TOOL USE GUIDELINES

Technical Capabilities of CAD & PLM Tools in Terms of Collaboration

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1. Why are CAD, CAE & PLM tools needed inside ELPID Project?

Nowadays, the use of computers aided engineering (CAE) is indispensable, as is the decentralized mode of operation. The decentralized mode of operation was established even before the COVID19 pandemic. Designers are no longer located in the same place but have to work together across national borders. The pandemic has further strengthened this way of working, as people could only work from home office over a long period.

The data exchange between the individual working place and the companies servers has to be secured with the aid of the PLM. On the one hand, this involves data security so that only the employees concerned have access to this data. This can be any type of file, such as CAD or Office files. Another important factor is that no information should be lost. There is a history for each file, where you can exactly track who worked on it. Also, there is no deletion or loss of work statuses if two people are working on a file. By checking out, only the person can edit the file and other people can only see the last status that was checked in. This is valid for design education at Universities in the same way.

ELPID is intended to give students from different universities (Zagreb, Ljublijana, Milano and Vienna) the opportunity to work together across Europe. Due to this geographical separation, the students had to master this fact of cross-border cooperation in joint design challenge even before COVID19, but it was further exacerbated by the pandemic. Since the students also had to work with CAD systems, it is the perfect opportunity to integrate PLM systems as well. This integration is intended to improve and simplify collaboration.

1.1. Product Lifecycle Management

The main task of PLM is the integration of all information that arises during the life cycle of a product. Since the design and production processes are becoming more and more complex, PLM is required to get a complete overview. PLM starts with brainstorming and continues through product development to manufacturing and maintenance. The entire life cycle of a product requires various IT systems and infrastructures.

The management of the data is mainly done by the following systems:

- Engineering Data Management (EDM)
- Product Data Management (PDM)
- Enterprise Resource Planning (ERP)

PDM and EDM are part of PLM. PLM systems also play a key role in enterprise information strategy.

Examples of PLM systems:

- 3DExperience
- Siemens Teamcenter
- PTC Windchill
- CIMDatabase
- Fusion Lifecycle

Examples of PDM systems:

- GrabCAD
- Fusion 360

The current and future development is moving more and more towards merging CAD and PLM systems.

Companies like Siemens integrated PLM (Siemens Teamcenter) into Siemens NX, PTC made deep integration from Windchill to Creo, as well as Autodesk Inventor also offers PLM approaches to its program. With 3DExperience, Dassault Systèmes also focused on combining CAx and PLM.

1.2. CAD Programs

With the help of CAD, the user can create geometric models and edit them. This allows for the creation of individual parts, but also entire assemblies. The complexity of the assemblies is constantly increasing. Furthermore, today's CAD programs offer integrated solutions for CAE (Computer Aided Engineering, e.g. simulation with finite element method) and CAM (Computer Aided manufacturing). The market for CAD programs has continued to change in recent years. Nowadays, companies are increasingly trying to integrate PLM directly into CAD systems or create new platforms where their entire product portfolio of CAx and PLM are embedded. Another trend goes towards developed platforms, where the users directly use the CAD programs in the browser. That has the big advantage of operating system independency and even works on thin clients like tablet and smart phone.

Most of todays CAD programs offer design, simulation (CAE) and manufacturing (CAM) capabilities:

- CAD/CAE/CAM programs:
  - CATIA V5
  - Inventor
  - SolidWorks
  - 3DExperience
  - Fusion360
  - Siemens NX
  - PTC Creo
  - …
- Computer Aided Engineering (CAE)
  - MSC Software
  - SimCenter STAR CCM+
  - Ansys Simulation
  - Comsol Multiphysics
  - Dassault Simulia
  - …
- Virtual Reality
  - 3DExperience
  - Fusion360
  - PTC Vuforia
  - …

2. How can CAD, Office programs and PLM be linked or integrated into each another?

Actually, there are three approaches for the connection and integration of different CAD programs in the PLM program.

The following table shows the three main approaches.

Type of PLM	Features	Examples
PLM and CAD as a unit	The CAD system is permanently connected to the PLM system, both are developed by one manufacturer	Dassault 3DExperience Autodesk Fusion 360
PLM and MultiCAD	The PLM system works with several CAD systems, optimal integration is in the inhouse CAD system	Siemens TeamCenter with NX PTC Windchill with Creo
PLM as stand-alone program and MultiCAD	The PLM system is offered as a stand-alone product by the company that does not develop its own CAD and provides CAD interfaces	Contact CIMDatabase PLM ARAS PLM, Eigner PLM SAP PLM

2.1. PLM and CAD as a unit

This approach corresponds to the current and future development. PLM and CAD are offered by the same company and have been coordinated. By combining these programs, usability and manageability are increased. Since everything takes place in one single program environment, the user no longer has to get used to new program interfaces. The 3DExperience and Fusion Innovation Platform programs are currently working with this approach. Another approach is to no longer make the applications computer-bound, rather the licenses are bound to the user. This enables the user to work on his project from anywhere. Browser-based means that the user directly works in his browser (MS Edge, Google Chrome, etc.). No additional software is required. The user only has to have the appropriate rights for his activity in order to use the respective programs in the browser

This approach, which includes the fusion of PLM and CAx, opens many new possibilities. Due to this implementation, development times and costs can be reduced.

This opens a lot of new advantages:

- Due to the direct storage in the cloud or on the company's own servers, there can be no more data loss in case of workstation fault, theft ore loss of USB data storage.
- The direct integration of PLM and community aspects makes it much easier to implement projects. The people involved are always in direct contact and are always kept up to date.
- Another advantage is the involvement of suppliers and project partners. Their integration is relatively simple and intuitive and everyone can be assigned their own roles and rights
- The complete project management takes place directly on this platform, so everyone is in the picture about deadlines, to-dos and the other projects
- The companies can design their platform individually and have complete control over all settings and can configure them as needed.

Due to the cloud principle and on-premise principle, some disadvantages can also arise:

- With on-premise, companies incur high costs in the maintenance of its infrastructure.
- Furthermore, the servers must be adequately protected against unauthorized access.
- The cloud-based approach must have a sufficiently stable and strong internet connection, otherwise, there will be considerable waiting times when saving and loading.
- There are separate interfaces necessary for external programs, fully integrated solutions are not open for MultiCAD Envirenoment in the same way as with standalone PLM.

2.1.1. 3DExperience

3DExperience from Dassault Systèmes combines all design products in one platform. With a uniform, easy-to-use user interface, it drives industry solutions based on 3D design, analysis, simulation and intelligence software in a team-oriented, interactive environment. The 3DExperience platform is geared towards collaboration for innovation.

There are two ways to use 3DExperience:

- **3DExperience on Cloud**: 3DExperience runs directly in the cloud on the Dassault Systemes servers.
    - A major advantage of the 3DExperience on Cloud version is that there are no investments in the area of network infrastructure and server infrastructure for the end customer or the company. Dassault Systèmes provides the complete network and server infrastructure.
    - A major disadvantage for 3DExpierence on Cloud is that the end customer or the company depends on the IT infrastructure of Dassault Systèmes. As soon as this fails or is serviced, the users do not have access to their data and therefore no possibility to continue their work. Furthermore, there is also a possible data security problem since it is on external servers. Internet connection speed can also be a problem.
- **3DExperience on Premise**: The entire platform runs on the company's servers. All settings are managed directly by the company. Companies can configure the platform as they need it.
    - The biggest advantage of 3DExperience on premise is that the entire projects and data do not leave the IT company infrastructure, since storage and calculation takes place directly on the own servers. This lowers the risk of industrial espionage. Another great advantage is that the entire 3DExperience can be configured as the company needs it. Also own roles can be defined. Furthermore, updates and changes to the programs can be made if they do not hinder the workflow.
    - A major disadvantage are the high investments in the area of the network and server infrastructure. This infrastructure must also be maintained and kept up to date.

The Dassault Systèmes programs were divided into the following 4 divisions in 3DExperience:

- **3D**: in this section, you can find all programs that are required for 2D and 3D design. (Sketching, Freeform Modeling, Parametric Modeling, Assemblies, Sheet Metal Design, etc.)
- **V+R**: This section contains all apps and programs that are required to create different simulations. The results of one simulation can be passed on to another simulation. (Finite Element Analysis, Topology optimization, Computational Fluid Dynamics, Multi-Body Simulation, Rotordynamics, etc.)
- **Social Apps**: In this section are all apps that are required for the internal social platforms. All communities can be viewed here.
- **Apps for information Intelligence**

Fusion 360 is a cloud platform that enables users to collaborate on projects, review designs and versions and provides the possibility to share ideas instantly.
It offers several features to the user:

Concept design and 3D Modelling
Sketching, Freeform Modeling, Surface Modeling, Direct Modeling, Parametric Modeling, Assemblies, Sheet Metal Design, etc.

Prototyping and Fabrication
CAM, Rendering, 3D Printing Toolpaths

Integrated Simulation
Finite Element Analysis, Topology optimization

Documentation
2D Manufacturing Drawings, Rendering, Animation

Product Data management
Administrative tools, User Management, Version Control, Cloud Storage

Collaboration
Enables distributed development, direct feedback on a design, Data can be accessed anywhere, Public/private design sharing, Set project deadlines and milestones

Fusion 360 can be used in offline mode only temporarily, but it is currently not possible to entirely switch to offline workflows. Also, there is no option to use individual on-premise solutions.

Advantages of the integrated cloud application:

- Cloud storage prevents data loss
- Operations that normally use up local computational resources can be solved by cloud computation (e.g. finite element simulation)
- CAD Models do not have to be exported for analysis
- Version Control enables the user to track changes and prevent conflicts through version management
- Internal and external stakeholders can be included in the development process through sharing options
- Feedback can be given directly in the design which makes the exchange of information very easy
- Data can be accessed from various locations and operating systems
- The offline mode enables continues workflows in the case that servers incur problems (but only temporary)
- Implementation of the whole system is easy and cheap

Disadvantages:

- Dependency on external server resources and stability
- Strong dependency on a stable internet connection
- Entrusting the security of proprietary documents to third parties

Autodesk Fusion has no Product Lifecycle Management tool included per se but can be complemented by Fusion Lifecycle and Fusion Connect, completing the triumvirate that Autodesk's Product Innovation Platform has to offer.

Fusion Lifecycle offers Product Lifecycle Management, whereas Fusion Connect is an Internet of Things (IoT) Cloud Service to easily connect, analyze, and manage digital twins.

2.2. PLM and Multicad

In this combination of CAD and PLM, the company develops both programs. Due to the simultaneous development of the programs in one company, PLM and CAD were developed directly to each other. It is also possible to operate this PLM system with external CAD programs over interfaces.

2.2.1. Siemens Teamcenter

Siemens Teamcenter is a widely used PLM software. Teamcenter makes it easier to control product data and processes, including 3D designs, electronics, embedded software, documentation and parts lists (BOM). Teamcenter can be flexibly adapted to business changes to meet all the challenges of product development. Siemens Teamcenter is integrated deeply with Siemens NX CAD software, but it is also possible to work with other CAD programs.

The subsequent points can be incorporated and managed in Teamcenter:

- **Adaptable PLM Foundation**: This is the base PLM engine in Teamcenter. The system can be used in three ways:
  - On-premise
  - Cloud
  - Pre-configured
- **Bill of Materials Management**: With this function, the entire parts list information can be managed.
- **Change Management and Workflow**: With the help of this function, the customer can reduce the costs for administration and tracking of PLM processes. This function can also be used across departments. The aim is to make the right decisions based on the right data at the right time
- **Document Management and Publishing**: With this tool, product documentation (2D / 3D derivations, spreadsheets, analysis reports) should be created with a high level of accuracy and effectiveness.
- **Electrical design management**: With this solution, all E-CAD data can be automated in the various processes (modification, validation and approval).
- **Environmental Compliance and Product Sustainability**: With this tool, the sustainability requirements for the environmental compatibility of the applicable regulations can be met.
- **Manufacturing data and process management**: People, systems and production planning are to be connected. The entire process knowledge is collected and managed. This procedure should lead to a continuous improvement of the processes.
- **Materials Data and Lifecycle Management**: This tool is used to manage the lifespan of all materials used in the products.
- **Mechanical design management**: Teamcenter combines all mechanical computer aided design data in one environment. The integration, validation and approval processes are to be automated through this integration. This leads to a reduction in throughput times and an improvement in product quality.

- **Model-Based Systems Engineering**: With this tool, Teamcenter brings together the individual disciplines of mechanical engineering and the connection with the aspect of cost and reliability
- **Product Configuration**: With this tool, the user is able to meet the demand for advanced and diverse product offers without increasing costs.
- **Product Cost Management**: This enables the user to make a cost calculation very early in the development process.
- **Product requirements engineering**: With the help of Teamcenter, the user is able to assign requirements to various downstream functions. Reports and documentation can be created automatically at the same time.
- **Planning and Project Execution program**: With Teamcenter, integrated planning and performance of complex products can also be created. This should facilitate cooperation between individual departments.
- **Search and Analytics**: Teamcenter is able to organize search results into logical groups. This can be especially helpful for the compilation of data of the entire life cycle from several data sources.
- **Simulation management**: The CAE and system simulations are managed and made accessible to all decision-makers.
- **Software design and asset management**
- **Sourcing and Supplier Integration**: This part of Teamcenter helps with collaboration and interaction with the suppliers.
- **Visualization, Digital Mockup and Virtual Reality**: All participants can access the data in Teamcenter and work together with this. In Teamcenter, virtual prototypes are created so that no physical models have to be created.

2.2.2. PTC Windchill

Windchill is PTC's industry-leading PLM software. The open architecture enables easy integration with other company systems. With the help of out-of-the-box functions and configurable, role- and task-based apps, users can extend access to valuable product data to stakeholders who do not usually use a PLM system without excessive adaptation and complexity. Windchill offers manufacturers who face digital transformation a solid foundation for an intelligently networked company. Thanks to a digital thread of information, manufacturers can create a digital twin, invest in IIoT technology, improve collaboration with augmented reality or explore generative design and additive manufacturing.

- **Product Data Management**: Manage multi-CAD data in a single system using tight integration with PTC Creo and all other common CAD systems.
- **BOM Management**: is used to configure and manage the Bill of Materials
- **Change and Configuration Management**: Make dynamic, coordinated changes across the enterprise to deliver accurate, real-time information.
- **Platforms, Options, and Variants**: Design with platform structures and manage options and variants
- **Manufacturing Process Planning and Work Instructions**: Ensure manufacturing planning and product development
- **Quality Management**: Continually improve the quality of the product and reduce service instances

2.3. PLM as single program + MultiCAD

In this combination, a company develops an independent PLM program. This means that there is no definition or favoritism of the in-house CAD program. The PLM system can be integrated into any CAD program.

2.3.1. CIMDatabase

CIM Database is an open, scalable system for PLM by Contact Software. It enables improved collaboration and accelerates processes within projects as well as beyond project boundaries. Another advantage is the open system architecture. This makes it relatively easy to add other technologies, such as Python or other services.

The system is based on the following points:

- **Use virtual product models for digitization**: This means that the data and processes can be used digitally and thus significantly more efficiently, from the first ideas to release in production. The use of digital models simplifies frontloading and helps to make decisions faster and to avoid costly changes. Virtual product models bring together a lot of information along the product creation process. For this, users need navigation and visualization functions that create transparency. CONTACT's Elements User Experience System supports users in optimally using their competence.
- **Promote collaboration - share documents and knowledge**: With the Single Source of Truth principle, your employees access the same information and share their knowledge throughout the company. For this, your employees have powerful integrations for MS Office, e-mail and CAD, the viewing of all common office, CAD and multimedia formats, reliable change and release procedures and fast research functions in the entire database.
- **Execute PLM processes with best practices and templates quickly and reliably**: The consistent definition and implementation of best practices make processes much more efficient and with the help of compliance management safer. This creates a more reliable and efficient interaction between employees and day-to-day business. Product development is characterized by a high degree of division of labour. The elimination of manual processes by digital processes leads to an improvement in the overall output
- **Combine project control and processing in a methodically perfect way**: With Agile Rules, CIM Database offers the best methodology to combine control and execution in projects. This procedure benefits the entire product life cycle. The main challenge is to work on changes within reliable limits. The functions need to leave both bottom-up and top-down
- **Connect systems for current data anywhere in the company**: CAD data and circuit diagrams are a central component in the development process. Use workspaces for cross-company collaboration with partners and suppliers. Use it to exchange CAD and product data more easily and securely. Thanks to the open architecture, SAP can also be integrated.

GrabCAD is a complete CAD collaboration tool and enables an easy exchange of cad files. The system prevents duplicate work and enables every engineer to work on a project. GrabCAD is not a real PLM system, but a PDM system.

It has the following features:

- **User-controlled desktop syn**c: Link desktop files to files in online Workbench projects and upload changes when you choose, keeping local files up to date.
- **Works inside your CAD system**: Upload and download files as well as resolve conflicts through an add-in to your CAD system
- **File locking:** Lock files for exclusive edit while letting the rest of the team know. Project owners can always override the lock.
- **Download as neutral format**: Save a Workbench CAD file in a neutral (STEP, IGES, STL) format even if it's uploaded in a proprietary format.
- **Partner Spaces**: Release product data to customers and manufacturers without them seeing all of your project data - or each other.
- **Visual version comparison**: Visually overlay two versions of a model to see what has changed.
- **Revision management**: Ensure that your team is always working off the right version to avoid wasted time and manufacturing mistakes.
- **Automatic version backup and restore**: Automatically tracks file versions, lets you browse version history, and instantly restore older versions.
- **CAD agnostic**: Supports all major CAD formats
- **Web-based viewing of CAD models and drawings**: Anyone can immediately see and markup a CAD model right in their web browser - no downloads or installs.
- **Markup and communication tools**: Markup tools let viewers start conversations and create sketches right on the model, while email alerts keep team members up to date.
- **Available anywhere**: Mobile application let users work from anywhere and share models with others away from their desktop.

2.4. Which approach to choose?

In educational environments at universities it is often necessary to have different CAD systems in use. The license costs are usually low and students have different prior knowledge from technical schools. An open solution of the independent PLM with integrated MultiCAD interfaces is ideal here. Participants in project-based courses thus have a common PLM user interface and can still work with different CAD systems within the project.

In industrial use, on the other hand, the advantages of a fully integrated CAD-PLM approach predominate. The support, which is extremely important in the productive environment, comes entirely from one manufacturer and there is less downtime due to incompatibilities or interface problems.

In the university environment, on the other hand, it can be an exciting challenge to operate this MultiCAD environment with all its problems and to help improve standards for data exchange.

3. PLM and communication programs used during ELPID

The main advantage of PLM system is the fact that they work with check in and check out functions as well as version controls. Other programs can also be used to only serve the purpose of data storage and transfer. In this case, however, the security of version control and protection against mutual overwriting during storage and simultaneous editing are not given. In the 3 years of ELPID course, the students used a wide variety of different PLM and communication programs. These were partly given by the supervisor or the students were allowed to choose the program by themselves. During the cwork on the design challenge came up various problems as a result. Therfore in this section feedback from students about advanteges and withdraws of the different systems are collected.

3.1. WhatsApp, Telegram and other

The student also used messenger services for partial data exchange.

advantages	disadvantages
quick exchange of data and all members in the group will be notified.	The data is stored on servers which may not comply with the GDPR.
	Version control and mutual deletion cannot be prevented through simultaneous editing

3.2. OwnCloud

OwnCloud was used during ELPID for the backup and transfer of data. The OwnCloud was hosted by the Technical University of Vienna, so all data could be safely managed according to GDPR.

Some of the students also used the OwnCloud as a pseudo "PLM" system and processed the cad data directly.

The direct editing was realized with the help of the OwnCloud client. The data was compared directly with the server and saved.

advantages	disadvantages
By self-hosting the OwnCloud storage software, the GDPR was fulfilled.	There is no real version control and the files are not protected against simultaneous processing, which can lead to data loss.
The access of the individual group members could be precisely determined, and the protection of the data guaranteed.	The host is responsible for the installation and maintenance as well as the IT infrastructure
Using the client, it was relatively easy to send the data directly to the server	

3.3. Dropbox

Dropbox was also used by the students during the courses to exchange their data. Problems like those with OwnCloud arise here.

advantages	disadvantages
Dropbox is a ready-made solution and is freely accessible. Every user has 2 GB of storage free of charge and only has to pay for additional storage space. The user does not have to worry about the IT infrastructure or the maintenance of the program.	There is no real version control and the files are not protected against simultaneous processing, which can lead to data loss.
Individual access can be precisely controlled	After Dropbox is a US group, attention must be paid to GDPR-compliant implementation. Because the students also work with files from the industrial partners.
With the help of the Dropbox client, the data can be transferred directly to the server and at the same time you work in a familiar file system. You do not need to call up the Dropbox page.	

3.4. One Drive

Microsoft OneDrive is the youngest member of the cloud storage platforms. However, this platform has significant advantages over the cloud providers described above.

advantages	disadvantages
OneDrive offers a direct connection to all Microsoft products such as Office applications and MS Teams. OneDrive and Teams have been increasingly used by ELPID over the past two years with the advent and persistence of COVID19	The data is on the Microsoft server and of course must comply with GDPR.
Thanks to the direct connection of OneDrive, Teams and Office, Office documents could be edited by several people at the same time. As a result, automatic version control was also achieved for Office documents.	Version control and simultaneous editing only work with Microsoft products, such as Office programs. There is no PLM functionality for CAD data
For students there are free accounts directly from Microsoft, but Microsoft accounts can also be requested from the universities.	

3.5. 3DExpierence

The 3DExperience from Dassault Systèmes was used on cloud with licenses from TU Wien. That means all data storage and communication is handled by servers at Dassault Systèmes.

advantages	disadvantages
Due to the direct storage on the cloud or on the company's own servers, there can be no more data loss if computers break.	With the on-premise variant, companies incur high costs and effort in the area of IT infrastructure.
The direct integration of the PLM and community aspects makes it much easier to implement projects. Because the people involved are always in direct contact and are always kept up to date.	Furthermore, the servers must be adequately protected against unauthorized access.
Another advantage is the involvement of suppliers and project partners. The integration of these is relatively simple and intuitive and to everyone can be assigned their own roles and rights	The cloud-based variant must have a sufficiently stable and strong internet connection, otherwise there will be considerable waiting times when saving and loading.
The complete project management takes place directly on this platform, so everyone is in the picture about deadlines, to-dos and the other project plans	For the CAD functionality the users have to download and install a huge software package. Browser connectivity works only for data management.
The companies can design their platform individually and have the complete control over all settings and can configure them as they need them.	
There are also separate interfaces for Dassault programs, which are still independent, but also for external programs	

3.6. Autodesk Fusion

Fusion 360 is a cloud platform that can only be used in offline mode temporarily, but it is currently not possible to entirely switch to offline workflows. Also, there is no option to use individual on-premise solutions. Autodesk Fusion has no Product Lifecycle Management tool included per se but can be complemented by Autodesk Fusion Lifecycle.

advantages	disadvantages
CAD Models do not have to be exported for analysis	Dependency on external server resources and stability
Operations that normally use up local computational resources can be solved by cloud computation	Strong dependency on a stable internet connection
Cloud storage prevents data loss	Entrusting the security of proprietary documents to third parties
Version Control enables the user to track changes and prevent conflicts through version management	Dependency on external server resources and stability
Internal and external stakeholders can be included in the development process through sharing options	
Feedback can be given directly in the design which makes the exchange of information very easy	
Data can be accessed from various locations and operating systems	
The temporary offline mode enables continues workflows in the case that servers incur problems	
Implementation of the whole system is easy and cheap	

3.7. GrabCAD Workbench

GrabCAD Workbench is a PLM cloud service which is stand-alone. There are integration modules, whith them GrabCAD can be inserted directly into the common CAD programs. This considerably simplifies the editing of CAD files.

advantages	disadvantages
It is easy to create an account and thus set up a joint project with the other students.	The data is on an external server and must again comply with the GDPR, as data from the industrial partners have also been processed.
At the same time there is a large database for CAD models in GrabCAD	
Version controls and revisions can be carried out. this secured the students against the loss and overwriting of their data	

3.8. CIMDatabase

CIMDatabase is a stand-alone PLM system and so above all it promotes faster and better collaboration and the simplification of processes within but also outside of a company. Users can also implement their own solutions in CIMDatabase with Python. A major advantage is that there are interfaces for many programs (Office package or CAD programs) that allow direct implementation of the PLM program.

It was planned to use the PLM program in the course of 3rd year for a group, but due to setup difficulties and delays it could not be used and therefore no direct experience of the advantages and disadvantages could be recorded.