The Dark Side of Concurrent Design:

A Story of Improvisations, Workarounds, Nonsense and Success

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ABSTRACT

The Concurrent Design is a powerful way to harmonize the work of many specialists in an iterative manner, especially in the early phases of a development project. Several agencies and industry in the space sector as well as related academic institutions are applying this Systems Engineering methodology increasingly for the last two decades. Concurrent Design is a customer-oriented, result-driven approach which facilitates both creativity and structured processes by continuously guided and highly-interactive working sessions. It is a serious business in which efficiency and effectiveness are given high priority in order to reduce time and cost of the design activity. All of this is true. However, what happens when you put between 15 and 30 very well educated people in one room?

What happens when mechanical engineers instantly have to use a model-based systems engineering tool although their last software course was Fortran and took place about 20 years ago? How does it end if four different nationalities discuss in a fifth language (i.e. English) the various applicable methods for option selection- and decision making processes in a study. And can you imagine what happens if scientists talk to engineers (and vice versa) about the minimum required and maximum desired scientific output of an exploration mission? It could go into chaos. But it does not need to.

The present paper describes a set of e.g. technical, infrastructural, social and cultural issues, which may rise and rose already in Concurrent Design studies. It points out the major important steps of how to handle them in general, based on experiences. Special attention is given to the fact, that with such a diverse set-up of experts, using various (new) tools within a complex multi-media environment, the key is a good atmosphere amongst the people and the awareness that the dark side of concurrent engineering could appear everywhere and should be turned into: fun.

KEY WORDS

Concurrent Design, Lessons Learnt, Human Factors

INTRODUCTION: THE UNBIASED AS-IS STATUS

During a Concurrent Design (CD) study, there are more than 10, 20 people sitting in front of their screens and are thinking, listening, performing calculations or chatting to someone in the audience or to their neighbors. Moreover, within a CD-study, a dedicated design model is used, many Excel workbooks are intensively updated and all parts of the media-world with big screens, Smartboards, cables, management panels and many more process supporting tools are stressed frequently. How can this be a smooth event? This paper is about experiences and lessons learnt related to troubles and trouble-shooting as part of Concurrent Design activities categorizing them according to the key elements and primarily the various phases of CD (i.e. preparation, study- and post-processing phase). Before discussing our “special experiences”, the here-called “Dark Side”, the five key elements [1] are briefly introduced and equipped with example information of how they “look like” in the real and daily work. The other main chapters point out a selection of bad situations and then try to provide recommendations to either avoid, or even eliminate them (if possible).

The Facility

Communication amongst people is essential. Moreover, personal face-to-face discussions are the most efficient and promising way to tackle design issues and to organize the team itself. This requires an environment which naturally facilitates the collaborative way of working. The team members, who are not always voluntarily nominated for attending the study, should feel comfortable working in this "room". Therefore, a proper facility is one of the key elements. However, since not all people are always present or certain experts have to be acquired from partner organizations, the facility should also have the capability to connect via videoconferencing systems. This might go against the "everybody-at-the-same-time-at-the-same-place" principle of Concurrent Engineering (CE) as it is certainly not as efficient as sitting on the same table but cannot always be avoided, especially when considering the environmental and time-related impacts of travelling.

In general, working in such a facility should not cause any problems. But making use of the different "supportive" elements, such as the multi-media features could – from time to time – lead to serious problems. The examples in this paper mainly refer to the work in the Concurrent Engineering Facility (CEF) of DLR and the Concurrent Design Facility (CDF) at ESA ESTEC.

The Software Infrastructure

The participating engineers apply domain specific tools (DSTs) and software (S/W) for their analyses as well as common S/W packages (such as Microsoft Office) for documentation purposes. The latter are usually pre-installed on any work station in the CDF/CEF and should be in-line with the versions the team members use in their offices. The DSTs include 3D-modeling S/W (e.g. CATIA, Unigraphics), Trajectory calculation and –visualization tools (e.g. Satellite/System Toolkit), ESATAN/ESARAD for thermal analyses or tools like Matlab/Simulink for simulations. Although there is a general desire to connect as many tools as possible to the central database and -model, there is still a lot of effort required to achieve that. On the contrary, a higher 'degree of automation' would increase the required interface maintenance and overall complexity.

Since the positions in a CD-study should be filled with experienced personnel in their domain, little or no effort should be required to familiarize with the respective S/W packages.

The (Integrated) Design Model

The first frequently used model in the European Space community for Concurrent Engineering purposes has been the ESA Integrated Design Model (IDM) which consists of a set of Excel workbooks representing the various disciplines (including their calculation models), a data exchange file as well as the relevant and linked domain specific tools mentioned above. Today, depending on the organization, there are various modifications which are based on these IDM workbooks or even different tools developed in the frame of Concurrent Engineering research activities (such as DLR's Virtual Satellite) which follow the same principles and standards but might include other features and graphical user interfaces. Recently, ESA has released the Open Concurrent Design Tool (OCDT) as successor of the IDM. This server-based tool includes the latest standards for data exchange and uses Excel as main interface for the engineering models.

The majority of such design models uses well-known S/W packages such as Excel and/or has at least interfaces to them. Still, there is a non-negligible complexity introduced for maintaining a consistent, organized data exchange and parallel access. On top of that there is the required tool flexibility to cope with totally different system- and mission design studies. All this leads to an "entry barrier" for most engineers when first exposed into a CD environment.

The Team

It is all about people. The core element of CD is the team. Without a tool, one can still make an assessment. Without a facility, one could use a less capable environment but still function, without a design model people could still maintain a certain progress by carefully sharing the data. Even without a 'process' the team members, being usually well educated, could somehow go through the different tasks, step-by-step, as it has been the case in many projects which applied the rather centralized or sequential methodology. But without the right person on the right position, or with people who are not capable to communicate, understand each other or to exchange the right numbers, things become more difficult.

Depending on the organization and type of study, the participants are either "in-house", external or a mix of both. Whereas ESA-studies in which the customer is usually from an internal department (e.g. in the frame of a feasibility analysis before starting an industrial R&D activity), people are usually members of the various ESA sections, which might have already some experience with working in the CDF. On the other hand, due to the internationality of this

organization, the team members have many different cultural backgrounds. At DLR for instance, where a high portion of studies are conducted in conjunction with industry or academia in the frame of third-party funded studies, there are usually many externals attending such an activity for the first time. Sometimes, this includes personnel from usually two or more (normally) competing industry partners. This has a high impact on the willingness of data exchange, especially when there is a lack of understanding how the data in the CEF is stored. Many of these aspects related to human behavior have been profoundly discussed in [2].

The Process

Whereas the team could be called the core of the study, the process can be considered as the shell. It consists of the overall time planning (on study- as well as on session-level), definition of tasks and actions in sequence or parallel, team organization such as group formation, identifying the level of detail and main objectives for certain sessions, defining required preparation (and results) to start and close a study, the facilitated communication amongst team members via verbal and tool-based means and everything else which is close to classical project management activities.

HAVING A BAD START…

One could get rid of many future conflicts and surprises by performing a proper preparation. However, this will be not always the case. Either due to lack of time, understanding, awareness or just laziness, stakeholders tend to overlook some critical aspects to prepare with care for such a condense event.

Customer expectations

Concurrent Design or -Engineering is still a fancy term. Often (especially external) customers approach the CD-teams with different or partially wrong expectations. As discussed in [3], the idea of how CD is done can be very diverging amongst not-so-experienced customer or team members and the full-time CDF/CEF people.

An often experienced aspect is that the customer (or any other person in charge initiating the study planning) would like to run system option identifications plus all related evaluation processes during a CD-study. “Let’s analyze 6-7 options and then we decide which one we will design in more detail”, is one possible statement. Generally, having multiple disciplines on board for this brainstorming task is helpful, but many decisions at this stage have to be done on system level, maybe with certain consulting efforts required from the domain experts. Performing a CD-study with up 30 people in one room would be still a waste of time in a too early stage of a project. This should be done in a smaller group prior to the study. A few years ago, NASA’s Team-X for example established a process to identify the concept maturity level (CML) which is supposed to be an indicator if the project is already sufficiently prepared to be further analyzed by a full team within a CD activity [4].

Another way to improve the full-CD-study-readiness-level is through the concept of a MiCRA (Mission Concept and Requirements Assessment) study [5]. MiCRAs were introduced in ESA’s CDF in 2012. A MiCRA is a study including a team of around five key domains, is performed in four sessions and with a very limited reporting effort. The objective is to improve the general understanding of a mission, its main drivers, bottlenecks and hence requirements.

Generally, for each party it has to be clear what the objectives are. Here it is important to distinguish between the “mission objectives” (i.e. the info the team needs to know what the system elements should achieve during the mission) and the “study objectives” (i.e. the info the team needs to know what they need to achieve during the time the study lasts). Additionally it has to be defined, which means will be used to perform the design. Especially at the DLR CEF, which offers and provides its facility to external entities quite frequently, there is the experience that new (and external) project managers/engineers think, a fully automatic model is used, including numerical simulations and other advanced principles and tools. Especially the modern infrastructures of the facilities insinuate the utilization of powerful mathematical operations which is rather misleading. In reality there is a strong focus on rapid and easy-understand models, often “simply” using Excel as user interface. But the expectations are usually higher.

What is CE all about?

For some team members, the CE-work is considered as additional work. Even if they are already part of the project, they think, they have to be there and to help someone out while additionally digging through the specifics of this environment (e.g. model use, process, moderator). They do not like to work with the model, they do not appreciate the given schedules, they do not want to explain to others what they are doing and some even do not want to ask others for their (required) inputs.

It has to be well explained, that the CE work will not be “on-top” of the current project work but rather “instead”, and not only this: it is actually supposed to reduce time and hence the effort to be spent on the project in general. In any case people would need to fill out tables, do their analyses, call people, respond to the systems engineer desires etc. CD is simply another way of working and is not just another bunch of work-load.

Lack of requirements

A frustrating example of incomplete preparations is the lack of requirements. For phases 0/A studies you do not need a list of 300 requirements down to the detailed performance of a certain sub-equipment. But the engineers have to know whether the desired operational lifetime is 5 or 15 years, whether there will be a piggy-back launch on a small transport system or rather a dedicated one using a heavy lift vehicle and whether there is a full-time operational payload mode or the instruments are just operated on demand.

This “open task”, which could have been prepared in advance, is not only confusing to the team and a real waste of several man hours but also a wrong indication for any first-time CDF attendee who will mentally link the subsequent and daunting requirement gathering phase with CD and loses motivation to participate in an upcoming study. At DLR we gained already experiences in both directions, a too fuzzy first session in which no one really knew what to do since almost no design constraint was given, and there was an exercise on Phase-B level in which it was apparently required to walk through a list of several hundred requirements for consolidation and re-formulation purposes. Both was frustrating for the team and very costly, considering 15 to 20 people in one room dealing with these kind of tasks which could have been avoided by a kind of “CDF readiness review” in advance.

On top of that, the availability of a very first iteration for the configuration is often underestimated. Having from day one already something visual “to fight about” helps sizing and placing components significantly.

Breaks and basics

Often dangerously taken for granted, are the basics; especially the ones which serve our daily needs such as eating, drinking and resting. Since we are all human, it is just nice if coffee (and cookies from time to time) is served free of charge as a compensation for the change of working environment.

Such “tea time” reduces stress caused by e.g. the additional support which is requested to help someone out and somehow values the fact that a team member still stays patient and polite even if she/he has been overlooked, outvoted or just been involved in a facility-related technical issue (such as a nasty CDF design model shutdown). Hot drinks and a sufficient amount of breaks make the day easier. Trading a “ten-minute time-off” against catching up with an already exceeded schedule does not help anyone. Some team member consider the coffee corner as a kind of particular splinter meeting environment, as the social atmosphere has proven to trigger ideas and initiate or close discussions directly related to the ongoing study.

Schedule & Time issues

Time is always critical. Many projects are calling. People often have private issues as well and might need to leave within a session without nominating a replacement for that time. Additionally, lunch habits of study attendees might not be in-line with the study schedule which could lead to disappearances every now and then.

The study has a natural end, and cannot be extended for days or weeks since another study is in the pipe and the resources (here: time allocation) of the experts are limited. However, it is recommended not to “fill up” every plenary session until the last minute.

Planning sufficient margins for the just mentioned brakes helps, either for the investigation on another very appealing design option or to solve a problem which is more difficult than expected. In theory, this sounds always easy and reasonable. But it is an art not to overload the session. Identify the most apparent time consumers which can be avoided and tackle them.

For example, during session preparation, make sure to ask for presentations to be shown by domain X and Y in advance. This helps to identify if the person (who was supposed to summarize something) has actually done anything thus and you do not blame him/her in front of the team if not. One could already try if the format works also on the presenting work stations. Some people show up with .pptx, / .ppt. / .pdf or open source file types. However, the team leader in this case needs to understand that there will always be updates, which is yet another argument to skip “PowerPoint engineering” as often as possible and present directly the work done in the workbook.

There are many more time-consuming traps which would exceed the scope of this paper. Unfortunately, not all of them are under the control of the involved personnel. If someone else is smoking on the toilet or drills a hole in the (wrong) wall as part of infrastructural maintenance work in the building, the fire alarm could potentially force the team to have an unplanned break within the session. Keeping some spare time is a must. And when the session finishes even earlier than expected, no one will complain.

THE DAILY STUDY MADNESS…

The most eventful time takes place within the main study phase itself in which the entire team comes together on a frequent basis, namely during the plenary sessions of the CD activity. Although preparation is the fundament for such an event, the time during the session is the most critical one since everybody is present and full of work and expectations.

Missing customer

During the sessions, the customer should be participating all the time in order to give instant feedback on the design status and to take the opportunity to observe and request certain figures, such as cost or related to remaining qualification effort, for instance. A missing customer could lead to unnecessary delays slowing the progress down when a negotiation is required but cannot be done. Reacting on misunderstandings can not only done by the team leader and systems engineer because they lack decision power for the study objectives and project budgets although they might have already internalized them.

Motivating the customer to attend all sessions by explaining his/her significance and that of feedback to close the loops and validate new assumptions is – as many other things – of high importance. Minimum a telephone connection should be envisages, which could be running in the background in case of his/her physical absence.

Videoconferencing

Although it is preferred to have all team members in one room, sometimes it cannot be avoided that a domain specialist, the customer or an entire entity needs to be involved remotely. Videoconferencing is generally a good thing since it reduces travel cost and time allows reacting on individual schedule changes and often even provides recording functions. However, inoperability and sometimes lack of experience with such systems could lead to delays. Due to security reasons, some entities cannot call directly other parties (or vice versa) and need to go via a third-party gateway.

Furthermore, some systems are calling using IP-addresses, other ones prefer (or are limited to) classical telephone numbers. In addition to technical issues, making use of videoconferencing sometimes imposes a too strong focus on the people which are “on the other side”. The effort to “report” to the colleagues exceeds by far the maintenance of proper on-side discussion since one could feel obliged to communicate also any whisper-activities in the room to the remote team. In this case, the team leader should be in charge of maintaining a proper balance of the communication amongst the involved parties.

WebEx sessions

Web conferencing can include video, audio or just be limited to screen sharing. There are several tools out there providing usually all of these options, naming WebEx or Adobe Connect. Unfortunately all of them have different features and capabilities. WebEx supports calls via phone as well as via headsets and the Internet connection. This might not be the case for other systems. Video signals create a more personal atmosphere but consume bandwidth and cause delays in voice transmission. Almost all of these tools require minor installations (e.g. Flash player updates) leading to troubles if the invited participant has no administrator rights on his/her own PC, which is not unusual in a corporate environment. As for any infrastructure- and media-related CD-aspect, clearly describing objectives and capabilities, plus a quick test-run, help to overcome annoying retards and ad-hoc troubleshooting.

Use of Tools

This sub-section addresses the use and also fear of new tools. Especially the latter is one is a quite negative aspect, although for a Concurrent Engineering activity one always tries to make use of the best S/W and media technology for increasing design efficiency. As *Joda* already said: ”Fear leads to anger, anger leads to hate and hate leads to suffering.”

The Design Model

The data model is the "formal connection" of the disciplines amongst each other and ensures a data exchange and use of a single data source for design parameters. One often proposed idea by externals is to use single Excel-sheets or models, covering any aspect of the design. This would ensure an easy and not complex approach with all data in one place.

However, in order to work simultaneously on the "problem" (i.e. design of mission/system) there is a not trivial need of multiple accesses to this tool and the desire to work together on the same time with the same data. This is ensured by prepared models such as the IDM, OCDT or the VirSat software, using design standards, right/access management and model-bases systems engineering principles to allow for proper data exchange and utilization.

The issue is that this is a new element the team members have to deal with, especially when they are new in Concurrent Design. Together with the fact that other participants know already how it works, this leads to following imbalances:

- Some disciplines do not use the tool at all while others completely rely on it [2].
- Some participants need a lot of attention, whereas other, rather "S/W affine" colleagues, work too proactively on the model due to overconfidence related to the tool, causing errors by creating or deleting e.g. parameters, finding out how to change settings or overstress their domain-related workbooks and models.
- Team members could be frustrated by the (perceived) overhead, and is stressed because she/he feels "behind".

It is necessary to point out to the team, that the tool is a supporting element which should structure the process and not to dominate it. It is all about the team and its accumulated experience. Additionally, at DLR we spend 30-45 min together (!) during each session to engage people in a "monitored design model update".

Having mentioned that, it is on the other hand of relevance that the developers of such design models understand the importance of user friendly interfaces which reduce the training and understanding effort of the team members. For new (ESA) CDF study team members for instance, there is a tutorial organized so that not only the design model but all tools can be tools and are not considered as "fancy toys".

Smartboards

Most Smartboard pictures are ugly. You need to have good drawing skills. Additionally, the use of this equipment requires a lot of discipline. You have to draw preferably with a rectangular angle to the board; you need to put down one "pen" before using another one. And you should not touch the surface with your body parts. Smartboards are very touch-sensitive. Especially when using them for presentations. If someone is too close, the electrostatic layer already leads to undesired slide changes or capturing of objects on a particular slide, which are then moved across the screen (caused by too long hair on the arm or the desire to physically and exactly point to something on the slide although the other team members are still sitting several meters away).

However, these type of boards are intended to be used especially in the beginning of a study in order to introduce a certain concept or the overall mission architecture, at least as a starting point. The "save as" or "print as" (e.g. PDF) function allow quick utilization of the pictures within other documentation means. However, there are several alternatives to Smartboards. Modern projectors allow drawing directly on paper and have capturing or photograph functions which could be used instead. Especially the current Smartphone generation should be able to grab a picture of a flip chart or something similar and instantly include it into a presentation. This even provides a charming alternative to the often clinical diagrams created on the PC. But taste might vary…

Endless discussions

Many engineers love details. Sometimes, before the overall system design is clear, people start talking about material selections and efficiencies on "nuts- and bolts" level, whereas the overall structural layout of the system is not even clear. It is the team leader's duty to facilitate discussions where an important result can be expected or where to cut people off when the information is not really relevant for anyone else. This is normal work.

However, it becomes interesting when this discussion is held by rather high-level people who think they need to "look ahead" and predict already some potential design Go's and No-Go's which are not really on the table at that time. As for late-comers, people in managing positions who attend the study as short-time visitors or ad-hoc experts could indirectly force the people to report to them (as it is the case for the "others" in a videoconference, as discussed above).

The core team and all other team members should understand at what time repeating information might support additional clarification, or when it is just reporting in order to satisfy one or two particular people who are not fully part of the design team. The latter definitely should be avoided.

Work load

Too much work regarding both, study-related tasks and as part of other projects is one major driver for inefficient and bad (or lacking) contribution from the team members. Here we would like to point out a few examples for the work load caused by the study itself.

Depending on the preparation, especially the ***configuration engineer*** might be overloaded due to the interaction and interdependence with all the other subsystem domains. Creating parts and doing the accommodation for the e.g. 3D-assembly file requires many iterations and negotiations. Although there is usually the split between the structural engineer (i.e. the force- / stress calculator) and design responsible, an additional person in the background could be useful for producing catalogue elements, which the main configuration engineer could use instantly in the overall assembly file.

The ***systems engineer*** – being in a similarly interconnected position – needs to have as well a good time and task management to deal with all the different requests. As foreseen in most CD-applying companies already, there is at least one assistant in the systems team. At DLR, there has been the consideration to establish something like a red "do not bother me right now"-flag to be put on the screen, which could be used for phases in which detailed research has to be done on his/her side.

Many ***subsystem***- or the ***watchkeeping domains*** on the other hand could have imbalanced work load, often with lot of work in the beginning (primarily true for technical domains) or at the end of the study (the case for rather non-technical domains). Excuses from disciplines being responsible for budgets (such as cost, risk but also sometimes thermal, power and communication) are frequently experienced since some of these domain representatives tend to postpone their tasks explaining that there is not much to do when other design issues are not clear yet.

However, they need to understand that this "I am waiting for input to complete my (cost-, power-, temperature- link -) budget" time should be used to prepare the models accordingly, looking over the shoulders of the other experts and preparing already e.g. sensitivity analyses for quick reactions and responses on design changes.

28 DAYS (OR LESS) LATER …

What happens after the main study phase is done applying a rather sequential or centralized engineering approach. The team is back in their offices but the members usually still have some actions to fulfil, which can lead again into the "Dark Side of Concurrent Design".

Excuses for report writing

Once the study is finished, everybody feels relieved, especially when a) the result was finally good and/or b) the pressure from the other demanding projects are continuously increasing. However, as long as not done already during the study (which is assumed to be the case rather seldom) the team members need to contribute to the data- and file storage and, most importantly, the report.

The information gathered during the study has to be written down. Team Leader, Systems Engineer and the Technical Author have the task to organize, participate and do exactly this. To facilitate this last phase of a study there have been attempts to introduce a voluntary report writing session after the final presentation. Appreciated by the participants, this session suffered due to the natural attraction of the next, upcoming, new project the domain experts had to work on.

Although PowerPoint presentations are less desired during the study phase, the Final Presentations session shall be a serious one, with one summary of the study including assumptions, design trades/evolutions, results and open issues per domain. These five to ten slides prepared by each discipline responsible shall serve as the baseline for the report. With proper "notes" in the presentation, only little effort should be required to complete the written documentation.

It is not your project

One partly emotional aspect is that the project leaves the CDF after the study, and the people normally stay, either in the facility or in the respective department.

Not all team members will continue participating in the mission which can be good (if it was difficult or an uninteresting one) or sometimes also sad (if the study was enjoyable or technically very promising).

THE “BRIGHT” SIDE…

Concurrent Engineering and especially the related study phase with all disciplines in one room is actually not “dark” at all. The sessions and the iterative and collaborative work approach is very enjoyable and comes along – besides the undoubtedly experienced content-related advantages – with many positive aspects which outnumber by far the bad ones. There are not many other activities in this field in which you are so intensively working together with other domains on interesting future missions. It is not only a team building exercise but also a great learning opportunity. If done right, the primary objective of shaping the mission and system design will be enhanced by a not trivial social component.

There are plenty of examples for the “awesomeness” of Concurrent Design, but as the title of this work indicates, these experiences should be written down in another document.

SUMMARY

The present work discusses some ideal and real world cases of Concurrent Design studies related to its various elements and during its major phases. The basic message is that the “Dark Side” could emerge at any time during the activity which is particularly critical when the entire team is present and the time is scarce. It has to be acknowledged that one needs to be prepared and stay calm in order to quickly find promising solutions or improvisations. This is primarily important for the systems engineer, team leader and/or the facility manager since they are the hosting and integrating parties of the study team. In the end, dealing with the “Dark Side” follows obvious principles, such as having your system-level requirements ready for session #1 (20-50 should be sufficient), introducing properly the objectives to the team and also the capabilities of team, approach & facility to the customer, being aware of people’s (other) obligations, provide “easy-to-digest” information and not getting stressed when things are running not so well.

Especially for the team leader it is true, that only by understanding both the Dark and the Bright Side one can become the most powerful Jedi manager for the study. This paper had the intention to increase awareness about things which are not always going as expected and to provide some ideas how to tackle them.

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