

TELEGENESIS: CROSS-LESSONS ON MANAGING DISTRIBUTED DESIGN ACROSS THREE SECTORS

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Abstract

Many engineering and construction schemes by nature involve teams that are located at disparate geographical sites and required to collaborate to deliver the requirements making up the project. Collaboration of members making a team often presents considerable challenges. Where members making up the team are geographically remote from each other, this often results in a heightening of the potential challenges associated with such teamwork. The possibilities of remote working through virtual environments made available by IT and other technological solutions equally give rise to new ways of interaction for project teams. The paper provides a description of the TELEGENESIS project as a background to enhancing the effectiveness of engineering and design teams. It also presents teamwork characteristics associated with engineering design teams from three project related sectors with regard to culture, project organization and communication based on a study undertaken to identify factors for enhancing performance of remote collaborating teams. The relevance of these factors to effective delivery of project objectives is highlighted and the significance of these factors to engineering and construction projects is discussed. The results from the research underpinning the paper clearly emphasize factors that are considered as “soft” for ensuring that remote teams develop the right cultural alignment and communicate more effectively to overcome what often is considered as “silo” effect at the design phase in project environments.

Keywords: Aerospace, Construction, Product Design, Collaboration, IT

1. Introduction

Many design-related organisations in construction and engineering are currently attempting to come to terms with the demands of collaboration in the form of distributed work environments. Intensifying global economic competition has compelled many engineering and construction organisations to pursue a path of exploring all possible options for achieving greater effectiveness and efficiency in their businesses and work environment [1], [2]. The availability of current technology and structured administrative systems for improving productivity, which is obtainable by all organisations, therefore shifts the emphasis for the required competitive improvement to the untapped potential of the workforce as the primary distinguishing factor in organisational performance [3], [4]. The possibilities of remote working through virtual environments made available by IT and other technological solutions equally give rise to new ways of interaction for project teams. These interactions ordinarily take place in co-located work environments and present their own contextual issues. The paper provides a description of the TELEGENESIS project as a background to enhancing the effectiveness of engineering and design teams. It also presents teamwork characteristics

associated with engineering design teams from three project related sectors with regard to culture, project organization and communication based on a study undertaken to identify factors for enhancing performance of remote collaborating teams. The relevance of these factors to effective delivery of project objectives is highlighted and the significance of these factors to engineering and construction projects is discussed. The results from the research underpinning the paper clearly emphasize factors that are considered as “soft” for ensuring that remote teams develop the right cultural alignment and communicate more effectively to overcome what often is considered as “silo” effect at the design phase in project environments.

2. Overview of Telegenesi

TELEGENESIS is an EPSRC-IMRC project (further details can be obtained from www.telegenesi.org) that focuses on the characteristics of distributed design teams involved in complex products within aerospace, construction and product design sectors. Its primary object is to explore options and then make recommendations for innovation and improvement in the use of distributed design teams. The Telegenesi project addresses these challenges through a series of scenarios on how the use of distributed design will evolve into the future, and more significantly how the principle of knowledge transfer can be employed to enhance design processes, practices and function across different sectors [5], [6]. The project involves three sectors to ensure that any potential know-how transfers are not of limited application within a bi-sector context.

Figure 1 shows a conceptual framework of the work entailed in the Telegenesi project indicating the differing levels of commonalities for design practices, management and organisation as well as processes across the three sectors.

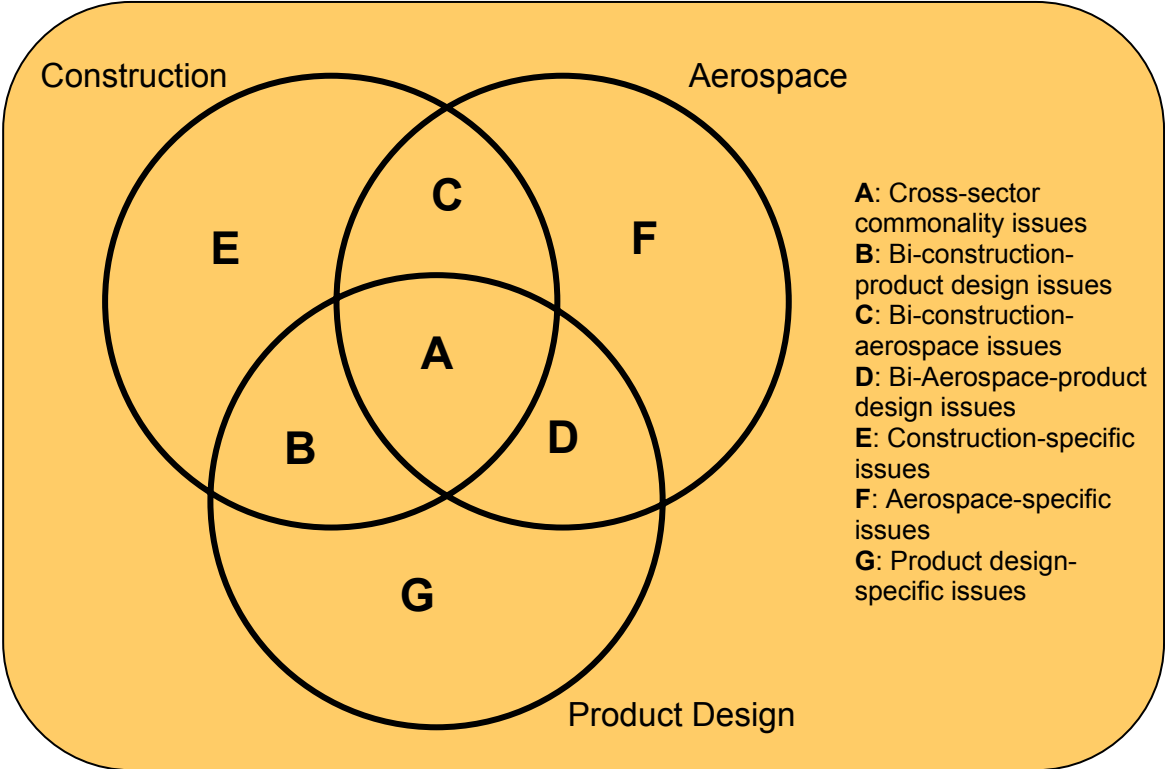


Figure 1. Conceptual form of Telegenesi indicating levels of commonalities

It also indicates the different hierarchies of commonality factors that feature in the Telegenesis project, which is detailed in Table 1 below.

Table 1. Hierarchies of commonality in design characteristics across sectors

Hierarchy	Nature of design factors
Level 1	sector specific factors that are often context-driven and lend themselves to minimal or zero transfer of know-how (Ref. Section EFG- Figure 1)
Level 2	bi-sector factors that are reflected by any two sectors but not shared across all sectors, which have considerable latitude for know-how transfer across the two sectors from one to the other and vice versa (Ref. Section BCD- Figure 1)
Level 3	cross-sector factors for which there is commonality across all sectors and for which there is ease of know-how transfer from any one sector to another (Ref. Section A- Figure 1)

The use of distributed design teams is a well accepted principle for complex engineering systems producers where advantages of concurrent engineering can be realised, and also to overcome the impracticalities of co-location for large multi-functional or multi-organisational or in some cases multi-national teams. This approach to design is typified in the aerospace sector. The construction sector is more fragmented and dominated by complex, and a multiplicity of contractual arrangements. This feature of construction has often mitigated against the full exploitation of the principles and protocols required for operating in distributed environments. The use of dispersed, cross-functional development teams - typified by distributed design teams - involves a wide range of business, technical, social and knowledge-based challenges in the dispersed work. Understanding and appreciating these challenges are fundamental to the competitiveness of distributed design organisations.

Working in a *distributed* way presents a shift that gives rise to *three* main imperatives for present and future design organisations and the environments in which designers work. These are:

- collaborative effort driven by high-intensity concurrency,
- growing emphasis on human skills and competencies, and
- enhanced corporate role for frontline designers.

The relevance of the three imperatives for designers is briefly discussed below.

From the beginning of the 1990s, proprietary groupware packages have found increasing usage by large organisations to aid communication and collaboration when operating in a distributed work environment. At the close of the 20th century, non-corporate network-based collaboration models, such as intranets and extranets, started gaining popularity as alternatives to support distributed teams. These internet-based alternatives bypass the need for corporate local area networks (LANs) or wide area networks (WANs) by using the Internet as their network infrastructure to connect remotely located, collaborating group members.

Equally, the transformation underway in the fields of data sharing and transmission, information processing, and telecommunication technology is opening up new possibilities in the way designers work. The dynamic nature of design processes in construction and

aerospace, the interdependence of various participating entities, and the need for teamwork, flexibility, and a high degree of coordination suggest that IT systems should be profitably employed for effective design management in these sectors.

The distinctive features of construction and aerospace projects make the task of design management particularly appropriate for applications of IT tools. Some of these features and the roles IT can play regarding the design function are discussed below.

1. The work atmosphere under which design projects are managed continually changes, requiring exchange of information in different forms. For this reason the design environment needs to be flexible to facilitate communication. IT systems can promote rapid communication, not only through voice media, but also by facilitating transmission of text and graphic information on a real-time basis.
2. The design process is based on complex relationships between a variety of individuals, entities, and groups. Processes are often not well defined. The interdependence of process segments can be critical to the success of the whole development of a design solution. Interaction between design team members can be helpful in providing effective leadership and in motivating team members. IT can reduce the need for bureaucracy and hierarchy of interaction and can enhance integration of organisational activities from different corporate establishments.

In theory, the opportunities provided by such technology for collaborative work arrangements should provide a number of advantages, including a reduction in duplication of effort and wastage of resources [7]. In practice, however, these advantages are often not realised due to limitations in current technology. For example Finley and Coleman [8], provide analysis of a multi-participant, distributed project and identified a number of problems that are likely to be magnified in distributed environments. These include problems in communication, information movement, collaboration, project co-ordination, and management. The continued use of existing technologies will however, ensure their maturation and so influence the way designers undertake their work. Reaching a critical mass of adoption is especially important for design-collaboration software for one major reason: If your partners don't use it, it's a lot less useful to you.

3. Sector selection

The selected sectors involved in the project were deliberately put together to take advantage of the synergy that comes from different perspectives of design. These range from design as a conceptual activity that reflects and is driven by subjectivity, to design as a rational activity driven by standards. The three sectors, aerospace, construction and product design employ these different perspectives to varying degrees. Together, they provide avenues for exploring what aspects of good practices in design can be transferred from one sector to another.

3.1 Distributed design in aerospace

Within the aerospace sector, the scale of investments required to support new product developments are often beyond the capacity of any one corporate organisation. This necessitates extensive collaboration between several organisations. Morris et al. [9], identify a growing trend whereby new aircraft design is predominantly undertaken by a distributed team of engineers from different companies and in different countries collaborating *virtually*. They further outline a system developed to assist the running of such distributed working for designers. This is presented as a *Core Team* and a number of task-oriented *macro* teams comprising human and information resources. The project identified the implications of such

a structure from the viewpoints of organisation, culture, decision-making, the role of information technology and the interfacing of the various tasks to the overall project management. The outcome of the project present evidence of the need for addressing the human and work environment aspects of these distributed design teams in order for the technical activities associated with the actual design to be delivered efficiently.

3.2. Distributed design in construction

Designing a building or facility within the construction sector naturally represents a collaborative effort among specialists from independent disciplines such as architecture, structure engineering, services engineering, cost engineering. These specialists have to make interdependent decisions to design the components of the various systems that make up the building or facility. For example, the decision of a services engineer to size the supply duct of a space depends, among other things, on the function of the space. The function of the space is a decision that is taken by another specialist, the architect. It is not uncommon for these two specialists to be located in different corporate organisations. They thus collaborate in temporarily structured team organisations in a distributed fashion to realise the required design project. Traditionally, physical meetings during which design details are reconciled underpin this arrangement in construction. Designers and design engineers are therefore schooled with the art and know-how for managing in such team environments. In virtual environments, a lot of the skills required for physical meetings, are not directly applicable and different skills and work orientation is demanded.

3.3 Distributed design in product design

Product design is one of the historic roles of the design team within manufacturing and is becoming increasingly important in other sectors. Design is now seen as an integral part of any manufacturing process and good design is highlighted as an important part of any sales and marketing campaign. While design remains largely an in-house function in many industries, such as the car industry, the production process is an area in which *product design* agencies are increasingly being used on a consultancy basis. This means working in harmony with other teams and specialist often in a distributed way.

4. Management of design teams

Traditionally, engineers are used to working in co-located design teams, where individuals working on the same project sit in adjacent cubicles, often described as the *down the hall* work environment. Designers and other team members could easily meet with one another to compare notes, share information, iron-out problems and co-ordinate activities. While this situation is still applicable for many construction organisations in today's globally distributed development environment, a company's various divisions and groups are often located around the world. This particularly so for organisations in product design and aerospace sectors, where no one company delivers the whole product. Furthermore, critical aspects of projects such as analysis and production are now typically separated from the design production group and are increasingly outsourced. This practice is well entrenched in the construction sector, where the norm is for one organisation to design the facility and another to build it. Equally, it is not unusual for a design company and its partners to be in different time zones [10]. Situations whereby work on the same design project is undertaken in sequence round the globe to achieve a round-the-clock work regime have been known.

The benefits of the traditional style of teamwork among designers and the collaboration that once occurred in hallways or in offices amongst engineers are being replaced by *virtual* interaction as the demands of time-to-market and the increasing pressure to cut development costs are complicated by greater fragmentation of the product development process. While e-mail, fax, and voicemail are valuable components of the design office environment, these are considered as inadequate substitutes for simultaneous real-time collaboration or what is generally described as face-2-face interaction. Any other mode of team interaction, such as video conferencing results in a loss of some of the social conventions that designers have taken considerable years of training and effort to develop. As such it is unlikely to be viewed as a perfect replacement for face-2-face until similar social and work conventions are established for the emerging modes of team interactivity are developed and established across the sector.

Team working at the design phase entails bringing together a diverse group of project participants and seeks to resolve differences, remove bottlenecks (social, organisational, and technical) and proactively build and develop the group into an aligned, focused and motivated work team that strives for a common mission and for shared goals, objectives and priorities. The team building requirements of working in such emerging design environments would be different from the much practiced team initiatives for co-located designers in construction. Significantly, the team working dynamics for designers operating in such environments is assumed to follow similar lines as that of co-located working. However, it is clearly self-evident that personal attitudes and levels of IT skills, as well as organisational culture will have influences on such team dynamics.

Collaborative efforts by teams are often represented within and/or between organisations in the form of group-work or teamwork. There is ample evidence that the use of team-based problem solving, innovation, and product development is on the ascendancy and could accelerate to become the standard operating processes in aerospace, manufacturing and construction sectors [9]. Some of the evidences for this changing trend towards team-based approaches in organising work include the following:

1. Growing use of employee teams
2. Re-design of workplace systems and physical space to enhance collaboration
3. An increase in team-based education at primary, secondary and tertiary levels
4. Evolution of team-centered software (e.g. Lotus Notes, Intranets, ERP)
5. An increasing re-definition of production away from functional to process models
6. A growing awareness of deuterio-knowledge as a key organisational asset.

Managing design teams in distributed environments present several issues that need careful consideration to ensure successful project delivery. While the technological aspects of these issues are currently attainable, the *socio-cultural conventions* that should attend them, especially where communication is dominated by electronic options are yet to evolve. This often produces considerable team frustration making available technologies a less favoured option for team interaction. Attendant to the social aspects of virtually collaborating in distributed design environments is the issue of new skills and competencies that designers would need to acquire to make them as efficient as they have been in their current work environments. This of course raises the question of transition as conventional design skills take on and incorporate additional requirements for operating in the distributed environments.

5. Exploring cross- and bi-sector commonalities

The cross sector commonality analysis is looking at different characteristics that reflect in design processes and the work environment of design teams in aerospace construction and product design sectors. As an exploratory study, it is essential that the basis for identifying such commonalities and their level of relevance is adequately structured to ensure that there is sufficient alignment in the outcome of the analysis. The nature of learning that occurs and the development that characterise the process by which groups of individuals transform into collaborative new product teams are often context based [11]. However, there are generic issues from different sectors that can provide lessons and benchmarks for improving the design process and its management, as well as the environment and nature of work designers have to confront. These generic features are best captured through a commonality analysis.

5.1 Research approach and method of analysis

The research underpinning this paper was conducted in close collaboration with industrial partners and is supported by the EPSRC-IMRC in the UK. The research agenda is driven by a steering group of practitioners and academics. The data source was primarily perceptions of industry practitioners structured to capture as wide coverage of design as practicable within each sector. This included both junior and senior designers as well as other staff who contribute to design without having ownership of the design output. It also included different specialisations of design, to bring out some of the contextual factors associated with design from a particular discipline, as well as multidisciplinary teams. The generic method for identifying and analysing commonalities adopted for the project is the *prioritisation matrix*. A detailed description of the prioritisation instrument adopted for the analysis of information can be found in Edum-Fotwe et al., [2]. By comparing two lists of items using a rectangular grid of cells, it can be used to document a team's perceptions of the interrelationships that exist, for various issues against a set of criteria. In a prioritisation matrix the relative importance of items in a list and the strength of interrelationships are given numerical weightings. The overall priority of the items of one list according to their relationships with another list, can then be calculated. The technique is well established and interested readers are referred to other sources that provide a more comprehensive coverage [12], [13], [14]. The prioritisation matrix should allow team members in design environments to collectively define common options using a systematic approach to compare choices.

6. Emerging issues

Analysis of the perspectives presented the following issues for making the transition from working in co-located design to distributed environments, and concomitant factors for designers in digitally enhanced work environments. This includes a number of challenges to the management of design as a process as well as how the physical function of design would be undertaken in future. These issues are organised and summarised here under four broad headings of technology related, organisation related, people related and process related.

Table 2 provides a listing key issues emerging from the analysis and indicate that while examples of these technologies and design procedures exist in some cases the current challenge their widespread acceptance and use.

Many design organisations are structured to work in the traditional co-located, and face-2-face mode. While there is a gradual transition from this traditional mode to other forms of working, the organisational structures that should underpin the new ways of working are not well developed to support this change. Many of these design organisations are beginning to

realise the implication of these new ways of working. In particular, that true design collaboration needs to move beyond just sharing CAD data. It needs to provide organisation structures that allow ideas from everyone in the design environment from all of the internal departments that are involved in the total design cycle to outsourcing companies and suppliers. Bringing all of these people into the same environment is a challenge, since they are undoubtedly working in different geographic locations around the world and are using a variety of technology tools to do their jobs. Within the different sectors, these factors emanate themselves to varying degrees.

Table 2. Emerging factors to inform design

Technology related	Organisation related	People related	Process Related
3D modelling	Flat organisations	Managerial skills	Integration across the design process chain
Designing in 3D	Team working	IT skills	A change in focus from the still dominant function approach to a process one for managing projects.
Interoperability issues	Disappearance of command and control	Cyber social skills	
Technology integration	Distributed and virtual working	Multi-tasking	The deployment of appropriate planning tools and standards to cover the conceptual phases of the design process
Push-pull approach to deploying IT tools for design	Mobile and tele-working		
Tools to support currently neglected aspects of design (conceptual design)	Virtual design organisations and networks		Development of process management protocols for implementing projects in virtual/ distributed environments.
IT as a design medium rather than a support tool for design			
Telematics			

7. Discussion

The traditional division of work between *thinking* and *doing* is gradually melding, requiring all workers to become *knowledgeable* and a part of an organisation-wide collaboration process [15]. This is because the development of design solutions for projects and products often involve complex processes, activities and resource inputs that demand participatory effort from several stakeholders. The presence of project-oriented consortia and short-term alliances in most design communities often means projects must be undertaken using a distributed work arrangement because of stakeholders who may be dispersed in different geographical locations.

Traditionally, designers are required to display a demonstrable level of high technical, some administrative, and decision-making abilities in the workplace. This orientation derives from the conventional thought that design engineers will be managed by a design manager who will

provide the organisational leadership and where necessary, to control the behaviour of employees in design organisations and environments.

With increased competition many design organisations have had to rethink design management/design worker configurations significantly, as this paradigm of work is being challenged. The control mentality is being replaced by a commitment mentality as workers are being asked to take on more responsibility and accountability. The ability of designers to cope with this added new roles will be driven by the acquisition of requisite social and human skills and competencies to combine with their technical demands.

Design is not a single action, but is a translation of ideas into reality through a set of process activities [13]. The order in which these process activities are undertaken, and the interaction between the various process activities, can affect rate of progress in arriving at the design solution and also, more importantly, the quality of the eventual completed product. The main characteristic of the design process is the large number of feedbacks or iterations. Such feedbacks and iterations emphasise considerable interaction and collaboration between individual designers and other participants involved in developing the design solution.

In today's globally distributed product development environments, a company's various divisions and groups are often located around the world. To complicate matters further, critical aspects of product development such as analysis and manufacturing are now typically separated from the design group and are increasingly outsourced. This practice is aptly reflected by the construction sector, where the norm is for one organisation to design the facility and another to build it. It is not unusual for a design company and its partners to be many time zones apart [10]. Situations whereby work on the same design project is undertaken in sequence round the globe to achieve a round-the-clock work regime have been known.

Current technology in the form of *view and mark-up* solutions all claim to be collaborative but what they really provide is only a sequential view and mark-up process. Typically, electronic documents are routed by means of a workflow process to reviewers who view them at the desktop, add comments, and send the comments back to the designer. This is repeated in an iterative cycle until all changes have been processed, agreed upon, and the next revision of the document is signed off and released. This method may take quite some time and the process really involves very little personal collaboration. Many design companies are yet to develop sufficient capability on how to implement this simple *view and mark-up process*.

8. Summary

This paper has presented early results from a research project exploring ways for improving the working environment of designers who operate in distributed teams. It can be appreciated that the influence of ICT tools is fostering a shift in the way designers will work into the future. Whilst their current skills would still be relevant in the emerging work environment, additional skills and know-how become apparent. These additional skills are predominantly human and social oriented. The paper has explored how technology is influencing the design environment of distributed teams including the use of groupware and extranet-based collaborative workspaces to aid designers operate in multi-participant, distributed projects. It explored a number of functionality issues involved in such a workspace and introduced an analytical framework for generating commonality factors from two sectors that could serve as support information for productivity improvement of designers who operate in such distributed environments.

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