Order Code RS22001
Updated December 21, 2004

CRS Report for Congress

Received through the CRS Web

Spent Nuclear Fuel Storage Locations and Inventory

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Summary

Spent nuclear fuel is principally stored at 83 locations throughout the United States, including reactor storage pools, independent spent fuel storage installations, national laboratories, and defense weapons sites. Additional sites include university research and training reactors. The104 commercial nuclear generating units[1] licensed to operate in 31 states discharge over 2,000 metric tons[2] of spent fuel annually. The total inventory could approach 54,000 metric tons at the end of 2004. This report will be updated when new statistics become available.

Commercial Spent Fuel Generation

A typical fuel rod used in commercial nuclear power reactors consists of uranium dioxide pellets surrounded by zirconium alloy cladding. The uranium oxide pellets consist of 3-4% fissionable[3] uranium-235, and a balance of nonfissionable U-238. An individual fuel assembly consists of arrays of fuel rods. The Energy Information Administration (EIA) notes 131 reactor fuel assembly types on its Nuclear Fuel Data Survey Form.[4] The assemblies range in weight from ~70 kilograms uranium for a boiling water reactor[5] to ~464 kilograms uranium for a pressurized water reactor.[6] During the sustained chain reaction in an operating reactor, the U-235 splits into highly radioactive fission products,

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[1] There are currently 69 pressurized water reactors (PWR) and 35 boiling water reactors (BWR) licensed to operate in the United States. *U.S. Nuclear Reactors*, U.S. Department of Energy, Energy Information Administration, at [http://www.eia.doe.gov/cneaf/nuclear/page/nuc_reactors/reactsum.html], viewed Nov. 29, 2004.

[2] A metric ton (1,000 kilograms) is approximately equivalent to 2,200 pounds.

[3] The splitting of the nucleus of a heavy atom into two lighter nuclei.

[4] Energy Information Administration, Department of Energy, *Nuclear Fuel Data Survey Form RW-859 (OMB No. 1901-0287).*

[5] Humboldt Bay Assembly Class.

[6] Babcock & Wilcox 15 x 15 Assembly Class.

while the U-238 is partially converted to plutonium-239 by neutron capture, some of which also fissions. Further neutron capture creates other transuranic elements.[7]

Commercial nuclear power reactors are refueled on a frequency of 18 to 24 months. During refueling, approximately one-third of the fuel (spent nuclear fuel) is replaced. The spent fuel is moved to a storage pool adjacent to the reactor to allow for thermal cooling, and decay of short-lived radionuclides. Due to the limited storage capacity at some reactor pools, reactor operators may transfer cooled spent fuel to specially designed casks licensed by the Nuclear Regulatory Commission (NRC) for dry storage.

Independent Spent Fuel Storage Installations

The NRC has licensed 30 independent spent fuel storage installations (ISFSIs) in 23 states.[8] Most of ISFSIs use dry cask storage and are co-located at the reactor site. The General Electric Company operates a wet pool ISFSI in Morris, Illinois (GE Morris Operation), that stores commercial spent fuel from a number of reactors. Private Fuel Storage, LLC (PFS), a group of eight electric utility companies that have partnered with the Skull Valley Band of Goshute Indians, has applied for an NRC license to build and operate an ISFSI on the Indian Tribe's reservation in Skull Valley, Utah.

Federal Facilities

Federally generated spent fuel originated from nuclear weapons production, the naval reactor program, and Department of Energy (DOE)-sponsored research programs. The spent fuel remains in interim storage at the Savannah River, Hanford, and Idaho National Engineering and Environmental Laboratory (INEEL) defense sites.[9] Small quantities also remain at the Argonne, Brookhaven, and Sandia National Laboratories, and various university research reactors. The DOE operates the ISFSI for the former Fort St. Vrain High Temperature Gas Cooled Reactor in Colorado.

In comparison with commercial power reactor fuel, the Navy's nuclear-powered warships use highly enriched U-235 fuel in reactors that can operate without refueling for their approximate 30-year life-cycles. The 103 naval reactors taken out of service are almost equal in number to those currently operating. Approximately 65 metric tons of spent fuel has been generated by the naval reactor program, which up until 1992 had been reprocessed to remove highly enriched uranium, plutonium-239, or other transuranic elements for reuse in the nuclear weapons program. Since 1992, approximately 9 metric tons of naval spent fuel has been transferred to INEEL for interim storage.[10]

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[7] Transuranic refers to elements with atomic numbers higher than that of uranium (92 protons). These include neptunium (93), plutonium (94), americium (95), and curium (96).

[8] U.S. Nuclear Regulatory Commission, *2004-2005 Information Digest*, Figure 42 — Licensed Operating Independent Spent Fuel Storage Installations.

[9] Appendix A, Final Environmental Impact Statement for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada, U.S. Department of Energy, Office of Civilian Radioactive Waste Management (2002).

[10] Detailed information obtained through specific request to the National Spent Nuclear Fuels

(continued...)

Spent Fuel Inventory at End of 2002

A total of 49,401 metric tons spent fuel had been discharged by commercial and federal-related activities by the end of 2002, based on data compiled by the Energy Information Administration[11] and the National Spent Nuclear Fuels Program.[12] (This does not include spent fuel that had been reprocessed to remove plutonium for weapons programs.) Commercial reactor storage pools separately accounted for 41,564 metric tons, and ISFSIs (mostly co-located at reactor sites) accounted for another 5,363 metric tons. Federal and other sites (national laboratories, defense sites, university research reactor and industrial reactors) made up the balance of 2,474 metric tons (reported at 2003's year end). The data are displayed geographically in **Figure 1** and summarized in **Table 1**. An additional ~20 metric tons of foreign research reactor fuel is scheduled to be eventually added to the overall inventory.[13] University research reactor spent fuel is discussed in the final section of this report.

Projected Inventory at End of 2004

No authoritative estimate of the spent fuel inventory exists for the end of 2004. EIA reported 38,418 metric tons[14] of commercial spent fuel discharged at 1998's year-end, and 47,023 metric tons at 2002's year-end. Averaging that difference over the four-year period, commercial reactor facilities annually discharged 2,152 metric tons of spent fuel. Projected on that basis, the cumulative amount of spent fuel from commercial and federal activities could approach 54,000 metric tons by the end of 2004. The operation and performance of individual reactors would affect this projection.

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[10] (...continued)
Program at the Idaho National Engineering and Environmental Laboratory, available at [http://nsnfp.inel.gov/snfData.asp], viewed Nov. 30, 2004.

[11] Energy Information Administration Form RW-859, "Nuclear Fuel Data" (2002). Note that the EIA reports an aggregate total of 47,023.4 metric tons spent fuel discharged from commercial reactors over the period of 1968 to 2002; 46,268 metric tons stored at commercial reactor sites, and 755.4 metric tons stored away from reactor sites. EIA does not distinguish between reactor pool and ISFSI dry storage, or publish data on individual reactors. Refer to EIA *Spent Nuclear Fuel Data, Detailed United States as of December 31, 2002*, at [http://www.eia.doe.gov/cneaf/nuclear/spent_fuel/ussnfdata.html], viewed Dec. 8, 2004.

[12] National Spent Nuclear Fuels Program (see footnote 10).

[13] The Record of Decision on a Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel was issued by the Department of Energy on May 13, 1996. Implementing this policy will involve acceptance of up to approximately 140 cubic meters or 19.8 metric tons heavy metal of spent fuel and target material from foreign research reactors. The acceptance duration is 13 years from May 13, 1996.

[14] Energy Information Administration EIA, *Prior Years 1998 Table*, at [http://www.eia.doe.gov/cneaf/nuclear/spent_fuel/ussnfdata.html], viewed Nov. 24, 2004.

Figure 1. Reactor Storage Pools, Independent Spent Fuel Storage Installations, Federal, and Other Sites
(numbered labels refer to facilities in Table 1)

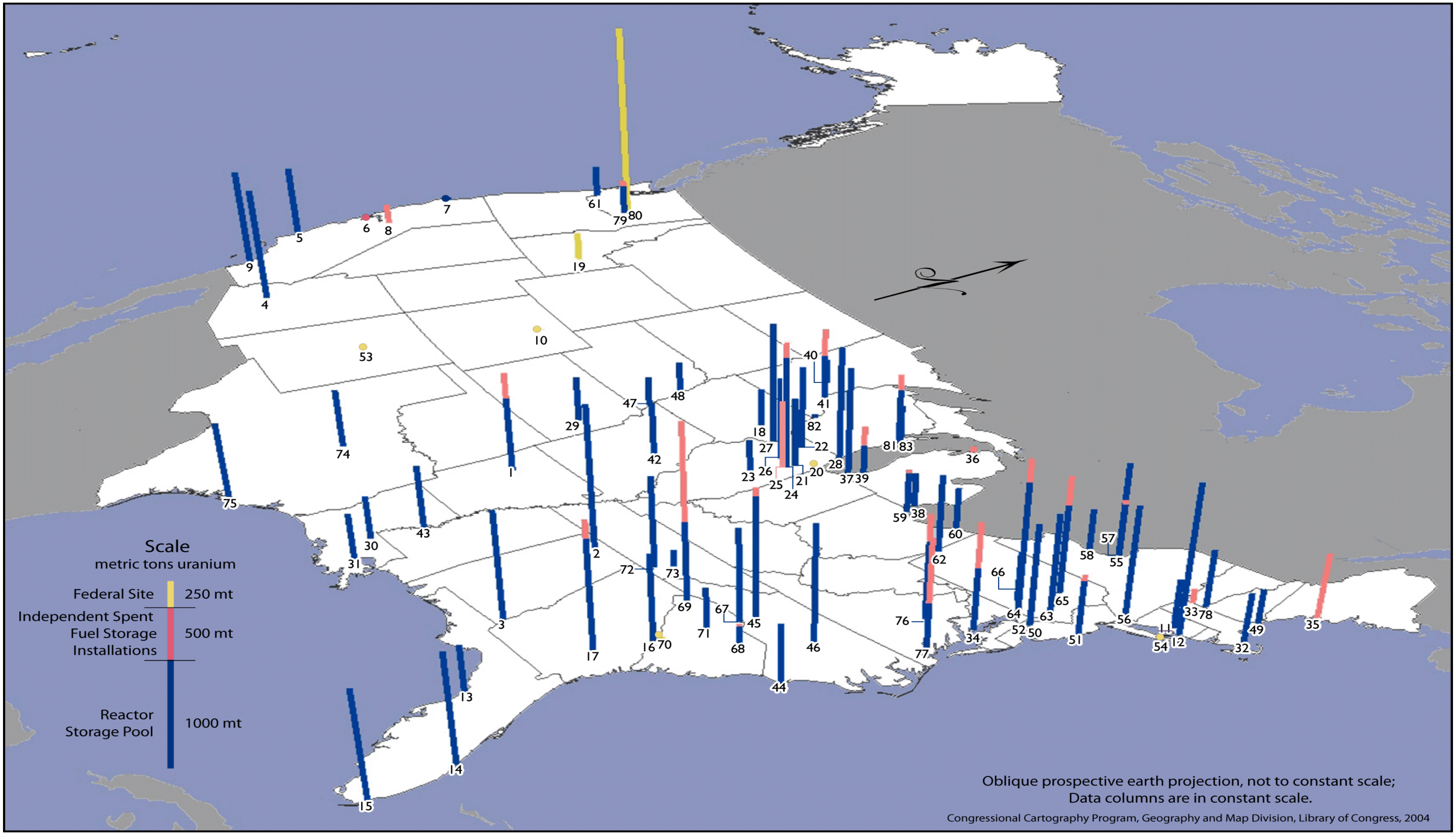

Table 1. Reactor Storage Pools, Independent Spent Fuel Storage Installations, Federal, and Other Sites (2002)

Facility			Assemblies	MT
1. Arkansas Nuclear One	AK	P	1,517	666.7
		I	552	241.4
2. Browns Ferry Nuclear Plant	AL	P	6,696	1,230.2
3. J M Farley Nuclear Plant	AL	P	2,011	903.8
4. Palo Verde Nuc Gen Station	AZ	P	2,747	1,157.8
5. Diablo Canyon Power Plant	CA	P	1,736	760.9
6. GE Vallecitos Nuc Center	CA	I	fragments	0.2
7. Humboldt Bay Power Plant	CA	P	390	28.9
8. Rancho Seco Nuc Gen Station	CA	I	493	228.4
9. San Onofre Nuc Gen Station	CA	P	2,490	1,013.3
10. Fort St. Vrain Power Station	CO	F	1,464	14.7
11. Connecticut Yankee Atom Pwr	CT	P	1,019	412.3
12. Millstone Nuc Power Station	CT	P	4,558	1,227.9
13. Crystal River Nuc Power Plant	FL	P	824	382.3
14. St. Lucie Nuc Power Plant	FL	P	2,278	870.7
15. Turkey Point Station	FL	P	1,862	851.7
16. AW Vogtle Electric Gen Plant	GA	P	1,639	720.8
17. EL Hatch Nuclear Plant	GA	P	5,019	909.3
		I	816	151.2
18. D Arnold Energy Center	IA	P	1,912	347.9
19. Idaho National Eng & Env Lab	ID	F	93522	299.3
20. Argonne National Lab East	IL	F	78	0.1
21. Braidwood Generating Sta	IL	P	1,485	628.7
22. Byron Generating Station	IL	P	1,786	756.4
23. Clinton Power Station	IL	P	1,580	288.8
24. Dresden Generating Station	IL	P	5,698	1,009.2
		I	1,155	146.9
25. GE Morris Operation	IL	I	3,217	674.3
26. LaSalle County Gen Sta	IL	P	4,106	744.6
27. Quad Cities Gen Station	IL	P	6,116	1,106.5
28. Zion Generating Station	IL	P	2,226	1,019.4
29. Wolf Creek Gen Station	KS	P	925	427.3
30. River Bend Station	LA	P	2,148	383.9
31. Waterford Gen Sta	LA	P	960	396.4
32. Pilgrim Nuclear Station	MA	P	2,274	413.9
33. Yankee Rowe Nuc Power Sta	MA	I	533	127.1
34. Calvert Cliffs Nuc Pwr Plt	MD	P	1,348	518.0
		I	960	368.1
35. Maine Yankee Atomic Pwr Plt	ME	I	1,434	542.3
36. Big Rock Point Nuc Plt	MI	I	441	57.9
37. D C Cook Nuclear Plant	MI	P	2,198	969.0
38. Enrico Fermi Atomic Pwr Plt	MI	P	1,708	304.6
39. Palisades Nuclear Pwr Sta	MI	P	649	260.7
		I	432	172.4
40. Monticello Nuclear Gen Plant	MN	P	1,342	236.1
41. Prairie Isl. Nuc Gen Plt	MN	P	1,135	410.3
		I	680	262.3
42. Callaway Nuclear Plant	MO	P	1,118	479.0
43. Grand Gulf Nuclear Station	MS	P	3,160	560.2
44. Brunswick Stm Elec Plt	NC	P	2,227	477.4
45. W B McGuire Nuc Sta	NC	P	2,232	1,001.1
		I	160	68.6
46. Shearon Harris Nuc Pwr Plnt	NC	P	3,814	964.5
47. Cooper Nuclear Station	NE	P	1,537	278.6
48. Fort Calhoun Station	NE	P	839	305.0
49. Seabrook Nuclear Station	NH	P	624	287.2
50. Hope Creek Gen Station	NJ	P	2,376	431.5
51. Oyster Creek Generating Sta	NJ	P	2,556	455.9
		I	244	47.6
52. Salem Nuc Generating Sta	NJ	P	1,804	832.7
53. Sandia National Laboratory	NM	F	503	0.3
54. Brookhaven National Lab	NY	F	40	<0.1
55. JA Fitzpatrick Nuc Pwr Plant	NY	P	2,460	446.5
		I	204	37.2
56. Indian Point Energy Center	NY	P	2,073	903.6
57. Nine Mile Point Nuclear Station	NY	P	4,456	801.6
58. R E Ginna Nuclear Power Plant	NY	P	967	357.4
59. Davis-Besse Nuclear Pwr Sta	OH	P	749	351.3
		I	72	33.9
60. Perry Nuclear Power Plant	OH	P	2,088	378.4
61. Trojan Nuclear Power Plant	OR	P	780	358.9
62. Beaver Valley Power Station	PA	P	1,456	672.9
63. Limerick Generating Station	PA	P	4,601	824.0
64. Peach Bottom Atm Pwr Sta	PA	P	5,905	1,062.7
		I	1,020	190.3
65. Susquehanna Steam Elec Sta	PA	P	4,240	738.4
		I	1,300	238.5
66. Three Mile Island Nuc Station	PA	P	898	416.1
67. Catawba Nuclear Station	SC	P	1,780	782.4
68. HB Robinson Steam Elec Plt	SC	P	344	147.9
		I	56	24.1
69. Oconee Nuclear Station	SC	P	1,419	665.8
		I	1,726	800.4
70. Savannah River Defense Site	SC	F	9,657	28.9
71. VC Summer Nuclear Station	SC	P	812	353.9
72. Sequoyah Nuclear Power Plant	TN	P	1,699	782.6
73. Watts Bar Nuclear Plant	TN	P	297	136.6
74. Comanche Peak Steam Elec Sta	TX	P	1,273	540.7
75. South Texas Project	TX	P	1,254	677.8
76. North Anna Power Station	VA	P	1,410	652.7
		I	480	220.8
77. Surry Power Station	VA	P	794	365.4
		I	1,150	524.2
78. Vermont Yankee Gen Station	VT	P	2,671	488.4
79. Columbia Generating Station	WA	P	1,904	333.7
		I	340	61.0
80. Hanford Defense Site	WA	F	110,140	2,128.9
81. Kewaunee Nuclear Power Plant	WI	P	904	347.6
82. La Crosse Nuclear Gen Station	WI	P	333	38.0
83. Point Beach Nuclear Plant	WI	P	1,353	507.4
		I	360	144.1
Other: University & Industry		F	4,834	1.7
Combined Total			383,653	49,401.2
Reactor Pool		P	145,589	41,564.1
ISFSI		I	17,826	5,363.2
Federal and Other		F	220,238	2,473.9

Sources: Energy Information Administration, and DOE National Spent Nuclear Fuels Program

MT: metric ton (1,000 kg)

The planned nuclear waste repository at Yucca Mountain, NV, has been scheduled to receive 63,000 metric tons commercial spent nuclear fuel and 2,333 metric tons DOE spent-fuel.[15] The Nuclear Waste Policy Act (42 U.S.C. 10101) prohibits disposal of more than the equivalent of 70,000 metric tons in the Yucca Mountain repository until a second repository is constructed. The balance of the 70,000 metric tons would be made up of the high-level waste equivalent of defense-related reprocessed spent fuel.

University Research and Industry Spent Fuel

University research reactors, in aggregate, reported approximately 1.5 metric tons of spent fuel. A few domestic reactors used for industrial purposes reported another 0.2 metric tons. Depending upon the facility, the spent fuel may either be pool or dry stored. The fuel elements in the generic General Atomics TRIGA[16] research reactor are initially enriched to 20% uranium-235 as compared to 3%-4% in commercial PWR and BWR fuel elements. Unlike conventional fuel, the fission rate of TRIGA fuel decreases with rising temperature (an inherent design safety feature). Twenty universities use this type of reactor. Other research reactors may use fuel with even higher uranium-235 enrichment. The International Atomic Energy Agency (IAEA) registers research reactors throughout the world that are either operating, operationally shut down, or decommissioned (decontaminated and dismantled).[17] Of the 65 U.S. university reactors registered with IAEA, 26 are operating, 12 are shut down, and 27 are decommissioned. The 24 U.S. university reactors reported to the National Spent Nuclear Fuels Program are listed in **Table 2**. Shut down reactors intended for decommissioning could increase the spent fuel total.

Table 2. University Research Reactors Reporting Spent Fuel

University of Arizona[O]	AZ	North Carolina State University[O]	NC
University of California (Irvine)[O]	CA	State University of New York (Buffalo)[S]	NY
University of California (Davis)[O]	CA	Cornell University[O]	NY
University of Florida[O]	FL	Ohio State University[O]	OH
University of Illinois (Urbana)[D S]	IL	Oregon State University[O D]	OR
Purdue University[O]	IN	Reed College[O]	OR
Kansas State University[D]	KS	Pennsylvania State University[O]	PA
Massachusetts Institute of Technology[O]	MA	Rhode Island Nuclear Science Center[O]	RI
University of Massachusetts (Lowell)[O]	MA	University of Texas (Austin)[D]	TX
Worcester Polytechnic Institute*	MA	Texas A&M[O]	TX
University of Michigan*	MI	University of Utah[O D]	UT
University of Missouri[S]	MO	University of Wisconsin[O]	WI

Source: National Spent Nuclear Fuels Program

[O]: operating [D]: decommissioned [S]: shut *: unknown status

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[15] *Appendix A — Inventory and Characteristics of Spent-fuel, High Level Radioactive Waste, and Other Materials; Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, DOE/EIS-0250 (February 2002).

[16] Training, Research, Isotopes, General Atomics.

[17] International Atomic Energy Administration, Nuclear Research Reactors in the World, at [http://www.iaea.org/worldatom/rrdb/], viewed Dec. 8, 2004.