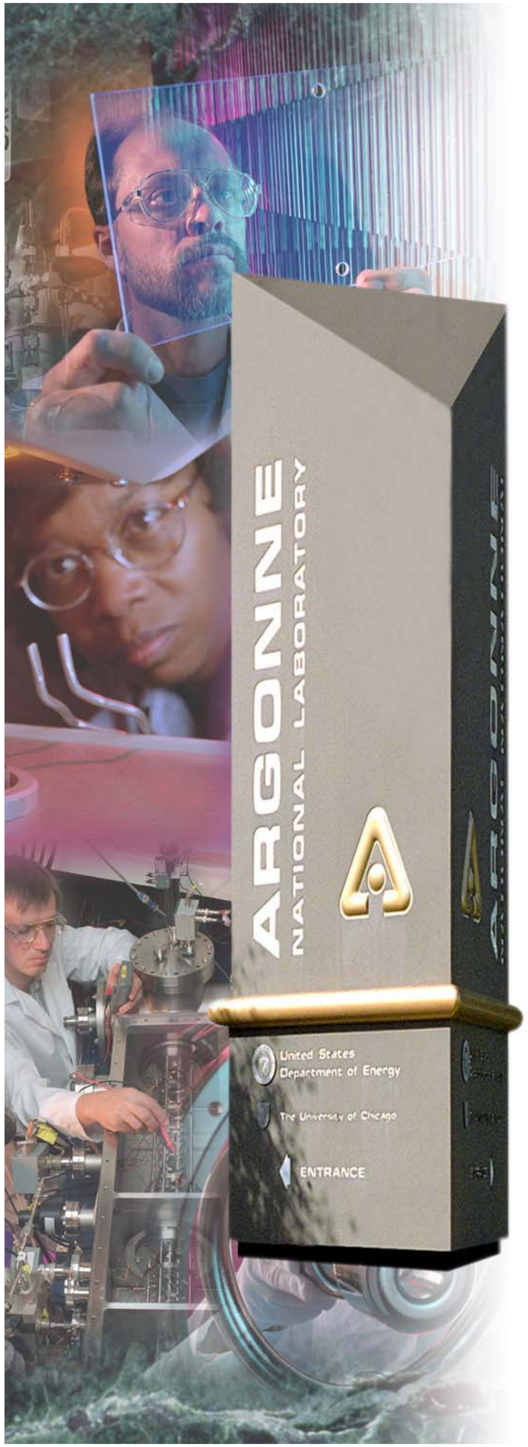

The RERTR Program

National Nuclear Security Administration

Fuel Issues:
Replacement of HEU

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Argonne National Laboratory

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MISSION

- Research and test reactors play a vital role in medical, agricultural, and industrial applications and in fundamental scientific research. However, many of them use fuels or targets containing high-enriched uranium (HEU) that could be used to make nuclear weapons.

- Since 1978, when the Reduced Enrichment for Research and Test Reactors (RERTR) program was established, the IAEA, the U.S. Congress and various U.S. Administrations have repeatedly expressed their strong support for converting research reactors to the use of low-enriched uranium (LEU) fuels and targets.

- Over 250 research reactors are currently in operation throughout the world. Approximately half of these reactors use HEU fuel.

STRUCTURE

The RERTR program includes four major tasks:

- Fuel Development
- Mo-99 Target and Process Development
- Reactor Analysis and Conversions
- Support for the Russian RERTR Program

LEU FUEL DEVELOPMENT

- The key to reactor conversions is the development of fuels with greater uranium density, because approximately the same amount of U-235 must be loaded in the reactor core. Since LEU fuels must contain approximately four atoms of U-238 for every atom of U-235, the uranium density in LEU fuels must be significantly greater than in HEU fuels.

- Several LEU dispersion fuels, culminating with uranium disilicide dispersion fuels with uranium densities up to 4.8 g/cm^3, have been successfully developed and implemented. LEU TRIGA fuels developed by General Atomics with densities up to 3.7 g/cm^3 have been demonstrated by the RERTR program.

- These fuel types are appropriate for the conversion of approximately 90% of the existing HEU research reactors supplied by the West.

LEU FUEL DEVELOPMENT (Continued)

National Nuclear Security Administration

Qualified suppliers of RERTR LEU research reactor fuels have been established in many countries. Thousands of LEU elements of the types developed by the RERTR program have been fabricated and successfully used in new or converted reactors.

Actively Fabricating:

CNEA, Argentina
(U_3O_8-Al)
CRL, Canada
(U_3Si-Al)
CERCA, France
(U_3Si_2-Al, $UZrH_x$)
BATAN, Indonesia
(U_3O_8-Al, U_3Si_2-Al)
BWXT, United States
(UAl_x-Al, U_3O_8-Al, U_3Si_2-Al)

Developing Capability:

IPEN, Brazil
(U_3O_8-Al)
CCHEN, Chile
(U_3Si_2-Al)
KAERI, South Korea
(U_3Si-Al)

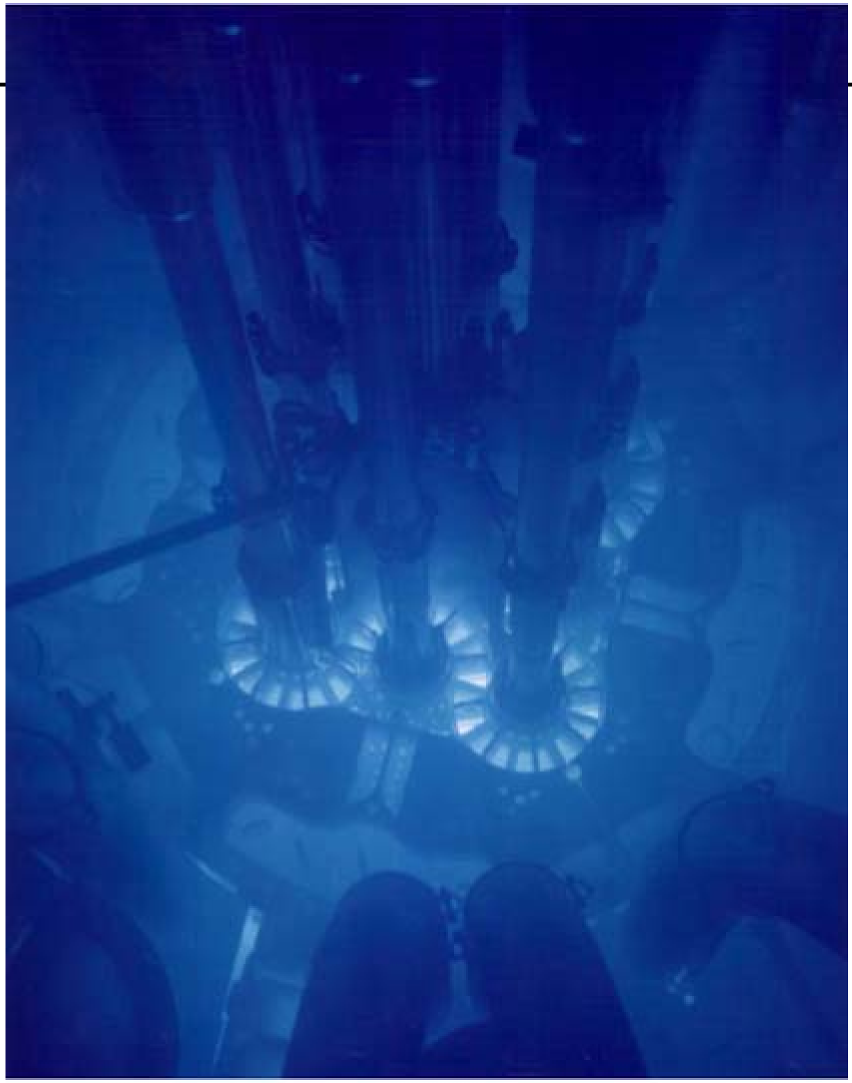
LEU FUEL DEVELOPMENT (Continued))

- Work is now in progress on LEU U-Mo materials, both in dispersion fuels (up to a uranium density of ~8 g/cm^3) and monolithic fuels (up to a uranium density of ~16 g/cm^3).

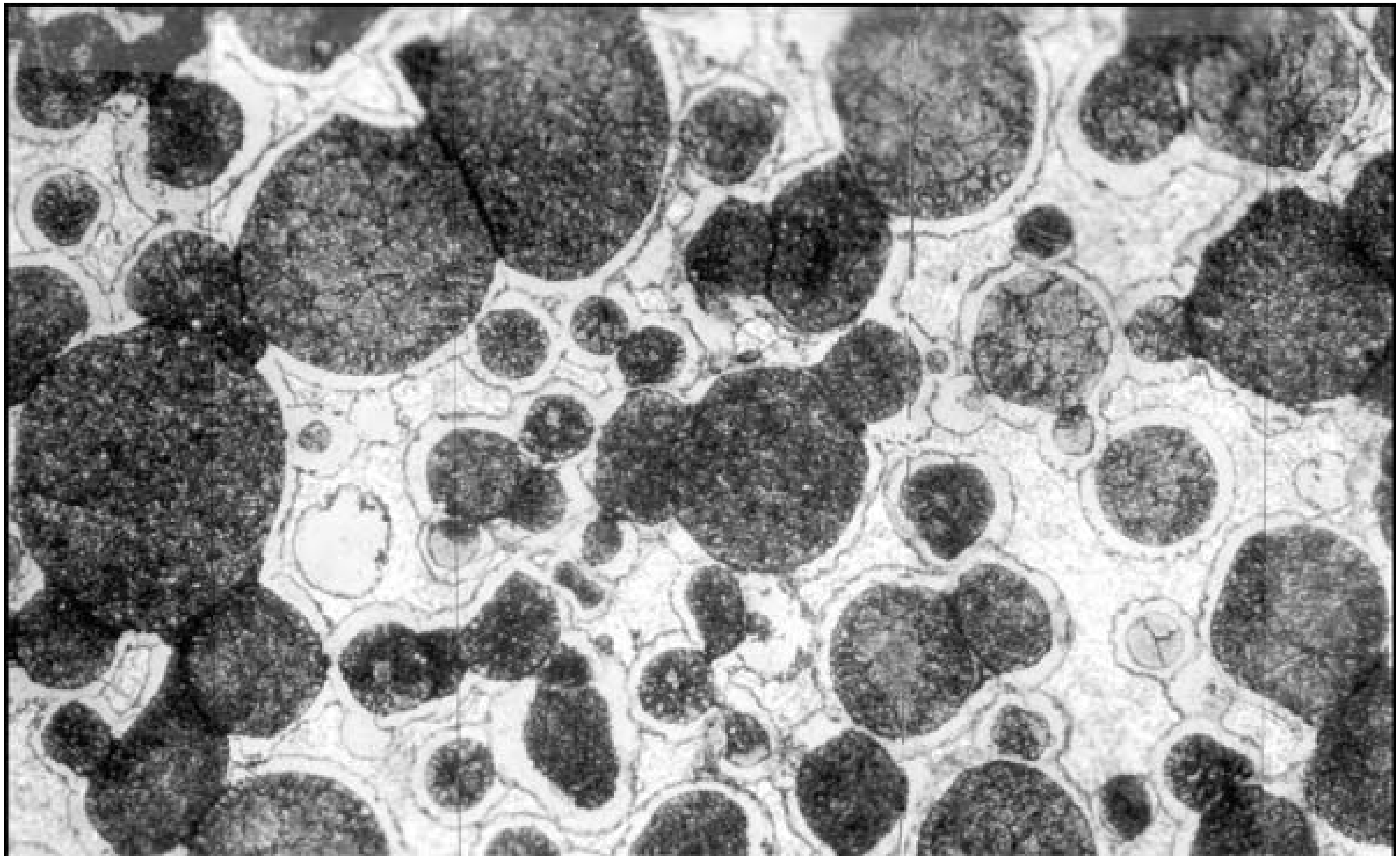
- Approximately 150 samples of many variations of these fuels have been irradiated in the Advanced Test Reactor (ATR), in Idaho. Initial results have been very encouraging for both fuel types.

- Recent irradiation tests on full-size plates/tubes by parallel French and Russian programs have revealed unexpected problems with the matrix of the dispersion fuel.

- We are now concentrating our efforts on identifying and eliminating the problem with dispersion U-Mo fuel, while accelerating development of monolithic U-Mo fuel.

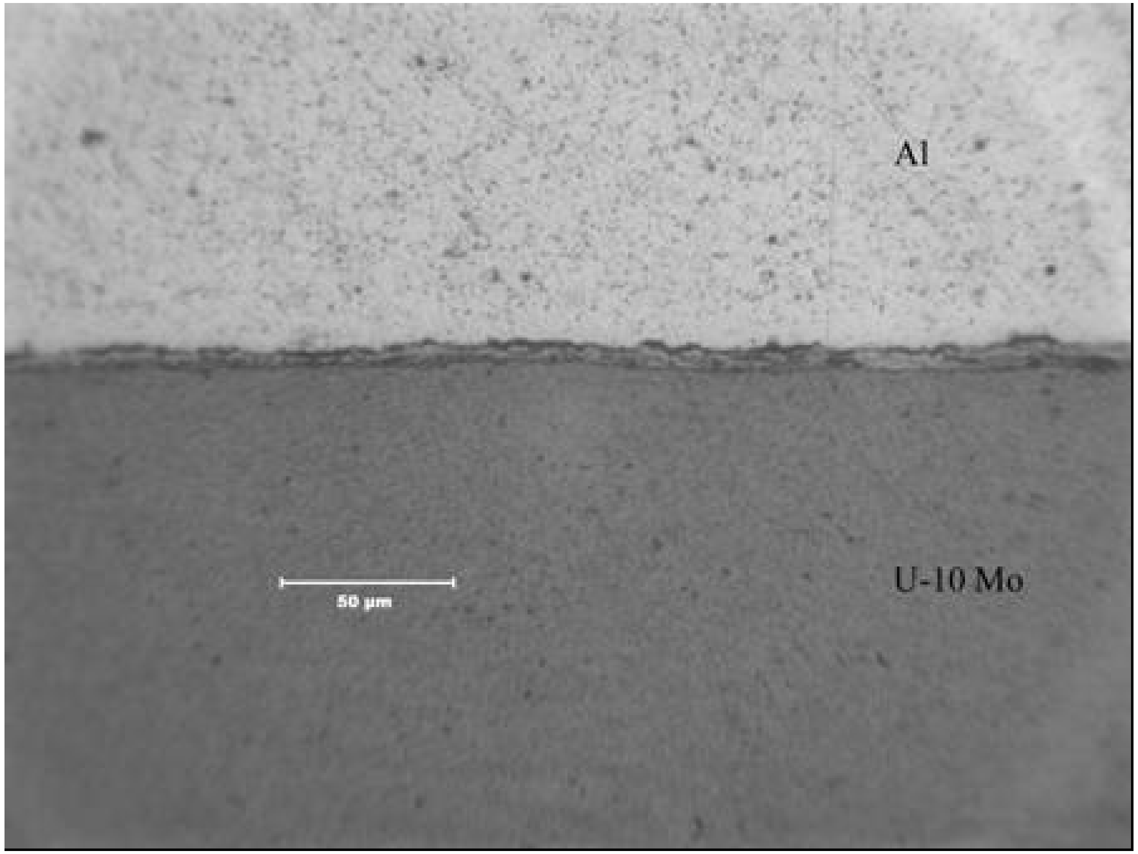


Samples of very high density U-Mo dispersion fuel are irradiated in the Advanced Test Reactor (ATR). Test results show the fuel behaved very well under irradiation.



Microstructure at center of fuel meat revealed excellent irradiation behavior of U-Mo dispersion fuel under irradiation conditions.

Interaction zone of a monolithic LEU U-Mo plate at 80% burnup



FISSION ^{99}Mo FROM LEU TARGETS

- An analytical/experimental program is in progress to determine the feasibility of using LEU instead of HEU in fission targets dedicated to the production of ^{99}Mo for medical applications.
- RERTR tests for an acidic process at BATAN (Indonesia) have been successful. A final demonstration of the system had to be postponed because of the 9/11 attacks.
- Cooperation with the CNEA (Argentina) is very active and has led to the successful implementation of a basic process applied to LEU targets.
- Cooperation with ANSTO (Australia) aims at the establishment of a successful acidic process based on the use of LEU targets.
- Cooperation with MDS Nordion (Canada) and its affiliates at AECL (Canada) and SGN (France) is centered on the development of a waste conditioning process compatible with the MDS Nordion process.

REACTOR ANALYSIS

- **Methods and computer codes were developed or adapted for**

  Neutronics,
  Fuel Cycle,
  Thermal-hydraulics,
  Transient Analysis, and
  Radiological Consequences

- **Many generic and specific analyses have demonstrated the validity of these methods. The results were published in three IAEA Guidebooks:**

  TECDOC-233 for H_2O-moderated reactors,
  TECDOC-324 for D_2O-moderated reactors, and
  TECDOC-643 for safety and licensing.

- **The program's computational and design capabilities for LEU reactors have created a standard which is internationally recognized and unsurpassed.**

CONVERSION PROGRESS

National Nuclear Security Administration

NO.	COUNTRY	REACTOR	POWER	BEGIN	END	NO.	COUNTRY	REACTOF	POWER	BEGIN	END
1	Argentina	RA-3	2.8 MW	1990	1990	20	Philippines	PRR-1	1 MW	1987	1987
2	Austria	ASTRA	8 MW	1983	** 1990	21	Romania	SSR	14 MW	1992	* 2006
3	Austria	TRIGA-V	250 KW	1997	* 2006	22	Slovenia	TRIGA-L	250 KW	1997	1999
4	Brazil	IEA-R1	2 MW	1981	1997	23	Sweden	R2	50 MW	1990	1993
5	Canada	MNR	5 MW	1999	2005	24	Sweden	R2-0	1 MW	2000	2000
6	Canada	NRU	125 MW	1992	1993	25	Switzerland	SAPHIR	10 MW	1986	** 1996
7	Canada	SL-M	20 KW	1997	1997	26	Taiwan	THOR	1 MW	1978	1987
8	Chile	La Reina	5 MW	1999	* 2006	27	Turkey	TR-2	5 MW	1995	* 2006
9	Colombia	IAN-R1	30 KW	1997	1997	28	USA	FNR	2 MW	1981	** 1983
10	Denmark	DR-3	10 MW	1988	**1990	29	USA	GTRR	5 MW	1998	** 1998
11	France	OSIRIS	70 MW	1979	1979	30	USA	ISUR	10 KW	1991	** 1991
12	Germany	BER-II	10 MW	1997	2000	31	USA	MCZPR	0.1 W	1992	** 1992
13	Germany	FRG-1	5 MW	1991	1991	32	USA	OSURR	10 KW	1988	1988
14	Greece	GRR-1	5 MW	1999	* 2006	33	USA	RINSC	2 MW	1993	1993
15	Iran	NCRR	5 MW	1993	1993	34	USA	RPIR	100 W	1987	1987
16	Japan	JMTR	50 MW	1993	1994	35	USA	ULRR	1 MW	2000	2000
17	Japan	JRR-4	3.5 MW	1998	1998	36	USA	UMRR	200 KW	1992	1992
18	Netherlands	HOR	2 MW	1998	2004	37	USA	UVAR	2 MW	1993	** 1993
19	Pakistan	PARR	5 MW	1991	1991	38	USA	WPIR	10 KW	1988	1988

* Conversion in progress
** Shut down after conversion

NEW RESEARCH REACTORS USE LEU FUELS

- **With one single exception, all research reactors built by Western countries since 1978 with power of at least 1 MW have been designed for LEU cores.**

Operational:
Algeria (NUR, 1 MW)
Bangladesh (TRIGA, 3 MW)
Egypt (ETRR-2, 22MW)
Indonesia (RSG-GAS, 30MW)
Japan (JRR-3, 20 MW)
Korea, South (HANARO, 30 MW)
Malaysia (TRIGA Mark II, 1 MW)
Peru (RP-10, 10 MW)
U.S. (McClellan, 2MW)
U.S. (U. of Texas, 1MW)

Under design or construction:
Australia (RR, 20 MW)
Canada (Maple-1, 10 MW)
Canada (Maple-2, 10 MW)
Canada (IRF, 20 MW)
France (RJH, 100 MW)
Morocco (MA-R1, 2 MW)
Thailand (MPR-10, 10 MW)

Cancelled after design:
Taiwan (TRR-II, 20 MW)

The FRM-II (20MW), in Germany, is the only exception to this international norm.

THE RUSSIAN RERTR PROGRAM

- Twenty-eight Russian-supplied research reactors (14 in Russia and 14 exported) are fueled with HEU and are included in the RERTR program.
- Cooperation between the US RERTR program and the corresponding Russian program began in 1996. The major participating Russian institutes include RDIPE, VNIINM, NZChK, RRC "KI", RIAR, PNPI, and IRM.
- Five LEU WWR UO_2-Al tube-type fuel elements, suitable for conversion of reactors in Hungary, Ukraine, Vietnam, and Germany have been successfully irradiated to more than 70% burnup at PNPI (St. Petersburg).
- Pin-type LEU U-Mo dispersion fuel elements intended for conversion of WWR, IRT, and MR research reactors have been fabricated by VNIINM and are being irradiation tested at RIAR and PNPI.
- Tube-type U-Mo dispersion fuel elements have been fabricated by NZChK using Russian funds. These elements were tested successfully at IRM up to 40% equivalent burnup, but failed at 60% equivalent burnup.
- Joint reactor analyses and evaluations have been performed for many Russian-designed research reactors.

GTRI

- On May 26, 2004, U.S. Energy Secretary Abraham announced at the IAEA a new important initiative, the ***Global Threat Reduction Initiative (GTRI)***, to which $450 million will be assigned over 9 years.

- GTRI aims to secure, remove, or dispose of, nuclear and other radioactive materials throughout the world that are vulnerable to theft by terrorists.

- In addition to the RERTR program, GTRI includes the Foreign Research Reactor Spent Fuel Return Acceptance (FRRSNFA) program, the Russian Research Reactor Fuel Return (RRRFR) program, and the Radiological Threat Reduction (RTR) program.

- In his speech, Secretary Abraham asked for cooperation from all countries, besides the U.S. and Russia, where these dangerous materials are located or from which they have originated.

Conversion Status of HEU Research Reactors

	U.S.-Designed				Russian-Designed				
	in the U.S.		Abroad		in Russia		Abroad		SUM
	<1 MW	≥1 MW	<1 MW	≥1 MW	<1 MW	≥1 MW	<1 MW	≥1 MW	
Converted	6	5	4	23	0	0	0	0	38
Convertible	4	4	13	8	0	0	3	4	36
Not Yet Convertible	1	5	0	4	3	11	2	5	31
SUM	11	14	17	35	3	11	5	9	105

Conversion Status of HEU Research Reactors (detail)

National Nuclear Security Administration

	U.S.-Designed								Russian-Designed								
	in the U.S.				Abroad				in Russia				Abroad				SUM
	<1 MW		≥1 MW		<1 MW		≥1 MW		<1 MW		≥1 MW		<1 MW		≥1 MW		
Converted	6	ISU MCZPR OSU RPI UMoR WPI	5	FNR GTRR RINSC ULR UVaR	4	IAN-R1 SL-M TRIGA-SL TRIGA-V	23	ASTRA BER-II DR-3 FRG-1 GRR-1 HOR IEA-R1 JMTR JRR-4 MNR NCRR NRU OSIRIS PARR PRR-1 R2 R2-0 RA-3 RECH-2 SAPHIR SSR THOR TR-2	0		0		0		0		38
Convertible	4	GENTR NRAD Purdue UF	4	OrSU TxA&M WI WSU	13	Consort KUCA LFR Minerve Neptune RA-6 SL-A SL-H SL-J SL-S Ulysee UTR-10 Viper	8	FRJ-2 HFR-P HIFAR IRR-1 KUR RPI SAFARI TRIGA-M	0		0		3	ZLFR IRT-1ca IRT-S	4	BRR DRR VVR-M(K) IRT-1	36
Not Yet Convertible	1	ATRC	5	ATR HFIR MITR MURR NBSR	0		4	BR2 FRM-II ORPHEE RHF	3	MIRca PIKca SM-3ca	11	IR-8 IRT-T IVV-2M MEPhI MIR PIK RBT-10/2 RBT-6 SM-3 VVR-M(G) VVR-TS	2	VR-1 VVR-Kca	5	IRT-DPRK LWR-15 MARIA VVR-CM VVR-K	31
SUM	11		14		17		35		3		11		5		9		105

ACCELERATED CONVERSION PLANS

National Nuclear Security Administration

The RERTR program plans to address the accelerated reactor conversions required by GTRI by:

- Qualifying both monolithic and dispersion LEU U-Mo plate-type fuels by 2010. Monolithic fuel, with a uranium density close to 16 g/cm^3, can be used to convert all the ten research reactors that cannot use existing LEU fuels in the U.S. and Europe. Dispersion fuel can facilitate fuel disposal by reactors not requiring monolithic fuel.
- Assisting in the parallel development of LEU pin-type and tube-type fuel assemblies appropriate for use in Russian-designed reactors. The fuel elements contained in these assemblies may contain UO_2-Al or UMo-Al dispersions, or monolithic UMo.
- Procuring and irradiation testing LEU prototype fuel assemblies to facilitate their qualification.
- Engaging with all remaining reactors in the feasibility studies, tests, and safety documentation needed for their conversion decisions.
- Coordinating with other GTRI components to accelerate conversions.

SUMMARY AND CONCLUSION

- The RERTR Program has been very successful and has achieved many of its original goals. Thirty-eight reactors operating in 19 countries have been converted to the use of LEU. More reactors are in the process of converting.

- The most significant technical events of the past year concern the successful testing of monolithic LEU U-Mo fuel samples in the ATR, and the unexpected failures of full-size fuel plates/tubes of LEU U-Mo dispersion fuel in European and Russian reactors. Corrective actions are in progress.

- The events of September 11 and the new GTRI initiative require a special effort to eliminate HEU traffic and to conclude the conversion effort in the shortest possible time. The RERTR program plans to achieve this goal during the next nine years, in close collaboration with other GTRI programs, so that all HEU materials used in research reactors can be returned to their country of origin or properly secured in place.