Decommissioning of the ASTRA Research Reactor: Planning, cost estimates, funding and budgeting

Franz Meyer, NES

presented by

Ernst Warnecke, IAEA

Adapted **S**wimming **T**ank **R**eactor **A**ustria - **ASTRA**

Arial view of the **A**ustrian **R**esearch **C**enters **S**eibersdorf - **ARCS** premises of **N**uclear **E**ngineering **S**eibersdorf - **NES** marked in blue

R^2D^2 Project: Workshop on „Cost Estimates“ - PNRI, Manila; 30 March – 03 April 2009

Decommissioning the ASTRA Reactor – contents of the presentation

Introduction - history of the reactor, the way to permanent shut down

Planning for decommissioning, goals, strategies, calculation, costs

Decommissioning phases, timescale, initiating the project

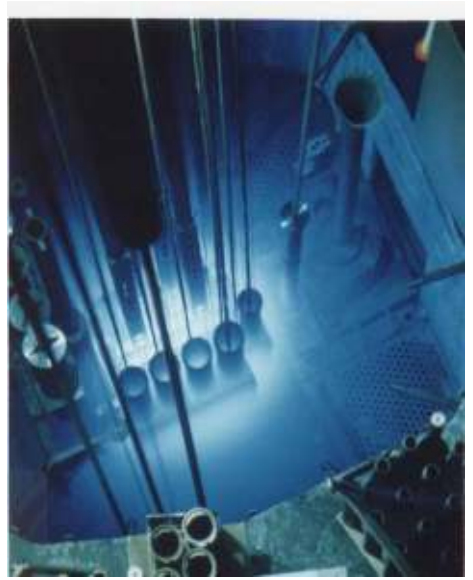
Typical tasks and results achieved during decommissioning phases

Termination of the project

Analysing costs, manpower, qualification, budget on a yearly basis

Analysing the costs and manpower related to the tasks, conclusions

Analysing the flow of the materials and low-level metals, conclusions



View of the ASTRA-core
during operation at 10 MW

The ASTRA Reactor – a brief history

1955	Foundation of the Österreichische Studiengesellschaft für Atomenergie Ltd - (ÖSGAE)
1958	Federal agreement to construct and build a 10 MW research reactor
29.09.1960	ASTRA Reactor reaches first criticality - testing at 100 W until 1962
1962	Power increased to 1 MW and subsequently raised to 5 MW thermal
1972	Another two cooling towers erected - power raised to 8 MW thermal
1982	Substitution of 90%-HEU by 20%-LEU U_xSi_y-fuel elements completed
1984	Reactor power increased to 9 MW, finally to a max. of 10 MW thermal
1994	Preparation of a preliminary decommissioning study
1995	Purchase of 16 fuel elements from shut down SAPHIR / CH, assuming operation of ASTRA until 2003
1999	Constitutional Law: Decision not to use nuclear power in Austria (BGBL 149; 13 August 1999)
1999	Last operation of the ASTRA Reactor (31.07.1999)

View of the ASTRA-core-area, decommissioning in progress

The ASTRA Reactor – the way to permanent shut down

1978 – public referendum: rejection of the use of nuclear power in Austria

The ASTRA Reactor – the way to permanent shut down

1978 – public referendum: rejection of the use of nuclear power in Austria

1994 – preliminary decommissioning study by the reactor management on behalf of the Austrian government audit office with the following results:

	ASTRA-DECOMMISSIONING - PROJECT COSTS AS CALCULATED IN 1994		[metric TONS]	[MAN-YEARS]	[M-EURO]	%
COST INDEX 1994	Decommissioning tasks and waste treatment performed by project staff	1)		21	1.953	*41.4*
	Treatment of radioactive waste performed by Hot Cell staff	1)		4	0.372	*7.9*
	Specialists for concrete cutting, contracted				0.291	*6.2*
	Disposition of spent fuel (60 elements estimated, 1000 MBq one year after shut-down)	2)	1		1.301	*27.6*
	Conditioning and intermediate storage of radioactive waste	3)	193		0.727	*15.4*
	Transport, conventional disposal of inactive waste (estimated 300 m^3 concrete)		1050		0.073	*1.5*
	TOTAL		**1244**	**25**	**4.717**	*100*

1) Calculated with averaging 0.093 M-EURO per man-year, overheads partly included

2) Calculation based on the costs of previous transports and communication with DOE

3) Calculation according price-list 1994 at averaging 0.0038 M-EURO per metric ton. A total of 193 metric tons of radioactive waste was assumed consisting of 3 tons ILW (1 m^3 metals, 5 MBq) and 190 tons LLW (60 m^3 alumina plus 15 m^3 concrete, 0.05 MBq), activities one year after shut down.

The ASTRA Reactor – the way to permanent shut down

1978 – public referendum: rejection of the use of nuclear power in Austria

1994 – preliminary decommissioning study by the reactor management on behalf of the government audit office

1996 – US-DOE resumes return program of research reactor fuel (suspended since 1988)

The ASTRA Reactor – the way to permanent shut down

1978 – public referendum: rejection of the use of nuclear power in Austria

1994 – preliminary decommissioning study by the reactor management on behalf of the government audit office

1996 – US-DOE resumes return program of research reactor fuel (suspended since 1988)

1997 – on behalf of the government, the new ASTRA management prepares for the earliest possible shut down for financial and political reasons

1999 – presentation of a comprehensive decommissioning study

ASTRA Reactor Decommissioning-Study of 1999 – defining the goals

a) With reference to buildings, structures and funds

- to remove activated and contaminated materials from the reactor to achieve unrestricted release
- to keep the amount of radioactive waste to a reasonable minimum
- to keep the costs of the decommissioning as low as possible
- to preserve the building for further use

a) With reference to people and the environment

- to protect the staff by administrative and technical means from unnecessary exposure (ALARA-principle)
- to apply the necessary physical surveillance to personnel and the environment
- to take appropriate measures to prevent contaminations and the spreading of contaminations
- to protect the environment from hazards implemented by the decommissioning process

Under observation of these objectives a decommissioning strategy was developed

ASTRA Reactor Decommissioning-Study of 1999 - deciding on strategies

Different strategies have been applied for the decommissioning of research reactors, ranging from immediate dismantling to deferred dismantling in stages separated by a few months and up to several decades. Advantages and disadvantages were compared under ASTRA circumstances considering the following key factors:

a) Activity inventory

The majority of the radionuclides identified for the ASTRA possesses

- **half-lives up to 80 days decaying sufficiently fast to allow immediate dismantling or**
- **half-lives of more than 50 years requiring long time periods to achieve a substantial reduction of dose rate**

b) Available manpower and experience

Throughout reactor operations, the staff was directly responsible for technical adaptations

- **with an outstanding experience in handling and cutting procedures under operating conditions**
- **being familiar with the technical features of the reactor and the necessary safety procedures**
- **with the practical experience, that personal exposure has always been at very low levels**

Based on these factors and with a maximum priority to safety and environmental compatibility immediate dismantling was recommended as the most viable option

ASTRA Reactor Decommissioning-Study of 1999 – Estimation of costs

a) Estimation of necessary manpower

A table of the tasks necessary to decommission the ASTRA was prepared

- **The working time was estimated based on experience from similar tasks carried out during reactor operation**
- **Based on the manpower available the overall decommissioning period was calculated**

PHASE 0: Disposition of the spent fuel-elements, preparatory work for phase 1		**Termination expected: 31.08.01**			
Work under reactor operating license					**Page 1**
Tasks under decommissioning license of ASTRA based on Executive Summary Shut Down of ASTRA, Rev.15. May 1999	Status of work 31. JULY 1999 until MAY 2001	Task Phase	Start of work	Termination expected	Termination actual
Preparations					
Preparing transport of spent-fuel, negotiations with DOE		**0**	Nov.98	Nov.99	Nov.99
Contract with DOE		**0**	Dec.98	Nov.99	Nov.99
Compilation of fuel-element data for für DOE (Appendix A)		**0**	Jul.99	Nov.99	Nov.99
Specifications of transfer cask		**0**	Jul.99	Sep.00	Sep.99
Contract with transport company		**0**	Jul.99	Sep.00	Sep.00
Notifying Euratom and IAEA about intention of spent fuel transfer	**(Delayed)**	**0**	Jul.99	**Apr.00**	**Apr.01**
Application for export documentation (Federal chancellery)		**0**	Jul.99	Mar.01	Mar.01
Planning work in Phase 1 and Phase 2		**0**	Jul.99	Jul.01	Jul.01
Decomm. proposal to Federal Chancellery to be forwarded to Europ. Commission		**0**	Nov.99	**Apr-00**	**May 00**
Forwarding decomm. Proposal to Europ. Comm. by Federal Chancellery	**(Delayed)**	**0**	May 00	**May 00**	**May 01**
Comment of European Commission	**(Delays expected)**	**0**	May 00	**Mar.01**	**Dec.01**
Preparation of disposition concept for radioactive waste (ARCS view)	Continuation in Phase 1 (EIA Documentation)	**0-1**	Oct.01	Phase 1	Phase 1
Preparation of storage tank at Hot Cell Lab. for spent fuel transfer		**0**	Jul.99	Apr.00	Apr.00
Conceiving and machining of dismantling tools for use in phase 1	Finished in Phase 0	**0-1**	Jul.99	Phase 1	Aug.01
Fuel-elements					
Removing fuel elements from ASTRA core, storage in ASTRA pool		**0**	Jul.99	Jan.00	Jan.00
Decay of fuel elements in the ASTRA pool for at least 1 year		**0**	Jul.99	Sep.00	Sep.00
Preparation of fuel elements for transport, dissecting Alu foot structures		**0**	Nov.99	Jan.00	Jan.00
Determination of fuel element specifications		**0**	Aug.99	May 00	May 00
Fuel element quality assurance (e.g. leak proving)		**0**	Dec.99	Feb.00	Feb.00
Dismantling work					
Transfer of fuel elements from ASTRA pool into storage tank at the Hot Cell Lab		**0**			
Transfer of fuel elements to USDOE Savannah River Plant	**(Delayed)**	**0**	Feb.00	**Oct.00**	**May 01**
Dismantling and removing irradiation facilities and reactor experiments		**0**	Jul.99	Jul.01	Jul.01
Dismantling cooling towers (secondary water systems, inactive)		**0**	Jul.99	Nov.00	Nov.00

ASTRA Reactor Decommissioning-Study of 1999 – estimation of costs

a) Estimation of necessary manpower

A table of tasks necessary to decommission the ASTRA was prepared

- The working time was estimated based on experience from similar tasks carried out during reactor operation
- Based on the manpower available an overall decommissioning period was calculated

b) Amount of radioactive waste to be expected

Preparation of a comprehensive catalogue of all parts of the reactor

- **Including technical data like materials, weight, size of contaminated surface and**
- **Calculated level of contamination or activation with characterization of possible radionuclides**

Component identity	Description	Remarks	Material	Mass [kg]	Surface [dm2]	Nuclide	Activity [Bq]	Dose-rate [µSv/h]	Ident. NF	Ident Store	Date	Respon-sible
4.01.01	**Primary outlet between valve P12 a. decay-tank (valve-pit and conduit)**	**10"-tube, L=19.5m, 2 flanges Dwg. VMW 3370, approx. 400 kg**			1556	Co-60	2.60E+05					
4.01.01.01	Primary outlet between valve P12 a. decay-tank (valve-pit and conduit)	10"-tube, L=12.5m, 1 flange Dwg. VMW 3370, part desected	Al 6061	260					661C	CO656	20 01 06	Urbanich
4.01.01.02	Primary outlet between valve P12 a. decay-tank (valve-pit and conduit)	10"-tube, L=7m, 1 flange Dwg. VMW 3370, part desected	Al 6061	150					665C	CO683	08 02 06	Urbanich
4.01.02	**Primary outlet between decay-tank to T-section near valve L2 (conduit)**	**12"-tube, L=7.7m, 3 flanges Dwg. VMW 3366, approx. 250 kg**			733	Co-60	1.30E+05					
4.01.02.01	Primary outlet between decay-tank to T-section near valve L2 (conduit)	12"-tube, L=1.5m, 1 flange Dwg. VMW 3366, desection DT to PP2	Al 6061	50					407C	CO634	15 07 04	Urbanich
4.01.02.02	Primary outlet between decay-tank to T-section near valve L2 (conduit)	12"-tube, L=1.2m, 1 flange Dwg. VMW 3366, near valve P4	Al 6061	40					407C	CO634	15 07 04	Urbanich
4.01.02.03	Primary outlet between decay-tank to T-section near valve L2 (conduit)	12"-tube, 2xL=1.9m, 1 flange Dwg. VMW 3366, between DT a. P4	Al 6061	120					484C	CO644	16 08 04	Urbanich
4.01.02.04	Primary outlet between decay-tank to T-section near valve L2 (conduit)	12"-tube, L=1.2m, Dwg. VMW 3366, between DT a. P4	Al 6061	35					486C	CO645	17 08 04	Urbanich
4.01.03	**Primary outlet between T-section to valve L2, PP2 a. PP3 (conduit)**	**12"-tube, L=4.2m, 4 flanges Dwg. VMW 3367, approx. 140 kg**			402	Co-60	1.00E+05					
4.01.03.01	Primary outlet between T-section to valve L2, PP2 a. PP3 (conduit)	12"-tube, elbow in front of PP2, 2 flanges, Dwg. VMW 3367	Al 6061	75					404C	CO631	14 07 04	Urbanich

ASTRA Reactor Decommissioning-Study of 1999 – estimation of costs

a) Estimation of necessary manpower

A table of the different tasks necessary to decommission the ASTRA was prepared

- In comparison to other tasks performed at the reactor under operation work-times were estimated
- With the manpower available an overall period for the decommissioning could be calculated

b) Amount of radioactive waste to be expected

Preparation of a comprehensive catalogue of all parts of the reactor

- Including technical data like materials, weight, size of contaminated surface and
- Calculated level of contamination or activation with characterization of possible radionuclides

c) Comparison with other research and prototype reactors

- **Contacts with other decommissioning projects in Europe were established**
- **Estimated and actual data were compared with the figures of the ASTRA**

Based on this data a rather clear picture of costs to be expected could be drawn

ASTRA Reactor Decommissioning-Study of 1999 – final calculation of the project

	ASTRA-DECOMMISSIONING - PROJECT COSTS AS CALCULATED IN 1999		[MAN-YEARS]	[M-EURO]	%
BASED ON INDEX 1999	Management, engineering, administration and documentation, project staff	1)	14	1.680	*12.8*
	Characterization, radiation protection, safety engineer, project staff	1)	3	0.360	*2.8*
	Decommissioning tasks and waste treatment performed by project staff	1)	46	5.520	*42.1*
	Specialists for concrete cutting, contracted			0.290	*2.2*
	Equipment and materials procured			0.870	*6.7*
	Purchase of Mosaik-shielding containers (estimation: 10 to 12 containers required)			0.360	*2.8*
	Conditioning and intermediate storage of radioactive waste (estimation: 160 metric tons)	2)		4.000	*30.6*
	Disposition of spent fuel (54 elements to be transferred to DOE)	3)		0	
	TOTAL		**63**	**13.080**	*100*

1) Calculated with 0.120 M-EURO per man-year, overheads fully included

2) Calculated with 0.025 M-EURO per metric ton covering the conditioning and the saving on storage. Funds for a future long-time storage were definitely excluded from the budget of the decommissioning project

3) During reactor operations 1.526 M-EURO were collected to cover expenses for the transfer and disposition of the spent fuel elements.

ASTRA Reactor Decommissioning – comparing calculations 1994, 1999 and actual costs

	ASTRA-DECOMMISSIONING - COMPARING CALCULATIONS TO COSTS	calculated 1994 [1]			calculated 1999 [2]			actual 2007 [3]		
		[MAN-YEARS]	[M-EURO]	%	[MAN-YEARS]	[M-EURO]	%	[MAN-YEARS]	[M-EURO]	%
PERSONNEL	Management, engineering, administration and documentation, project staff				14	1.680	*12.8*	15.6	2.058	*13.5*
	Physicists (radiation protection and reactor), on free working contract							8.5	0.854	*5.6*
	Characterization, radiation protection, safety engineer, project staff				3	0.360	*2.8*	19.1	2.540	*16.7*
	Decommissioning tasks and waste treatment performed by project staff	21	1.953	*41.4*	46	5.520	*42.2*	19.5	2.585	*17.0*
	Personnel replacing retirees on the project, contracted							8.6	0.871	*5.7*
	Treatment of radioactive waste performed by Hot Cell staff	4	0.372	*7.9*				10.7	1.435	*9.4*
	Specialists for concrete cutting, contracted		0.291	*6.2*		0.290	*2.2*	5.8	0.597	*3.9*
PROCUR.	Equipment and materials procured					0.870	*6.7*		0.498	*3.3*
	Purchase of a whole-body monitor								0.070	*0.5*
	Purchase of Mosaik-shielding containers					0.360	*2.7*		0.186	*1.2*
WASTE	Conditioning and intermediate storage of radioactive waste		0.727	*15.4*		4.000	*30.6*		2.791	*18.3*
	Transport, conventional disposal, insurance etc.		0.073	*1.5*					0.531	*3.5*
	Disposition of spent fuel		1.301	*27.6*		0			0	
	Additional funds required for fuel-disposition								0.207	*1.4*
	TOTAL	**25**	**4.717**	*100*	**63**	**13.080**	*100*	**87.9**	**15.223**	*100*

1) 1994	**0.093 M-EURO/MAN-YEAR, company-overheads partly included**	**0.0038 M-EURO/ton rad. Waste, 193 tons calculated**	**Calculation see slide 5**
2) 1999	**0.120 M-EURO/MAN-YEAR, company-overheads fully included**	**0.025 M-EURO/ton rad. Waste, 160 tons calculated**	**Calculation see slide 13**
3) 2007	**0.133 M-EURO/MAN-YEAR, company-overheads fully included**	**0.034 M-EURO/ton rad. Waste, 83 tons calculated**	**Final figures slide 27 to 30**

For further comparison and explanation of the figures see next slide!

ASTRA Reactor Decommissioning – comparing calculations 1994, 1999 and actual costs

a) Calculation in 1994 (slide 5) under the following presumptions:

- **Part of the work (e.g. at the Hot Cells and radiation protection) performed by so called "internal" staff**
- **The costs for waste storage were calculated until 2003, then transfer to a disposal facility was expected**
- **Conditioning and storage of radioactive waste calculated under the philosophy and at the price level of 1994**

b) Calculation in 1999 (slide 13) under a new management of ARCS applying different rules:

- **Calculations under a full-cost scheme under consideration of all efforts at the conditions of a free market price**
- **Between 1994 and 1999 the storage period was extended to 2030 resulting in a drastic increase of waste costs**
- **Provision for disposal: each 200 litre drum of conditioned radioactive waste is subjected to a fee of 10 000 EURO**

Remark: Since disposal is considered a federal duty, the disposal fee was not included in the cost calculation of the project. Nevertheless, a strict management to minimize the amount of radioactive waste was requested.

c) Reference to the actual figures after termination of the project by end of 2006 (slide 27-30)

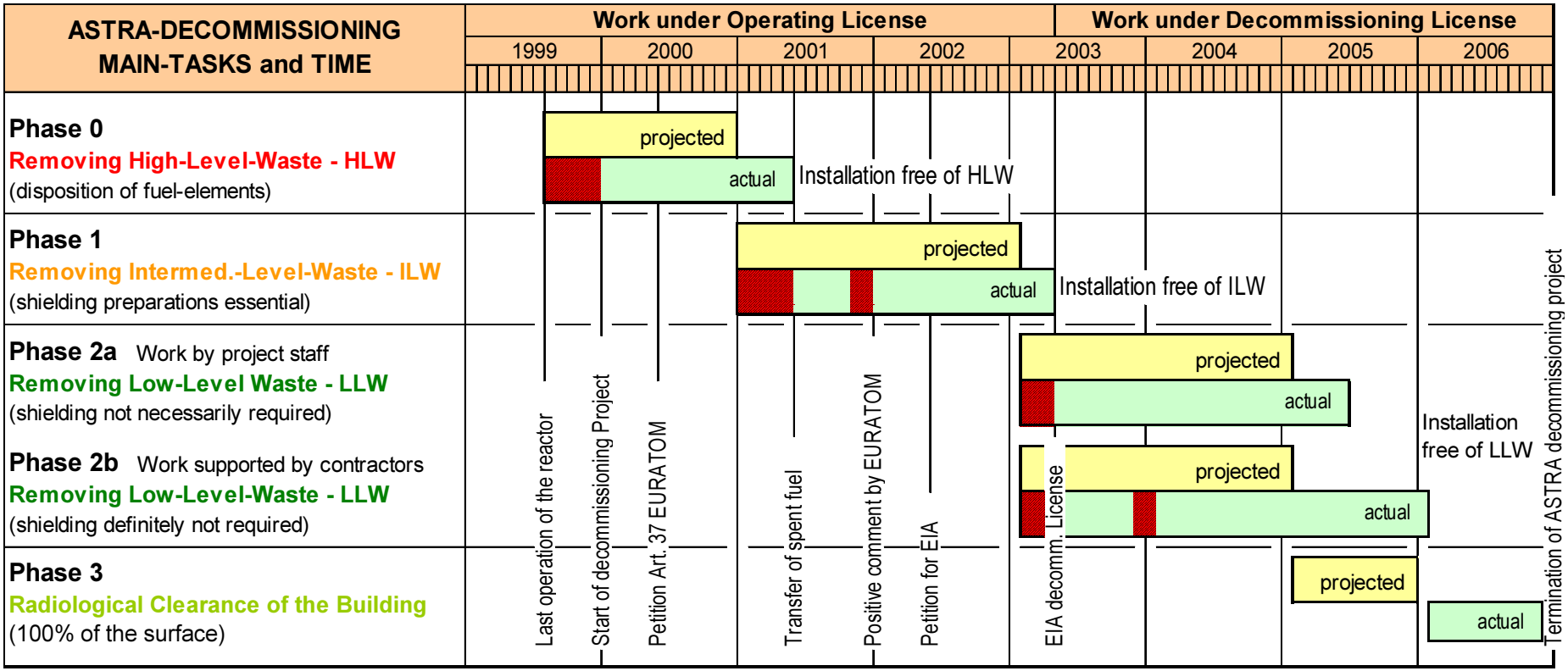
- **The efforts necessary for radiology, characterization, protection and safety were underestimated in 1999**
- **The increase of the costs for fuel disposition due to unfavorable exchange-rates US$/EURO were unforeseeable**
- **The investments into whole body monitoring and a new clearance building were not part of the planning in 1999**

ASTRA Reactor Decommissioning-Study of 1999 – main-tasks, projected and actual

To simplify administration the project was structured into four phases:

Phase 0	**– removal and ultimate disposition of the fuel elements**	Aug.1999 – Dec.2000 Jan.2000 – Jun.2001
Phase 1	**– recovering and treating of remote handled waste - ILW**	Jan.2001 – Jan.2003
	recovering and treatment of ILW from the vicinity of the core	Jul.2001 – Apr.2003
	handling and conditioning of neutron exposed graphite	
	(phase-1 conditioning work at Hot-Cell-Laboratory continued until Dec. 2005)	
Phase 2	**– recovering and treating of contact handled waste - LLW**	Feb.2003 – Jan.2005
	"fingerprinting" contamination of the primary water systems	May 2003 – Jan.2006
	dismantling of the primary water systems	
	processing of contaminated and activated metals	
	"fingerprinting" activation of Barite concrete	
	dismantling of the biological shield	
	radiological clearance of the surface of the concrete	
Phase 3	**– radiological clearance of the reactor building**	Feb.2005 – Dec.2005 Feb.2006 – Oct.2006

ASTRA Reactor Decommissioning-Study of 1999 – main-tasks and timescale



Remark 1: Red bars indicate times lost through delays outside the power of the project management. Some of the delays were compensated by parallel work and by contracting external support.

Remark 2: The preparations of the fuel transfer and the loading of the transport containers with the 54 spent fuel elements were within the projects costs (phase 0). The cost of the transfer and disposition of the spent fuel were covered by funds collected on a continuous annual rate during reactor operation.

ASTRA Reactor Decommissioning-Study of 1999 – initiating the project

Austrian legislation:

- **Operation of nuclear facilities is under federal supervision.**
- **The return of the spent fuel to the US Department of Energy (DOE) and the removal and conditioning of ILW on site was carried out within the operational license (phase 0 and phase 1).**
  Remark: Tasks that had already been performed during reactor operation, e.g. disposition of spent fuel, were performed in the initial stages of decommissioning still under the valid reactor operating license.

- **Decommissioning of nuclear facilities is under supervision of the federal state (Lower Austria).**
- **To continue the project (phase 2 and phase 3) without an interruption a decommissioning license through an Environmental Impact Assessment (EIA) had to be obtained in parallel to the work of phase 1.**
- **Austria as an EU member had to involve EURATOM in an 'Article 37 procedure' in the decommission of ASTRA.**

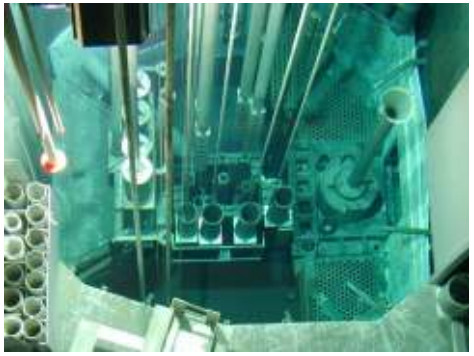
Obtaining permission to proceed with the project:

- **In June 1999 the project was finally presented to parliament and implemented by law. The funding of the project, divided into six equal parts over 6 years (2000 to 2005), was granted.**
- **The budget was formally approved late in December 1999 by the Austrian federal ministry of science.**

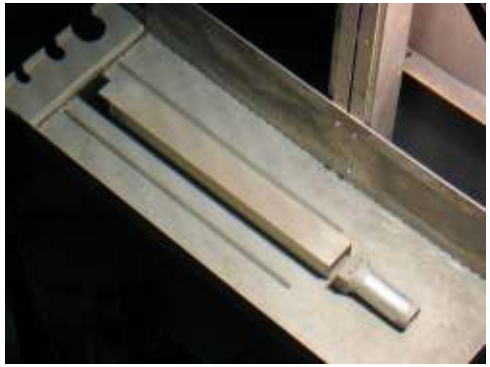
With the necessary funds guaranteed and with the expectation of a positive statement according to Article 37, EURATOM as well as a decommissioning license within an EIA, work on the project (phase 0) commenced immediately in January 2000.

ASTRA Reactor Decommissioning: Phase 0 – disposition of spent fuel elements (HLW)

Work carried out under the operating license of the reactor; typical tasks:



Emptying the ASTRA core from fuel



Preparation of a MTR-fuel element for transfer to the Hot Cells

Transfer of the last fuel element to the Hot Cells

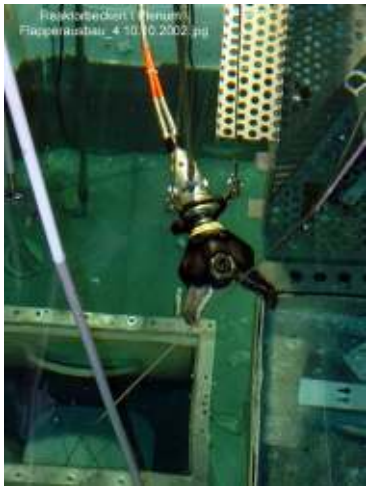
Unloading of a transport flask in the Hot Cell Department

Transfer of a fuel element into the transport flask

Transport of fuel elements: leaving the ARCS premises

ASTRA Reactor Decommissioning: Phase 1 – Removal of remote handled waste (ILW)

Work carried out under the operating license of the reactor; typical tasks and results:



Under water cutting with hydraulic pliers

Under water loading of a Mosaik container, activity content 370 GBq Co-60

Opening of the inactive secondary side of a heat exchanger unit

Transfer of activated parts to the Hot Cells for further dismantling

- **3 tons of material with activities requiring shielding for handling and storage (reactor components, beryllium reflector elements, reactor and beam tube experiments) were conditioned in 5 Mosaik shielding containers**
- **55 tons were collected as radioactive waste (66% of the radioactive waste with more than 99% of the total activity)**
- **140 tons of material could be released from regulatory control after appropriate decontamination**
- **198 tons (metric) total of materials associated with the reactor internals were removed in phase 1**

ASTRA Reactor decommissioning: Phase 2 – removal of contact handled waste (LLW)

To continue work a decommissioning license had to be obtained within an Environmental Impact Assessment (EIA). This license was granted in May 2003.

For practical reasons phase 2 was structured into two sub-phases:

Phase 2a

Primarily contact handled activities carried out entirely by project staff

- **Preparation of the biological shield for diamond wire cutting**
- **Removing and treating the graphite from the thermal column and from different moderators**
- **Dismantling primary water circuits and auxiliary circuits within the reactor building**
- **Dismantling primary and secondary water circuits within the pump room**
- **"Fingerprinting" activations in metals and barite concrete**
- **Characterising and processing of contaminated and activated low level materials**

Phase 2b

Contact handled activities supported by contracted staff and specialists

- **Dismantling of the biological shield**
- **Radiological and chemical clearance of the various types of concrete**

ASTRA Reactor decommissioning: Phase 2a – work performed by project staff

Work carried out under the decommissioning license; typical tasks:

Dismantling primary circuit components in the valve pit within the reactor building

Sampling at the biological shield and the pool liner for „fingerprinting“

Removing contaminations from concrete structures

Removing and opening the „inner“ thermal column to recover the graphite rods for further heat treatment at the Hot Cells

Cleaning the surface of the pool liner

Characterization of metals using ISOCS and collecting metals for further treatment

ASTRA Reactor decommissioning: Phase 2b – work supported by contactors

Work carried out under the decommissioning license:
Dismantling of the biological shield, clearing the remains

General data of the biological shield

Height of biological shield: 10 m

Construction material: Barite concrete (450 $m^{3)}$

Density of Barite concrete: 3.5 tons/m^3

Contents of reinforcement iron within concrete: 7 %

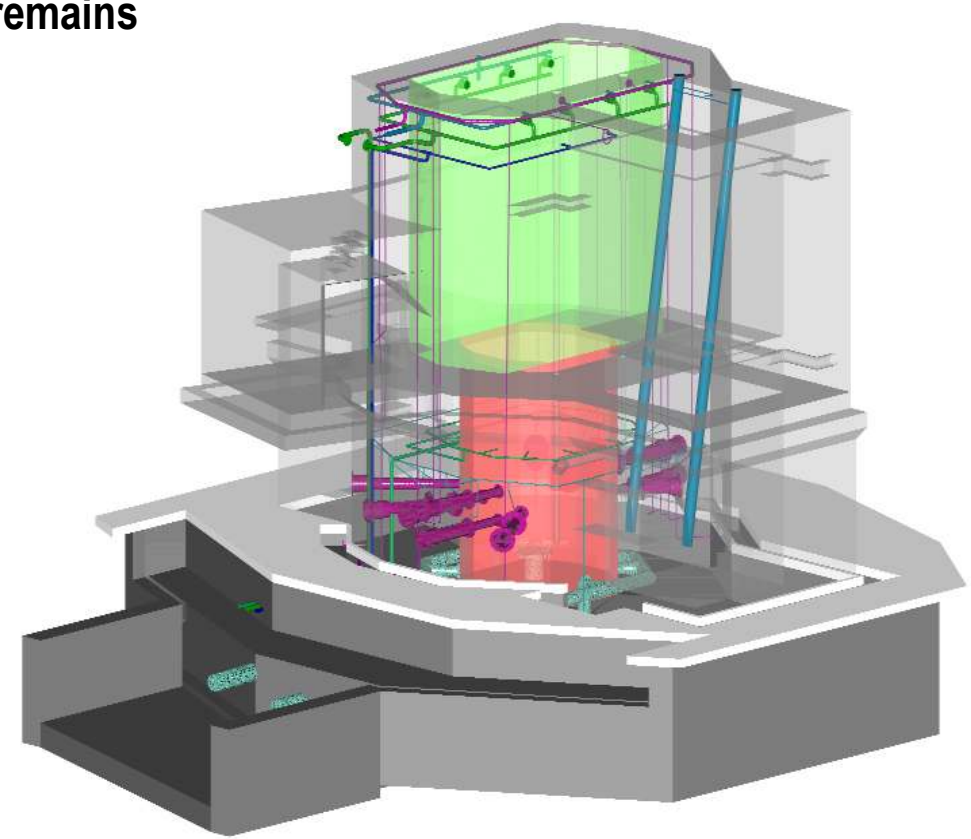
Wall thickness in the upper pool area (green): 0.9 m

Thickness of walls of auxiliary structures: 0.9 m

Wall thickness in the lower pool area (red): 2 m

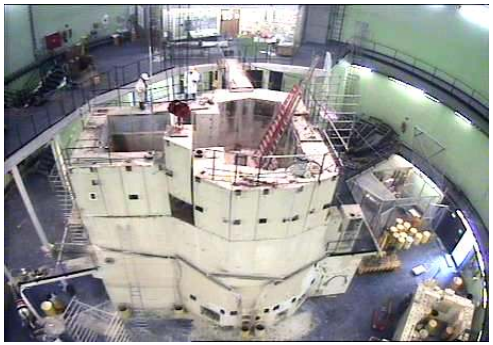
Concrete to be removed: 1600 tons

Concrete in activated area: 25 tons



ASTRA Reactor decommissioning: Phase 2b – work supported by contactors

Dismantling of the biological shield and clearing the remains; typical tasks:



Block cutting at the upper shield

Application of diamond wire cutting saw

Block cutting at the lower shield area

Dismantling at the activated zone

Concrete blocks stored in Konrad Type 2 container

Cleaning the blocks and clearance measurement with a Canberra ISOCS detector

ASTRA Reactor Decommissioning: Phase 3 radiological clearance of the building

Scope:

- Clearing 100% of the inner surface of the building for unrestricted re-use (2500 m^3 of remaining structures and floors)

Equipment:

- Using available ISOCS*) at required sensitivity was too time consuming (15 minutes per 1 m^2, amounting to 600 hours of measuring time)
- Decision to use a large area (40x60 cm) gamma contamination monitor (1 minute per m^2: calculated measuring time is 40 hours)

Procedures:

- Establishing 'radionuclide relationships' (sometimes termed 'radionuclide vectors') by core sampling and analysis of the samples ('fingerprinting')
- Calibrating the large area contamination monitor based on the typical 'radionuclide relationship' established for the surfaces of the building
- After careful 'worst-case' analysis and approval by the authorities, the threshold value of the monitor was finally adjusted at 25% of the calculated clearance levels

Tasks:

- 12380 single measurements were carried out and documented
- 145 areas with contaminations exceeding the defined threshold values were detected and decontaminated, incl. removal of minor amounts of concrete

Typical grid pattern at upper floor level to ensure the traceability of measurements

*) In Situ Object Counting System – ISOCS with Canberra BeGe 3830-pure germanium detector

ASTRA Reactor Decommissioning: Termination of the project

The final goal of the project was the release of the buildings for re-use. Immediate dismantling was chosen to be the optimum decommissioning strategy.

Decommissioning work started with the disposition of spent fuel. It was immediately continued with the removal of remote handled waste (ILW), followed by the removal of contact handled waste (LLW) and finalised with the decontamination of the reactor building to achieve the clearance level for unrestricted re-use.

With the release of the reactor building from regulatory control the decommissioning of the ASTRA was terminated in October 2006, approximately 10 months behind schedule.

The following tables give an overview over the development of the actual costs, the necessary manpower and the expenditures on an annual basis.

ASTRA Reactor Decommissioning: Actual costs of the project per year, 2000-2006

	ASTRA-DECOMMISSIONING - ANALYSIS OF COSTS IN 2007		2000	2001	2002	2003	2004	2005		00 to 06	
PERSONNEL	Management, engineering, administration and documentation, project staff		0.210	0.251	0.264	0.343	0.343	0.277	0.370	**2.058**	*13.5*
	Physicists (radiation protection and reactor), on free working contract		0.202	0.171	0.081	0.100	0.100	0.100	0.100	**0.854**	*5.6*
	Characterization, radiation protection, safety engineer, project staff		0.343	0.304	0.304	0.397	0.437	0.437	0.318	**2.540**	*16.7*
	Decommissioning tasks and waste treatment performed by project staff		0.398	0.398	0.398	0.398	0.371	0.358	0.264	**2.585**	*17.0*
	Personnel replacing retirees on the project, contracted						0.263	0.304	0.304	**0.871**	*5.7*
	Treatment of radioactive waste performed by Hot Cell staff		0.343	0.397	0.224	0.210	0.116	0.145		**1.435**	*9.4*
	Specialists for concrete cutting, contracted					0.334	0.263			**0.597**	*3.9*
PROCUR.	Equipment and materials procured		0.076	0.080	0.036	0.068	0.093	0.061	0.084	**0.498**	*3.3*
	Purchase of a whole-body monitor				0.070					**0.070**	*0.5*
	Purchase of Mosaik-shielding containers (finally 7 container purchased)			0.186						**0.186**	*1.2*
WASTE	Conditioning and intermediate storage of radioactive waste		0.438	0.311	0.191	0.436	0.375	0.283	0.757	**2.791**	*18.3*
	Transport, conventional disposal, insurance etc.		0.056	0.069	0.054	0.097	0.063	0.062	0.130	**0.531**	*3.5*
	Disposition of spent fuel									**0**	
	Additional funds required for fuel-disposition			0.207						**0.207**	*1.4*
	TOTAL	[M-EURO]	**2.066**	**2.374**	**1.622**	**2.383**	**2.424**	**2.027**	**2.327**	**15.223**	
		%	*13.6*	*15.6*	*10.6*	*15.6*	*15.9*	*13.4*	*15.3*		*100*

1) The expected costs of the disposition of the 54 spent fuel elements was covered by funds of M-EURO 1.526 collected during reactor operation. Due to the unfavourable exchange-rate of the EURO to the US$ at the time of the fuel transfer in 2001, the funds were short by M-EURO 0.207. These additional costs were covered by the budget of the decommissioning project.

Remark: The actual average costs per man-year was calculated to be 0.133 M-EURO per person; roughly a 10 % increase over the 1999 figure of 0.120 M-EURO per person. The actual average cost of waste was calculated to be 0.034 M-EURO; an increase of almost 40 % over the figure of 0.025 M-EURO.

ASTRA Reactor Decommissioning: Manpower employed per year, 2000-2006

	ASTRA-DECOMMISSIONING - ANALYSIS OF MANPOWER		2000	2001	2002	2003	2004	2005	2006	2000 to 2006	
QUALIFICATION	Management, engineering, administration, documentation		1.6	1.9	2.0	2.6	2.6	2.1	2.8	**15.6**	*17.7*
	Physicists (radiation protection and reactor)		2.0	1.7	0.8	1.0	1.0	1.0	1.0	**8.5**	*9.7*
	Characterization, radiation protection, safety engineer		2.6	2.3	2.3	3.0	3.3	3.3	2.4	**19.1**	*21.7*
	Workforce on the project-Team		3.0	3.0	3.0	3.0	2.8	2.7	2.0	**19.5**	*22.3*
	Support by Hot Cell Department [1]		2.6	3.0	1.7	1.6	0.9	1.1		**10.7**	*12.2*
	Workforce leased externally [2]						2.6	3.0	3.0	**8.6**	*9.8*
	Specialists for concrete cutting [3]						3.3	2.6		**5.8**	*6.6*
TOTAL (27 persons involved)		[MAN-YEARS]	**11.8**	**11.9**	**9.8**	**11.2**	**16.4**	**15.7**	**11.1**	**87.9**	
		%	*13.4*	*13.5*	*11.1*	*12.7*	*18.8*	*17.9*	*12.6*		*100*

1) The preparation and the loading procedures of the spent fuel-elements (phase 0) and the conditioning of the highly exposed graphite and beryllium-reflector elements (phase 1 and 2) was primaly carried out in the on-site the hot-cell-facilities by the hot cell staff.

2) In order to cope with delays usually caused by administrative difficulties outside the competence of the decommissioning management e.g. unexpected waiting for licenses, it was decided to enforce the project-team by suitable co-workers leased from an outside company and to run tasks parallel where possible e.g. dismantling the biological shield and the primary water-systems in the independent underground pump-room.

3) To engage external workforce for specialised tasks e.g. the cutting of concrete was already decided during the planning for decommissioning.

ASTRA Reactor Decommissioning: Development of the project funding 2000-2006

	ASTRA-DECOMMISSIONING - BUDGET DEVELOPMENT	2000	2001	2002	2003	2004	2005	2006	Total
BUDGET	*Project budget as estimated in 1999 (not validated)*	*2 180*	*2 180*	*2 180*	*2 180*	*2 180*	*2 180*		*13 080*
	Project budget - average annual inflation-rate of 2.5% considered [1)]	2.235	2.290	2.348	2.406	2.466	2.528		**14 273**
	Costs exceeding provisions for fuel-transfer [2)]	(due to exchange rate EURO / US$ - not foreseen in 1999)							**0.207**
	Purchase of a whole-body monitor [2)]	(further use after decommissioning - not calculated in 1999)							**0.070**
	Additional funding in 2006, necessary to finish the project [3)]	**additional expenditure + 4.7 %**						0.673	**0.673**
	Actual costs of the decommissioning of the ASTRA [M-EURO]								**15 223**

1) The estimated costs of the decommissioning project were calculated based on the price-index of 1999 with a budget of M-EURO 13.080. The money was equally distributed at a rate of 2.180 M-EURO per year over the period 2000 to 2005. A compensation for the annual inflation was agreed in 1999. The average inflation rate in Austria during the years of 2000 to 2006 was 2.5% annually.

2) The costs exceeding the provisions for the fuel disposition and the purchase of a whole-body monitor were subject to special approvement by the authorities and covered out of project-funds. The money was reimbursed in 2006.

3) To compensate for the inflation rate and to cope with unexpected delays and expenditures, another 0.673 M-EURO were approved in 2006 to finish the project. The project was finally terminated 10 months later than scheduled with an overdraw of 4.7 %.

Remark: The construction of a new building for clearance measurements was not calculated in 1999. The costs for this building (M-EURO 0.164) were counterbalanced by the sale of the remaining fresh fuel-elements to a German reactor.

ASTRA Reactor Decommissioning: Summarizing the years 2000-2006

ASTRA-DECOMMISSIONING - ANALYSIS OF COSTS IN 2007		2000	2001	2002	2003	2004	2005	2006	00 to 06
Manpower	[MAN-YEARS]	11.8	11.9	9.8	11.2	16.4	15.7	11.1	**87.9**
Costs	[M-EURO]	2.066	2.374	1.622	2.383	2.424	2.027	2.327	**15.223**
Materials	[METRIC TONS]		22	21	46	566	974	545	**2174**

a) With reference to manpower

Except the years 2004 and 2005 where the main tasks of dismantling the bio shield and dismantling the primary water systems were running in parallel, an average of approximately 11 staff members was sufficient to carry out the decommissioning work.

b) With reference to the costs

Since the funds were distributed in equal parts over the projects life time, it was essential to plan the tasks on a steady scale. The low figure in 2002 can be related to the accumulated delays for the fuel disposition and the EIA.

c) With reference to the materials removed

The first half of the project is characterized by dealing with remote handled materials comprising more than 99% of the total activity. The second half is characterised by dealing with contact handled materials and a significant increase in the clearance of materials and the management of cleared materials.

A more comprehensive picture can be drawn by analyzing costs, manpower and materials in relationship with staff qualification and the decommissioning phases as follows:

ASTRA Reactor Decommissioning: Analysing costs in relation to the tasks

ASTRA-DECOMMISSIONING TASKS and COSTS		Operating License			Decommissioning License				2000 to 2006	
		2000	2001	2002	2003	2004	2005	2006		
		Phase 0	Phase 1		Phase 2			Phase 3	[M-EURO]	%
CATEGORY	Management, engineering, administration, documentation	0.317	0.528		0.883			0.330	**2.058**	*13.5*
	Characterisation, radiation protection, safety engineer	0.747	0.820		1.446			0.381	**3.394**	*22.3*
	Personnel (project staff and contractors)	1.078	1.287		2.611			0.512	**5.488**	*36.0*
	Equipment and materials procured	0.194	0.489		0.407			0.195	**1.285**	*8.5*
	Conditioning and intermediate storage of radioactive waste	0.568	0.518		1.011			0.694	**2.791**	*18.3*
	Additional funds required for fuel disposition	0.207							**0.207**	*1.4*
TOTAL	[M-EURO]	**3.111**	**3.642**		**6.358**			**2.112**	**15.223**	
	%	*20.4*	*23.9*		*41.8*			*13.9*		*100*

Key factors with reference to the costs:

- **The employment of qualified dismantling staff amounts to approx. 70% of the total cost and is by far the dominant cost factor**
- **The cost for conditioning and storage of radioactive waste with approx. 20% of the total is the second key cost factor**
- **Equipment, materials procured and expenditures for the disposition of inactive waste amount to less than 10% of the total costs**
- **The combined costs for management and radiation protection are in the same order as the costs for the dismantling staff**

The following conclusions can be drawn:

ASTRA Reactor Decommissioning: Conclusions with reference to budgeting

After the decision to dismantle the reactor immediately after the final shut down, using the expertise of the reactor staff, a swift continuation of the work was essential (time is money!).

Due to retirements only two out of ten members of the original staff remained until the end of the project. Replacements had to be contracted.

The costs of manpower (project staff, personnel leased and specialists employed) is dominating the budget with 72% of the total costs.

Realistic early planning, preventing delays and flexibility in the implementation of a project is crucial.

The costs for conditioning and storage of radioactive waste amount to 0.034 M-EURO per metric ton, i.e. 18 % of the total costs. In addition, liable funding for radioactive waste disposal (not included in the project budget) of 0.030 M-EURO per metric ton (i.e. 10 000 EURO per drum and approximately 3 drums per ton) require strict waste management and waste minimisation.

In order to keep the project within the financial limits it is necessary to apply a continuous trade off between decontamination efforts (expenditures in terms of man-hours) versus minimisation of radioactive waste (savings in storage and disposal costs and funding provisions).

ASTRA Reactor Decommissioning: Analysing manpower in relationship to the tasks

ASTRA-DECOMMISSIONING TASKS and MANPOWER		Operating License			Decommissioning License				2000 to 2006	
		2000	2001	2002	2003	2004	2005	2006		
		Phase 0	Phase 1		Phase 2			Phase 3	[MAN-YEARS]	%
PROJECT STAFF	Management, engineering, administration, documentation	2.4	4.0		6.7			2.5	15.6	*17.8*
	Characterization, radiation protection, safety engineer	3.6	4.6		8.8			2.2	19.1	*21.7*
	Decommissioning tasks and waste treatment by project staff	4.3	5.8		7.7			1.8	19.5	*22.2*
	Support by Hot Cell Department [1)]	3.8	3.9		3.0				10.7	*12.2*
CONTRACT	Physicists (radiation protection and reactor)	2.7	2.1		2.8			0.9	8.5	*9.7*
	Personnel replacing retirees [2)]				5.8			2.8	8.6	*9.8*
	Specialists for concrete cutting [3)]				5.8				5.8	*6.6*
TOTAL (27 individual persons involved)	[MAN-YEARS]	**16.7**	**20.5**		**40.5**			**10.2**	**87.9**	
	%	*20.0*	*23.3*		*46.1*			*11.5*		*100*

1) The preparation and the loading procedures of the spent fuel-elements (phase 0) and the conditioning of the highly exposed graphite and beryllium-reflector elements (phase 1 and 2) was primaly carried out in the on-site hot cell facilities by the hot cell staff.

2) In order to cope with delays caused by difficulties lieing beyond the powers of the decommissioning management, e.g. unexpected waiting for licenses, it was decided to strengthen the project-team by qualified staff leased from another company and to carry out tasks parallel whenever possible, e.g. dismantling the biological shield and the primary water-systems in the independent underground pump-room.

3) To engage external workforce for specialised tasks e.g. the cutting of concrete was already decided during the planning for decommissioning.

ASTRA Reactor Decommissioning: Conclusions with reference to manpower

It is the function of the project management to plan and prepare the decommissioning tasks on the technical, administrative and legal levels properly and well in advance.
Flexibility in coping with unforeseen difficulties or delays is another important obligation.

Therefore all the technical and administrative skills necessary to plan and execute the tasks must be represented within the project to react and cope immediately with unexpected occurrences. Regular contacts and open cooperation with authorities is essential.

It is of utmost importance to carry out a proper radiological survey before and during the work to ensure a smooth execution.
Good quality of the established data is essential for quick and reliable clearance procedures, the reduction of hazards and the minimisation of waste.

This important aspect in decommissioning was neglected in the 1999 project calculation.
The increase from 63 man-years (1999, slide 13) to approximately 88 man-years (end of project, slide 28) can be related to that fact.

Technical education and familiarity with safety procedures is vital.

The intimate knowledge of the operational staff of the technical features and the peculiarities of the reactor and the working conditions to be encountered during decommissioning is an asset.

ASTRA Reactor Decommissioning: Analysing materials in relationship to the tasks

ASTRA-DECOMMISSIONING - TASKS and MATERIALS		Operating License			Decommissioning License				2000 to 2006	
		2000	2001	2002	2003	2004	2005	2006		
		Phase 0	Phase 1		Phase 2			Phase 3	[metr.TONS]	%
RADIOACTIVE WASTE	High. Level Waste - spent fuel (special treatment required)	1)							*)	
	Intermed. Level Waste - metals (shielding required, 5 Mosaik container)		3						3	*0.1*
	Low Level Waste - metals (no shielding required, 1 Konrad type 2 cont.) 2)		9						9	*0.4*
	Low Level Waste - graphite (no shielding required, 1 Konrad type 2)		7						7	*0.3*
	Low Level Waste - concrete (no shielding required, 3 Konrad type 2)				25				25	*1.2*
	Low Level Waste - solid unburnable (no shielding required, 200-L-drums)		34						34	*1.6*
	Low Level Waste - solid burnable (no shielding required, to incinerator)		5						5	*0.2*
	Total radioactive waste								**83**	***3.8***
INACTIVE WASTE	Waste (cleared for conventional disposal)		7		137				144	*6.6*
	Metals (cleared for re-use through melting process)		42						42	*1.9*
	Materials (cleared for unrestricted re-use)		91		1430				1521	*70.1*
	Materials (removed from building after clearance for re-use on site)							384	384	*17.6*
	Total inactive waste								**2091**	***96.2***
TOTAL AMOUNT OF WASTE	[metr. TONS]	**0**	**198**		**1592**			**384**	**2174**	
	%	*0*	*9.1*		*73.3*			*17.6*		*100*

1) The preparation of the fuel transfer and the loading of the transport containers with the 54 spent fuel elements were within the projects costs (phase 0). The costs of the transfer and disposition of the spent fuel were covered by funds collected on a continuous rate during reactor operation.

2) Konrad-Container, steel box with sealed lid developed for the German Konrad repository. Type 2 refers to an almost cubical container with a capacity of about 4 m^3

ASTRA Reactor Decommissioning: Conclusions with reference to materials

3	metric tons	waste, radioactive, requiring additional shielding for handling and storage	0.1 %
80	metric tons	waste, radioactive, to be conditioned into Konrad-containers and 200 l drums	3.7%
42	metric tons	low level contaminated metals, cleared for re-use through melting process	2.0 %
144	metric tons	waste, inactive, cleared for conventional disposal	6.6 %
1905	metric tons	inactive, cleared for unrestricted re-use	87.6 %
2174	**metric tons**	**TOTAL**	**100 %**

- **The obligation to reduce radioactive waste has been followed ambitiously**
- **The conditioning of contact handled materials and special materials, i.e. graphite and beryllium, had to be carried out by the project staff in order to fulfil the acceptance criteria at the storage facility**
- **Due to extensive characterization efforts rather large amounts of material could finally be cleared for unrestricted re-use**
- **Immediate dismantling with traces of e.g. Co-60 still present in low level activated or contaminated areas simplifies detection and clearance and assist in defining reliable radionuclide relationships**
- **In applying the melting process, rather large amounts of metals could be re-introduced into the market**

ASTRA Reactor Decommissioning waste reduction: Example with reference to metals

Under Austrian conditions there are no established routes to introduce metals into the market, even though the radionuclide content is well below the established clearance levels for unrestricted re-use. Such metals would have had to be considered “radioactive” waste. The following costs including disposal funds would have to be expected for such metallic waste:

Conditioning of 42 metric tons (mainly Alumina) into 200-litre-drums:
42 t x 0.034 M-EURO / ton = 1.428 M-EURO for conditioning and storage
42 t x 0.030 M-EURO / ton = 1.260 M-EURO funds for disposal
TOTAL 2.688 M-EURO

Germany has established routes for the recycling of cleared metals. In cooperation with a German company licensed for the melting of those metals, the 42 metric tons of cleared ASTRA metal were recycled for re-use at the following costs:

Recycling of 42 metric tons (mainly Alumina) via melting process:
42 t x 0.004 M-EURO / ton = 0.168 M-EURO

This is a major difference in costs without compromising safety.

Finally it can be concluded, that the dismantling of ASTRA in the 50th year after the founding of the Austrian Research Center Seibersdorf within the given limits of time and financial resources and under strict observation of the legal and radiological requirements was performed without any incidents, neither in terms of personal safety nor of radiological hazards to the environment.

The decommissioning team in December 2005

Thank you for your attention!