Virtual Laboratory Enabling Collaborative Research in Applied Vehicle Technologies

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ABSTRACT

The virtual laboratory is a new technology, based on the internet, that has had wide usage in a variety of technical fields because of its inherent ability to allow many users to participate simultaneously in instruction (education) or in the collaborative study of a common problem (real-world application). The leadership in the Applied Vehicle Technology panel has encouraged the utilization of this technology in its task groups for some time and its parent organization, the Research and Technology Agency, has done the same for its own administrative use. This paper outlines the application of the virtual laboratory to those fields important to applied vehicle technologies, gives the status of the effort, and identifies the benefit it can have on collaborative research. The latter is done, in part, through a specific example, i.e. the experience of one task group.

1.0 INTRODUCTION

Applied Vehicle Technology (AVT) panel chairmen have reiterated at Research and Technology Organization (RTO) Symposia over the past several years the need for task groups to operate in a virtual laboratory (VL or VLAB) environment. There appear to be at least three valid reasons why they have encouraged the groups to do so. The first is that VLs have become increasingly used in many fields of study, as noted in a literature survey of recent citations involving: education [1-26], space science [27], molecular science/mechanics [28-29], physics [30], structures and materials [31-32], environment monitoring [33-34], computer science (VL improvement) [35-52], simulations [53-64], mechanics [65], medical [66], aerodynamics [67-72] and a range of other fields [73-83]. (Some of the preceding reference citations, including those for simulation, aerodynamics and 'range of other fields', involve real-world applications.) A second is that the AVT and RTO are organizations that seek to be on the cutting edge of technology and the VL technology is one in which they are not fully vested; and a third is that task groups functioning within a VL environment are anticipated to realize increases in efficiency and collaboration.

Moreover, the Research and Technology Agency (RTA) has established within its Information

Management Committee (IMC) an emphasis of developing such a capability for its own and task group use. One product that has been created is the ‘Science, Technology and Research Network’ (STARNET). “The purpose of this network is to facilitate access to information elements existing worldwide, in terms of science, technology and overall research; it is a database of Web-based data sources, which will allow comprehensive and sophisticated searches. STARNET is designed as a virtual library to provide a “one stop” information resource for policy makers, program managers, scientists, engineers and researchers. It has been designed as a system that can be adapted to address specific information needs as they arise within the NATO community”[84]. In addition to these organizational encouragement efforts, individual task groups have identified similar and other needs during the same time frame.

To that end the AVT Panel, through its executive, organized a meeting in Williamsburg during the June 2004 Spring Symposium for those task group chairmen and others interested in VLs to exchange information. The needs identified at that meeting were reported by its chairman [85] to the AVT Panel and include: (1) tools for collaborative interactions – person/person in a closed group; (2) team workspace (interactive with team – show documents on computer); (3) electronic meetings; (4) electronic library (team data, hyperlinks to other data); (5) ability to have interactions/workspace for the team both during and after the task group’s work is completed; and (6) firewalls on computer. The NATO tools of RTO Forum and STARNET were identified as being available and new ones, such as Web Information Services Environment (WISE) [86] and the Aerospace Materials Technology Consortium Environment (AMTCE) [87], were highlighted as offering real possibilities to many task groups. (After the meeting it was learned that the “… RTO Forum was first developed by the RTA Staffs in June 2002 as a first generation collaborative environment for the RTO Scientific Community. The system was taken off line in November 2004 where it was replaced by the RTO WISE Collaborative Environment.”)[88]

However, none of these VL tools completely addressed the needs of AVT-113 whose topic is the “Understanding and Modeling Vortical Flows to Improve the Technology Readiness Level for Military Aircraft”. In particular, the VL needed by this task group must be able to handle restricted data subject to the ‘International Traffic in Arms Regulations’ (ITAR), as the geometrical data for the F-16XL aircraft, expressed in either its IGES description or by computational grid files, fall in this category. In addition, these data are only releasable by NASA to those NATO/PfP member nation organizations that have signed Memorandum of Agreements (MOAs) in place regarding the data usage. Moreover, in order for this VL to be truly collaborative, it must allow designated members from those organizations to upload results from CFD solutions to a mass storage and retrieval system for download by other members. Since the VL is hosted at NASA Langley, the preceding created a problem because the upload of data by foreign nationals to the Langley mass store system was not allowed when this effort commenced. Lastly, the VL must be able to accommodate more than one set of users, one with restrictions and one without, as there are two facets of work within AVT-113. In particular, one set will use CFD to predict the F-16XL flight measurements of [89] in the Cranked Arrow Wing Aerodynamics Project International (CAWAPI) facet, and the other set will obtain new data for a 65^{o} delta-wing model or use CFD to predict it, along with existing data, in the Vortex Flow Experiment-2 (VFE-2) [90] facet. (This multi-user-set feature could be expanded – with appropriate funding and support – to include other international groups who need relational database storage and retrieval as a part of their collaborative efforts.)

The following sections address how the AVT-113 requirements were taken into account and resolved, as well as provide examples of VL content and usage.

2.0 NOMENCLATURE

AMTCE Aerospace Materials Technology Consortium Environment

AVT Applied Vehicle Technology (one of six technical panels within the RTO)

CAWAPI	Cranked Arrow Wing Aerodynamics Project International
CD	Compact Disk
CGNS	CFD General Notation System [91]
CFD	Computational Fluid Dynamics
DMZ	De-Militarized Zone
ECO	Export Control Officer
F-16XL	An extensively modified version of the F-16 aircraft which is longer and has a cranked arrow wing instead of a trapezoidal wing with leading-edge strake
IGES	Initial Graphics Exchange Specifications –> geometry descriptor
IMC	Information Management Committee
ITAR	International Traffic in Arms Regulations
LaRC	Langley Research Center
MOA	Memorandum of Agreement
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NLR	National Aerospace Laboratory in the Netherlands
PfP	Partners for Peace
PKI	Public Key Infrastructure
POC	Point of Contact
RTA	Research and Technology Agency – administrative agency in which the RTO functions
RTO	Research and Technology Organization – scientific arm of NATO
SA	System Administrator
SSH	Secure Shell
STARNET	Science, Technology and Research Network.
VFE-2	Vortex Flow Experiment-2
VL, VLAB	Virtual Laboratory

WISE Web Information Services Environment

Note: All computer and network related terms used in this report are defined in http://www.techweb.com/encyclopedia/ (Staff of 'The Computer Language Company' [92]).

3.0 VIRTUAL LABORATORY SOLUTION FOR AVT-113

3.1 CAWAPI facet

As the VL requirements of the CAWAPI facet were more advanced than those of the VFE-2 facet, they are addressed first and depicted in Figure 1 by a primitive solution. This depiction highlights many key elements, including the recognition that only international organizations with MOAs in place with NASA can participate. It works as follows: All data requests and transmissions between members must first pass through the NASA point of contact (POC). Data and its associated meta-data are sent to the POC, who would turn this information over to the database manager for encryption and placement in the mass storage system. Likewise, a data request sent to the POC results in a request to the database manager who would retrieve the data, decrypt it, and put it on a CD for the POC to forward. However, if geometry or grid data are requested, the POC must obtain the approval of the Export Control Officer (ECO) before completely fulfilling the request. Subsequently, the ECO sends a periodic report to the State Department on those export-controlled items transmitted within a specified time period.

Details of the process used to develop and implement a VL for AVT-113 have been documented [72] and these include the various personnel, actions and coordination that were required across multiple areas of expertise. A portion of the report is highlighted here. "The initial requirements for the system were defined by the researcher/aerodynamicist, and molded into an initial application design by the web and database application personnel. This design was then presented to security personnel, who added specific additional system and data security requirements. Since some of the data archived in the system are considered ITAR, the export control personnel were consulted and specific reporting requirements were added. Once a complete set of requirements was defined, networking personnel implemented the De-Militarized Zone (DMZ) network and the necessary rule sets."[72] A hardware platform was chosen and installed on the DMZ by system administration personnel who were also responsible for the installation of system software, such as the web server. The result of the preceding is that the VL web server platform is located outside of and electronically isolated from the NASA Langley network, except through a secure port or shell (SSH). "Database administration personnel were required to install the relational database engine, and provide connectivity between the database server and the web server. Additional security personnel were utilized to obtain Public Key Infrastructure (PKI) certificates used in the encryption of data designated as needing to be protected. Database application developers defined the data schema and implemented structured query language for the database interface, while the web application developers defined and implemented the user-interface. Mass storage personnel were consulted for file storage requirements and backup procedures."[72]

Once all these requirements were turned into a viable hardware/software set, the resulting system architecture looks like that shown in Figure 2 and consists of a user's desktop, a web server located in the DMZ, a database server and a mass storage system which are connected to the web server by a secure link, shell or port. The associated web pages – see Figure 3 as an example – allow authorized members to enter the CAWAPI system and perform the following functions:

- Add a CFD Test and associated meta-data to the archive
- Add a CFD Run and associated meta-data to the archive

- Update meta-data and add new files associated with an existing CFD Run
- Search the archive for CFD data files based on a set of test conditions
- Search the archive for Flight Test data files based on a set of test conditions
- Search the archive for geometry/grid files used in archived CFD Runs
- Upload new geometry grid files to archive
- Download non-ITAR data files
- Download ITAR data files to verified users and Report Activity to Export Control Officer [72]

Figure 4 shows how this VL functions as a replacement for the primitive system.

3.2 VFE-2 facet

The VL for CAWAPI facet was extended to include the VFE-2 facet; however, more than a simple extension was performed. This facet also makes use of other database products developed for wind-tunnel data archiving and transmission. The final result is that database searches can be made on additional data types for both wind-tunnel and CFD, and the keywords used for searching have been significantly extended to cover most all of the CFD associated input features or solution variables.

3.3 Web server access

The VL has three web servers member groups, AVT-113, CAWAPI and VFE-2. All members have access to the their own web server group and AVT-113, but those in CAWAPI also have access to VFE-2, as it is unrestricted to task group members.

3.4 Data types supported by AVT-113 VL

Any data type for which the relational database schema with defining appropriate meta-data has been prepared is acceptable. This includes a large range of experimental and computational data. In addition, any associated information that can be put on a Web page, such as documents, meeting notes, presentations, etc., can also be accommodated. Since unsteady data collections or predictions result in many large files, this type of VL could potentially be used in that scenario due to its ability to deal with such files.

4.0 SURPRISES AND ADJUSTMENTS

Once the VL was developed and others began to use it, some surprises became apparent with respect to its functionality and sustainability. In particular, there were two issues that had to be addressed expeditiously and they are detailed in the following sections.

4.1 File size

Based on some previous studies for a structured grid, it was anticipated that the maximum file size would be no larger than about 100 MB. However, it was soon learned that unstructured grid files could be ~ 1 GB and the structured grids could also be larger than first thought. This led to restricted downloading from the VL due to having insufficient space on the Web server to hold both the encrypted and decrypted files in memory simultaneously prior to responding to the request. The consequence of this was that complete files were not available, an unacceptable result. In other instances, the time to download such large files over the internet was excessive for non-USA participants and that led to incomplete files being received.

The adjustments made to accommodate this problem were twofold. First there were IT changes made by both NASA and non-USA participants to address the download time problem. This lead to the download of files that were ~300 MB file in ~ 20 minutes, of which 6 minutes is decryption time on the web-server and is common for any file size. The second change was to implement the use of the CGNS [91] format for grids. This change led to file size reductions from 880 MB to 254 MB and the smaller size has already been demonstrated to be downloadable in a reasonable amount of time. Of course, there will always be the need for some users to create pre-processors to read CGNS formatted files and to put them into a format readable by their particular solver.

4.2 Out-years maintenance cost

The cost of sustaining such a VL was not given much thought when this effort began or during its development because NASA was under one set of financial accounting; however, as full cost accounting became the standard, the situation has changed. The estimate for sustaining the effort based on its initial system layout (Figure 2) was $40-50K/yr. – a value not even sustainable under the old financial system – and included system administrator (SA) services for the web and database servers, as well as the annual license renewal fee for the relational database software.

The adjustments made to accommodate this problem were also twofold. First, move the database server function onto the web-server platform. This resulted in only one machine needing maintenance and that could be done by a part-time SA for ~$10K/yr. The second involved rewriting a small portion of code in order to use **free** relational database software [93], thus avoiding the annual fee. These adjustments led to the current configuration for the AVT-113 VL as shown in Figure 5.

5.0 COLLABORATIVE CAWAPI RESEARCH EXAMPLES

Three collaborative research examples follow: (1) the original purpose; (2) structural grid generation by partners; and (3) a place to upload large files.

5.1 Original purpose

The purpose for the creation of this VL was to allow CAWAPI members to share CFD results, computer images, comparisons and data files in a secure environment while meeting all the restrictions associated with ITAR data. This purpose has been accomplished as attested to by the number of solutions added to the database since the effort started. Moreover, the use of a common data format has facilitated the creation of data comparisons added to the database. Figure 3 shows the list of 'CAWAPI Data Archive' options available to the members and Figure 6 illustrates the user process envisioned by the developers; wherein a member downloads geometry/grids and other data from the archive to obtain a solution and subsequently uploads the CFD grid/solution/results and data comparisons back into the archive.

5.2 Structured grid creation

Space was provided in the VL so that two members of the CAWAPI facet – one at the Netherlands National Aerospace Laboratory (NLR) and the other at the U.K. University of Glasgow (UGlasgow) – could collaborate in the development of the structured grid for their own use as well as for others. This is a risky endeavor even if the developers are co-located or on the same hall, but certainly more-so if they are in two different countries and having to rely on the VL for all grid exchanges. The plan was for the NLR to produce the blocking strategy with implementation and for UGlasgow to adjust the grid spacing, as needed. Alternatively, NLR could produce and test the grid then UGlasgow would perform a second test on the grid before its general release to the facet. In either case, both would use and support the same grid file. For this problem, it turned out that the alternate plan was the one implemented due, in part, to the difficulties experienced with the transfer of large files, noted previously, from this newly developed VL.

5.3 Large file storage

Because the collaborative work area existed, it served another purpose and that was the location to which members could store large files. There were two occasions in which it has proven useful in this regard. The first was the storage of CGNS formatted files for others to download and use in their solvers, but for which no solution existed and therefore not uploadable into the 'Archive a New CFD Run' provided area. The second was the storage of the minutes and presentations from one of the task group meetings. Once the NASA team learned that the zipped file containing this information was stored on the VL, it was downloaded, unzipped and the components placed in their proper location on the VL for access by all facet members, one file at a time.

6.0 COLLABORATIVE VFE-2 RESEARCH EXAMPLES

Two collaborative research examples are available for this facet in advance of its planned data archive system being implemented. They are cited here because the VL was used to transmit needed grid data for this unclassified model between facet members. The fist is the structured grid developed in the USA that was used by Pressure Sensitive Paint experimenters in Germany; and the second is an unstructured grid, also developed in the USA, but reformatted in Sweden and placed on the VL for download by others

7.0 CONCLUDING REMARKS

This paper, after outlining a literature survey of recent citations associated with the technical usage of the virtual laboratory (VL), details the needs of Applied Vehicle Technology task groups for use of such a tool. Among the needs are those primarily associated with team-workspace, document and minutes/presentation storage and retrieval, and higher-ordered meeting facilitation – e-meetings, white-boarding, webex, etc. – with all leading to or enhancing collaborative research. Many of these can be met with existing VL packages or new ones becoming available. However, there can be impediments to collaborative research if data sets are exchanged and a relational-database search capability employed. This is especially true if some of the data are subject to ITAR restrictions and the uploading of new data to the employed mass storage system is restricted to only citizens of one of the participating NATO/PfP nations. The solution to this problem is outlined and examples are provided of collaborative research benefits associated with the latter. Collaborative examples are also provided for the VFE-2 facet.

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9.0 FIGURES

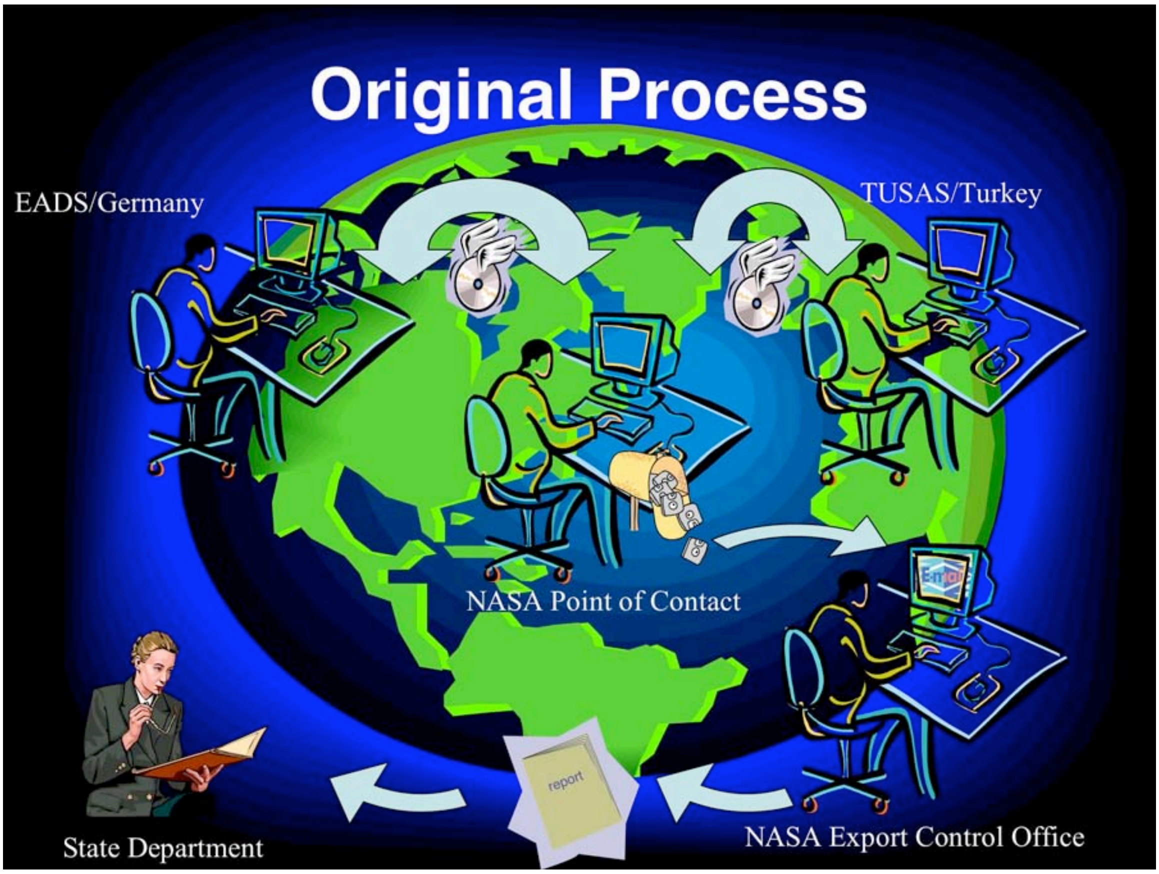

Figure 1. Primitive AVT-113 solution: original process.

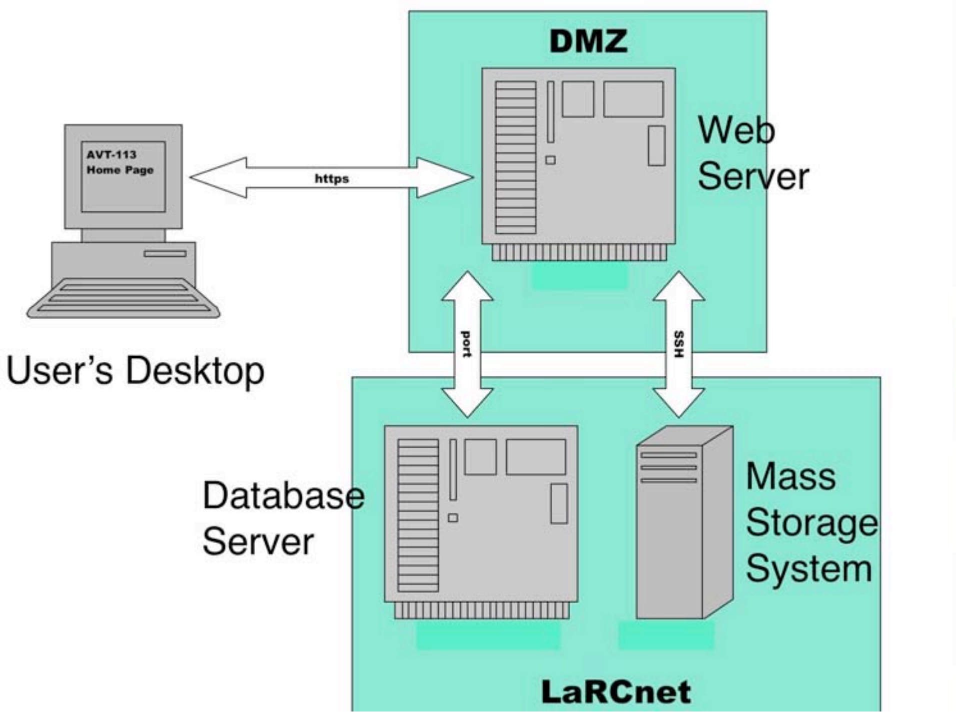

Figure 2. Components needed to create a Virtual Laboratory solution for AVT-113.

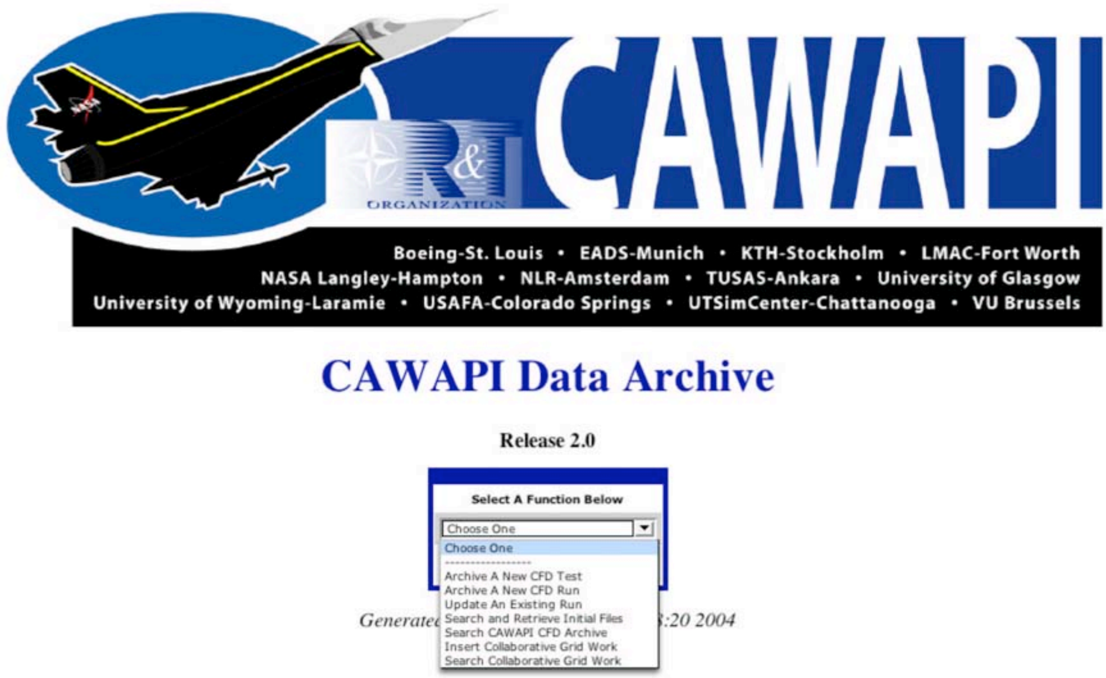

Figure 3. CAWAPI Data Archive options.

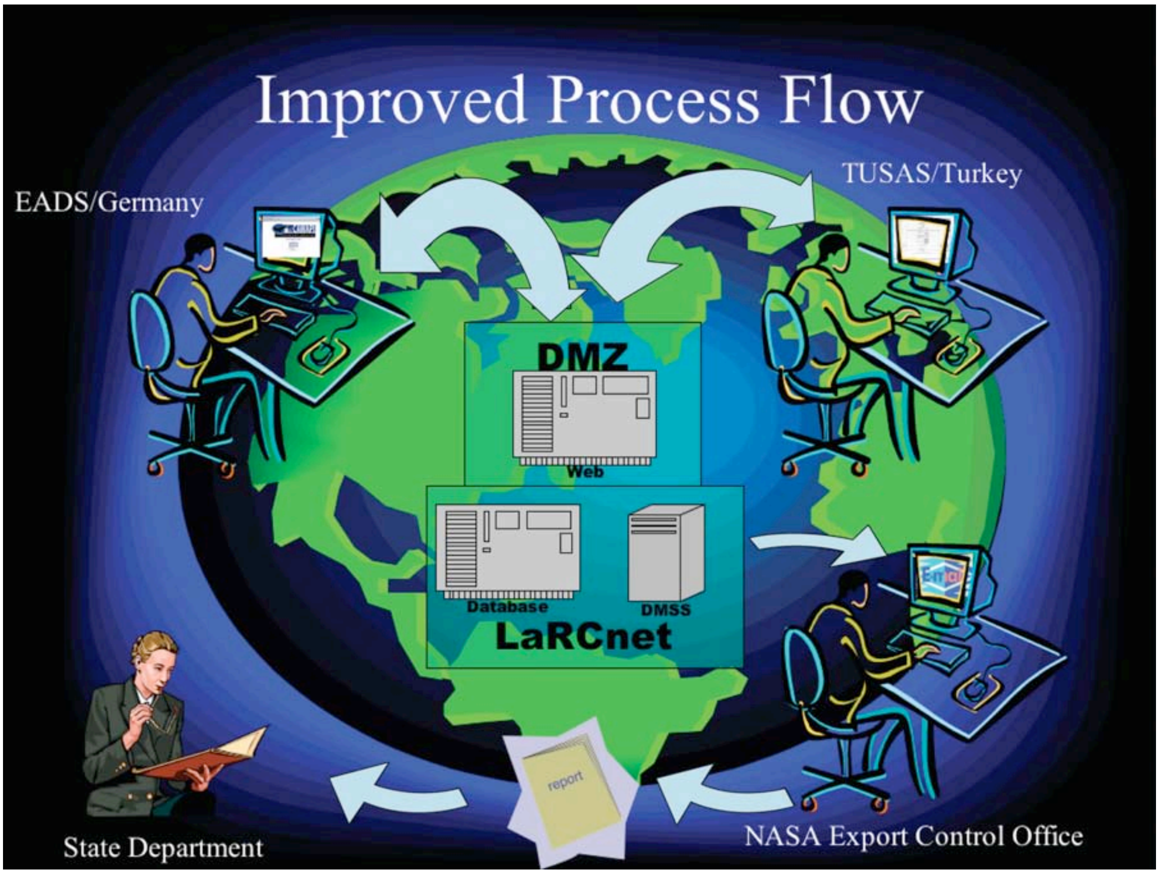

Figure 4. Replacement of primitive solution with Virtual Laboratory: improved process.

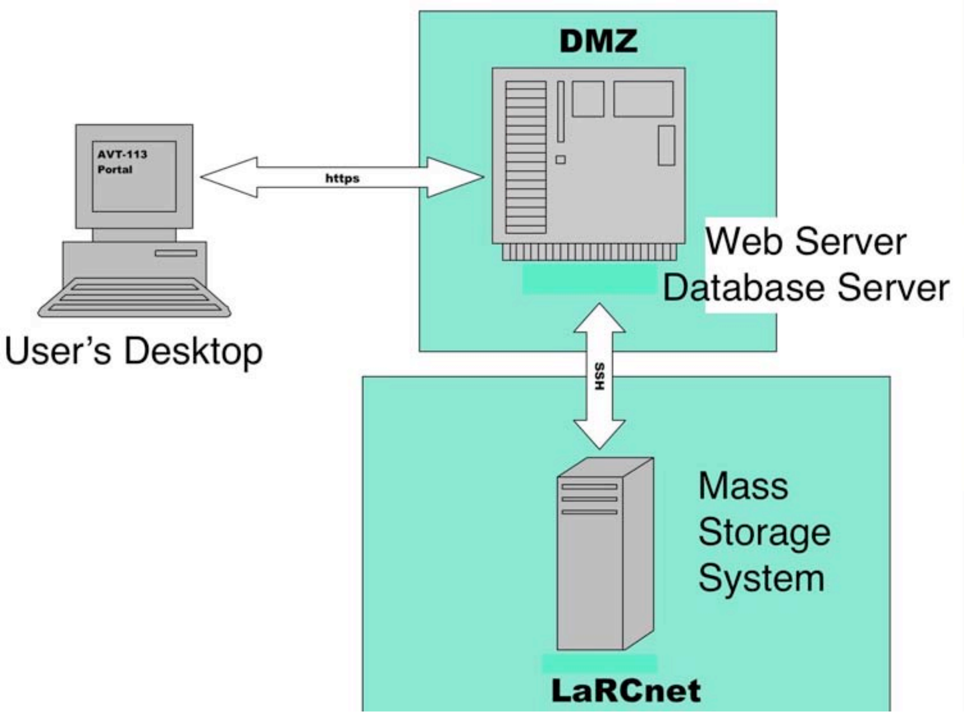

Figure 5. Updated Virtual Laboratory for AVT-113 to satisfy reduced annual cost.

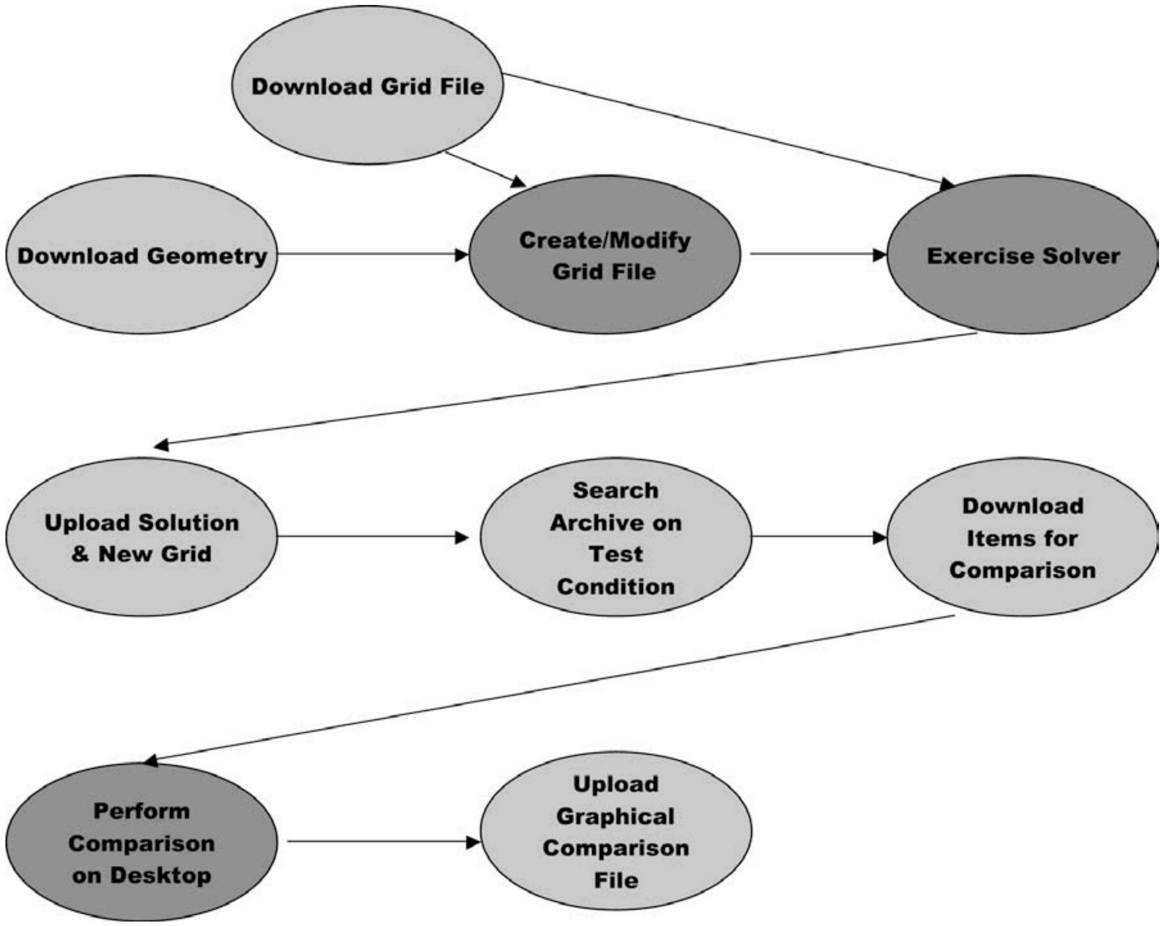

Figure 6. Virtual Laboratory process.