Developing a Toolkit for Virtual Laboratory Builders and Participants

Part 1

Tools and Technology

K. Froitzheim, University of Ulm, Germany

Part 2

Feasibility Study of the Development of a VL Toolkit

M. Simioni, Swiss Federal Institute of Technology, Zurich
UNESCO consultant for this presentation
Abstract

To promote dissemination and use of Virtual Laboratory (VL) techniques, UNESCO plans to initiate the development of a VL Toolkit along with an enabling environment to facilitate its updating and use. The project will cover appropriate information, communication and telematics tools. Virtual Laboratories, enabled by the recent revolutionary development of the Internet, are of great interest for researchers and research institutions in developing countries since they can enable them to collaborate more effectively in development-oriented research and to integrate with more highly developed science communities, while reducing the information and knowledge gap between developing and developed countries and by mitigating social imbalances, such as ‘brain drain’. Therefore, the VL Toolkit should especially be designed to be used with the level of ICT expertise and infrastructure resources typically available for developing country scientists.

The first part of this paper provides an analysis of present situation and an outlook on future development of information and communication technology (ICT) and telematics, as applied to VL’s. This is inherently one of the most important considerations for any Virtual Laboratory, since it is one of the major factors determining the type and quality of collaboration a VL will support.

The second part treats more specifically the proposed VL Toolkit. It therefore looks at the current situation of VL’s in developing countries, including available skills and infrastructure, and their needs for such a toolkit. A concept for the structure of the toolkit is proposed, as well as a methodology for international cooperative implementation, making use of Virtual Laboratory techniques to support collaboration of participating institutions.
# Table of Contents

## Part 1: Tools and Technology

1. A Taxonomy of Virtual Laboratory Tools ................................................................. 3  
   1.1. Person-Person ........................................................................................................ 3  
   1.2. Person-Equipment (person-experiment) ............................................................ 4  
      1.2.1. Teleoperation ............................................................................................... 5  
      1.2.2. Teleprogramming ......................................................................................... 6  
   1.3. Person-Metamachine ........................................................................................... 7  
   1.4. Quality of Service (QoS) - the core problem of synchronous communication tools.... 8

## Part 2: Feasibility Study of the Development of a VL Toolkit

1. Context ...................................................................................................................... 10  
   1.1. Motivation for Virtual Laboratories ................................................................. 10  
   1.2. Different types of Virtual Laboratories ............................................................. 11  
      1.2.1. Large Facility VL ...................................................................................... 11  
      1.2.2. Research Capacity Building VL ............................................................... 11  
      1.2.3. Project Driven VL .................................................................................... 11  
   1.3. Virtual Laboratory and Developing Countries ................................................... 11  
      1.3.1. Infrastructure ............................................................................................. 12  
      1.3.2. Skills .......................................................................................................... 13  
      1.3.3. Access to Information .............................................................................. 13  
      1.3.4. Needs for VL’s ............................................................................................ 13  

2. Contents of the VL toolkit .......................................................................................... 15  
   2.1. Initiation .............................................................................................................. 15  
   2.2. Set up .................................................................................................................. 15  
   2.3. Use & Maintenance ............................................................................................ 16

3. Developing the VL Toolkit and its Environment ....................................................... 18  
   3.1. Toolkit Structure .................................................................................................. 18  
   3.2. Enabling Environment ........................................................................................ 18  
      3.2.1. Development & Evaluation ....................................................................... 18  
      3.2.2. Dissemination, Distribution and Support ................................................. 19  
      3.2.3. User Platform ............................................................................................. 19  
   3.3. A Project driven VL to Develop the VL Toolkit ................................................ 19  
      3.3.1. Objectives for the Toolkit Development .................................................... 20  
      3.3.2. Development Teams ................................................................................. 20

4. Appendices ............................................................................................................... 22  
   4.1. Appendix A: Examples of Potential Pilot Projects ............................................. 22
Virtual Laboratories

Part 1: Tools and Technology

1. A Taxonomy of Virtual Laboratory Tools

As geographically distributed organisations virtual laboratories are based on communication between researchers and in many cases the control of experiments. One arrives at two major communication tool classes:

- person to person communication in a network of scientists
- person to equipment communication to control a network of tools

Recently a specific form of supercomputing, metamachines, have been discussed in the literature. One important application of these metamachines is working in large, distributed data sets. This class of communication will be called

- person to metamachine

in this document.

Part of a taxonomy should be a classification of what is communicated, i.e. the media streams. The selection of appropriate media streams is not only influenced by the subject of research, but also by the network available for the communication. The essential media streams for virtual laboratories are:

- textual information
- graphics, audio, video and their combination (commonly called multimedia)
- data streams and data sets
- discipline specific information representations such as models and formulas from mathematics or chemistry.

The next three sections are devoted to a more detailed analysis of these three communication scenarios given above. An analysis of media types and their interaction with the communication infrastructure should be included in designing a VL project.

1.1. Person-Person

The communication services in this class, which includes many-to-many scenarios, are typically modelled after conventional techniques of human interaction such as a conversation, a telephone call, a conference, a book, TV, or a letter. The computer supported equivalents are video conferences, Internet telephony, multicast and broadcast conferences, the WWW, and E-mail. The standard approach to their classification is a division along temporal
relationships (synchronous versus asynchronous, see table 1). A scale based on roles versus interactivity has been proposed\(^1\) (see figure 1) to reflect the characteristics of the services.

<table>
<thead>
<tr>
<th>synchronous</th>
<th>asynchronouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>chat, telephony</td>
<td>E-mail, file exchange</td>
</tr>
<tr>
<td>Internet audio,</td>
<td>CSCW, joint authoring</td>
</tr>
<tr>
<td>video conference</td>
<td>project management,</td>
</tr>
<tr>
<td>teleteaching</td>
<td>WWW</td>
</tr>
<tr>
<td>virtual awareness</td>
<td></td>
</tr>
<tr>
<td>application sharing</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: person-person communication

---

**Figure 1: person-person communication**

1.2. **Person-Equipment (person-experiment)**

A key part of many virtual laboratories is experiments. They are operated by manipulators and the results are collected by measuring equipment, which can then again be controlled. In virtual laboratories this operation and control can be performed remotely. The control of the equipment can either be performed interactively (typically called teleoperation), which may either be directly to the device or through mediating software or asynchronously with a predefined procedure, script or program (teleprogramming). Depending on the chosen method, synchronous feedback to the scientist may be necessary.

---

\(^1\) Froitzheim, K.: *Multimedia-Kommunikation*, University of Heidelberg. 1997
1.2.1. Teleoperation

In the teleoperation scenario a scientist gives commands to remote equipment. The equipment is typically a measuring device (telescope, camera), a manipulator, or a probe. The commands can be of a 'strategic' nature (move to position x, fill tank, explode, etc). Fine control will be performed by the equipment itself, which also prevents catastrophic behaviour. During synchronous operation of an instrument, operational parameters may change in a manner unknown to the remote operator. An intervening processing program will accordingly modify the commands. Thus, for example, accessing a mass spectrometer while degassing a previous experiment will require re-sets, which the control program would sense and implement. In this case the feedback channel (mostly video or sample streams) is used to inform the remote scientist of the status of the system and whether a strategic goal has been achieved.

![Diagram of operator-controller-equipment](image1)

Figure 2: operator-controller-equipment

In the second mode the commands are on a lower level (move right, pour fluid, stop). In this mode the feedback channel is of utmost importance, since very high interactivity is required. The critical nature of the feedback imposes high QoS requirements on the communication channel with respect to delay and throughput.

In both operational modes the control of the experiment is based on mediastreams for the human operator (video, audio) and sensor output. The scientist uses the combination of both feedback stream to operate the experiment.

![Diagram of operator-motor-equipment](image2)

Figure 3: operator-motor-equipment
The result of the experiment, i.e. the data (media) stream obtained can either be collected and stored at the equipment site for later transfer, or it can be transmitted live to the user site. The second is often the case when the feedback channel also contains results.

Examples:

- the interactive model railroad at the University of Ulm, Germany is a small model railroad. It can be controlled through a WWW based interface. Feedback is given through WWW-based video - WebVideo.
  http://rr.vs.informatik.uni-ulm.de
- A remote controlled robot at the university of Western Australia has a WWW-based user interface for all six degrees of freedom. Feedback is again provided with WebCams
  http://telerobot.mech.uwa.edu.au

**Application sharing** can be used as a tool for teleoperation. The local computer based equipment control program to operate the experiment will in this case be used remotely. The application sharing service transmits the user interface of this program to the remote site and the remote input is fed back into the program. Application sharing systems include WTS (Windows Terminal Server, Citrix), Proshare, and Timbuktu.

**WWW-based** control interfaces are implemented with a WWW-server and the CGI-mechanism or by integrating a small WWW-server into the instrument control software. The user interface is then based on simple or advanced html-pages with certain embedded links pointing to the equipment control software complete with parameters. The Internet Model Railroad, WebIR - a WWW-based infrared remote control for VCRs, the Materials MicroCharacterization Collaboratory (http://tpm.amc.anl.gov/mmc/) and various WebCams (see http://www.rearden.com) are examples for this technology.

In both cases measures are needed to recover from failures of the communication link. In a virtual laboratory, remotely controlled equipment needs software in the devices, that takes over control in the event of network failure to continue or safely end the experiment.

1.2.2. **Teleprogramming**

Teleprogramming is an asynchronous approach to the operation of equipment in a virtual laboratory. The scientist creates a series of commands for the device, which is then downloaded into the device and executed. The result stream is recorded and later sent back for evaluation by the scientist. This command series is in many cases either a script or a program. Most programming languages can be used as long as the equipment manufacturer supports them. Today Java is certainly a good choice, as long as the programs created are not time-critical. Two problems should be mentioned in this context:

---

- Programming is a task intimately associated with errors and bugs. Since the remote programming task is especially tedious with respect to turnaround times, local simulation of the programs is very important.
- In order to write a program for a given experiment, a formal description of the functionality of the equipment and of the controllable parameters is a prerequisite. This can be in the form of interface files or distributed programming interfaces (CORBA, RMI-objects, etc).

These two issues lead to the fundamental problem of abstract equipment description, which should be solved in order to simplify remote experimentation.

1.3. Person-Metamachine

The concept of metamachines has been discussed in the November 1998 issue of Communication of the ACM3. The idea is that scientific projects will be increasingly based on large, distributed datasets manipulated by transformation algorithms on supercomputers. Access to data (digital library) and control of computing power may therefore become part of a VL-communication infrastructure.

The above reference gives 2 examples of such problems. The first is the digital sky project, where a huge multi-wavelength database of astronomy-data is provided on-line, so that statistical analysis of this data in many different supercomputers will become possible. The second area presented is the 'Mapping the brain' effort, where neuroscientists deal with multiple gigabytes of volumetric data.

The data sets are typically stored in huge databases, they are then filtered to extract pertinent data for certain questions, and finally transformed and analyzed by sophisticated algorithms in supercomputers or networks of distributed processors.

Several techniques related to this communication class have been used in computing and networking for some time:

- client-server computing (Corba, RMI, ODBC, JDBC, Java, etc.)
- remote database clients
- remote computer operation based on Telnet, X-Window, and application-sharing (Windows Terminal Server, Timbuktu, QuiX) to operate the supercomputers remotely.
- remote program preparation for the supercomputers
- agent technology as an interesting approach to the data-filtering task described above.

A systematic taxonomy of this class is not known to the authors. Research has to explore this field in more depth to make recommendations to the architects of virtual laboratories.

1.4. Quality of Service (QoS) - the core problem of synchronous communication tools

Quality of service is a set of performance parameters associated with a certain service, especially with data transmission services. Typical parameters are:

- throughput, the amount of data (packets, bits) transmitted per time unit [packets/sec]
- delay, the time a packet needs from entering the network to delivery [seconds]
- delay jitter (variations of the delay)
- error probability (lost packets, bit errors)
- error detection probability (effectiveness of checksums)
- error correction measures (retransmission, forward error correction)
- topology (unicast, anycast, multicast, broadcast)
- availability (probability of a successful connection set-up)

A given network may ensure certain minimum values of these parameters (guaranteed QoS), achieve them on average over a given time (statistical QoS), or just strive to maintain the desired values of QoS (best-effort). Guaranteed QoS is, for example, provided by the ISDN telephone system with respect to data rate, but not in all the other areas.

The current publicly available Internet is based on the best-effort QoS paradigm. In reality Internet QoS is completely unpredictable. Although research and development are trying to add true QoS to the Internet (IntServ, DiffServ), reliable QoS in today's Internet is based on overdimensioning the system (links and routers).

Dramatic improvements in overall Internet bandwidth have taken place and will be achieved in the immediate future. However:
Internet performance for the individual user will not increase as long as the user number growth remains in the double-digit range.
Part 2: Feasibility Study of the Development of a VL Toolkit

1. Context

1.1. Motivation for Virtual Laboratories

Virtual Laboratories are in widespread use in scientific research today, mainly in sciences closely related to or heavily using ICT (e.g. physics, astronomy, gene sequencing or computational chemistry) which dispose of substantial resources and skills to implement and adapt ICT tools for VL use. These researchers have several motivations to use VL technologies:

- Increasing size and scale of efforts
- Combination of results from different facilities
- Gains in scientific productivity
- Benefiting from available human resources and expertise
- Shared access to unique or scarce scientific instruments
- Regional participation

UNESCO in particular has the following additional interests:

- Integration of developing countries into international scientific efforts
- Avoiding information isolation
- Reducing ‘brain drain’ from developing countries

For other scientific disciplines or countries, where enabling resources are inherently more scarcely available, Virtual Laboratories are not often used because of awareness gaps—caused by social and/or scientific isolation - or cost/resource barriers for VL implementation and use. A VL toolkit could make VL technology available for potential users who dispose of a less developed infrastructure and skills.

In this context, a VL toolkit must meet the following demands:

- reduce required skills and expenses to set up, use and maintain a VL
- provide tools for limited infrastructure
- provide tools, documentation and training presented in appropriate languages
1.2. Different types of Virtual Laboratories

Definition: A Virtual Laboratory is an electronic workspace for distance collaboration and experimentation in research or other creative activity, to generate and deliver results using distributed information and communication technologies.

VL's may be built up and run for different purposes. We have identified the following categories: Large Facility VL, Scientific Capacity Building VL, Project driven VL

1.2.1. Large Facility VL

The Motivation is to increase effectiveness in doing science by providing 'location independent access to instruments, data handling and analysis processing'. Therefore, Large Facility VL's heavily rely on person-to-machine and person-to-metamachine interaction (teleprogramming or teleoperation).

1.2.2. Research Capacity Building VL

The goal of such a VL is to provide a framework for scientific communication and collaboration by regularly providing basic ICT services. This means that services are constantly available in the background which can be used by participants on demand, much like the use of a telephone. Services may include research facilities, but we should not forget that there are many important scientific disciplines which rely much more on person-to-person communication and collaboration than on scientific equipment or computing resources, e.g. some of the social sciences. Synchronous and asynchronous person-to-person technology with user friendly interfaces are in any case needed to make such a VL popular.

1.2.3. Project Driven VL

This type of VL has the clearly specified objective to support a research project with a fixed time horizon and budget; with the achievement of its objective, the VL will be shut down. Basically, such a project driven VL can have a combination of the tool requirements of the other two types. Since such VL's are likely to have shorter lifecycles, special attention has to be paid to distributed project management and coordination. Use of workflow tools should be examined.

1.3. Virtual Laboratory and Developing Countries

The current evolution of available bandwidth at fixed price is extremely dynamic – at an estimated growth of 60% per year, even exceeding Moore's law. As of July 1999, the Internet consisted of some 190 million users and 56 million hosts, but only 6% of the latter were

---

located in developing countries (0.6% in Africa, with 13% of world population). Although these disparities carry over to research and academic institutions in developing countries - the main potential beneficiaries of Virtual Laboratories - the distinctions there mainly concern capacity and quality of service, since most of such institutions have basic connectivity (although still often limited to dial-up access in the least developed countries).

In the following treatment, Africa is often taken as an example since it is generally the least developed region in the informatics and telematics areas and could therefore be seen as a sort of ‘lowest common denominator’ in ensuring wide access to VL facilities in developing countries.

The following factors mainly determine the feasibility of setting up a VL: the needs of the users of the Virtual Laboratory, media parameters of the content to be transmitted, ICT infrastructure and available skills for set up, use and maintenance.

User needs for industrialised and developing countries are quite similar. If the media requirements do not change, this makes infrastructure a crucial problem, raising the danger of creating different classes in benefitting from VL’s. The present situation is mitigated by two facts: first, it is modem technology where the main improvements concerning bandwidth have been achieved, compared to relatively static broad and medium bandwidth technology. Secondly, already small improvements of connectivity in developing countries can lead to major impacts on productivity in scientific research, as is theoretically proven by I. Lerch.

1.3.1. Infrastructure

A liberalised telecom market and increasing demand for ICT services from commercial units are leading to a fast development of ICT infrastructure in developing countries (e.g. Thailand has tripled its international Internet bandwidth during the last 11 months from 35 to 112 Mbps, with about a third of the connectivity provided by satellite). In Africa, annual growth of bandwidth has been as much as 38% in some countries, but only 10 countries have a bandwidth exceeding 1 Mbps, and intracontinental backbones still do not exist. However, although universal access in developing countries is still not realistic, in most of the developing countries, there are some research institutions that have reasonable access: satellite connections can be very useful to provide connectivity, though bandwidth remains limited.

---

6 Internet for Development, ITU, Oct 1999, p. 4
8 http://www.cybergeography.org/atlas/isp_maps.html
But even if better connectivity can be guaranteed, high relative connectivity costs still impose problems for the use of ICT to support VL’s: in the U.S.A. 20 hours of Internet access cost $29, while the African average is about $60. An international 9.6 Kbps link in Africa costs $130,000 per year.

Finally, developing countries suffer from a low level of computerisation, i.e. hardware for computing and networking is widely underavailable, although relatively small key investments could improve the situation for the academic and research sector.

Enabling national public policies for the academic and research sector, as well as self-help action (research networks, public service consortia) will also be needed to improve the infrastructure of these sectors. International efforts have to be made to promote institution-commercial-government partnerships to exploit the possibilities of the improvement of infrastructure, where international organisations can play an active part.

1.3.2. Skills

In the U.S.A. and Europe scientific research institutions were at the basis of the spread of the Internet for communication and collaboration (e.g. CERN); ICT skills were strongly developed in these institutions. In many if not most developing countries, today private and commercial organisations are leading the development of ICT and Internet. This means that ICT skills are more available in most of those countries in the commercial sector (e.g. ISP’s) then in the poorer public service and governmental sectors.

1.3.3. Access to Information

Access to technical information on ICT and VL tools, as well as to content on the Internet in general, most often requires mastery of the English language (e.g. more than 90% of Web Pages are in English, 1.2% in French, 0.9% German).

The trend away from the open science paradigm and policy strongly influences cost of information; even for European scientists access to knowledge can be a problem, caused by high cost barriers. The situation is being made even more threatening by new legal rules for accessing data, e.g. the European Database Law. On the other hand, the situation is improving in some countries through major public programmes with the intention to provide tools and information adapted to local circumstances (e.g. China, Japan, Korea).

1.3.4. Needs for VL’s

Models on how to build up, spread and use scientific knowledge have to be elaborated. Instead of an unidirectional technology transfer, a sustainable local development of skills is

---

required. To support these objectives, access of researchers and research institutions in
developing countries to relevant information, laboratory equipment and facilities and
international expertise are clearly urgently needed. Several concrete VL projects to satisfy
these needs were proposed at a recent UNESCO sponsored expert meeting\textsuperscript{10} (see Appendix A).

\textsuperscript{10} Expert Meeting on Virtual Laboratories, Ames, Iowa, May 10-12
2. Contents of the VL toolkit

To be useful for both developing and industrialised countries the VL toolkit has to offer an integrated set of tools which require only limited skills for set up. It should offer possibilities for use with normal as well as with low QoS of the underlying ICT infrastructure, e.g. by offering variants of tools with reduced functionality and bandwidth requirements.

This section will provide a short analysis of the different phases of the lifecycle of any Virtual Laboratory – initiation, set up, use and shut down – and discuss content of the VL toolkit appropriate for each.

2.1. Initiation

Lack of awareness of decision makers concerning VL's at the initiation stage is a problem for developing countries and for scientific disciplines that do not heavily rely on ICT. At the initiation stage there should also be a possibility for matching requests for collaboration with offers of scientific resources. Since VL’s are inherently international, legal implications (e.g. intellectual property rights) have to be considered. Careful consideration should also be given to the time frame and available resources for a VL and the benefits expected, remembering that today approximately 50% of commercial ICT projects do not fully meet their objectives or budget\(^\text{11}\).

The VL toolkit and its enabling environment therefore must diffuse VL awareness, offer a ‘market place’ for VL demands and resources and provide information on requirements on ICT resources to build a VL, including hardware, software, time and skills. Those services should be understood as a support to initiate new VL projects by potential new users.

First, there should be an information package to diffuse VL awareness including a short introduction to VL’s, the technologies they employ, the services they can provide and how these can be used to improve the effectiveness of scientific collaboration. Then, a guide for assessing required resources and infrastructure should be provided. Template forms will help to set up a project plan and budget for an VL project. A Web based and conventional (fax, phone) support interface should allow potential users to get support in making a decision on whether or not to set up a VL.

2.2. Set up

Set-up time and cost are important aspects to be considered in a VL toolkit. Since Virtual Laboratories will generally have relatively short lifecycles (e.g. Project Driven VL’s), their success is sensitive to a quick set-up.

\(^{11}\) Orfali e.a., ‘Client Server Survival Guide’, 1998
To determine the services to be provided, the following procedure is recommended: (1) analyse work patterns; (2) analyse parameters of required media, existing infrastructure and available skills; (3) determine the types of collaboration to be supported; (4) select the tools, and determine the necessary extensions and local additional infrastructure needs; (5) training of operators and users; (6) implementation; (7) acquisition and migration of data; (8) testing. This procedure has to be supported by adequate documentation and tools which should be accessible by Web or CD-ROM.

Training material and courses should be provided to support projects in developing countries aiming to improve locally available ICT skills. The following units are required to set up any VL: (1) use of operating system (e.g. Linux); (2) build LAN’s and connect them to the Internet; (3) install and maintain servers and applications of the VL toolkit (mail, Web, specific tools); (4) build Web based applications; (5) enhance Internet connectivity as required (leased lines, VSAT, etc.). Training can be provided on-site as well as by teleteaching tools.

2.3. Use & Maintenance

Tools already exist for virtually every VL need. But the development of software tools is very dynamic what makes it difficult to find tools to support a sustainable toolkit. Many of the academic tools offer free use or Open Source licences. It is of major importance to the VL toolkit to use tools that guarantee free use, provide the source code and the possibility of further local and cooperative development. Security aspects and intellectual property rights are rarely covered by scientific tools and have not been primordial in much scientific work, though we think they deserve deeper consideration; they may not be immediately critical, but will become so as soon as some results of commercial interest are be produced.

The following training elements, already discussed above, should be contained in the toolkit: basic use of computer; use of networks and Internet; guide to the use of VL toolkit components.

The tools themselves should include:

- Multimedia document and information management: general access to unstructured documents (e.g. BSCW, Lotus Notes) and structured data (e.g. relational and object-oriented databases) on a portable platform (e.g. JDBC Interface, Web Client) with tools to reduce network traffic (e.g. mirroring)
- Conferencing and informal communication and collaboration: mail, listserver, news server, audio, video, graphics, electronic shared notebook
Virtual training environments: creation, management and use of teleteaching courses\textsuperscript{12}, e.g. MTS, Webct, Tango, Learn Space, VirtualU, Superscape

- Remote experiments and resource brokerage: tools for use and administration of person-to-machine and person-to-metamachine interaction
- Workflow & scheduling (ad hoc workflow)
- Utilities: services which are transparent to the user (e.g. security, distributed component architecture, directory, remote maintenance)

For each tool, the toolkit has to provide the executables, state of the art documentation and training material. The latter two have to be available at least in English, French and Spanish with the goal to extend it to other official UNESCO languages. Emphasis should be given to Open Source tools, for which source code will be provided. Documentation has to be provided in printed form as well as on CD-ROM and by a Web interface.

The toolkit should require minimal maintenance. ICT experts are very scarce in some countries, which makes remote maintenance a critical aspect for the use of VL’s in these countries. Today, tools for remote maintenance are available for all platforms (e.g. BO2000 for Win9x). Already in the selection of the tools for the toolkit, this aspect has to be taken into account. This is an area where further consideration is required to find appropriate models for the use of remote maintenance in VL’s. User training has to be available by teleteaching methods to avoid high costs to reach a broad user basis.

Today, at least in developed countries, there is a trend to enforce use of synchronous tools for distance collaboration, since they require a smaller effort to adapt personal work patterns to available tools at the cost of higher infrastructure demands\textsuperscript{13}. However, to meet the demands of developing countries, asynchronous tools should be considered very carefully, since they are by far less sensitive to problems of QoS of underlying infrastructure.

But asynchronous tools will also be interesting for a large user community in industrialised countries since, although worldwide available bandwidth is increasing at a astonishing rate, the vast majority of users only have medium or low bandwidth access to the Internet. This is caused by a still exponential growth of Internet users leaving only a relatively small elite with high bandwidth access.

\textsuperscript{12} http://cii.unesco.org/virtrain/table/index.html
\textsuperscript{13} G. Olson, ESF-IIASA-NSF Workshop, Laxenburg, December 3-5, 1999
3. Developing the VL Toolkit and its Environment

3.1. Toolkit Structure

The VL toolkit should be designed from the point of view of the final user, i.e. the structure will follow the VL lifecycle. Given the scope of this project, the toolkit will have to provide tools which can be used with a range of existing infrastructure. This implies that (a) adequate tools with low bandwidth demands have to be included, and (b) the toolkit will nevertheless target users with access to a minimum defined ICT infrastructure. Furthermore, different tools should be available for Large Facility VL’s, Research Capacity Building VL’s and Project Driven VL’s.

The toolkit will offer two variants of tools: (a) ‘ready-to-use’ tools’, with appropriate variants for different user groups with a main focus on users with low demands, (b) analysis and recommendations on the functionality and infrastructure requirements of the tools. It is clear that one tool or even a fixed set of tools cannot cover all aspects of a VL. Instead the toolkit should provide a repository of different tools, where a potential user is supported to choose the ones best suited to his needs.

In most informatics projects, data is the most expensive component. Therefore, data acquisition and migration has to be supported by a standard data model, to be used throughout the VL toolkit, along with a mechanism for effective navigation and searching.

Two approaches could be chosen: (a) create an ‘unified’ toolkit with low functional redundancy and integrated security architecture; (b) create a first usable toolkit with loosely coupled components. We favour the second approach to provide a first usable as soon as possible at minimum cost. The first approach would require substantial development efforts, while in the second case, one will mainly have to evaluate existing applications. The products of the second approach could subsequently be upgraded if required.

3.2. Enabling Environment

The VL toolkit will be embedded in an enabling environment, which will perform the following functions:

3.2.1. Development & Evaluation

First, the environment has to provide a testbed for the development and evaluation of the components of the toolkit. It shall inform about, and provide access to, current VL development projects and the different participating development teams. A central tool repository must be available, containing tools and related information; for this, a general data model for ‘tool records’ should be adopted. Criteria to measure tool quality also have to be defined and included.
3.2.2. **Dissemination, Distribution and Support**

Recently, the ‘Group of 77’, representing the developing countries, stressed the United Nations the importance of ensuring the continuation of distribution of knowledge on traditional media. VL knowledge, information and tools must be distributed by means that reach potential users. Therefore, in addition to a Web interface, tools for the *initiation* of a VL should be disseminated on printed media, as well as on CD-ROM. DVD has a rising importance as a distribution medium, enforced by its fast spreading and capacity to carry a large amount of data. Since for the *use* of Virtual Laboratories a minimum level of ICT infrastructure and connectivity is required, which will normally provide the QoS needed for file transfer, access to the full toolkit in electronic form (file transfer and CD-ROM) shall generally be sufficient.

Training opportunities have to be offered as content of the toolkit or as related programmes. Finally, there has to be a help and support interface for all users of the VL toolkit.

3.2.3. **User Platform**

The user platform should provide access or interaction with running projects which use the VL toolkit. It should implement a forum for exchange of knowledge and experience. The objective is to get feedback from the VL toolkit users, to stimulate knowledge transfer among projects as well as to promote the VL toolkit. The platform will also help to initiate new projects using the VL toolkit by providing a ‘market’ for resources and institutions willing to participate in such projects.

3.3. **A Project driven VL to Develop the VL Toolkit**

For the development of the VL toolkit there are two possibilities:

- Organisation as a traditional project, with subgroups responsible for the development of one or more components of the VL toolkit interacting on an *ad hoc* basis with common communication means, such as Email, phone and file servers;
- Development of the toolkit as a project driven Virtual Laboratory, ensuring that newly selected tools get deployed in the Virtual Laboratory to be immediately available for, and tested in, the work.

We recommend the second variant for the following reasons:

- The toolkit can be extended step by step, beginning with most important tools
An overall view of the toolkit will be guaranteed during the development stage. Problems concerning VL set-up, maintenance and use will be discovered in the course of the project; this will reduce testing and disfunction in the final product. Experiences in the use of a VL will improve help define services to be provided to future users. The VL to develop the toolkit will enable an estimation of productivity gains and can serve as a reference implementation for future VL’s.

3.3.1. Objectives for the Toolkit Development

Since the Toolkit Development VL will be project driven, we have to specify objectives and a time horizon to reach them. The proposed objectives are:

- Collect existing tools and create a repository and catalogue
- Select suitable tools for a VL toolkit
- Initiate development teams
- Set up the enabling environment (infrastructure) for the VL toolkit and its development
- Develop the VL-toolkit
- Develop the environment to help and support VL-toolkit users
- Promote and disseminate the VL toolkit

3.3.2. Development Teams

Due to its limited financial and human resources, UNESCO can only act as an integrator and coordinator for the VL toolkit project. Therefore it is crucial to find persons or institutions to provide the required workforce to develop the VL toolkit. For every development team there should be at least one person who acts as a continuous partner for coordination with other teams.

The development teams will first have to create a snapshot of presently available tools in their specified area. Then (or in parallel) they create the enabling environment for the project driven Virtual Laboratory to develop the VL toolkit. This will consist of a Web entry site, a directory of participants and a repository containing tools and data.

The initial tools will be integrated in a toolkit repository and their quality will be assessed and rated. Based on an analysis of available functionality, the teams should make a basic decision on what functionality should be provided in the toolkit.

On this basis, definitive evaluation, selection or development of further tools for the VL toolkit can begin. Tools to be integrated in the VL toolkit will first be tested in this Virtual Laboratory.
When the toolkit finally is completed, the teams will stay connected to provide support and its further development.

The following development teams are required:

- **Enabling environment**
  This team will implement and host the enabling environment, including the infrastructure to support collaboration to develop the VL toolkit and distribution of the VL toolkit.

- **Person-to-Person**
  This team has to establish a snapshot of currently available tools for conferencing and informal communication and collaboration and virtual training environments. Those tools have to be evaluated. Documentation and courses have to be created for the most promising ones.

- **Person-to-Equipment & Person-to-Metamachine**
  Today, person-to-equipment interaction is very much done by a case-by-case approach. To reduce required skills and costs and to improve reuse of existing applications, a standardised framework for the based access for scientific equipment within a VL has to be implemented. This may be based on CORBA or JINI, etc., providing guidelines for the design and implementation of standard interfaces. This approach has already been chosen by several commercial branches, e.g. telecommunications.

The last two teams described above will be responsible for collection, evaluation, selection and documentation of the specific categories of tools (as defined in part 1).

- **Data Base Management Systems**
  This team will be responsible for developing a standardised approach for data storage and retrieval in VL’s, enabling general data access, as well as data interfaces with the various VL tools and applications.

- **Integration, Presentation, Dissemination and Support**
  This team will be responsible for the finalisation of the toolkit and organising the follow-up user services, including hotline and training.

Before starting to implement the proper toolkit, it is proposed above to undertake a snapshot of presently available tools, which then can serve as a basis for evaluation of appropriate tools. UNESCO is searching for development partners to help in establishing this snapshot and later provide the ICT resources and to implement and host the VL toolkit and its enabling environment.
4. Appendices

4.1. Appendix A: Examples of Potential Pilot Projects

At the recent UNESCO supported expert meeting on Virtual Laboratories in Ames, the following pilot projects were proposed;

PROJECT 1: Laser Science in Africa

\textit{Submitted by}: Ahmadou Wague

PROJECT 2: The Information and Communication Technologies (ICT) Decision Modelling Collaboratory

\textit{Submitted by}: Joseph Potvin

PROJECT 3: Remote Material Characterization and Environmental Monitoring in Central America

\textit{Submitted by}: Abdoulaye Diallo

\textit{Stakeholders}: Countries in the region, ICTP, UNESCO, Organization of American States (OAS), and others

PROJECT 4: Virtual Computer Lab (or Open Computing Environment)

\textit{Submitted by}: J. P. Vary

PROJECT 5: CollaborArt: Cultural Environment Exchange

\textit{Submitted by}: Barbara Bianchi (under the guidance of IITAP, ICTP, and Alexei Gvishiani of Earth Data Network for Education and Scientific Exchange [EDNES])

PROJECT 6: Network of Asynchronous Learning Nodes for Science Education

\textit{Submitted by}: Liangyao Chen, Yunsheng Ma, David Tehyu Kao, Doug Fils

PROJECT 7: International Condensed Matter Physics and Engineering Laboratory

\textit{Submitted by}: Anatoli Frishman

PROJECT 8: Real-Time Experimentation within the Virtual Laboratory Environment

\textit{Submitted by}: Najeh Jisrawi

\textit{Region}: Middle East

PROJECT 9: Development of a Network to Link the Participants in a Multinational Collaboration Focused on Sustainable Development in Henan, China

\textit{Submitted by}: Joel A. Snow, Bing-Lin Young
PROJECT 10: Use of Central Laboratories, Central Computing Facilities, and VL Concepts for Post-Graduate and Post-Doctoral Research in Developing Countries with Africa as a Case Study

Submitted by: G. O. Ajayi

PROJECT 11: ICTP-VSAT-based VL for scientific collaboration—Pilot Project

Submitted by: S. M. Radicella, F. Postogna, A. Nobile, E. Canessa, G. O. Ajayi, ICTP, Trieste, Italy, Atef Sherif, Egypt

PROJECT 12: Simulation Games for Peace and Conflict Resolution

Submitted by: Alfredo Rojas, Galileo Violini