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Appendix A System Dynamics

Extract of the presentation on System \Design analysing system dynamics by Dr G Viljoen presented at the INCOSE conference during August 2007, [22].

SYSTEM DESIGN

Dr. Gerrit Viljoen

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1.2. Systems Theory

1.2.1 Systems Theory (Ludwig von Bertalanffy 1928, 1952, 1968)

- Fundamental concepts of the Machine Age (Descartes et al.)
  - Reductionism
  - Analysis
  - Mechanization
- Fundamental concepts of the Systems Age
  - Holism
  - Open vs. Closed systems
  - Hierarchies
  - Systems view of Nature
  - Systems view of ourselves (Mankind)

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1.2. Systems theory

1.2.2 Systems Theory (Ludwig von Bertalanffy 1928, 1952, 1968)

- A dynamic system can often be described mathematically as follows:
  - If Q_i is the ith state that describes the p elements of the system we have:

$$\frac{dQ_1}{dt} = f_1(Q_1, Q_2, ..., Q_n)$$
$$\frac{dQ_2}{dt} = f_2(Q_1, Q_2, ..., Q_n) \quad (1)$$
$$...$$
$$\frac{dQ_n}{dt} = f_n(Q_1, Q_2, ..., Q_n)$$

1.2. Systems theory

1.2.3 Systems Theory (Cont.)

- This system has equilibrium points which can be stable, or unstable. At the equilibrium point there is no change in the system states, so we have:

$$f_1 = f_2 = ... = f_n = 0$$

- We then have n equations for n variables that can be solved:

$$Q_1 = Q_1^*, \quad Q_2 = Q_2^*, \quad ..., \; Q_n = Q_n^*$$

- If we introduce a new variable which represents a perturbation around the equilibrium $Q_i = Q_i^* - Q_i^{'}$, we can reformulate the system in (1) with respect to $Q_i^{'}$ and then do a Taylor expansion:

1.2. Systems theory

1.2.4 Systems Theory (Cont.)

$$\frac{dQ_1^{'}}{dt} = a_{11}Q_1^{'} + a_{12}Q_2^{'} + \ldots + a_{1n}Q_n^{'} + a_{111}Q_1^{'2} + a_{112}Q_1^{'}Q_2^{'} + a_{122}Q_2^{'2} + \ldots$$

$$\frac{dQ_2^{'}}{dt} = a_{21}Q_1^{'} + a_{22}Q_2^{'} + \ldots + a_{2n}Q_n^{'} + a_{211}Q_1^{'2} + a_{212}Q_1^{'}Q_2^{'} + a_{222}Q_2^{'2} + \ldots$$

$$\ldots$$

$$\frac{dQ_n^{'}}{dt} = a_{n1}Q_1^{'} + a_{n2}Q_2^{'} + \ldots + a_{nn}Q_n^{'} + a_{n11}Q_1^{'2} + a_{n12}Q_1^{'}Q_2^{'} + a_{n22}Q_2^{'2} + \ldots$$

- A general solution of this system of equations is:

$$Q_1^{'} = G_{11}e^{\lambda_1 t} + G_{12}e^{\lambda_2 t} + \ldots G_{1n}e^{\lambda_n t} + G_{111}e^{2\lambda_1 t} + \ldots$$

$$Q_2^{'} = G_{21}e^{\lambda_1 t} + G_{22}e^{\lambda_2 t} + \ldots G_{2n}e^{\lambda_n t} + G_{211}e^{2\lambda_1 t} + \ldots$$

$$\ldots.$$

$$Q_n^{'} = G_{n1}e^{\lambda_1 t} + G_{n2}e^{\lambda_2 t} + \ldots G_{nn}e^{\lambda_n t} + G_{n11}e^{2\lambda_1 t} + \ldots$$

1.2. Systems theory

1.2.5 Systems Theory (Cont.)

- Where G are constants and λ the roots of the characteristic equation:

$$\begin{vmatrix} a_{11}-\lambda & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22}-\lambda & \ldots & a_{2n} \\ \ldots & & & \\ a_{n1} & a_{n2} & \ldots & a_{nn}-\lambda \end{vmatrix} = 0$$

- Inspection of the roots allow a number of conclusions to be drawn about the system. If all the real parts are negative, the system is stable. If the roots are imaginary with negative real parts, the system is asymptotically stable. If there are any real roots that are positive, the system is unstable.
- These effects can be graphically described on the phase plane

Apendix B Problems experienced

1. Management related project problems

Problem Area	Problem Statement	Cause	Impact
Project Meetings	Project meetings particularly at subsystem level not always regularly held.	Time constraints and major role players' availability	5
Facility meetings	Facilities meetings not structured to cater for the specific needs of individual aspects of the projects	Facilities in a matrix organisation generally provide resources for a number of projects, making it impractical to cater for the individual aspects of a specific project.	4
Guidance Meeting	Development personnel in general not familiar with the lower level client requirements and the user environment.	No initial guidance meetings were held.	5
Lack of knowledge of the user operational doctrines and support environment	Personnel involved with the development of the logistic products did not always understand how the user operates during a typical deployment exercise.	Initial project focus was technical requirements and no study of the operational and support environment was done.	4
Lack of knowledge of the user training doctrines and training environment	Personnel involved with the development of training do not always understood the details on how the user training project functions.	Initial project focus was technical requirements and no study of the operational and support environment was done.	4
Scope creep	The requirements baseline at the lower system hierarchies was not fixed.	Particularly the lower system hierarchy did not always receive the full PM and SE attention and sometimes leading to unplanned baseline shifts.	4
Resources	The extent and scope of the logistic product development was under estimated due to a wrong assumption that the existing pre-upgrade ZT3 products could be adapted.	The project team did not pickup that the client changed their documentation and training material standards since the original ZT3 system, resulting in the logistic product development team being under resourced and over worked, contributing to expensive mistakes and quality problems. There was no spare capacity or contingency planning	4
Increase level of effort (LOE) for source info	Wrong information was sourced due to sub-contractor inputs.	Unfamiliarity with the new client technical manuals and training standards and wrong selection of expert consultant	3
Client Guidance	Availability of expert client personnel	The client has changed its standards since the original ZT3 system	2
Clarity of logistic requirements	The internal technical authors were not familiar with the new client documentation and training material standards.	The client has changed its standards since the original ZT3 system	3

Problem Area	Problem Statement	Cause	Impact
Outsourcing technical manuals and training definition phase	Wrong information was sourced due to sub-contractor inputs.	The scope of work for the consultant tasked with the development of the technical manuals and training definition work was inadequate resulting in the wrong sub-contractor being selected	2
Client management	Sound client management was sometimes lacking leading to unplanned baseline shifts.	The impact of ostensibly small change requests was sometimes under estimated at PM level and allowed without detailed impact investigation.	3
Tasking (Task Structuring)	Not enough detail task structuring for logistic product development because task managers themselves did not always fully understood the task. Also no single clearly demarcated responsibility areas for logistic product development team members leading to inefficiency and quality problems.	Unfamiliarity with the new client technical manuals and training standards.	2
Logistics engineering availability	Logistics Engineering was not contracted to perform assessments of the technical integrity of the logistic products development team outputs.	PM did not make provision for engineering assistance during technical manuals and training material development.	2
System Engineering and subsystem expertise availability	The development team availability particularly during the final system qualification phase was very limited.	PM wrongly assumed that the technical information in the product data pack would be adequate for the technical authors.	3
System Engineering and subsystem expertise availability	System Engineering not sensitive regarding their responsibility towards the Logistic Development Process.	PM wrongly assumed that the technical information in the product data pack would be adequate for the technical authors.	2
PRACA form completion not enforced	Problems were not made visible to enable effective management and co-ordination resulting in persistence of a problem.	PM due to pressure of work did not always schedule regular FRB meetings to timeously address and resolve problems.	3
Contracting / Projects	Inadequate facility contracting	Contracting and in particular outputs were sometimes vague.	3
CFE Data integrity	Source information in particular Customer Furnished Items (CFE) data was not verified up front leading to expensive time consuming re-work later in the project.	PM wrongly assumed that the CFE data supplied by the client was adequate and complete.	3
Planning	Detail planning lacking resulting in inability to measure progress and timeous identified problem areas.	PM due to pressure of work did not always integrate the detail task planning into their project plan.	3
Planning	Task managers not always involved.	PM time constraints.	3
Cost Management	General task overspending.	Task overspending was not always immediately followed-up by PM.	2
Cost Management	Full scope of CFE impact not always visible.	The full scope of CFE generally only became visible late in the program	2

Problem Area	Problem Statement	Cause	Impact
Risk Management	Risks were not identified and managed early enough in the program.	Risk management started too late.	2
Procurement delays	The company rule required that all procurement including engineering proto type components be handled by the company procurement section.	Procurement priorities did not make special provision for small quantity highly specialised development contract procurement items.	3
Technical manuals and training development	Technical authors were not always au fait with the prescribed templates and standards.	Lack of editorial assistance and training.	3
Process	No clear technical manual and training material development process that all team members could follow.	The new client manual and training standard aggravated the problem.	3
Change Control	ECPs were generally not reviewed and counter signed by all the stake holders.	Stakeholder availability.	4
Discrepancies between hardware and data	Redlining of drawings sometimes lagged behind.	Tight schedules and pressure for hardware availability.	5
Fragmented Quality Assurance function	Each facility provided its own QA function.	Company rules did allow indirect personnel on direct programs.	3
Fragmented configuration function	Each facility provided its own configuration management function.	Company rules did allow indirect personnel on direct programs. Project QA manager primarily focussed on top level system QA.	3
Fragmented procurement function	Procurement was a centralised corporate function geared for production procurement.	Company rules did allow indirect personnel on direct programs.	3
Incidents	32	**Sub Total**	**100**

2. Systems Engineering related project problems

Problem Area	Problem Statement	Cause	Impact
Data availability	The system development data pack only addresses the "**WHAT**" the system must do, not the "**HOW**" the system works. .	The systems engineering process is requirements driven. No provision is made for documenting **HOW** the designs work and interact within the rest of the system.	5
System Engineering and subsystem expertise availability	The development team availability particularly during the final system qualification phase is very limited.	Expert resources a scarce resource and once a task is complete, the resource is allocated to another project under the matrix organisational structure.	4
System Functional Block Diagram (FBS) not inline with product Breakdown Structure (PBS)	There was virtually no link between the system FBS and final PBS. The PBS also kept changing during the program. These uncoordinated changes resulted in much fruitless work and reworks of documentation.	Design iterations resulted in changes being accepted and implemented but retrospective data pack updates were not always done due to pressure of work.	4
Maturity of System	Log Products were required before the acceptance and freezing of the system production baseline.	Design iterations (ECPs) resulted in subsystem baseline changes that were not incorporated into the log products development schedules.	4

Problem Area	Problem Statement	Cause	Impact
Hardware availability	Tight schedules and technical development program slips resulted in lack of verification of log products by the log product development team.	Primarily due to cost and time constraints only one demonstration model of each hardware item was built. This resulted in a conflict between qualification testing and log product verification.	4
Hardware availability	The hardware was not available for the documentation development team	Hardware was continuously modified during qualification testing and not released for other use until late in the project. Also the documentation redlining process often lagged behind the hardware status.	4
Terminology List updates	A large number of log product changes late in the project were as a result of terminology changes. The impact of these on cost and schedules were generally under estimated by all parties involved.	The ripple effect of ostensibly minor terminology changes was under estimated.	1
Logistics engineering availability	Logistic engineering expert availability particularly during the final system qualification phase is very limited.	Expert resources a scarce resource and once a task is complete, the resource is allocated to another project under the matrix organisational structure.	2
PRACA form completion not enforced	Problems were not made visible to enable effective management and co-ordination resulting in persistence of a problem.	SE due to pressure of work did not always schedule regular FRB meetings to timeously address and resolve problems.	1
Change Control	ECPs were generally not reviewed and counter signed by all the stake holders.	Stakeholder availability, time constraints.	3
CFE Data integrity	Source information in particular Customer Furnished Items (CFE) data was not verified up front leading to expensive time consuming re-work later in the project.	The CFE data information was accepted on face value without verification.	2
Electronic data control	Drawing office sometimes placed data on the server that was not always verified and approved.	Schedule pressure and fragmented configuration management.	1
Incidents	12	**Sub Total**	**35**

3. Quality Assurance related project problems

Problem Area	Problem Statement	Cause	Impact
Client documentation and training standards	QA not familiar with logistic product requirements and the relevant RSA-MIL-STDs.	Fragmented Quality Assurance function as a result of the matrix organisation structure and company rule of no indirect personnel on direct programs.	3
Technical manuals template problems	QA not familiar with logistic product requirements and the relevant RSA-MIL-STDs.	This is a specialist field outside the scope of general QA.	2

Problem Area	Problem Statement	Cause	Impact
Change Control	ECPs were generally not reviewed and counter signed by all the stake holders.	Stakeholder availability and fragmented QA function.	1
Continuous Evaluation	QA not contracted for continuous evaluation of the logistic products throughout the development phase.	Facility workloads prevented continuous evaluation of one project output.	2
Continuous Evaluation	QA was generally passive and only involved with the project hardware instead of all deliverables (including the log deliverables).	Facility workload.	2
Continuous Evaluation	QA has not been contracted for the evaluation of logistic products.	QA was considered an indirect function as part of a facility.	2
Continuous Evaluation	QA is not competent to evaluate the technical integrity of the Technical Manuals and Training Material.	Limited specialist availability as part of the matrix organisation structure.	3
Incidents	7	**Sub Total**	**15**

4. Configuration Management related project problems

Problem Area	Problem Statement	Cause	Impact
Baseline/ Moving	The baseline kept changing due to enforced ECPs creating difficulty with the log development. (Moving target).	Problems at integration levels very often led to urgent ECPs to resolve the problem. This had a ripple effect throughout the system hierarchy.	4
Data availability	The system development data pack only addresses the "**WHAT**" the system must do, not the "**HOW**" the system works.	The systems engineering process is requirements driven. No provision is made for documenting **HOW** the designs work and interact within the rest of the system.	2
System Block Diagram not in line with PBS	There was virtually no link between the system FBS and final PBS. The PBS also kept changing during the program. These uncoordinated changes resulted in much fruitless work and reworks of documentation.	Design iterations resulted in changes being accepted and implemented but retrospective data pack updates were not always done due to pressure of work.	3
Source info	The technical authors had difficulty in getting data on how the system/subsystem worked.	The systems engineering process is requirements driven. No provision is made for documenting **HOW** the designs work and interact within the rest of the system.	2
Source info	The technical authors had difficulty to get access to the design experts.	After the CDR, facilities immediately reallocate expert resources to other programs.	2
Fragmented CM	Each facility had its own CM. Only at program level was the program CM who could not go into detail of all the subsystem configuration aspects.	Documentation configuration control was part of the company management information system and available on the intranet. Project CM was then reduced to a coordination and audit function.	3

Problem Area	Problem Statement	Cause	Impact
Templates	Technical manual templates were not user-friendly leading to time wasting mistakes by technical authors.	Unfamiliarity with the new client technical manual led to outsourcing of templates.	2
Templates	Templates were not approved prior to population of data.	Templates were accepted at face value and not put through an approval process with the client in order to save time.	3
Templates	Tolerances of the templates must be realistic and within the capabilities of the printers and PCs used in the facility.	The page units of measure in the client technical documentation standards were metric rather than point units for printer drivers. Client QA personnel were rejecting pages due to printer tolerances. Despite the templates being correct.	3
Change Control	ECPs were generally not reviewed and counter signed by all the stake holders.	Stakeholder availability, time constraints.	2
Incidents	**10**	**Sub Total**	**26**
Total	**61**	**Total**	**176**

Summary:

Problem area	Consolidated incidents	Total impact	average %
Management related project problems	32	100	56.8
System Engineering related project problems	12	35	19.9
Quality Assurance (QA) related project problems	7	15	8.5
Configuration management (CM) related project problems	10	26	14.8
Total	**61**	**176**	**100**

Apendix C Design Iteration Impact Study

1. Introduction

Design influencing during the optimization of a design for a configuration item (CI) of a complex system results in design iterations of the item. These iterations are not always contained to the configuration item itself. Project pressures may result in the premature release of a design for that particular CI. Latent design defects in the CI may only surface during the integration process of the system under development. Under concurrent engineering methodology a number of other CIs are being developed concurrently. Any change of the Form-Fit and Function (FFF) of a CI after its baseline has been frozen generally results in a ripple effect throughout the system hierarchy by affecting the FFF of all the other CIs under development. The impact of these system design changes is related to the complexity of the system and the functional couplings between the different system elements. In this study an attempt is made to quantify the impact or ripple effect of a CI change to the whole system.

2. Unconstrained design iterations – ideal design environment

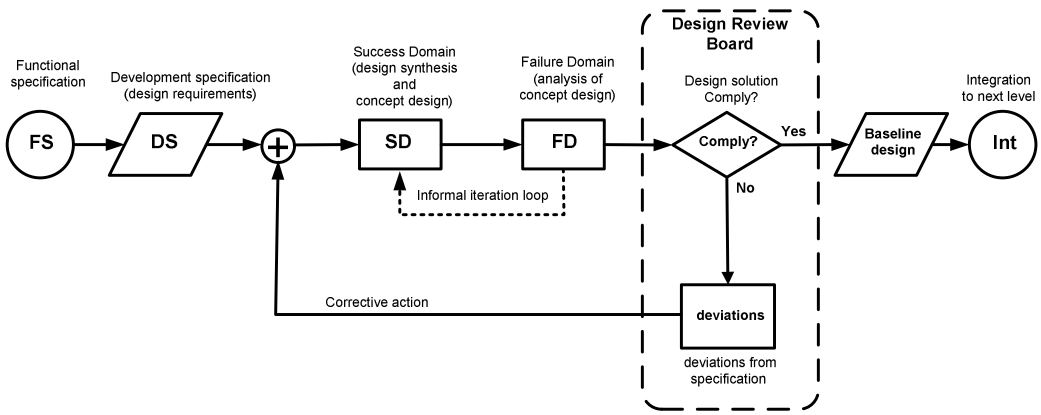

Figure 36: Unconstrained *effect-to-cause* design influencing model

The design engineer as part of the Success Domain team by synthesis of the requirements and constraints produces a draft design. The logistic engineering analysts as part of the Failure Domain team analyse the draft design for the "***-ility***"[10] performance against the requirements. The Design Review Board (DRB) refers any shortcomings or deviations from the requirements back to the Success Domain team for another design iteration. This iterative design process continues until the design complies with all the requirements and the design is base-lined in preparation for the next level of integration. The number of iterations required is generally determined by the maturity of the technology selected and the technical complexity of the design. The Failure Domain team can only perform the analysis ***after*** a concept design has been provided by the Success Domain team. In other words design influencing is an after the fact or an ***"effect-to-cause"*** process.

3. Constrained design iterations – real life environment

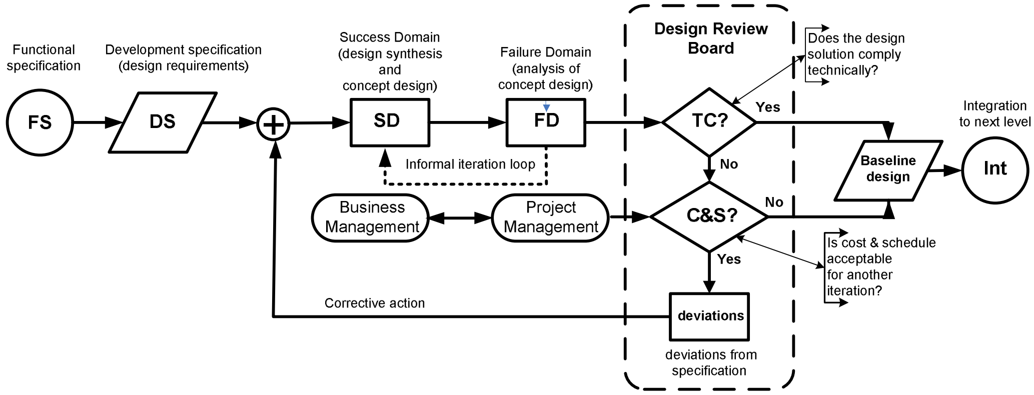

Figure 37: Constrained *effect-to-cause* design influencing model

The iterative design process for a constrained ***"effect-to-cause"*** design influencing model is identical to the unconstrained design process with the addition of a gate in the iterative design process by the project manager. The project manager, depending on his constraints, generally cost and schedule, can allow another design iteration or force a ***premature*** design release. The design is therefore not fully mature to the satisfaction of the Success Domain and Failure Domain teams and may increase the technical risk at the next level of integration.

4. Design change impact in a complex hierarchical system

A complex system generally has several layers in its hierarchical structure. Individual configuration items (CI) in the system structure may have functional coupling to other system CIs. Also real systems are a multi-dimensional hierarchy of functions e.g. the logistic system hierarchy actually lies behind the operational system hierarchy with functional couplings between them. For convenience and simplicity, it is customary to present the logistic system, software system, hydraulic system, pneumatic system, and optical system, etc. hierarchies on separate hierarchy structures leading to the misconception that these hierarchies are separate and independent when in actual fact they are not. In practice most systems are a mix of functional coupled and decoupled functions between the CIs in the different hierarchies of a system.

A hypothetical system presented by means of a simple two-dimensional hierarchy is shown in figure 38.

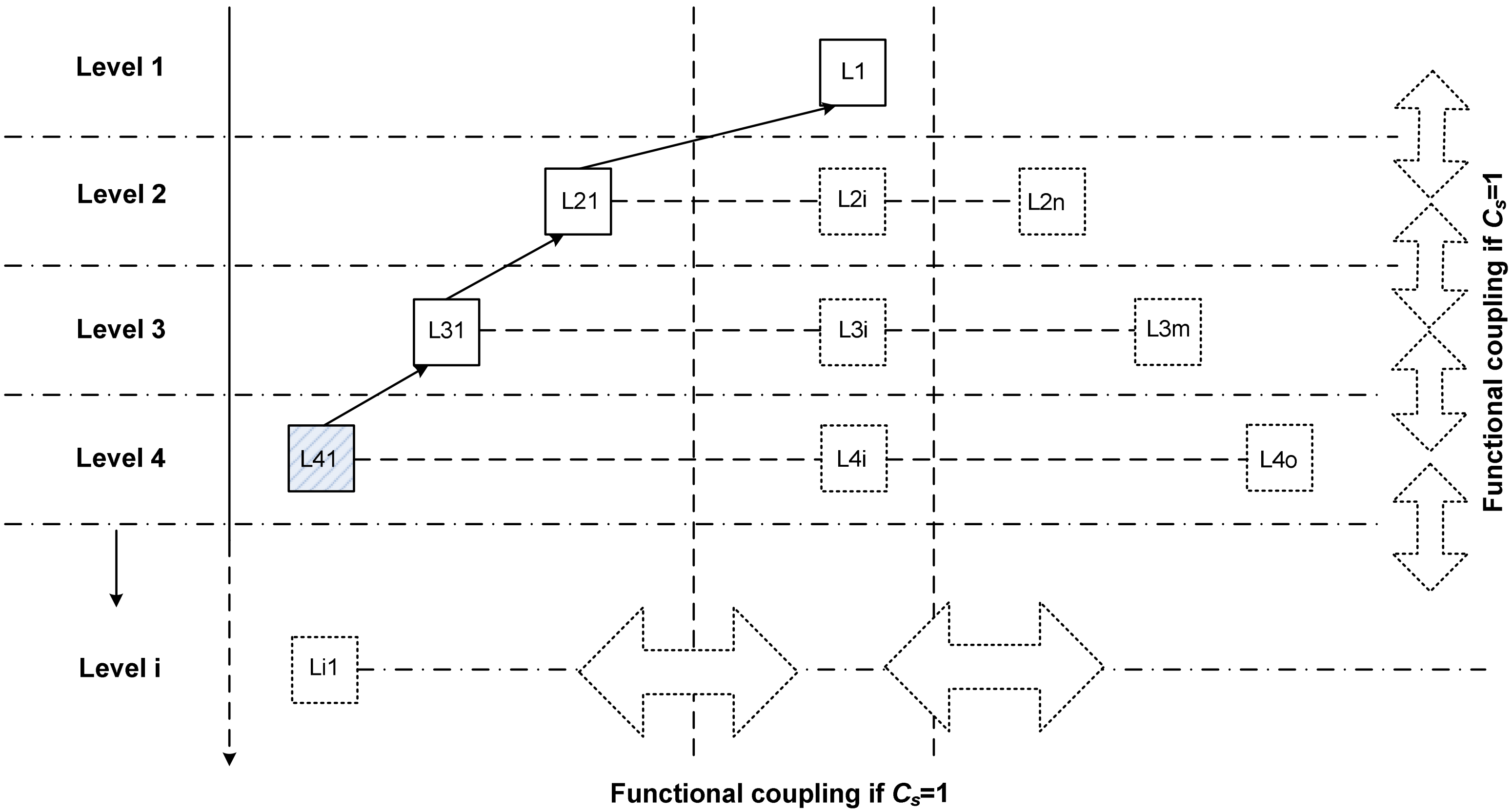

Figure 38: Hypothetical system hierarchy

Functional Coupling rules

- If there is functional coupling between affected CIs, the coupling constant C_s=1.
- If there is no functional coupling between affected CIs, the coupling constant C_s=0.
- There is ***always*** functional coupling between an affected CI and its own parent and C_s=1 in that case (emergent properties).
- There is ***always*** functional coupling between an affected CI and its own children and C_s=1 in all those cases (emergent properties).
- There may be functional coupling between the affected CI and its peers, other parents and children, in all those cases C_s=1.
- If there is no functional coupling between the affected CI and any other CI in the system hierarchy then, C_s=0.

A. Impact of CI change of an affected CI on its parents and children:

Using the system hierarchy in figure 38, assume that the affected CI is L41.

Then L31, L21 and L1 are the parents and functional coupling exists and therefore C_s = 1.

Similarly, L51 to Li1 are the children of the affected CI L41 and C_s=1.

Let R_p be the impact of an affected configuration.

Then
$$R_p = C_s L_1 + C_s L_{21} + C_s l_{31} + C_s L_{41} + - + - + C_s L_{i1}$$
$$R_p = \sum_{i-1}^{l} C_s L_{i1} \qquad (1)$$

Where *l* is the total parent and children CIs and *i* is a real integer reflecting the parent or child CI.

Note

Equation (1) ≥ 1

B. General Impact of CI change in the system hierarchy

Let R_c be the impact due to functional couplings

Then $$R_c = R_p + \sum_{j=1}^{m} C_s L_j$$

Where

- *m* is the total configuration items in the system structure not related to the affected CI structure.
- *j* is an integer reflecting the j_{th} configuration item in the system structure.
- C_s is the functional coupling (C_s=0 if functionally decoupled or C_s=1 if functionally coupled).

Generalising $$R_c = R_p + \sum_{j=1}^{m} C_s L_j$$

$$R_c = \sum_{i=1}^{l} C_s L_{i1} + \sum_{j=1}^{m} C_s L_j$$

Since $l+m = n$

$$R_c = \sum_{k=1}^{n} C_s L_k \qquad (2)$$

- Where *n* is the total number of configuration items in the system.
- C_s=1 for all the configuration items where functional coupling exist between the affected configuration item.
- C_s=0 for those configuration items where no functional coupling exist with the affected configuration item.

C. Summary

- From equation (2), it can be deduced that in order to reduce the ripple effect of a design change to a configuration item, a design objective should be to minimise equation (2) by avoiding functional couplings between configuration items.
- Since equation (1) is always) ≥ 1 it precludes equation (2) from ever becoming zero.
- Totally decoupled designs can only be found in simple single hierarchical level systems such as components or simple products.

D. Some Case-study Examples

The following case-study calculations are based on hypothetical figures to illustrate the cost and schedule impact of design changes in a concurrent engineering environment. The two examples also illustrate the advantage of de- or uncoupled designs.

A simple 3 level system hierarchy structure with 9 CIs at the lowest level was considered as a case-study, refer to figure 39. The summarized findings for the case-study examples in appendix C are:

- A simple 3 level system hierarchy structure with 9 CIs at the lowest level and with minimum functional couplings. This is considered a best-case system design of only functional couplings between parent and children and no peer functional couplings. If these remaining functional couplings for example were to be removed there would be no system but only a collection of CIs without any emergent properties.

- Using the same simple 3 level system hierarchy as above, but this time all the CIs are functionally coupled to one another providing a worst-case system hierarchy design, refer to figure 40.

General assumptions:

- Sufficient design iterations to achieve design optimisation and maturity

- Level 1 (L1) Design iteration: cost=ZAR1000k/iteration
Schedule=18 weeks/iteration

- Level 2 (L2x) Design iterations cost=ZAR500k/iteration
Schedule=12 weeks/iteration

- Level 3 (L2xy) Design iterations cost=ZAR100k/iteration
Schedule=6 weeks/iteration

- No concurrent iterations are possible

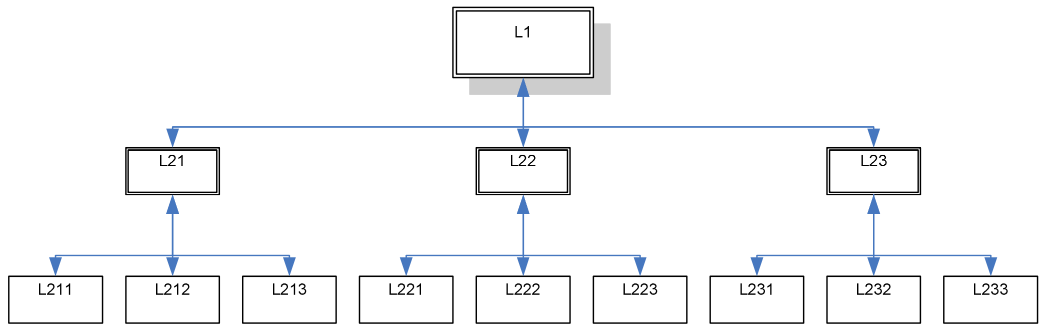

Figure 39: System structure with maximum functional decoupling

Assuming the affected CI is L211, using equation (2), $C_s = 1$ for the functional coupling to the parent L21 and its parent L1.

Cost impact: R100k + R500k + R1000k = **ZAR1600k**
Schedule impact: 6 + 12 + 18 = **36 weeks**

Taking the same hierarchical system structure but with functional coupling between all the configuration items shown in figure 40:

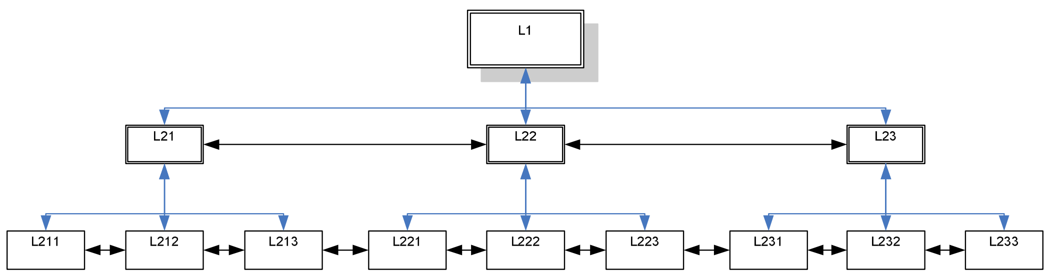

Figure 40: System structure with maximum functional coupling

Again assuming the affected CI is L211, using equation (2), $C_s = 1$ for the functional coupling to the all the other configuration items in the system hierarchy:

Cost impact: 9(R100k) + 3(R500k) + R(1000k) = **ZAR3400k**
Schedule impact: 9(6) + 3(12) + 18 = **108 weeks**

5. CONCLUSIONS

The hypothetical case-study examples above clearly demonstrate the escalating cost and schedule impact of a design change on a concurrent systems engineering development project. This impact is a function of the number CIs and functional couplings in system hierarchy. Design changes in a concurrent engineering development project have the following consequences:

- Design changes in coupled designs are generally not feasible due to the detrimental project cost and schedule impact. Design changes, discussed above are invariably Class I changes and result in a ripple effect due to the functional couplings throughout the system hierarchy.

- Limited design changes for uncoupled and decoupled designs may be possible for simpler systems.

- The project impact in terms of cost and schedule is generally too high to implement any design changes of a CI for complex multi-level systems without impacting on the project cost and schedule.

- ***"effect-to-cause"*** design iterations essential in the Integrated Product Support (IPS) development model places a severe system optimisation constraint on the system design.

- Design changes are major development project constraints in a concurrent engineering environment. Very often a band aid fix is the only practical non project intrusive way of solving the problem, which can lead to a non optimal design. This will be discussed further below.

- Research into techniques and design processes should be performed to reduce design iterations for optimal system design.

- The impact for a design change in this case-study example was a cost increase of 213% and a schedule penalty of 300%.

The case-study examples are hypothetical for illustrative purposes only. In reality, real systems are much more intricate with multiple level system hierarchies and numerous different discipline CIs. Computer simulation is required to analyze these systems. Such a model would provide quantified CI design change impact information to enable design review boards to make informed decisions. Computer modeling development falls outside the scope of this research.

From the analysis it can be concluded that a design change of a CI in a complex multi-component, multi-hierarchical system during system integration in a concurrent engineering environment invariably has a detrimental effect on project cost and schedule. In practice, design modifications/changes during system integration of a complex multi-hierarchical system are virtually unavoidable. The impact of forced changes can only be improved by optimizing the system architecture to keep the system data content or functional couplings to a minimum.

Apendix D Revised Problems experienced using AD

1. Management related program problems

Problem Area	Problem Statement	Cause	Impact	Revised impact
PCMB meeting	Project meetings particularly at subsystem level not always regularly held.	Time constraints and major role players' availability	5	1
DSRB meetings	Facilities meetings not structured to cater for the specific needs of individual aspects of the projects	Facilities in a matrix organisation generally provide resources for a number of projects, making it impractical to cater for the individual aspects of a specific project.	4	1
FRB meetings	Development personnel in general not familiar with the lower level client requirements and the user environment.	No initial guidance meetings were held.	5	1
Lack of knowledge of the user operational doctrines and support environment	Personnel involved with the development of the logistic products did not always understand how the user operates during a typical deployment exercise.	Initial programme focus was technical requirements and no study of the operational and support environment was done.	4	3
Lack of knowledge of the user training doctrines and training environment	Personnel involved with the development of training do not always understood the details on how the user training programme functions.	Initial programme focus was technical requirements and no study of the operational and support environment was done.	4	3
Scope creep	The requirements baseline at the lower system hierarchies was not fixed.	Particularly the lower system hierarchy did not always receive the full PM and SE attention and sometimes leading to unplanned baseline shifts.	4	3
Resources	The extent and scope of the logistic product development was under estimated due to a wrong assumption that the existing pre-upgrade ZT3 products could be adapted.	The project team did not pickup that the client changed their documentation and training material standards since the original ZT3 system, resulting in the logistic product development team being under resourced and over worked, contributing to expensive mistakes and quality problems. There was no spare capacity or contingency planning	4	3

Increase level of effort (LOE) for source info	Wrong information was sourced due to sub-contractor inputs.	Unfamiliarity with the new client technical manuals and training standards and wrong selection of expert consultant	3	2
Client Guidance	Availability of expert client personnel	The client has changed its standards since the original ZT3 system	2	1
Clarity of logistic requirements	The internal technical authors were not familiar with the new client documentation and training material standards.	The client has changed its standards since the original ZT3 system	3	2
Outsourcing technical manuals and training definition phase	Wrong information was sourced due to sub-contractor inputs.	The scope of work for the consultant tasked with the development of the technical manuals and training definition work was inadequate resulting in the wrong sub-contractor being selected	2	1
Client management	Sound client management was sometimes lacking leading to unplanned baseline shifts.	The impact of ostensibly small change requests was sometimes under estimated at PM level and allowed without detailed impact investigation.	3	2
Tasking (Task Structuring)	Not enough detail task structuring for logistic product development because task managers themselves did not always fully understood the task. Also no single clearly demarcated responsibility areas for logistic product development team members leading to inefficiency and quality problems.	Unfamiliarity with the new client technical manuals and training standards.	2	1
Logistics engineering availability	Logistics Engineering was not contracted to perform assessments of the technical integrity of the logistic products development team outputs.	PM did not make provision for engineering assistance during technical manuals and training material development.	2	1
System Engineering and subsystem expertise availability	The development team availability particularly during the final system qualification phase was very limited.	PM wrongly assumed that the technical information in the product data pack would be adequate for the technical authors.	3	2
System Engineering and subsystem expertise availability	System Engineering not sensitive regarding their responsibility towards the Logistic Development Process.	PM wrongly assumed that the technical information in the product data pack would be adequate for the technical authors.	2	1
PRACA form completion not enforced	Problems were not made visible to enable effective management and co-ordination resulting in persistence of a problem.	PM due to pressure of work did not always schedule regular FRB meetings to timeously address and resolve problems.	3	2
Contracting / Programmes	Inadequate facility contracting	Contracting and in particular outputs was sometimes vague.	3	2

CFE Data integrity	Source information in particular Customer Furnished Items (CFE) data was not verified up front leading to expensive time consuming re-work later in the project.	PM wrongly assumed that the CFE data supplied by the client was adequate and complete.	3	3
Planning	Detail planning lacking resulting in inability to measure progress and timeous identified problem areas.	PM due to pressure of work did not always integrate the detail task planning into their programme plan.	3	2
Planning	Task managers not always involved.	PM time constraints.	3	2
Cost Management	General task overspending.	Task overspending was not always immediately followed-up by PM.	2	1
Cost Management	Full scope of CFE impact not always visible.	The full scope of CFE generally only became visible late in the program	2	1
Risk Management	Risks were not identified and managed early enough in the program.	Risk management started too late.	2	1
Procurement delays	The company rule required that all procurement including engineering proto type components be handled by the company procurement section	Procurement priorities did not make special provision for small quantity highly specialised development contract procurement items.	3	2
Technical manuals and training development	Technical authors were not always au fait with the prescribed templates and standards.	Lack of editorial assistance and training	3	2
Process	No clear technical manual and training material development process that all team members could follow.	The new client manual and training standard aggravated the problem.	3	3
Change Control	ECPs were generally not reviewed and counter signed by all the stake holders	Stakeholder availability	4	1
Discrepancies between hardware and data	Redlining of drawings sometimes lagged behind	Tight schedules and pressure for hardware availability.	5	1
Fragmented Quality Assurance function	Each facility provided its own QA function.	Company rules did allow indirect personnel on direct programs.	3	2
Fragmented configuration function	Each facility provided its own configuration management function.	Company rules did allow indirect personnel on direct programs. Programme QA manager primarily focussed on top level system QA.	3	2
Fragmented procurement function	Procurement was a centralised corporate function geared for production procurement	Company rules did allow indirect personnel on direct programs.	3	2
Incidents	32	**Sub Total**	**100**	**57**

2. Systems Engineering related programme problems

Problem Area	Problem Statement	Cause	Impact	Revised impact
Data availability	The system development data pack only addresses the "**WHAT**" the system must do, not the "**HOW**" the system works. .	The systems engineering process is requirements driven. No provision is made for documenting **HOW** the designs work and interact within the rest of the system..	5	5
System Engineering and subsystem expertise availability	The development team availability particularly during the final system qualification phase is very limited	Expert resources a scarce resource and once a task is complete, the resource is allocated to another programme under the matrix organisational structure.	4	5
System Functional Block Diagram (FBS) not inline with product Breakdown Structure (PBS)	There was virtually no link between the system FBS and final PBS. The PBS also kept changing during the program. These uncoordinated changes resulted in much fruitless work and reworks of documentation	Design iterations resulted in changes being accepted and implemented but retrospective data pack updates were not always done due to pressure of work..	4	4
Maturity of System	Log Products were required before the acceptance and freezing of the system production baseline	Design iterations (ECPs) resulted in subsystem baseline changes that were not incorporated into the log products development schedules	4	2
Hardware availability	Tight schedules and technical development program slips resulted in lack of verification of log products by the log product development team.	Primarily due to cost and time constraints only one demonstration model of each hardware item was built. This resulted in a conflict between qualification testing and log product verification.	4	2
Hardware availability	The hardware was not available for the documentation development team	Hardware was continuously modified during qualification testing and not released for other use until late in the programme. Also the documentation redlining process often lagged behind the hardware status.	4	2

Terminology List updates	A large number of log product changes late in the programme were as a result of terminology changes. The impact of these on cost and schedules were generally under estimated by all parties involved.	The ripple effect of ostensibly minor terminology changes was under estimated.	1	1
Logistics engineering availability	Logistic engineering expert availability particularly during the final system qualification phase is very limited	Expert resources a scarce resource and once a task is complete, the resource is allocated to another programme under the matrix organisational structure.	2	2
PRACA form completion not enforced	Problems were not made visible to enable effective management and co-ordination resulting in persistence of a problem.	SE due to pressure of work did not always schedule regular FRB meetings to timeously address and resolve problems.	1	3
Change Control	ECPs were generally not reviewed and counter signed by all the stake holders	Stakeholder availability, time constraints	3	3
CFE Data integrity	Source information in particular Customer Furnished Items (CFE) data was not verified up front leading to expensive time consuming re-work later in the project.	The CFE data information was accepted on face value without verification.	2	2
Electronic data control:	Drawing office sometimes placed data on the server that was not always verified and approved.	Schedule pressure and fragmented configuration management.	1	1
Incidents	12	**Sub Total**	**35**	**32**

5. Quality Assurance related programme problems

Problem Area	Problem Statement	Cause	Impact	Revised impact
Client documentation and training standards.	QA not familiar with logistic product requirements and the relevant RSA-MIL-STDs.	Fragmented Quality Assurance function as a result of the matrix organisation structure and company rule of no indirect personnel on direct programs.	3	3
Technical manuals template problems	QA not familiar with logistic product requirements and the relevant RSA-MIL-STDs.	This is a specialist field outside the scope of general QA	2	2
Change Control	ECPs were generally not reviewed and counter signed by all the stake holders	Stakeholder availability and fragmented QA function	1	1
Continuous Evaluation	QA not contracted for continuous evaluation of the logistic products throughout the development phase	Facility workloads prevented continuous evaluation of one programme output.	2	2

Continuous Evaluation	QA was generally passive and only involved with the programme hardware instead of all deliverables (including the log deliverables)	Facility workload	2	2
Continuous Evaluation	QA has not been contracted for the evaluation of logistic products	QA was considered an indirect function as part of a facility.	2	2
Continuous Evaluation	QA is not competent to evaluate the technical integrity of the Technical Manuals and Training Material	Limited specialist availability as part of the matrix organisation structure.	3	3
Incidents	7	**Sub Total**	**15**	**15**

4. Configuration Management related programme problems

Problem Area	Problem Statement	Cause	Impact	Revised impact
Baseline/ Moving	The baseline kept changing due to enforced ECPs creating difficulty with the log development. (Moving target).	Problems at integration levels very often led to urgent ECPs to resolve the problem. This had a ripple effect throughout the system hierarchy.	4	4
Data availability	The system development data pack only addresses the "**WHAT**" the system must do, not the "**HOW**" the system works. .	The systems engineering process is requirements driven. No provision is made for documenting **HOW** the designs work and interact within the rest of the system..	2	2
System Block Diagram not inline with PBS	There was virtually no link between the system FBS and final PBS. The PBS also kept changing during the program. These uncoordinated changes resulted in much fruitless work and reworks of documentation	Design iterations resulted in changes being accepted and implemented but retrospective data pack updates were not always done due to pressure of work..	3	3
Source info	**T**he technical authors had difficulty in getting data on how the system/subsystem worked.	The systems engineering process is requirements driven. No provision is made for documenting **HOW** the designs work and interact within the rest of the system..	2	2
Source info	**T**he technical authors had difficulty to get access to the design experts.	After the CDR, facilities immediately reallocate expert resources to other programs	2	2

Fragmented CM	Each facility had its own CM. Only at program level was the program CM who could not go into detail of all the subsystem configuration aspects.	Documentation configuration control was part of the company management information system and available on the intranet. Programme CM was then reduced to a coordination and audit function	3	3
Templates	Technical manual templates were not user-friendly leading to time wasting mistakes by technical authors	Unfamiliarity with the new client technical manual led to outsourcing of templates.	2	2
Templates	Templates were not approved prior to population of data	Templates were accepted at face value and not put through an approval process with the client in order to save time.	3	3
Templates	Tolerances of the templates must be realistic and within the capabilities of the printers and PCs used in the facility	The page units of measure in the client technical documentation standards were metric rather than point units for printer drivers. Client QA personnel were rejecting pages due to printer tolerances. Despite the templates being correct.	3	3
Change Control	ECPs were generally not reviewed and counter signed by all the stake holders	Stakeholder availability, time constraints	2	2
Incidents	**10**	**Sub Total**	**26**	**26**
Total	**61**	**Total**	**176**	**130**

Summary:

Problem area	Consolidated incidents	Total impact	Revised Impact	average %	Revised Average
Management related programme problems	32	100	57	56.8%	43.8%
System Engineering related programme problems	12	35	32	19.9%	24.6%
Quality Assurance (QA) related programme problems	7	15	15	8.5%	11.5%
Configuration management (CM) related programme problems	10	26	26	14.8%	20.0%
Total	**61**	**176**	**130**		