CIFE CENTER FOR INTEGRATED FACILITY ENGINEERING

Understanding Enterprise Behaviour: A Feasibility Study

By

Dr. Ben Clegg and Dr. Mathew Turner

CIFE Working Paper #074
August 2002

STANFORD UNIVERSITY

If you would like to contact the authors, please write to:

c/o CIFE, Civil and Environmental Engineering Dept.,
Stanford University
Terman Engineering Center
Mail Code: 4020
Stanford, CA 94305-4020

Understanding Enterprise Behaviour: A Feasibility Study

Dr Ben Clegg
De Montfort University,
Leicester, LE1 9BH England
clegg_ben@hotmail.com

Dr Mathew Turner
Elipsis Ltd.,
76 Botley Road, Southampton,
Hampshire, SO31 1BA England

Publication date
July 2002
International refereed conference of the
International Council of Systems Engineering (INCOSE),
Las Vegas.

ABSTRACT

This paper describes work conducted as a joint collaboration between the Virtual Design Team (VDT) research group at Stanford University (USA)[1], the Systems Engineering Group (SEG) at De Montfort University (UK) and Elipsis Ltd[2]. We describe a new docking methodology in which we combine the use of two radically different types of organizational simulation tool. The VDT simulation tool operates on a standalone computer, and employs *computational agents* during simulated execution of a pre-defined process model (Kunz, 1998). The other software tool, DREAMS[3], operates over a standard TCP/IP network, and employs *human agents* (real people) during a simulated execution of a pre-defined process model (Clegg, 2000).

This docking study was conducted to develop a supporting tool-set for the concept of Enterprise Systemics, an approach designed to address the increasing commercial volatility of enterprises. It has largely been funded by the PISCES network project[4], which has drawn together a cross-disciplinary resource for comprehending the dynamics of the extended enterprise.

KEYWORDS

Role based and computational based simulation, docking, extended enterprise, value web management

[1] Supported by Prof. Ray Levitt and the NSF (USA): Knowledge and distributed Intelligence. IIS-9980109.
[2] A company specializing in developing collaborative software and systems, http://www.elipsis.com.
[3] Dynamically Reconfigurable Enterprise Activity Management System.
[4] Supported by EPSRC (UK): Product Innovation across Supply Chains using Enterprise Systemics. GR/R12299/01. http://www.seg.dmu.ac.uk/picses. Also discussed in INCOSE *Insight*. Vol. 4, Issue 2, p.19.

BACKGROUND: ENTERPRISE SYSTEMICS

Enterprise systemics is systems thinking for plotting strategy at the level of the extended enterprise (Fairbairn, Farncombe 2001). It incorporates a portfolio of systems approaches, both hard and soft, running from traditional Systems Analysis through to System of Systems and Complexity Theory. The distinct phases are:

- **S**ystemic Business Modelling (using the Soft Systems Methodology) (Checkland 1993) and its successor BSSM (Boardman, 1995), (Clegg 1999);
- **A**nalysis and Capture of the Existing System (the hard and soft characteristics of the system at its full extension into the commercial environment);
- **G**ap Analysis (judging the existing system against the required system in various dimensions);
- **E**volving the System of Systems (the implementation phase, with appropriate technologies to bind the enterprise while maintaining adaptability).

The approach is conceived specifically to address the management of rapid and unpredictable change within an extended enterprise, so that it may be easily reconfigured to meet a changing business requirement. According to (Fine 1998) this typically take place through a continual regenerative cycle of horizontal-modular and vertical-integral design for products, processes and supply chains.

Fine emphasizes that supply chain *design* is the core capability of any successful modern business, in that an enterprise must not simply engage in a multitude of product-supply relationships but successfully embed itself within a complex web of value creation itself embedded within a mutable industry architecture that is in turn affected by the fortunes of other industries. PISCES has investigated how product introduction can, in this context, be made a seamless process despite the given complexity of supply webs and the volatility of the commercial world. One salient theme has been the improvement of orchestration within the extended enterprise 'value web model', to ask ourselves: just how do we accommodate insights regarding the complexity and unpredictability of commercial systems within the pragmatic management of an enterprise? A radical idea is to define and implement a *value web manager* who would have the task of managing – in concert with colleagues within the other partner companies comprising the extended enterprise – the entire web of collaboration, rather than merely ensuring that the one dominant party receives what it needs from the others (a policy that perpetuates the control paradigm of producer-supplier). The value web manager is a function akin to that of existing supplier development engineers except that it requires a much greater level of experience and breadth of training, and carries a higher burden of responsibility in that it is a vital strategic function. This research posits the question: how would support tools to facilitate this implementation operate?

Value web managers will be plotting the long-term future of the enterprise and not simply shifting immediate blockages, and as such must have key skills in process definition and alignment in order to manage the enterprise interfaces. The value web manager will need to translate process across the enterprise, and also to evaluate various process alternatives with a view to modifying the supply base. In turn they must possess a broad understanding of the external impacts that lead to shifts in the supply architecture so that they can predict and respond to changes in the commercial context. They will need to be supported by appropriate management tools and also by a core principle agreed by enterprise partners termed within PISCES the *collaboration imperative*, which empowers the value web manager to seek trade-offs between customer responsiveness, the value added, and the return on resources at the extended enterprise level. Only if *value web members* are prepared to make individual trade-offs in favour of the good of the value web will the value web manager enjoy the requisite freedom to sustain the direction of a dispersed web of companies amid variable markets, technologies and processes (Ring, 2000). Therefore, a key marker of the success of value web management will be the 'agility' of the enterprise: defined by Agility International as, '…an enterprise-wide response to an increasingly competitive and changing business environment, based on four cardinal principles: enrich the customer; master change and uncertainty; leverage resources; and co-operate to compete'[5].

[5] Http://www.agility.co.uk/ab2.html.

METHODOLOGY: ENTERPRISING BEHAVIOR

Figure 1 outlines the docking methodology and shows the inputs and outputs for each tool. Both of the simulation tools use the same data set, which is used to create a model of the workflow (i.e. that runs across separate companies and creates a 'value web membership'). The process model defines the sequence of activities that comprises the workflow, as well as the specific actors that are responsible for each activity. VDT's primary output of simulation is a forecast increase in the lead-time breaking down how project schedule, process quality and human resource costs are affected. When applied to relatively routine work processes (i.e. where details of the workflow can be 'codified' in sufficient detail to model) these predictions provide guidance to support managerial interventions that can be made to improve process performance and enterprise integration. However, in this particular feasibility study these forecast problematic issues are used to enrich the simulation experience for the *human agents* that execute a DREAMS simulation. A VDT simulation is inherently limited in its ability to provide useful insights into the 'real world' if demands placed on it fall outside the scope of the underlying theoretical framework that it represents (Galbraith 2000). This docking methodology reflects our attempts to address this inherent limitation by using the output of a VDT simulation as a critical input to a DREAMS simulation. In contrast, DREAMS is not restricted by an underlying theoretical framework, but only by the expertise of the *people* participating and executing the simulation.

A DREAMS simulation is executed by *human agents*. People holding specific tacit expert knowledge assume definite project roles within the process model, and when the matching between a person's specific expert knowledge and the defined role is strong the person is said to be *role-capable*. Together, all the participating role-capable people make the simulation *role-based*.

The tool allows the role-capable people to operate within a synthetic environment provided by the IP/TCP client-server architecture and execute the simulation through such functionality as: an internal messaging system, a Gantt chart that has activity durations and state updated in *real time,* and a journal facility to record creative dynamic thinking about enterprise interventions. The DREAMS tool is specifically designed to improve *non-routine* cross-company processes that typically escape codification (and that cannot be codified by a tool such as VDT), for instance competitive bidding for complex systems (e.g. a fuel pump control system for a newly developed jet engine). It requires the users to 'walk-through' the process, complete the activities, and improve the overall design and duration of the inter-company processes in a synthetic environment (this is rather like a flight crew using an aircraft flight simulator). The DREAMS simulation allows the role-capable players to suggest specific solutions to resolve enterprise issues that have been predicted by VDT *as well as* suggesting additional process improvements relating to issues outside VDT's predictive abilities. Since the DREAMS tool is best suited to developing *joint consensus about non-routine* cross-company processes, which may typically be the customer- and supplier-facing processes, this docking feasibility study may have a great impact on how the value web members enterprise engage with one another.

A DREAMS simulation can even be conducted in a distributed fashion (e.g. some of the users in the UK and some of the users in the USA), and can be repeated a number of times with different players to increase the expert knowledge thrown at the solution. Thus, by combining the two simulation tools, risks predicted by VDT can be resolved specifically within a DREAMS simulation. This takes place in an environment of 'free speech' as political dimensions can be reduced by the nature of role-playing. However, all user actions – such as process improvement intervention suggestions, activity duration reduction, comments to other users about how they conduct their aspects of the process, and which users talk to whom, about what, when and why – are *all* recorded in the DREAMS database, and can be referred to during the later phases of an enterprise improvement initiative. This methodology can be repeated again and again to iteratively improve the process being simulated.

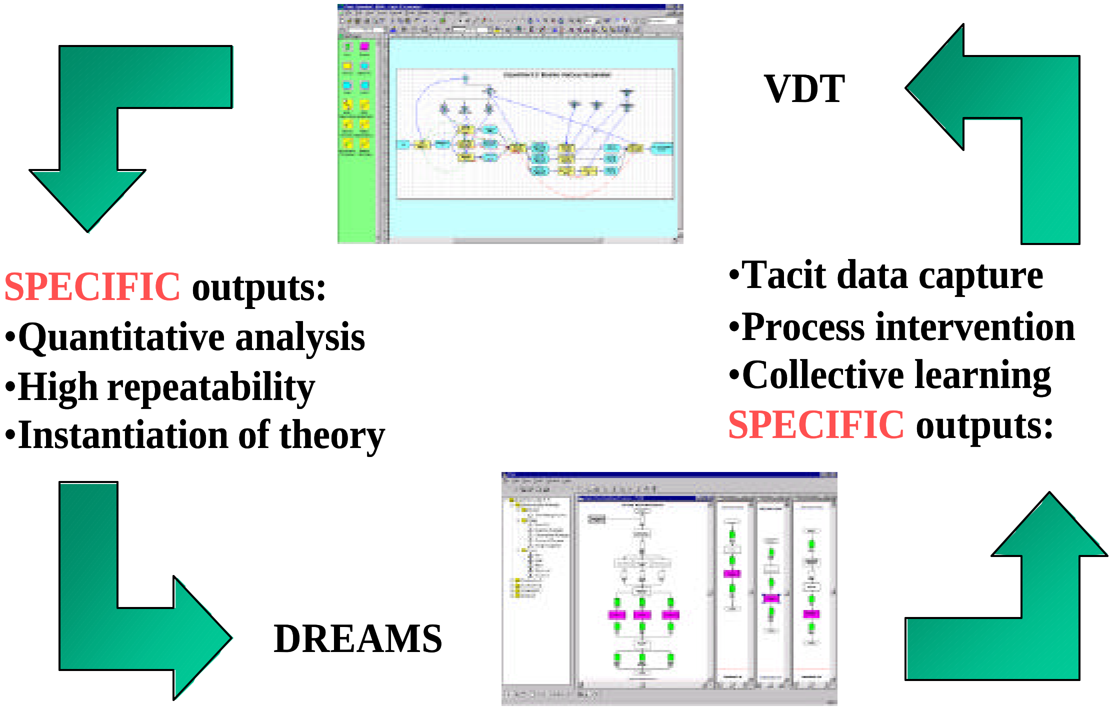
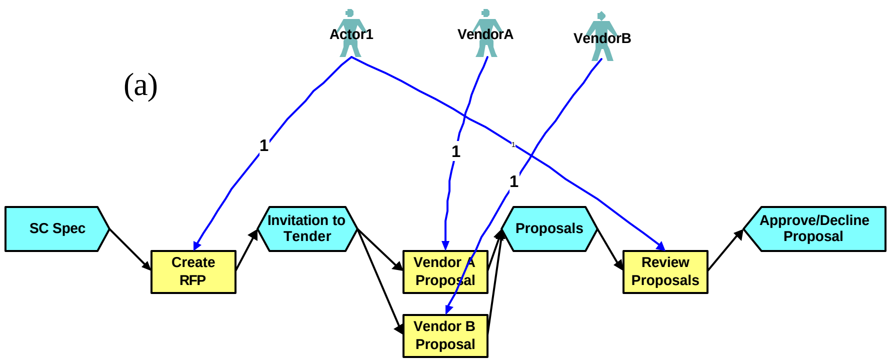


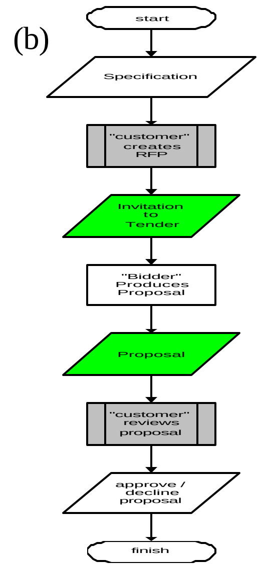
Figure 1: Docking Methodology

A FEASIBILITY STUDY

We illustrate the docking methodology using the synthetic test case shown in Figure 2. The test case reflects a simplified competitive bidding process, where two vendors ('Vendor A' and 'Vendor B') compete for a contract from a single 'Contract Owner' ('Actor 1'). 2(a) shows the work process represented in VDT. 2(b) shows a portion of the work process represented in DREAMS.

It is predicted by VDT that Vendor B will take twice as long (20 days) to produce a proposal than Vendor A (10 days) (see Table 2(c)). This is based on a scenario where Vendor A has low technical skill and relevant experience, but is known to be cheap. In contrast, Vendor B has high technical skill and much experience, but is expensive (these factors are represented in VDT as 'skill level', 'application experience' and 'cost' respectively). The 'Contract Owner' has expectations that the whole bidding process will be completed in 40 days. However, VDT predicts the overall duration of the bidding process to be 57 days (17 days over schedule), as this includes unexpected activity dependencies and communication failures within the process. The main contribution to the absolute increased lead-time was Vendor B, taking an extra 8 days. A simple solution to this would be to increase the number of full time equivalents (FTEs) on this activity from 1 to 2, in other words to throw more people at the problem in order to shorten the lead-time. However, a smart manager should explore other possibilities to improve enterprise performance; these can be generated through a DREAMS simulation and informed by the VDT output.





(c)

Activity	Activity Output	Responsible Actor	Planned Work Volume
Create RFP	Invitation to tender	Actor 1	10 days
Vendor A Proposal	Proposal A	Vendor A	10 days (fixed)
Vendor B Proposal	Proposal B	Vendor B	20 days (fixed)
Review proposals	Approve/decline proposal	Actor 1	10 days

Figure 2: Test Case (a) VDT Process Model (b) DREAMS Process Model (c) Activities & Attributes

The competitive bid process was then simulated in DREAMS *using role-capable human agents instead of computational agents as the responsible actors*. The users executed the same competitive bid process that had previously been simulated in the VDT model, using information regarding the schedule increase predicted by VDT. Role-capable users were charged with developing strategies for mitigating the predicted schedule risk. For example, a role-capable player (e.g. an experienced contracts manager) assuming the role of Actor 1 recommended that, "…we should abandon using Vendors A and B altogether and use a new dedicated Vendor C, because neither are exactly what we are looking for, and I've used Vendor C before on another similar project in my old company; they're cheap, technically competent, and I trust them to do a good job like they did before… we could even go single source, and save manpower and cost by not needing a competitive bidding process at all! Let's integrate better with our supply base …". This particular process intervention was clustered together with complementary interventions suggested by other players, to make a single collaboratively designed 'what-if' process model scenario: this required a relatively significant modification to the original process model, i.e. the elimination of two roles and two activities, and the addition of one new role and one new activity. Other groups of complementary interventions are similarly grouped into different scenarios and implemented in a compound fashion in the VDT tool, so that it is possible to analyse the effects of each scenario in isolation. Currently, recommendations such as these are given as part of a consultative process *following* VDT simulation, and the *rationale* for each recommendation is not captured. However, this particular proposal was *volunteered, discussed, and agreed upon* by all the other players *during* the DREAMS simulation[6].

The work to date, recorded on the PISCES website[7], illustrates the potential benefit that computational agent and human agent based systems have when deployed together. However, at this stage these tools are still only docked conceptually. Value web members who use this system, to improve understanding about enterprise systemics, should address the following issues:

- be aware that forecast lead-time increase incorporates potentially positive effects such as 'communication time', which should not be reduced (as simulated time is made up from 'waiting', 'rework' and 'communication' time). It was noted that most users automatically wanted to set the increased 'simulated time' back to zero again, as if they expected to complete all their tasks as originally planned, but when quizzed could offer no realistic mitigation plans for how this would be achieved.

---

[6] Thanks to MH Lambert and R Buettner for help in designing these test cases.

[7] Http://www.elipsis.com/pisces.

- be imaginative enough to translate job functions into activities performed in the simulator, and remain loyal to the behaviour of value web members who are outside the simulation but maintain an interface with it. Also, maintain the notional content of tokens denoting inputs/outputs and logical dependencies within processes, that are passed between relevant role-capable users.
- steer people through their reflections on activity completion and process redesign in a structured way. When a user submits a revised parameter for an activity duration or suggests a logical process redesign, the system's value web manager should ask them to, 'Please give the assumptions upon which your statement is founded!'
- consider the extent of logical change made to the process by DREAMS users. Generally, each time you go back to making a new VDT model based on the insight of DREAMS users, you must consider it to be a new baseline, because the modeller, representing the value web manager, must interpret and synthesise these comments into VDT scenarios. However, if little or no logical change is suggested in DREAMS the new VDT model may be considered a later version of the same original. The degree of change to the model is important because if change is found to be logically insignificant the lead-time in the DREAMS Gantt chart can be equated to the initial VDT simulated time (that includes the same set of enterprise issues that must be addressed). If not insignificant, then a new VDT model must be created, the Gantt chart equated to the CPM VDT time, and another simulated time must be calculated (predicting a totally new set of enterprise issues to be addressed).
- allow that user behaviour in the DREAMS simulator can be typified in three ways. Users either: focus excessively on reducing durations to minimal amounts and so lack the confidence to declare duration increases; execute the process as quickly as possible without giving quality rationale for their actions; or get overly involved in one process issue with another user at the expense of the rest of the process. They rarely seem to pursue all the process improvement methods the simulator enables simultaneously. This can be rectified with careful coaching and again is an interesting reflection of behavior in the real world business environment.
- incorporate a strategic management function within your simulation. A carefully designed simulation scenario and some in-progress intervention (via e-mail messages) within DREAMS by a role defined as the 'value web manager' allows specific enterprise issues to be focused on. For instance, the assigned value web manager may contact the subcontractors saying, '… please collude and submit a joint bid' (e.g. where a tugboat supplier and a heavy-plant supplier on a harbour extension project have complementary bids). The effect on other users in dealing with this type of perturbation can then be observed: if at the same time the 'contract owner' isn't notified of this deviation a serious negative impact could be incurred by the value web of the enterprise. Thus the most appropriate sphere of influence of the value web management role can be determined.
- consider that user changes to metrics provide a potentially valuable data source. Updates to estimated activity durations, along with the user's justification for any update, can be viewed as a means of capturing intelligence on a *cause and effect* situation.

OBSERVATIONS: CAPTURING ENTERPRISE SYSTEMICS

The most important issue within enterprise systemics is how to comprehend the operation of individual businesses, and the interaction of distinct businesses, by modelling systems of human activity. Research on this issue within the PISCES project has focused on the interplay in human activity systems between 'codified' and 'natural' processes. A 'natural' process in this context is ontologically distinct from a 'codified' process: it is the complex set of human interactions in pursuit of a given goal, which is often achieved not by process definition but by unspoken consensus. It exists independent of its being recorded. A codified process, by contrast, is the formally agreed representation of an existing or desired natural process. Business practice can then appropriately be viewed as a constant cycle in human behaviour towards the improvement of natural processes through the practice of incremental re-codification. The ability of an enterprise to evolve and adapt to meet new challenges given by the changing commercial context will be dependent on the quality of this process improvement cycle so far as it governs the human activity system. This raises several questions regarding how best to capture processes, using which taxonomy and at what level of detail, and when to abandon a captured and codified process in light of the continuously evolving natural process. The codified process is created for an explicative purpose, so how do we know when to reinforce and correct deviation from it and when to abandon it?

Two extremes are to be avoided: an absolute lack of codified processes would tend towards unruliness, while an over-reliance on codified processes could result in the stifling of innovation and the propagation of a negative, adversarial attitude towards process definition throughout an enterprise. Therefore, a central challenge is to accommodate the essentially static nature of a codified process within a turbulent stochastic environment, which can be modelled in a VDT-type simulation tool. While it is true that ‘codification always represents a simplification’ (Aslaksen 2001), given that the full complexity of an newly evolving process is unknowable, there is still a value in attempting comprehension so long as this is acknowledged as merely a purposeful illustration and thus subject to error and doubt. This comprehension exercise is well suited to the DREAMS-type simulation tool.

The usefulness of a codified process therefore resides in its appropriate level of detail and the agreed mechanism by which it can be updated regularly, swiftly and accurately. To address the continuous evolution of natural processes within human activity systems we should perhaps treat codified processes as simply scaffolding, within which natural processes are built up. Once the natural process is built and embedded the codified process can then be transferred to a new scenario for process improvement.

SUMMARY

This docking methodology has been designed to utilize the relative strengths that computational-based and role-based simulation tools have for simulating organizational systems. The documented feasibility study demonstrates that risks can be predicted about *routine* processes that can be codified by simulations using stochastic modelling techniques and *computational agents*. In contrast, the test case also illustrates how people assuming roles as *human agents* and interacting through a *role-based* simulation environment can provide innovative, experience-based solutions to *non-routine* issues occurring in ‘natural’ processes.

The combined properties of the hybrid system, although still only conceptually docked, provided an insightful reflection on the dynamics of enterprise behaviour. For instance, one seemingly simple suggestion by a user in DREAMS can effect the whole system to behave differently and so effectively require a different computational-based model to be produced enabling an informed ‘what-if’ enterprise scenario to be prototyped before being implemented. Also, users were myopic about their work behaviour and want to be seen to be doing the best locally even if globally the effect is adverse.

Computational-agent based simulation such as VDT can provide us with tremendous insight into looking at cause and effect of ‘what-if’ scenarios. However, the inherent limitation here is that when using this type of simulation a modeller must either take the cause or the effect as the independent variable and cannot mix them (e.g. the user must always change skill levels of an agent and look at the lead-time effect). Since DREAMS can capture both cause and effect simultaneously without setting one as a dependent variable it lends itself to the possibility that classical organizational theory, which forms the underlying execution of predictive simulation systems such as the VDT tool, can be validated. This same property of DREAMS enables a direct record between user action and substantiation to be created from which a rich tacit data set about enterprise systemics can be produced.

The next logical step in the development process of this system is to transfer real documents with actual project content rather than use ‘token documents’. In this mode the DREAMS simulator is effectively being used for real-time project management, with an additional capability of producing off-line simulation workshops (using tools such as VDT) for redesign of the extended enterprise. This mode of use is currently being practiced within a large USA-based aerospace company. The vision for the long-term future is to have a single integrated system with further properties based on the principle that to understand enterprise systemics we need systems to replicate the codified behaviour of enterprises and inform us how real people using the system can evolve the non-codified nebulous non-routine aspects of enterprise behaviour that must require human intervention to resolve. Therefore, there is a great mutual benefit in docking these differently based types of software in order to develop a hybrid system for continual learning about enterprise systemics

REFERENCES

Aslaksen, E. "Comments on PISCES Launch Meeting Report". Website, www.elipsis.com/pisces. 2001.

Boardman, J.T. "Wholes and Parts – A Systems Approach". *IEEE Transactions on Systems, Man and Cybernetics.* Vol. 25, No. 7 July. 1995.

Checkland, P.B. *Systems Thinking, Systems Practice*. Wiley. 1993.

Clegg, B.T., Boardman, J.T. *et al*. "Tool Support for Integrating Extended Enterprises". *IEE Proceedings, Software*. Vol. 147. No. 4. 2000.

Clegg, B.T., *"A Systems Approach to Reengineering Business Processes to Concurrent Engineering Principles"*. PhD Thesis. 1999.

Fairbairn, A., Farncombe, A., *"Enterprise Systemics: Systems Thinking for plotting Strategy at the 'Extended Enterprise' level"*. Website, www.elipsis.com/pisces. 2001.

Fine, C. *'Clockspeed: Winning Industry Control in the age of Temporary Advantage'* Perseus Books. 1998.

Galbraith, J. *'Designing the Global Corporation'*. Jossey-Bass. 2000.

Kunz, J.C., Levitt, R.E., Jin, Y., "The Virtual Design Team: A Computational Simulation Model of Project Organisations". *Comms. of the Association for Computing Machinery*. Vol 41, No. 11, pp84-92. 1998.

Ring, J. 2000. 'Concept of Operations (ConOps) for a Value Chain Manager'. Website, www.elipsis.com/pisces.

BIOGRAPHIES

Ben Clegg graduated from Loughborough University (UK) with a degree in Management Science. He has worked as a project manager for GEC. He has a PhD in engineering of human activity systems from De Montfort University (UK). He has recently completed a sabbatical year at Stanford University (USA) working with the VDT group directed by Prof. Ray Levitt. Currently, he is a Senior Lecturer with the Technology Innovation Centre (tic-online.ac.uk) at the University of Central England. He has also acted as a consultant for Elipsis Ltd., a company developing integrated software and systems for enterprise integration.

Matthew Turner has a BA in English and Philosophy (First Class Honours) from Keele University (UK); an MA in Modern Literature (Since 1850) (Distinction) from University of Kent at Canterbury (UK); and a PhD in English Literature from University of Sussex (UK). His thesis explored modernist literature, theories of culture, and early twentieth-century British society. He has subsequently developed a wide scope of research interests regarding the complex relations between culture and society in diverse settings, including commercial organizations. Since 2000 he has worked for Elipsis Ltd, with responsibilities including coordination of the PISCES research network project.