 (1980), 59:172 (1980). See also A.B. & L.H. Lovins, "'The connection is tenuous,'" *Bull. atom. Scient.*, pp. 62-63, May 1983.