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Summary of the Workshop on the Unified Accelerator Library

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A workshop on the Unified Accelerator Library was held at Brookhaven on February 2-3, 1998 whose main goal was to review the present and plan the future of the UAL collaboration. The software requirements and plans for the US-LHC collaboration were also discussed as well as the most recent developments and plans of the Tech-X corporation accelerator physics software. The workshop agenda and a list of attendees is included in the Appendix of this documents.

What follows comprises a short summary of the talks presented at the workshop, but the focus of the document is on the summary of the discussion sessions where we tried to coordinate and prioritize software projects. The document is organized in sections that reflect the workshop organization:

1. UAL Status, Development and Priorities
2. The Accelerator Description Standard (ADS)
3. Online Models
4. Tech-X Software
5. LHC Software

1. UAL Status, Development and Priorities

The Unified Accelerator Library (UAL) has been released in alpha version to BNL, FNAL and CESR. It was used for analysis of helical dipoles in RHIC for the RHIC Machine Advisory Committee review in December 97 [1]. LHC studies and comparisons with MAD have been underway within the UAL/Teapot++ environment since the Fall of 97 [2].

N. Malitsky summarized the status and plans for UAL development. The application of the UAL environment for RHIC modeling and CESR modeling were described respectively by G. Trahern and T. Pelaia. A detailed and informative overview of the CERN accelerator physics software environment was given by H.Grote, which underlined the convenience of the DOOM database as a possible bridge for a software interface.

During the discussion a wish list of UAL and Standard Machine Format (SMF) enhancements were suggested and prioritized. We first list the requests for Teapot++ and then for SMF.

Teapot++ (alpha) --> version 1.0

1. Longitudinal tracking with synchrotron oscillations
2. Coupled Twiss analysis
3. Local decoupling.
4. Two family decoupling algorithm
5. Closed orbit allowing for intentionally displaced elements
6. Ramping with errors and RF

The last capability was requested and accepted, but was deferred to future work.

SMF (alpha) --> version 1.0

1. Machine file format. (See discussion in the following section)

2. Allow for unique element names (SiteWideName's in case of RHIC) at the lattice level. Provide methods to get lattice index by the unique name.
3. Develop sets/families to allow more flexibility in the definition of magnetic field (or alignment) deviations. Evolve the FieldMigrator module to become a hash instead of an ordered array, with backward compatibility to the previous structure (if possible).
4. Introduce misalignment handling.
5. Allow specification of maximum multipole order (possibly element by element).
6. Provide for description of overlapping (i.e. multi-layer and multi-knobbed) magnetic elements.

2. Accelerator Description Standard

The US-LHC and CERN --LHC collaborative efforts require close communication of machine designs. In this framework Richard Talman discussed a memo by Iselin, Keil and Talman (included in the Appendix) to appear in the Particle Accelerator Newsletter which proposes a new standard for the description of accelerators called the Accelerator Description Standard (ADS). There was an extensive discussion at the workshop about possible realizations of (and exclusions from) the ADS requirements. Some of the conclusions from that discussion are listed below. However, since the ADS discussion is highly preliminary at this time, we concluded that a more detailed document should appear subsequently that discusses requirements more concretely. In addition, we felt that a group of involved experts should convene to jump start the effort.

A full realization of the ADS should have the following capabilities.

a. The standard will use the notion of sequences (as well as nested sequences). The sequence notation is basically of the form:
<element_instance name>: <generic_element name> at=position, {...}
Generic elements are defined by name with typical MAD like attributes and values. The element instance inherits the generic element values. This is the only level of inheritance supported by the standard.
b. Drift elements are allowed
c. Deviations (from design values) in both magnetic field and alignment for all elements are supported.
d. Superimposed elements (multi-layer magnetic elements) are supported
e. Intentionally displaced elements are supported.
f. Girder (or cryostat) element correlations (along with the ability to correct the entire assembly as a whole) are supported

Not allowed in the ADS:

a. The MAD Type=xxxx characterization of elements
b. Multiple inheritance of element definitions
c. Abbreviations of element types (quad for quadrupole, etc.)

Because the process of adopting a universal ADS standard is expected to be long, while the need for exchanging lattice descriptions within the US-LHC collaboration is immediate, a tentative standard for the exchange of machine description was agreed upon at the workshop. For more discussion of the Standard eXchange Format (SXF) see Section 5.

3. Online Models

Discussions on online modeling were introduced by a talk by J.Holt who described the existing FNAL online model and its capability. That offered a benchmark and motivation for the outline of development of a RHIC Online model by T.Satogata.

Preliminary requirements for the online machine model of RHIC were outlined and discussion started about the suitability of UAL as an environment for the RHIC online model.

Some of the requirements for the RHIC online model are:

a. "machine" file for input/output of model which is also a fully instantiated machine with field and alignment deviations incorporated
b. Shared memory residency
c. Interface to operational magnet settings for ramping and stepping stones
d. Minimal parsing requirements for analysis
e. Accessibility to many modeling engines such as Teapot++ or bl (an interactive code used at RHIC).

Given that a machine file standard (SXF) was created during the workshop that we expect will be functional within the UAL environment shortly, item (a) is expected to be satisfied. The ability to select a family of magnets to change their operational settings is already a feature of the UAL shell interface. However, some development may be needed to provide for the overlapping bus structure of the RHIC interaction region quadrupoles. The other items in the above list are contingent on (e) bl's ability to read the machine exchange format since Teapot++ will be able to read it, (d) as a flat instantiated description, every element is named uniquely so one must direct actions to named lists of elements. No parsing should be necessary. Finally, whether the SMF model can be made memory resident is an open question.

4. Tech-X Software

Tech-X Corporation is developing accelerator physics software relevant to the design and analysis of high-energy rings such as RHIC and the LHC. David Bruhwiler presented the status of MAPA (Modular Accelerator Physics Analysis), which includes a C++ accelerator physics modeling library and an interactive GUI. John Cary discussed future plans for MAPA, which include the possibility of linking the GUI with other C++ accelerator libraries. Sveta Shasharina presented preliminary results on txdalib, an optimized C++ DA library still under development, which promises to run an order of magnitude or so faster than existing DA libraries. Workshop discussions of Tech-X software focussed primarily on the desired features which should be implemented in the MAPA code.

MAPA includes a parser for SIF / MAD-8 input files and an intuitive GUI that allows one to interactively modify an accelerator design and see the effect of this modification on the beam dynamics. MAPA includes an accelerator class library with relatively complete physics that is appropriate for both large and small machines, and the GUI runs on most UNIX platforms, including Linux. The initial beta release of MAPA is scheduled for April 1, 1998. The accelerator library and other Tech-X class libraries required for non interactive use will be provided free to the entire community via the Tech-X web site at http://www.txcorp.com. The full GUI application with source code will be provided to three beta testers: BNL, FNAL and SLAC.

The MAPA parser will be upgraded over time to follow the ADS (accelerator description standard) guidelines as they become available. Near term plans include adding the following capabilities to the code: parse sequences, beam parameters and initial conditions from MAD-8 input files;

misalign elements; edit formulas within the GUI; plot Twiss parameters, tune footprints, etc. from within the GUI. MAPA development is funded by a Phase II SBIR (small business innovation research) grant through June, 1999.

Tech-X will seek additional SBIR funds for further development of MAPA. The proposed work will include porting to a new GUI capable of threaded calculations that will run on Windows 95 and NT as well as Unix, a fundamental generalization of the interface to the accelerator class library allowing for linking of other C++ accelerator libraries to the GUI, and a general interface within the GUI for arbitrary user-defined simulations. If successful, this work would be funded by a Phase II SBIR grant beginning July of 1999.

Tech-X is also developing txdalib, an optimized C++ DA (differential algebra) library with SBIR funding. Proof-of-principle work completed during Phase I indicates this library will be faster than existing Fortran and C++ libraries by an order of magnitude or so, depending on the computer platform, as well as the truncation order and number of DA variables. For example, use of the expression template technique speeds up addition and subtraction by an order of magnitude, and use of reference counting reduces the cost of assignment and copy constructor invocation to a negligible level.

The computational effort of computing with DA vectors is dominated by multiplication, and multiplication in txdalib is optimized in two ways. First, the many nested loops that commonly occur in DA libraries have been carefully unrolled, and the use of "*if*" statements has been eliminated, resulting in nearly an order of magnitude speed increase. Second, blocking techniques to optimize the use of cache promise a further increase in speed by a factor of 2-3, depending on the computer architecture and the truncation order. The larger the DA vector (i.e. higher truncation order and/or more variables), the greater the relative increase in speed with respect to existing libraries.

Tech-X will soon apply for Phase II SBIR funding to continue work on txdalib. The proposed work will include development of a complete arithmetic and function library, use of complex Taylor coefficients, calculation of normal forms, perturbative calculations of nonlinear tune shift with amplitude, etc. Because implementation of the blocking technique depends on the architecture of the computer hardware, it will also be necessary to optimize the library for a variety of computer platforms.

Workshop participants suggested that the following capabilities be implemented in MAPA: read initial conditions from a file, plot tune footprints and tune vs. amplitude, plot Twiss functions and coupling functions, and dump data to a file. Also, the desire was expressed to use MAPA as a post-processor for tracking data generated by other codes, such as TEAPOT++.

5. LHC Software

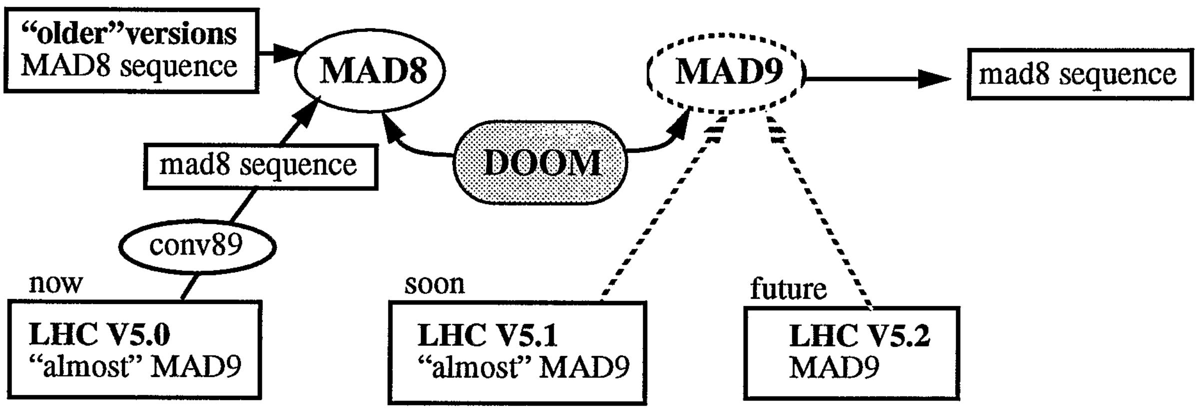
The session on LHC software started with the description of software plans and needs for the US-LHC accelerator physics activities at FNAL and BNL, by Jim Holt and Jie Wei respectively. What clearly emerged from both presentations was the need of a communication tool among CERN and the US laboratories. A machine representation which is external, exchangeable, code and language context free and extendable will foster collaboration by easy comparison of results and avoid duplication of efforts. All this reinforced very naturally the previous workshop discussions about the ADS. A possible format (SXF) was agreed upon and will be described in the following.

R. Talman discussed an example of application of the UAL software to the study of the LHC dynamic aperture, more specifically the dependence of LHC aperture on integer tune separation. An integral part of the study was the discussion of the quality of the LHC thin lens models as a function of the number of splits in the magnets.

F. Pilat talked about the status of the LHC SMF model. An SMF model of the ideal LHC (machine without errors) is already in place, as discussed in the previous talk. By using the RHIC Shell, deviations derived from the FNAL HGQ harmonics tables have been added to the triplet quadrupoles. This model has been compared with an equivalent Fortran Teapot model and found in agreement. The focus is now on a the development of an LHC SMF with all errors and imperfections to be compared to the CERN MAD model.

The ensuing discussion time clarified what software is available for LHC accelerator physics studies and what we agreed to develop.

On the CERN side, as presented by H.Grote, the software organization can be summarized by the following diagram:



DOOM among its other services provides a bridge between MAD8 and MAD9. It is important to notice that MAD9 will support a way to generate MAD8 sequences, if desired, so that the conversion program conv89 can be phased out when MAD9 will be fully developed and operational.

Existing LHC related software in the US comprises:

The FTPOT model

LHC lattice descriptions for study by FTPOT have been obtained in three different ways, with the third being recommended for the future if complicated field errors are to be reliably included from other sources:

(i) The MAD "twiss" output file is parsed to generate a Fortran Teapot. The model has been used to study the dynamic aperture at collision after triplet errors from FNAL HGQ tables were added to the triplet quadrupoles in the low beta regions.

(ii) With minor editing the output of conv89 can be converted to a Teapot input file.

(iii)Via SMF (see below) and UAL. Within UAL the MAD to SMF parser includes an option for generating a Fortran Teapot input file.

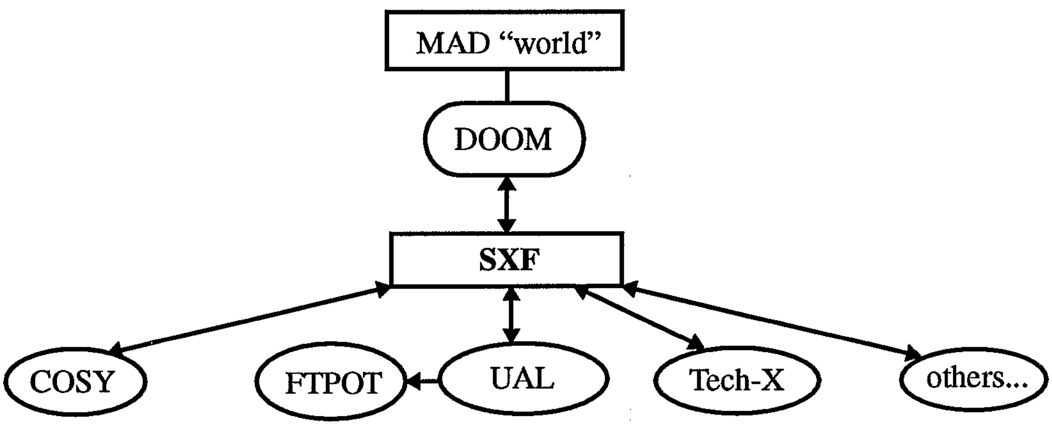
The COSY model

A parser for Standard Input Format/MAD8 exists and the COSY program is used for analysis. It provides a detailed modeling of fringe fields beyond the traditional delta function approach to describe magnet ends

LHC SMF

A description of LHC lattice for the ideal lattice exists by means of a parser that reads the LHC MAD8 sequence and loads the SMF structures. Recently, deviations have been added to the triplet quadrupoles with errors derived from the FNAL HGQ harmonics tables. Development of a LHC SMF representation with all deviations and errors has started.

A very fruitful discussion about the **Standard eXchange Format (SXF)** followed which allowed us to reach an agreement about its main characteristics and format. Although it was agreed that the SXF should evolve towards the specifications of ADS, we took the decision to keep it simple at the moment with the goal to have it implemented on a short time scale, given the pressing needs of the US LHC collaboration, but with enough flexibility to allow for further improvements.
The SXF will be the bridge between LHC codes and projects in the following way:



H. Grote agreed to write an external representation of DOOM in the SXF format and code developers agreed to provide parsers for SXF files. The format resembles a flat mad8 sequence but a syntax is implemented which allows for deviations (such as magnetic and alignment errors) to be added to elements. Following the workshop a subset of participants met to make a first draft at the definition of the format and to discuss its application as an exchange tool. The SXF file will be used also as a base for filter software, much in the way the fortran teapot machine file was used. An example of element definition and syntax rules will be distributed soon for comments, review and implementation.

References

[1] RHIC AP Note 146

[2] N.Malitsy, R.Talman, "Study of thin lens representations of LHC using Unified Accelerator Libraries", LHC Project Note

List of participants

Assadi Saeed	FNAL
Bruhwiler David	Tech-X
Cary John	Tech-X
Grote Hans	CERN
Holt James	FNAL
Kewisch Jorg	BNL
MacKay Waldo	BNL
Malitsky Nikolay	Cornell
Mishra Shekhar	FNAL
Peggs Stephen	BNL
Pelaia Thomas	Cornell
Pilat Fulvia	BNL
Ptitsin Vadim	BNL
Satogata Todd	BNL
Shasharina Svetlana	Tech-X
Talman Richard	Cornell/CERN
Tang Chunmei	Stony Brook University
Tepikian Steven	BNL
Trahern Charles G.	BNL
Wan Weishi	FNAL
Wei Jie	BNL
Wilson mark	DOE

Workshop on the Unified Accelerator Library (UAL)

Agenda

Monday, February 2		**UAL Status and Development**
		(Secretary: G.Trahern)
9:00	S. Ozaki	Welcome address
9:05	F. Pilat	Workshop goals and organization
9:15	R. Talman	The ADS (Accelerator Description Standard) Initiative
9:30	N. Malitsky	Status of UAL
10:00	H. Grote	Status of DOOM, MAD9 and Sixtrack
10:30	*Coffee Break*	
10:45	G. Trahern	The RHIC UAL Model
11:00	T. Pelaia	The CESR UAL Model
11:15	J. Holt	The FNAL Online Model
11:30	T. Satogata	Towards a RHIC Online Model
11:45	T. Pelaia	CESR Off-line Simulation
12:00	*Lunch*	
1:30	Discussion	UAL development: - Requirements and priorities - Interface with CERN software - ADS, flat ascii SMF representation
3:00	*Coffee Break*	
		Tech-X Software
		(Secretary: D.Bruhwiler)
3:15 Library	D. Bruhwiler	Status of MAPA and the Tech-X Object Oriented Accelerator
3:30	J. Cary	Future directions for MAPA
3:45	S. Sasharina	Efficient C++ libraries for Differential Algebra
4:00	Discussion	Tech-X/MAPA interface and development
4:30	Adjourn	

Tuesday, February 3 LHC Modeling

(Secretary: F.Pilat)

9:00	J. Holt	FNAL US-LHC plans and software needs
9:15	J. Wei	BNL US-LHC plans and software needs
9:30	R. Talman	Use of UAL to study the dependence of LHC aperture on tune separation
9:45	F. Pilat	Status and plans for LHC SMF
10:00	*Coffee Break*	
10:15	Discussion	US-LHC software development - physics/software capabilities needed for US-LHC - interface with CERN software - priorities - coordination
12:00	*Lunch*	
13:30	Preparation of Workshop Summary	
15:00	*Coffee Break*	
15:15	Workshop Summary	UAL Status, Development and Priorities (G.Trahern) Tech-X Software (D.Bruhwiler) LHC Software (F.Pilat)
16:30	Adjourn	

MEMORANDUM

DATE: 21 January 1998

TO: Beam dynamics newsletter, CLASSIC collaboration, and BNL Workshop on the Unified Accelerator Library

FROM: Christoph Iselin, Eberhard Keil and Richard Talman

SUBJECT: Call for a new accelerator description standard.

Future colliders, such as the LHC, are or will be designed, constructed, commissioned and operated by international collaborations, often working remotely. This makes it essential for faithful lattice descriptions to be network-retrievable from a centrally-maintained, up-to-date source, for use by a variety of beam-dynamics programs.

It is now 14 years since the Snowmass Summer Study when Carey and Iselin[1] defined a standard input format (SIF) which successfully led to implementations in programs like MAD, SAD, TEAPOT and TRANSPORT. At the same time, Iselin, Keil and Niederer[2] introduced the concept of *common* database programs, which did not, however, lead to any effective standardization. Though there have been similarly intentioned efforts such as CLASSIC, the DOOM database to MAD implemented recently by Grote, and the SMF lattice description by Malitsky *et. al.* at BNL-Cornell, there has been no commonality.

It is therefore time to try again to define an accelerator description standard (ADS?) with the following objectives:

1. It should serve from the early phases of conceptual *design*, through the engineering design and *analysis*, to the *operation* of the accelerator.

2. It should generalize (but not replace) SIF in ways that experience has dictated appropriate.

3. Containing only element and lattice description and no beam dynamics, it is to be usable without prejudice by any physical method.

4. It should respect modern computer science standards, especially concerning database management and accessability over networks.

To improve prospects for its broad adoption as a standard, ADS should mimic SIF where possible (retaining basic accelerator objects and their attributes for example), deviating only in essential ways, some of which are:

- *Flexibility.* Examples are: freedom (but not encouragement) to introduce additional elements or additional attributes to existing elements in a standard (for other purposes ignorable) way, support for shared lines (such as two rings), provision for definition of "families" of elements, and inclusion of algorithmic-specific data that is ignorable by default.

- *Full-instantiation.* Every ring element has its own parameters and may have its own name (laboratory-wide, for example).

- *Multiple-realization,* in forms optimized for efficient computation (independent of particular computer language), ease of modification, network transmission, database management, and human editing. (Existing programs show that such flexibility is feasible.)

- *Minimal Completeness.* All elements that can influence single particle motion (in their idealized operation) and only those elements are contained.

- *Extensions of the standard* such as aperture sizes and shapes, and hardware limits on element strengths.

Other features that have been suggested include: *Ideal-actual* distinction between design lattice and lattice with deviations (be they intentional or unintentional, constant or time dependent), *error bars* for element parameters, and *nested line* preservation from an underlying SIF design.

Therefore we seek a small committee of representative and knowledgable experts to volunteer to draft such a standard for later consideration by a broader community.

1. D.C. Carey and F.C. Iselin, A standard input language for particle beam and accelerator computer programs, Proc. 1984 Summer Study on the Design and Utilisation of the Super-Conducting Super Collider (Snowmass, 1984) 389.

2. F.C. Iselin, E. Keil and J. Niederer, Common database programs for accelerator physics, Proc. 1984 Summer Study on the Design and Utilisation of the Super-Conducting Super Collider (Snowmass, 1984) 392.