20th ISPE International Conference on Concurrent Engineering
C. Bil et al. (Eds.)

doi:10.3233/978-1-61499-302-5-560

A Low Cost CDF Framework for Aerospace Engineering Education based on Cloud Computing

Dajun Xu[a,1] , Cees Bil[b] and Guobiao Cai[a]
[a] *School of Astronautics, Beihang University, Beijing, China*
[b] *School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Australia*

Abstract. Concurrent Design Facility (CDF) is an effective and efficient manner to implement Concurrent Engineering methodology. In aerospace engineering education, CDF is invaluable to lecturers by enabling the entire student team to gain cross-discipline skills and at the same time stay at the cutting edge of technology. Establishment of CDF is always consuming much money on hardware and software. This paper presents a low cost CDF framework which is suitable for aerospace engineering education in class room based on cloud computing. An important aspect of CDF is collaboration between multidisciplinary specialists or virtual specialists in the environment of engineering education. Collaboration in CDF requirement some dedicated hardware or software to exchange file, manage knowledge, collaborative work on writing report, and even remote communicate with other work teams in traditional means. Emergence and development of cloud computing have made above-mentioned requirements become very easy to be fulfilled. Some public cloud computing servers, such as Google Drive, SkyDrive, Dropbox, Mendeley, can be used in CDF for education to save investment on hardware and software related to data, file, and information exchange. Google Talk and Skype can be used to remotely communicate with work team at other location. This CDF framework has many benefits, include low cost on hardware, software and human, reduce preparation time, and easy to deploy in classroom education.

Keywords. Concurrent Design Facility, Aerospace Engineering Education

Introduction

Concurrent Design Facility (CDF) is a workspace and information system allowing multidisciplinary experts working in a focused environment and conducting design collaboration. The development of CDF has a history of near 20 years from the first facility PDC was opened in 1994 [1]. Up to now, more than 20 CDFs [2]~[26] have been established around the world and they have been implemented to design aircraft, spacecraft and space mission.

With the rapid developing of new technologies, aerospace industry is facing the huge challenge that how to design aircraft or spacecraft mission in a fast and low cost manner. There are many design alternatives need to be evaluated and screened. CDF

[1] Corresponding Author. xdj@buaa.edu.cn

based on concurrent engineering methodology is an effective and efficient approach to solve this problem. Applications of modern information systems enabled fundamental improvements to the system engineering process through the use of real time concurrent engineering. Many design teams have demonstrated dramatic savings in time and money compared with the traditional process for systems conceptual design. CDF is effective and efficient has been proven by design cases and experiences of research team which apply CDF in their work. Many industry and academic research institutes in the field of aerospace are implementing or are developing their own CDF. It is obvious that more aerospace vehicle designs and flight mission assessments will be conducted in CDF and aerospace engineering education in the CDF environment will also be a trend in many universities.

This paper summarize some CDFs in universities for aerospace engineering education and based on analysis of essential requirements of a general CDF a low cost CDF framework is presented, which is suitable for aerospace engineering education in class room based on cloud computing. An important aspect of CDF is collaboration between multidisciplinary specialists or virtual specialists in the environment of engineering education. Collaboration in CDF requirement some dedicated hardware or software to exchange file, manage knowledge, collaborative work on writing report, and even remote communicate with other work teams in traditional means. Emergence and development of cloud computing have made above-mentioned requirements become very easy to be fulfilled. Some public cloud computing servers, such as Google Drive, SkyDrive, Dropbox, Mendeley, can be used in CDF for education to save investment on hardware and software related to data, file, and information exchange. Google Talk and skype can be used to remotely communicate with work team at other location. This CDF framework has many benefits, include low cost on hardware, software and human, reduce preparation time, and easy to deploy in classroom education.

1. CDF for Aerospace Education

University as an academic research power always stands at the leading edge of new technology. Some universities had paid attention to CDF at the beginning of it emerged, and they also have established their own CDFs to study this new design methodology for aircraft or spacecraft. These CDFs are also applied to aerospace engineering education.

1.1. Design Environment for Integrated Concurrent Engineering (DE-ICE) at MIT

A teaching concurrent engineering environment can be found in the Design Environment for Integrated Concurrent Engineering (DE-ICE) at MIT. This center is 14 design stations and two projectors. PCs are not provided in the environment as each student receives a campus laptop upon entering the college. The facility is designed around two modes: design mode and teaching mode [6] .

1.2. Space System Concept Center (S^2C^2) at Technical University of Munich

The Technical University of Munich has also developed a concurrent engineering environment as a teaching tool. Using approximately 10 user stations, the environment

provides students with hands on exposure with tools and methodologies used in the aerospace industry. Excel based models are used to integrate the design and MuSSat is used to allow the students to design as he or she finds the time [6].

1.3. Laboratory for Spacecraft and Mission Design (LSMD) at California Institute of Technology

The Laboratory for Spacecraft and Mission Design (LSMD) at California Institute of Technology was developed in 1999 and is modeled after JPL's PDC. It currently houses three Macintosh and five PCs and is primarily used as a teaching tool. The LSMD uses self-developed tools to teach students about concurrent engineering design over the course of a semester. Since the design is drawn out over the course of a long period of time, little has been required in the form of automation of the processes [6].

1.4. Space Systems Analysis Laboratory (SSAL) Concurrent Engineering Facility at Utah State University

Utah has a growing interest in space system design and has, for two reasons, established a concurrent engineering environment. The first and foremost is to augment the existing space research teachings at the university. The second is to perform system level designs on space systems. They chose the PDC and CDC as models for development of an in house center and intend to team with other centers to test distributed concurrent design in the near future [13].

1.5. The Collabrative Design Environment(CoDE) at Georgia Institute of Technology

CoDE belongs to The Aerospace Systems Design Laboratory (ASDL) of Georgia Institute of Technology. The objective of CoDE is to rapidly execute collaborative design conceptualizations by fostering designers' creativity in multidisciplinary design teams. The environment set out with two missions: "Enhance the fidelity of simulation models for design space exploration and robust design methodologies," and "create a national asset for the development of next-generation conceptual design facilities and approaches" [14][16].

1.6. Concurrent Design Facility at International Space University

the International Space University (ISU) received its own Concurrent Design Facility (CDF) under the continued support of the European Space Agency (ESA). This facility comes to open the possibility to ISU's students of getting to know the principles of Concurrent Engineering and its means of application. During the two years of operations of the ISU CDF, workshops and assignments for some of ISU's programs were devised and put into practice where technical and non-technical students are exposed to the process of Space Mission Design applying Concurrent Engineering, in particular to Remote Sensing and Telecommunications spacecraft design [20].

2. Essential Requirements of a General CDF

2.1. Team, Hardware, and Software

The paper [27] compared collaborative engineering environments that are reported in the literature with respect to three specific aspects: software, hardware, and peopleware configurations. A taxonomy was presented in it to fully describe each of the different environments. Using this taxonomy, an intersecting set of features from these environments may be used to develop future environments for customized purposes.

In modern engineering, design software has taken an enormous role. These tools are now commonplace and used to communicate business, financial, and technical information. There is numerous software required or desired to operate a successful concurrent engineering environment. They include software to facilitate collaboration, support analysis, support integration, perform modeling, and to support visualization. Further, these software packages can be commercial off the shelf (COTS) items, modified COTS, and custom in house software tools. Different combinations of software are found in each CEE.

Another key consideration in establishing a concurrent engineering environment is the electronic/computational hardware. The hardware serves many different functions within the environment including supporting the individual engineer/designer, servers to tie the individual hardware components together, visualization hardware, communication hardware, and individual domain specific pieces of hardware. All of these hardware items work in concert to support the concurrent engineering activities within the environment. Hardware for the individual engineer may include permanent desktop systems, mobile preconfigured systems within the CEE, and support for external mobile systems. Like the software, multiple combinations of hardware solutions are deployed at the concurrent engineering facilities around the world and no one solution stands out as the best.

The final key aspect is how human beings interact with each other and the design, peopleware. Although engineering design is meant as a technical activity, it truly functions as a social activity. It was confirmed that team introductions, pooling of knowledge, and team maintenance accounts for 10-20% of design time. At the heart of concurrent engineering lie five distinct decision areas when establishing a concurrent engineering environment: the roles of the team members, definition of process, team formation strategies, who addresses conflict, and how concurrent is the operation of the environment.

2.2. Essential Requirements of a General CDF

A survey of concurrent engineering environments (CEE) was presented in the paper [27] and summarized key similarities and key differences of those CEEs. The peopleware is a key aspect for CDF, but the first step to establish CDF is to prepare software and hardware. The bigger part of investment to establish CDF will be put on hardware and software, thus essential requirements of a general CDF are tabulated in Table.1. Satisfying these requirements would make CDF has basic capabilities and functions to analyze, simulate, integrate, exchange data, visualize design status and communicate with remote design center.

Table 1. Essential Requirements of a General CDF

		Essential Requirements of CDF
Hardware	Workstation	PCs Interface for Laptops
	Server	Information Server
	Visualization	Projectors Smart Board
	Communication	Audio Systems
Software	Collaboration	Commercial: [Novell]
	Analysis	Commercial: [….; in house tools]
	Visualization	Commercial: [Pro/E; CATIA; Solidworks]
	Integration	Commercial: [iSight; ModelCenter]
	Modeling	In house tools: [Excel+VB]

3. A Collaborative Architecture based on Cloud Computing

3.1. About Cloud computing

The term 'Cloud Computing' emerged in publications in the year 2009. Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [28].

3.2. Requirements of Collaboration in CDF

An important aspect of CDF is collaboration between multidisciplinary specialists or virtual specialists in engineering education. Collaboration in CDF require some dedicated hardware or software to exchange file, manage knowledge, collaborative work on writing report, and even remote communicate with other work teams in traditional means. Requirements of collaboration in CDF can be summarized as four items: document collaboration, file exchange, knowledge management, and remote communication. In CDF, Spreadsheets are usually used as a simple integrated model collecting data from each specialist and calculate performance of vehicle or system. Many files, such as CAD file, need to be sent to other specialist for flow field simulation or structure analysis. Some literatures related to current project need to be managed and classified. Sometimes remote communication is also necessary to connect with people who are at other location.

3.3. Collaboration based on Cloud Computing

A general CDF usually are equipped with dedicated hardware and software to realize requirements mentioned above, such as information server and communication software, and those equipments will consume much funds. But now this problem will be solved by cloud computing with low cost. Table 2 show a solution for collaboration in CDF based on cloud technology.

Table 2. Collaboration based on Cloud Technology

Requirements of Collaboration in CDF	Options based on Cloud Technology
Document Collaboration	Google Drive (Google Docs)
File Exchange	Dropbox, or SkyDrive
Knowledge Management	MENDELEY
Remote Communication	Google talk, or skype

Google Drive is a file storage and synchronization service provided by Google, released on April 24, 2012, which enables user cloud storage, file sharing and collaborative editing. Google Drive is now the home of Google Docs, a suite of productivity applications, that offer collaborative editing on documents, spreadsheets, presentations, and more [29][30].

Dropbox is a file hosting service operated by Dropbox, Inc., that offers cloud storage, file synchronization, and client software. Dropbox allows users to create a special folder on each of their computers, which Dropbox then synchronizes so that it appears to be the same folder (with the same contents) regardless of which computer is used to view it. Files placed in this folder also are accessible through a website and mobile phone applications [31]. SkyDrive is also a file hosting service and has some similar function with Dropbox, but It can integrated with Microsoft Office [32].

Mendeley is a desktop and web program for managing and sharing research papers, discovering research data and collaborating online. It combines Mendeley Desktop, a PDF and reference management application (available for Windows, Mac and Linux) with Mendeley Web, an online social network for researchers. Mendeley requires the user to store all basic citation data on its servers - storing copies of documents is at the user's discretion. Upon registration, Mendeley provides the user with 2 GB of free web storage space, which is upgradeable at a very low cost [33].

Google Talk is an instant messaging service that provides both text and voice communication [34]. Skype allows users to communicate with peers by voice using a microphone, video by using a webcam, and instant messaging over the Internet. Phone calls may be placed to recipients on the traditional telephone networks. Calls to other users within the Skype service are free of charge, while calls to landline telephones and mobile phones are charged via a debit-based user account system. Skype has also become popular for its additional features, including file transfer, and videoconferencing [35] .

3.4. Benefits

Applications of cloud technology in CDF environment will bring some benefits. First, the costs on hardware, software, and human are reduced, as dedicated equipment and software are not needed to purchase and there is no need to employ persons to maintain computer system. Secondly, preparation time is saved then project of establishing CDF will be completed in advance. Third, all these cloud technologies are familiar to almost everyone, thus they are very easy to use and to realize collaboration in CDF without

any special training. If a classroom has equipped projector and large screen, and Wi-Fi is provided in campus, CDF education environment will be built easily and quickly in classroom by using those cloud servers that mentioned above.

4. Conclusion

CDF is effective and efficient has been proven by design cases and experiences of many research teams in past twenty years. Some universities have also established their own CDF for academic research and aerospace engineering education. Essential requirements of a general CDF are analyzed by comparing collaborative engineering environments that are reported in the literature with respect to three specific aspects: software, hardware, and peopleware configurations. Some cloud computing technologies, include Google Drive, Dropbox, SkyDrive, MENDELEY, Google Talk and skype, are presented to realize collaboration in CDF environment, with many benefits, such as reducing cost on hardware, software and human, reducing prepare time and easy to use. This simple and low cost CDF framework is adaptable to be implemented in classroom education of aerospace engineering.

References

[1] Jeffrey L. Smith. Concurrent Engineering in the Jet Propulsion Laboratory Project Design Center. 98AMTC-83.
[2] Aguilar, Joseph A., Andrew B. Dawdy, and Glenn W. Law. The Aerospace Corporation's Concept Design Center. 1998.
[3] M. Bandecchi, B. Melton, B. Gardini. The ESA/ESTEC Concurrent Design Facility. Proceedings of EuSEC 2000, pages: 329-336.
[4] Julie C. Heim, Kevin K. Parsons, Sonya F. Sepahban. TRW Process Improvements for Rapid Concept Designs. 1999, pages: 325-333.
[5] Joseph A. Aguilar, Andrew Dawdy. Scope vs. Detail: The Teams of the Concept Design Center. IEEE Aerospace Conference Proceedings 2000, pages: 465-481.
[6] Robert Shishko. The Proliferation of PDC-Type Environments in Industry and Universities. 2000.
[7] F. Pena-Mora, K.Hussein, S. Vadhavkar. CAIRO: a concurrent engineering meeting environment for virtual design teams. Artificial Intelligence in Engineering, No.14, 2000, pages:203-219.
[8] Donald W. Monell, William M. Piland. Aerospace Systems Design in NASA's Collaborative Engineering Environment. IAF-99.U.1.01, 1999.
[9] Michael N. Abreu. Conceptual Design Tools for the NPS Spacecraft Design Center. Master Thesis, NAVAL POSTGRADUATE SCHOOL, 2001.
[10] Charles M. Reynerson. Developing an Efficient Space System Rapid Design Center. IEEE Aerospace Conference Proceedings 2001, pages: 3517-3522.
[11] Karpati, G., J. Martin, and M. Steiner. The Integrated Mission Design Center (IMDC) at NASA Goddard Space Flight Center. IEEE Aerospace Conference Proceedings 2002, pages: 3657-3667.
[12] Linda F. Halle, Michael J. Kramer, M. Denisa Scott. Space Systems Acquisitions Today: Systems Modeling, Design and Development Improvements, Integrating the Concept Design Center (CDC) and the NRO Analysis Center (NAC). IEEE Aerospace Conference Proceedings 2003, pages: 3647-3656.
[13] Todd J. Mosher, Jeffrey Kwong. The Space Systems Analysis Laboratory: Utah State University's New Concurrent Engineering Facility. IEEE Aerospace Conference Proceedings 2004, pages: 3866-3872.
[14] Jan Osburg, Dimtri Mavris. A Collaborative Design Environment to Support Multidisciplinary Conceptual Systems Design. AIAA 2005-01-3435.
[15] Thomas Coffee. The Future of Integrated Concurrent Engineering in Spacecraft Design. Research Report of Massachusetts Institute of Technology, 2006.
[16] Hernando Jimenez, Dimitri N. Mavris. A Framework for Collaborative Design in Engineering Education. AIAA 2007-301.

[17] Schaus, V., Fischer, P., Ludtke, D. Concurrent Engineering Software Development at German Aerospace Center – Status and Outlook. Engineering for Space, No.1, 2010.
[18] Daniel Schubert, Oliver Romberg, Sebastian Kurowski. A New Knowledge Management System for Concurrent Engineering Facilities. 4th International Workshop on System & Concurrent Engineering for Space Applications, SECESA 2010.
[19] Fischer, Philipp M., Volker Schaus, and Andreas Gerndt. Design Model Data Exchange Between Concurrent Engineering Facilities By Means of Model Transformantion. 13th NASA-ESA Workshop on Product Data Exchange 2011.
[20] Paulo Esteves, Emmanouil Detsis. Concurrent Engineering at the International Space University. 2011.
[21] M. Marcozzi, G. Campolo, L. Mazzini. TAS-I Integrated System Design Center Activities for Remote Sensing Satellites. SECESA 2010.
[22] First Studies of ASI Concurrent Engineering Facility (CEF). SECESA 2010.
[23] A. Ivanov, M. Noca, M. Borgeaud. Concurrent Design Facility at the Space Center EPFL. SECESA 2010.
[24] CO2DE: A Design Support System for Collaborative Design. Journal of Engineering Design, Vol.21, No.1, 2010. Pages: 31-48.
[25] Vasile, Massimiliano. Conccruent Design Lab in Glasgow. 2006.
[26] Kazuhik Yotsumoto, Atsushi Noda, Masashi Okada. Introduction of Mission Design Center in JAXA. 2005.
[27] Jonathan Osborn, Joshua D. Summers, and Gregory M. Mocko. Review of Collaborative Engineering Environments: Software, Hardware, Peopleware. International Conference on Engineering Design, ICED11, 2011.
[28] Moises Dutra, Minh Tri Nguyen, Parisa Ghodous. An approach to adapt collaborative architectures to cloud computing. Advanced Concurrent Engineering, DOI: 10.1007/ 978-0-85729-799-0_19, Springer-Verlag London Limited 2011.
[29] http://en.wikipedia.org/wiki/Google_Docs
[30] http://en.wikipedia.org/wiki/Google_Drive
[31] http://en.wikipedia.org/wiki/Dropbox_(service)
[32] http://en.wikipedia.org/wiki/SkyDrive
[33] http://en.wikipedia.org/wiki/Mendeley
[34] http://en.wikipedia.org/wiki/Google_Talk
[35] http://en.wikipedia.org/wiki/Skype