INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

**ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600**

UMI[®]

**Modeling Human Performance
in a Telecommunications Network
by
Gabriella Nagy**

**A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of
Master of Arts**

**Department of Psychology
Carleton University
Ottawa, Ontario
July, 2001**

© 2001, Gabriella Nagy

**National Library
of Canada**

**Acquisitions and
Bibliographic Services**

**395 Wellington Street
Ottawa ON K1A 0N4
Canada**

**Bibliothèque nationale
du Canada**

**Acquisitions et
services bibliographiques**

**395, rue Wellington
Ottawa ON K1A 0N4
Canada**

Your file Votre référence

Our file Notre référence

The author has granted a non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

0-612-66840-1

Canada

The undersigned recommend to the
Faculty of Graduate Studies and Research
Acceptance of the thesis:

"Modeling Human Performance in a Telecommunication Network"

submitted by

Gabriella Nagy

in Partial fulfillment of the requirements for

the degree of Master of Arts

A handwritten signature in black ink, appearing to be 'K. ...', written above a horizontal line.

Chair

A handwritten signature in black ink, appearing to be 'R. West', written above a horizontal line.

Thesis Supervisor

Carleton University
July, 2001

Abstract

The proportion of system downtime related to human error is on the rise in telecommunications networks. The need of the industry for examination of human performance led us to the development of Situated GOMS (SGOMS), a unique modeling system that captures not only the goal driven aspects of human behavior but also some of the event driven aspects. An SGOMS model of telecommunications installation work was developed by adding domain knowledge to the modeling system and tested on data collected after the model was completed. The model predicted behavior well and allowed for the integration of different task domains within the sociotechnical system. This modeling system could help researchers ask better questions and may simulate human behavior in complex domains more realistically than those methods that currently apply.

Acknowledgements

I would like to express my sincere thanks and appreciation to several individuals who have helped me in the process of completing this study.

Special thanks go to those people who volunteered for my study, invested time and effort explaining what their work is all about, and allowed me to be around even at very busy times. Thank you, Helen Maskery, who made it possible to conduct my study within the industry.

I wish to thank to my advisor, Dr. Robert West, who has great ideas, as well as Dr. Richard Dillon who is always there for his students. Thanks to Dr. Gitte Lindgaard, and to Dr. Jo Wood for their support and guidance throughout this project.

I am thankful to Patricia Frazier, who edited and corrected my English, and who has struggled through with me on every paper since my first undergraduate course.

Finally, I want to thank my husband Tamás, who always encouraged me to keep at it, even in the darkest times. Thank you for putting up with my absence for three years.

Table of Contents

	Page
Thesis Acceptance Form	ii
Abstract	iii
Acknowledgements	iv
Table of Contents	v
List of Tables	viii
List of Figures	ix
List of Appendices	x
Introduction	1
A Telecommunications Network	2
The Human Element	3
Sociotechnical Systems	4
Complex Systems	6
Distributed Cognition	8
Methodologies for Understanding Complex Human Performance	9
Task Analysis	9
Field Observation	11
Cognitive Modeling	12
GOMS Models	14
The Unit Task	16
GOMS Model Variations	17
Expanding GOMS Models	18

Planning Unit	20
The Template	22
Methodology	24
Participants	24
The Task	24
Apparatus and Material	25
Procedures	25
Model Building, Interview Sessions	25
Model Building, Observations	27
Model Testing	28
Results	29
Sequence of Steps between Planning Units	29
Sequence of Steps within Planning Units	30
Constraints	31
Interruptions and Problems	31
Dealing with Problems	32
Unexpected Planning Units	34
Generalizing the Importance of Social Information	35
Discussion	36
The Human Element	39
Sociotechnical Systems	45
Distributed Cognition	47
Complex Systems: The Importance of People	48

Future Studies	50
Recommendations	52
Conclusions	53
References	54
Appendices	58
Tables	117
Figures	130

List of Tables

Table	Description	Page
1	Observed Planning Units during Model Building Phase	117
2	Predicted and Observed Steps of Planning Units	118
3	Modified Predicted Steps and Observed Steps of Planning Units	119
4	Conditional Sequential Analysis	120
5	Frequency of Problems during Planning Unit Execution	121
6	Types of Problems Encountered during Planning Unit Execution	122
7	Types of Communication during Planning Unit Execution	123
8	Media Utilized for Communication	124
9	Media Utilized for Information Requests	125
10	Media Utilized for Orders	126
11	Media Utilized for Information Exchange	127
12	Media Utilized for Interruptions	128
13	Information Obtained by Communication	129

List of Figures

Figure	Description	Page
1	Template Describing the Flow of a Unit Task	130
2	Template Describing the Flow of a Planning Unit	131
3	Predicted and Observed Steps of Planning Units	132
4	Modified Predicted Steps and Observed Steps of Planning Units	133
5	Frequency of Problems during Planning Unit Execution	134
6	Types of Problems Encountered during Planning Unit Execution	135
7	Types of Communication during Planning Unit Execution	136
8	Media Utilized for Communication	137
9	Media Utilized for Information Request	138
10	Media Utilized for Orders	139
11	Media Utilized for Information Exchange	140
12	Media Utilized for Interruptions	141
13	Information Obtained by Communication	142

List of Appendices

Appendix A: Examples of Questions Generated by the Template	58
Appendix B: Interview Sheet	61
Appendix C: Informed Consent Form	62
Appendix D: Planning Units	65
Appendix E: Constraints	72
Appendix F: Observation Notes (Model Testing Phase)	78
Appendix G: Example of How Observation Notes were Associated with Planning Units	111

Modeling Human Performance in a Telecommunications Network

Our everyday lives are dependent on the Internet. A network problem can create delays and frustrations for hundreds of thousands of telephone and data line users. Since 1992 the Federal Communications Commission (FCC) has required reporting large service outages by telecommunications service providers. The Federal Communications Commission (1998) defines an outage as "... a significant degradation in the ability of a customer to establish and maintain a channel of communication as a result of failure or degradation in the performance of a carrier's network." An outage has to be reported to the FCC if it potentially affects 30,000 or more customers and if such outage continues for 30 or more minutes.

Since 1992 the "Alliance for Telecommunications Industry Solutions/ Network Reliability Steering Committee" (ATIS/NRSC) has performed various analyses on the FCC outage data. According to the NRSC Annual Report (1998), in that year procedural errors were the root cause of 32% of outages. The FCC (1998) defines procedural error as "... problems with documentation, training, supervision, maintenance or some sort of human error." The NRSC (1998) recognized that the frequency of outages due to procedural errors is significantly increasing, about 2.2 % per quarter year since 1992, while non-procedural causes demonstrated no change over time.

The NRSC analysis clearly indicates a growing human performance problem in the telecommunications industry that must be explored in more depth. The need of the industry for examination of human performance highlights the need for appropriate theories and methodologies for understanding the role that people play in such systems.

There has been little research into the factors influencing the behavior of telecommunications technicians, and even less to develop techniques that could capture the pattern of their behavior. The purpose of this thesis was to understand work in the telecommunications network by investigating the characteristics of the networking domain, its effect on technicians' behavior, and to identify a technique that realistically represents work behavior.

A Telecommunications Network

According to Tittel, Hudson, & Stewart (1999), a network is a connection among a large number of computing devices called hosts or end systems that share resources. Network applications, such as the World Wide Web and e-mail, run on those end systems. Kurose & Ross (2000) state that end systems connected by communication links run protocols that manage the sending and receiving of information within the network. Links are made up of different types of physical media -- coaxial cable, copper wire, fiber optics, and radio spectrum transmitting data -- at different rates. End systems are not directly attached to each other via a single communication link. Instead, they are indirectly connected through intermediate switching devices known as routers. Routers, links and other "pieces" of the network transfer messages between the distributed, communicating components of a network. A router takes information arriving on one of its incoming communication links and forwards that information on one of its outgoing communication links. Equipment such as repeaters and amplifiers are implemented to combat signal attenuation.

A network consists of many complex, interacting pieces of hardware and software from the links, routers, hosts and other devices that comprise the physical components of

the network, to the many protocols (in hardware and software) that control and co-ordinate these devices. Yet without human contribution, the network is not able to provide services. Technicians perform various activities to reach an overall goal to provide service to customers of the telecommunications company.

The Human Element

Human activities are situated within the operations of the telecommunications network. There are various roles and job types such as surveillance, maintenance, support, set-up, and field technicians' activities with different responsibilities.

Surveillance teams monitor equipment, identify problems, recognize meaningful alarms and contact maintenance teams for resolution of alarms. They also keep track of alarm activity and system performance data. Maintenance teams perform hardware installation, identify and determine hardware-related problems in detail, and initiate actions to fix them. Set-up teams test and configure new equipment installed at sites to ensure network connectivity. Field technicians maintain an assigned territory for installation, maintenance and repair of system equipment. Support teams are responsible for trouble-shooting and also for interfacing with the manufacturer in the case of outages.

Technicians' expertise is somewhat different than it was 20 years ago. As technology continues to change, demands on networking technicians become more cognitive and less perceptual-motor in nature. Easily performed tasks are transferred to the network, while delegation and decision-making stay within the technician's task space.

To understand the interaction between individual technicians and the system that they interact with, it is necessary to understand the nature of the system.

Telecommunications networks can be characterized as *sociotechnical systems*, as *complex systems* and as *distributed systems*. Each of these characterizations is described below.

Sociotechnical Systems

According to Vicente (1999) a sociotechnical system is composed of technical, psychological and social elements. Technicians are not only interacting with the physical components of the telecommunications system but they are elements of the sociotechnical system. From a sociotechnical perspective, humans and computers are both elements of the system, and both are capable of intelligently performing some aspects of specific tasks. For example, either computers or craftspeople can perform protection-switching procedures. When a working path that carries network traffic fails, either technicians or computers can force the traffic to a backup, protection path. In sociotechnical systems the human behavioral and social subsystems affect, and are affected by, the non-human, technological subsystems and these subsystems in turn affect, and are affected by, a dynamic social and natural environment (Hopkins, 1973).

Vicente (1999) describes the sociotechnical systems as having four layers: (1) technical system; (2) workers; (3) organizational and management infrastructure; and (4) environmental context. He explains that the technical system is located in the core of the sociotechnical system. In our case the technical system is composed of all of the technical factors necessary to have a reliable telecommunications network.

The next layer of the sociotechnical system is composed of the workers. This layer is concerned with psychological factors, technicians' capabilities and limitations;

behaviors, perceptual, motivational, decisional, attitudinal aspects that are manifested by people. DeGreene (1973) emphasized that the investigation of the human sub-system could not be dealt with only on the level of the individual. He states that the focus should be also on those features of behavior that are revealed by people working with other people.

The third layer of the sociotechnical system is the organizational and management infrastructure. According to Vicente (1999) recognition of the political, decision-making environment reveals problems confronting humans. In telecommunications networks these may involve value changes that stem from company mergers, changes in aspiration level as a project gets cancelled, or teams are out-sourced, etc. Reason (1991) points to other factors, such as goal conflict that can stem from organization or people pursuing several goals at the same time; and inadequate communication, where information does not reach the appropriate recipients. Poor management decisions concerning planning, design, construction and maintenance can be just as detrimental to human performance in telecommunications networks as poor operating procedures can.

The environmental context, the fourth layer, would consist of factors related to the industrial environment such as regulatory requirements, competition amongst companies for a significant share of the market, and the physical environment. Vicente (1999) states that the technical engineering aspect of the sociotechnical system is just as prominent as the psychological and social aspects of the workers, their organization, management infrastructure, and the environmental context of their work.

When human performance is investigated in a telecommunications network, it is key to understand that the unit of the analysis is a sociotechnical system composed of

individuals and machines with their related contexts. Suchman (1987) states that planned, purposeful actions have to be taken in the context of the particular, concrete circumstances. Even though any goal can be represented in the human mind independently of the situation in which it takes place, action to achieve that goal cannot be detached from the conditions of the concrete situation (Bardram, 1997). Human performance examination must consider the social factors, because the system comprises not only telecommunications equipment, but is a collection of equipment and a number of technicians operating the equipment.

Complex Systems

Telecommunications networks, in addition to being sociotechnical systems, are also complex systems. According to Wieringa & Stassen (1991) a system is called complex whenever the number of subsystems and components is so large that is hard to see the existing causal relations between components. Vicente (1999) defines a system as complex when it rates high in several of the following dimensions: “...(a) large problem spaces, (b) social, (c) heterogeneous perspectives, (d) distributed, (e) dynamic, (f) potentially high hazards, (g) many coupled subsystems, (h) automated, (i) uncertain data, (j) mediated interaction via computers, (k) disturbances” (p. 14).

The massive number of factors that telecommunications technicians must take into consideration while working qualifies as a large problem space. The social aspect of work is also inevitable. Communication and co-ordination with people working in collaboration adds to system complexity. The fact that people in a telecommunications system often come from different disciplines and have different perspectives may mean that conflicting value systems introduce additional complications. Furthermore, technicians are frequently

at separate geographical locations. When technicians act, they may not be aware of a remotely located co-worker's action. As well, the telecommunications system is generally dynamic; the work domain can respond very quickly to the action of the technicians. The dynamic aspect of the system requires technicians to anticipate the future state of the system.

In a telecommunications system, problem-solving activity often becomes more complex because of the uncertainty of data. Vital information for problem solving is often absent or data is deceptive because of inappropriate performance of sensors or equipment. Complexity is increased by the fact that technicians are required to deal with unplanned events and to adapt to changes quickly while maintaining system productivity. An important role of technicians is to control spontaneous situations where pre-defined procedures are usually either deficient or completely lacking. In this case, the person may contribute significantly to the robustness and adaptability of the system, or may contribute to an outage.

Unplanned events, because of their uniqueness and infrequent occurrence, can create huge cognitive demands on operators. It is common practice within the telecommunications industry to require operators to follow documented step-by-step procedures. Problem solving performance, which is needed when faced with a novel situation, is not encouraged. This lack of exploration results in very limited opportunities to learn and explore the system. While people problem-solve and make actual choices depending on very subjective and situation-dependent features in challenging situations, factors such as the urgency of dealing with the problem intelligently make the situation

even more complex. A telecommunications system has all the attributes of a complex system.

Distributed Cognition

Telecommunications systems, while they are sociotechnical and complex, are also distributed. There is not a single person who is able to understand and run the network on his/her own without the help of others. Hutchins (1995), who spent a month in a U.S. navy ship observing the work of the navigation team, came to a similar conclusion: no single person had enough knowledge to navigate the ship. Hutchins claims that a highly social activity involving frequent interaction of many people and artifacts that participate in the performance can be considered a distributed cognitive system. An individual is a functional component of a distributed cognitive system if the person needs to acquire information from other humans or from specialized equipment to perform a task.

Hutchins (1995) claims that complex cognitive systems have properties that are distinct from the properties of the individual. These properties are deduced from the effectiveness with which a group utilizes its physical environment, and also by social organizational factors. Such properties can be identified through analysis of the representation of knowledge both inside the heads of individuals and in the environment, the real-time interactive distribution of information between people performing a collaborative task.

Here is an example from the telecommunications industry to illustrate distributed cognition. On a conceptual level network maintenance and restoration can be considered as an information-processing activity. In this activity a problem has to be detected, identified, and interpreted; and the appropriate changes of the system defined and

executed. Such cognitive processes, however, are not related to a single brain, but rather distributed, among many teams. The surveillance team detects system disturbance. They perceive unusual events in the network, thereby becoming the eye of the information-processing system. The support team interprets problems and defines appropriate change for the system. They problem-solve, thereby becoming the brain of the information-processing system. Field technicians execute system changes. They act, thereby becoming the hand of the system. These groups of people work collaboratively on a complex problem acting as a complex cognitive system by using a large number of artifacts such as various intelligent software applications. The system can be understood by recognizing how it achieves its goal; i.e., by the representation inside and outside the head and the transformations these structures undergo.

Methodologies for Understanding Complex Human Performance

This section describes the three main methodological approaches used for understanding human performance in complex tasks. In practice, they are not distinct and researchers often combine them. Differences lie mainly in the fields from which they emerge. Task analysis is derived from an engineering approach, field observation comes out of anthropology and sociology, and cognitive modeling originates from psychology and cognitive science.

Task Analysis

According to Hollnagel (1993) task analysis is a systematic description of the appropriate actions that a person is expected or required to carry out, including how the actions are related. He further states that task analysis is a proper basis for human performance assessment. Even though task analysis represents a diverse set of approaches,

it generally makes an attempt to identify the ideal way(s) in which the job should be performed (Kirwan & Ainsworth, 1992). The strength of task analysis is that it describes the user's behavior and the structure of the task.

According to Vicente (1999) the input/output task analysis identifies the inputs that are required to perform the task, and the outputs that are achieved upon completion of the task. Task analysis can also list constraints that must be taken into account in selecting the actions that are required to achieve the task. The input/output type of task analysis deliberately ignores process details: the sequence of the actions that transform input into output. In contrast to the input/output task analysis, the sequential flow task analysis identifies the temporally ordered sequence of actions required to complete the task (Vicente, 1999). This type of analysis is dependent on the tools people have available to perform the task. For example, network cable testing can be performed by using a variety of test equipment, some requiring distinctively different actions.

Sequential task analysis can describe various tasks for various tools by incorporating branching to represent alternative paths in the process, but the result could lead to complicated sequential flow charts. However flow chart branching is generally not utilized because of the complex task representation (Vicente, 1999).

The time-line type task analysis identifies a temporally ordered sequence of actions with duration estimated for each action. This method is very detailed, and works well if there is only one right way to perform the task. This method excludes all of the possible deviations, and produces one, very detailed procedure to be followed.

In a complex system such as a telecommunications system, it is impossible to identify a flow of sequence or timeline appropriate for every possible situation. As

cognitive task content increases, the diagrammatic time-line task description representation becomes less satisfactory (Kirwan & Ainsworth, 1992).

Field Observation

Field observation is an activity involving watching and recording subjects' naturally occurring behavior while participants are in their natural environment (Mitchell & Jolley, 1996). While approaches such as task analysis focus on what people should do, observation looks at what people actually do and what they would like to do. The goal of field observation is to find patterns and design-relevant activities, such as work processes or computer usage patterns while people work. Casual observation can be used to gain a basic understanding of a situation quickly and at minimal cost. Systematic observation can categorize and quantify observations.

Field observation, like task analysis, is tool-dependent because observation represents those strategies and tasks that people use to get the job done with whatever tools are available (Vicente, 1999). Observations will always be incomplete because it is impossible to observe every scenario under all possible conditions. It is impossible to know what factors have been missed. Actions that may be an important part of work but not used during the observation period are ignored with this methodology. These actions may currently not be feasible for technicians because they are too effortful or time consuming, based on today's set-up of work, or on available tools or interfaces. However, acknowledging these actions is useful since these unexplored possibilities could become appropriate when unplanned events occur.

Vicente (1999) states that observational methodologies stress the importance of context-determined variability, and recognize that while people work they continuously

adjust to their changing circumstances. As well, these methodologies emphasize the fact that people do not work in isolation but rather in teams, and must communicate to reach their goals.

Cognitive Modeling

Cognitive modeling involves constructing a model of how a person processes information during a task, not just what actions they take. Hollnagel (1993) states that there are two main classes of cognitive models: procedural prototype models and contextual control models (also known as situated action models). A procedural prototype model describes goal-directed behavior, implicitly expressing the view that there exists a characteristic or pre-defined structure of actions, which represent a natural or preferred way of doing things. This type of model is often associated with a task analysis approach. A contextual control model captures event-driven behaviors and implies that actions are determined by the context. Choice of the next action at any time is determined by the current context, i.e., by situation cues. This type of model is often associated with a field study approach.

The approach taken in this paper was cognitive modeling, although the process of creating the model also involved task analysis and field observation. However, since telecommunications technicians engage in both goal-directed behavior and context dependent behavior, a model that integrates these two approaches was required.

A major problem with current modeling practices is that they advocate separate models to account for the social dimension and the technical dimension. Schraagen, Chipman, and Shalin (2000) state that the literature is weak in specifying the methodology of integration. Newell (1990) states that a single type of cognitive system

(the human mind) produces all aspects of behavior and that the goal for cognitive modeling should be to produce unified theories and unified models of cognition. Such unified models focus on how different aspects of a task are integrated to produce intelligent behaviors.

There are over 50 well-known modeling systems designed for use with complex systems. These include operators' action event trees (Kirwan & Ainsworth, 1993), decision/action flow diagrams (Duncan & Gray, 1975), cognitive task analysis techniques (Schraagen, Chipman & Shalin, 2000), human error and reliability analysis techniques (Murgatroyd & Tait, 1987), ergonomics checklists (Bellamy & Geyer, 1988), root cause analysis (Leplat, 1982), to name but a few. Even though there are major differences among approaches to models, their basic structure is similar. All of the models approach human performance applying the terms of production system rule i.e., "if...then" rules. Experienced users rely on such rules to choose between distinctive ways of achieving task completion when they are dealing with a routine task. For example, when technicians perform cable testing, they perform a different task sequence based on what type of cable they are testing: *if fiber then* perform fiber testing procedures, *if copper then* perform copper wire testing procedures. For assessing knowledge-driven tasks, i.e., when users know what to do and simply just follow the usual steps of a procedure, production system rules provide an effective framework for models.

None of these modeling systems was designed for combining goal directed and context dependent behavior, and none address the integration of social and technical aspects of the task. It is necessary to develop a new modeling approach capable of integrating different types of behavior.

GOMS models have been shown to be able to integrate goal directed and context directed behavior (John & Vera, 1992), and to be able to handle both technical and social information (West, Wong & Vera, 1998). In the John and Vera study, the work was limited to a very restricted environment (playing a Mario Brothers video game) and involved modeling a single person acting in isolation. In the West et al. study, the work was limited to a theoretical discussion. To use GOMS models in a complex sociotechnical environment, the traditional GOMS approach must be modified.

GOMS Models

GOMS (Goals, Operators, Methods and Selection rules) is a family of techniques that model human performance. Card, Moran and Newell (1983) introduced GOMS models to represent the procedural knowledge of humans required to operate a system. GOMS models describe the task and the user's knowledge of how to perform the task in terms of goals, operators, methods and selection rules.

Goals represent what a user is trying to accomplish, and are usually specified in a hierarchical manner (John, 1995). A goal is often a specified condition or state of the system that signifies completion of a task or a task step. For example, in network troubleshooting the highest goal is to return the system to its functioning state. It is often the case that a task cannot be carried out until a precondition has been met. When a pre-condition exists, it is considered a sub-goal, since it describes a condition that must be satisfied for a task step to be carried out. A sub-goal for troubleshooting might be to clear alarms on the system.

Operators, the O in GOMS, is a set of actions (either physical, perceptual or cognitive) with which a user composes a solution to a goal. In the network

troubleshooting example, the operators could log on to the system, or save alarm reports on the system. If psychological processes are too complex to be practical to represent in the model, analysts can denote these processes by defining operators that act as placeholders for the mental activity that is not further analyzed. For example, when the task is to recognize alarm messages on the screen, the researcher can represent this activity in the model as an operator, instead of breaking it down further.

Methods, in Goals, Operators, Methods, Selection rules represents a sequence of operators, grouped together to accomplish a single goal (Kieras, 1997). Methods may call for sub-goals to be accomplished so the methods have hierarchical structure. For example, one method to accomplish the goal of re-routing traffic to working equipment is to identify what equipment is still functioning and has available capacity, notify team members that traffic will be routed to that equipment, and switch the traffic to that equipment.

If there is more than one method to achieve a goal, then *selection rules* are necessary to represent the user's knowledge of which method should be applied. For example, another method to accomplish the traffic re-routing goal would be to identify the capacity needed, select appropriate equipment from the storage room, temporarily install the new equipment, notify team members that new equipment has been installed and route traffic to the newly installed equipment. Selection rules can arise through personal experience with the equipment or through explicit training. For example, a technician may have a rule for the traffic routing goal that says *if* the lost traffic is larger than the general free base capacity of the system *then* use the new equipment installation method, otherwise use the available capacity allocation method.

The difference between a goal and an operator is a matter of detail chosen by the analysts (John & Kieras, 1996). A goal is something to be accomplished, while an operator is an action to be executed. A goal is always broken down into methods described by a collection of lower-level operators. While methods are broken down into operators, operators are not broken down into any more detail.

Any GOMS analysis assumes a certain grain of analysis. In principle, the goals and operators of a task could be described at much higher levels, for example collaborative troubleshooting, or ever-deeper levels of detail, e.g., muscle movements of the actions. It is not necessary to specify all parts of an analysis to the same level of detail. Different parts of a task or a system may require different levels of detail. The analyst should expand only those parts of the goal hierarchy that are necessary for the question at hand.

The Unit Task

Card, Moran & Newell (1983) explain that when people start to perform a task, they fragment the task into smaller sub-tasks. These sub-tasks are labeled unit tasks. People impose unit task structure on their behavior to keep unit tasks within their performance limitation. In knowledge-based behavior, to ensure the appropriate performance, the flow of information has to be managed in working memory. When the information output flow cannot keep up with the input, or vice versa, then the behavior is structured into a series of units, each called a unit task. Users impose unit-task structure on their behavior because of the constraints imposed by their cognitive, perceptual and motor systems, and also the constraints imposed by the task. For example, if a person learns to open a word processor and then open a file, the unit task concept suggests that

they would store this process as two separate unit tasks: open word processor and open file. This would allow flexibility (e.g., a person might want to open another file while in the word processor so would need the capability to access the open file procedure independently of opening the word processor). The system also reinforces this task division because one must wait while the word processor is being opened and while a file is being opened. According to the unit task concept, waiting will usually result in coding the subsequent actions as a separate unit task so that the brain can process something else (e.g., scan the environment) while waiting.

GOMS Model Variations

According to John & Kieras (1996), the GOMS' family of techniques can be broken down into four major groups: KLM, CNM, NGOMSL, CPM-GOMS model. Different techniques were developed to capture different situations even though all of the following techniques are based on the same GOMS concept.

KLM, the Keystroke Level Model, was developed by Card, Moran, and Newell (1983). This version of GOMS uses a single stream of operators, no goals, methods or selection rules. KLM is based on a serial stage model of human information-processing activity with no parallel activities and no interruptions involved. The primary application of the KLM model has been to text-editing tasks.

CMN-GOMS is a term that refers to a form of GOMS model presented in classic reference (Card, Moran & Newell, 1980) where CMN refers to Card, Moran and Newell. CMN-GOMS demonstrates how to express goals and sub-goals in a hierarchy, methods and operators, and how to form selection rules. This form of GOMS model is capable of predicting not only the operation sequences but also the execution time of the whole task.

While KLM is in basic sequence form with a fixed sequence of operators accomplishing a particular task instance, CMN-GOMS is in program form, where methods take any legitimate set of task parameters and execute the corresponding instance of the task, often resulting in conditional branching of sub-methods, and sub-goals.

Natural GOMS Language (NGOMSL) was developed by Kieras (1988).

According to John & Kieras (1996), NGOMSL presents a procedure for clearly identifying all the GOMS components expressed in a form with syntax similar to a computer programming language. It presents methods in terms of Cognitive Complexity Theory (CCT: Kieras & Polson 1985). Because the CCT theory's purpose is to support the design process of dialogues with respect to the expense and transfer of learning, execution time, and the user friendliness of the system, it facilitates NGOMSL to provide quantitative prediction of learning.

CPM-GOMS Cognitive, Perceptual, Motors-GOMS, the most complex type of GOMS, was developed by Gray, John & Atwood (1993). Unlike the other GOMS techniques, it does not make the assumption that the operators are performed serially, but maps sequential dependencies amongst the perceptual, cognitive and motor operators allowing parallel information processing based on demands. While each of these extended modeling are valuable and useful in particular situations, other types of useful extensions could be made to give GOMS modeling even more scope.

Expanding GOMS Models

John (1995) states that generally the GOMS approach applies well to situations where people have already learned a task, where they are not problem-solving, nor hunting for what they need to do next. GOMS works very well in a single user situation

in closed systems, where the user tells the system what to do, the system does it, and reports back to the user.

On the other hand, West and Yuen (1999) state that it is possible to use GOMS models to model human-computer interaction tasks within the social context in which they occur. By using the GOMS approach, researchers can model the complex action of a single operator or a group of people working in context as a distributed cognitive unit. To demonstrate how this is possible, a template was created by West and Yuen in 1999 (see Figure 1).

West and Yuen (1999) explain that when people begin a task they have a goal in mind (see box 1, Figure 1). They then retrieve the first method of the unit task from memory (see box 2, Figure 1) and execute it (see box 3, Figure 1). Their action changes the environment somewhat, and also the environment can change while they are acting. Communication can be described as placing and retrieving information into and from the environment, which also changes the environment. Before taking the next step, they examine the environment and update their situational knowledge (see box 4, Figure 1).

A unit task is only appropriate in a certain context. If there is any change in the environment, then the people must re-evaluate whether or not the unit task is still appropriate, i.e., decide if continuing their activity is still meaningful in the new context. If they find the unit task is still appropriate even though changes occurred, they proceed to the next method of the unit task (see box 2, Figure 1). If it is discovered that the unit task is not appropriate in the new context, additional steps will be performed to change the environment back to its previous state so that the unit task will be meaningful again. If people know how to change back the environment then they retrieve the solution (see

box 6, Figure 1) and execute it (see box 7, Figure 1). When the context is appropriate to continue with the unit task, they examine the environment for any changes that may have happened while they were modifying the context and then re-evaluate appropriateness of the unit task. When there is no immediate solution as to how to modify the context, thinking then shifts from routine activity processing to creative problem solving to regenerate a new, more appropriate unit task for the new context.

West and Yuen (1999) state that this looping mechanism does not take into consideration all aspects of environmental changes in people's behavior since it only deals with change in the environment at a particular time during the course of unit task performance. Change in the environment can occur at any time during the performance of a unit task: for example when retrieving the first method of the unit task. A module called Parallel External Monitor (see box 8, Figure 1) was introduced to address people's actions related to such change in the environment. The Parallel External Monitor indicates that people continuously monitor the environment for certain changes that can make the unit task meaningless. When such changes happen in the environment people stop and pay attention, no matter at what stage of the unit task execution. As can be seen, West and Yuen's model describes human performance as goal-driven, but also constantly adapting to changes in the environment.

Planning Unit

West and Yuen's approach (1999) was developed for describing how pairs of architects work in collaboration on a well-defined architectural problem while using computers. The organizing unit of the model was the unit task with its specific constraints related to the limitation of the working memory of the human brain. However,

preliminary investigation led to the conclusion that the West & Yuen model was focusing on the description of human behavior at a level that is too low to construct a clear picture of behavior in a complex sociotechnical system, such as telecommunications network management. The result would be a massive number of unit tasks with no structure to organize them or to supply knowledge about the context in which they are performed. This thesis suggests incorporation of a higher concept, a new element called a planning unit to the basic GOMS model.

The planning unit is similar to a unit task in the sense that it explains how people control their behavior in response to resource limitation. With a unit task, limitations of the human brain and also constraints imposed by the task lead to structuring tasks into a series of units. With the planning unit, social constraints imposed by the sociotechnical system force people to chunk the tasks. While a unit task is related to a single person working in a system without disturbances, a planning unit is based on group dynamics and group level constraints related to people working in an open system environment where disturbances are frequent. Also, since one purpose of the planning unit is to provide a structure for coordinating with others, specific names should exist to identify and label the planning units.

Another important difference is that unit tasks are meant to be units that are performed from start to finish, unless the context changes in such a way that a new unit task must be performed to accommodate the change. In contrast, planning units are meant to be flexible. They can be stopped, postponed and started where it was stopped again to accommodate the changing dynamics of the work place. Planning units are meant to be

reorganized and shuffled based on the constraints imposed by the current state of the sociotechnical system.

To integrate the unit task and planning unit concepts, this thesis proposes that unit tasks are steps contained in planning units. Therefore a task is broken down first to large sub-tasks based on the constraints of the sociotechnical system, and each large sub-task is further broken down to a smaller sub-task, called unit tasks, based on limitations of the human brain. First a planning unit must be selected based on contextual constraints, then the first unit task selected related to that planning unit. After the execution of the unit task the process is identical to that suggested by West and Yuen.

The Template

The template structure used for describing the flow of the planning units is very similar to that used by West and Yuen (1999) to describe the flow of a unit task (see Figure 2). This template describes the flow of a planning unit, and how the unit task is situated in the planning unit structure. A recursive system that handles events at both levels (i.e., unit task and planning unit) was proposed, although only the planning unit level was examined. This template can also drive data collection; i.e., the kind of information practitioners should look for or ask, from subjects when human behavior is assessed in a complex system. Some examples are listed in Appendix A.

The template illustrates goal-driven behavior since the original GOMS Unit Task is an integral part, along with event-driven behavior such as interruptions and various other effects of the environment. Different sides of the template are active depending on whether event- or goal-related actions are dominant. If much event-driven behavior is

taking place, the left side of the template is more active; if more goal-driven task performance occurs, the right side of the model is more active. Goals and events determine the activity pattern of the model.

The new model developed was named SGOMS, for Situated GOMS, and this is how it will be referred to from now on. Below are predictions this research has made based on the model:

- (1) In the SGOMS model, planning units do not occur linearly, as with unit tasks. Instead they should be shuffled based on the current set of constraints imposed by the sociotechnical system.
- (2) The constraints used to select between planning units should be observable through the self-report of the technicians.
- (3) Within a planning unit, steps (i.e., unit tasks) should be completed in linear sequence. Thus, within a planning unit the model should be highly predictive of the sequence of actions.
- (4) Planning units can be interrupted and resumed at a later time.
- (5) More generally, this model suggests that communication is a significant part of the work. Since planning units are meant to be frequently stopped when problems surface, it would be essential for technicians to be able to pass on information concerning the current state of the problem. This stands in contrast to current models, which emphasize procedures that run from start to finish.

Methodology

To test the above predictions, participants were interviewed and observed while performing LAN Installation as part of daily work activities. A LAN Installation Model was created by using SGOMS as a theoretical base for the specific model creation. The goal was to develop a modeling tool, SGOMS, that takes into consideration the unique attributes of the complex system in which human performance is embedded. This research asserts that specific models can be developed by using the theory of SGOMS to appropriately represent the task performed in the complex system.

Participants

To perform necessary testing of SGOMS, access was gained to a representative member of the telecommunications industry, to be referred to as “Telco”. The operational group of Telco’s Intranet consisted of 12 technicians who volunteered to participate in this study. Approximate age range of group members was 21-55, with the majority in their thirties. All were males.

The Task

Since participants were currently performing Telco’s Intranet system infrastructure upgrade, one of their frequently performed tasks, LAN installation, was the subject of our study. Task selection was based on the availability of tasks, frequency of performance, ease of observation, and task complexity. A large task was selected, because more than one person would be involved. The task would be performed on a daily basis throughout the next three months and permission was granted to the researcher to attend various work sites while the configuration process was ongoing.

Apparatus and Material

Realistic Micro-16m microcassette tape with recorder was used to document some interviews and observation sessions, while others were captured by note taking. An interview sheet (see Appendix B) was developed for the study.

Procedure

The SGOMS modeling technique was tested by an iterative method that consisted of a model-building phase that included an interview session and a field observation session, followed by a model-testing phase that included a second observation session. During the interview and the first observation session, data was collected and entered to create a model of LAN installation. The purpose of the final observation was to test the LAN Installation Model by looking at how well it validates the model obtained in the earlier phase.

Prior to the first interview, the researcher reviewed the LAN installation documentation and customer reports to become familiar with the procedure. At a meeting prior to the first interview, technicians who participated completed an informed consent form. Each person was assured that the purpose of the study was not to test his ability but to assess the LAN installation process and develop a model of the process. Participants were also assured that all personal data would be kept strictly confidential. Further information was given about the possible time for the first interview and to give feedback on results of the study. This material is presented in Appendix C.

Model Building, Interview Sessions

The first part of the study consisted of an approximately 2-hour semi-structured interview session with three participants. Data from a fourth participant was not recorded

and does not appear in the model, because the participant felt uncomfortable providing answers. Since massive LAN installation was only performed for a limited time, technicians' availability and willingness determined the number of participants and the re-use of participants in the study.

At the beginning of the first interview, subjects were read a statement about the purpose of the study and told that their comments and answers to questions would be collected throughout the study to test the LAN Installation Model. Then background questions related to their experience on the job and also their experience with LAN installation were asked.

Participants were asked what LAN installation is, to describe the process, and were encouraged to talk freely about the task. Only clarifying and facilitative questions were asked, to ensure that the researcher understood what the participants were saying. One interview was tape-recorded, since the participant appeared to be very relaxed and was very talkative about his job. Notes were taken during the interviews, ensuring that the transcriptions were accurate summaries.

Participants had difficulty talking about details of their work. According to Beyer and Holtzblatt (1998) people sometimes do not remember how they do their work, because they depend on the environment and objects within it to remind them what to do. Since objects and environment are not available to help them talk about details of their work, often they give an overall impression, or overview. Moreover, there is a tendency to ignore many activities because they may seem trivial. Therefore, some aspects of work were not mentioned during an interview. Prior to the interview, it was not anticipated that people would omit so many details. The researcher tried to draw out details, but it was not

possible at this stage. More time than planned was spent with observation and less with interviews to counter this problem.

The next step in the process was to create a flow chart of LAN installation and to identify the planning units and unit tasks. Two job locations were visited twice during the next two weeks, and six technicians were asked, individually, to assist with the flow chart creation. Two of these technicians had previously participated in an interview. Prior to the flow chart creation, each step of the task was written on a Post-It Note and notes were placed on a large sheet of paper randomly (the steps were extracted from the earlier interviews). Technicians were asked to organize the Post-It Notes to accurately describe the LAN Installation process. Four people added steps to the process but no steps were eliminated. As technicians grouped the steps of the installation process to chunks, they named them. They said things like “these are the steps of cabling”, or “these are the steps of configuration.” Thus, they spontaneously grouped steps into units, and gave specific names for these units without prompting from the researcher. The groups were the indication of planning units. People did not see each other’s work and each chart creation started with the randomly arranged Post- It Notes to ensure that decisions were not affected by others’ opinions. When each task flow chart was completed, transparent tape was used to secure the Notes to the paper.

Model Building, Observations

The second part of the study involved approximately 50 hours’ observation of various participants at different job sites as they performed LAN installations. Four of the six technicians who participated in the first stage of the study were observed. Five technicians who had not participated in the first stage were also subjects of the

observation. A total of nine people were involved in the observation sessions. Six of the nine were observed more often than the others based on their willingness to participate.

Technicians performed the LAN installation procedure while “thinking aloud” and providing a verbal explanation (e.g., Van Someran, Barnard, & Sandberg, 1994). Notes were taken of what was said and of the technicians’ work activity. When physical actions, gaze, non-verbal cues suggested that specific tasks were performed but not explained spontaneously by the participants, questions were asked when the situation allowed. The goal of the observations was to capture the structure of technicians’ behavior and those details of their work that were not indicated by the interview sessions. Special attention was given to observing and recording concepts that the technicians used to indicate the segments of the LAN installation process. When the observation sessions were completed all of the planning units were identified (see Appendix D) and a list of constraints related to the planning units was generated (see Appendix E) to finalize the model.

Model Testing

The final observation phase of LAN installations served to verify the model developed in earlier interviews and observations. These observations took place at two sites in six instances within a two-week time frame. Observations lasted 2-7 hours. Five technician, all participants in earlier phases of the study, participated in the model-testing phase.

The researcher silently observed the work of the technicians, and wrote down every activity of the technicians and also relevant activities of any people on the job sites during the observation sessions (see Appendix F). When all of the observations were

finished, the planning units were identified by the researcher from the observation notes, similarly to the following example: “The technician obtained the LAN engineer’s LAN diagram, and then added the IP address to the diagram.” These steps appeared as activities in the Create LAN Diagram Planning Unit of the LAN Installation Model in the first phase of the study. Therefore these steps indicate that the technicians executed the Create LAN Diagram Planning Unit. All of the planning units that were seen during the second phase of the study were identified and compared to the steps of the planning units of the LAN Installation Model to the observed steps of the planning units (see Appendix G).

Results

Based on the interviews and observations, fourteen planning units were developed during the model-building phase (see Table 1). During the testing phase 18 planning units were observed. Six planning units were observed once, 4 planning units were observed twice, and one planning unit was observed four times.

Sequence of Steps between Planning Units

First, analysis examined whether or not overall work linearity existed, i.e., whether or not the planning units occurred in linear order as suggested by procedural documents and discussion with members of the management. This was definitely not the case. The technicians performed the various planning units in a non-linear manner. They re-arranged the planning units of one project while working on it, and they frequently interleaved the planning unit of different projects together. Technicians often worked on 10-15 different LAN installation projects at the same time.

Sequence of Steps within Planning Units

Next, the analysis examined how well technicians followed the steps (i.e., unit tasks) described in the planning unit. Out of the 146 steps that the model suggested, 39 steps were observed (see Table 2, and Figure 3).

Figure 3 shows the number of steps completed compared to the total number of steps contained in the planning unit. As you can see many steps were not completed. However, this was mainly due to the fact that the technicians frequently started planning units in the middle and stopped before completing them. Figure 4 shows the same data, with the number of steps predicted by the planning units adjusted so that steps occurring before and after the observation were not included. Taking this into consideration, the model was highly predictive (see Table 3, and Figure 4).

As indicated in Table 4, the model predicted the correct sequence of actions 85% of the time (i.e., 85% of the time a step was followed by the next step predicted by the model). The observed steps were always carried out in the order indicated by the planning units. Deviations from the model were due to skipping steps and occurred 4 times (i.e., 15% of the time a step was followed not by the next step but by a subsequent step predicted by the model).

The fact that the order of the steps was linear within the planning unit supports the original GOMS theory, that people have goals and plans with a predetermined sequence of actions in their head. They execute the steps in sequence if the context is concordant with the anticipated context. When circumstances were concordant with the anticipated circumstances, e.g., information, equipment, tools that others worked with and worked on

were at the appropriate places, in the appropriate forms, at the appropriate time, the plans were performed routinely step by step.

Constraints

To understand planning unit organization, a description of the constraints of the actions is useful. During the study a number of constraints that forced the technicians to shuffle planning units were observed. Some constraints were general, affecting all of the planning units, some were specific to a planning unit. An example of general constraints was how company politics affected the installation process. For instance, one of the work sites provided network access to Telco's cutting edge product design team. Since this design team's performance was crucial for the company, installation related to their subnet was given high priority. An example of a constraint specific to a planning unit is network traffic time and the Turn-Up System Planning Unit. The Turn-Up System Planning Unit could only be performed in slow network traffic time so that network traffic is disturbed as little as possible because this planning unit is traffic-affecting in nature. See more constraints in Appendix E.

Interruptions and Problems

Why did technicians not carry through a planning unit to completion? Nine planning units were observed that contained 27 instances where technicians ran into problems while working (see Table 5, and Figure 5). Sixty-six percent of these 27 instances were interruptions by another person i.e., another technician initiated a discussion because he needed information, tools, parts, etc. for his job (see Table 6, and Figure 6). Nineteen percent of the time information necessary to the technician's task was lacking, for example, knowing the password to log on to equipment, or work ID

number for database update. Eleven percent of the time technicians obtained contradictory information related to the task so that the correct course was no longer clear. For example, when a technician had to remove equipment from the database, he found the equipment in the database by its IP address but that IP address was associated with a domain name that he had not anticipated. Four percent of the time necessary parts (cable with appropriate connector, equipment with appropriate ports, etc.) for the task were unavailable.

Dealing with Problems

When technicians ran into major problems that they were unable to solve, they diverted from the steps described in the planning units (see Table 7, and Figure 7). They initiated communication with others to find solutions to their problems. Sixty instances were observed in eleven planning units where technicians were involved in communications during task performance.

In 40% of those 60 cases the participant of the observation requested information from other technicians, while in 10% of the 60 cases the participant ordered others to complete some segment of the work which prevented the participant to progress further. In 20 % of the 60 cases communication was not clearly related to problems. Technicians reported to each other what they had accomplished by casual information exchange. Such communication often occurred when a technician switched from one planning unit to another. These communications update the individuals on progress of the projects and let them know that the constraints have changed. According to the LAN Installation Model, this type of communication plays an important role in choosing planning units, as our evidence suggests that planning units are chosen on the basis of the current constraints.

In 30% of the 60 cases communication was related to interruptions where other technicians initiated communication and stopped the participant. Most of these interruptions were information requests that related to other technicians' information need for their work. Two planning units were excluded from the rest of the analysis on communication because they were performed in collaboration. Technicians continuously exchanged information making these planning units qualitatively different from the rest of the planning units.

The medium chosen by technicians for communication differed (see Table 8, and Figure 8). Fifty five percent of the 60 instances was performed by using phones, 32% in person, 13 % carried out via e-mail. Information requests were presented mainly by phone (22 instance of 24 information requests) since participants wanted immediate responses to progress further with a task (see Table 9, and Figure 9). Orders, on the other hand, were given out mainly by e-mail (3 out of 6 instances) so that a technician could prove he had no further responsibility for progress of the work (see Table 10, and Figure 10). Forty two percent of the information was exchanged by e-mail and 58% in person (see Table 11, and Figure 11). Fifty percent of the interruptions (9 out of 18) occurred in person, fifty percent by phone (see Table 12, and Figure 12).

The method of communication may indicate the type and importance of the problem they were dealing with. Information obtained by phone is more likely to be the answer to a specific question, whereas walking to other colleagues and asking them in person may suggest either an extreme situation when the progress of the task was crucial, or one where one's presence may facilitate a solution to the problem (e.g., troubleshooting). Further studies should clarify these issues.

Communication facilitated the participants' problem-solving in 39% of the 60 instances (see Table 13, and Figure 13). In these cases technicians obtain the specific technical information that they were seeking. Partial success was achieved 3% of the time, meaning that specific information was not obtained, but relevant information brought the technician one step closer to the solution (e.g., a colleague's name was provided who had the necessary information). In 28 % of the cases the obtained information was not related to that specific planning unit on which the technician was working at the time. Instead it was essential to another planning unit that he would be working on in the future, or that he might have started earlier but could not finish because of missing information. In 15 % of the cases communication was unsuccessful, where the technician was not able to obtain the necessary information and could not continue further with the planning unit. This fact indicates that social information may not always be available when needed. In the event that such instances happened, technicians switched to other planning units. Since the LAN Installation Model suggests incorporating social information into work analysis, such instances come to light.

Unexpected Planning Units

One of the main reasons for including observation in the creation of task analysis models is the belief that people fail to report important aspects of the task when interviewed (Beyer & Holtzblatt, 1998). The research found a very important instance of this. In the technician's descriptions, getting the necessary parts appeared to be a unit task component of the Install Planning Unit. However, since the company had equipment shortage problems (which is the nature of the industry), obtaining equipment became an

effortful and time-consuming process that manifested as a separate planning unit called Get the Equipment. Get the Equipment Planning Unit incorporated various steps including “stealing” and hiding of the equipment. The word “stealing” was used by technicians for such activities whereby equipment or parts were obtained from other teams’ project-pile, in secret. In general, unexpected planning units can serve as indicators of work-around activities, which might suggest possibilities for work improvement.

Generalizing the Importance of Social Information

Generally speaking, the type of information considered to be important in technological areas is procedural information, such as can be found in a manual. This research defined social information as any information that can be created, altered, or replaced on an ongoing basis by people (e.g., e-mail, personal notes, conversation). This type of information is frequently viewed as unimportant or a nuisance by system designers. In observations for this study, social information seemed to play a very important role. To generalize this claim a post-hoc analysis was conducted of a study carried out by Telco on procedural outages. However, Telco’s survey did not have a specific question-set developed to elicit difficulties related to missing or inappropriate information, or problems in communication. However, the technicians, in their recorded comments, did imply that social information plays an important role. Here are examples quoted from the report: “... The customer is supposed to be informed of assigned maintenance.... X Company might turn down the power, and Y Company did not log it.” “We deal with two groups of engineers.... We ask for bay space and find that it is already taken when we arrive at the site.” “The field (technician) is not telling the Network

Operation Center why they are there.” Our post hoc analysis found that 30% of the comments in Telco’s report related to problems with the flow of social information. Few of the comments were adopted in the report’s suggestions for improvements. The reason for this would appear to be that the importance of social information is not so obvious and is rarely taken into consideration. This illustrates both the importance of social information and the effects that a modeling system has on the outcome of a study.

Discussion

The focus of this thesis was to analyze and understand routine, goal-directed behavior of experts who also exhibit adaptive behavior in a rapidly changing complex sociotechnical environment. This study was based on a series of observations and a number of ideas suggested by the sociotechnical system theory, distributed cognition, complex system theory, all of which were integrated into a single modeling system called Situated GOMS (SGOMS).

SGOMS modeling system was built on the basic assumption of GOMS modeling approach that represents how humans carry out specified routine tasks. GOMS models originally were intended to provide a description of the goal-directed approach by representing desired actions or world states by goals, the sequence of operators (physical or mental acts) by methods, and the decision rules in case of alternative methods by selection rules. But the basic GOMS approach is too simplistic.

Nardi (1996) states that GOMS modeling technique only focuses on expert behavior and neglects the always changing and developing aspects of human performance. According to Kieras (1997) GOMS does not deal with the origin of the

goals, therefore practitioners must identify those goals that people try to accomplish. Because the GOMS approach was originally used to predict execution time of tasks performed by skilled users, many believe that GOMS approach is only appropriate to capture low-level issues, such as legibility of typefaces related to speed of performance. Nardi (1996) claims that GOMS does not consider users' situations and working context and represents human behavior as unaffected by the environment.

To eliminate some of the shortcomings of the GOMS approach, Nardi (1996) suggested applying a contextual approach such as ethnography in the first phase of an assessment process and GOMS model in the second phase. Likewise, other approaches tackle the problem by using separate studies to address different aspects of the sociotechnical context. For example, Beyer and Holtzblatt's (1998) contextual design consists of 5 distinctive segments (flow model, cultural model, sequence model, artifact model and physical environment model), each focusing on different aspects of work. Vicente's Cognitive Work Analysis (1999) also contains five phases: work domain analysis, control task analysis, strategies analysis, social organization and co-operation analysis, and worker competencies analysis, where each analysis identifies one layer that affects human performance.

Nardi (1996) noted that the co-ordination of various analyses could be a potential source of numerous problems. Newell (1990) suggested that various theories should be unified, rather than kept separate, when seeking to understand human behavior. Recognizing that GOMS modeling is limited, this thesis extends GOMS ability to handle human behavior assessment in a complex sociotechnical system. Since a single modeling system could have the ability to explain how the parts fit together, SGOMS meshes

appropriate theories into one system while applying a human performance assessment template which is seated on the traditional GOMS approach. The aim of the template was to facilitate the practitioner's model building attempt by providing a skeleton for model building. The template represents the structure of a model. When domain knowledge is added to the template, the building blocks of SGOMS models, unit tasks and planning units can be created. In this case, the finished model consists of the planning units and the unit tasks as processed by the template. The model could also go deeper by including the GOMS models of the unit tasks, although this was beyond the scope of this study. In this research the steps of the planning units (the unit tasks) were not broken down to methods and operators.

As a starting point, this researcher used West and Yuen's (1999) cognitive modeling system, and proposed that a higher level of organization exists as well as the suggested unit task. West and Yuen's modeling system was used in the new modeling system as a good description of human behavior on a micro level. The concept of planning unit was introduced, which is the unit of understanding cognitive constraints at a higher social group level, and this was incorporated into the new modeling system. Unit tasks were kept within the template as the natural unit of understanding cognitive constraints on the knowledge level. As demonstrated by the results, the planning unit maps well into actual behavior.

Revisiting the theories that motivated the creation of SGOMS while looking at the rich data source illustrates what is actually happening in the real world.

The Human Element

According to SGOMS, goal driven behavior is an important part of human performance in complex sociotechnical systems. Nardi (1996) mentions that the goal of activity motivates the activity, giving it a specific direction: therefore actions are goal-directed processes that must be undertaken to fulfill the goal. Actions are actually “conscious,” because people hold a goal in mind. The actions have operational aspects, a way in which they are actually carried out. Operations become routine and “unconscious” with practice. For example, when LAN installers learn to retrofit equipment, they consciously attend to the process whereby information related to the physical activity must be updated in the database. With practice database update eventually becomes routine.

However, operations depend on the conditions in which the action is carried out. In the telecommunications domain, work aspects are rapidly changing since the network state depends on a large number of factors, such as the previous performances of many engineers and technicians. Procedural documents prescribe task sequence for technicians, while assuming specific circumstances. Since human error occurs when an inappropriate action or intention to act is performed, attending to the context is a must.

Because the telecommunications environment is dynamically changing and therefore uncertain, technicians orient to the changes before and while the prescribed plan of the procedural document is executed. Often, only the intent related to the goal of the plan stays fixed, but the action sequences change; some activities are eliminated, others are incorporated or replaced by different actions.

According to Miller, Galanter, Pribram (1960) intention is “the uncompleted parts of a Plan whose execution has already begun.” Brand (1984) states that intentions concern the completion of the actions within the plan in progress. People can state their intentions without having to describe the actual course their action will take. From an SGOMS perspective, the planning units represent the intention to complete a certain task.

While observing LAN installers, such intentionality was recognized. Technicians often started a task, but are restrained or interrupted during the course of their actions. People are oriented to constraints, but as soon as obstacles are cleared away, they turn back to the original task. As SGOMS suggests, technicians constantly attend to the environmental changes, and when the specifics of the environment are so distinct from those that the procedural document assumes, their task steps become inappropriate. In this study missing, inappropriate or ambiguous information was the most frequent specific that influenced people’s behavior.

Technicians coped with the uncertainties of the complex system by actively looking for the correct information, by seeking help from colleagues as they initiated communication. However, when the necessary information was not obtainable, technicians stopped the planning unit, and waited until the uncertainties were resolved rather than going ahead by guessing the necessary information. Task suspension was also an applied solution to uncertainty and because of time pressure, the waiting period was often filled by execution of a new planning unit that was short in nature. Short planning unit initiation indicates that technicians had the intention to follow their original planning unit and complete the original activity when running into obstacles.

While SGOMS explains one method of coping with uncertainties (i.e., seeking for a solution) related to the dynamic changes of the complex system; i.e., for activating a previously encountered solution, this does not say what the underlying rules of task suspension are. These would depend on the specific task's constraints. Future studies should further investigate the underlying mechanism of planning units' suspension, re-organization, and prioritization.

An example from the observation notes clearly illustrates the intent of an individual to complete a particular task despite many interruptions:

Observation Notes: Day 2. 8 -10 a.m.

The task: A machine was physically removed from the network. The corresponding information had to be deleted from the database to achieve the appropriate representation of the state of the network in the database.

Expected behavior:

Step 1 - Log on to the database.

Step 2 - Identify the information corresponding to the machine.

Step 3 - Delete the information

Observed behavior:

“RayL was finishing up the system turn-up from yesterday. He pinged the box, and saved the configuration info on the server. He checked his e-mails. He was mainly looking for change management info, or other info that was communicated to him and could have affected his job. RayL called the HPOV guy (yesterday he sent an e-mail to him). But he just wanted to make sure that the group knows what happened. Last night he did the change in the network

(removed equipment to be replaced with new equipment) but did not do the database update (did not remove the info related to the equipment from the database). He informed the HPOV guy that the data base update will be done today.

He went to NetID (telnet, logged on) to update the database. But he did not save the appropriate sub-net range under his favorites in NetID. He has not worked on this sub-net segment recently, but will in the future. So it seemed reasonable right now to log on the full range of sub-nets, select the appropriate sub-net range and save it in his favorites. (In future he will only need to log on to the sub-net segment, not to the full range of sub-nets. This will save a lot of time for him.) So he logged on to the full range of the sub-nets. He had to wait to get in, just as he expected.

RayL got a phone call from BennyS, relating to previous work they did together. BennyS told RayL to change the info in TOSS about some circuits, since the traffic was going to different ports of different routers right now. The CSR person came by and told RayL that some ports of some equipment had to be changed from 10 BaseT to 100 BaseT ASAP. He handed a hard copy of an e-mail to RayL with the specs. The CSR person also asked RayL whether he could borrow a drill from him. RayL went to his locked drawer, and handed the drill to the CSR guy. RayL went to TOSS and verified the node name related to the port speed change, just in case. He wanted to make sure that he would be changing the port speed of the appropriate equipment. He set the port speed to 100 BaseT Full-Duplex by modifying TOSS. While doing the modification he received a phone

call from BennyS regarding the circuit that had to be created in TOSS. RayL did not stop what he was doing. He had the phone to his ear, but his eyes were on the screen and he kept adjusting the port speed.

RayL wrote down the port info and the name of the routers that BennyS gave him, on a yellow sticky note for future reference. He attached this to his computer screen. RayL selected the appropriate sub-net range in NetID and saved it under his favorites. RayL got another phone call from DorinaP. The CSR person came by with the drill. RayL told him that the ports were set to 100 BaseT. RayL went back to NetID. Now he had the sub-net range saved under his favorites. Logged on to the appropriate sub-net range, he located the sub-net within that. He looked at the domain name (that also identifies the equipment). It seemed that the router related to the domain name is not the one that RayL was expecting to see there.

He decided to make a phone call. He called ArtZ with whom he did the cut over last night. He wanted to let ArtZ know that he will delete the nonexistent interface from the database. Some people from the recycling department knocked on the door, wanting to come in. RayL let them in. They came to pick up the Cox router that RayL removed from the network. Now they just wanted to see the size of the equipment. RayL walked to the equipment with them, showed them and walked out with them. Now he went back to NetID again. He got really confused, did not understand why the IP address was associated with a different domain name. He phoned ArtZ back. The recycling people came back with an appropriate size of dolly and took the equipment. They asked RayL to sign a piece of paper

regarding the equipment removal. RayL was on the phone with ArtZ, and kept pinging various node names by using iTrace while he was signing the paper, and kept talking to ArtZ. ArtZ and RayL agreed that the info in NetID was not appropriate. Who ever did the install before had not entered the appropriate info into NetID. The CSR guy came by, but seeing that RayL was multitasking, he left.

RayL logged on to the router while he was talking to ArtZ. ArtZ told RayL that some interfaces must be deleted, and some must be left untouched because Virtual LAN must be left alone. Now RayL really got confused. After the phone call he told me that he has never done anything like this before. Now he wrote down every router's name and every port number that was related to this job on a piece of paper and started to compare them with the LAN Engineering plan. He tried to make sense of the information.

He did not understand what was going on, so he called BillB the LAN Engineer. BillB was not at his desk, so RayL left a detailed message explaining his problem and asked for clarification. RayL called JeffJ, the New Technology Prime, for help. Not much luck here either. He left a message. The CSR guy came back again and told RayL that Saturday there will be a scheduled power outage. RayL will have to be here, to make sure that all of the network equipment will come alive after the power outage is over. RayL acknowledged the overtime. RayL decided to create a Word document with all of the router's name and port numbers included, for future reference. He saved the file but also printed it out. Now he was waiting for BillB or JeffJ's phone call. He checked his e-mail..."

Sociotechnical Systems

According to Nardi (1996) a human is often reduced to being another system component that needs to be factored into the design equation for the overall human-computer system. Individual motivation, membership in a community of workers, and the importance of the setting in determining the human action are just a few of the issues that cannot be neglected.

Sociotechnical system theory states that not only the technical system and its technical context but also the user with his/her social context must be taken into consideration when human performance is addressed. Technical systems, workers, organizational and management infrastructure, and environmental context, are all notable factors that affect human performance. It is a mistake to fail to consider the organizational and social context of the task and only focus on the technical aspects.

For instance, consider the example where the technician's task was to delete information from the database. For him, not only knowledge related to the technical aspect of the work was crucial information, but also knowledge related to the social context. To know who to call when stuck in a situation is just as important from the task's completion perspective as knowledge of the appropriate command for deleting data from the database.

Another effect of social environment on technicians' jobs was manifested in the planning unit describing what technicians called "stealing." This research found that the reason for such behavior is actually determined by the way the company was organized, in this case, how the "Purchasing" department was organized.

The Purchasing department required the technicians' budget to be approved before March of the previous calendar year by an 8 to 10 steps financial approval process. Even though the yearly purchasing was approved, a specific document called "Clip" had to be created immediately before the equipment order took place. When this second approval was obtained, Purchasing sent the items out for competitive bids. Necessary parts often arrived 6-26 weeks after the selection of an appropriate vendor through the bidding process. Since manufacturers do not stock products, they needed this purchase order to start to produce the parts or the equipment, which further delayed the process.

The Purchasing department organization was designed to be rigid, very structured, with a purposefully long approval process, to ensure that money was spent wisely within the company. However, technicians' projects were rapidly changing, requiring flexibility and continuous adaptation. The project's deadlines were short, such as 6-8 weeks, not allowing time for lengthy planning. Since technicians were unable to tell what projects they would be working on, and parts needed for their jobs, "stealing" evolved as a reaction to the effect of the organizational environment on their work. We can see that such stealing can only be explained if the context of work such as the effect of the social environment is recognized. "Stealing" demonstrates that the principles of the sociotechnical system approach cannot be neglected when dealing with a complex system.

An example from the interview notes:

"RonD: We have deadlines. We don't have the equipment, but we make the deadlines. We have to steal. We steal and hide stuff from others' equipment pool. Sometimes we find hidden stuff. I heard a story about somebody who hid a bunch of equipment under the floor tiles. Some guys were doing cabling once,

and when the floor tiles were lifted up, they found about 30-35 routers below the tiles. This is our answer to not having the equipment. When we decommission, we do not send back the equipment to people who own it. Hubs, racks, bolts, all stay. We must hide them, otherwise we could never deliver the projects by the deadline. This is the only way we can make sure to be done on time.”

The environmental context, such as the physical environment (another layer of the sociotechnical system) also had an effect on technicians’ work behavior. One aspect of the physical environment, which was identified as a constraint on planning unit choice, was walking distance amongst various job sites. Since technicians were always overworked and overloaded with projects, they tried to cut down time wasted on walking from site to site. Since efficiency is a key decision factor, technicians often grouped tasks into otherwise illogical sequence impacting planning unit organization. Often, an unexpected grouping of planning units was observed, just because particular planning units related to the same job site.

SGOMS captures and integrates these different effects of the sociotechnical system into one system. As illustrated above, these can be captured through problem-solving knowledge (e.g., knowing who to call), through planning units (e.g., stealing) and through the constraints on planning unit choice (e.g., walking distance). The ability to interrupt is also critical as this allows SGOMS to respond fluidly to changes in the environment.

Distributed Cognition

A system has goals, for example, in the telecommunications system the goal is to provide services to the customers of a telecommunications company. Because the system

is not relative to an individual but to a distributed collection of interacting people and artifacts, we cannot understand how the system achieves its goal if we do not understand that the technicians and the network elements form a single cognitive system. Coordination among individuals and artifacts is essential; appropriate knowledge representation is important since information is both inside and outside of the head. The full knowledge necessary to perform a task is not in anyone's head, but rather distributed among people and objects relevant to the project. For example, when technicians work on an installation procedure, they need to retrieve information from various sources. Some information can be retrieved from memory, some from their own notes, some from manuals, some from the interface, some obtained by phone from colleagues, or from the management team. As illustrated by the results of this study, this way of operating is ubiquitous in network telecommunications systems. One of the advantages of using SGOMS is that it explicitly attempts to model this process and reveals where in the system this type of behavior plays an important role.

Complex systems: The Importance of People

Extreme complexity and dynamism characterize telecommunications systems. Automation that was designed to deal with this complexity works well when conditions are normal. When conditions become difficult, for example the redundancy of equipment fails, or a power supply dies, automation is also likely to fail. Automation often gives up when it is most needed. When the equipment fails, often with no advance warning, people are suddenly asked to figure out the current state of the system, what has gone wrong, and what should be done. Because of this dynamism and suddenness, people's best ability, adaptation, is often utilized. Often in such situations, no procedural descriptions apply,

there is no manual to rely on. Generally speaking, the procedural document describes the appropriate actions related to a specific situation, which often may be slightly different from the technician's immediate situation. Expert technicians who avoid blindly following the procedural requirements recognize such discrepancy. Violating official requirements is considered to be the greatest sin in the telecommunications domain. However, only a few understand that technicians frequently keep the network alive by not following procedure, but adapting to the specifics of the environment.

In complex systems such as the nuclear industry and telecommunications, humans are often viewed as the weakest link in the chain, the least reliable element of the system that must be replaced by automation to improve system reliability (Norman, 1993). As computer and software technology improve, researchers see a decrease in the number of technical errors caused by computers, yet there is also evidence of a corresponding rise in errors attributable to humans (Reason, 1991). Humans are well known to be distractible, emotional, illogical and disorganized, while machines are undistractible, unemotional, logical and orderly. But technology, even the smartest computer system, is relatively single-minded, incapable of self-direction or flexibility. While machines are consistent in their decisions, humans are capable of producing flexible decisions modified by special circumstances and context. While machines are rigid and insensitive to change, humans are creative, compliant, resourceful, and attentive to change. According to Nardi (1996) situated action theory explains well the emergent nature of human activity, the way that activity grows from the particularities of a given situation. It emphasizes responsiveness to the environment and the improvisatory nature of human activity.

SGOMS does not model how people react to novel situations through the use of creativity and ingenuity. However, it does allow for this type of behavior to be triggered through the mechanism of recognizing when the use of routine procedures will not work. Formally, creative problem solving can be represented as a planning unit representing the intention to engage in this type of behavior. However, this planning unit would be different in that it would not contain a list of unit tasks but would instead represent a way of stepping outside the model. Thus, while SGOMS is not a model of creative problem-solving, it does describe the context in which this occurs, which can be important in terms of creating a system that will support creative problem-solving when appropriate. This is quite important since, as noted above, what workers do to keep a complex system running will often be at odds with official procedure. SGOMS can document why this is the case, and prevent workers from being scapegoated for failures of the system.

Future Studies

Although the SGOMS model predicted behavior quite well, there were still cases when the model did not follow the technicians. For the most part, these were due to two problems with the modeling procedures. The first was that planning units were developed by observing specific instances of the task. However in some cases there were variations. For example, when the planning units of the LAN Installation Model were developed, the model was tailored to capture the installation of specific equipment from start to end. In the testing phase however, two instances were observed where technicians retrofit rather than install equipment. Since the task itself changed, there were different elements, resulting in obvious differences between the observed and predicted behavior. This type

of problem can be dealt with by further iterating the model building process to capture the full range of the behaviors.

The second problem was that some planning units could be scaled up. For example, when technicians install a large amount of equipment, they reorganize the task in such a way that they chunk the same activities into one. That is, instead of proceeding from start to finish with planning each unit, they perform the first step for all of the units, then the second step and so on. The result of this is that a unit task becomes blown up to a planning unit. For example, an activity such as cable testing was one unit task in the Lay Cable Planning Unit, but when not one but 60 cables were tested, it grew into a planning unit on its own. The task itself became not only much longer, but qualitatively different. For instance, technicians might create a specific testing plan to do such a large amount of cable testing, or apply some method to keep track of those cables already tested. Again, it should be possible to deal with such problems through further iterations of the modeling process.

In addition to these two issues the researcher also observed situations in which the technician did not know what to do, such as never having seen a particular network topology or a new configuration to a specific set-up. These instances were excluded from the analysis as the model was meant to capture expert and not novice behavior. However, it may be possible to include these instances if we view the technicians as expert in finding out how to do new tasks. In this case a technician would engage a planning unit to acquire the necessary information to proceed.

Recommendations

The results of this study suggest that providing further support for the flow of task related information could reduce errors. Computer support should be provided to allow people to keep track of the state of the task and provide awareness of who is doing what in any instance. Support should allow technicians to proceed with their current work while presenting the state of the current activities, and also indicating upcoming events. It also should provide workers with the information on the latest state of the network, changes in the network, and also changes in the constraints.

Equipment should have the capability of self-assessment and provide appropriate information to the user about the equipment's current state: e.g., what it is, what types of cards are included in the equipment, what card is active, what fiber is active in the equipment, and what part of the equipment carries traffic. Beside technological information, it also should provide social information. For example, who preformed what activities on the system, who worked on the equipment the last time, what that person was doing, and what is their contact number.

According to Reason (1991) people can operate well in dynamic environments when slips and mistakes have visible effects and can be corrected immediately (e.g., driving downtown in rush hour). In telecommunications networks the system does not always respond immediately when mistakes happen, so the results of erroneous acts are left in the system. Several independent events have to coincide before the system responds by showing visible changes in its behavior. The effects of technicians' actions need to be made visible, so technicians can evaluate their own actions and recognize the problems right away.

Conclusions

SGOMS modeling technique has been shown to be an effective tool for understanding work in complex sociotechnical domains. It represents work more accurately than other existing methods that fail to integrate the different aspects of the sociotechnical system. SGOMS facilitates the identification of those factors that influence human performance and also helps researchers to clarify what to assess, what type of behavior to observe and how to organize data when human performance is investigated.

References

Bardram, J.E. (1997). Plans as situated action: An activity theory approach to workflow systems. *Proceedings of the 5th European Conference on Computer Supported Cooperative Work, Lancaster, UK*. Kluwer Academic Publishers.

Bellamy, L. J. & Geyer, T.A.W. (1988). Addressing human factors: Issues in the safe design and operation of computer controlled process systems. In B.A. Sayers (Ed.), *Proceedings of SARSS '88. Human Factors and Decision Making: Their Influence on Safety and Reliability*, 19-20 October, Altrincham, Manchester. London: Elsevier Applied Science.

Beyer, H., & Holtzblatt, K. (1998). *Contextual design: Defining customer-centered systems*. San Francisco: Morgan Kaufmann.

Brand, M. (1984). *Intending and acting, Toward a naturalized action theory*. Cambridge: MIT Press.

Card, S. K., Moran, T. P., & Newell, A. (1983). *The psychology of human-computer interaction*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Card, S. K., Moran, T. P., & Newell, A. (1980). Computer text editing: An information-processing analysis of a routine cognitive skill. *Cognitive Psychology*, 12, 32-74.

DeGreene, K. B. (1973). *Socio-technical systems, factors in analysis, design and management*. Englewood Cliffs, New Jersey: Prentice Hall.

Duncan, K. D. & Gray, M. J. (1975). Scoring methods for verification and diagnostic performance in industrial fault-finding problems. *Journal of Occupational Psychology*, 48, 93-106.

- Federal Communications Commission (1998). *Telecommunications*. 47CFR63.100. [On-line]. Available: <http://www.fcc.gov/oet/outage/47cfr63.100.html>
- Gray, W. D., John, B.E., Atwood, M. E. (1993). Project Ernestine: A validation of GOMS for prediction and explanation of real world task performance. *Human-Computer Interaction*, 8: 3, 237-209.
- Hollnagel, E. (1993). *Human reliability analysis, context and control*. San Diego: Academic Press.
- Hopkin, D. V. (1991). Verification and validation: concepts, issues, and applications. In J.A. Wise, V.D. Hopkin & P. Stager *Verification and validation of complex systems: Human factor issues*. (pp.9-33). Berlin: Springer-Verlag in cooperation with NATO Scientific Affairs Division.
- Hutchins, E. (1994). *Cognition in the wild*. Cambridge, MA: MIT Press.
- John, B. E. (1995). Why GOMS? *Interactions*. October, 1995.
- John, B. E., & Kieras, D. E. (1996). Using GOMS for user interface design and evaluation: Which technique? *ACM Transactions on Computer-Human Interaction*, 3, 287-319.
- John, B. E., & Vera, A. H. (1992). A GOMS analysis for a graphic, machine paced highly interactive task. *Behavior and Information Technology*, 13, 4, 255-276.
- John, B. E., Vera, A. H., Newell, A. (1994). Towards real-time GOMS: A model of expert behavior in a highly interactive task. *Behavior & Information Technology*, 13 (4), 255-267.
- Kieras, D. E., (1997). A guide to GOMS model usability evaluation using NGOMSL. *The Handbook of Human Computer Interaction*. Amsterdam: North-Holland.

Kieras, D. E., & Polson, P.G. (1985). An approach to the formal analysis of user complexity. *International Journal of Man-Machine Studies*. 22, 365-394.

Kirwan, B., & Ainsworth, L.K. (1992). *A guide to task analysis*. London: Taylor & Francis.

Kurose, J. F., & Ross, K. W. (2000). *Computer networking, a top-down approach featuring the Internet*. New York: Peach Pit Press.

Leplat, J. (1982). Accidents and incidents in production: Methods of analysis. *Journal of Occupational Accidents* 4(2-4), 299-310.

Miller, G. A., Galanter, E., & Pribram, K. H. (1960). *Plans and the structure of behavior*. New York: Holt, Rinehart and Winston.

Mitchell, M., & Jolley, J. (1996). *Research design explained*. Fort Worth: Harcourt Brace.

Murgatroyd, R.A., & Tait, J. F. (1987). *A case study of the application of the SHERPA Technique to the Dinorwig Spiral Casing Ultrasonic Testing System*. Human Reliability Associates, 1 School House Higher Lane, Dalton, Wigan, Lancs., UK.

Nardi, B. A. (1996). *Context and consciousness, activity theory and human computer interaction*. Cambridge: MIT Press.

Network Reliability Steering Committee (1998). *Annual Report 1998*. [On-line]. Available: <http://www.atis.org/ATIS/NRSC/view.htm>

Newell, A. (1990). *Unified theories of cognition*. Cambridge: Harvard University Press.

Norman, D. A. (1993). *Things that make us smart. Defending human attributes in the Age of the Machine*. Reading, Massachusetts: Addison-Wesley.

Reason J. (1991). The identification of latent organizational failures in complex systems. In J.A. Wise, V.D. Hopkin, & P. Stager, *Verification and validation of complex systems: Human factor issues*. (pp.223-237). Berlin: Springer-Verlag in cooperation with NATO Scientific Affairs Division.

Schraagen, J. M., Chipman, S. F., & Shalin, V. L. (2000). *Cognitive task analysis*. Mahwan, New Jersey: Lawrence Erlbaum Associates.

Suchman, L. A. (1987). *Plans and situated actions*. Cambridge: Cambridge University Press.

Tittel, E., Hudson, K., & Stewart, J. M. (1999). *Networking essentials Microsoft certified system engineer*. Scottsdale, Arizona: The Coriolison Group.

Van Someren, M. W., Barnard, Y. F., & Sandberg, J. A.C. (1994). *The think aloud method: A practical guide to modelling cognitive processes*. London: Academic Press.

Vicente, K. J. (1999). *Cognitive work analysis: Toward safe, productive, and healthy computer-based work*. London: Lawrence Erlbaum Associates.

West, R. L., & Yuen, K. L. (1999). *A framework for incorporating social context into GOMS models*. Poster presented at Cognitive Science 1999, Vancouver, B.C.

West, R. L., Wong, A., & Vera, A. H. (1998). GOMS, distributed cognition, and the knowledge structures of organizations. *Proceedings of Cognitive Science 1998*.

Wieringa, P. A., & Stassen, H. G. (1991). Assessment of complexity. In J.A. Wise, V.D. Hopkin, & P. Stager, *Verification and validation of complex systems: Human factor issues*. (pp.173-180). Berlin: Springer-Verlag in cooperation with NATO Scientific Affairs Division.

Appendix A

Examples of Questions Generated by the Template

The following examples illustrate a list of questions generated by the template, which can be useful for practitioners investigating human behaviour in complex sociotechnical systems. These questions can facilitate systematic data gathering and data organization by helping practitioners to ask the right kind of questions.

1. Choose Planning Unit

How do people choose planning units?

Are there any rules for planning unit selection?

Are there any planning units that could not be followed by another planning unit?

2. Retrieve the Next Unit Task

Where do people retrieve information regarding what comes next in the process?

Do they ask colleagues?

Do they look up the next action in their notes, documents, or on the Web?

How do people know where to get the information?

3. Execute Unit Task

What kind of activity occurred?

Was the activity mental, perceptual, or physical?

Was the action successfully completed?

How difficult was the activity?

Did the activity require people to keep lots of information in memory?

4. Update Situational Knowledge

Was there communication where people asked co-workers if they were ready with some part of the job?

Did people focus at some element of the software or hardware?

If yes, what did they do?

Were they checking something?

Did they run any diagnostics?

Did they ever double-check anything?

5. Evaluate

If the situation changed in some unplanned way did people make any judgments about what to do next, or did they ignore the change?

What evaluation rules are associated with various expected outcomes?

Did people run into any obstacles that prevented further progress?

If yes, what went wrong?

6. Check for Routine Fixes

How much thinking was required to fix the problem?

If people did not know how to fix it, what did they do?

Did any communication occur to deal with the problem?

If yes, what was the form of communication?

Was the communication useful?

7. Execute Fix

Were people able to fix the problem?

How did they fix it?

Did they backtrack, undo steps, use trouble ticket, etc.?

8. Parallel External Monitor

Has the task ever been interrupted? By what?

How often was the task interrupted?

Do interruptions provide any value to those people who were interrupted?

If yes, what kind of values did the interruptions have?

What are some of the rules to interrupt task flow?

Are there general rules for dealing with interruptions?

Appendix B

Interview sheet

Participant's background information

First name of participant _____

What are your job responsibilities? _____

How long have you been at this job? _____

How long have you been working in this group? _____

What other jobs did you have before? For how many years? _____

What kind of formal education do you have? _____

What kind of relevant courses have you taken? _____

How much experience do you have with the installation of a LAN? _____

How much hands-on training did you receive? _____

Interview Questions for Task Flow

Statement: "The overall goal of this job is to install a LAN".

Question A: Can you fill in some of the details of this step, i.e. install a LAN?

Question B: Are there different ways of achieving each step?

Question C: Under what circumstances would you perform specific ways?

Comments:

Appendix C

Informed Consent Form

The purpose of a consent form is to ensure that you understand the purpose of the study and the nature of your involvement. The form must provide sufficient information such that you have the opportunity to determine whether you wish to participate in the study.

Title of the Study: Modeling Human Performance in a Telecommunications Network

Researcher Personnel: Gabriella Nagy (Principal Investigator, 228-6835).

Dr. Robert L. West (Carleton University, Faculty Advisor, Tel: 520-2600, ext. 2258).

Helen Maskery (Telco).

The above-mentioned people are involved in this research project and may be contacted at any time. Should you have any ethical concerns about this study, please contact Dr. K. Matheson (Carleton University, Chair, Department of Psychology, 520-2600, ext. 2648).

Purpose: The purpose of this study is to develop and assess a modeling system that captures expert knowledge.

Task Requirements: You will be asked questions related to a task and your answers will be recorded to test the modeling tool.

Duration: The session will last approximately 2 hours.

Potential Risk/Discomfort: There are no potential physical or psychological risks in this study.

Anonymity/Confidentiality: The data collected in this study is confidential. All data is coded such that your name is not associated with the data. The coded data is made available only to the researchers associated with this project.

Right to Withdraw: You have the right to withdraw from the experiment at any time.

Name of Participant: _____ (Please print)

I understand that this study in which I have agreed to participate will involve answering questions related to a specific task. I understand that my verbal response to questions will be collected throughout the study. I understand that the purpose of the study is not to test my ability but to assess the modeling system developed by the researchers. I understand that my participation is voluntary and that I may withdraw from the study at any time and for any reason without penalty. I understand there is no obligation to participate in any aspect of this project that I consider invasive. I understand that all personal data is strictly confidential and that all information will be coded so that my name is not associated with my answers. I understand that the researcher named above will have access to the data. I have read the above description of the Modeling Human Performance in a Telecommunications Network study and understand the conditions of my participation.

My signature indicates that I agree to participate in the study.

_____	_____
Participant's Signature	Date

Feedback about the use of the data and the outcome of the study will be e-mailed to participants.

Thank you for your participation.

I have fully explained the procedures of this study to the above volunteer.

Researcher's Name: Gabriella Nagy

_____	_____
Researcher's Signature	Date

Appendix D

Planning Units

The following planning units of LAN installation were identified in this study:

Understand the Project

1. Obtain the plan
2. Familiarize with the plan (priority of the plan, what equipment groups, people who will be involved, where it will be held)
3. Write appropriate information on the plan (IP address, node name, etc.)
4. Understand what the project is all about
5. Check plan for appropriateness
6. Resolve any issues (if plan seems incorrect)

Get the Equipment

1. Identify what equipment is needed for the project
2. Locate the equipment
3. Obtain the equipment
4. Hide the equipment, if necessary

Install

1. Familiarize with the installation (what equipment, where it will be installed, what is the priority of the work, etc.)

2. **Make sure appropriate infrastructure is in place (room, cabinet, cabling, power, cooling, cleanliness). If anything missing notify the appropriate groups (Electricians, Cable Plant, Building Control)**
3. **Obtain the equipment**
4. **Obtain and pack the appropriate tools, parts**
5. **Take the equipment to the site**
6. **Locate the place of the equipment**
7. **Mount the equipment in place**

Lay Cabling

1. **Familiarize with the work (what equipment is to be cabled; where; what is the priority of the job)**
2. **Obtain appropriate information (what kind of cabling will take place, copper or fiber; how many cables are needed, what length, with what kind of connectors, etc.)**
3. **Create detailed notes about what ports will be connected to what ports (if ports are not available let higher-ups know)**
4. **Obtain equipment or dummy equipment (dummy meaning fake equipment that has the appropriate dimension of the equipment)**
5. **Bring cables, connectors, tools, tie wraps, etc. to the site**
6. **Attach connectors to the equipment**
7. **Create a hinge from the bundle of cables**
8. **Run cables from equipment to cable tower or patch panel**

9. Terminate cable at the cable tower
10. Flip cables
11. Perform physical layer testing
12. Label fibers
13. Pass the notes that were created at the beginning of the cabling to others who will enter the information in to the database
14. Report that the work is completed

Obtain IP Address

1. Log on to the database
2. Locate appropriate sub-net
3. Look at last IP address that was already taken
4. Take next available IP address
5. Check IP address to ensure that it has not been taken yet
6. Create a node name
7. Enter the node name to the database
8. Assign the IP address to the node name, and the vendor's MAC address
9. Save the information
10. Write IP address to the LAN Engineering plan

Configure

1. Prepare for configuration (have handy node name, IP address, laptop, procedures, power cords, PCMCIA card with the current software, telephone)

2. Unpack equipment from the paper box
3. Write down the asset number of the equipment
4. Log on to the equipment
5. Make sure that software revision is appropriate (download the appropriate software version from the PCMCIA card if necessary)
6. Enter configuration information
7. Save the configuration information on flash and PCMCIA cards
8. Check equipment password
9. Put the equipment back in its paper box

Lay Cross-Connect

1. Identify the ports that are to be cross-connected
2. Obtain appropriate cables
3. Run the cables
4. At the network port flip down the cables
5. Terminate the cables
6. Make notes where the cables are coming from and going to

Turn-Up System

1. Notify on-call person just before system turn-up starts
2. Log on to the router
3. Route the traffic to the new LAN
4. Enable configuration (system turned up)

5. Check the uplink ports (if one is up and the other down flip the cross-connect)
6. Test LAN
7. Get port statistics
8. Test router capabilities
9. Save configuration information
10. Let others know that the work is completed

Update Database for Generics

1. Log on to the database
2. Enter generic information about the equipment to the database (if possible find the same equipment with the same number of ports in database, and copy and paste the generic information related to that equipment)
3. Change manually only the specific information (IP address, node name, sub-net number, sub-net mask, etc.)
4. Obtain the necessary information from the LAN engineering plan, or from notes
5. Create console port
6. Save the information

Update Database for Circuits

1. Build circuits and segments
2. Enter information that defines how the equipment connects to each other
3. Obtain necessary information from notes
4. Save information

Create LAN Diagram

1. Obtain the LAN Engineer's LAN diagram
2. Add IP addresses
3. Save the diagram with the new IP addresses
4. Send LAN diagram to the LAN Diagram Prime
5. Keep a copy for personal record

Label equipment

1. Locate labeling machine
2. Start the TouchEditor software
3. Obtain the files of one of the old labels related to similar equipment
4. Change the alias and sub-net information
5. Save the file
6. Print and cut the labels to appropriate size
7. Get plastic strips
8. Stick the labels on plastic strips
9. Slide the plastic strips into the appropriate place

Barcode the Equipment

1. Obtain the barcode sticker and the scanner
2. Put barcode stickers on the equipment
3. Scan the barcode
4. Enter the data to the database

Hand Out the Operation

1. Notify Operation Supervisor (Operation Supervisor evaluates the job)
2. Sign that equipment status changed to full ownership after obtaining approval

Appendix E

Constraints

The following constraints of LAN installation were identified in this study:

Global Constraints

People Related

- People's negative attitude (unwillingness to provide appropriate information)
- No power to make a decision (if a decision is necessary to proceed with work)
- Missing personnel (if collaboration is necessary to proceed with work)
- Other groups' involvement (their timeline and schedule, if collaboration is necessary)
- Group norms: group preferences about doing or not doing overtime
- Group norms: preferences about the process of installing equipment (e.g., assembling related equipment in the same location versus assembling it in distributed locations)
- Number of projects a technician has
- Type of customer (e.g., customers who affect Telco's revenue more, get faster service)
- Ability or inability to contact higher-ups and colleagues for information (e.g., you need to know their number)

Project or Activity Related

- Priority of the project

- Deadline of the project
- Size of the project (amount of equipment)
- Company politics (e.g., equipment removal is given high priority if they are competitor products)
- Unplanned projects (e.g., responding to requests from Customer Service Representatives which are given high priority)
- Traffic-affecting aspects of the project (e.g., may mean the work must be performed after hours)
- Changes that affect the project (e.g., when layoffs occur projects get downsized)

Infrastructure Related

- Access to infrastructure
- Walking distances
- Access to software (i.e., passwords)
- Jurisdiction of teams (i.e., teams have different levels of responsibility at different sites)
- New buildings or new sub-nets or new equipment are often associated with new processes and procedures which may require more time, assistance, and new knowledge
- Rate of site development. If a site is being developed at a rapid rate there will be more disorganization and more unexpected constraints. So more time should be allocated.
- Hardware aspects (novel ports, fibers, connectors, etc)

- Availability of infrastructure (hydro, cooling system)
- Access to equipment, parts, tools, computer, Internet, telephone
- Access to information

Planning Unit-Related Constraints

Understand the Project

- Must have sufficient and accurate information
- Information must be communicated well to the technicians
- Circumstances must not change since the plan was created
- No information should contradict the plan
- Technician's experience should not tell differently than the plan

Get the Equipment

- Must know what equipment needed (written or verbal plan needed)
- LAN Engineer, operation supervisor must be available for clarification
- Must know contact numbers for higher ups and colleagues
- Must know the place where the equipment is located
- Must have access to the rooms where the equipment is (key, badge, door-code)
- Must be able to locate the equipment in the room
- In certain cases it is a must to have a hiding place

Install

- Must understand the project

- Must have the equipment (parts, tools)
- Must have access to the room where the installation takes place
- Must have access to the room where the equipment is stored
- Must have space on the appropriate rack

Obtain IP Address

- Must have access to the database and to iTrace software
- Must know the sub-net number

Configure

- Must have IP address from the database
- Must have appropriate passwords
- Must have appropriate configuration information
- Must have the LAN Engineering Plan
- Must have working computer, and patch cord
- Must have PCMCIA card with the appropriate software
- Must have access to the equipment

Lay Cabling

- Must have enough ports on patch panel and cabinet space for the patch panel
- Must have enough space on the fiber management system or on a cable tower
- Must have the equipment installed, or dummy equipment
- Must have appropriate parts, fiber or cable, connectors, tools, etc.

- Preferred to have a helper

Lay Cross-Connect

- Must be done in change management time (between 5-9 p.m.) if ports are enabled
- Must have access to the cables
- Preferred to have a helper

Turn-Up System

- Must be done in change management time (between 5-9 p.m.)
- Good to have the New Technology Prime on site if working with new equipment

Update Database for Generics

- Communication port must be created 24 hours before change
- management time, if update is related to a new sub-net
- Generic information about the equipment must already be entered into the database
- Must know asset number of the equipment
- Must know node name of the equipment
- Must know alias of the equipment

Update Database for Circuits

- Port information about the equipment must already be entered into the

database

- Must know asset number

Create LAN Diagram

- Must have access to the LAN Engineers' diagram
- Must know IP addresses

Label Equipment

- Must have labels, labeling machine
- Must know the node name, alias
- Must have access to the equipment

Barcode Equipment

- Must have the bar coding equipment
- Must have labels
- Must have access to the equipment

Appendix F
Observation Notes (Model Testing Phase)

Date: Day 1

Place: Saturn

Participants: GlenD, RobH, and ChrisW

1. RenoT was on site, because of a problem. He was babysitting the network. In case of emergency he wanted to be on site. GlenD was telnetting to TOSS. He logged on by typing in his password.
2. GlenD wrote down all of the info related to the connections while he was doing the install (prior to today). Equipment ID number (= asset number) entered to TOSS by the stock people. When Telco obtains any hardware it has an asset number. The stock people enter this number to TOSS.
3. GlenD opened two Windows sessions of TOSS.
4. GlenD hit 'find', and entered alias name. He was looking for info of similar equipment in the database. His plan was to just copy and paste the info, and then modify it with the specs.
5. TOSS asked him to enter Work ID number, but GlenD had no idea what that was.
6. GlenD phoned GeorgeF, told him the segment number and asked for the Work ID.
7. GeorgeF gave a phone number to GlenD.
8. GlenD phoned the number. The number was CraigB's number who is the TOSS administrator.
9. CraigB was not at his desk. GlenD left a message.

10. GlenD then phoned GordK, a CSR person. Both of them worked for hardware a while ago. They still had a good relationship.
11. GordK promised help from his own desk to complete the SVO.
12. GlenD shifted to fiber labeling.
13. He had a sheet full of numbers, and got a bunch of plastic tie cables from the drawer. He started to copy the numbers on the tie cables.
14. ChrisW and RobH came back from Tau. They both checked their e-mails.
15. GlenD finished the label creating. Called GordK and told him the node name of the equipment. Also the port number of the console port.
16. JohnZ, the LAN Engineer came by, since it was Wednesday. (JohnZ always visits the installers on Wednesday to discuss any hot issues.) GlenD started to talk to JohnZ about ongoing work.
17. RobH and ChrisW left for fiber testing.
18. RobH and ChrisW came back, started to have lunch.
19. ChrisW told GlenD there were not enough available ports on a patch panel that would be necessary for a future job.
20. GlenD decided to trace down the fibers in TOSS. He believed there should be enough space. He thought that some of the ports that seemed taken were not in use. He believed that TOSS could clarify this.
21. RobH went back to Tau and looked at the patch panel, and tried to identify what terminated there.
22. GlenD found out from TOSS that 60% of the patch panel should be free. GlenD, RobH and ChrisW tracked down each free fiber mentally.

23. The result of this showed (since 2 ports were defective, and a large number of ports would be needed for this future job) that there were not enough ports. They decided that a new patch panel would be needed for the job.
24. RobH went to the storage room and found a new unused patch panel.
25. GlenD asked RobH and ChrisW about a deadline for the work. Since it was not urgent, GlenD was told to wait till SamR came back (he was off today).
26. GlenD started to learn about a new project. He was looking at a LAN diagram, and also reading a LAN Engineering plan. He has already been in NetID and got the IP addresses for the work.
27. GlenD had a meeting with the customer regarding the job that he was reading on. He left the office.
28. RobH and ChrisW planned for cable testing. RobH took a briefcase that had the Fluke meter in.
29. RobH put small parts and small tools into his bag.
30. RobH, ChrisW and I went to Volans to do cable testing.
31. (ChrisW's battery died, so we had to push the car and get cables to start it.)
32. At Volans, RobH knew where the equipment room was, and where the specific cables were, since he had done the cabling work before.
33. We went to the room, RobH entered the door code number.
34. Cables from 4 machines had to be tested. RobH opened the briefcase, put the Fluke A on the shelf beside the equipment.
35. ChrisW took Fluke B to the Bix Tower, located the cable termination on the BIX Tower, and testing started.

36. First they made sure that the Fluke meter was running fine, than RobH took one cable and plugged into Fluke A. Then he shouted the name of it "Cable 1". ChrisW plugged Fluke B into the termination on the BIX Tower and read the reading on Fluke. When the reading was good, ChrisW shouted "Clear" and RobH moved to the next cable.
37. When all of the cables were checked and found good, we finished the testing.
38. We went back to Saturn and took back the Fluke meter and the rest of the parts and tools.

Date: Day 2

Place: Corina

Participants: RayL

1. RayL was finishing up the system turn-up from yesterday. He pinged the box, and saved the config info on the server.
2. He checked his e-mails. He was mainly looking for change management info, or other info that was communicated to him and could have affected his job.
3. RayL called the HPOV guy (yesterday he sent an e-mail to him), but just wanted to make sure that the group knows what happened. Last night he did the change in the network (removed equipment to be replaced with new equipment) but did not do the database update (did not removed the info related to the equipment from the database). He informed the HPOV guy that the data base update will be done today.
4. He went to NetID (telnet, logged on) to update the database. But he did not save the appropriate sub-net range under his favorites in NetID. He did not work on this sub-net segment recently but will in the future. So it seemed reasonable right now to log

on the full range of sub-nets, select the appropriate sub-net range and save it in his favorites. (In future he will only need to log on to the sub-net segment, not to the full range of sub-nets. This will save a lot of time for him.) So he logged on to the full range of the sub-nets. He had to wait to get in, just as he expected.

5. RayL got a phone call from BennyS, relating to previous work they did together. BennyS told RayL to change the info in TOSS about some circuits, since the traffic was going to different ports of different routers right now.
6. The CSR person came by and told RayL that some ports of some equipment had to be changed from 10BaseT to 100BaseT ASAP. He handed a hard copy of an e-mail to RayL with the specs.
7. The CSR person also asked RayL whether he could borrow a drill from him. RayL went to his locked drawer, and handed the drill to the CSR guy.
8. RayL went to TOSS and verified the node name related to the port speed change, just in case. He wanted to make sure that he would be changing the port speed of the appropriate equipment.
9. He set the port speed to 100BaseT Full-Duplex by modifying TOSS.
10. While doing the modification he received a phone call from BennyS regarding the circuit that had to be created in TOSS. RayL did not stop what he was doing. He had the phone to his ear, but his eyes were on the screen and he kept adjusting the port speed.
11. RayL wrote down the port info and the name of the routers that BennyS gave him on a yellow sticky note for future reference. He attached this to his computer screen.
12. RayL selected the appropriate sub-net range in NetID and saved it under his favorites.

13. RayL got another phone call from DorinaP.
14. The CSR person came by with the drill. RayL told him that the ports were set to 100 BaseT.
15. RayL went back to NetID. Now he had the sub-net range saved under his favorites. Logged on to the appropriate sub-net range, he located the sub-net within that. He looked at the domain name (that also identifies the equipment). It seemed that the router related to the domain name is not the one that RayL was expecting to see there.
16. He decided to make a phone call. He called ArtZ whom he did the cut over last night. He wanted to let ArtZ know that he will delete the nonexistent interface from the database.
17. Some people from the recycling department knocked on the door, wanting to come in. RayL let them in. They came to pick up the Cox router that RayL removed from the network. Now they just wanted to see the size of the equipment.
18. RayL walked to the equipment with them, showed them and walked out with them.
19. Now he went back to NetID again. He got really confused, did not understand why the IP address was associated with a different domain name. He phoned ArtZ back.
20. The recycling people came back with an appropriate size of dolly and took the equipment. They asked RayL to sign a piece of paper regarding the equipment removal. RayL was on the phone with ArtZ, and kept pinging various node names by using iTrace while he was signing the paper, and kept talking to ArtZ.
21. ArtZ and RayL agreed that the info in NetID was not appropriate. Whoever did the install before had not entered the appropriate info into NetID.
22. The CSR guy came by, but seeing that RayL was multitasking, left.

23. RayL logged on to the router while he was talking to ArtZ. ArtZ told RayL that some interfaces must be deleted, and some must be left untouched because Virtual LAN must be left alone. Now RayL really got confused.
24. After the phone call he told me that he has never done anything like this before.
25. Now he wrote down every router's name and every port number that was related to this job on a piece of paper and started to compare them with the LAN Engineering plan. He tried to make sense of the information.
26. He did not understand what was going on, so he called BillB the LAN Engineer. BillB was not at his desk, so RayL left a detailed message explaining the problem and asked for clarification.
27. RayL called JeffJ, the New Technology Prime, for help. Not much luck here either. He left a message.
28. The CSR guy came back again and told RayL that on Saturday there will be a scheduled power outage. RayL will have to be here to make sure that all of the network equipment will come alive after the power outage is over. RayL acknowledged the overtime.
29. RayL decided to create a Word document with all of the router's name and port numbers included, for future reference. He saved the file but also printed it out.
30. Now he was waiting for BillB or JeffJ's phone call. He checked his e-mail.
31. Since there was no phone call returned to him, he paged BillB. RayL started to make labels. He logged on the Ptouch software, and created some labels that were missing from yesterday's work. He pulled a previous label file, modified the info, and saved it.

Then he printed the labels out. He did not cut the labels to appropriate shape because right now, for this job, the size of the label was appropriate.

32. RayL logged on to TOSS, and started to create the circuit that BennyS had mentioned earlier today.
33. DerekF called and said that ArtZ would need some fibers. RayL told DerekF to give him a piece of fiber 5 meters in length. Then they started a discussion about a job (removing jumpers) that later on they will perform.
34. RayL located in TOSS the ports that he was supposed to work with to create circuits, however he found out that one of the ports was actually already in use according to the database.
35. RayL called TinaE, whose name was in TOSS associated with this data, and told her to make the ports free. RayL recognized that somebody had already touched the ports that he wanted to remove. TinaE said that she would make the adjustment ASAP.
36. RayL received a phone call from one of the HPOV guys asking, "What is this mess in the database?" RayL told him that the NetID was not clean yet, he had to wait a little longer.
37. RayL started to update the circuits just as BennyS had told him to do. There were 4 circuits to be modified. Two had to be removed (since traffic was moved to two other routers), and two had to be modified from 100BaseT to 1 Gig uplink.
38. He looked at the circuits; however, there was no info entered about the cabling of the circuits. RayL just wanted to take the info and copy and paste it to the new circuit info since the cabling did not change. Only the traffic was going from the equipment to

different equipment. RayL said that Cable Corp did the cabling and they were supposed to enter the info into TOSS but they had not done so.

39. RayL called ArtZ and left a message. He asked for the specs of cabling and also the WorkID number.

40. Shortly after this ArtZ called back with the appropriate info (Work ID number, cable type = N, cable # = 01-50, etc.) He told RayL to enter it to the database, however RayL did not follow ArtZ's advice.

41. RayL called TedM from Cable Corp. He told TedM that the cabling info was not in TOSS. TedM told RayL to call RaphK.

42. Now RayL paged RaphK, and was waiting for him to call back.

43. Now RayL was stuck with the TOSS work and with the NetID work also. He was waiting for phone calls. He explained to me that he did not want to do anything without getting clarification or an explanation from those people who were responsible for that part of the job. He told me that he wanted to understand what was going on and said that he does not do anything mindlessly because he is responsible for everything he does. Since he had to wait, he decided to have lunch immediately.

Date: Day 3

Place: Saturn

Participants: GlenD, ChrisW, RyanJ

1. GlenD called NealY, the LAN Engineer, and asked about the equipment in the morning. NealY said that most things are on site, and the rest will be shipped there today.

2. ChrisW was at Volans recently and told GlenD that he has seen one machine that was already placed into the cabinet. While ChrisW was there, he wrote down the equipment name, and gave it to GlenD who compared this info with the LAN Engineering plan and realized that this equipment is related to his job.
3. GlenD started to look at the LAN Engineering plan.
4. He now made another phone call. He double-checked that everything was there. He wanted to know whether or not it was worthwhile to drive to Volans to do the install.
5. GlenD checked his e-mails. He sent an e-mail to BennyS since BennyS sent out a notice about urgent exchange, but GlenD believed some people were not able to get BennyS's e-mail.
6. GlenD went back reading the LAN Engineering plan.
7. BennyS called, there was some discussion about the recipients of his e-mail.
8. JohnZ, the LAN Engineer arrived, since today was Wednesday, and started to talk to SamR about various issues.
9. GlenD called NealY again about the equipment. "What equipment is delivered to Volans? Just the Nethopper? "You want me to go to Volans and mount only two boxes?"
10. GlenD explained to me that NealY wants this project completed this week (today is Wednesday). GlenD had not seen anything like this before. He told me that he did not realize how complicated this project was, and on top of that he was going for a week-long vacation (to Mexico) on Friday.
11. NealY told GlenD on the phone to at least do the install, so while he is not here, others could do the cabling. They agreed to meet at Volans right away.

12. GlenD made another phone call.
13. We went to Volans to meet NealY.
14. NealY was there and brought two pieces of equipment for GlenD to install. NealY told us that he configured the boxes in his office.
15. He showed GlenD the Nethopper, and they also opened up the paper boxes of two pieces of equipment. He showed GlenD places for this equipment in the cabinets.
16. NealY spent half-an-hour drawing out on the back of the LAN Engineering Plan how this equipment would be connected. The drawing included at least 10 different things (XLR, Splitter, Baystack450, CoreWan, BayStack Hopper, Fiber Patch Panel, Analyzer, Christal Hopper, etc) connected in a rather complicated way. GlenD has never worked with some of the equipment before.
17. GlenD understood what he was supposed to do. Now he asked NealY what he needed to do during this week: installation, cabling, or what?
18. NealY explained that someone would be flying in from the States just to do the cabling part of this job.
19. NealY said that he prefers to have everything that is related in one cabinet. They went to a cabinet that he preferred but it was not empty.
20. NealY realized that to do the job, some equipment had to be removed from the cabinet. It was probably not in use anymore, anyway. NealY realized that he had to call (RyanJ) the Transport guy and ask him to remove the boxes, since it was his group's responsibility.

21. Since the cabinet was identified, GlenD wanted to make sure that everything would fit into the cabinet that needed to go in. He also looked at the fibers. and realized that he will need 48 fibers for expansion in this cabinet.
22. The meeting was over, we went back to Saturn with GlenD.
23. Since JohnZ was still there, GlenD asked JohnZ about a box that he wanted to log on to change the port speed but could not. What to do now?
24. GlenD got a phone call from SamR. and started to check a Word document. SamR said that the server side was having some problems, and now they wanted to know what was on the other side. So SamR was looking for detailed info about each box that was connected to that server.
25. GlenD got another phone call from Marke.
26. BlakeH walked in and started to complain about network performance. He talked about some missing packets...
27. GlenD checked his e-mail and started to write one to the server people regarding their info request.
28. GlenD also sent an e-mail to the transport guy. He asked to have a meeting with him right after he gets back from his vacation, to discuss equipment removal from that cabinet.
29. GlenD started to look at the password update list. Every month their passwords are changed that they use to log on to boxes.
30. ChrisW and RyanJ came back from somewhere. GlenD told them the story about his Volans project, how big and complicated the job was, and how unfamiliar he is with it. He also told them that NealY wanted him to be done with this job by Friday, and

that someone would fly here next week and the install will not be done. The most important part of the discussion was to tell ChrisW and RyanJ that he would need 48 fiber expansions at Volans. (I assumed ChrisW and RyanJ would do that part of the job.)

Date: Day 4

Place: Saturn

Participants: SamR, RenoT, ChrisW

1. (9 am) SamR suspected that he was having a heart attack. He called a doctor and scheduled an appointment for 10 am. Last week he worked 40 hours overtime.
2. JackT called SamR and asked to adjust port speed.
3. ChrisW read the configuration documentation and cleaned his desk.
4. AdamE phoned SamR, but ChrisW picked up the phone because SamR was on the other line.
5. SamR called AdamE back.
6. RenoT asked what was the story about the server. SamR said number 2 was working fine. RenoT said number 1 was working fine for him also.
7. RenoT and ChrisW had a discussion about ChrisW's future responsibilities at the new company. ChrisW complained that for troubleshooting he would have only 15 minutes to respond in the future. By the time he would understand the problem and log on to TOSS the 15 minutes will be up. RenoT showed a drawing of a topology that he created for the buildings at Pluto. Every box and every connection was on the drawing. He said that this diagram speeds up the process. This was what he used.

8. SamR left, went to the doctor. PaulB came by because 2 IP addresses were not reachable. ChrisW looked at the configuration of the boxes, then he pinged them.
9. RenoT and ChrisW troubleshooted together PaulB's problem. They pinged the box. They tried to get to the box, but could not log on to it. They could however log on to another box on the same LAN, and also to the router of that LAN.
10. RenoT left with PaulB.
11. ChrisW called AdamE since he was waiting for RenoT and let him know that RenoT stayed to help the guys with the Hydra problem. The Hydra problem is related to the badger readers. In some buildings they did not work.
12. LevO called. He wanted to borrow a light meter (Exfo) for fiber testing. ChrisW told him that they had it and he could come to pick it up.
13. ChrisW started to check IP addresses for PaulB.
14. Tower 12 security desk phoned. RenoT was on the phone, wanted to get a Fluke meter.
15. ChrisW went to the storage room, checked the Fluke meter, and told RenoT on the phone that they had it.
16. RenoT asked who was the CSR for this job, and how could he get that person. He wanted the CSR to check the drop.
17. Two people arrived for the light meter. ChrisW pulled 3 out of a drawer and started to check them. He looked for the light source. He tried to figure out which set of light meters was complete. He said that he was not familiar with the equipment.
18. RenoT walked by and took one Fluke meter.
19. The people took a light meter set and left. ChrisW checked his e-mail.

20. RenoT phoned from the IT room. ChrisW told RenoT that he tried to get into TOSS but could not log on. The other phone rang, LevO called. ChrisW and told him to wait because he was helping RenoT on the other line with troubleshooting.
21. ChrisW went to SamR's desk, since TOSS was open on his desktop. He tried to find the IP address in TOSS, and looked at the elements of the circuit, but found none. He told this to RenoT who was still on the phone.
22. ChrisW went to the storage room and moved huge boxes of fibers from an open area to a closed area. He said they must hide the fibers because people have a tendency to just come by and grab them as they need them. They decided to lock the fibers away. SamR actually asked ChrisW to do this before he left for his doctor's appointment.
23. (11 am) Phone call for RenoT. ChrisW picked up the phone and told the caller that RenoT was working on a problem.
24. ChrisW went back to the equipment room, and before he would put the fibers into the locked cabinet, checked the length of each fiber. He organized the fibers by length.
25. RenoT came back with PaulB, and went to SamR's computer. He went to TOSS and double-checked the elements of the circuits that ChrisW had already checked for him. RenoT could not find them either and was upset because the database was not up to date. Somebody had not done his job well. Because of this, he could not see how the boxes were connected.
26. PaulB said to RenoT that he knew how the boxes were connected. He asked RenoT whom to call, whose responsibility it was to update TOSS. RenoT told him to talk to CSR about this issue. RenoT said, "We have no control over this."

27. JackT called again at the same time NancyD called. ChrisW put NancyD on hold and pinged the box that JackT was asking about. JackT was looking for a sub-net mask. Another phone call came from JeffJ for RenoT. Since RenoT had just walked in, ChrisW gave the phone to him. RenoT and JeffJ arranged a time tonight for troubleshooting.
28. ChrisW tried to locate the mask on the net. RenoT explained to him how to find it.
29. ChrisW found the sub-net mask and called back JackT with the mask number.
30. RussellY phoned. RenoT picked up the phone. RussellY complained about a box "mtre1010101". RenoT told RussellY to call somebody else, and provided a name. He went to troubleshooting mode. He said that he remembered that "mtre1010101" was the box that was not labeled. RenoT was upset: "I have to go through a lot of shit here: I need to trace the cables back."
31. Two guys came and asked RenoT how was the troubleshooting for the Hydra problem. RenoT said it would take some time. (He was still busy with PaulB's problem).
32. RenoT went to the equipment room and tried to locate the box. He said he knew it was the one with no label on it.
33. SamR's wife phoned and asked about SamR. ChrisW told her that he was not back yet.
34. We went to the equipment room and ChrisW pulled the jumper while looking over the equipment. Since it went dead, they identified that this router was related to PaulB's problem.

35. We went back to the IP room, RenoT put the Fluke meter on, and found that the signal was okay now. He said, "We have a cable problem, since just by touching the cables, the reading became normal".
36. We came back and RenoT pinged various boxes to see if the entire speed and error rate was normal now. RenoT said that some re-wiring must take place, and this was the CSR's responsibility since it was on the desktop side.
37. But RenoT changed his mind. He said, "people would keep bugging me," so he decided to fix the problem even though it was not his responsibility. He re-wired the problematic section.
38. (1pm) SamR came back. He said that he had only "viral pneumonia," not a heart attack and kept working even though he was sick.
39. SamR started to check his e-mails for requests.
40. RenoT came by and explained to SamR what had happened during the time he was not around. He said that he re-wired a box that had caused some problems; however there was another box that did not advertise even though the Fluke meter showed that the box was fine.
41. RenoT logged on to the router on ChrisW's computer.
42. SamR filled out a questionnaire about his pager. His new company asked him to do this.
43. RenoT told SamR that he had checked that other box in TOSS but it was not there, so he was left with no choice but to trace the wires. By using Fluke he also found out that the port speed was incorrect (100 instead of 10).

44. RenoT explained why TOSS was not up to date. A while ago the CSRs had to create a label for each desktop. Because of outsourcing it was not required anymore. So CSRs do not need to care about the appropriateness of TOSS now.
45. RenoT called PaulB and told him that one box must be labeled. RenoT provided the node-name, port name, and port speed for labeling. (While he was working on the problem he found this info out, and made a note of it.) He also told PaulB that PaulB should get the other box re-configured.
46. ChrisW was still pinging the boxes. He changed the port speed back to 10, since 100 was not the appropriate speed.
47. SamR got a phone call, that the "Eridanus session was dropped". SamR told the caller to take the issue to BillB, because he could not do anything about the problem. Telco did not support Eridanus over the router.
48. A discussion started about the Eridanus session in the room: "When router hits 100% it drops the Eridanus sessions. This is the reason why Eridanus is not supported."
49. In the meantime SamR ran a ping test to the server. He sent 200 packets from on sub-net.
50. ChrisW was preparing for configuration. He put his laptop into its case, packed a communication cable, a mouse, some documentation, notes, pen and paper. He had the IP addresses, and node names in his notes. SamR had given this info to ChrisW a while ago.
51. ChrisW and I went to the little equipment room on the 7th floor to perform a configuration. There were 5+5 Baystacks, however they were not alive yet. To get into the room ChrisW had to punch the door code in.

52. ChrisW took his laptop out of its case, and started to read the config documentation.
53. Then he looked at the Baystacks, and made a phone call. He asked SamR which Baystack should have the uplink? SamR said the number 2.
54. ChrisW un-powered the Stacks and took the uplink module out of the number 1 Stack and put it into number 2 Stack. Then he powered up the Stacks again.
55. ChrisW now connected his laptop to the Baystack's communication port, and also connected port #1 to the Ethernet.
56. He assigned an IP address to his laptop and rebooted it.
57. ChrisW logged on to the Baystack, and started the configuration of that Baystack module that oversees all of the 5 elements of the Stack.
58. He downloaded the software from his laptop to the number 1 Stack.
59. The system automatically rebooted itself.
60. ChrisW went through the configuration: he did the port configuration, set port speed to 100 BaseT Full-Duplex, and disabled auto-negotiation, etc.
61. ChrisW went to the 8th floor and checked a similar set-up. He wanted to know which fiber goes into the right and which into the left port out of the fiber pair.
62. He plugged the 4 fibers into the uplink ports.
63. Now ChrisW wanted to ask SamR to ping the box from his desk, so he phoned SamR. SamR was not at his desk.
64. Logged on to the number 2 Stack, and checked its configuration info and software release.

65. Just in case, he checked the first Stack software release by doing an event log,
however he found it inappropriate. It seemed that the Stack did not take the previous
downloading process.
66. ChrisW logged back to the first Baystack and started to download the software again.
67. He plugged the uplink into Stack #2.
68. ChrisW called SamR to ping the box.
69. SamR did this, but only Stack #1 was visible from the network. Stack #2 was not.
70. ChrisW unplugged Stack #2 then powered it up again.
71. He called SamR again and asked him to ping Stack #2. SamR still could not see Stack
#2 from the network. SamR told ChrisW on the phone to power the box down, plug
the fibers into the other uplink (they have 2 uplink ports per Stack for redundancy)
and power it up again.
72. After following SamR's advice, ChrisW called SamR again to ping the Stacks. But
SamR was not at his desk.
73. We went back to the main room, where SamR, ChrisW and the rest of the team sit.
74. SamR was there. ChrisW told him that " I put back the MDA where it was supposed
to be."
75. SamR explained to ChrisW that while we were away he had resolved the server
problems related to the Eridanus session drop. He said that he looked at the 2 routers
that were connected to the server and realized that "router 8" was probably the one that
came up first after the scheduled power down. He said that this had toasted "router 8".
To solve this problem he talked to RenoT., who told SamR to reboot the "router 8".
RenoT said not to waste time, to solve the problem right now. He assured SamR that

he could do whatever he wants to, because he is “the troubleshooter” of the group and has the authority, and because of this they do not need any kind of permission for the reboot. SamR did reboot “router 8”, and that solved the problem. RenoT was right, everything was now running smoothly again.

76. ChrisW told the story about the configuration that we just did.

77. SamR started to write an e-mail. He was reporting a problem to higher-ups and to colleagues. He believed there was a problem with one of the software they were working with. Yesterday and today 5 people called him that the server did not come up on their system. SamR found out that if he enabled auto-negotiate, the server would come up. This did not make sense so he believed there was a problem with the software. Now he wanted to inform the engineers and let them know what he thinks. He hoped the engineers would check and test the software. The engineers may leave the software like this until the next release, or they may not; this is up to higher management. SamR also wanted his colleagues to know the solution he had come up with. “They may run into a similar problem,” said SamR. “It is good to have a solution handy”.

Date: Day 5

Place: Saturn

Participants: SamR, RobH

1. SamR and RobH were discussion cabling. RobH had a sheet of paper with a table that ChrisW prepared a while ago. The table had the following headings: “port #, patch panel, cable over the other building, patch panel, port number of the other device.

” Today RobH would do the 3rd and 4th floor cabling. RobH had already been at the locations and knew the length of cables needed.

2. RobH started to create a list that included the fiber number, the length of the fibers, and the type of connectors for each fiber. He needed 16 x 2-meter cords and 16 x 4-meter cords.
3. SamR was reading his e-mails, and the on-call summary.
4. RobH showed his cable needs to ChrisW, and they started a discussion about it.
5. RobH went to the storage room, where ChrisW had locked the cables in yesterday, and started to get the appropriate cables. He found all of the 2-meter long cables, but did not find any of 4-meter length.
6. ChrisW went to the storage room and RobH asked him about the 4-meter fibers. ChrisW said there was a box with SamR’s name on it, and that the box contained 4-meter length fibers.
7. RobH started to look for the box, found it, but did not find 4-meter length.
8. ChrisW told RobH to use 3-meter, but RobH disagreed and said he would go for 5-meter, just in case...
9. RobH found the 5-meter cables, but their connectors looked somewhat different from what RobH was used to working with. RobH did not like the connectors, but took them anyway.
10. RobH pulled an empty paper box from the storage room and put the fibers in it with his notebook, and with the sheet that ChrisW had prepared. He also put a black marker into the box.

11. RobH and I went to Tau. LloydW was there (a cabling guy) and also 2 more cabling people from Cable Org. There was some social discussion, people greeted each other.
12. RobH located the cabinet and took all of the 2-meter long fibers out of the box.
13. He went to the other side of the cabinet, to the patch panel, and wrote down the port number of the fiber patch beside the box port numbers on his sheet.
14. RobH took the black marker and wrote the port number on each end of the fiber pair.
(This end goes into this equipment = equipment port number is so and so, the other end of the same fiber goes into the patch panel = patch panel port number is so and so).
15. RobH ran the fiber from the box to the patch panel.
16. He plugged the fibers to the appropriate ports of the patch panel.
17. RobH went to the Fiber Management System (FMS) and unwrapped the fibers.
18. A Cable Org. guy came by and asked RobH how long he would be working here, because he wanted to work in the very same area of the FMS. They were in each other's way. RobH said the job would take him a half-hour. The Cable Org. guy said that was okay and left.
19. RobH identified where the fibers of the patch panel terminated on FMS.
20. Then he went to the other side of the FMS and identified the port numbers of the fibers that went from the FMS to the 2nd floor. He wrote these port numbers down too.
(His familiarity with the layout of the connections made him realize earlier that Tau is not connected to the 3rd floor straight. Fibers go from Tau to the 2nd floor and from the 2nd floor to the 3rd floor meaning an additional step that he had to perform because of this specific set-up.)

21. RobH plugged the fibers into the FMS and started to write with a black marker on the other end of each fiber. He wrote those port numbers on them that told him where he had to plug the other end of the fiber into the FMS.
22. Then he ran the fibers to the other side of the FMS.
23. He checked the little numbers on the fibers, and started to plug them in one by one to the ports.
24. We went to the 2nd floor. RobH entered a door code to get into the equipment room.
25. RobH identified on the 2nd floor's FMS where the fibers terminated that came from Tau.
26. He also identified from what port of the FMS had fibers going to the 3rd floor. He wrote down the FMS port numbers on his sheet.
27. RobH started to plug the fibers into the FMS ports, where Tau terminated.
28. Then while the fibers were hanging, he wrote one by one with the black marker the port numbers on the connectors to make sure he would not mix them up.
29. He plugged each fiber in.
30. We went to the 3rd floor. RobH entered the door code. On the 3rd floor there was only a single cabinet with one patch panel. RobH wrote down the port number of the patch panel.
31. He plugged the fibers in, and left the other end of the fibers hanging beside the equipment (Baystack), since fiber testing would take place next.
32. While RobH was working he wrote down all of the port numbers for the 3rd- and 4th- floor work. However, he physically did the cabling of the 3rd floor from end to end,

- and then decided to start the 4th floor work (end to end). Next day he planned to do the fiber testing with ChrisW. Fiber testing is always faster if two people do it.
33. RobH went back and started to do the 4th floor cabling. I left RobH and went back to the NCC room.
34. SamR was already working on TOSS. He had started work on it when I left with RobH, and had almost finished the Volans' TOSS work.
35. Lunch time.
36. SamR logged on to TOSS again. He went to "inventory, find," trying to locate similar equipment (XLR switch) that had a similar card structure to the one he needed to enter right now. (The chassis is entered to TOSS when arrived at Telco; however, how it was filled up had to be entered by operation people because it is always specific.) He found similar equipment.
37. SamR copied and pasted the equipment info to the database. While he did that, the generic info was automatically entered to TOSS, and also all of the ports were created.
38. SamR ran a check. He clicked on 'Find', entered the equipment ID, wanting to see that the ports of the XLR were already in TOSS. They were.
39. SamR had to create a Service... Order (SVO) because TOSS was used for billing in the past. SVO required SamR to enter where the box was sitting, who did the job, what user group, etc. Console Port must be created within SVO.
40. He defined the Console Port. (Fictitious port, the database is set up in such a way that people must create this before they can create the circuits. It associates a piece of

equipment with a node name. After this people can assign where ports are connected to.)

41. Today SamR had to create info in the database about the XLR connections. The XLR was connected to 2 routers. He installed a new box (XLR) that actually replaced an old box (Cox). So only the end device changed, the rest of the info in TOSS had to be left intact.
42. SamR clicked on Find, and located the 2 routers in TOSS. Since the circuits were already in existence, he had only to delete the old equipment's name and add the new equipment's name.
43. SamR had to repeat this 4 times, since there were 2 connections to each of the routers, and they had 2 routers for redundancy.
44. A phone call came in. SamR picked up the phone but he was not happy to stop the TOSS work while he was in the middle. He was on the phone for a while. He was told to add 18 more ports to the server sub-net.
45. After the phone conversation he just sat there and had a hard time finding where he had stopped working on TOSS. TOSS is really hard to work with, because lots of information must be kept in mind while working.
46. SamR went to the storage room and got the asset number of the Baystacks that he had to enter into TOSS. The Baystacks were still on the floor (not installed yet), however they were already configured.
47. He typed the asset number (connection to 2 servers) into TOSS, but TOSS told him that one of those boxes were already sitting in the server sub-net.

48. SamR started to wonder. "It was maybe on the network, and then was removed. It is possible that the database was not updated after removal."
49. Since TOSS told SamR where that equipment was sitting in the network, he decided to go there and look at it, which he did.
50. SamR came back and said there was a typo in TOSS. There was a box in that location but its number differed by one digit.
51. Baystack is considered as one unit in TOSS, however it can consist of 7 physical boxes. Since some boxes were already in TOSS and already installed in the network, SamR had to add just one more to TOSS. He only had to add some ports to the Baystack manually. Twenty-four ports were already created, so he just had to add some more (48) to it.
52. SamR checked his e-mail. He wrote an e-mail about network problems that people had bugged him with today.

Date: Day 6

Place: Saturn

Participants: SamR, RobH, ChrisW

1. SamR was checking his e-mails. PeterS sent an e-mail about the Gig cards that were out there and hard to keep track with. He suggested setting up a certification process.
2. RobH was reading his notes.
3. SamR searched for some info in TOSS.
4. ChrisW asked a question from SamR regarding some firmware. He was supposed to upgrade the firmware, and sent out a change management notice a while ago.

However HPOV was supposed to recognize that the firmware went down because of the scheduled power down, but did not come up. HPOV did not get that the firmware stayed down.

5. SamR made a phone call regarding the power shut down. “ Traffic analyzer is on the SNP sub-net, we have to coordinate with them to move this off the sub-net...”
6. RobH prepared for fiber testing. He brought the EXFO out of the storage room, and checked what was in its case. He packed 3 fiber pairs, his notes, and some patch cords to the case.
7. SamR wrote an e-mail regarding the phone discussion he had had a couple of minutes ago.
8. RobH went to the storage room and filled the toolbox with tie wraps and small parts.
9. ChrisW was checking the “Telco4Help” database. If there was some network-related problem that the helpdesk files, they had to look into it. ChrisW was using iTrace to ping those boxes that the database suggested as being problematic.
10. It seemed that RobH was waiting for ChrisW.
11. ChrisW wrote an e-mail and asked RobH “Shall we?”
12. ChrisW and RobH looked at RobH’s note and ChrisW copied the table that RobH created yesterday to his notebook. (floor, Box, patch panel, FMS out, FMS out, Box).
13. ChrisW went back to the “Telco4Help” and looked up something, then closed the program.
14. SamR was still writing e-mails.
15. ChrisW told SamR that they were leaving for fiber testing, and would be back in an hour or so.

16. SamR suggested they take a cordless phone with them, but ChrisW said, "We do not need it".
17. ChrisW, RobH and I headed to Tau. RobH brought everything he packed, ChrisW carried his notes.
18. In Tau ChrisW got a cart and put the fiber tester on it. They started to look at ChrisW's notes about fiber testing (procedure).
19. First they plugged a patch cord into the testers and tested the tester, making sure that they get 0 counts (db loss) by sending a signal down from one tester unit to the other unit.
20. RobH wrote down the Tau's phone number, took an insert and a patch cord with him and went to the 3rd floor to start the testing. He took the patch cord in case of a defective fiber, so that he could replace it right away.
21. ChrisW connected the first fiber of a fiber pair to the tester. He started to send a signal down the fiber. RobH, on the other end, by using an insert, plugged a fiber pair into each other creating a loop. The signal went from the tester through the one fiber of the fiber pair and came back to the other tester through the other fiber of the fiber pair. Or at least this is how it was supposed to happen. Instead of that, ChrisW had some difficulties figuring out what to plug where.
22. RobH phoned that he was ready to start the testing. ChrisW told him to call back in 5 minutes, since he was not yet ready.
23. ChrisW went through his notes, and figured out how to attach the tester to the fibers.
24. RobH phoned him back and testing started. ChrisW picked the first fiber, told RobH which fiber pair to attach together, sent the signal down, and read on the second tester

- the strength of the signal. They went one by one, testing the 4 fiber pairs. All of the reading looked fine, (db loss was less than 8) except one. One showed 9.5 db loss.
25. RobH went to the 4th floor and they tested those fibers also one by one. The reading there was fine.
26. Since they had identified one fiber as problematic, troubleshooting started. ChrisW went to the FMS, did a loop back and checked the signal loss of that segment. It was 3.75.
27. RobH called from the 2nd floor and they tested this segment. It looked okay.
28. RobH went to the 3rd floor and they tested this segment. The reading was too high.
29. ChrisW told RobH to replace the patch cord with the spare patch cord. RobH did so. The reading now became 8.85 db loss. Since 8-9 is an acceptable level, they decided that the fiber was okay now
30. RobH came back to Tau, they packed everything and we went back to NCC.
31. SamR asked them what happened. ChrisW explained. SamR was not happy with the borderline reading. He told ChrisW and RobH to go back and replace that fiber. SamR explained to ChrisW that each hop should not lose more than .5 or 1 db. If at the FMS the reading was 3.75, then the problem is there. That db loss is too high in one hop.
32. SamR logged on to the XLR, and shut down the port, so later on RobH and ChrisW could hook these Baystacks to the XLR.
33. SamR also told RobH and ChrisW that labeling had to be done, because some of the labels were falling off the Bix Tower. "I'll get you the Ptouch to do labels." SamR

also stated that no change management notice will be sent, because he shut down the port of the XLR, and nobody was on the Baystacks yet.

34. ChrisW went back to the “Telco4Help” database. Somebody complained that she wanted to move her port from one sub-net to another and ChrisW now called the person to find out what the story was.

35. RobH started to work on the labels. He was looking for designation strips for the labels.

36. SamR told the rest of the people that AdamE had sent an e-mail about a chronic equipment shortage. AdamE said if Baystacks were lying around to notify him. They actually had a few Baystacks in the network with a few people on it. They considered some reorganization so they could remove some Baystacks and send them to AdamE. However, removal would result in major TOSS work. Being busy enough, they decided to drop the idea.

37. JohnZ the LAN Engineer came by and there was a discussion about NetID and TOSS. JohnZ has meetings with customers on a weekly basis, and this week he was asked about the re-booted router by a customer. JohnZ did not know anything about this (he was upset that SamR did not tell him what had happened). He asked the customer about trouble tickets. They said there were none. JohnZ told them that if no trouble ticket had been issued, then there was no way for him to know anything. They also discussed an issue regarding others populating sub-nets. JohnZ said he had no idea what was out there and the situation must change. SamR told JohnZ that he was slapped in the face because of the outage on Monday. He said that he would not do any favors for anybody anymore. They all agreed that trouble ticketing is important.

JohnZ said that this is the best way in having an idea about problems and problem trends.

38. SamR showed me an e-mail regarding the outage: "Equuleus server outage, from 8 am till 3.30 pm pointing to network problems." SamR was upset about it. He was sick that day (when he believed he was having a heart attack). He acknowledged the outage around 2, after he returned from the doctor. He had fixed the problem (even though he was sick and there was no trouble ticket, so it was not his problem) by 3 pm. Now it seems that he ignored the outage and it took him 7 hours to respond. Since the e-mail said "it is pointing to network problems" this clearly suggested that he was responsible for such long troubleshooting. Most people who read the e-mail knew who was responsible for this network segment. SamR felt that this was not a fair e-mail. On top of this, the e-mail was sent to many people.
39. RobH and ChrisW left to replace the fiber with the "borderline db loss".
40. SamR was reading and writing e-mails.
41. SamR created a label for one of the boxes they were not responsible for. He opened up a Word document and typed from his notebook all of the info that identified the box. Even though the box was not theirs, he had to move it, so he had to learn about the box. He wanted to provide this info to those who were responsible for it. The most convenient way was to write it on the box.
42. SamR started to work on a LAN diagram. This was a follow-up of yesterday's TOSS work. He went to Power Point and pulled a template. He modified the template by adding more pictures of the boxes, and typing the IP addresses, node names, etc. He

saved the file and told me that he would print it out and put it into a folder. He would take this printout home, where he would be on call.

43. SamR got a phone call from the manager of the people who had issued the outage report. He explained to the manager that he had not been fairly treated, and had received negative feedback from higher-ups. He explained that he had reacted right away, and had done a favor, since no trouble ticket had been issued. However, because of the outage report, in future he wants trouble tickets issued. "You want to bring the two groups (SamR's team, and that group which sent the e-mail out) together; well, issues like these don't do a good job. The way the outage report was written pissed me off. 7.5 hour-long outage, written by red letter...pointing to network problems. I got to know that there was some problem around 2.30 p.m. and I solved the problem by 3.30 p.m."
44. RobH and ChrisW came back. They replaced the fiber.
45. SamR told them to send a notice about completing the testing.
46. RobH and ChrisW started to do fiber labeling. RobH entered by hand the node names and hit 'print' on the Pan Quick device. It printed the labels out.
47. A guy came by and brought a color printer. SamR signed a piece of paper and started to unpack it. He found a place for it, and put the printer there.

Appendix G

Example of How Observation Notes were Associated with Planning Units

The right side of the table presents the data from the observation notes, the left side shows the corresponding Planning Unit of the LAN Installation Model. All of the observation notes of the model testing phase were compared to the corresponding Planning Unit of the LAN Installation Model.

Observed Planning Units: Turn-Up System, Label Equipment, and Update Database for Circuits

<u>Planning Unit:</u> Turn-Up System	<u>Observed Behavior</u>
Notify on-call person just before system turn-up starts	
Log on to the router	
Route traffic to the new LAN	
Enable uplink port (system turned up)	
Check the uplink port (ping LAN from sub-net, and from off sub-net)	"RayL was finishing up the system turn-up from yesterday. He pinged the box.
Test LAN	
Get port statistics	
Test router capabilities	

Save configuration information	and saved the config info on the server.
Let others know that the work is completed	<p>He checked his e-mails. He was mainly looking for change management info, or other info that was communicated to him and could have affected his job.</p> <p>RayL called the HPOV guy (yesterday he sent an e-mail to him). But he just wanted to make sure the group knows what happened. Last night he did the change in the network (removed equipment to be replaced with new equipment) but did not do the database update (did not remove the info related to the equipment from the database). He informed the HPOV guy that the data base update will be done today.”</p>

<u>Planning Unit: Label Equipment</u>	<u>Observed Behavior</u>
Locate labeling machine	<p>“RayL started to make labels. He logged on the Ptouch software, and created some labels that were missing from yesterday’s work</p>
Start the TouchEditor software	

Obtain the files of one of the old labels related to similar equipment	He pulled a previous label file,
Change the alias and sub-net information	modified the info,
Save the file	and saved it.
Print and cut the labels to appropriate size	Then he printed the labels out. He did not cut the labels to appropriate shape because right now, for this job, the size of the label was appropriate.”
Get plastic strips	
Stick the labels on the plastic strips	
Slide the plastic strips into the appropriate place	

<u>Planning Unit</u> : Update Database for Circuits	<u>Observed behavior</u>
Build circuits and segments	<p>“RayL logged on to TOSS, and started to create the circuit that BennyS had mentioned earlier today.</p> <p>DerekF called and said that ArtZ would need some fibers. RayL told DerekF to give</p>

him a piece of fiber 5 meters in length.

Then they started a discussion about a job (removing jumpers) that later on they will perform.

RayL located in TOSS the ports that he was supposed to work with to create circuits, however he found that one of the ports was actually already in use according to the database.

RayL called TinaE, whose name was in TOSS associated with this data, and told her to make the ports free. RayL recognized that somebody had already touched the ports that he wanted to remove.

TinaE said that she would make the adjustment ASAP.

RayL received a phone call from one of the HPOV guys: "What is this mess in the database?" RayL told him that the NetID was not clean yet, he had to wait a little longer.

RayL started to update the circuits just as BennyS had told him to do. There were 4

	<p>circuits to be modified. Two had to be removed (since traffic was moved to two other routers), and two had to be modified from 100BaseT to 1 Gig uplink.</p>
<p>Enter information that defines how the equipment connects to each other</p>	<p>He looked at the circuits; however, there was no info entered about the cabling of the circuits. RayL just wanted to take the info and copy and paste it to the new circuit info since the cabling did not change. Only the traffic was going from the equipment to different equipment. RayL said that Cable Corp did the cabling and they were supposed to enter the info into TOSS but they had not done so.</p> <p>RayL called ArtZ and left a message. He asked for the specs of cabling and also the WorkID number.</p> <p>Shortly after this ArtZ called back with the appropriate info (Work ID number, cable type = N, cable # = 01-50, etc.) He told RayL to enter it to the database, however RayL did not follow ArtZ's advice.</p> <p>RayL called TedM from Cable Corp. He</p>

	<p>told TedM that the cabling info was not in TOSS. TedM told RayL to call RaphhK.</p> <p>Now RayL paged RaphhK, and was waiting for him to call back.</p> <p>Now RayL was stuck with the TOSS work and with the NetID work also. He was waiting for phone calls. He explained to me that he did not want to do anything without getting clarification or an explanation from those people who were responsible for that part of the job. He told me that he wanted to understand what was going on and said that he does not do anything mindlessly because he is responsible for everything he does. Since he had to wait, he decided to have lunch immediately.”</p>
Obtain necessary information from notes	
Save the information	

Tables

Table 1.

Observed Planning Units during Model Building Phase

Planning Units

Understand the Project – A
 Understand the Project – B
 Get the Equipment – A
 Get the Equipment – B
 Install
 Lay Cabling – A
 Lay Cabling – B
 Lay Cabling – C
 Lay Cabling – D
 Obtain IP Address
 Configure
 Turn-Up System
 Update Database for Generics – A
 Update Database for Generics – B
 Update Database for Circuits – A
 Update Database for Circuits – B
 Create LAN Diagram
 Label Equipment

Note: A, B, C, and D refers to different instances of a single planning unit, indicating that certain planning units were observed more than once.

Table 2.

Predicted Steps and Observed Steps of Planning Units

Planning Units	Steps	
	Predicted	Observed
Understand the Project – A	6	1
Understand the Project – B	6	2
Get the Equipment – A	4	1
Get the Equipment – B	4	1
Install	7	2
Lay Cabling – A	14	1
Lay Cabling – B	14	1
Lay Cabling – C	14	2
Lay Cabling – D	14	1
Obtain IP Address	10	3
Configure	9	4
Turn-Up System	10	3
Update Database for Generics – A	6	3
Update Database for Generics – B	6	4
Update Database for Circuits – A	4	2
Update Database for Circuits – B	4	2
Create LAN Diagram	5	2
Label Equipment	9	4
Total	146	39

Table 3.

Modified Predicted Steps and Observed Steps of Planning Units

Planning Units	Order of Steps	
	Modified Predicted	Observed
Understand the Project – A	1	1
Understand the Project – B	3	2
Get the Equipment – A	1	1
Get the Equipment – B	1	1
Install	2	2
Lay Cabling – A	1	1
Lay Cabling – B	1	1
Lay Cabling – C	5	2
Lay Cabling – D	1	1
Obtain IP Address	3	3
Configure	4	4
Turn-Up System	5	3
Update Database for Generics – A	3	3
Update Database for Generics – B	5	4
Update Database for Circuits – A	2	2
Update Database for Circuits – B	2	2
Create LAN Diagram	2	2
Label Equipment	4	4
Total	46	39

Note: The number of steps (unit tasks) predicted were adjusted by eliminating the predicted steps that occurred before and after the observation.

Table 4.

Conditional Sequential Analysis

Steps Completed	Percentage	Instances
Sequence Correct (e.g., 2, 3, 4)	85%	39
Instances of Unit Tasks out of Order: (e.g., 2, 4, 3)	0%	0
Instances of Leaving out Unit Tasks (e.g., 2, 4)	15%	7
1 step skipped	4%	2
2 steps skipped	2%	1
3 steps skipped	2%	1
Total	100%	

Table 5.

Frequency of Problems during Planning Unit Execution

Planning Units	Number of Problems
Understand the Project – A	0
Understand the Project – B	1
Get the Equipment – A	1
Get the Equipment – B	0
Install	3
Lay Cabling – A	0
Lay Cabling – B	0
Lay Cabling – C	2
Lay Cabling – D	0
Obtain IP Address	10
Configure	2
Turn-Up System	0
Update Database for Generics – A	1
Update Database for Generics – B	0
Update Database for Circuits – A	5
Update Database for Circuits – B	2
Create LAN Diagram	0
Label Equipment	0
Total	27

Table 6.

Types of Problems Encountered during Planning Unit Execution

Planning Units	Types of Problems			
	Missing Parts	Missing Information	Contradictory Information	Interruptions
Understand the Project – A	0	0	0	0
Understand the Project – B	0	0	0	1
Get the Equipment – A	0	0	0	1
Get the Equipment – B	0	0	0	0
Install	0	0	0	3
Lay Cabling – A	0	0	0	0
Lay Cabling – B	0	0	0	0
Lay Cabling – C	1	0	0	1
Lay Cabling – D	0	0	0	0
Obtain IP Address	0	1	1	8
Configure	0	2	0	0
Turn-Up System	0	0	0	0
Update Database for Generics – A	0	1	0	0
Update Database for Generics – B	0	0	0	0
Update Database for Circuits – A	0	1	1	3
Update Database for Circuits – B	0	0	1	1
Create LAN Diagram	0	0	0	0
Label Equipment	0	0	0	0
Total	1	5	3	18

Table 7.

Types of Communication during Planning Unit Execution

Planning Units	Types of Communication			
	Information Request	Ordered Others	Exchanged Information	Interrupt
Understand the Project – A	0	0	0	0
Understand the Project – B	2	1	2	1
Get the Equipment – A	3	0	0	1
Get the Equipment – B	0	0	0	0
Install	1	3	2	3
Lay Cabling – A	0	0	1	0
Lay Cabling – B	Not Analyzed			
Lay Cabling – C	1	0	2	1
Lay Cabling – D	Not Analyzed			
Obtain IP Address	5	0	1	8
Configure	5	0	1	0
Turn Up System	0	1	1	0
Update Database for Generics – A	3	1	1	0
Update Database for Generics – B	0	0	0	0
Update Database for Circuits – A	4	0	0	3
Update Database for Circuits – B	0	0	1	1
Create LAN Diagram	0	0	0	0
Label Equipment	0	0	0	0
Total	24	6	12	18

Note: Two planning units were excluded from the rest of the analysis on communication because they were performed in collaboration. Technicians continuously exchanged information making these planning units qualitatively different from the rest of the planning units.

Table 8.

Media Utilized for Communication

Planning Units	Media Types		
	Phone	E-mail	In Person
Understand the Project – A	0	0	0
Understand the Project – B	3	2	1
Get the Equipment – A	3	0	1
Get the Equipment – B	0	0	0
Install	2	3	4
Lay Cabling – A	0	0	1
Lay Cabling – B	Not Analyzed		
Lay Cabling – C	0	0	4
Lay Cabling – D	Not Analyzed		
Obtain IP address	8	1	5
Configure	5	0	1
Turn-Up System	1	1	0
Update Database for Generics – A	4	0	1
Update Database for Generic – B	0	0	0
Update Database for Circuits – A	7	0	0
Update Database for Circuits – B	0	1	1
Create LAN Diagram	0	0	0
Label Equipment	0	0	0
Total	33	8	19

Table 9.

Media Utilized for Information Requests

Planning Units	Media Type		
	Phone	E-mail	In Person
Understand the Project – A	0	0	0
Understand the Project – B	2	0	0
Get the Equipment – A	3	0	0
Get the Equipment – B	0	0	0
Install	0	0	1
Lay Cabling – A	0	0	0
Lay Cabling – B	Not Analyzed		
Lay Cabling – C	0	0	1
Lay Cabling – D	Not Analyzed		
Obtain IP Address	5	0	0
Configure	5	0	0
Turn-Up System	0	0	0
Update Database for Generics – A	3	0	0
Update Database for Generics – B	0	0	0
Update Database for Circuits – A	4	0	0
Update Database for Circuits – B	0	0	0
Create LAN Diagram	0	0	0
Label Equipment	0	0	0
Total	22	0	2

Table 10.

Media Utilized for Orders

Planning Units	Types of Media		
	Phone	E-mail	In Person
Understand the Project – A	0	0	0
Understand the Project – B	0	1	0
Get the Equipment – A	0	0	0
Get the Equipment – B	0	0	0
Install	0	2	1
Lay Cabling – A	0	0	0
Lay Cabling – B	Not Analyzed		
Lay Cabling – C	0	0	0
Lay Cabling – D	Not Analyzed		
Obtain IP Address	0	0	0
Configure	0	0	0
Turn-Up System	1	0	0
Update Database for Generic – A	1	0	0
Update Database for Generic – B	0	0	0
Update Database for Circuits – A	0	0	0
Update Database for Circuits – B	0	0	0
Create LAN Diagram	0	0	0
Label Equipment	0	0	0
Total	2	3	1

Table 11.

Media Utilized for Information Exchange

Planning Units	Types of Media		
	Phone	E-mail	In Person
Understand the project – A	0	0	0
Understand the project – B	0	1	1
Get the Equipment – A	0	0	0
Get the Equipment – B	0	0	0
Install	0	1	1
Lay Cabling – A	0	0	1
Lay Cabling – B	Not Analyzed		
Lay Cabling – C	0	0	2
Lay Cabling – D	Not Analyzed		
Obtain IP address	0	1	0
Configure	0	0	1
Turn Up System	0	1	0
Update Data-base, generic – A	0	0	1
Update Data-base, generic – B	0	0	0
Update Data-base, circuits – A	0	0	0
Update Data-base, circuits – B	0	1	0
Create LAN diagram	0	0	0
Label Equipment	0	0	0
Total	0	5	7

Table 12.

Media Utilized for Interruption

Planning Units	Media Types	
	Phone	In Person
Understand the Project – A	0	0
Understand the Project – B	1	0
Get the Equipment – A	0	1
Get the Equipment – B	0	0
Install	2	1
Lay Cabling – A	0	1
Lay Cabling – B	Not Analyzed	
Lay Cabling – C	0	0
Lay Cabling – D	Not Analyzed	
Obtain IP Address	3	5
Configure	0	0
Turn-Up System	0	0
Update Database for Generics – A	0	0
Update Database for Generic – B	0	0
Update Database for Circuits – A	3	0
Update Database for Circuits – B	0	1
Create LAN Diagram	0	0
Label Equipment	0	0
Total	9	9

Table 13.

Information Obtained by Communication

Planning Units	Types of Information Obtained				
	Helpful Technical	Helpful Social	Helpful for other PU	Not Helpful	Not Analyzed
Understand the Project – A	0	0	0	0	0
Understand the Project – B	2	0	2	1	1
Get the Equipment – A	4	0	0	0	0
Get the Equipment – B	0	0	0	0	0
Install	3	0	5	0	1
Lay Cabling – A	1	0	0	0	0
Lay Cabling – B	Not Analyzed				
Lay Cabling – C	1	0	0	1	2
Lay Cabling – D	Not Analyzed				
Obtain IP Address	1	0	8	4	1
Configure	5	0	0	0	1
Turn Up System	1	0	0	0	1
Update Database Generics – A	2	1	0	1	1
Update Database Generics – B	0	0	0	0	0
Update Database Circuits – A	3	1	1	2	0
Update Database Circuits – B	0	0	1	0	1
Create LAN diagram	0	0	0	0	0
Label Equipment	0	0	0	0	0
Total	23	2	17	9	9

Figures

Figure 1. Template Describing the Flow of a Unit Task

Figure 2. Template Describing the Flow of a Planning Unit

Figure 3. Predicted and Observed Steps of Planning Units

Figure 4. Modified Predicted Steps and Observed Steps of Planning Units, excluding steps that occurred before and after observations

Figure 5. Frequency of Problems during Planning Unit Execution

Figure 6. Types of Problems Encountered during Planning Unit Execution

Figure 7. Types of Communication during Planning Unit Execution

Figure 8. Media Utilized for Communication

Figure 9. Media Utilized for Information Requests

Figure 10. Media Utilized for Orders

Figure 11. Media Utilized for Information Exchange

Figure 12. Media Utilized for Interruptions

Figure 13. Information Obtained by Communication