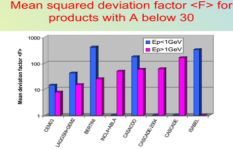
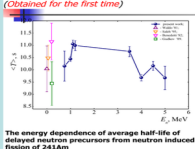
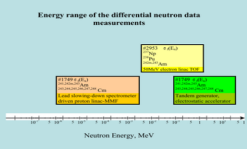
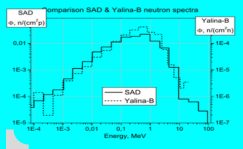
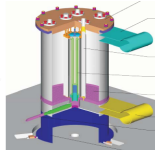
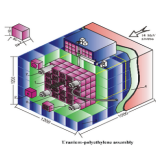
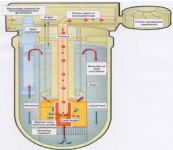


# Early ISTC Activities related to the Backend of the Fuel Cycle of Nuclear Fission Reactors

Summary of results of ISTC project investigations in the period 1995-2010  
C.H.M. Broeders W. Gudowski M. Hugon A. Stanculescu L. Tocheny

## LEGACY INTERNATIONAL SCIENCE AND TECHNOLOGY CENTER



# Outline I

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# Outline II

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# Preface

The objective of this compilation is to preserve the most relevant information on digital resources (computer and storage media like CD, disks, sticks,..) accumulated in the responsibility of the first author C.H.M. Broeders in the framework of his participation to ISTC related activities. This compilation started in the beginning of 2019. The discussions with key-persons resulted in an extended list of authors, W. Gudowski the driving force of these activities and the key representants M. Hugon of EC, A. Stanculescu of IAEA and L. Tocheny of ISTC in this period.

The intention is to create a documentation as a beamer presentation with internal links to all applied references.

The documentation is realized for modern LINUX computer, utilizing the Opensource typesetting system LaTeX. Depending on 1 definition line in the source code (ipadr.tex), the resulting pdf-file may be only full functional on the local computer with failing links in internet application. For the management of the document contents the Opensource data management code subversion (svn) is applied.

# Introduction I

- After the reforms in USSR around 1990 the cooperations between scientific groups in USSR with western partner could be extended significantly. In most cases these groups consisted of experienced experts and young scientists on both sides.
- In order to handle these increasing contacts, the International Science and Technology Center (ISTC) was established in 1992.
- New contacts were started particularly in the area particle physics focussed on applications for nuclear energy production.

Main reasons were

- a) Excellent resources for these problems of the eastern partner
- b) Broad international interest for the proposal by Nobel Prize winner Carlo Rubbia for a safe fission reactor system, driven by an external neutron source (so-called Energy-Amplifier).
- c) International interest for the application of "Energy Amplifier" technology for inceneration of nuclear wastes as long-lived fission products and minor actinides.



# Introduction III

The ISTC projects related to nuclear waste incineration may be assigned to the following scientific areas:

- Research for the new innovative heavy metal cooling with lead / bismuth eutectics.
- Research related to the impact of external neutron sources in subcritical multiplying material zones.
- Enhancement of the experimental database for minor actinides.
- Enhancement of the experimental database for high energetic proton and neutron irradiation of lead / bismuth isotopes and structural materials.
- Creation of evaluated nuclear data libraries for neutrons and protons in extended application areas

# Introduction IV

## Resources for this review.

This review aims to preserve information related to the activities to establish cooperations between scientific groups in the involved countries after the political movements in Russia around 1990. The main primary resources are documents from dedicated meetings, especially from the contributions collected in the framework of the contract ISTC TME-019-01 on a password protected area of the private server *chmbllh.eu*.

During preparation of this presentation additional documents were provided by the co-authors or could be extracted from E-Mail archives.



# Heavy Metal Coolant Technology

Heavy metal coolant technology (HMCT) was a key issue in one of the first ISTC projects. The outcome was the basis for further projects.

The ISTC project #0017 (1993-1997), "Feasibility study of technologies for accelerator based conversion of military plutonium and long-lived radioactive waste" and the direct successor

ISTC project #0559 (1996-2002), "Pilot Flow Lead-bismuth Target of MW power for Accelerator-Driven Systems"

are presented in a video-presentation by W. Gudowski, click [here](#) to play the video.

# Lead Isotope Separation I

A very interesting neutron physics based aspect was proposed in ISTC project #2573 (2002-2005), "Laser Separation of Lead Isotopes". The next slides give information for this project.

# Lead Isotope Separation II

## ISTC project #2573 (2002-2005), "Laser Separation of Lead Isotopes".

In the project #2573 the idea to utilize lead isotope separation techniques to improve neutronics performance in reactor systems with main lead components was promoted strongly by G. Khorasanov, INPE Obninsk ([Photo](#)).

Nuclear data aspects were contributed by A. Blokhin, IPPE Obninsk. Experimental support was provided by a team from FSUE "D.V. Efremov Scientific Research Institute of Electrophysical Aparatus", St. Petersburg, represented by A.M. Yudin (see [Photo](#) with 3 key persons).

The ISTC project #2573 had a successful start with a very interesting collaborator meeting in St. Petersburg, June 29-30, 2005 (impressions of this meeting, click [here](#) to view).

# Formal ISTC #2573 Project Problems

Unfortunately ISTC support was not approved for continuation of the first phase of project #2573. The following Appendix from the minutes of a meeting in Brussels 2007 [view](#) gives a summary of ISTC #2573 related issues.

Here it should be noted that subsequent information exchange of the collaborator with representatives of EC, ISTC and FSUE indicated that the main problem could have been caused by activities of the participants in St.Petersburg to utilize the experimental setups used for ISTC #2573 for cooperation with non ISTC partner.

# Theoretical Studies Impact of Lead Isotope Separation

After the closure of project ISTC#2573 the participants from Obninsk continued their interesting theoretical studies with several contributions to international journals.

An open source article has been published, click [here](#) to view.

# Integral Neutron Source Experiments.

A main innovative aspect of the proposal for a source driven sub-critical nuclear reactor system is the characterization of the external neutron source. In the first proposal by Rubbia for the Energy Amplifier Concept, the external neutron source was based on the application of proton irradiation on dedicated targets as lead and lead-bismuth eutectic. Two alternative approaches for source experiments were proposed in the framework of ISTC support:

- High power neutron generator JIPNR Minsk
- Phasotron proton beam JINR Dubna

For the coordination of these ISTC projects a dedicated ISTC Contact Export Group (CEG) was created.

# High power neutron generator JIPNR Minsk

At the International Workshop Advanced Nuclear Systems Consuming Excess Plutonium, 1996 in Moscow, S. Chigrinov from JIPNR Sosny Minsk, ([Photo](#)) promoted to utilize the capabilities of the powerful 14 MeV neutron generator in his Institute to perform fundamental investigations on target physics for the new neutron source driven reactor concepts. The resulting YALINA project was mainly managed and represented at meetings by H. Kiavitskaya, JIPNR Minsk, ([Photo](#))

Links to publications

# Phasotron proton beam JINR Dubna

V.S. Barashenkov Dubna ([Photo](#)) proposed in 1996 at the International Workshop Nuclear Methods for Transmutation of Nuclear Waste in Dubna to utilize the 600 MeV proton beam of the Phasotron proton generator at JINR Dubna for prototype ADS target investigations. The resulting SAD project was mainly managed and represented at meetings by V. Shvetsov, JINR Dubna, ([Photo](#))

Links to publications



# SAD YALINA Steering Committee I.

## Motivation.

Around 2000 the incineration of dangerous isotopes from nuclear fission reactor utilization with the help of dedicated source driven installations (ADS) was an important option. Recognizing the, at that time, available unique experimental ISTC resources for basic research in the area of external neutron sources, at the CEG meeting in Brussels Feb 16-17-2004, click [here](#) for the minutes, a steering committee was proposed to coordinate support of the projects SAD and YALINA (SYSC).

# SAD YALINA Steering Committee II.

## Realisation.

The objectives of the SYSC were formulated in a charter document, click [here](#) to view. After its establishment in 2004, the SYSC had a fast sequence of working meetings in the involved institutes JINR Dubna and JPINR Minsk.

The presentation of W.Gudowski at the CEG meeting in Brussels 31.1.2006 gives details about the SYSC activities, click [here](#) to view.

A summary of the SYSC activities was presented by the chairman C.Broeders at the CEG P&T meeting in Brussel Jan 22-23 2007. See Appendix 2 from the minutes of that meeting, click here [here](#) to view.

One of the last SYSC activities of the chairman was a presentation at the CEG P&T meeting in Brussel Feb 29 2008. See Appendix 12 from the minutes of that meeting, click [here](#) to view. The personnel comments in this reference indicate that the obtained results were somewhat disappointing with respect to the objective "ADS source" research.

# SAD YALINA Steering Committee III.

## SAD related information I.

The initial idea of V.S. Barashenkov to utilize the PHASOTRON 600MeV proton generator at JINR Dubna for basic research related to incineration of artificial isotopes from nuclear fission reactors was proposed at a time where serious efforts were ongoing to come to collaborative work by partner from the former cold war opponents.

After discussions at JINR Dubna, the proposal for the ADS source experiment with the PHASOTRON, the ISTC Project #2267 SAD was established with project manager V. Shvetsov.

The project SAD had a very good start with several detailed internal (SYSC) and external presentations, e.g. the presentation of V. Shvetsov at the meeting on "Application Libraries for ADS and Transmutation", 15-17 Dec. 2004, Vienna, click [here](#) to view.

Also a short leaflet document was created for the SAD project, click [here](#) to view.

# SAD YALINA Steering Committee IV.

## SAD related information II.

Unfortunately, the very valuable contributions from many involved persons could not prevent the final decision not to realize this project; at this point the estimated costs became too high (increase from  $\approx 6$  to  $\approx 15$  M€).

A very unfavourable event certainly was the serious fire in the key experimental device PHASOTRON at JINR Dubna in April 2005.

More information about the impact of this fire for JINR projects may be found in a JINPR presentation, click [here](#) to view.

Two journal contributions related to the SAD project were published: click [here](#) for document 1 and [here](#) for document 2.

# SAD YALINA Steering Committee IV.

## YALINA related information I.

The initiative of S. Chigrinov from JIPNR Sosny Minsk, 1996 in Moscow, to utilize the capabilities of the powerful 14 MeV neutron generator in his Institute to perform fundamental investigations on target physics for neutron source driven reactor concepts for nuclear spent fuel incineration was very successful and resulted in various interesting activities.

- The ISTC project #B70 focussing on ADS source research. The progress of this project was reported on all SYSC meetings. A comprehensive overview of the YALINA program was presented at the CEG P&T meeting in Brussel Jan 22-23 2007, click [here](#) to view.
- The follow-up ISTC project #B1341 was strongly influenced by the ISTC-USA partner with the objective to study aspects of experiment conversion from high enriched uranium (HEU) to low enriched (LEU). The document ANL-10/05, click [here](#) to view, gives information on this issue, including a summary of YALINA experimental efforts.
- Successful educational exchange with ISTC project partner.

# SAD YALINA Steering Committee V.

## YALINA related information II.

### Educational activities I.

The operational experimental facilities for ADS target research at JIPNR Sosny Minsk proved to be a very good environment for educational activities. Strongly promoted by Swedish partner, click [here](#) to view a SKB document, several doctoral thesis were completed in ISTC partner countries:

Sweden click [here](#) for thesis Persson, [here](#) for thesis Bergloeft, Germany click [here](#) for thesis Becker, Spain click [here](#) for thesis Palacios.

Moreover, participation of Belarussian young scientists to scientific activities in the western ISTC partner countries was supported on several levels, e.g. visiting FREDERIC JOLIOT / OTTO HAHN Summer School on nuclear reactors, click [here](#) for link to website, being a very good international platform for contacts between young people interested in nuclear reactor engineering.

# SAD YALINA Steering Committee VI.

## YALINA related information III.

### Educational activities II.

The successful integration of students work by ISTC partner in the YALINA project initiated serious efforts to establish an International Centre of Excellence for Transmutation Research (ICE-TR) at JIPNR Sosny, Minsk. The proposal was inspired by a comparable cooperation between Belarussian and West-European partner for Laboratory For Optical Diagnostics (LOD), click [here](#) for LOD document. Some details of the ICE-TR proposal were presented by H. Kiyavitskaya at the CEG P&T meeting in Brussel Jan 22-23 2007, click [here](#) to view. At this meeting also detailed documents for future cooperation were discussed: click [here](#) for MoU and [here](#) for Agreement. It is really pity that this ICE-TR effort coincided with the changing ISTC mode of operation as discussed e.g. in the presentation of W. Gudowski and L.V. Tocheny at the CEG P&T meeting in Brussel Jan 29 2008, click [here](#) to view. ICE-TR was not established in the proposed framework.

## Minor Actinide Delayed Neutron Data Experiments.

It is well-known that delayed fractions of neutron fission play a decisive role for the dynamic behaviour of multiplying nuclear reactor systems. In view of the proposed incineration of spent fuel from nuclear reactors with dedicated new systems, the characteristics of the man-made heavy fissionable isotopes from nuclear fission reactors is an important issue. In the framework of ISTC very valuable research related to this topic was represented by W. Furman ([Photo](#)) at several meetings.

A comprehensive overview of activities in the key ISTC#2253 project was presented by W. Furman at the CEG P&T meeting in Brussel Jan 22-23 2007, click [here](#) to view the presentation entitled

**”Project 2253 : Investigation of the delayed neutron characteristics from the fission of compound nuclei  $^{233}\text{Th}$ ,  $^{234}\text{U}$ ,  $^{235}\text{U}$ ,  $^{244}\text{Am}$ ,  $^{238}\text{Np}$ ,  $^{246}\text{Cm}$ ,  $^{233}\text{Pa}$ ,  $^{234}\text{Pa}$ ,  $^{239}\text{Np}$ ,  $^{240}\text{Np}$  at the excitation energies from 5 to 20 MeV”**

It was highlighted that some of the experimental results were ”Obtained for the first time”.



# Minor Actinide Cross Section Data Experiments.

For the enhancement of the knowledge for minor actinide cross section data several ISTC related activities were organized. An important partner in this work was L. Ponomarev ([Photo](#)). He gave a detailed presentation of these activities at the CEG P&T meeting in Brussel Feb 29 2008, click [here](#) to view.

# Experiments for Enhancement of High Energy Proton and Neutron Databases

In the framework of ISTC very extensive research related to this topic was represented by Y. Titarenkov ([Photo](#)) and V. Batyaev ([Photo](#)) from the Institute for Theoretical and Experimental Physics (ITEP) Moscow. ITEP contributed significantly both to the experimental and to the international cooperations efforts to improve the High Energy Proton and Neutron Database in view of ADS application.

- ISTC#2002. The project ISTC#2002 was reviewed at the CEG meeting in Brussels 31.1.2006, click [here](#) to view.
- Follow-up ISTC#2405 and ISTC#3266. A detailed presentation on status and perspectives of these projects was presented at the CEG P&T meeting in Brussels Jan 22-23 2007, click [here](#) to view.

These investigations resulted in several publications, e.g. final ISTC#2002 report, click [here](#) to view and conference presentation, click [here](#) to view.

# Creation of High Energy Proton and Neutron Evaluated Data Libraries

After the reforms in USSR, very early cooperations of USSR scientists with western partner, e.g. FZK Karlsruhe, were established for the creation of specific evaluated nuclear data bases by Y. Korovin ([Photo](#)) from the Institute of Nuclear Power Engineering (INPE) in Obninsk. In the framework of ISTC, Y. Korovin was a key person in related projects. He participated to many of our meetings. In his presentation of project ISTC#2578 at the CEG meeting in Brussels 31.1.2006, click [here](#) to view, an exhaustive summary of related ISTC project work is given. More details were presented at the CEG P&T meeting in Brussel Jan 22-23 2007, click [here](#) to view.

# Systematic development of nuclear library data for nucleon-induced reactions on heavy nuclei in wide energy region.

V. Eismont of the Khlopin Radium Institute St. Petersburg proposed to contribute with systematic development of nuclear library data for nucleon-induced reactions on heavy nuclei in wide energy region. S. Yavshits ([Photo](#)) presented these activities at several CEG meetings:

- CEG P&T meeting in Brussel Jan 22-23 2007, click [here](#) to view and
- CEG P&T meeting in Brussel Feb 29 2008, click [here](#) to view.

## Related other projects.

In this review many available relevant minutes of meetings with a large number of references are collected. Most of these meetings were not restricted to the objectives of this compilation:

*“Activities related to the Backend of the Fuel Cycle of Nuclear Fission Reactors”.*

The presentation of W.Gudowski at the CEG meeting in Brussels 31.1.2006 gives a comprehensive overview of CEG activities, including lists of ISTC projects evaluated at the CEG-P&T meetings, click [here](#) to view.

Among these other issues the topic “Application of Molten Salt fluids in advanced nuclear reactor systems” was included several times. On the next slide some more information related to the project ISTC #1606 is presented.

# ISTC #1606: Molten Salt Reactor Technology.

In the workplan for the project, click [here](#) to view, the following objective is formulated: *The mission of the Project # 1606 is to perform an integral re-evaluation of the Molten salt (MS) Technology potential as applied to safe, low-waste and proliferation resistant treatment of RadWaste and Pu management as well as to develop some suggestions on program plan for the Technology commercialization.*

Interesting documents are a draft of the final report, click [here](#) to view, and a EC mission report by M. Hugon, click [here](#) to view.

The presentation by V. Ignatiev of the project ISTC #1606 at the CEG Meeting Brussels 31.1.2006 gives a detailed overview of the prolonged project, click [here](#) to view.

Click [here](#) to view pictures from the Ural meeting from several resources.

# Information from important project meetings

In the following information from reporting from important related meetings is collected. Completeness is certainly not yet achieved...

# Contact Expert Group (CEG) on ISTC ADS projects I

Summary Records of the Fourth (or First EU CEG) Meeting  
KTH, Stockholm January 2001

Link to the minutes of this meeting: click [here](#) to view.

Link to other information from this meeting: Currently no data



# Contact Expert Group (CEG) on ISTC ADS projects II

Summary Records of the Fifth (or Second EU CEG) Meeting  
Forschungszentrum Karlsruhe February 1 2002

Link to the minutes of this meeting: click [here](#) to view.

Link to other information from this meeting: Currently no data

# Contact Expert Group (CEG) on ISTC ADS projects III

Summary Records of the Sixth (or Third EU CEG) Meeting  
European Commission Brussels January 31 2003

Link to the minutes of this meeting: click [here](#) to view.

Link to other information from this meeting: Currently no data

# Contact Expert Group (CEG) on ISTC ADS projects IV

Summary Records of the Seventh (or Fourth EU CEG) Meeting  
European Commission Brussels February 16-17 2004

Link to the minutes of this meeting: click [here](#) to view.

Link to other information from this meeting: Currently no data

# ISTC-Contact Expert Group on Nuclear Transmutation related Projects I

Annual meeting - 2006, Brussels January 30-31 2006

Link to the minutes of this meeting: click [here](#) to view.

Link to other information from this meeting: Currently no data

# ISTC-Contact Expert Group on Nuclear Transmutation related Projects II

Annual meeting - 2007, Brussels January 22-23 2007

Link to the minutes of this meeting: click [here](#) to view.

Link to other information from this meeting: Currently no data

# ISTC-Contact Expert Group on Nuclear Transmutation related Projects III

Annual meeting - 2008, Brussels February 29 2008

Link to the minutes of this meeting: click [here](#) to view.

Link to the executive summary of this meeting: click [here](#) to view.

Note: links in the executive summary document to Appendices are partly broken, the minutes document could be updated in 2019.

Link to other information from this meeting: Currently no data

# Retrospective notes of C.H.M. Broeders I

My participations to the conferences ICENES 1996 in Obninsk and ADTT 1999 in Prague were the basis for a number of fruitful collaborations with senior scientist and their younger co-workers from member states of the former Sowjet Union. Some details about these contacts are included on my website presentations since many years, click [here](#) to view the last version.

In retrospect these events caused that I could participate in the last 20 years of my professional life to international activities in a very interesting slice of history around millenium change with the detente in west-east confrontations. My personnel driving force allways was to support the eastern scientists with teams to utilize their capabilities for peaceful projects of common interest.

It was somewhat disappointing to observe how mode of operation of ISTC support slowly moved to commercial cooperation with a break around 2010, leading to a reorganized ISTC with headquarter move from Moscow to Astana in 2015.

# Retrospective notes of C.H.M. Broeders II

Despite some attempts were initiated to find replacement for the chairman position of SAD-YALINA Steering Committee and Contact Expert Group P&T, these activities did silently end with the CEG meeting Feb. 2008 in Brussels, click [here](#) to view the minutes of this meeting.

The current compilation documentation on my private server is intended to be completion of my ISTC efforts.

Transferring a copy to a dedicated international web portal would be a good finish.