Cape Peninsula University of Technology

DEVELOPMENT OF THE USER INPUT SYSTEM FOR THE CONTROL ROOM UPGRADE OF SOUTHERN AFRICAN LARGE TELESCOPE (SALT)

by

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Declaration

I; Christopher Justin Hendrickse declare that the contents of this dissertation/thesis represent my own unaided work, and that the dissertation/thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Signed: ______________________ **Date:** 20 October 2015

Abstract

Whether one is fascinated by the night sky as a child, or as a professional astronomer looking back to the beginning of time solving life's big questions; at some point in our lives we have curiously looked up at the heavens above. The desire to explore the universe has lead us to constructing larger and more advanced telescopes, with the sole focus of observing deeper into the cosmos in an attempt to unravel its secretes. Like with most other technological advances, it has created advanced and technically complex control rooms. Based on a design ethnographic study this thesis will focus on the exploration of the effects of complex interfaces of a control room environment and its users, where one of the leading twenty first century telescopes of its kind, Southern Africa Largest Telescope (SALT), is studied.

While the STS framework and policy debates concerning the rapid development and integration of complex human and non-human systems into larger systems become common practice. The design ethnographic study revealed that the operation of the SALT telescope and the research being conducted by the astronomers is clearly hindered by poor control room design. The study identified relationships between the framework and the empirical findings, which was used to frame a design pilot study to determine if further design intervention would have a positive impact on the interaction of a control room system. This project will consist of: a literature review, an ethnographic study and the analysis of the findings, design framing of a pilot study, a design pilot study, and an evaluation of the study.

The results from the design pilot study clearly show that the application of a design intervention to a control room environment could potentially impact the space positively and reduced frustration, improve comfort, increased efficiency in the users work practices, and ultimately amplified productivity. Providing an appropriate starting point for the exploration of possible solutions for identified challenges experienced in complex control room environments, more importantly it contributed to narrowing the socio-technical gap, between the mechanical and research departments of a leading international optical telescope, SALT.

Key Words

Co-design, Design Framing, Pilot study, Design Ethnography, Interaction, Observations, Observatory, South African Astronomical Observatory (SAAO), Southern African largest Telescope (SALT), Work Practice, User.

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Glossary/Definition of Terms

Terms/Acronyms/ Abbreviations	Definition/Explanation	Reference
Design Ethnography	A researcher makes systematic detailed observations of people and cultures to explore and understand a particular problem area of interest from the user's perspective.	Baskerville, & Myers, 2015: 23
Design Framing	Using observational data to facilitate the construction of a design pilot study.	Author, 2016
Design Pilot Study	A trial learning test to validate a future design intervention within a focused area.	Author, 2016
HET	Hobby-Eberly Telescope at the McDonald Observatory in Texas.	The University of Texas of Austin, 2008
Observatory	A particular area set up with observational devices, used to observe astronomical or meteorological phenomenon.	Enchanted Learning, 2015
Primary Mirror	The first light-gathering reflective surface, which light is reflected off when entering a reflective telescope.	Telescopes, 2015
SAAO	South African Astronomical Observatory.	South African Astronomical Observatory, 2015
SALT	Southern African largest Telescope.	SALT Foundation, 2015
STS	Socio-Technical Systems.	Whitworth, 2006
User-centred design (UCD)	The user being the focal point of design.	Baxter & Sommerville, 2009:3
Work Practice	The way in which a user goes about completing a given task to achieve a desired result after a period of time context.	Kaptelinin & Bannon, 2012

Source: Collated by Author

Chapter 1: Introduction

1.1 Introduction

Nelson Mandela told many stories about his former days; how he witnessed the great Xhosa *Imbongi* speak about the night sky constellation, and how certain objects in the heavens above represented different countries. These stories can be found in His autobiography, *Long Walk to Freedom* (Mandela, 1995: 8). There are many records of archaeological astronomical records from around the world; nevertheless Africa has the oldest astronomical observations, which date back thousands of years (Ta Neter, 2011).

Studies of these archaeological astronomical records show a variety of African cultures who used their knowledge of the stars to predict not just the seasons, but also to predict when to expect ostrich eggs to hatch and when the earth was ready to be prepared for planting of crops (Buckley, Lombard, Lomberg, Meiring, and Theron, 2005: 10). Over the years this lead to the development of a strong astronomical interest in the South African people. Today, many individuals still observe the night skies as a hobby, and some make it their profession. Like with most other advances technology has redefined the professional field of astronomy and with that it has created advanced telescope systems allowing the professional astronomer to unravel very complex questions about the universe and its workings. However this has created advanced and technically complex control rooms for the researchers to work with. Based on a design ethnographic study under a STS framework, this thesis will focus on the effects of complex interfaces of a control room environment and its users, where one of the leading twenty first century telescopes of its kind, Southern Africa Largest Telescope (SALT), has been studied to explore if design changes to the environment could impact the work practice. A pilot design study was initiated and grounded in the ethnographic findings. The design process is not the focus of this project, but merely an applied exploration of findings.

1.2 Background

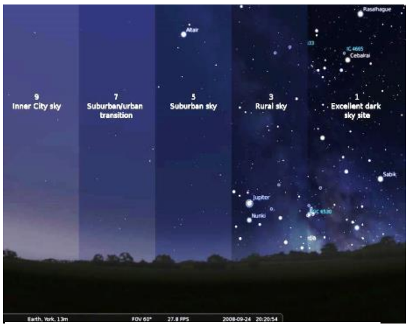


Figure 1.1, Bortle's Dark-Sky Scale (Filmer, 2014)

Figure 1.2, Location of SALT (Google Maps, 2015)

Figure 1.3, Sutherland Observatory (SAAO, 2015)

The first telescope, a 61cm, was constructed in Cape Town however, due to excessive light pollution from a rapidly growing urban environment; the telescope had to be relocated. Light pollution from urban areas is a problem in that it deteriorates the viewing quality of a telescope; see Figure 1.1

(Buckley et al., 2005: 12). In 1972 the observatory was relocated to a remote plateau not far from the town of Sutherland in the Karoo (Figure 1.2 and Figure 1.3). The area's dry air, high altitude, and dark unpolluted skies are ideal when viewing the skies (American Museum of Natural History, 2007).

During the late 1980's, astronomers in South Africa found it increasingly difficult to keep up with the international astronomy community as the largest SAAO (South African Astronomical Observatory) telescope was only 1.9m. This proved counterproductive as the observing condition at the observatory's locations outside Sutherland was exceptional (American Museum of Natural History, 2007). It was during this period that Mike Feast, then director of SAAO, supported the need for a larger telescope at the observatory to ensure that the local astronomical community could contribute internationally, at the forefront of astrophysical research (Whitelock, 2004: 45).

South African stakeholders had the unique opportunity to review the completed Hobby-Eberly Telescope (HET) at the McDonald Observatory in Texas (The University of Texas of Austin, 2008: 1). HET was at the forefront of a new category of telescope design, which employed a segmented primary mirror that allowed for a large mirror arrangement. The new mirror and structure design cut back on construction cost; however it yielded only a partial view of the sky (81%) as the tilt of the telescopes Y-axes was fixed. The telescope can still rotate 360° on the X-axes (ibid).

Fifty million rand was earmarked for the construction of the SALT telescope, which would be a larger, 11m primary mirror, revised version of the HET telescope (Buckley et al., 2005: 23). Half of the cost had to be from international partnership funding, which was secured with the proposed new telescope design, and international partners included; the United States, Germany, Poland, the United Kingdom and New Zealand (Whitelock, 2004: 49). Construction on SALT began on the 1st of September 2000; it was officially opened on the 10th of November 2005, and was in a phase of testing from 2006 to 2009. From 2011 it has been in full operation, producing spectacular data on the universe and fulfilling its expectations from first concept. The telescope has been operational ever since (SALT Foundation, 2015).

1.2.1 What is SALT and How Does it Work?

There are different types of telescopes, discussed briefly in the literature review; nevertheless, most large telescopes work on a system with more than one mirror. Light traveling from a star through space and into our atmosphere on earth would be captured by a telescope. The light enters the telescope and is reflected off the first mirror, called a primary mirror, focused onto the second mirror, and finally the light would be reflected off the secondary mirror, down through a hole in the primary mirror, and into the instrument or focal plan of the telescope (Strobel, 2015). The larger the primary mirror, the further the telescope can 'see' as it will collect more light from faint objects. Therefore engineers have been striving to building larger and larger telescopes, pushing telescope technology and engineering to their limits yet a problem arose when telescopes grew over a certain size (ibid). The single primary mirror became so large and heavy that it became impractical to move them and recoating the mirror became too expensive therefore new telescope concepts were proposed (Mullen, 2011). The segmented mirrors become the next best choice, a group of hexagonal mirrors, which are placed in an array like a honeycomb to act as one large single mirror.

Southern African Largest Telescope (SALT), Figure 1.4, has an 11m primary mirror comprising 91 individual 1.2m hexagonal mirrors, seen in Figure 1.5. This 11m primary mirror classifies SALT as the largest telescope in the southern hemisphere at the moment, which is what makes SALT so special (American Museum of Natural History, 2007). This system removes the problem of having one large mirror however it brings about a whole new set of challenges, which mirror alignment is the major challenge. In order for the correct operation of the telescope all the mirrors need to be aligned perfectly, to a 100th of a millimetre accuracy, and because the materials expand and contract as a result of weather fluctuations, the mirrors cannot be set once off as they would move (SALT Foundation, 2015). The engineers built a grid for the mounting of the mirrors on special hydraulics with three contact points so the mirrors can be adjusted and aligned correctly as they did for the HET telescope (The University of Texas of Austin, 2008: 1). The tower (centre of curvature sensor) on the side of SALT has a laser in it, which is used to align the mirrors and this is done by the SALT operator. The frequency of the mirror alignment procedure is dependent on the weather as this causes the material holding the mirrors and the mirrors themselves to expand and contract moving things ever so slightly yet enough to distort the image, which the telescopes sees (Whitelock, 2004: 49).

The SALT telescope can only rotate 360° around its Y-axes and has a fixed vertical angle, as the cost of building a fully steerable telescope of this size would be too expensive. This means that SALT has to wait for the target to be in its viewing window, which only has access to about 80% of the night sky, as the sky moves overhead (Whitelock, 2011: 591).

Figure 1.4, Outside SALT
(Author, 2015)

Figure 1.5, Inside SALT
(Author, 2015)

1.2.2 First Contact SAAO and SALT

Contact was made with Dr Crause, a SAAO astronomer, who arranged an initial meeting to explore the possibility of an ethnographic design study being conducted at SALT. With the assistance of Dr Crause ('gate keeper' into the SALT community), contact was made with the various departments within SAAO. The staff from the SALT department was working on a control room upgrade at the time of the visit and was encountering multiple problems. There were too many people working on the project and the engineers and researchers were not always in agreement regarding the changes that were proposed, this hindered the upgrade and its progress. This situation created the opportunity for a design ethnographic study to review the control room and its Socio-Technical Systems (STS) in collaboration with all parties involved.

An overnight visit was arranged shortly after meeting part of the SALT team at head office in Cape Town. During this visit to SALT, in Sutherland, the researcher was introduced to the staff and the control room upgrade project was explained by the head engineer. This presented the opportunity to observe and explore the then current control room conditions, with some initial observations of the environment.

1.2.3 Summary

The SALT staff expressed their support for an ethnographic study to be conducted as the possible findings may support the design of socio-technical interactions. The first contact with SALT provided the opportunity to meet the staff and familiarise the researcher with the control room, in addition it provided an opportunity to acquire the relevant permissions to collect and use data from SALT and its users.

SALT granted permission for an additional five night research visit, focussed on gathering data for context mapping, translating to design framing for a design pilot study. This visit allowed for the observation of both the astronomers, who worked at night, and the engineers, who worked during the daytime. The aim of the ethnographic study was to explore the users of the control room, their work practices, what hindered their work practices and how they viewed their work practice. These observations, in conjunction with note taking, determined the primary users of the control room. The objectives of the ethnographic study were to explore any difficulties and hindrances in the control room space, the work practice of the staff, and the socio-technical system. The study established that working with the astronomer and operator would provide this project with the best data and research context. This was based on findings that the astronomer and telescope operator spent the most time in the control room environment, compared to the engineers who used the space for their morning meeting and briefing. Research, observations and collaborative design sessions with the astronomer and operator, were conducted at the telescope and at their offices in Cape Town.

1.3 Problem Statement

The operation of the telescope, and the research being conducted by the astronomers at SALT, is hindered by poor user input methods resulting in a frustrating work environment, as well as uncomfortable and inefficient work practice.

1.4 Hypotheses/Propositions/Objectives

This is a master's thesis research project in the field of design focusing on a design ethnographic study while including areas of user-centred design. This project will use design ethnographic observations to explore and support the design of socio-technical interactions in work practices, like the SALT control room.

Socio-Technical Systems (STS) has become a vital role in the human computer interaction system and within different levels of the systems (Whitworth, 2006: 533). Therefore by using STS as the framework foundation of the project, the current human computer interaction within the control room can be deeply mapped and better understood. The project is split into two main phases; the first is a design ethnographic study (the main focus of research), the second an analysis and exploration of the findings and design framing (developing a design pilot study, to determine if design interventions based on the ethnographic findings would have a positive impact on work practice within the control room system).

1.5 Importance of the Research

The research study will have external relevance to the astronomical field, which has grown significantly, as there have been ground breaking advancements in electronics, engineering and technology. The design research will help bridge the gap between engineers and astronomers (researchers) to find a common ground and design solution that addresses the needs of both. The research will place emphasis on the design ethnographic study and slightly less on the design pilot study to identify whether or not design will positively impact a control room and its users sub-optimal work practices, like SALT.

Little consideration has been taken for the users of the control room while constructing the controls for the telescope. The engineers focused on building a state of the art telescope that would break new ground, and the astronomers were focused on gathering quality data. It resulted in a lack of focus on the interaction between users and the system, leading to a poor and inefficient work practices. This scenario has led to less data being collected during a work shift at night and by improving the interaction methods, and the work practice, more data could possibly be collected during the same night of work.

This study has internal relevance in the field of Design, specifically the problems associated with using multiple devices in context, and design ethnography research and complex working environments. It also has internal relevance for research into computer navigation systems and input devices in control rooms of similar kind to the SALT set up. The research will help explore the Information system levels in gaining a deeper understanding, not only of the computing and psychology levels, but will aim at better understanding how design, based in ethnography and co-design, can contribute to more efficient control room environment on all STS levels.

1.6 Selected Methodology

A design ethnographic approach was selected as methodology in order to gain the best understanding of the users in their professional setting. Data was gathered through interviews (structured and unstructured), video observations, note taking, event logs, and shadowing of the users to establish current work practises at SALT. Through the use of holism and descriptive methods in analysing the data collected, the gaps or difficulties found in their work practices were explored. Mixtures of collages and mind mapping, as well as discussions with astronomers were used to aid in the exploration of the work practise.

For the design framing and a design pilot study, brainstorming and co-design were chosen as appropriate methods. This was carried out within the control room environment at SALT as it made for a stronger connection to their context, resulting in easier idea generation for the users and quicker understanding of the ideas for the researcher. A full exploration of the project methodology can be found in Chapter 3.

The design pilot study and the results employed planned workshops with the users and researcher. From the many ideas generated, a specific idea that fulfilled the requirements of the design pilot study was implemented, however a few alternate ideas were theoretically prototyped and evaluated accordingly. The design pilot study took place at SALT however there were many limitations due to restriction of the control room environment, yet the study was sufficient for its intended purpose and met the objectives set out. This stage also includes; critical reflections on the previous stages of this process; choices of methods; reflection of the designs and any changes that were taken into consideration.

1.7 Delineations of the Research

The research is limited to the SALT telescope and its control room, even though there may be similar problems experienced at other telescopes. SALT is presently the most advanced and complex telescope at the Sutherland observatory. SALT also has the largest control room with the most staff. The research will only be conducted with users of SALT's control room; however, the findings of this study may later be explored in the context of other local and international telescopes.

The control room is a large complex system with many variables and sub systems; this study has not been conducted on the telescopes operating programs unless the study suggests moving in the direction of the software display. The study has not explored any of the technical or engineering aspects of the physical telescope, nor has it looked at altering the telescope or its instruments. Consequently the study has explored the gaps and difficulties in the users work practices; the users input and output methods and the interfaces that display the relevant information.

SALT is located outside the town of Sutherland in the Northern Cape, South Africa. The SAAO head office is based in Observatory, Cape Town, Western Cape. There is sufficient data to be collected from SALT and the astronomers at both the location of the telescope in the form of observations in the natural environment and at the head office in the form of interviews (structured and unstructured). The design pilot study, including co-design workshops, prototyping and testing of prototypes was carried out at both locations.

1.8 Research Question, Sub-questions and Objectives

1.8.1 Research Question

What are the design principles of supporting socio-technical interactions within a control room environment?"

1.8.2 Sub Questions

1) How do the SALT astronomers and operators currently work in the SALT control room?

   (The objectives of this question are to explore, understand, and uncover the astronomers' perceptions of their working environment, the input and feedback systems, and its socio-technical system, which will be achieved with the use of design ethnography.)

2) What is the challenge experienced by the SALT astronomers and telescope operator?

   (The objectives were to; frame a feasible design pilot study that would underpin a design, using the knowledge gained from the observations.)

3) How can a control room environment be designed to support a more efficient work practise?

   (Finally, a design pilot study will determined the role of embedded understanding of environments before embarking on a design intervention, and that design (if user driven) can contribute to 'improved' control room spaces)

1.9 Conclusion

The initial research, the first overnight visit to SALT, found that the engineers have focussed on building an advanced telescope, which would break new ground and the astronomers were focussed on gathering quality data, yet little consideration was given to the users and their work practices. The lack of control room design resulted in a poor work practice for the users, and a system, which was not operating at its full potential. Thereafter SALT granted permission for an additional five night research visit allowing for the observation of both the astronomers, who worked at night, and the engineers, who worked during the daytime. This focussed on gathering holistic data for context mapping, which translated to design framing for a design pilot study. The aim of the ethnographic study was to explore the users of the control room, their work practices, and the socio-technical system.

The following problem statement was formulated to guide the research direction, " The operation of the telescope, and the research being conducted by the astronomers at SALT, is hindered by poor user input methods resulting in a frustrating work environment, as well as uncomfortable and inefficient work practice."

SALT is presently the most advanced and complex telescope at the Sutherland observatory, therefore it was appropriate for the research to be limited to the SALT control room. This set the delineations of the project yet the research outcomes were not isolated to SALT. The following chapter is reviewing current literature on this subject, finding patterns, trends, and or gaps in order to gain a deeper understanding on the subject at hand.

Chapter 2: Review of Literature, Cases, and Socio-Technical Systems

2.1 Introduction

The following chapter will review relevant literature. It will include; control rooms, system complexity, inputs and outputs of systems and challenges in the design field, regarding the development of everyday objects and systems. It will also explore social and behavioural Influences, work practices and core characteristics of user-centred design (UCD). A brief exploration and analysis of different existing control rooms, and how they have developed over the years, is addressed through the use of appropriate cases. The last section of the chapter focuses on a review of the framework: Socio-Technical Systems (STS) and the application of STS.

2.2 Literature Review

2.2.1 Introduction to Literature

From the Industrial Revolution in the 1760s, to the current technological twenty-first century, humans have been producing products and services (Deane, 1979: 2). Products and services such as; housing and its accessories, complex transportation vehicles, advanced telescopes that are able to peer back to the beginning of time, and the international Space Station (ISS) capable of sustaining life in the hostel environment of outer space. As a result of humankind researching the functioning of the human body and mind, a greater understanding of design principles and processes has emerged. The research should direct the designs of products and their intuitiveness to use, yet users still find themselves stuck with simple tasks, such as not knowing whether to push or pull a door of a building (Norman, 2002: 66). This complexity forces most of today's products or artefact into requiring thick user-manuals to navigate their use, or interaction with the user. This questions why modern work environments and products need excessive instructions, often graphically represented on the surface to save the user time, lessen user frustration or guide the interaction between the user, the space and elements within the environment.

The control rooms, of various systems, are typical environments where users note a lack of usability-focussed spaces that support work practice. To support possible primary findings of this project, the exploration of existing research, relating to current control rooms, technologies, environments, and other relevant areas, need to be explored. Focus areas explored in this chapter include; challenges in the field, social and behavioural influences, system complexity, control rooms, good work practices, accessibility considerations, and user centred design. These peripheral regions will help support and direct the fieldwork and primary studies of the SALT control room. The last section will explore Socio-Technical Systems (STS) and how it can be used as a framework.

2.2.2 Control Rooms

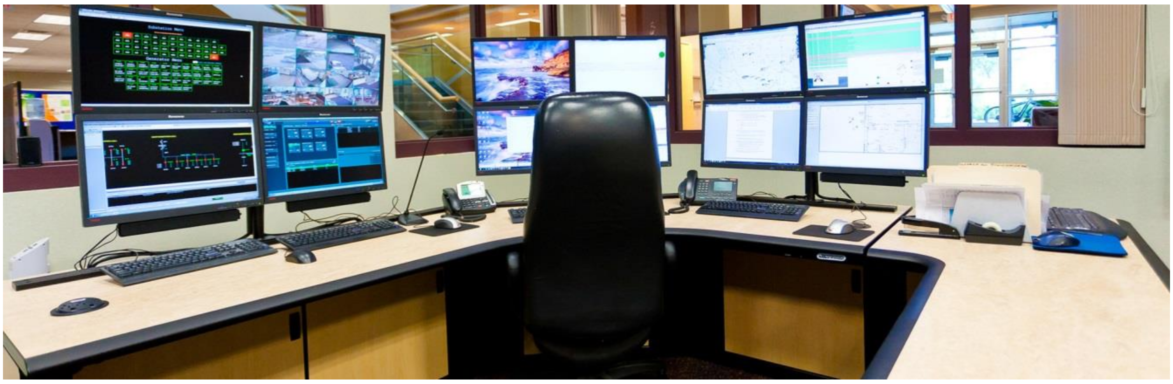


Figure 2.1, Complex Control Room
(Winsted Corporation, 2015)

A control room, common to all domains, is a specialised area from where an operator is tasked with monitoring and controlling complex, dynamic processes (Schwarz, Kehr, Hermes, & Harald, 2010: 1). The last few years have shown great advancements of; new technologies, new ergonomic standards, and improved public awareness of workplace health issues (Winsted Corporation, 2015). This has pushed the complexity of control rooms, Figure 2.1, as larger volumes of information can be processed and the system can handle more technical devices. As a result there has been an increase in the complexity of the human interface as the number of input and output components; keyboard, mouse, indicators, annunciators, graphic terminals, mimics, audible alarms, and charts, increase (Health and Safety Executive, 2015). Today's control rooms are compact, more functional, and more aesthetically appealing than earlier generations as they moved from analogue to digital systems (Winsted Corporation, 2015). It has become a challenge for design teams to create a holistic work environment for the modern complex control room as the designers need to consider new technologies and Human-Computer Interaction design principles (Schwarz, et al., 2010: 1). This has forced designers into developing coherent approaches to embrace both the technical infrastructure (interface, input, output, and communication devices) and workflows of the physical surroundings and social interaction (Schwarz, et al., 2010: 1).

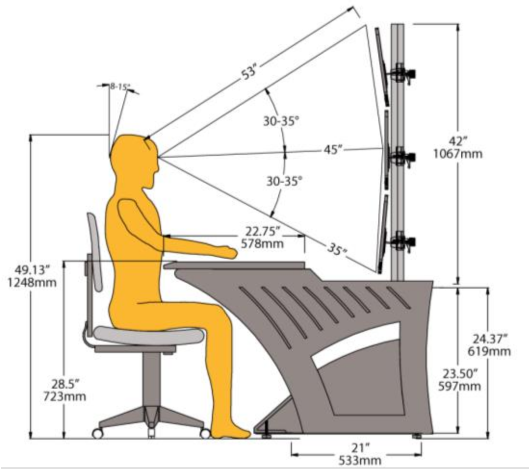


Figure 2.2, Revised Ergonomic Position
(Winsted Corporation, 2015)

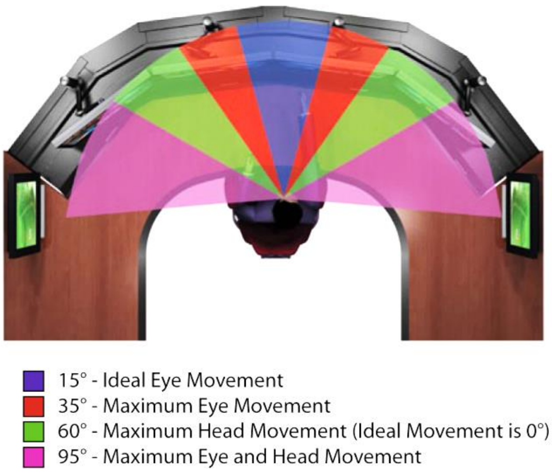


Figure 2.3, Ergonomic Viewing
(Winsted Corporation, 2015)

The design and development of most control rooms' focus on the process units, control systems and production or operation however it is important to design a comfortable and safe environment for the users as this will increase their efficiency (Naito, Takano, Inamura, & Hadji, 2011: 33). It is of benefit to the designer when considering improving the efficiency of a control room that the sub systems are all identified and understood. Most control rooms consist of; ergonomics, displays or monitors, control room layout, and the environmental design (Winsted Corporation, 2015). An effective design of these sub-systems will contribute to achieving the performance objectives established for the control room environment (ibid). This ensures that all aspects of the interaction between human, machine and the environment are considered, especially the overall well-being, health, and safety of each operator (Health and Safety Executive, 2015).

Ergonomics is the study of the relationship between the workers and their environment pertaining to the human factors (CAP, 2006: 1). With the advancement of knowledge on human biomechanics, the understating of how the head, neck, and eyes operate has improved ergonomic research (Szeto, Chan, Chan, Lai, Lau, 2014: 460). The new understanding of human biomechanics gave way for a revised ergonomic working position, see Figure 2.2, which is a more relaxed and realistic position, and Figure 2.3 represents ergonomic viewing of multiple display screens and how it affects the users head and eye movement (Winsted Corporation, 2015).

Displays or monitors are a vital part of any control room as they provide feedback to the users (Winsted Corporation, 2015). It is important for the designer to know the details of the information needed as this determines the size, type, resolution, and number of displays (CAP, 2006: 6). The decisions made here will impact positively or negatively on the users' well-being as correct font size, well matched display and software resolution, and correct monitor positioning will reduce user fatigue and improve productivity (Health and Safety Executive, 2015).

The layout of a control room has a great influence over the design as some of the involved factors can be difficult to change. These factors consist of; the room's dimensions the number of stations, the dimensions of each station, electrical outlets and other electronics entering the room, and the width of the aisles (Winsted Corporation, 2015).

Environmental design refers to the eco-system of the space, hazard factors, layout, posture, seating, room temperature, lighting, and audio (Health and Safety Executive, 2015). Sometimes these areas need to full fill specific requirements because of the equipment being used. For example; if the working environment requires speech communication then all ambient noise levels must adhered to appropriately specified requirements (Winsted Corporation, 2015).

2.2.3 System Complexity

Over hundreds of years humans have been developing more complicated systems. This includes everything from the machines that are used to support human activity to the informational systems and laws that keep modern civilisation together (Arbesman, 2014). Complex working environments describe a particular area were multifaceted work is conducted. This space supports the actions of the users in achieving their objectives, yet how this space and its devices shape the users behaviour is poorly understood, allowing for inefficient work (Spinelli, Perry, & O'Hara, 2005: 111).

Biological systems are more complex than technological systems, however technological systems are man-made constructs that are products of evolution and should be understood by its creators (Leydesdorff, 2000). As technology advances exponentially with every year that passes, so too does the complexity of the systems that have been created to support efficient human action, however this has started to come at a price to the users (Arbesman, 2014). The increasing sophistication and interconnectedness (also known as the internet of things) of these larger systems create a complexity that has become difficult for humans, particularly the specialists who build and maintain them, to fully understand (Pfautz, Ganberg, Fouse, & Schurr, 2015: 42).

The design of complex working environments should enable and encourage interactions within the system; therefore designers need to develop the interactions between the human and technological system instead of trying to control the interactions (Obal & Stojmenova, 2013: 98). Research in participatory design has uncovered ways and arguments for user integration into the design process (Obal & Stojmenova, 2013: 97). Consequently when dealing with complex work environments, designers need to create efficient work practices for the users as this leads to enhanced results instead of using the “whatever works” mind-set (Berg, 2012).

Over the last few years, the number of individual parts and sub-systems of larger systems and machines has increased exponentially. As the internet of things grows, systems and machines are becoming autonomous in the way they communicate with each other; Arbesman (2014) describes this well:

> Machines are interacting with each other in rich ways, essentially as algorithms trading among themselves, with humans on the sidelines.

These systems should provide the right information, at the right time, in the most appropriate format. However technology has becomes more interconnected and less comprehensible, resulting in complex working environments that are inefficient (Pfautz et al, 2015: 42). These spaces vary in complexity therefore designers are forced to develop intelligent adaptive systems that; account for user’s expectations, support individual differences, and capture the users’ intent (Pfautz et al, 2015: 43), with the application of; user centred design, user integration, and participatory design help create more user centred work environments (Obal & Stojmenova, 2013: 97).

2.2.4 Input Device Complexities

Information display is a large area to thoroughly explore, as there are many variables, and personal preferences, from user to user, that are involved. Many control rooms have conducted explorative research into various input methods. The research shows that the technical development of computer hardware and software has pushed control room design into becoming ever more automated and adaptive (Lina, Yennc, Jouc, Hsiehb, & Yangb, 2013: 161).

Johanson, Hutchins and Winograd (2002: 229) describe the *Pointright* concept for operating multiple computers with a single mouse and keyboard in a coherent manner, with variety of different applications. It is challenging to fully operate a standard operating system without a convenient input of a tangible mouse and keyboard. However there are software keyboards available for touch screen devices like the iPad and touch desktop computer. They cannot be used for large volumes of typing as they are not practical for extended periods of use due to poor typing ergonomic conditions (Bachynskyi, Palmas, Oulasvirta, Steimle, & Weinkauf, 2015: 3).

During the initial set up of the multiple displays in the *Pointright* case study, each display had its own wireless mouse and keyboard, as is the current SALT control room. This was both confusing and cluttered, and set the starting point for the *Pointright* system to reducing the multiple devices to a single mouse and keyboard (Johanson, Hutchins, & Winograd, 2002: 228). The single mouse and keyboard for the multiple displays worked seamlessly for a single user however it was troublesome for multiple users unlike having the convenience of being able to use any mouse and keyboard at hand. This problem is also explored by Brumitt, Meyers, Krumm, Kern, and Shafer (2000). Additionally, the case study brought to light the need for a smooth operation from screen to screen no matter the screen orientation, size, or aspect ratio, while using the single keyboard and mouse (Johanson, *et al.,* 2002: 229).

The study showed the categorisation of different types of inputs into three cases and the mappings they support. Screen-bound inputs are input devices that operate directly on the display surface either using a device such as a pen or finger. This method had a natural fixed mapping from the pointing position to a matching point on the screen. Machine-bound inputs, consisted of devices whereby the user used tangible input devices separately from the display, like a mouse or track pad, and the relative point and motion was displayed on the screen with an identifying image like a cursor. This type of input motion was not naturally tied from device to the display but instead is conceptually tied to a specific machine; hence using a mouse upside down to a display is challenging (Johanson, et al., 2002: 229). Free-space inputs consist of any relative input device that can be freely used on any workspace within the environment. It includes a wireless keyboard and mouse; however these input devices need a clear starting screen to avoid confusion (Cocilova, 2013: 73).

There is a debate over a mouse and keyboard being the optimal input methods. *Tobias Schwarz* looks into the concept of a gamer's navigation joystick as a means to navigate the information across multiply displays (Butscher, Mueller Reiterer, & Schwarz, 2012: 250). This input method is very close to a mouse and keyboard, and pushes this study to explore other forms of input methods such as multi-touch tables, and speech and gesture applications.

Exploring different user interfaces and inputs and what technologies have been developed around single user applications. When comparing the *Pointright* system to what the researchers found in air traffic control rooms and military command posts. These complex environments contained advanced digital technologies available to the users yet the users prefer using paper media as an extra means of sharing of information with their colleagues (Tse, Shen, Greenberg, & Forlines, 2006: 336). This can be compared to printed proposal sheets used by the astronomers to confirm certain portions of the data to what is been displayed.

Single user systems should work differently to multiuser systems yet the multiuser system, SALT control room, has been designed with the constraints of a single user computer such as a personal desktop computer. The concept of an input method cognisant of multiple users by a speech method of input with a multi touch surface concept is proposed by Tse (2006) in his paper. The bases of his proposed input method would not be ideal for many complex work environments as it relies heavily on speech recognition that still has more disadvantages than advantages at this stage of its development. The multi-touch input method is discussed in *Shadow Tracking on Multi-touch Table* were they juxtapose the everyday mouse, laptop track pad, and direct-touch input device (Echtler, Huber, & Klinker, 2008: 388). In their work they explore the use of multi-touch input methods, which apply to mouse and keyboard based applications. This is valuable to the research being conduct in this project as the software currently being used by SALT astronomers is based on the keyboard and mouse.

2.2.5 Good Work Practices

It is in our nature as humans to make mistakes as it is how we learn. When designing products or services, the designer should take this 'human error' tendancy into consideration (Norman, 2002: 227). A product may be designed to be used in a particular manner; however what would happen if the user misused? And how could this be prevented?

How can incorrect operation be minimised without the need for unsightly warning labels and thick instruction manuals? The instructions on how to use the product should be designed into the product so that there is a natural awareness for the user, whether it is physical or digitally based (Hsiao *et al*., 2012: 125). This can be related to a user scanning a webpage; they do not read every single word on a webpage, instead the user scans through a page with a few key words in mind and stops at the first instance that matches or closely matches their key words (Krug, 2006: 22). The user selects the first option, which might not always be the best one that the particular webpage provides. The user will follow this first choice as they are not aware of the other 'better' options, which they could have chosen. This forces the user to move to the next page, which they had selected and if it is not what they desire they would have to return to the previous page and try the next option and so on. This pattern will continue until the user finds what they are looking for or gives up and moves on to a new website (Pak, 2015).

Therefore when designing digital products such as web pages, computer programs, and the digital controls (interfaces) of products, the movements between steps should be considered as a user does not want to become halted, waiting for a page or program to load, or worse, become lost in the website or program were they cannot return to the previous step (Norman, 2002: 52).

According to Krishna (2012) and the example of the car door, it is about eliminating interfaces to embrace natural processes. The example shows thirteen steps for the user to open their car door when utilising an app based method for the unlocking procedure (Krishna, 2012). This removed the need for a key; however, it created many usability and signifier issues for the user (jnd, 2016). The user required instructions regarding the multiple steps to open the car door (Hsiao *et al*., 2012: 192). The process should essentially be three steps; a driver approaches their car, the car doors unlock, and the driver opens the car door (Krishna, 2012). The Mercedes-Benz design team cleverly solved this in 1999; they designed a wirelessly key, which automatically unlocked the car when the driver approached it (Krishna, 2012). This required no interface, which meant the user did not have to learn any new procedures for unlocking the car. Locking the car was just as simple and intuitive as unlocking as the driver would only need to press and hold a touch button on the handle that would lock the car, unless the key was still inside the car (Krishna, 2012).

The designers of the car security application were deeply involved in the designing of the application, and as a result their knowledge of the extra functions was excellent. Therefore it seemed straight forward and logical to the designers yet the opposite was true for the users as they never considered the first time user (van Eijka *et al*., 2012: 1010).

2.2.6 Design Considerations

Norman (2002: viii) discusses the problems with simple design oversights, which can be the difference between total frustration and absolute pleasure for the user. It is easy to point out the simple problems with everyday objects for example a clutch-pencil that takes surgical precision to refill. Many tasks appear simple at first glance and are challenging for the user despite the product or service being designed for them (Speier, Valacich, & Vessey, 2007: 339). According to Krug (2006: 11), "Don't make me think" is one of the first laws of usability. When a designer creates a product or digital service, the design should be self-explanatory to an appropriate degree. It should be transparent to the operator as to how the product or service should be used, unless a learning period is required for complex professional environments. The user should not need to think about how to use it, nevertheless ask themselves what it is that they are looking at. A well designed product or service will enable the user to "get it" without much thought going into its operation (Design for humans, 2007).

Whether products are digital or physical there is always a relationship between how the user wants to use it, to how it actually works or operates. This is referred to as 'mapping' (Norman, 2002: 5). This mapping is influenced by many factors. Cultural influence has one of the greatest impacts on mapping, this means the users logical thinking affects the way that they would use a product, and can differ greatly from person to person. There is a natural connection that is obvious to each individual user and requires very little or no thought for them. If the operation of the product or service aligns with this mapping it creates a pleasant and smoother experience for the user (Chamorro-Koca, Popovica, & Emmisonb, 2009: 648). This intuitive mapping plays a large role in the design process so that products and services require minimal instructions (Design for humans, 2007).

Mapping can be applied to many different products, such as a digital website and the manner that the user uses the inputs of a digital device. For example, when a user drags the scroll bar down with a mouse, the page moves up yet on a touch enabled device the user will touch the screen and move it up in the same manner they would do with a paper page in the physical world. A laptop trackpad works opposite as the hand motion is linked to the scroll bar, resulting in a down hand motion producing an up page motion (Pak, 2015). A user should not be haphazardly thinking about the task or service at hand (Friedman & Lennartz, 2015). This self-talk or questioning, even though it is very brief, slows the use of the website down as well as creating a noisy and cluttered experience for the user (Krug, 2006: 16). Whether a user is using a digital or a physical product, the user should not have to expend much time and thinking power on how to use the desired product (Friedman & Lennartz, 2015). However this cannot always be the case with all designed products or services as some systems, like control rooms, require a learning period (Hsiao, Hsu, & Lee, 2012: 130).

Understanding that products and services should be designed so that their operations are obvious to the user seems logical, yet this is not always the case. The user would need to involve some thinking about their interactions with the product or service, which can be placed on a scale; obvious on one end, requires thought on the other end (Krug, 2006: 29). The designer always wants it to land closest to the *obvious* side of the scale, for example, a well-lit shop, where everything in the shop appears grander; the user feels like their experience takes less effort and the same should be applied for digital products like a webpage. Webpages that contain a good layout and obvious navigation make the user feel like less effort from their part is needed, and will most likely spend more time at the webpage as they are not frustrated over small details, which they do not wish to be thinking about (Speier *et al*., 2007: 339).

2.2.7 User Centered Design

It is unlikely that a product will be designed perfectly during its first iteration; therefore a product usually goes through multiple iterations. During these iterations, the idea is evolved and developed into a final product or service (Design Council, 2015). During the evolution of the product or service it is good practice for real users to test it, and it is best to do the testing as close to the living context of the product or service as possible. The purpose of conducting user testing is critical to the process as it will highlight strong and or problem areas. Hence it is useful for the designers as they can make necessary changes to improve the product or service, which will be tested again (Shimomura, Nemoto, & Kimita, 2015: 145). It is repeated as many times as possible, until there are no further problems or the project resources are depleted such as funding or time (Design Council, 2015).

Usability testing is next in the design process of a product or service, which is closely tied to the development stages (Chamorro-Koca *et al*., 2009: 649). It should not be confused with a focus group; the difference between the two can be explained simply (Krug, 2006: 128). A focus group is not for the testing of the final version of a product or service. It should be conducted early on in the developmental stages of a product or service to establish what people think of the concept and who the target audience might be. A focus group consists of people who discuss their ideas and opinions of what was presented to them (Merton, 2013). Usability testing on the other hand is conducted with individuals and a prototype of the product or service. This interaction gives the designer an idea of the life of the product, and how it will be received, and used, by its user (Quesenbery, 2001). It can be done with a semi-completed product, and in the case of Industrial Design; the product may be left for an extended period of time in its intended context with its user. The user may take notes, record videos of them using it or the designer may be present to observe the products interactions (Design Council. 2015).

Usability testing etiquette recommends that the researcher shares any required information with the users before testing and without creating a biased influence on the user (Quesenbery, 2001). Consequently it can be said for both the facilitating of the test and the observations during the test (Krug, 2006: 134). The testing should start as early as possible in the design process, and is especially applicable with the development of digital products such as web pages. Continual testing ensures the development of the product is always focused on the user and anything, which is not obvious to the user, will be noted early, thus avoiding final products that are unintuitive and frustrate the user (Merino, Teixeira, Schoenardie, Merino, & Gontijo, 2012: 1046).

It is important to remember that these design processes are managed, and carried out by professional designers, who know the design process, but may not form part of the end user group. A designer might be an expert in the field of designing the product however the user is still the expert of the tasks that they are performing (Norman, 2002: 156). Many designed products were created by engineers, programmers, marketing designers, and even managers, however companies and business are realising the importance of involving designers in the development of their products or services, as the market becomes tougher and the need to be innovative a different becomes greater (Fast Company, 2015).

2.3 Brief Control Room Case Studies

With the help of a User-centered Design (UCD) framework of processes an exploration and analysis of different existing control rooms, and how they have developed over the years, is addressed through the use of appropriate cases. The following images, and analyses, represent current telescope control rooms display variations and equipment. These studies have been contrasted with UCD as it tries to optimize the product around how users rather than forcing the users to change their behaviour to accommodate the product (Design Council, 2015).

The Hobby-Eberly Telescope, which is the older sister of SALT, see Figures 2.4 and 2.5, in 2015 and 2009 respectively. There is a single user with multiple displays, which appear to be at the correct working height, the user has one keyboard and mouse and the desk is in an ‘L’ shape layout, Figure 2.4 (The University of Texas McDonald Observatory, 2015).

Figure 2.6, the Blanco control room (Osuwomeninphysics, 2013), there are eight flat screen computers that are mounted in a two row line for use by a single user. The two displays at either end are slightly angled to face the user who would sit central to the setup with one keyboard and mouse. The computer screens are not lined up well due to poor screen mountings, which are resting unsecured on the table. There is a laptop on the desk yet there is still enough free desk space for the user’s other work.

Figure 2.7, the Keck HQ control room (Smith, 2012); there are six flat screen computers, which are mounted in a two row line for use by a single user. The displays are slightly tilted to face the user who would sit in front of the centre screen with one keyboard and mouse. There is a hand held radio on the desk in the top right corner and a phone on the left side of the desk.

Figures 2.8 and 2.9, the 40" Telescope Control Room at Mt. Laguna Observatory (Mintaka. 2002), there are five CRT computer screens. These computer screens were bulky and used a large portion of the available space, hence the lack of desk space. The single user has two sets of keyboard and mouse, and a laptop that the user needs to work on. This is an old control room and one can clearly see the development of the equipment from the 2002 control room to the 2013 one.

Figure 2.4, Hobby-Eberly Telescope Control Room
The University of Texas McDonald Observatory, 2015

Figure 2.5, Hobby-Eberly Telescope Control Room
Rottman, 2009

Figure 2.6, Blanco Control Room
Osuwomeninphysics, 2013

Figure 2.7, Keck HQ Control Room
Smith, 2012

Figure 2.8, 40" Telescope Control Room Left
Mintaka, 2002

Figure 2.9, 40" Telescope Control Room Right
Mintaka, 2002

Good content display is of key importance within any control room, however many control rooms lack a good interface for the users to efficiently navigate the information creating a system which is not user centered. The case study on content-aware navigation, a traffic control centre explores the interaction concepts for monitoring large displays, and comparing different navigation techniques (Butscher, Mueller, Reiterer, & Schwarz, 2012: 249).

The practices of process control, in a digital control room, contain many possibilities and threats, which is explored further (Salo & Savioja, 2006: 121). Traffic control rooms, technical facilities for monitoring and controlling automobile traffic, have large displays. The users find these displays problematic in navigating and the growing information and road networks over the last few decades have increased the user's task complexities (Butscher *et al*., 2012: 249). An analysis of the control room revealed a lack of work support for the users while using the large displays, as navigation was poor, hampering the users work flow, an indication of the lack of UCD. The users had to navigate between vertical and horizontal scrolling and panning. This splits the single navigation process into a two-step process, therefore the researchers proposed a redesign of the navigation concept that offers an operator-guided navigation (ibid). The new proposed navigation concept was a self-centring input device (Space Navigator), which would increase the effectiveness of vector scrolling. The Space Navigator took both steps and combined them into a joystick like device that also included haptic feedback, resulting in better feedback and faster navigation for the user across the large displays (Butscher *et al*., 2012: 250), in turn creating a user centered system.

The following research was conducted in four conventional power plants, which were experiencing control room modernisations. They studied user experiences of the effects of control room modernisation and digital control room technology on operator work (Salo & Savioja, 2006: 121). The aim of the research was to understand, how process control work is carried out in digital control rooms, potential threats for safe and productive work, and what possibilities new technologies offer to increase the performance of the socio-technical system. This was achieved by developing a method for the Human-System Interface (HSI) evaluation of the control rooms (ibid). Over the past 5 to 10 years there have been widespread modifications to control room technology, such as analogue wall and desk panels, which have been exchanged with digital technology, computers (Krishna, 2012). The modernisations of control rooms have altered the users work process from manual to the supervision of the automated systems, nevertheless this did not mean that the users were not required to understand the systems (Baxter & Sommerville, 2009: 5).

The users had to check the progress of the operations by cycling through the displays on the computer screens. The lack of UCD meant that some users reported that it was easily done yet occasionally it was time consuming. Some of the users valued the flexibility of the computer systems as they could set up the interface according to what was required and on which screens to place them, however they did not always have sufficient screen real-estate (Salo & Savioja, 2006: 122).

An activity-driven design approach to the novel control room environment explores our understanding of a comprehensive control room. A control room has mainly focused on technically fulfilling process monitoring, and controlling functions from a single location through the use of a human system interface but lacking in a UCD framework.

This interface provides process information and control thereof (Koskinen, Laarni, & Norros, 2009: 1). This also challenges the users' abilities to process and navigate the amount of data presented by the system.

The keyhole effect describes the digitalisation of the old analogical system operators whereby the users withdraw from the physical interaction of the system and only interact with a small part of it at a time, through a digital window (Koskinen, Laarni, & Norros, 2009: 1). This creates the sensation that the user is looking at the system through a small hole from another room. When comparing this to current telescope design and operations, the keyhole effect is extremely evident. Before the digitalisation and automation of telescopes the users had to physically be in the same room as the telescope and move it themselves, yet today's telescope designs have the users located in a control room adjacent to the telescope from where they control it (Mullen, 2011). The preliminary study of the SALT control room found that the users were not required to see or physically interact with the telescope for the duration of their work. The interface elements and the work activity by itself have been designed separately, which resulted in the interaction between the users and the telescope becoming more passive. Maintaining situation awareness became a focal problem area (Koskinen *et al*., 2009: 1). This is a classic example of a system dysfunction, where Socio-technical System Design provides a way to synthesis the interface elements and the work activity (Whitworth & Ahmad, 2002). The need for technological support for situation awareness is important as the users need control of the outside system that they are controlling from within the control room.

For better understanding of the control room environment, it can be separated into three spaces, see Figure 2.10, consisting of; physical, virtual and social space (Koskinen *et al*., 2009: 3). This can be used to aid in the analysing of the signifiers rooted in each space. The physical space of a control room is not only the room, however it includes aspects that supports operators physical activities and control operations. The interaction between the user and the physical space allows for some actions to be accomplished easier while hindering other actions (Baxter & Sommerville, 2009: 20). The virtual space should realistically represent the complex object of an activity and its state, which can be easily understood by the user (Koskinen *et al*., 2009: 3). Finally, the social space of the control room covers the users' cooperation and communication with one another. This also includes any actors in the control room system and the larger system, which the control room belongs to, to achieve the goals of the activity (ibid). These three separated spaces cover the control room environment and fall within the four STS information system levels (Whitworth, 2006: 533).

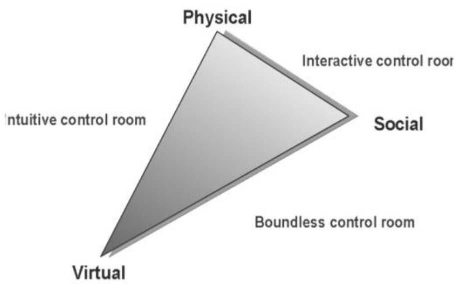


Figure 2.10, Space Qualities
Koskinen *et al*., 2009

In order to proceed forward with any control room redesigning and upgrading it is important to have solid understanding of the functioning of the control room environment as a whole (Koskinen et al., 2009: 4). These case studies of the various control rooms from different contexts, which have similar challenges, provides the research with a good direction and understanding of a control room environment, what has been done and what was achieved or not. However a deeper understanding needs to be attained on the challenges in the field and social and behavioural influences.

2.4 Socio-Technical Systems (STS)

Design ethnography has been identified as an appropriate holistic study method for the SALT control room system, as an emic perspective is vital to gaining an understanding of the users work. However the SALT control room environment is a system with many human and non-human subsystems. Therefore a STS framework has been utilised to help focus and direct the research and analysis, and bring new and interesting insights to the research area (Trent University, 2012). Socio-Technical Systems (STS) has allowed for the; sociology, psychology, computing, and engineering disciplines to be explored and integrated into a single complex working environmental concept (Whitworth, 2006: 533).

2.4.1 Foundation/Background

The integration of technological systems and people has become more prevalent in today's society; thus creating new complex systems between computers and people; and people with people, through computers (Fischer & Herrmann, 2011: 2). Despite the knowledge of adopting a Socio-Technical approach to the development of systems, which are more satisfactory to the end users, it is not commonly practiced, like the SALT control room (Baxter & Sommerville, 2009: 1). This section will briefly explore the start and development of STS, followed by a deeper exploration of STS.

There are three different interpretations of a system. Firstly the structural system, this describes the system having different components and the relations between these components. An updated concept is the functional system; this changes the inputs to outputs depending on the internal states of the system, also known as *black box* (Ropohl, 1999: 62). Finally there is the hierarchical interpretation where the original system is actually a subsystem of a much larger system, also known as a super-system. When these three concepts are thought of and used as one system it is called *General Systems Theory* (von Bertalanffy, 1968: 48). However it did not bring the social and mechanical systems, and their relationship, under a common roof (Baxter & Sommerville, 2009: 2).

A case study of a 1948 mining company, which had two different projects running, is explored to facilitate the understanding of STS. The first mining company project was concerned with the management and labour interface and the second focused on the inclusion of innovative work practices and organisational management, which would improve the productivity of the company (Trist, 1981: 7). The first project was only approached as a social system yet the second project was to include the focus of the technical and the social systems, and their relationship. This would be a new field of enquiry known as Socio-Technical Systems (Trist, 1981: 8). It was new territory, as the engineers who developed the technical systems ignored the social concerns and the social scientist did not have a deep understanding of the technologies being applied by the engineers (Baxter & Sommerville, 2009: 2). The case study was based on a coal mine, which was not doing well even though there was a large demand for coal and the mechanisation of the mine (Trist, 1981: 8). There was a drop in the productivity as well as many other problems with the workers that were not expected from management, which is described in the four information systems levels. If the lower levels were not satisfied there would be a loss in the higher levels, and inevitably production (Whitworth, 2006: 533). A research team was approached to investigate the reason for this. They chose to conduct a comparative study with an equivalent, yet high producing mine. In the second mine the researchers found autonomous groups who interchanged their roles and shifts, and regulated their own affairs with very little supervision. The researchers noted that the problems that the first mine were encountering was; high absenteeism and frequent accidents, which were of the exact opposite from the second mine (Trist, 1981: 8). When speaking with the workers, it was found that the introduction of the machines and the externalisation of the supervision, and control, had a negative social impact due to the separation of the group (ibid).

This is typical of the unsatisfaction of the lower information systems level, affecting the high social level in a drastic way (Baxter & Sommerville, 2009: 2 & 3). The workers rotated positions with the machines, which meant the whole group took responsibility for the entire work cycle. They participated in the decision making concerning their work arrangements, allowing for recovery of group cohesion and self-regulation, which was lost when the mine became mechanised (Trist, 1981: 8). This case study along with some later research gave way for a new paradigm of work, which would aim to bridge the Social-Technical gap (Whitworth, 2006: 534).

2.4.2 Socio-Technical Systems

In 1960 Emery and Trist coined the term Socio-Technical Systems (STS) that described the complex interactions between humans, machines and the environment; this is true for most systems in today's time (Baxter & Sommerville, 2009: 1). It is also commonly recognised that implementing a socio-technical approach to system development results in a system that is more acceptable to its end users, which creates an improved output (ibid). By not applying the STS design to a system, it could result in the system meeting the technical requirements, yet failing to meet the goals of the organisation. Therefore the system can be considered a failure as it does not provide support for the real work (Maguire, 2014: 162). STS refers to the relationship between humans and technological devices, for example, an aeroplane is a mechanical system with inputs and outputs (instrument feedback, etc.) that is operated by a human yet the human is also an individual system (Whitworth, 2006: 533).

As technology and human systems have evolved over time, it has seen a systems performance increase. For example, technology has become an integrated part of human socialising, through the use of online social networking structures (Fischer & Herrmann, 2011: 2). The platform is technological yet the overall system is, from the individual user to virtual communities, and social groups (Pao-Yen Wu et al. 2015: 17). These different levels of a systems performance can be broken down into a hierarchy where the higher level is dependent on the satisfaction of the lower level. The way one builds computing systems are affected by the way one views it, and how social levels affect technology design is socio-technical design, therefore socio-technical design includes hardware, software and HCI requirements, Figure 2.11 (Whitworth & Ahmad, 2002). What one sees as simply hardware now has requirements outside itself as represented in Figure 2.11, and these levels are the reason why computer design has evolved from hardware engineering to socio-technology. These levels also give way for socio-technology to acknowledge the community and the technology as one, providing a holistic observation of the system (Baxter & Sommerville, 2009: 1). Table 2.1, *Information System Levels,* represents an individual system with overlapping views of the same system. These different views can be placed into levels where a higher level cannot be achieved without the lower levels first being satisfied. For example, for the information level to be satisfied, the mechanical system such as the telescope and computers need to physically work before the information can be processed by the software and so the higher level relies on the previous (Whitworth, 2006: 533).

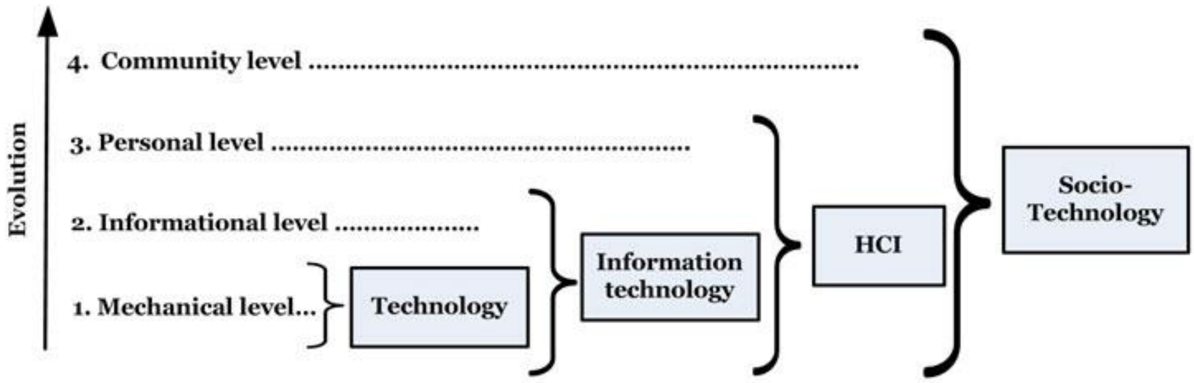


Figure 2.11, Evolution of Information System Levels,
Courtesy of Brian Whitworth and Adnan Ahmad. Copyright: CC-Att-SA-3
(Creative Commons Attribution-ShareAlike 3.0).

Level		Example	Discipline
4	Social	Norms, culture, laws, zeitgeist, sanctions, roles	Sociology
3	Cognitive	Semantics, attitudes, beliefs, opinions, ideas, morals	Psychology
2	Information	Software programs, data, bandwidth, memory, processing	Computing
1	Mechanical	Hardware, computer, telephone, fax, physical space	Engineering

Table 2.1, Information System Levels,
Whitworth, 2006

Explaining these levels from the bottom up:

Level one: mechanical is based on the actual work space that falls within the engineering discipline. Researchers working at this level want to study hardware, computers and other physical artefacts, which affect the users work, to help them design a work space that is more humanistic as a manufacturing systems (Baxter & Sommerville, 2009:2). In recent time's computer integrated work spaces have become predominant resulting in the limitations of the work practices being determined by the computer systems (Whitworth, 2006: 533).

Level two: information is based on the actual work space, which falls within the computing discipline. Researchers working at this level are interested in the information systems on a larger scale than the mechanical entities that supports the system (Baxter & Sommerville, 2009: 3). This area of early STS research takes a broader perspective on the relationships of the information being processed by the users and the system, instead of the mechanical entities of the computer supported work (Maguire, 2014: 162).

Level three, cognitive is based on the actual work space, which falls within the discipline of psychology. Researchers working at this level are interested in the computer cooperative work, which focuses on the small details of the work system (Whitworth, 2006: 533). Using ethnographic methods to study the work environment, small details were found that profoundly influenced the use of the computer-based system work practices (Whitehead, 2004: 5). These types of environments were largely found in the co-located work area such as control rooms, where the designs did not always take into account the wider issues, which affects the system as a whole (Baxter & Sommerville, 2009: 3).

Level four, social is based on the actual work space, which falls within the discipline of sociology. Researchers working at this level are mainly interested in control rooms and health care systems; the relationships between the human and the organisation; however, not focusing on the wider information system (ibid).

As seen in figure 2.14, the study utilised a STS framework to focus on putting the relationship between the individual and technology/system in the middle to incorporate all aspects of the system, while a design ethnographic study was applied to inform the human part of the STS perspective, as it focused on putting the human in the middle, which helped in the understanding of the system/relationship.

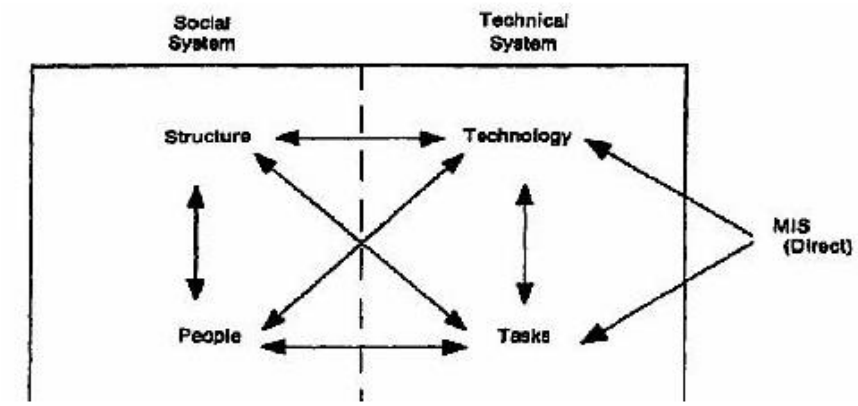


Figure 2.11, A Socio-Technical Perspective,
Courtesy of Bostrom, R. P., & Heinen, J. S., (1977). MIS problems and failures: A socio-technical perspective, MIS Quarterly, Vol. 1, No. 3, pp. 17-32

2.4.3 STS Framework Application

It must be noted that the ethnographic view focuses on a very personal experience, by putting the person in the middle, while the STS framework focuses on putting the relationship between the individual and technology/system in the middle. Therefore in this project the design ethnographic study informed the “people” part of the STS perspective, which helped in the understanding of that side of the system/relationship, and not creating conflict between the two approaches.

According to the four levels discussed in the previous section, one can see that this project falls within the third level, cognitive; in the discipline of psychology. Nevertheless the project does contain elements that fall within the other levels as well (Whitworth, 2006: 533). The mechanical level does have room for improvement, which is linked to improving the work practices for the users yet the research is broader than just that level as it is suggested by Socio-Technical Systems framework (Baxter & Sommerville, 2009: 3). Looking at social systems and how they are constantly evolving though change, the control room is also evolving through equipment upgrades of equipment and the constant change in users. There is a clear need to address these two areas in a manner that considers all the different levels and how to improve the system holistically. According to the description of the third level, the control room is an ideal environment for STST to be applied.

The aim of the project was to verify if a design intervention could have a positive impact on the work practice of a control room system, which was best approached thorough STS where design ethnography informed the human side of the STS while focusing on problem areas. By applying a STS framework to the study, the way in which the control room environment is perceived, how it is understood, and what they mean is approached differently and has holistically impacted the findings and results.

2.5 Conclusion

Although there has been some development in complex work environments, not only within the astronomy field, there is still a lack of coherence within it. The research conducted in user input and output systems of complex work environments have suggested the need to heavily incorporate a holistic design approach, however little effort has been made to achieve this. Telescopes have developed rapidly in recent years as technology and engineering advance their capabilities for telescope instruments and design yet the control room is in much need for development as a user centred space. The literature suggests that in order to achieve a successful system, the user should not have to think about what they are doing or how they are using the system, and instead the system should adapt itself and guide the user in a subtle and unobtrusive manner where possible to achieve the best work practices. The integration of technological and sociological systems within the same working environment has become more customary in today's society. Despite the knowledge of adopting a STS approach to the development of these interconnected systems for a more satisfactory user experience, it is not commonly practiced like that in the SALT control room.

STS, which describes the complex interactions between humans, machines, and the environment, can be broken down into four information system levels. Table 2.1, represents an individual system with overlapping levels with each level building on the satisfied lower level (Whitworth, 2006: 533). According to the description of these four levels it is clear that the SALT control room falls mostly within the third cognitive level, in the discipline of psychology yet not excluding the other STS information system levels.

Therefore using STS as the framework foundation, it suggests the following relevant methods for the project; ethnography as a method for work places analysis. Contextual Design based on the understanding that any system embodies a certain way of working, and User Centred Design, which focuses on designing with clear understanding of users, their work, and the environments where work is carried out (Whitehead, 2004: 5). As the SALT sits at the forefront of optical telescopes, it lacks the fundamentals of satisfying and supporting a good work environment for its operators. The lack of social or user awareness from the engineer's perspective, while designing and constructing the telescope, has become a drawback for an advanced work environment. The relationship between the engineers and the machines, and the astronomers and their research seems to be lacking, as the one system advances ahead of the other system.

Chapter 3: Methodology

3.1 Introduction

The following chapter will present and justify the selected methodological framework and research methods for this study. The design methods have been used and adapted, to gather the relevant data in the most appropriate manner possible. Design ethnography enabled the collection of photos and video footage of the control room and its users, with the users consent. Unstructured Interviews and discussion have been conducted with the users, some in their natural workplace and some at their head office at SAAO. Co-designing facilitated concept development for improving the work practices of the users, and this was used for the design framing of the pilot study. The design pilot study used low fidelity prototyping to determine if a design intervention, grounded in ethnographic observation, would have a positive impact on the work practice of a control room system. The pilot study was conducted according to the defined objectives, and within the limitations of the control room, over a three month period. Lastly, this chapter will include how the data collected was managed, and the ethical considerations that have been actioned for the protection of all those involved in this study.

3.2 Design Ethnography as Research Methodology

Design ethnography has been identified as an appropriate holistic study method for the SALT control room system. Visual methods cannot be appropriate or ethical for the use in all research contexts; however in the case of the SALT control room, an emic perspective is vital to gaining an understanding of the users work practices (Hoey, 2014: 2).

3.2.1 Design Ethnography

The term ethnography describes any qualitative research project but not excluding quantitative methods, to provide a detailed, holistic, and comprehensive documented description of a practice or cultural system (Hoey, 2014: 1). It is important to note that design ethnography lives in "problem spaces". Although ethnography consists of data collection methods it extends further as it also has ontological and epistemological properties (Whitehead, 2004: 5).

Design ethnography can be applied to absolutely everything that has a significant human component tied into it somewhere (Dudek A. 2011) and the process can be divided into three areas. Realising; by familiarising the problem area to be studied so that it becomes real to the researcher. This creates an understanding of the scene of a problem area and a way to render it, in order to find ways to study it, facilitating the flow of information from the users into the research (Dudek A. 2011). An emic perspective is having an inside view or understanding of the system while an etic perspective by contrast, is a distant, analytical experience of the system (Hoey, 2014: 2). The collecting of data on a system needs to be conducted daily and continuously, and can be carried out by an individual or a team of researchers (Whitehead, 2004: 5). Sympathising; the researcher becomes connected to the users and gain insights into their lives, the up's and downs. This is where the analysis begins and a synthesis of the insights about how the problem area can affect its users (Dudek A. 2011). It is a highly flexible and creative process of discovery, constructing inferences, and continuing inquiries in an attempt to achieve validity from both emic and etic perspectives (Whitehead, 2004: 5).Empathising; the researcher becomes immersed in the users lives to the point where the researcher feels with them, which is necessary to be able to derive representative insights about the users but not letting go of their expertise and filters (Dudek A. 2011).

Therefore design ethnography as a method for work place analysis focuses on the nature of action within the natural environment of work, which best informs the design of a STS (Baxter & Sommerville, 2009: 7). Design ethnographic studies have revealed the importance of the users work knowledge. They apply dynamic problem solving capabilities and resourcefulness in modifying entities in their work environment to better complete their work (Baskerville & Myers, 2015: 25).

For this project the design ethnographic method of data collection has mainly focused on identifying problems in the control rooms functionality and usability. It would also be challenging to predict the exact ethnographic methods for a particular research project (Kensing & Simonsen, 1997: 83). Therefore it was appropriate for the researcher to first visit the SALT control room as a means of assessing the context, and to evaluate which methods would suit the research needs of this project (Blomberg, 1993: 124). In this way an immersed understanding of the control room context was established.

3.2.2 Brief Ethnography Background

Ethnography can be traced back to ancient Greece times where Herodotus travelled from one cultural group to the next to document the people's practices (Clair, 2003: 3). During the mercantilist period in Europe and through the 1800s ethnography gained a new interest as a manner of saving cultures that were quickly disappearing through colonialism (Clair, 2003: 4). Ethnography's disciplinary home is rooted in anthropology however unlike the domain of an anthropologist, documenting events and details of experience, an ethnographer aims to explain the meaning and how it fits into the system, also known as webs of meaning (Whitehead, 2004:1). Therefore ethnography is an ideal research method as it allows for in-depth exploration of human, social and organizational aspects of information systems (Baskerville & Myers, 2015: 25). Ethnography started gaining recognition as a design tool as it started forming part of the design process, however still being based on the traditional ethnographic model. This meant the ethnographer only observes and participated in the research without actively seeking to change the situation (Baskerville & Myers, 2015: 23). In recent years ethnography has evolved into what is known as design ethnography (DE), this has come about as the researcher is not simply a learner of the culture and people, as suggested by traditional ethnography, but allows and even encourages active engagement. This is a significant advancement as it allows the researcher and the people, participants, to learn from one another during the process (Baskerville & Myers, 2015: 24).

3.2.3 The Pilot Visit to SALT

The objective of the pilot visit was; to gain access to the SALT control room, which granted by SAAO and SALT (Appendix A), and to make contact with the SALT staff, to assess the nature of the control room environment. Firstly, there is one astronomer out of a team of approximately ten and one telescope operator out of a team of four, who work a seven night shift together. This intense collaboration over a longer period allowed the researcher to establish a relationship with the two users over the seven-night period. Secondly, interactions in the SALT control room environment can very successfully be documented using visual observation methods as all users tasks are accomplished within this area. Lastly, there were no culturally sensitive activities taking place, where visual documentation would be deemed inappropriate or unethical to the people (Blomberg, 1993: 139). Since the researcher had clearance to engage and interact within users in the space, it was an ideal platform for the application of a visual research method (Kensing & Simonsen, 1997).

3.2.4 Design Ethnography in Practice

The researcher employed design ethnographic methods for capturing data and observing all interaction. These interactions were considered in line with an analysis of Socio-technical system in the SALT control room. Design ethnography is the most relevant method for gathering qualitative data from the control room as it provided a detailed, in-depth description of everyday life and practice of the astronomer and telescope operator of SALT (Hoey, 2014: 1). The chosen methodology for observing the SALT astronomers was practical as their workspace is a closed and private environment, allowing for easy undisturbed visual observations (Blomberg, 1993: 130).

According to Hoey, the study had to be conducted over a specified period of time, to observe the work practices and attain the best possible understanding of those practices (2014: 2). There were multiple observations, each with its own objectives and appropriate durations, which ensured a thorough understanding of the tasks, conducted and the users work.

Table 3.1 represents; the dates of data collection or testing, a description of each session, the methods of data collection or testing for each, and the objects for each visit.

Table 3.1: Data Collection Methods and Dates

Data Collection Methods and Dates			
Date	**Description**	**Applied Methods**	**Objectives**
2012- 08-09	First contact	Unstructured interviews and note taking	To find an appropriate project for my degree
2012- 08-28	SALT Observation (Day and Night)	Ethnographic method including, photographs, video recording, note taking, unstructured interviews	Meeting the SALT staff and becoming familiar with the SALT environment
2012- 02- 12 to 16	Extended Observation	Ethnographic method including, photographs, video recording, note taking, interviews and discussions	Exploring and obtaining a holistic view of the control room system.
2014- 06-17	Post upgrade observation and co-design session	Ethnographic method including, photographs and video recorded interviews and discussions	Evaluate the condition of the control room post upgrade
2014- 08-26	Design pilot study implementation	Low fidelity prototyping and evaluation survey	To implement the Design pilot study prototype for testing and evaluation

Source: Collated by Author

There were multiple short visits due to accommodation restrictions nevertheless one extended observation visit was organised to identify any patterns or changes in the control room over the period of several nights (Blomberg, 1993: 124). The extended observational period also gave way for sociological ethnography as the researcher spent time getting to know and building a relationship with the users (Pink, 2013: 24). This approach has aided in a first-hand understanding of the current work practices as a basis for the design process. The ethnographic study used various forms of ethnographic data collection methods including; interviews, discussions, videos, photographs, field notes, and note taking, which has been carefully analysed (Hoey, 2014: 5). This is necessary as the work practices described by the users may differ from the actual events because a user's interpretations and perceptions of their own work practices are occasionally influenced by their emotions, which alter their interpretations of their work (Kensing & Simonsen, 1997: 86).

As described by Blomberg (1993: 125), the researcher should first take a holistic approach to the data collection, by observing the users' natural everyday tasks as an outsider to the research space – observing users' interactions with each other and equipment. Using video, with consent of the users, is one method to achieve this, however this does have limitations. Video recording over an extended period can quickly generate enormous quantities of video footage that can be challenging to process thoroughly (Pink, 2013: 24).

3.3 Methods of Observations

Following the initial observations and note taking, the study attempted to develop a descriptive understanding of the users' activities and work practice, as they perceive it in the complex control room environment (Blomberg, 1993: 139). This was achieved through a combination of field notes, video recorded discussions, unstructured interviews, and photos to document the work practices. This explored the work practice without intruding on the users in order to gain an understanding of what the users work practice entails, and possibly identify any areas of friction within the users' environment.

Some of these methods allowed for clarification of observations that were unclear or unfamiliar to the researcher in the complex work environment with people and technology. This ensured that the researcher understood the users; actions, work practise, behaviour and technology. It also aided in an understanding of how the users viewed their own work environment (Kensing & Simonsen, 1997: 82). The interviews conducted away from the workspace were focus on a reflective understanding of the participants' work practise and environment. These interviews have also aided with the exploration of the design framing for the design pilot study and gave insight to what the users want, need, and expect from their work space. These observation methods fall under an ethnography study method, Blomberg (1993) and Hoey (2014).

Experiential learning is the gaining of knowledge through actual experience; this is accomplished by participating in real-life activities (KaYuk Chan, 2012: 1). One part of Experiential learning, as described by Kolb's learning theory, (KaYuk Chan, 2012:30):

> Kolb's theory posits that learning is a cognitive process involving constant adaptation to, and engagement with, one's environment. Individuals create knowledge from experience rather than just from received instruction. Conflicts, disagreements and differences drive the learning process as learners move between modes of action, reflection, feeling and thinking.

This was used as a means of data collection, and a way to evaluate information gathered though other methods. Experiential learning was achieved by the submersion of the researcher into the users working environment, using the space and being in the environment for the same duration, as is appropriate and without disrupting the users (Bergsteiner, Avery, & Neumann, 2010: 406).

The researcher did not always understand the tasks being carried out by the users, therefore the researcher was not able to do any of the tasks, nevertheless the researcher gained a deeper understating of the data already gathered, as they used the space in a similar role-playing manner.

Design Discipline Map

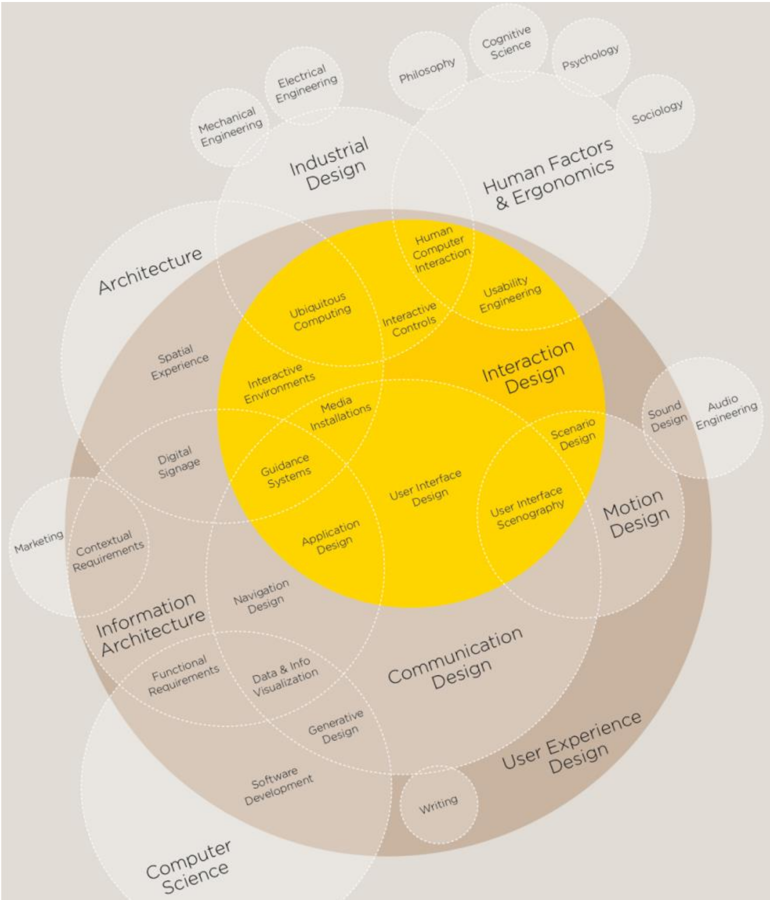


Figure 3.1, The Disciplines of User Experience Design
envis precisely GmbH (2009, Redesign 2013), based on "The Disciplines of User Experience"
by Dan Saffer (2008)

3.4 Design Result Mechanisms

To understand the way in which people interact in a space (and to design for that space) we need to observe them and gain contextual understanding plus reflecting on the framework that helps explain how they work with technology. If one considers this, one could design more appropriate solutions for work practice and work environments with the users (co-design)? A small design pilot study aimed at supporting what was found, and to explore if this deeper understanding would yield user centred results. The following section will discuss the design methods that have been used, and adapted to gather the relevant data in the most appropriate manner possible, refer to Figure 3.1, Design Discipline Map for an overview of how the disciplines relate to one another. This section will also include methods of user testing, feedback, and analysis for the design framing and pilot study.

3.4.1 Design Mechanism

Contextual design is based on the understanding that any system embodies a certain way of working. When the designer understands how the user works with the system they can design improved products, which would affect how the system is structured and used. This design method focuses mainly on the front end of design specifically on the users and their work (Kaptelinin & Bannon, 2012: 297). The design of the product to improve the system should be contextually sensitive as the SALT control room is a specialised space.

User-centred design (UCD) focuses on designing with clear understanding of users, their work, the environments in which their work is carried out, as many other hybrid disciplines take up the word 'user' (Kelly, & Matthews, 2014: 354). UCD also takes the context of the system to be used and pays particular attention to the social and cultural factors, work practices, and the structure of the system (Steen, 2012: 75). This is an important part of the design pilot study as it considers the users as the most central part of the system, being that the research project focuses on the potential improvement of the users work environment through design.

Co-design, which is a subset of a wider notion of participatory, co-creation and open design processes, is a well-established approach to creative practice (Cruickshank, Coupe, & Hennessy, 2015: 49). Co-design developed in Scandinavia in the 1970s and its roots can be found in participatory design, and there are traces of it coming from the UK in 1971 (Elizabeth, Sanders & Stappers, 2008: 7). Koskinen & Thomson define co-design as (Cruickshank et al., 2015: 49):

> A community centred methodology that designers use to enable people who will be served by a design outcome to participate in designing solutions to their problems.

Traditionally co-design takes citizens deeper into the shaping of public services however it has also proven to be a well-established method for designing alongside the user for private services and products (Cruickshank et al., 2015: 49). Co-designing helps the professional designer develop services and products that meet the users' needs by designing alongside them. As a result this method helps the professional gain a better understanding of the users, their interactions with the product or services and the impact it has on the users' life (Francis, 2015: 4). The following four key areas were considered while dealing with co-design tools and methods (Francis, 2015: 7, 8).

1. Involve service users early – don't wait until you have a set of polished options to 'present'.
2. Create an environment where service users and service professionals can talk and work on an equal footing.
3. Start by understanding the outcomes not just the service.
4. Take an asset-based approach.

Co-design projects vary according to the project details and requirements; therefore each project might potentially have a different starting point. The co-design session was conducted at SALT in Sutherland. It consisted of two sessions during the night, first at 21h00 and the second at 01h30, giving the participant's time to reflect on the first session. Both sessions consisted of one researcher, two astronomers, and one telescope operator. Each session lasts approximately 45 minutes. The sessions were video recorded allowing the researcher to fully engage the participants, which enabled better flow and idea generation. The video also made processing of the sessions easier as the researcher could go back or pause when required however it was time consuming. The researchers roll in the co-design process was to facilitate the conversation without overpowering the conversation and in turn hindering the participants and their ideas. The research had to clearly introduce the topic, problem, and what the objectives for the session were. The researcher guided the discussion by prompting the participants with thought provoking questions to start the session off. The researcher made notes of the ideas brought up, and bring the participants back to ideas that had be tabled for later discussion during the session. The following three tools and methods were used where appropriate in the design framing for the design pilot study. Idea farms are better suited to community work as they involve a structured workshop with multiple individuals who start off fresh. This method does encourage the community members to take ownership over the project and ideas rather than simply providing their opinions (Francis, 2015: 9). For this project it was not possible as there was a small sample group nevertheless multiple idea sessions with fewer users were conducted. This gave the users a chance to take action during each session with each users input being heard due to the small group size. The users took ownership of the design concepts even while the design pilot study was being conducted, as they made appropriate modifications; see Figure 6.1 in Chapter 6.

Using the scenario method was not appropriate for this design pilot study as the groups were small and each participant had a good understanding of the complex work environment (Cruickshank et al., 2015: 49). Scenarios are dependent on the topic and the need for the group to have a collective understanding of the problem at hand (Francis, 2015: 9). The use of scenarios aids in the group discussion by creating a realistic but fictionalised (or anonymised) case as a basis. This also brings all the users to the same level as they would be working with the same data (Elizabeth et al., 2008: 14). The use of customer journey mapping was appropriate for this project as it described a method for mapping out and documenting the users' journey through a service (Francis, 2015: 9). The journey mapping documented the users' interactions with their environment throughout the night, helping to identify user problems and what the potential objectives should be (Cruickshank et al., 2015: 51). This was a vital method to the design framing of the design pilot study as it incorporated the complex work environment with people, technology, and their interactions.

3.4.2 User Testing/Feedback Mechanism

The prototyped solution, yielded by the user driven design pilot study, was tested in the control room environment. Theoretical aspects were discussed with the users, and feedback was documented. The design pilot study consisted of colour being added to the computer displays and their input devices, and left there for the users to use over a three month period. Users were given no instructions about the addition of colour to their devices however they were asked to continue their work as usual. This was intentionally done as not to create preconceived ideas. After the testing period, feedback was gathered in the form of a survey and via emailed from some of the users. Users were given a multiple choice question, which could be compared, and an open ended question. This was done to achieve the best possible feedback without suggesting any desired answers.The survey was divided into the four identified key areas however the main focus being on the design pilot study prototype. There was a multiple choice question for each key area and the open ended question was constructed in the same manner as the multiple choice question, which the users could answer freely**.**

The survey available online: https://www.surveymonkey.com/s/YX3GQ9Y. [20 October 2015]

3.4.3 Analysis Mechanism

The analysis of ethnographic content can be contrasted with conventional or more quantitative content analysis (Altheide, 1987: 66). While ethnographic content analysis verifies the theoretical relationships, it is instinctive and highly interactive for data collection and analysis (Altheide, 1987: 68). Co-evaluation was found to be a suitable method for this project as it involved the researcher and the users in the evaluation of the design pilot studies outcome. Co-evaluation is the combination of both parties involved in this project, the users were presented with concepts from the design framing and they had to evaluate them, and the researcher evaluated the designs according to the literature and findings (Zornoza, Garcés, Climent, & Sánchez, 2013). This proved useful while framing the design pilot study so that it may yield optimal results with the least disruption to the SALT control room and require the least amount of resources. Therefore analysing the designs using the feedback received and the research conducted, which is discussed systematically in Chapter 6, under the following sections; description, responses, analysis, relation to framework. This analysis of the design pilot study determined if further design intervention would have a positive impact on the interaction of a control room system.

3.5 Ethics

Ethics is a set of guidelines or rules that apply to the way in which a researcher interacts and behaves in relation to a project, stakeholders and research participants. These guidelines are to protect research participants according to their worldly views (National Institute of Environmental Health Science, 2015). Ethical considerations define what type of research, prototyping and testing may be conduct, and the manner in which it is conducted. Most ethical considerations speak to the preservation of the subject's human dignity and rights (UNISA, 2007: 9).

3.5.1 Ethics Regarding Usability Testing

A few of the important ethical issues that should be taken into consideration while conducting research usability testing, are described by Burmeister in Table 3.2

Table 3.2: Ethical Considerations During Usability Testing

Pre-test	During	Post-test	Informed consent
- Be prepared, ready and on time for the test meeting. - The subject is well informed about the contents of the test and what is required of them with no hidden agendas. - Ensure the subject is aware that the test is voluntary and that they may stop at any given time.	- The subject may stop the test at any time. - Avoid outside disruptions during the test as it is disrespectful and distracting to the subject. - Try and make the subject comfortable by using a suitable venue and providing some refreshing beverages.	- Ensure the subject is aware that their identity will remain anonymous and private unless they give permission. This is especially important as many individuals are concerned about the footage ending up on social networks. - Informing the subject that their input was of value to the project.	- Informed consent, the researcher had explained to the user what he will be doing during the duration of the study, which they will be partaking in. The users fully understood and agreed to participate in the study, at their freewill.

Source: (Burmeister, 1999:2, 4)

3.5.2 Ethical concerns: Video Recordings

An ethnographic study documenting current work practises, and testing of prototypes, can be done with the use of video recording (Blomberg, 1993: 133). Understanding what ethical rules associated with this method is important. Table 3.2 documents the concepts taken into consideration during the study to engage ethically and responsibility:

Table 3.3: Ethical Considerations When Using Video Recordings

Before	During	After
- The researcher ensured that appropriate consents (Appendix B) were obtain from the subjects who have been video recorded. - Informed the subject where the video camera is and that that was the only one. - Explained why the video recording was necessary the test and the reasons therefore. - Explained who will have the right to view the video. - Answer any questions the subject might have about the project to the best of your ability before the test commences.	- Inform the subject when you are going to start recording and once again when you stop recording. - Assure the subject that they may ask for the video to be stopped at any time for example, bathroom break, time out or if they become uncomfortable with the questions.	- Assure the subject that the video footage will remain confidential unless they give permission for the video to be viewed and if so they still have the right to remain anonymous in the video via editing. - If possible give the subject the opportunity to view the video. - Do not alter the original content of the video in a way that it would become untruthful.
(Wiles, Prosser, Bagnoli, Clark, Davies, Holland, & Renold, 2008: 13)	(Burmeister, 1999: 3)	(Wiles *et al*., 2008: 22)

Source: Collated by Author

Participants consent forms available on request to ensure privacy, however see Appendix B for consent form structure.

3.5.3 The Importance of Ethics in the Research Field

As human beings we all have human rights which protect our basic needs and desires as humans however these needs extends further into the emotions, privacy and awareness of one's self (National Institute of Environmental Health Science, 2015: 1). Ethics are important while conducting research to protect the users of the test as well as to control the standard or researcher of the test. These controls or rules ensure that no inhuman actions are allowed during a test as well as ensuring that there are no hidden aspects of the test which the user has not been justly informed of (UNISA, 2007: 9).

There are many rules to consider before a research test is conducted for example. You should try, making sure the subject is aware that the test is voluntary and that they may stop at any time. During the test there are slightly different rules such as, stopping the test if the user becomes uncomfortable at any point. The researcher needs to ensure that all project documentation is kept private and only used in the described research and to what the user has agreed upon.

All participants of this study are adults, are able to give consent, and are cognisant that they are part of this study. There was no sensitive topics discussed, nor were there any procedures that were invasive, intrusive or potentially harmful to the participants of this study. This study has not involved harmful materials or processes that could potentially damage the environment.

3.6 Storage

The collection and analysis of the data gathered during this study has been stored on a secure computer at CPUT Cape Town campus in a locked office. Any paper work completed, has been stored securely in the same location. This is to ensure the protection of the information relating to SAAO, SALT and any users who participated in this study. Only the supervisors and researcher have access to the data from the observations, and any other part of this project. The appropriate permissions have been obtained before any data from SALT is released in the form of a thesis, conference paper, and journal article or research poster. This is in accordance to the storage requirements of the Economic and Social Research Council (E.S.R.C, 2015: 17)

3.7 Conclusion

A design ethnographic methodology has been followed as it has been found to be the most appropriate and will provide the best research results. The design ethnographic methodology followed comprised of a number of approaches, including; field observations, note taking, video recording, photographing, discussions, and experiential learning. Co-design was used to support the design framing for the design pilot study, which was used to determine if further design intervention would have a positive impact on the interaction of a control room system.

The appropriate permissions have been obtained from SAAO. In addition, separate permissions were acquired from each user of the telescope, with regards to taking notes, pictures and videos of them in their workspace

Chapter 4: Ethnographic Observations, Findings, and Analysis

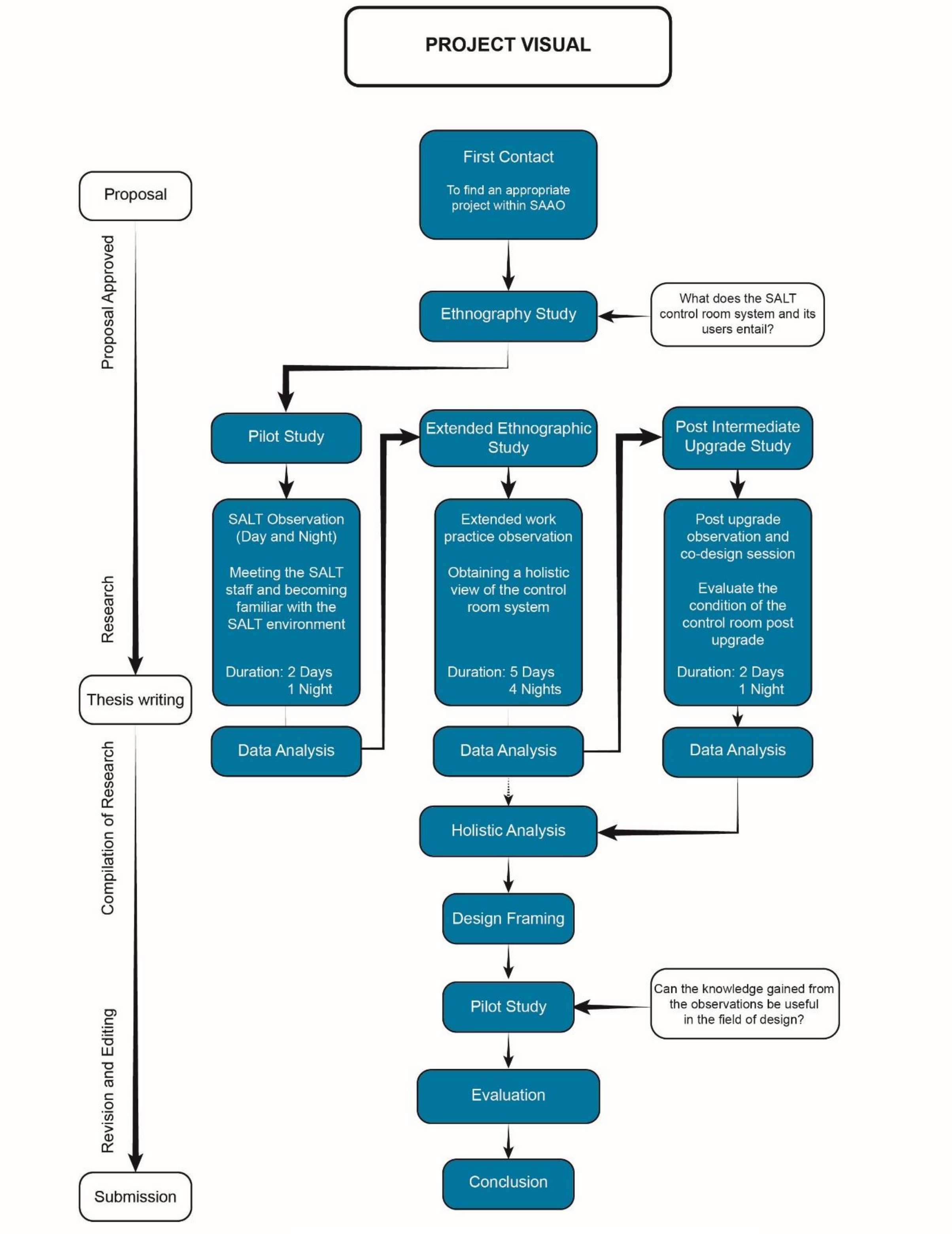


Figure 4.1, Project Visual
(Author, 2015)

4.1 Introduction

Ethnographic observations, from the initial visit to the extended observational visit, taking place in the SALT control room environment explaining what the control room consists of and its appearance, answering the first sub question. The ethnographic study was conducted before the first phase of the control room upgrade, see Table 2.1. Pre phase-one upgrade, there were no subsequent changes to the original control room, except for the computer monitors, which were changed a few years prior to this study. The second part of this chapter will explore the ethnographic observations from each day and or night. The data gathered from the second part of the chapter is discussed in greater detail under specific areas of interest. The study captures the user's difficulties, challenges, and likes and dislikes with the space. An ethnographic study was conducted after the phase-one upgrade regarding the changes made and how the users work practices had improved or not improved.

4.2 Initial Ethnographic Findings (The Control Room Explained)

The first visit to the Southern African Large Telescope (SALT) at the SAAO observatory consisted of; a general ethnographic study and evaluation of the space, and first contact with the staff. This revealed the basics of the control room; who worked in the control room, what was the purpose of the control room, how the control room functioned, and how was the control room organised. A word flow diagram, figure 4.3, represents a simplified overview of the astronomy field and some of the connections between the sub-sections.

No.	Description
1	Aluminising Room
2	Spectrometer Room
3	High Resolution Spectrograph
4	Control Room
5	Pier
6	Louvres
7	Building
8	Primary Mirror
9	Air Conditioning
10	Telescope Structure
11	Tracker
12	Payload
13	Dome
14	Dome Shutter
15	Centre of Curvature Alignment System

Table 4.1, Telescope Layout Description (SAAO, 2015)

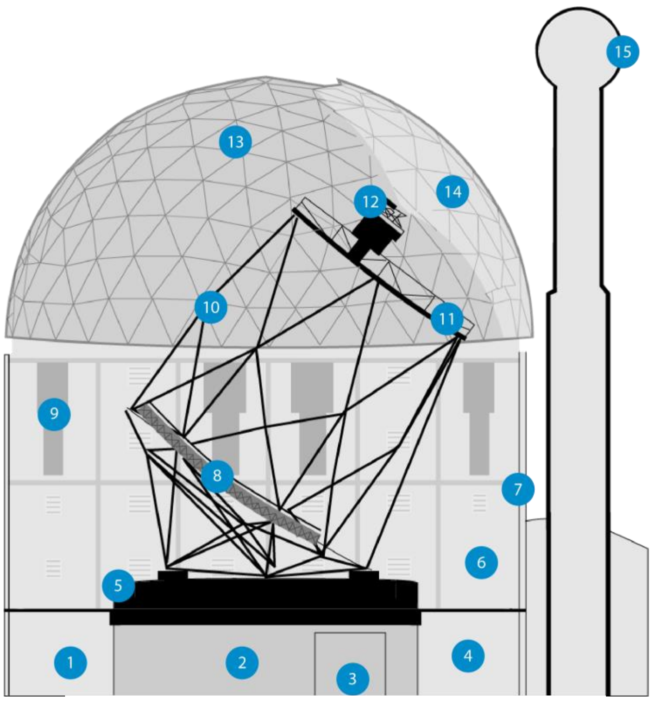


Figure 4.2, Telescope Section View of Layout (SAAO, 2015)

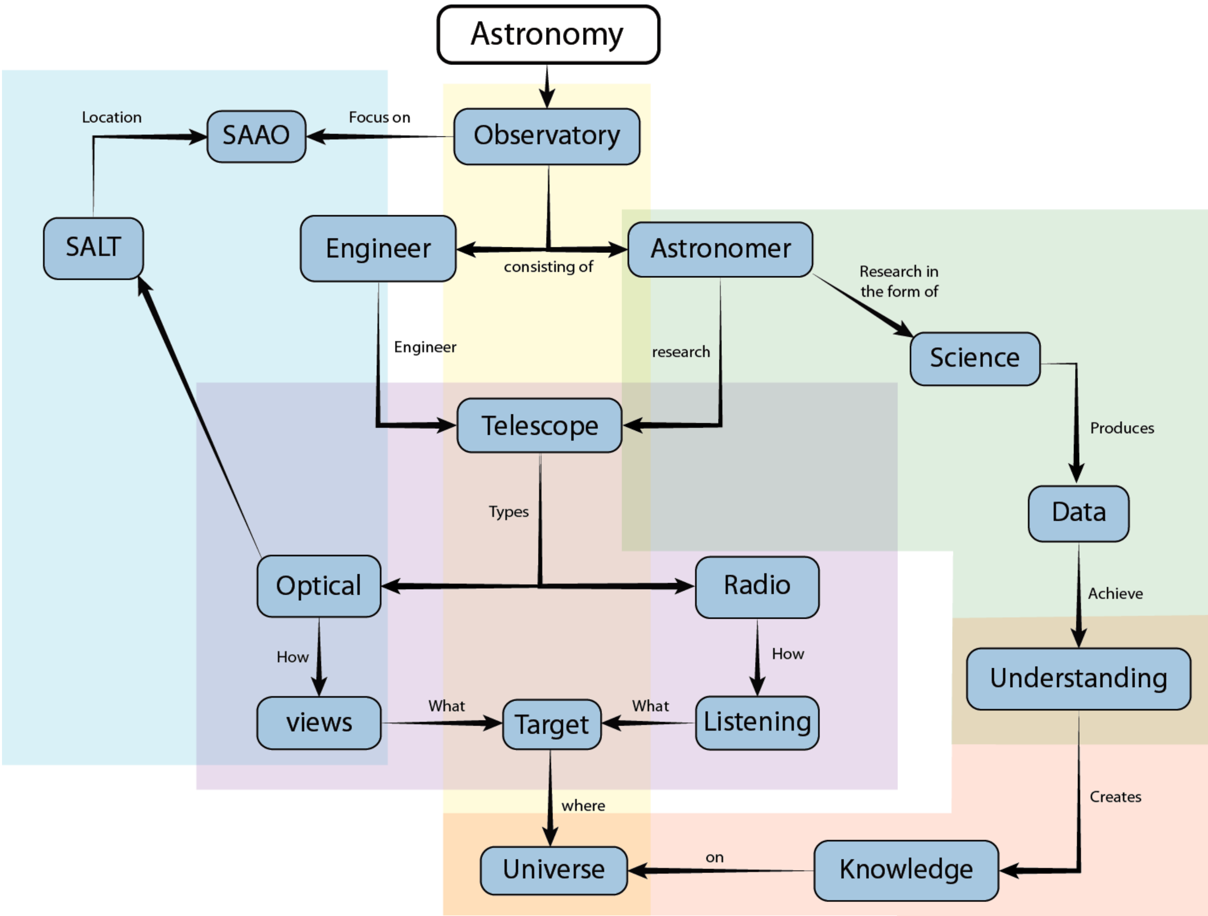


Figure 4.3, Word Flow Diagram
(Collated by Author, 2015)

4.2.1 The SALT Control Room

During the site visit, field notes were taken, images were captured and discussions with staff were noted. This enabled a description of the control room to be formulated. The control room is an allocated space from where the telescope is operated and astronomical science is conducted and partially processed via the computers by staff and according to the proposal requirements. This is done by a telescope operator and an astronomer or two. The control room is also used as office space by some of the managers of the telescope.

The control room is located on the ground floor, underneath the telescope structure, as seen in Figure 4.2. The location on ground floor helps in keeping any generated heat away from the telescope, in addition to allowing for easy access for any disabled staff. It is close enough to reduce the need of unnecessary lengths of cabling and thereby decreasing the risk of communication problems between the controls and the telescope and costs. The control room consists of office space, server rooms, telescope operating computers and safety controls for the engineers while they work and maintain the telescope. The control room did not have enough space, as a result some of the staff were forced to place their desks in other areas of the telescope, for example in the spectrometer room, which was very uncomfortable as it was not designed for that purpose.

4.2.2 The Appearance

Figure 4.4, Entrance to the Control Room
(Author, 2015)

Figure 4.5, Inside the Control Room
(Author, 2015)

4.2.4 The Layout

When entering SALT, there is a short hallway with the kitchen on the left and the control room on the right. The kitchen is equipped with a refrigerator, stove, sink, cupboards, coffee machine and a few other basic essential items. The kitchen is an open-planned space with a small lounge area with two couches and a coffee table. The coffee table has a glass top in the same shape and size as one of the mirrors used on the telescope, which is a nice touch to that area. The space is used for refreshments and meal breaks, as it gives the staff an opportunity to have a small break during long, and often physically exhausting, working shifts.

When entering the control room from the main door one will see a long slanted desk running the length of the room. There are six screens that have been numbered from one to six from the right hand side of the desk, for easy referencing. This does not include the laptop screen or the two weather monitoring screens that are on a shelf above screens three and four, which are partially visible in Figure 4.5. As seen in Figure 4.10 the control room is very cramped as the space was shared by all the staff, this was not well organised and the space was unpleasantly cluttered. Each screen has its own, computer, mouse, and keyboard to control certain parts of the telescope as the scientific software can only be run on separate computers. Screens five and six however are linked to one computer, which is configured as an extended desktop. This computer is used by the SALT operator for the operation of the telescope, discussed further in section 4.4, *The Control Room at Night.*

The desk is at such a steep gradient that the computer mouse and keyboard slide down to the edge where there is a ridge. This ridge, at the bottom of this desk, prevents the mouse and other items from sliding and falling completely off the desk. There are wooden slats, which support the desk at 90 degrees to the length of the desk and are spaced 1.5 meters apart along its entire length. The desk supports are painted black, but one can see the paint has been chipped off where the chair wheels collide with them, close to the ground as well as midway. This is a clear sign that the users often bump their chair wheels, but worse of all their knees while moving along the length of the desk to the different screens.

Working on multiple screens became a problem for the users as the layout of the computer screens and keyboards are all configured in one straight line. This resulted in the user having to continuously move up and down the length of the desk. The height of the desk was not ideal for all users to sit at; according to the human solution, an individual's height determines their correct desk height (The Human Solution, 2015). As a result of the high desk, the chairs have to be high making it difficult for the users to reach the ground with his or her feet. The lack of contact with the floor forces the user to use his or her arms by holding on to the ridge on the desk when moving back and forth from screen to screen. This puts strain on the arms and hands that results in the user sitting poorly as they try to reach the floor with their feet to help them move. This action of many different users, of various heights and of both genders was witnessed by the researcher.

The chairs and floor are not appropriately matched, as the floor is carpeted and has a high rolling resistance. This high coefficient of friction creates drag, making it challenging for the user to move from one position along the desk to another. This puts a great amount of strain on the users arms, as previously mentioned, resulting in the user either jumping up from their chair to briefly look at a different screen, or forcing them to simply stay in their current position and lean over to the next screen. When a user planned to work at a particular screen for at least 70% of the time, they would angle the other screens, and position the mouse and keyboards of the other computers to make it easily accessible for them to stretch over and work on those computers. This leaning action, which was observed, will have a negative effect on the body and should be avoided (Kneelingofficechairs. 2015).

4.2.5 The Information Display

When SALT was built and the control room installed, LCD flat computer screens were not popular yet and therefore the desk space was designed to accommodate the old CRT (cathode ray tube) screens, which are large, bulky, and heavy (Buckley et al., 2005: 169). The CRT screens limited the layout options of the control room; this forced them to have all the screens in one long row, which was less than ideal for the users. The CRT screens were updated to flat screens a few years later, and these screens did not have to be next to each other in a long row, resulting in extra unused space behind the screens.

4.2.6 The Emergency Devices *(Phone and Stop Button)*

There is a red button in-between screens three and four which is an emergency stop to the telescope in case of any major problems, such as the telescope getting stuck on a crane which was not packed away properly. This button should be easy to access, yet it is positioned flat on the desk where the astronomers usually place their laptops. This is the most convenient place to work on for the astronomer however it obscures the stop button. The landline telephone is next to the emergency switch and is used by the night staff for any problems or enquires which they cannot sort out. On the pillar above the phone is a list of contact phone numbers for the relevant personnel on call duty. The name of the technician, who is on duty for the week, is written with a whiteboard marker in a designated space for the night staff. This was used on the third night of the five day study (see Table 3.1, *Data Collection Methods and Dates*) as the SALT operator had problems with the computer timing of the telescope and could not fix the problem.

4.2.7 The Lock-out Panel

One of the staff members developed this feedback board which connects directly to the power supply of the telescope. The board has an image of the telescope with the relevant parts or sections labelled and a LED representing its status. When the particular item is in a safe working position for the telescope it will indicate green, and if the crane for example is in use it will indicate red, representing that it will obstruct the telescope's normal working operation. If this light is red the telescope will not be able to move. The locks which one can see on the sides of the board, Figures 4.2.6 and 4.2.7, are for the isolation lock outs. This is used by the technicians who need to switch off and lock the section they are working on. The technician is required to keep the key on their person, as well as write their name in the space above the lock, so that they can be contacted via the walkie-talkie. This prevents anyone from accidently unlocking and switching on the section where the technicians are working. The telescope is very large and if someone from the control room was to unknowingly rotate it while a technician was working underneath, it may result in serious injury (Hendrickse, 2013). A safety lock-out panel was installed in the control room to secure the telescope during the night, and while working on the telescope during the day, see Figures 4.6 and 4.7. This was installed after a close incident when an operator in the control room moved the structure while a technician was working on the telescope. The lock out panel allows an engineer to lock a power switch, cutting off power to the corresponding part of the telescope, to ensure his or her safety while working on it.

4.2.8 The Office Space

The lack of space resulted in the managers of SALT being forced to have their desks and office space in the same area from which the telescope is controlled. This caused friction between the different SALT staff as the desks were never kept clean or tidy, which was unsightly for the astronomers at night. These office desks are along the left wall upon entering the control room, where mostly paper work is kept, and LCD screens to which additional laptops could to be connected.

4.2.9 Power Points

The staff who worked in the control room all had their own laptops, either Macintosh or Windows. This meant at some point during the night or day they needed a power point. The night staff each needed a power point, which was close to their work space. The only available plugs were behind the computer screens, which were also plugged into those power outlets. These outlets were not easily accessible as the desk is high and deep and the screens were obscuring them, thus resulting in the staff being forced to climb on chairs, even on the desk at some point, to reach the power outlet. It was potentially dangerous and this occurred on more than one occasion, mainly during the night, as the night staff used their laptops for long durations.

4.2.10 Control Room Lighting

The control room was built without windows as light from the room must not filter into the telescope at night while operating. However the day staff found the space uncomfortable and a window was installed. There was lots of debating between the day and night staff over this window (Hendrickse, 2013). During the research observations (Table 3.1, 2012-02-12 to 16) the window was always shut at night, however during the day it was open two out of the five days. The day lighting for the space is fluorescent lights, which gives the room a very artificial look and feel. This was not a concern as it was day time, and working in the space was fine. On the other hand the night staff could not work under these lights. They preferred to use the dimmable down lights, which gave the space a soft warm feel, creating the feeling of night time. This was enough lighting to work under as well as to keep the users awake throughout the night (Health and Safety Manager, 2015).

Figure 4.6, Telescope Lock-out Panel in the Control Room
(Author, 2015)

Figure 4.7, Telescope Lock-out Panel
(Author, 2015)

Figure 4.8, Office Desk in the Control Room
(Author, 2015)

Figure 4.9, Office Shelving in the Control Room
(Author, 2015)

Figure 4.10, Cluttered SALT Control Room
(Author, 2015)

Figure 4.11, Users and Researcher in the SALT Control Room
(Crause, 2013)

4.3 Extended Ethnographic Observations

Using ethnographic observations as described in the methodology chapter, data was collected over a five day, four night period post the overnight visit to SALT, refer to Table 3.1 for clear overview of visits. This longer visit allowed the research to explore patterns that may only be noticed over multiple nights of observations. As previously discussed the participants where not comfortable with being video recorded however they consented to photographs being taken of them while working in the control room environment. Therefore separate event logs were used to document the proceedings during each day and night respectively, see Appendix C for first night event log extract. The event log consisted of a short introduction to the setting of the day or night, followed by the log, which consisted of a time entry with a description of what was being observed or spoken about. The event log also had additional side notes included where appropriate information was thought to be useful but not directly involved. This was combined with photographs taken throughout the day and night to create a holistic description, as best as possible, of the SALT control room environment. This section will cover a summary of each event log however each area is unpacked and analysed in sections,4.4 The Control Room Day, and 4.5 The Control Room Night.

4.3.1 Observations Day 1, 2, & 3

Every morning, the day staff meet at 08h00. The observations counted an average of sixteen individuals in the control room for the meeting. There was never adequate seating for all the individuals and the observations noted a few individuals sat on the tables, some manged to acquire a chair and the rest stood. The meeting discussed the required events and objectives for the day, and the workers brought any concerns they had to the attention of the head engineers.

A discussion was held between the head engineer and the researcher about the control room environment, as this gives the researcher first-hand knowledge from a day staff member. To highlight a few points from the discussion with the engineer; he mentioned the idea of having power outlets for mobile desks when they have commissioning of new instruments as it was lacking. He also mentions that the carpets are going to be replaced, and that he wants down lighting added to the control room, yet still keeping the florescent lights. The head boss would like his own office space as he needs privacy for meetings and his work as he has to currently work from a desk with in the control room, which has no privacy.

There are public tours of the telescope, which take place throughout the day. They have a viewing window that the public can see into the control room environment without disrupting the users. Lastly, despite the large morning meeting that was held for a short period, the control room was not excessively busy as most of the work being carried out during the day was conducted on the telescope structure or within the other rooms of the SALT building. This was the same for all three days of ethnographic observations.

4.3.2 Observations Night 1

The event log started at 20h15 on the first night of the observations where it was the current astronomers last night of observations. The current astronomer would be handing over to the next astronomer for their week shift. Both astronomers were not in favour of me taking video footage however ethnographic observations were instead documented via an event log, keeping track of the event being observed and the time of it happening, this was joined with images taken to provide holistic data.

Each astronomer was using a MacBook, and three telescope computers, each with their own input and display devices. This was all placed on slanted desks that were too high for them. The chairs that the users used had a high coefficient of friction as a result of the type of carpet, which was complained about throughout the week by all users. There are walkie-talkies on the top counter to monitor the telescope via sound as it is not visible from the control room. The first night everything was new to the researcher and the work being done was not well understood allowing for the researcher to focus on what was visually observed; the users' movements, and the control room functions.

4.3.3 Observations Night 2

The second night was a good night for observing as the sky was clear and the air was warm, however there was a threat of the wind speed picking up later that night, which could potentially become a hazard. There were two visiting astronomers who were there to work with the temporary instrument installed on the telescope. The one astronomer would be working with the telescope operator as she knew how to operate the temporary instrument when it was functioning. The second astronomer would analyse the data received from the temporary instrument.

There was lots of excitement from all three astronomers as they were all happy with the focus and the alignment of the temporary instrument. The one astronomer explained to the researcher about the fuss that they were making about the temporary instrument. It was the first time they are able to see what they were doing. Normally the telescope would focus all the incoming light to the instrument while taking science; this meant they could not see what light was being captured during this procedure. However this new instrument and programme allowed all the light to go the instrument to take science yet also allowed the astronomers to view the incoming light and therefore they could take better science. They were looking at a pulsating white dwarf star, and how it pulses. 4 Gigs of data was collected in 15 minutes, which equated to 100mbs per 40sec. The rest of the night continued with the usual procedures until a target for the temporary instrument became available in the telescopes viewing window, where they would switch back to the new and exciting procedure.

4.3.4 Observations Night 3

There were weather concerns on the third night of observations as it was cloudy and the astronomers were not sure if it was going to clear up, hopefully the wind would clear the cloudy situation. There was a problem with one of the instruments, which was heating up and a technician was attempting to sort out that problem. A Software engineer was working in the control room on one of the computers as the system was currently running on windows 2000 and they were in the process of updating them, however they were still encountering errors in the system and he had to fix problems that might crop up during the night.

As the night went on the humidity started rising to around 80%, which was the limit for keeping the telescope dome open. With high humidity comes dew, which is bad for the telescopes operation and it would mean that they would have to close the dome for the night. By 00h45 the weather was not suitable and the astronomer and telescope operator decided to close the tower. The forecast showed no signs of improving later into the night and we all left for the hostel; normally they would wait for the conditions to improve.

4.3.5 Observations Night 4

The weather conditions were looking good on the fourth night of observations however there were concerns about the sound of the wind over the monitoring radio in the telescope area. The additional astronomers from the previous two nights were not with us as they had completed their tasks, making for a quieter atmosphere. The first mirror alignment was completed by 20h00 allowing for observations to start earlier. Unfortunately there was a problem with the payload, which crashed for a second time and the humidity had become a problem by 01h00. The astronomers closed the telescope dome due to bad weather, and decided to wait for a short while, hoping the conditions would improve. By 02h20 the conditions had not improved because of 'rich cloud' conditions (this is when the clouds form on the top of the plateau where the telescopes are situated because the area is so high it creates the overcast). According to the astronomers this seems to happen when seasons change. We packed up and proceeded to the hostels as it was evident that the cloudy condition would not clear before the end of the night.

4.4 The Control Room Day

4.4.1 Daytime Control Room Users

During the daytime the control room is used by the engineers and technicians (SALT Foundation, 2015). The design of the SALT telescope and its technology requires constant maintenance as each mirror requires recoating once a year. Only two mirrors are removed at a single time therefore it takes a year to completely recoat all 91 mirrors, Figures 4.12 and 4.13 (SALT Foundation, 2015). The design of the segmented primary mirror allows for the dirty mirror segments to be removed and recoated while still allowing the telescope to operate. This gives the engineers constant work however the work is all conducted in the telescope building and mirror coating room.

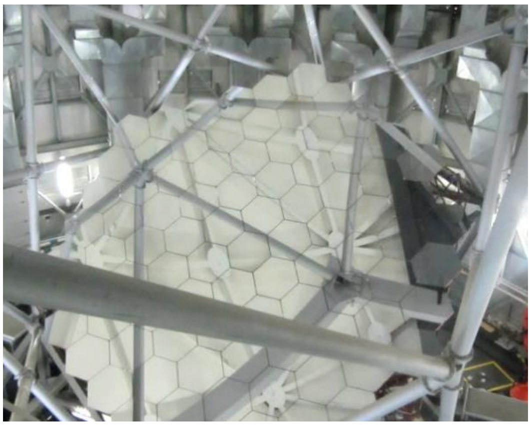


Figure 4.12, Top View of Segmented Mirror
(Author, 2015)

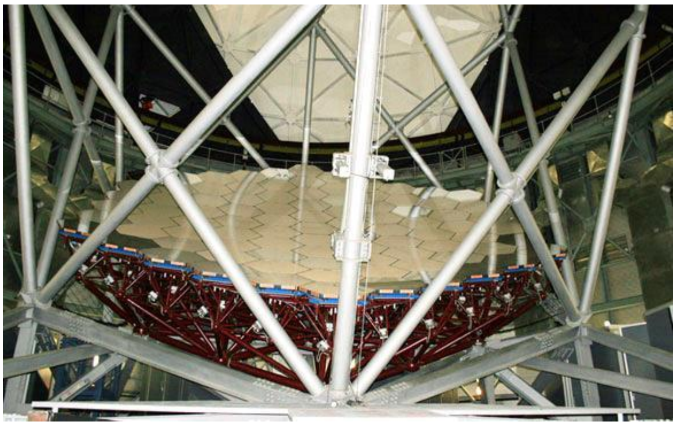


Figure 4.13, Front View of Segmented Mirror
(Author, 2015)

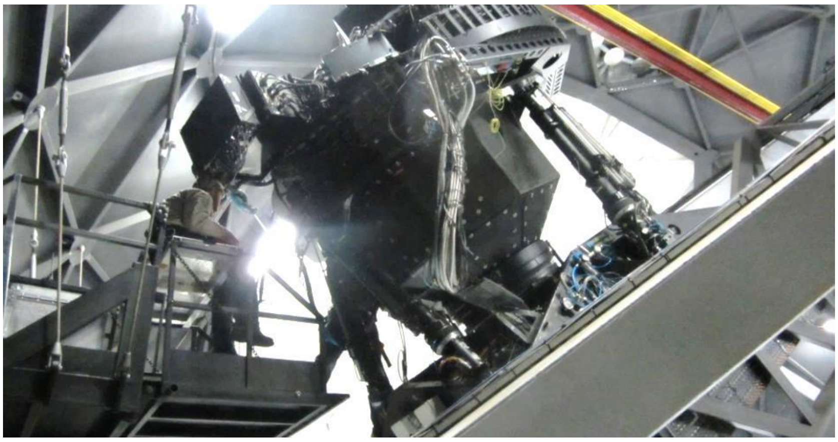


Figure 4.14, Telescope Payload
(Author, 2015)

Occasionally new optical instruments need to be installed into the payload, which is situated atop of the telescope structure as seen in Figure 4.14. These new instruments need to be fitted precisely for optimal use, however sometimes the astronomer or telescope operator encounters problems during their night of observations.

The astronomer or telescope operator depending on who is affected by the problem, log the faults in a digital log with the details of the problems and how they attempted to resolve it. This helps the mechanics to follow up in the morning and work on the problems during the day before the following night of observations. In the control room, at 8am every morning, the engineering personnel and technicians have their morning brief to ensure everyone knew what they were expected to accomplish. This was the only time the control room was essentially full of workers, however their meetings were short and once complete most of the staff continued their work elsewhere.

4.4.2 Daytime Control Room Environment

As previously mentioned, some of the staff used the space as offices for their paper work and other desk related tasks. Unstructured interviews were conducted with the staff for more clarification of this area. The head engineer reported that the space was indeed used as office space however it was not ideal for them as they often needed privacy while having meetings with important clients. Another concern was the lack of secure storage space for their paper work and documents as everyone who had access to SALT could access anybody's work. The lack of storage space for the operation manuals and other documents, which the engineers needed to work from during the day, was another problem area. The documents were placed all over the room, on any available shelf with insufficient organisation making it difficult for the staff to quickly access the necessary information while working, Figures 4.9 and 4.10. All of this added to the cluttered control room, which, as seen in Figure 4.10, appears to be an untidy office space with many computers in it.

4.5 The Control Room Night

Figure 4.15, Telescope Operator and Astronomer in the Control Room
(Author, 2015)

The night time users consist of two people, the SALT operator and the astronomer and sometimes there is a second astronomer. The second astronomer will use a temporary auxiliary instrument, which is attached to the telescope to perform other specific functions over and above the normal procedures. During the researchers observations (Table 3.1, 2012-02-12 to 16), two astronomers used an instrument called *BVIT,* which was setup by the SALT astronomer and operator, to take science (collection of data from the target, this is explained in more detail later on). The BVIT instrument is a visible photon counting detector, which is designed to provide observers, with very high time-resolution, photometric imaging and observations of astronomical objects (SALT Foundation, 2015).

4.5.1 What Does The SALT Operator Do?

The operator, seen on the left in Figure 4.15, uses the two computer monitors directly in front of her as well as sharing the top left computer monitor, which displays the current weather conditions. She also uses the shared monitor in the middle with the grey background and black strip, which displays what the telescope, is aimed at. The lady to the right of the image, Figure 4.15, is the astronomer. She uses the shared grey monitor, her laptop, the three monitors to her right, and the two monitors on top, which display the current weather and telescope position respectively.

The telescope operator, who has an IT background, controls the movements of the telescope, with fairly complex software. The operator is responsible for aiming the telescopes at the correct astronomical target and to ensure that the payload tracks the target accurately. Tracking is a telescope function which automatically follows celestial objects as it moves across the night sky due to the rotation of the earth (Starizona Adventures in Astronomy & Nature, 2014). The operator receives the location of the astronomical target from the astronomer.

The primary mirror of SALT is so large that it had to be segmented into 91 individual 1m hexagon mirrors, which need to function as one single mirror (SALT Foundation, 2015). These mirrors need aligning to ensure that all individual mirrors operate as one large mirror. The operator is responsible for aligning the mirrors. This is vital for the astronomer and their work.

The original telescope design incorporated capacitive mirror edge sensors, to help align the mirrors, for optimal focus as one large mirror. The misalignment of the mirrors was due to the fluctuations in the air temperature that caused the telescope components to expand and contract (Buckley, Schindler, Gajjar, Levequed, Menzies, & Sändig, 2008: 1). These edge sensors were not operating correctly, resulting in the mirrors needing to be refocused using a laser and the curvature sensor at given intervals throughout the night. This is the responsibility of the telescope operator. Figure 4.2, the mushroom shaped dome on the right holds the *Centre of Curvature Sensor,* which is used for the mirror alignment procedure. During the mirror alignment, which is a complex and time consuming process of approximately 30min, no astronomical observations can be conducted, and the astronomer continues with work from the other proposals. This is unique to SALT as the other telescopes at the SAAO observatory are less complex and are operated by the astronomer.

4.5.2 What Is The Proposal System?

The SALT astronomer receives a list of proposals for the week. These proposals are not the astronomers own research projects but that of other astronomers. Astronomers need to submit a successful proposal to SALT for any research that they are conducting and require data for.

The proposals are rated by priority, *P1* being the highest and *P4* the lowest. The exception is when a temporary instrument like *BVID,* was attached to SALT for two weeks during the observations of the control room for this project. These proposals need to be passed by the board and they need to meet certain requirements. Some of the basic requirements would include having the coordinates for the target and the time it would be visible on SALT. Seeing conditions are determined by the weather and the moon, for example a particular target might need dark seeing conditions because it might be too feint to take science when the moon is out. It is the astronomer's responsibility to calculate which targets need to be and when they can be observed. The astronomer needs to take the following factors into account; the length of time for the correct instrument exposure; the position in the sky; the visibility in SALT's window on the sky and also factoring in the time lost due to mirror alignments.

4.5.3 The Astronomer

The astronomer uses the telescope to observe and study particular points of interest in the night sky to further our understanding of the universe. SALT works on a 'queue-scheduled' system, whereas on the other traditional telescopes, an astronomer is entitled to use it for the entire night for their own research (Erasmus, 2015).

The astronomer on duty for the week receives a schedule of proposals which need to be covered for that week, and does not perform his or her own research. This schedule has the details of; the object to be investigated with its coordinates; and when it is visible; the science to be conducted on the chosen object; the viewing conditions; and the priority of the project and a few other details. The astronomer decides in which order the proposals are to be conducted and if the viewing conditions are appropriate according to the requirements. It is the astronomer's job to ensure that accurate data is gathered for each proposal and that all the requirements are met as best as possible, they need to log all the operations they performed and any problems they may have encountered. Once set up by the astronomer the software performs the required science operations and collects the data which then gets sent off to the relevant astronomers who submitted the project proposal, where they process and analyse the collected data.

4.6 Description of Work Process at Night

The working night of a SALT astronomer would start off shortly after supper. The staff went to the telescope at 7:30pm as sunset is later during the summer season. No observations can be conducted during twilight, which lasts for an hour after sunset. From the time of arrival at the telescope until dark, the astronomer prioritises the list of proposals and arranges them best for the night of observation and when they would be visible in SALTs viewing window. This is all done on screen three and the users' laptop, which is connected to the network of computers. While this is happening the SALT operator will make sure the telescope is operating correctly and would get ready for the first mirror alignment.

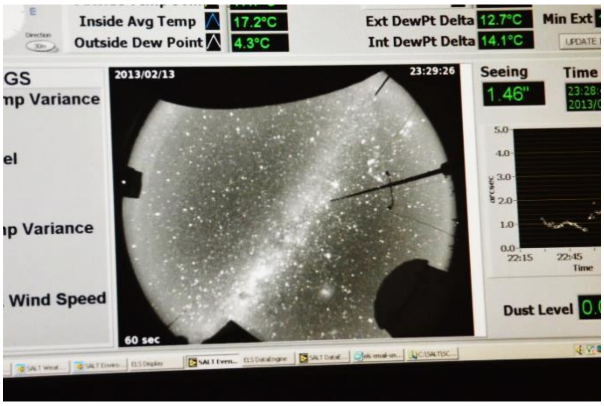


Figure 4.16, Screen Shot of Weather Display
(Author, 2015)

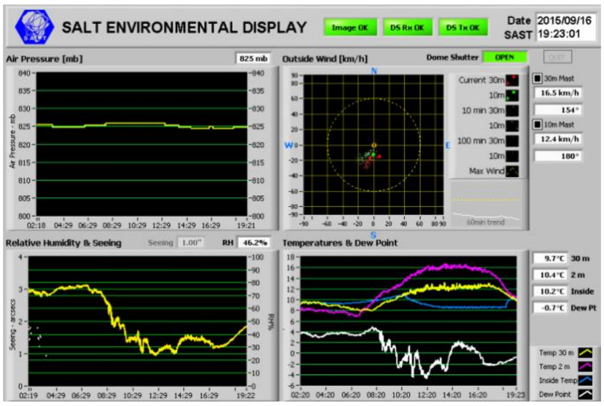


Figure 4.17, SALT Environment Display
(SAAO, 2015)

15-20 minutes before the first target is ready to observe, the astronomer will check the top two screens, which are vital, as they indicate the outside weather conditions that they cannot see nor feel. Figure 4.16, this black and white image of the sky taken by a camera mounted outside and away from the telescope building is visible to the control room operators. Information like; dew point and temperature in graphs, wind speed and direction, and a few other important weather conditions are can be seen in Figures 4.16 and 4.17. These indicate a seeing number which ranges from 0.5 being perfect, up to a useless 3 when the sky is too bright, or overcast, or raining.

The astronomer would give the go ahead to the operator to alignment the mirrors. Once the mirror alignment is complete the astronomer will pass the coordinates to the operator for the first astronomical target, for example, see Figure 4.18. Once the telescope is aimed at the correct target and they can see it on screen 1, see Figure 4.5, the astronomer needs to select a bright enough star for tracking. This is sent over to the operator and they will need to keep the star in focus on screen 5, Figure 4.5. Depending on many variables the target will have a tracking time in seconds, for example 950 seconds and not in minutes. The astronomer will have to initiate the science procedure, which will expose the relevant instruments in the payload to the light from the astronomical target.

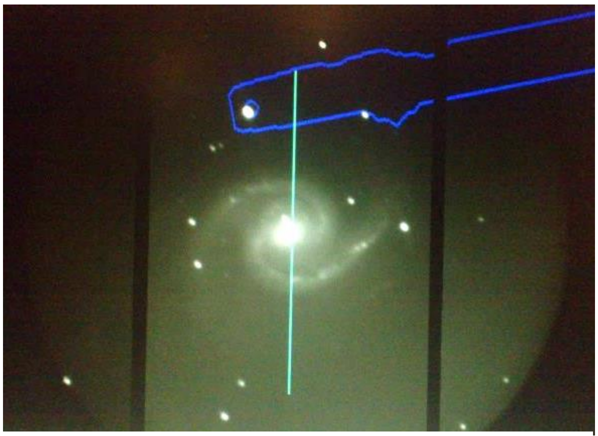


Figure 4.18, Galaxy and Star Tracking
(Author, 2015)

Once the telescope is set up and aimed at the target, the astronomer can run the science. This procedure will expose the light from the target to different filters or instruments depending on what data needs to be collected. A night log is used by the astronomer to keep a record of all the problems, solutions and general running of the telescope. All events must be logged, including some of the results, even though the procedure will automatically save the data. This log is used during the day by the engineers who will try and rectify any problems from the previous night.

While the procedure is running the astronomer would source the next target from the proposals. Sometimes it might be necessary to set another procedure on the same target. If it is a long procedure, which can be around 30 minutes, the astronomer would take a coffee break or continue with some other work in the meantime. The operator has very little to do during this time except monitor the focus and the tracking. There is an audio which announces 'procedure complete' when it is finished, the reason for this is that when there is a long procedure and they were taking a break, they would not know when it was finished. This audio is saving time as they previously would have had to continually check the screen for the end of the procedure.

Once the astronomer has gathered all the data from the particular target they would give the next target's information to the operator who would need to reposition the telescope. While the telescope was moving they would monitor it over the radio system via sound because the telescope moves by lifting itself up with compressed air, then turning and finally placing itself back down by releasing the air. This release of air can be heard over the radio and acts as confirmation of the telescope having moved successfully.

The sound monitoring was a make shift plan as the operator had no direct contact with the telescope because the control room is sealed off, as the telescope must not receive any light from the control room. If light was to filter into the telescope it would contaminate the data with false information.

When the new target is in sight again the same setting up procedure is carried out and the astronomer runs their science on the object according to what is requested in the proposal. This whole cycle is run a couple of times before a mirror alignment is needed again. The frequency of the mirror alignment is dependent on the weather conditions and what the proposal requires for the science of the target. The astronomer will inform the operator about the requirements and they will discuss the best options.

4.7 Research Analysis

Other ethnographic observations in the SALT control room included discussions, unstructured interviews, visual observations, and self-testing.

The observations saw almost all the staff bring their own laptops and other electronic devices, which they used during their time in the control room. These devices needed to be charged at some point and the power outlets were hard to access. The easiest power outlets to access were at the desks on the opposite side of the room from the computers where the astronomers worked which was not practical. The astronomer and telescope operator had to use the spare power outlets from the desktop computers which were out of reach and behind the computer monitors. This saw the staff climbing onto the slanted desks to reach the outlets to plug in their own chargers. When asked about the purpose of them using their own portable devices, a few different reasons were provided. Their own devices are set up to their preferences and there was information from certain programs which they preferred to use instead of those on the SALT computers.

The astronomers used their own laptops to continue with their research during the night while the telescope is running the science procedure. If the weather conditions become unsuitable and hazardous to the telescope, high dew point or rain, the telescope dome is closed and no further observations can proceed. Sometimes they close the telescope when they encounter technical difficulties and are forced to call and wait for the engineer who is on standby to assist them. They have their laptops where they can continue with other work so as not to waste any time. One of the astronomers had her laptop and iPad with her, see Figure 4.15, and she explained that she preferred viewing the results from the observation on her iPad as it is displayed larger and clearer, it is easier to navigate with the touch feature and it allowed her to share the findings with other astronomers who might be sitting in on a particular night. The portability allows the other astronomer to observe the data while not getting in the way of the astronomer and the telescope operator.

4.7.1 The Control Room Desk

The first and most obvious observation is how high the desk is and the angle of the working surface. This can be seen in Figure 4.19, in the bottom right hand corner of the image there is a flat desk which makes for a good comparison of the height and angle of the old desk. The desk seems to work for someone who would stand at it while working for short periods and moving from one computer to the next (shown by user during observation). The angle of the desk coupled with the smooth wooden surface causes the keyboards and mouse to slide down into the 20mm lip and get stuck there. This lip however does create discomfort for the users as they would have to rest their forearms on it or suspend their arms above it and straight onto the keyboard, according to the discussions, this was a point of great frustration and discomfort.

The poorly designed desk also meant the users could not place anything besides some paper, stationery or a cell phone on it. A mug of tea or coffee would slide off and spill, as a result the users had to resort to placing their beverages on the flat area of the desk, which was above the keyboards and in-between the computer monitors. This clearly increased the risk of spillage due to having to reach for the beverage and if spillage occurred there was a higher risk of damaging the equipment.

4.7.2 The Computer Screens

When this space was originally put together the only computer monitor option was the CRT monitors (Cathode Ray Tube) which required a deep desk to accommodate the tube behind the screen. This resulted in the desks protruding far from the walls. When the computer monitors were upgraded for the LCD flat screens (Liquid Crystal Display) they did not upgrade the deep desks, which resulted in wasted space behind LCD flat screens. This space was filled with cables in an untidy manner, see Figure 4.5. Not only did the desk size and shape consume a large portion of the control room real-estate, it made the room appear much smaller than it was. The bulky desks were supported with wooden support panels which sat perpendicular to the wall resulting in the users painfully and constantly knocking their knees against it see Figure 4.5.

4.7.3 Control Room Seating

Some of the chairs were old and not functioning very well, wheels missing or jammed, back rests and height adjusters difficult to operate and loose foot rest bars. The high desk meant the chair heights had to constantly be adjusted to accommodate the different users' heights for an ideal work height to be achieved. The shorter users found, that raising the chairs to a comfortable height to work at the desk resulted in the user's feet not reaching the ground. This made it difficult for them to change position from one computer to the next. The computers were spread out across the desk and the users would have to hang onto the desk to relocate them to the next computer, which put a lot of strain on their arms. The combination of the chair castors and the carpet where not matched well which resulted in a high rolling resistance, this lead to the user having to use excessive amounts of energy to move themselves between computers.

4.7.4 Observation and Experiential Learning

One of the most noticeable discomforts while observing the users in the control room is the high angled desks, the chairs and the carpet, none of which functioned well together. One of the suggested methods from section, *3.3 Methods of Observations,* is experiential learning. The following section discusses the use of this method to confirm some of the observations conducted in the control room.

As described in the previous section, the desks and chairs were observed to be problematic on many levels. As the researcher, I set up my laptop in a free part of the desk where I could continue conducting my research without disturbing the users, approximately 45min spent at this location, see Figure 4.21.

Figure 4.21 clearly shows a left to right comparison of the height and angle of the old and new desk respectively. The experiential learning clarified and confirmed that the desk was indeed uncomfortable to work at. The angle of the desk was ergonomically poor, the chairs and lack of possible adjustments made it difficult for the researcher to adjust appropriately, and the carpet made it difficult to move from one computer to the next. The bad posture, poor angle of the desk, and the lip, which prevented the laptop, keyboard and mouse from sliding off the desk, all created a very unpleasant working space for the researcher. This was noted from the ethnographic observations and interviews and confirmed with experiential method by the researcher.

Figure 4.19, Partially Modified Desk
(Author, 2015)

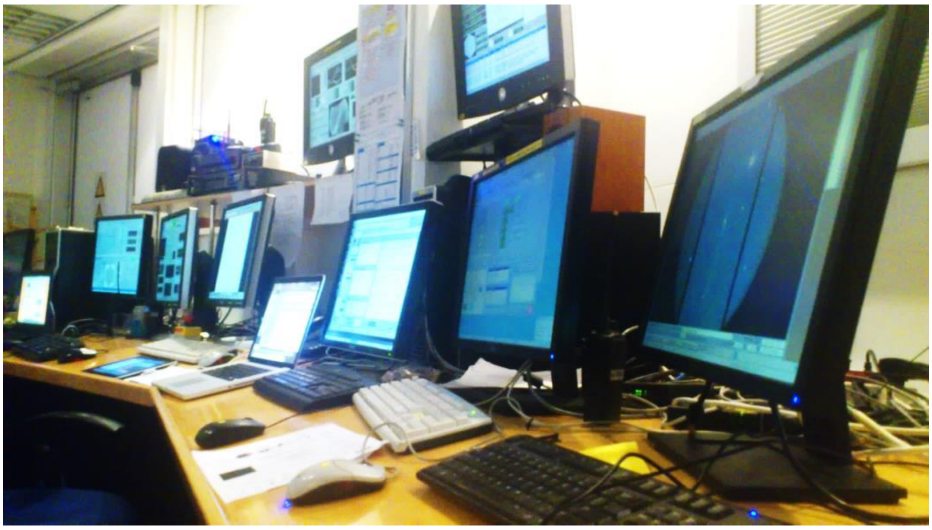


Figure 4.20, Desk with Personal Laptop and iPad
(Author, 2015)

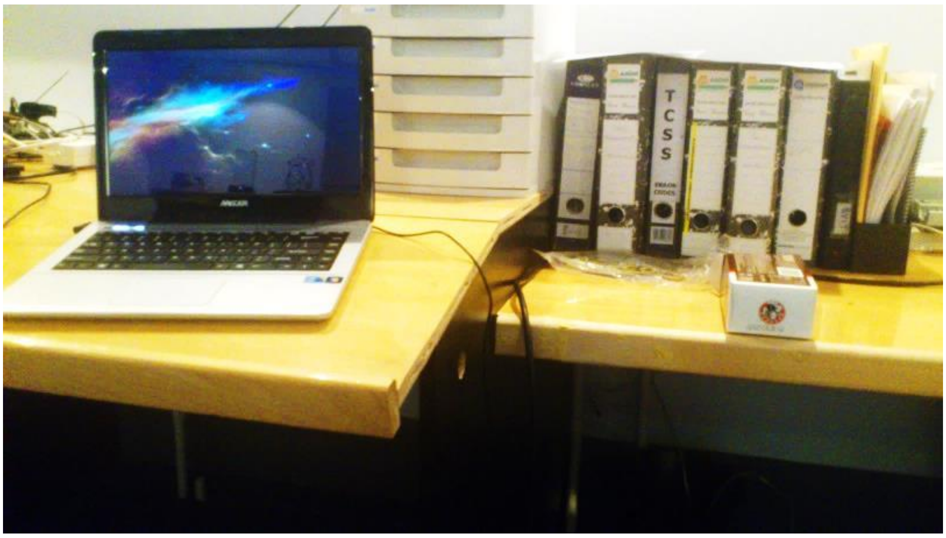


Figure 4.21, Authors Laptop on Desk
(Author, 2015)

4.7.5 Navigation of Multiple Computer Monitors

The SALT telescope is a complex piece of equipment, and the required operating software would have to run from multiple computers. These programs required large amounts of processing power, and more than one user was required to complete the tasks. The telescope is split into two main sub-systems, the telescope operations and the scientific data collection. The telescope operations sub system controls the position of the telescope, tracking and guiding of the instrument payload, alignment of the telescope primary mirrors, to mention a few. The second sub system consists of the instruments and software which takes the science. The programs conducting the scientific research have to process large amounts of data and are computer resource intensive. This meant that the tasks had to be split across multiple computers for optimal performance. Having a number of different computers to operate by two users created multiple problems, for example; having to work across multiple computer screens, keyboards and mouse, and the users own personal laptops, see Figure 4.20.

An extended desktop configuration has been used with certain computers allowing for two computer screens to be connected together acting as one large screen yet only have one keyboard and mouse. Finally, the two computer screens, above the work station, display weather information and telescope structural feedback, they do require keyboards and mouse however these computers are not used for control room work, and instead they are used during the night to monitor external control room conditions.

4.7.6 Multiple Computer Hardware

There are four keyboards and mouse excluding the user's laptop keyboard and track pad, see in Figure 4.20. It was observed that the users would sometimes grab the incorrect mouse or keyboard for the incorrect screen; this was frustrating for them, as stated in discussions, which created a challenging work flow. Navigation of the multiple computers and their corresponding monitors was another problem area, because the users would want to use a mouse across another computer screen however the two were not part of the same computer, keyboard and mouse system.

4.7.7 Complex Control Systems and Software Engineering for the SALT Telescope

The requirements for telescope control software are an advanced complex computer system with limited resources such as budget and time constraints. The initial telescope construction started in 2000 and was completed in 2005, in Table 4.2; the various sub-systems can be viewed (Buckley et al., 2005: 189). There have been many technological improvements in all aspects of the telescope for example; computer monitors have changed from low quality CRT screens to high definition LCD screens (HDLCD). The rapid advancements in technology has resulted in the telescope software needing continual updating, modifying, and maintaining to keep up with newly developed instruments and science collecting techniques. This is all necessary to keep SALT as one of the leading spectroscopic telescopes in the world (Swart, Bester, Brink, Gumede, & Schalekamp, 2004).

Subsystem	Software Items	Description	Developer
Primary Mirror	SPS, actuator controller	Co-ordination of 273 actuator movements, maintenance user interface, health monitoring/ reporting	SALT, Polytec PI (Germany)
	SAMS[4], Numeric modules	Calculation of 91 mirror tips,tilts, pistons based on 480 edge sensor readings, maintenance user interface, health monitoring/ reporting	Fogale Nanotech (France)
	CCAS, Wavescope	Shack-Hartmann sensor determines 91 mirror tips, tilts, pistons optically, user interface, health/status monitoring	Adaptive Opt. Assoc. (USA) and SALT
	MACS	Mirror alignment control loop, maintenance user interface, health monitoring/ -reporting, implement TCS commands	Synapp (South Africa)
Tracker	TC	Generate commands to move Tracker precisely along a pre-defined trajectory, maintenance user interface, health monitoring/ reporting, implement TCS commands	RRS (South Africa)
	Interferometer	Measure Tracker angle w.r.t. Primary Mirror	Fogale Nanotech (France)
Facility	BMS	User interface, health/status monitor for BMS PLC, implement TCS commands	TFD (South Africa)
	BMS PLC	Control cooling plant, air, report on power, UPS, fire	TFD (South Africa)
	Weather Station	Measure outside and inside conditions	Campbell Scientific
	Weather Model	Predict temperature at telescope opening time based on national predictions and local measurements	E-Squared Research (South Africa)
Dome and Telescope Structure	SDC	Control Dome and Structure to command position, monitor health/status, maintenance user interface, implement TCS commands	RRS (South Africa)
	Shutter PLC	Low-level control of shutter	RRS (South Africa)
Payload	TPC	Control of: fold mirrors, pupil mask, moving baffle, ADC, guidance probes (4), maintenance interface, status/health monitoring, calculate guidance corrections, implement TCS commands	SALT
TCS	TCSS	Receive SOMMI/SAMMI cmnds, co-ordinate movement, pointing model[5], health monitoring/handling	SALT
	SOMMI	Display telescope info, operator telescope control interface, problem reporting, send commands to TCSS	SALT
	SAMMI	Display telescope info, astronomer control interface, observing log, problems reporting, send cmnds to TCSS	SALT
	PIPT	PI's planning tool, generate observing proposals	SALT
	OPT	Observation Planning Tool, part of SAMMI, used by astronomer to schedule observations for the night	SALT
	SDB	Database to store observing proposals, required/actual telescope configuration, science data, observing log.	SALT
	ELS	Log maintenance data, log critical events, user warnings	SALT
	EDS	Display weather information and provide on Web	SALT
SALTICAM Instrument	SKER, SDSU	Read/control acquisition CCD, monitor status/health, control camera mechanisms, science interface	SAAO (South Africa)
	SCON	Maintenance interface, control SKER, implement TCS commands	SALT
PFIS Instrument	PDET	Read/control acquisition CCD, manipulate image, monitor status/health	SAAO (South Africa)
	PCON	Maintenance and Astronomer interface, control PDET and instrument mechanisms, implement TCS commands	Univ. of Wisconsin (USA)

Table 4.2, List of SALT software and its suppliers
(SALT Foundation, 2013)

Little trouble was perceived from the users interacting with the software as they knew their way around the programs and the functions in order to accomplish the required work (from 2012-02-12 to 16 observations on Table 3.1). On closer examination of the software interface, Figures 4.22 and 4.23; the software's appearance is out of date with current software interface styles. The interface is not pleasant to look at and this can possibly negatively affect the users' attitude towards the programs. It was also brought to attention that the multiple program tabs can be irritating at times as the lack of screen real-estate to display all the needed information clearly forced the users to continually flip back and forth while working. The users also pointed out the testing of a larger computer screen had been briefly done however the font size scaled up with the screen size and when decreased in size, the low pixel resolution put strain on their eyes which was uncomfortable. Due to the technical limitations of the control room and telescope, the first two levels have been found satisfied during the pilot ethnographic study and evaluation of the complex working environment owing to the telescope requiring very specific hardware and software.

Figure 4.22, Screen Shot of Computer Software 1
(Author, 2015)

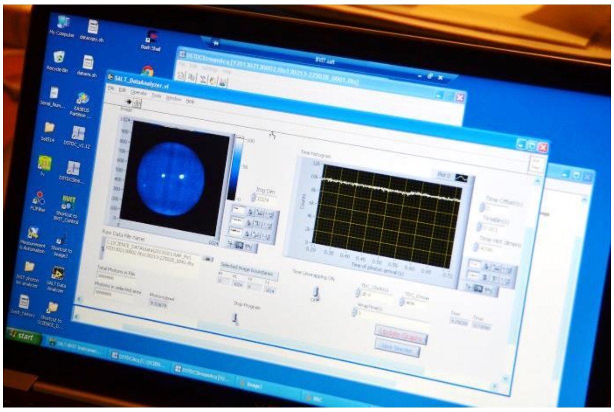


Figure 4.23, Screen Shot of Computer Software 2
(Author, 2015)

4.7.8 The General Layout of the Control Room

The control room is a fairly large space, see Figure 4.11, yet it has been poorly designed and large amounts of the space are being wasted. This can be observed throughout the images in this chapter; for example, the telescope operating computers take up an entire side of the control room as they are spread out to accommodate the old CRT computer screens. The desks for the 'offices' are shop bought and have been placed in the space without much consideration to the control room space, creating a cultured and inefficient working environment. There is a large space in the centre of the control room, which is not being utilised, refer to Figure 5.3 in Chapter 5. This does however make the space wheelchair friendly, nevertheless it could be optimised. The control room does have foot traffic during the day time. When the engineers need to access the server room or other parts of the telescope on the other end of the control room this large free area through the centre allows for uninterrupted traffic flow for the workers allowing them to pass through the room while the other staff work at the computers.

4.8 Key Problem Areas Identified in the Control Room

The following Table 4.3 identifies and summarises the key problem areas and the source of the problems which have been extracted from the ethnographic observations and interviews of the control room and the users respectively.

Key Problem Areas Identified in the Control Room	
Identification of Problem ***What was found from the Ethnographic study***	**Source of the problem Identified** ***Where does this come from?***
Poor ergonomically designed work desks for astronomers	Observation and Interview experiential learning method
Poorly placed, not adjustable computer monitors	Observation and Interview
Multiple Input devices for astronomers, slowing down the work practice	Interview
Lack of power outlets for laptops and other mobile devices	Observation and Interview
Incorrect chair and carpets making it challenging for the astronomers to move across the room to view all the computer screens	Observation, Interview and experiential method learning
Poor visual user interface of software	Interview
Lack of office or private space	Interview

Table 4.3, Key Problem Areas Identified in the Control Room
(Author, 2015)

4.8.1 Intermediate Control Room Upgrade, 2014

During 2014 some funding was approved for a partial upgrade of the control room, which covered the layout of the control room as there was a desperate need for some office space, and the modification of the desks where the telescope monitors were housed. Shortly before this upgrade, a water pipe had burst and flooded the control room, the kitchen, and most of the ground floor in approximately 120mm of water. This damaged the carpet and furniture, and resulted in part of the upgrade to take place sooner than originally planned. The following Table 4.4 identifies key problem areas post this upgrade.

Key Problem Areas Identified in the Post Intermediate Upgrade	
Identification of Problem ***What was found from the Ethnographic study***	**Source of the problem Identified** ***Where does this come from?***
Poor ergonomically designed work desks for astronomers	Observation and Interview experiential learning method
Poorly placed, not adjustable computer monitors	Observation and Interview
Multiple Input devices for astronomers, slowing down the work practice	Interview
Lack of power outlets for laptops and other mobile devices	Observation and Interview
Incorrect chair and carpets making it challenging for the astronomers to move across the room to view all the computer screens	Observation, Interview and experiential method learning
Poor visual user interface of software	Interview
Lack of office or private space	Interview
Incorrect placement of weather and telescope feedback monitors	Interview and experiential method learning

Table 4.4, Key Problem Areas Identified in the Post Intermediate Upgrade
(Author, 2015)

4.8.2 Post Intermediate Control Room Upgrade

A short observation period, one night and two days (2014-06-17, Table 3.1), took place post the upgrade and the following problem areas were identified from visual observations and discussions with the users, refer to Table 4.4.

4.8.3 Summary of Intermediate Control Room Upgrade

Analysing and compiling information from Tables 4.3 and 4.4 into a third Table 4.5, consisting of changes and upgrades to the control room. The upgrade saw changes to the space in the form of office space creation and the modification of the astronomers work desk. These two important changes affect the users in a positive way; however there is still room for further improvement as there is still a lack in the Socio-Technical System (STS). Many of the areas, which would be recognised and impacted by STS design, are unresolved on the mechanical and social level (Maguire, 2014: 162). The upgrade altered the environment creating private office space and making the control desk compact, allowing for easier use however it did not fully address the usability of the controls for the astronomer and telescope operator. Their systems remained the same other than the desk modification and they continued to struggle with the multiple input devices. The development and better satisfaction of the lower levels of the system would positively affect the control room STS, which was not undoubtedly achieved with the intermediate upgrade (Whitworth, & Ahmad*,* 2002). Table 4.5 represents the status of each key problem and if any new problems may arise.

Summary of Intermediate Control Room Upgrade		
Identification of Problem *What was found from the Ethnographic study*	**Upgrade** *Where does this come from?*	**Status of Problem** *Does the problem still exist and to what extent*
Poor ergonomically designed work desks for astronomers	Observation and Interview experiential learning method	Resolved
Poorly placed, not adjustable computer monitors	Observation and Interview	Not Resolved
Multiple Input devices for astronomers, slowing down the work practice	Interview	Not Resolved
Lack of power outlets for laptops and other mobile devices	Observation and Interview	Resolved to some extent
Incorrect chair and carpets making it challenging for the astronomers to move across the room to view all the computer screens	Observation, Interview and experiential method learning	Not Resolved
Poor visual user interface of software	Interview	Not Resolved
Lack of office or private space	Interview	Resolved
Incorrect placement of weather and telescope feedback monitors	Interview and experiential method learning	Upgrade created new problem area

Table 4.5, Summary of Intermediate Control Room Upgrade
(Author, 2015)

4.9 Critical Reflection

The following section will critically reflect on the chosen method for the data collection within the context of the SALT telescope. This is a more personal reflection on the methods and it is divided into three parts.

4.9.1 What was the Study Conducted on and How?

The study took place at SALT in Sutherland and it was found appropriate, from the first contact visit, to use an ethnographic approach to best capture a holistic view of the control room environment and its users. This study focused on the users of the control room, the astronomer and the telescope operator, because they spent the most time interacting with the computers therein. It was also found appropriate to focus on the chosen users, astronomer and telescope operator, as they were using the telescope for its primary function unlike the engineers and technicians who maintain it. The engineers and technicians spent most of their time physically working on the telescope during the day, to ensure it worked optimally for the astronomers during the night. The observations conducted had to be planned as transport and accommodation arrangements had to be made with SAAO and SALT. After a one night contact visit to the observatory in Sutherland, a five day extended ethnographic study period was arranged where time was spent with the users in their work environment.

4.9.2 Reflecting on What Happened During the Observations at SALT

On first arrival the users were not informed that a researcher would be there for a week, even although approval had been received from management. This was an oversight from the researchers' side, however the users were welcoming once the reason for the research visit was explained to them. Observations in the form of video recordings were planned, however the users did not want to participate in the recordings and an alternate method had to be implemented with the resources available to the researcher. While visually observing the users and their actions in the control room, the researcher proceeded to log the time and sequence of events. The users were far more comfortable with this method and would explain some of their actions or the actions of the equipment, which were unclear to the researcher. The users were happy for the researcher to take photographs while they worked. The photographs in conjunction with the event log provided an acceptable amount of data with a clear understanding of the control room system. This was done for five nights in a row to explore any patterns from one night to the next. The event log turned out to be a superior option to the video recording because five nights of video recording would have been extremely challenging to sort through and process. The method of video recording would have had many challenges like, storage space and dying batteries from the lengthy recording duration.

If conducting a similar study, time lapse recording can be utilised as an alternate option to using a standard video recording method. The drawback with time lapse recording is the absence of sound as a time lapse video takes pictures at set intervals, usually between 1 and 5 seconds, over a given length of time, 8 hours. The time lapse video is not smooth like a video, yet many hours of footage can be viewed in a very short time and it would therefore require far less storage space. Images are easily extracted from this method as the time lapse is essentially a compilation of multiple images. The time lapse video can unfortunately miss data in between the capturing time from frame to frame and it should therefore be used in conjunction with an event log, which worked really well in all of the observation sessions.

Other challenging areas included a return trip to the control room as a result of the upgrade, and working with different users, who were happy with video recording and unstructured interviews. A brainstorming session, of possible design solutions was video recorded during this visit, to be used in the design framing of the design pilot study.

4.10 Conclusion

With a successful ethnographic study taking place across multiple days, nights, and visits to the SALT control room; it is clear that a lack of design has hindered the users and their work. The researcher's observations gathered sufficient data for analysing the users, the environment and their interaction with one another, as described in the sections of this chapter. Not being granted permission by the users to video record forced the researcher to use alternate methods, although not perfect, it proved to be faster to process and analyse while still providing sufficient data for a thorough investigation and understanding of the control room environment.

According to *Table 4.4 Summary of Intermediate Control Room Upgrade*, the intermediate SALT control room upgrade still maintained problem areas, which could prove useful in the design framing of a design pilot study. These areas mainly consisted of the user input, navigation, feedback methods, and social systems as the users did not see the desired improvement and in some aspects it became worse for the user. The design pilot study will focus on the astronomer, the telescope operator, and their work practise during the night in the control room environment.

Chapter 5: Design Framing and Pilot Study

5.1 Introduction

The following chapter will cover the design framing through the use of the conducted design ethnographic research, answering the second sub question. A short design pilot study will verify the validity of a possible design intervention, which would indicate the benefits of design to improving the Socio-Technical System (STS). The first part of the chapter will explore design framing. This will include key areas identified from the observations that could be used in a short pilot study. The key design areas are broken down into their respective sections and discussed further and different possibilities are explored to assess their validity to be taken further in an appropriate pilot study.

The second half of this chapter will discuss the design pilot study. This includes the co-design and prototyping of one of the highlighted areas derived from the analysis of the ethnographic study was implemented as a prototype for testing and evaluation. The design pilot study was tested for a specified period and the results evaluated. The pilot study also included insights into how the different socio-technical levels would be affected. Even though the pilot study focused on at the mechanical information level (referrer to 2.4.3, *Socio-Technical Systems &* Table 2.1, *Information System Levels*, page 38) the results showed that it affected the higher levels as it satisfied the lower levels of the system (Whitworth, 2006: 533). Finally, two additional areas identified in the observations that could help support the users work practices were explored with the users and documented as additional areas to the design pilot study.

The goal of the pilot study was not to resolve the challenges experienced in the control room, but rather to explore the impact of design if imbedded in ethnographic observation. A focus on user centred practice, and contextual immersion, as applied elements in a design situation is investigated. The results support design practice, within the framework of STS, driven by observation to potentially impact work practice in a positive manner, within a complex control room environment.

5.2. Design Framing From Observations

The following section concentrated on information learned from the observations conducted in the ethnographic study and will explore potential areas that may be used as a design pilot study within the constraints of the allocated time, and budget and equipment allowances within a given duration. The control room setup is complex and fragile, not allowing the users much freedom when it comes to the testing of ideas and prototyping of concepts, therefore testing has to be conducted without disturbing the existing equipment.

5.2.1 Overview of the Intermediate Control Room Upgrade

As previously mentioned, the SALT control room underwent a preliminary upgrade during the duration of the project where some of the problems were addressed however not all the identified problem areas were resolved; as a result new problems arose from the upgrade. The following images, Figure 5.1, 5.2, and 5.3, display a comparison of the control room before and after the upgrade. Note how cluttered Figure 5.1 appears, this clearly shows how unpleasing to the eye the space is compared to Figure 5.3 where it appears cleaner, less cluttered and organised.

The dimensions of the room have not been altered; yet after the upgrade the space appears larger even though an office has been built at one end of the room, see Figure 5.2. The desks are smaller yet there is more desk space, because the desk surface covers all four sides of the room except for the doorways, Figure 5.2 and 5.3

5.2.2 Potential Focus Area

When reviewing the SALT control room environment, Figures 5.1, it is visible and noted, in the interviews, that the users have to fit to the job. Interviewing the different users of the work space, astronomers, telescope operators and software programmers, the discomfort of the setup, from the high and difficult to move chairs, to the incorrect positioning of the computer displays was mentioned by the majority of the users. This was not true for all the users as some were tall enough to fit the chairs and some were short enough for the computer displays to be the correct height for them. Based on these findings and evaluations, there is clearly a problem in this particular sub-system of the control room. These areas should be addressed in order for there to be an improvement in the work space and work practice. The following problem areas, which were identified from the ethnographic study, are potentially suitable as a design pilot study, further investigation, and design intervention.

5.2.2.1 Ergonomics of SALT Workstations

Workstation ergonomics is about fitting the job to the person rather than the person having to adapt their activity, in an unnatural or detrimental manner, to fit to the job or task at hand (CAP, 2006: 2). While using the control room work space all the users experienced discomfort in the neck, back, and shoulders (Hendrickse, 2012). If not corrected the long term effects of poor ergonomics could result in the users suffering from various injures that may have been prevented, (*AFSCME,* 2015). The ethnographic studies (visual observations, informal interviews and surveys) verified these findings on the users and their environment. According to the Ontario Ministry of Labour (Canada, Government of Ontario, 2004) the findings from the users are a result of a combination of incorrect screen, desk and chairs heights. During a discussion with the users, one of them indicated that only one of the computer displays could be adjusted in the Y-axis (Hendrickse, 2012). This was of some help yet far from ideal. Noted in Figure 5.6; that the computer display screens are placed onto the desks, which take up work space and are difficult to adjust for the different users' needs. The control room would be ideal for adjustable screens as seen in Figures 5.4 and 5.5, as the users change shifts on a weekly basis, therefore the setup for the user should be quick and simple to do, yet at the a same time allowing for maximum customisation, within the limited space.

Figure 5.1, Control Room Pre Preliminary Upgrade
(Author, 2014)

Figure 5.2, Left Side of Control Room Post Preliminary Upgrade
(Author, 2014)

Figure 5.3, Right Side of Control Room Pre Preliminary Upgrade
(Author, 2014)

5.2.2.2 Multiple Computer Navigation

Through observation and interviews, the navigation and use of the multiple computers by only two users appeared strongly as a large problem area within the control room (Hendrickse, 2012). The following section will focus on and explore the possibility of using different ways to overcome and navigate the use of multiple computers and their input devices see Figure 5.5, as a design pilot study. This had to be accomplished without infringing on the technical limitations of the telescopes' operating system such as the maintaining of the separate computers while exploring the design framing for a pilot study

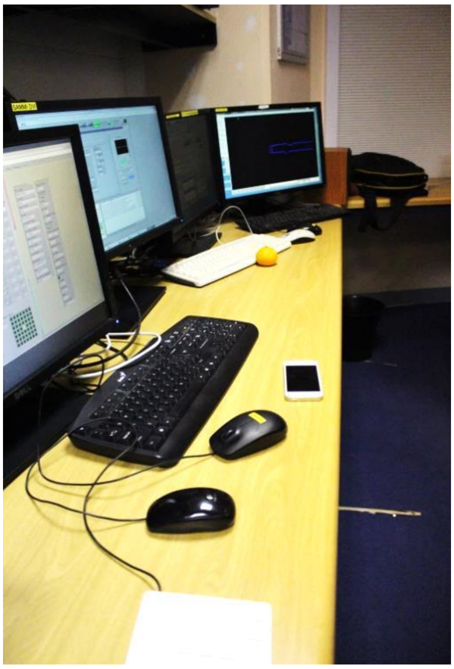
Figure 5.4, *User Built Laptop Stand*
(Author, 2014)

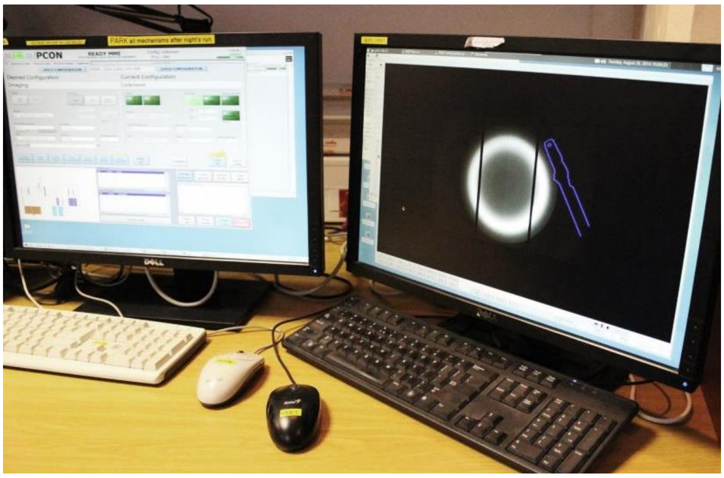
Figure 5.5, Astronomers Work Space
(Author, 2015)

5.2.2.3 Multiple Screens by a Single User

When dealing with multiple screens by a single user there are nine computer screens for two users. This can be broken down into smaller groups; the telescope operator uses two screens, and the astronomer, who uses four screens for his or her work. There is one shared screen between the operator and the astronomer and finally there are two feedback screens: one with weather details and the other with telescope details. Note the current position of the weather monitors results in users having to stand up regularly to view them. When SALT was built and completed in 2005, Cathode Ray Tube (CRT) screens were used; as they were the most affordable option, however, since then LCD flat screens have become affordable and popular in many different sizes. Currently, with exception of the user's laptops, the control room has mostly 19 inch screens with a resolution of 1440 x 900, which is acceptable for the viewing of text and digits with minimal eye strain (Hendrickse, 2012).

5.2.2.4 Addressing Multiple Keyboards and Mice





Left: Figure 5.6, *Four of the ten computer screens, keyboards and mice* (Author, 2014)

Top: Figure 5.7, *Two of the ten computer screens, keyboards and mice* (Author, 2014)

A single computer, keyboard and mouse for a single user is the ideal situation; an expansion would be to have an extended desktop set-up where the user can view two display screens from the same computer while still operating the system with one keyboard and mouse. More displays can be added, however it becomes problematic, as the user has trouble keeping track, of which information is displayed on which screens, and the location of the cursor. Yet when a single user has to use more than one computer and each computer has its own keyboard and mouse, the process became complicated, as the user has to switch between each computer and physically move to the next station to continue their work, Figures 5.6 and 5.7. This is the reason of much frustration to the user and the constant interruption of having to move to the next computer station can significantly reduce the efficiency of the work practice.

5.2.3 Design Framing From Literature

Further support of the design framing can be found in Appendix D, section 2. This additional support was gathered from the literature to cover areas that other researchers have already explored, however it was not directly observed nor will it be used in the design pilot study.

5.3 Design Pilot Study *(Multiple Keyboards and Mice)*

The problem area of multiple keyboards and mice has proven to have the greatest potential as a design pilot study when using the data gathered from the observations conducted earlier in this research study. This area as a design pilot study could potentially fulfil the limitations and the requirements of the control room and the objectives of the study, respectively. This was used to test the validation that a design intervention could possibly have an impact on a control room system and its socio-technical system levels.

5.3.1 Aims and Objectives

The objective of the design pilot study would be to explore a control room environment using an ethnographic method to conduct research and test whether or not a design intervention could potentially have a positive impact on a control room and its users and its socio-technical system levels. The aim of the design pilot study is not to resolve a specific problem area in a control room by redesigning or designing solutions to the identified problems, as that would fall out of the scope of this research project. Instead it is aimed to identify if a design approach may have a positive impact on the system, and is worth taking further as part of a separate project.

5.3.2 Multiple Input Device Design Pilot Study

Derived from the design framing discussed in the previous section, the problem area of multiple input devices are addressed as the crux of the design pilot study as it is both practical and should fulfil the aims and objectives of the design pilot study. This would fall within the limitations of the SALT control room, and it would provide the greatest indication that a design approach to improving the workflow for the users within a control room is beneficial. The existing solution can be seen in Figures 5.4, 5.5 and 5.6, which show the proximity of the current input and output devices and the current identifying method on the; mouse, keyboard, and screen.

5.3.3 Design Pilot Study Concept

The users felt that the current device navigation solution did not satisfy their needs in improving the input system of the telescope control room. After discussing some of the ideas raised under the design framing from literature with the users, the group decided to explore alternate concepts using lateral thinking, by Edward da Bono (1970). Lateral thinking implies that one abandons the previous ideas and move across to completely different ideas instead of developing the same ideas over various iterations (De Bono, 1970). This method of idea generation proved to be successful and some great ideas were produced. The idea of implementing colour to the workspace in the form of coding the equipment was strongly supported and approved by all members. Colour coding the keyboard, mouse, and screen enabled the users to easily identify which devices were connected to the relevant computers without adding unnecessary information to the already saturated control room environment. This would also fulfil the requirements of the design pilot study and its limitations.

Figure 5.8, Users in Control Room
(Author, 2014)

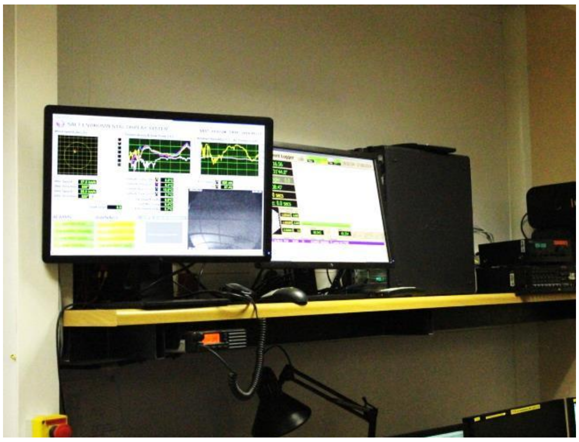


Figure 5.9, Weather Display Screen on Top Shelf
(Author, 2014)

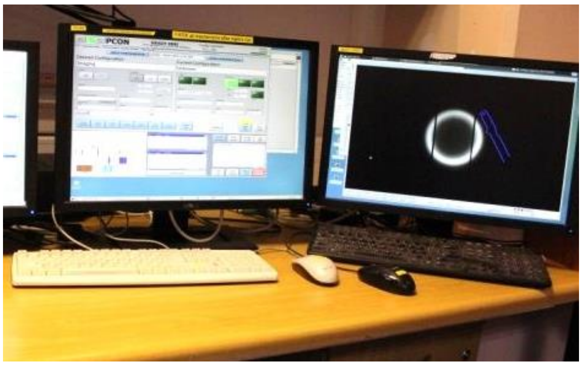


Figure 5.10, Layout of Input Devices
(Author, 2014)

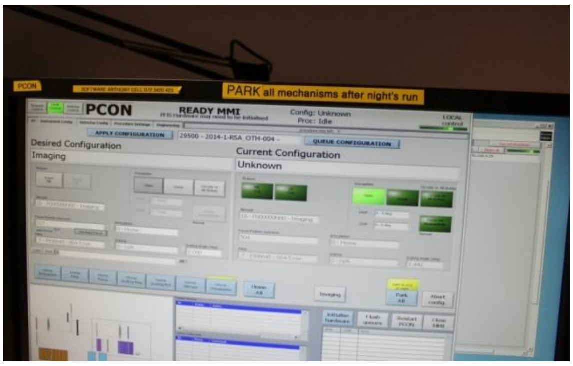


Figure 5.11, Labels on Display
(Author, 2014)

Figure 5.12, Labels on Input Devices
(Author, 2014)

Figure 5.13, Chosen Vinyl Colours
(Author, 2014)

5.3.4 Concept Implementation

Different colours of self-adhesive vinyl were chosen for this prototyping phase. Vinyl with the most noticeable colour differences were selected to allow for easy identification, red, green, blue and yellow were found to be suitable colours, which were approved by the users, see Figure 5.13 for the vinyl colours. The self-adhesive vinyl was chosen for its relatively low cost, high quality finish, ease of application and removability. The self-adhesive vinyl meant the existing equipment did not need to be removed or permanently altered, saving time and costs.

It also allowed the users to use the vinyl applied equipment in the control room for testing for a period of time, and to be evaluated at a later stage.

It was found that the most appropriate placement for the vinyl would be the computer screen border which faces the user. This is a narrow smooth black plastic frame, which holds and finishes the display screen. The self-adhesive vinyl was cut into strips and applied to the frame of each display screen, see Figure 5.14. By applying the vinyl to this relatively small surface area, it did not cause a distraction to the user while working and was still visible enough for them to be aware of the colour in a subconscious manner. The various coloured vinyl’s were applied to an open space across the bottom, top or centre of each keyboard safeguarding that it would not impact on the operation of the devices, for example cover the characters on the individual keys. It would not interfere with the devices function nor would it be overpowering to the users as the device was not oversaturated with colour, see Figure 5.14.

The compound curve of the mouse was challenging as it was not suitable for the application of sheet vinyl. However each mouse was colour coded to correspond with the relevant keyboard and screen, without covering the click buttons or scroll wheel. Ideally this colour could be designed into each mouse, keyboard and screen display that would be seamless and allow for the application to other environments nevertheless this is for testing of the idea and is intended for a short period of time.

An overview of the colour coded screens can be seen in Figure 5.14, which was only applied to screens 5 to 8. There is no confusion as to which mouse, keyboard and screen are a set and this can be observed from a distance without having to read a label and think about it. As a result this should improve the users work flow as they move between computers. This was left in the control room for 6 months to allow for an effective evaluation, discussed further in Chapter 6.

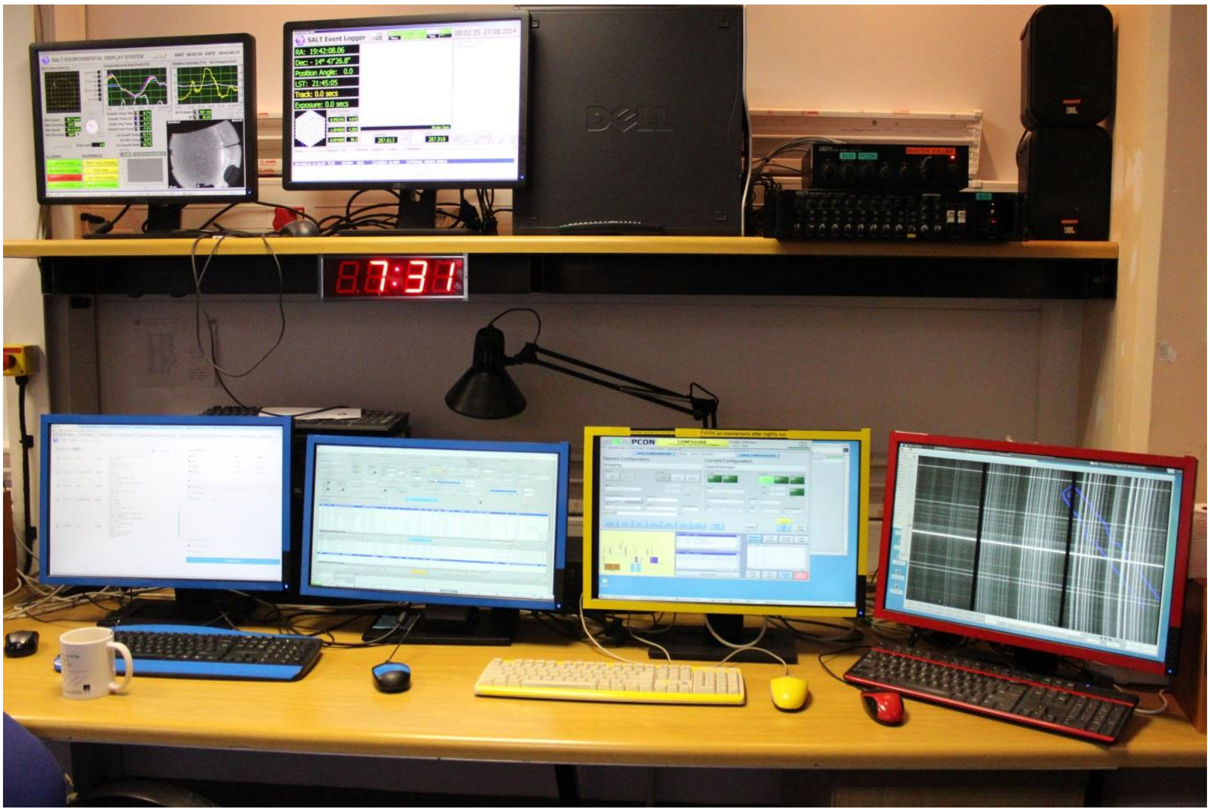


Figure 5.14, Device Colour Prototyping
(Author, 2014)

5.3.5 Co-Design and Additional Features

The SALT control room is a complex system, which incorporates many subsystems as discussed in the previous section.

As stated in the design mechanism section, 3.4.1, two co-design sessions were conducted in the same night, this was a result of the remote location and access could only be gained for one night at SALT for the co-designing. The first co-design session took place early into the night when the participants had a short interval in their work. During this session the research discussed ideas and possible problem areas within the control room, which were noted during the ethnographic research phase. The participants disused the noted problems, pointed out further problems and rate the significance of each problem. The session ended with them having to reflect on the problems discussed and think of possible solutions. The second session took place later the evening where the ideas were discussed. Four key areas were identified and each one was individually discussed. Each problem was clearly defined, Appendix E Control Room Poster, and possible solutions were discussed between the participants and the researcher, where the researcher guided the discussion.

The users and research showed that certain areas that were focused on would have the greatest impact in improving the Social-Technical System. However there are a few additional areas, which should be considered in the ongoing upgrade that would be beneficial to explore and improve. These concepts do not fall within the requirement of the design pilot study as they could not be implemented and tested however continue in Appendix D, section 3 and 4.

5.5 Conclusion

The design framing was broken into two main subsections, design framing from observations and design framing from literature. For the nature of this research the design framing from observations conducted in the ethnographic chapter was explored while the design framing from literature was also explored it was included in appendix D as it provided support from other research.

Key problem areas of the control room were brought to light in the previous chapter of analysis, which suggested two main areas of focus. However, a brief overview of the current control room situation since it had undergone an intermediate upgrade was needed. This allowed for the researcher to eliminate any design areas, which might have been resolved. Once this had been reviewed the key areas of the control room were explored, starting with workstation ergonomics. This was the first approach to the work flow as it was the first point of contact between the user and their environment, and any problems here would impact on every other area of the users work practices however proved impractical for the design pilot study.

Working with multiple computers and input devices was the other area of exploration, which was broken down into smaller manageable areas. The design framing from the literature looked at the implications of information display that included; adjustable mounting brackets for flat screens and ideal screen sizes, alternatives to the flat screens such as digital projectors, which have become very popular (2015), and switching devices (auto and manual). The design framing from the observations looked at the implications of using multiple screens and input devices such as, multiple keyboards and mouse, by a single user. However the design framing requirements and nature of this study suggested that the implications of using multiple input and feedback devices are ideal for the exploration within the design framing, which proved to suitable for the design pilot study.

The design pilot study consisted of a device identifying method, which was conducted in the SALT control room along with testing, within the limitations of its environment, and within the allocated time frame of the project. The device identifying method would be accomplished with the use of colour, as it was found that adding colour to the computer screen frame, keyboard, and mouse respectively would prove to be a sufficient design intervention. This was accomplished with the use of self-adhesive vinyl and would be tested for a specified period and thereafter evaluated by the users. This would provide sufficient data to determine if a large scale design intervention would positively impact the socio-technical system of a control room.

Finally, additional concepts and features, which could help support the users work practices were explored further in appendix D as the users and research provided excellent ideas. This included the expansion of the audio notification system including a visual, the mounting of the screens and laptops on adjustable brackets and their positions, and a brief look at the inaccessible power outlets. These potential improvements were compiled into a single poster (Appendix E) to indicate a clear overview and potential improvement of the user input system for the control room upgrade at SALT, which may be taken further as an external project to this one.

Chapter 6: Design Pilot Study Analysis and STS Synthesis

6.1 Introduction

Feedback from the users on the design pilot study is compiled and analysed in the follow section and the results would show if a large scale design intervention in a control room setting would in fact have a positive influence on the socio-technical system, answering the third sub question.

The explorations from the design framing found medium sized LCD or LED computer screens on adjustable mounting brackets to be better suited for the control room environment compared to alternative display methods however this was not practical for the design pilot study. The necessity for an unobtrusive device identifying method was noted as a key problem area, which would have the greatest impact to the third level of the socio-technical system as well as being practical as a design pilot study. It would therefore be deemed fit to explore and prototype a device identifying method for the design pilot study. The co-design and prototyping of a device identifying method was conducted in the SALT control room. Contextual design was used for testing within the SALT control room environment. The device identifying method was achieved using colour, as it was found adding colour to the input and computer displays respectively created a viable design solution for prototyping and testing within the nature of the design pilot study. Additional concepts and features, which would help support the users work practices were also explored however added as appendix D as they did not fit into the mould of the design pilot study. This included the expansion of the audio notification system, a visual notification display, and mounting methods.

The following section will discuss the evaluation of the prototype. The evaluation will cover two subsections; the description of the samples and respondents, and the analysis of designs and prototypes, and an analysis of problems with existing approaches to Socio-Technical Systems design juxtaposed to the research and finding of the design pilot study.

6.2 Design Pilot Study Analysis

6.2.1 Description of the Samples and Respondents

The colour coding of the input devices was prototyped as previously discussed in Chapter 5. The colour application was left on the devices for the users to use for a period of time, which would allow them to note any differences in their activities. After several months, feedback was gathered from the astronomers, however, this was challenging as the user group was very small and not all of the astronomers were involved in the project. A description of each area was collated and compiled in an overview poster see Appendix E, which was sent to the users along with a questionnaire. See Appendix F and G for responses. One user responded with an image via email, which is discussed further in the design pilot study analysis. Feedback was collected on each area however only the area used in the design pilot study is focused and the rest can be found in appendix D. See Appendix E for visual with description of each area however it must be noted that only number four, *Reduced Confusion of Multiple Inputs,* was used for the design pilot study.

6.2.3 Descriptions of Design Pilot Study *(Multiple Display and input device)*

One of the largest negative impacts on the work practice of a single user is the use of multiple computers. The user often confuses the mouse, keyboard, and display, which is frustrating and creates a poor work flow for the user. After a few brainstorming and co-design sessions, it was found that the best manner in which to overcome this particular problem is by colour coding and matching the display, keyboard, and mouse. It was simple yet effective in comparison to the other options, which involved crafty technical solutions but with the downfall of having more parts to a system that could potentially fail. Therefore the colour coding was ideal for the design pilot study. This change did not add additional steps or require the need for instructions and was perceived by the user subconsciously.

6.2.4 Respondents Feedback

The following section will only discuss the results from the feedback on the design pilot study (*Multiple Display and input device*); see 3.4.2 User Testing/Feedback Mechanism in Chapter 3 and the other three areas can be found in appendix D section 5.

The respondents noted that this would provide an average improvement, and would provide an excellent improvement to the users work practices respectively. The respondents were able to test the prototype over a few months and noticed a significant help in reducing the confusion, even though the improvement is modest. They stated that it had definitely been useful to them and their work practices. Another respondent simply stated that the colour coding was working very well. Over all the respondents found the prototype testing extremely helpful. The engineer said that he has not had the time to continue with any further control room upgrades however he has explored some minor items as part of the original proposal of implementing large UltraHD (UHD) screens (Rabe, 2015), which would fall in this key area of the control room. The engineer explained that the colour coding was a marvellous idea and he noted a reduction in device confusion.

6.2.5 Analysis

Analysing the design pilot study using the feedback received and the research conducted is discussed systematically on the multiple device input design concept, which was prototyped and tested at SALT. This is discussed in the following section, to determine if a large scale design intervention within a control room setting would in fact have positively impact the socio-technical system of a control room.

6.2.5.1 Prototype Analysis, Astronomers and Operators Perspective

The colours were not accepted by some individuals due to personal colour preferences; however this did not affect the effectiveness of reducing device confusion. Participant one stated that: “The colour coding has worked very well and has made my work easier.” One of the users felt comfortable enough to draw black dots onto one of the input devices (mouse), which was covered in red vinyl, as it looked like a ladybug, see Figure 6.1. The users were a part of the design process and felt a sense of ownership and that their contributions to the project were valuable. This gave the users ownership of the outcomes and allowed them to add to the design concept right into the prototyping and testing phase. This is especially important when applying co-design methods as the active involvement of the user, the use of their ideas, and input in the design process is of great importance.

6.2.5.2 Prototype Analysis Engineering perspective

The engineer reported that they were investigating the implementation of a matrix switch or splitter device, which would allow for the integration of all the different computers. Nevertheless the engineer is not hundred percent sure that this device is appropriate for the control room context. He stated that adding colour to the devices has definitely made an improvement in a simple and low cost manner, and that the matrix switch or splitter device would disturb the users work flow unlike the colour coding system, which does not add any additional steps to the work.

6.2.6 Design Pilot Study Outcome

The goal of the design pilot study was to determine if the knowledge learned from the ethnographic study conduct in this research could be applied to a design approach to improve the socio-technical system of a control room. This was achieved using a design pilot study of which the results and analysis of the results undoubtedly shows a positive improvement in the control room when using a design approach, noted by all users of the test. The design pilot study, although small and of low fidelity prototyping clearly showed improvement suggesting that a large scale design intervention in a control room environment, not just SALT, would in fact be viable.

Figure 6.1, Ladybug Styled Mouse by User
(Colmenero, 2014)

6.3 Analysis of STS Implication

6.3.1 Reiteration of Socio-Technical Systems

As discussed in Chapter 2, Socio-Technical Systems described the complex interactions between humans, machines and the environment. This is true for most technologically advanced systems in today's time (Baxter & Sommerville, 2009: 2). STS was not applied to the SALT control room system, which resulted in it meeting the technical requirements, yet failing to meet the goals of the users, and therefore the system was not running optimally as it did not provide support for the real work.

According to the four information levels of STS, it is clear that design pilot study fell within the third level, Cognitive, in the discipline of psychology, nevertheless the design pilot study did contain elements which fell within the other STS information levels (Whitworth & Ahmad*,* 2002). STS was an appropriate framework for this research project as it provided a solid foundation with excellent guidelines from the research, design framing, design pilot study, and evaluation nonetheless STS is not a perfect framework and problems were encountered with its use.

6.3.2 Socio-Technical Systems Design Evaluation

The following section will look at the problems with existing approaches to Socio-Technical Systems design and the relation to the project, where appropriate.

6.3.2.1 Conflicting Value Systems

The ethnographic view focuses on a very personal, making meaning through experiencing – putting the person in the middle, while the STS framework focuses on putting the relationship between the individual and technology/system in the middle creating a potential conflict between the two. However this project used a design ethnographic study to inform the human part of the STS perspective, which helped in the understanding of the system/relationship, and thus not creating conflict between the two approaches.

According to the four levels discussed in the previous section, one can see that this project falls within the third level, cognitive; in the discipline of psychology. Nevertheless the project does contain elements that fall within the other levels as well (Whitworth, 2006: 533). The mechanical level does have room for improvement, which is linked to improving the work practices for the users yet the research is broader than just that level as it is suggested by Socio-Technical Systems framework (Baxter & Sommerville, 2009: 3). Looking at social systems and how they are constantly evolving through change, the control room is also evolving through equipment upgrades of equipment and the constant change in users. There is a clear need to address these two areas in a manner that considers all the different levels and how to improve the system holistically. According to the description of the third level, the control room is an ideal environment for STST to be applied.

The designer focuses on the work life of the user and how the designer can improve the quality and job satisfaction for the user, a good work practise. It has been noted that there is a direct relationship to the improvement of the users working life, to the increases in productivity which will automatically generate added value for the company (Maguire, 2013: 167). In the early days of STS design, the design and deployment of a system particularly favoured the use of humanistic principles (Baxter & Sommerville, 2009: 9). The second key area focused on the managerial values. This area uses socio-technical principles to focus on helping the company achieve its objectives, especially the company's economic objectives (Whitworth & Ahmad*,* 2002). Humanistic objectives are often undervalued as they have limited inherent value; nevertheless if they help the users work performance, which affects the company in a positive manner, they can be extremely beneficial to the company.

Even though the humanistic approach of STS design may be somewhat of a problem for large corporations chasing large financial goals, it is a different case regarding SALT and other smaller scale control rooms. The SALT telescope may not be a company with economic objectives however SALT can benefit greatly from STS design from a humanistic approach. The improved working quality and job satisfaction would potentially result in more research being conducted in the same duration of time. This increase in research will help keep SALT at the forefront of its field.

The aim of the project was to verify if a design intervention could have a positive impact on the work practice of a control room system, which was best approached thorough STS where design ethnography informed the human side of the STS while focusing on problem areas. By applying a STS framework to the study, the way in which the control room environment is perceived, how it is understood, and what they mean is approached differently and has holistically impacted the findings and results.

6.3.2.2 Lack of Agreed Success Criteria

STS has had significant design theorising yet there is a lack of successful examples which have been published. As a result of the lack of publications, there has generally been even less written on the evaluation of the efficacy of using STS design approaches (Baxter & Sommerville, 2009: 10). It has however been noted that the existing STS theories are not ideal for empirical testing as they can be too vague. Most design projects that apply STS design methods often focus the research heavily on the system design rather than evaluation, contributing to the lack of success criteria, yet this is not always the fault of the researcher, as many projects need to run for extended periods and funding such projects can be challenging (Whitworth & Ahmad*,* 2002).

Social elements are difficult to evaluate against any criteria and for STS this is no exception, unlike the technical system, which can be assessed against appropriate criteria with the use of benchmark tests (Baxter & Sommerville, 2009: 10). Some of these assessing criteria are; the change in levels of absenteeism, improvements in health, and increases in productivity, nonetheless these factors are influenced by other external factors, which makes it difficult to measure the changes as a result of the new designed system (Land, 2000: 119).

STS looks at the social system, which also includes various stakeholders, particularly operators, middle management, and top-level management, and they have varying perspectives of the criteria for success of the system (Land, 2000: 122). This makes it difficult to define an accurate evaluation, which can be used for other studies.

There have been similar problems in other fields such as Human Computer Interaction, where the cost versus benefits of implanting STS design methods are not well perceived, nevertheless demonstrating its cost effectiveness should be an important goal (Baxter & Sommerville, 2009: 10).

The design pilot study at SALT also encountered the same problems as mentioned above, evaluation criteria were difficult to establish because of the social aspects and lack of other STS evaluations to use as a guide or to assess against. Furthermore the technical design could be evaluated from the engineer's or technical perspective with ease, yet the users' workflow proved challenging.

6.3.2.3 Analysis Without Synthesis

STS is an excellent method for the analyses of existing systems yet these methods lack in the support of a more constructive synthesis of the process. This means STS provides a systematic analyses yet it does not always suggest a solution or an appropriate re-engineering of the system (Maguire, 2013: 168). As previously mentioned, there is a lack of recorded examples of successful use of STS especially when it comes to new types of systems, which may be a result of the envisioned world problem (Baxter & Sommerville, 2009: 10). This is a result of the difficulty of anticipating the relationships between people, technology and context in an area, which is still theoretical at the time. New systems do however bring the advantage of having the ability to learn from the previous fieldwork (Whitworth & Ahmad*,* 2002).

Using STS for analysis of the control room system proved to be effective yet it was lacking when it came to the evaluation of the STS design within the design pilot study, and this is where the design process could be brought in for a better analysis. The wide field of design means there is abundant support, other appropriate contexts, and it could suggest solutions from other areas, which can be applied to the current research project bringing about a synthesis of STS design.

6.3.3 Project in Relation to Methodology and Framework

6.3.3.1 Method

The suggested ethnographic method for environment analysis was ideal for this project as the control room was a textbook space for visual observations. The SALT control room was a closed space with specific users doing almost all of their work within the space, and a video camera could easily and safely be set up for observations. Opening and closing or checking on a telescope abnormality was the only action that needed to be conducted outside of the control room however still within the telescope building. The suggested form of data collection with video recording is technically ideal for the control room, although socially, it was problematic in some instances.

The researcher arrived at the SALT control room and was ready to record the users performing their duties, however one of the users refused to be filmed and an alternative method had to be implemented. Many of the users were apprehensive about consenting to any form of visual recording, as they were concerned about the footage being uploaded to a social-media platform. They were reassured that the research would only be used within the project parameters. Subsequently the users were in favour of images being taken.

The rise of social-media has clearly affected the use of ethnographic methods as users become fearful around the misuse of the digital imagery and video, which could affect their personal lives.

Unable to video record, observations were recorded on an electronic document where the time and events were logged. Although this method was not ideal as finer details within the control room could have been missed. The log was quicker to process and used far less storage capacity, and combined with photographs, this gave very good insight into the users and the control room. It was easy to recognise patterns in the work and reflecting on the observations over 5 days, Table 3.1 in Chapter 3, Data Collection Methods and Dates, as the video recording would have become monotonous and time consuming to analyse. Ethnography also suggested that interviews be conducted, some of the users were happy with being video recorded in an interview, which allowed for better interaction between them and the researcher (Hoey, 2014: 5). This was done for the co-design session as well. Some interviews with other users were voice recorded and later analysed, which removed the need for distractive note taking.

The analysis of the design pilot study was challenging as there is a lack of published STS design cases and even fewer analysis as mentioned earlier in this chapter (Maguire, 2013: 168). The technical system was less problematic to analyse as there are criteria, which the evaluation can be based on, however the social system encountered a different story.

6.3.3.2 Design

The control room, being a system had various subsystems and all of them could not be explored nor were they appropriate for the design pilot study. A potential few key areas had to be selected from the observations and explored further through design framing for an appropriate design pilot study. It was found that reducing the confusion of multiple input devices would have a great impact in the users' workflow and was the most practical for the nature of the design pilot study. Nevertheless three additional areas were explored on a theoretical basis to show and support the customisability of the STS. The control room had a weekly rotation of users who had their own requirements according to their ergonomics and feedback preferences for the control room, helping the design pilot study reach more users for greater impact and feedback.

Identified problems were presented to the user, and with the use of co-design, within the context of the control environment, ideas to improve the problem areas were developed. This had a few challenges as there were only three users available at the time, two astronomers and one telescope operator. The group size allowed for good sharing of ideas and developments, yet it limited the variety of the input, which would have happened with a larger group, but the risk losing the quieter user was greater. The co-design session proved to be a good method as many of the ideas came from the users as they are the experts in their work.

A comparison of the expectations versus the real events of the co-design session is compared for clarity on the process. The researcher clearly explained to all participants what the co-design session would entail and gave them the option to opt out of the session before starting and at any time they no longer wanted to participate for any particular reason. Permission was gathered for the recording of the co-design sessions and participants were fully aware and had the option to stop the recording at any time. This all took place as predicted in the methodology.

The sessions ran smoothly and the participants required minimal guidance however, the researcher/designer had to refine the ideas and develop them further for the design pilot study, which was implemented and analysed later.

6.3.3.3 STS Framework

The customisation of the control room, where appropriate, theoretically created happier users who were more comfortable, and therefore could work more efficiently producing more research from the telescope. This was difficult to analyse as the published agreed upon criteria was scarce.

Upon finishing the design pilot study and analysing it, it is clear that the relation of the design and the STS hierarchy of information system levels are strong. The current problems with STS design were confirmed with this project and the gap is clearly present. The need and development for social criteria evaluation within STS is problematic. The research has exposed problems with this framework, as socio technical interactions become integrated throughout complex working environment.

The proposed design improvements and the design pilot study sit in the mechanical level, which affects the cognitive and social levels while the information level remains untampered. The connection between the mechanical and the social levels was achieved though customisation of the mechanical level. Socially the individual users had different preferences yet it did not always mean that it was the best setup for good work practices. Referring to the theoretical input/feedback customisation solution, the users could learn from each other's personal style of setting up the control room and refine their own set up, hence the social system and the relationship with the mechanical working as a STS.

6.4 Conclusion

The research results explored three main areas namely; the design pilot study analysis, framework analysis, and the project in relation to the STS framework. The design pilot study analysis looked at the description of the samples from the respondents, which were received via email and online surveys. The responses were broken into four key areas however only the response on design pilot study, reduced confusion of multiple inputs, was included, explored and described in the previous chapters. Feedback was gathered from the astronomers who are the primary users of the control room, yet it also included feedback from an engineer who gave an engineering perspective on the design pilot study and additional concepts. The feedback on the design pilot study showed a positive outcome as it had changed the users work practise for the better, despite the engineers' research into other solutions to reduce confusion of multiple inputs. The research showed problems with the route which the engineer was exploring, nevertheless the colour coding, even if temporary, appeared to positively impact, to some degree, the control room STS levels.

The STS framework analysis was divided into two sections, which looked at a reiteration of Socio-Technical Systems that recapped the framework of STS from Chapter 2, and the second section focused on the STS design evaluation. This explored the problems with existing approaches to STS design and its relation to the project. To make sense of the problems of STS, they were discussed over three sub sections; conflicting value systems, which looked at the humanistic principles, versus the managerial values. The second area focused on the lack of agreed success criteria, where STS has had significant design theorising, yet there was a lack of successful published examples.

Lastly, the research results explored the project in relation to the STS framework; the method, the design, and the framework. The project found that the ethnographic method for the control room analysis was ideal even though minor problems were encountered. The outcomes clearly indicates that a control room system can potentially be positively improved though the application of design thinking and design. It also exhibited signs of improving areas of the SALT control room that fell within different STS levels. This suggests that the application of design interventions in similar control room systems would potentially impact the environment positively and that it is beneficial to conduct further large scale design work in this area, thus answering the third sub question.

Chapter 7: Conclusion and Implications

The study was set out to; observe, study, and analyse the control room of the Southern African Large Telescope (SALT), and determine if further design intervention would have a positive impact on the interaction of a control room system. The ethnographic study has identified some key problem areas throughout the STS levels, including user dissatisfaction and poor work practices. The study has also sought to discover whether an ethnographic study of work practice within a control room system can support the design of socio-technical interactions. The literature on this subject and specifically in the context of South African astronomy is lacking even though SALT is a state of the art telescope at the forefront of international optical astronomy. The study sought to answer a main research question, which was supported by three sub-questions through the use of; ethnographic observations, design framing, and a design pilot study:

1. How do the SALT astronomers and operators currently work in the SALT control room?
2. What is the challenge experienced by the SALT astronomers and telescope operator?
3. How can a control room environment be designed to support a more efficient work practise?

After discussing the design pilot study analysis and STS synthesis, in Chapter 6, this chapter will provide a synthesis of the observed findings from the study, with respect to the separate research questions and their answers, respectively. The framework implications have provided a contribution to the syntheses with respect to the research questions and how they have impacted on existing theories and understandings. The policy implication will explore the position of this study against the main STS framework, an understanding on the research bases, and how this study could influence the debate. While researching the topic, some areas provoked more questions than answers consequently pointing to areas of recommendations and further research. This also identified various limitations of the study that were encountered within the research, and finally concluding the project.

7.1 Reflection on Research Questions and Findings

This section will reflect on the findings and summarise the answers to the study's three sub-questions and in support to answering the main research question; "What are the design principles of supporting socio-technical interactions within a control room environment?"

The following three sub questions helped build and answer the main research question, which was found not only in the mechanical Information system levels but included addressing the social level by means of improving the mechanical level.

The first sub question; "How do the SALT astronomers and operators currently work in the SALT control room?" The objectives of this question where to explore, understand, and uncover the astronomers' perceptions of their working environment, the input and feedback systems, and its socio-technical system, which was achieved with the use of design ethnography. Design ethnography was utilised, as it lives in "problem spaces", to better understand a control room space and its socio-technical system, where the SALT control room was used. This question was used to determine and understand the users' perceptions of their working environment, the control rooms technological and social aspects, its input and feedback systems, as well as the users' needs, expectations, and experiences. The design ethnography informed the human aspect of the STS frame work, which produced enough data to gain the knowledge required to better understand and uncover problem areas within a control room system. This was addressed in Chapter 4, *Findings and Analysis*. The study aimed to observe without being intrusive, aiming to gain a non-bias (as far as possible) understanding of the SALT control room environment.

The second sub question; "What is the challenge experienced by the SALT astronomers and telescope operator?" The objectives of this question where to frame a feasible design pilot study that would underpin a design, using the knowledge gained from the observations. Identified challenges noted by users, and through observation, was utilised to underpin a design of work practice in the control room. An analysis of the findings, found in Chapter 4, explored the identified common problem areas, or themes, which will lead to a poor control room environment despite it being technically advanced. Using design framing from the knowledge gained, the project set out to establish a feasible design pilot study.

Finally, the third sub question; "How can a control room environment be designed to support a more efficient work practise?" The objectives of this question were to determine, through the use of a design pilot study, the role of embedded understanding of environments before embarking on a design intervention, and that design (if user driven) can contribute to 'improved' control room spaces. The results from the design pilot study indicate that the application of a design intervention to a control room environment could potentially impact the space positively and reduce frustration, improve comfort, increase efficiency in the users work practices, and ultimately amplify productivity. By applying a UCD approach within a STS framework while designing a control room environment, it can be designed to support a more efficient work practise.

By collating the answers to the sub questions an answer to the main research question, "What are the design principles of supporting socio-technical interactions within a control room environment?" Irrespective of the various limitations that the study encountered, the successful ethnographic study gathered sufficient data where the use of holism and descriptive methods in analysing the data collected; of the users, the environment, and their interaction with one another, identified that the lack of UCD in the SALT control room environment has hindered the users and there work. With the use of a socio-technical framework, this study identified the relationship between the STS framework and the empirical findings, and that the application of a design intervention could potentially result in improvements of the users work practices. Therefore the application of a UCD approach within a STS framework while designing a control room environment would indeed support the socio-technical interactions within the work space.

7.2 Contribution to Theory

The additional cases for STS needs to be revisited in order to further understand the SALT control room system and how it can be made more user-centred with an improved work practice. The STS framework describes the complex interactions and relationships between humans, machines and the environment (Baxter & Sommerville, 2009). This framework looks at more than the technical system; it includes the social and computer systems and the relationship between the two. By not applying the STS design principles to the system, it usually results in a system that meets the technical requirements yet fails to meet the goals of the organisation; therefore the system can be considered inadequate as it does not provide support for the real work (Whitworth, 2006).

The study has added to the understanding of the importance of STS in a control room system, however it has also revealed its weakness, such as the lack of agreed upon analysis criteria in STS (Land, 2000). This weakness needs further development by substantiating the problem areas. SALT has a unique control room in comparison to the other telescopes at the SAAO observatory. It is however noted from this study that the problem areas and focus on one particular telescope control room may prove to be difficult to transfer to another telescope control room. Nevertheless, the concepts may be refined through the use of STS, as all telescope control rooms are based on a system with human and non-human systems, remotely operated telescopes included.

7.3 Policy Implication

One particular policy program with extended STS framework underpinnings that where the approach of the SALT control room, which was an ideal environment for such a policy due to the control room's human and non-human systems and their relationship. However, evidence from several studies, including (Whitworth, 2006) and (Trist, 1981) and this thesis, note that the system meets the technical requirements of the environment yet fails to be user centred resulting in an inadequate work environment. Therefore the control room environment can be considered incomplete as it does not provide real work support, as described by Baxter (Baxter, & Sommerville, 2009).

This study has used empirical findings to show that the current SALT control room policy is not making the anticipated impact. The STS framework arguments for this justification suggest the need for policy review, which could potentially enable improvement in the efficiency of the work practises in all STS information system levels, particularly the sociology level (Whitworth, 2006). It is appropriate to say that the research findings and design pilot study, generated as part of this thesis, prove that a further design intervention could potentially have a positive impact on the interaction of a control room system.

7.4 Recommendation for Future Research

The scale of this discussion is extensive and multi-layered, even at the local astronomy level, as the research, in some areas, produced more questions than answers. To generate achievable policy strategies and development targets with regards to telescope control room and its STS. There is a need for further studies and analyses at the local level to allow for further exploration and assessment of the different layers of this project, specifically UCD driven intervention of a control room system. Exploring the following in future research projects may facilitate the attainment of this goal:

- The engineers wanted a redesign of the control room space; desks, chairs, carpeting, lighting, power outlets, room layout, however this all falls within the field of Interior Architecture Design (dealing with the interactions of the people in a space that has structural boundaries). The observations clearly noted the space being poorly designed, and research into the layout of the space, and a redesign by a consultant from the field of Interior Architecture can possibly take this further.

- On a software level, the SALT control room system is very crude. The software interfaces are very basic in design, with a *Windows 95* styling. This can be developed and improved through the use of user-centred design. The users noted that they are not too concerned with the visual appearance of the interface as long as it functions correctly. Nonetheless it is speculated that a visual and interactional improvement of the interface would affect the user's experience of their work in a positive manner, hence increased productivity.

- It is recommended for future action that when Socio-Technical Systems has gained better agreed upon social analysing criteria, it would be appropriate to revisit this project for further social analysis.

7.5 Limitation of the Study

The study has offered an explorative perspective on the relationship between the users' systems and the technological systems within a complex control room environment, SALT. A direct consequence of the selected methodology is that the study encountered a number of limitations that need to be considered. The location of SALT posed some limitation to the research as the number of visits were limited and spread out over a period of time, yet this forced the research to be well planned and executed efficiently.

During the ethnographic observations, video recording was anticipated as the primary method for data collection on the users and their environment, however due to user's not consenting to the use of video recording it was not possible. On the other hand, users agreed to the use of photographic documentation. Photographs in combination with field notes (event logs) replaced the usual videography as a means of observational data capturing, which produced satisfactory data for the analyses. This proved to be beneficial to the study as it made in-depth data analysis possible within the projects' available resources.

7.6 Conclusion

The study was set out to ascertain if a design ethnographic study of work practices within a control room system can support the design of socio-technical interactions, using the Southern African Large Telescope (SALT) control room. Irrespective of the various limitations that the study encountered, the design ethnography informed the human aspect of the STS frame work, which produced enough data to gain the knowledge to better understand and uncover problem areas within a control room system.

The framework and policy debates concerning the rapid development and integration of complex human and non-human systems into larger systems are becoming common practice. However the operation of the SALT telescope and the research being conducted by the astronomers, is clearly hindered by poor control room design, which is also true for many other control room environments. With the use of a socio-technical framework, this study identified the relationship between the STS framework and the empirical findings, and that the application of a design intervention could potentially result in improvements of the users work practices. This offered clear identification of the prevailing, and persistent lack of awareness regarding the relationship between the social and mechanical systems. The results from the design pilot study clearly show that the application of a design intervention to a control room environment could potentially impact the space positively and reduced frustration, improve comfort, increased efficiency in the users work practices, and ultimately amplified productivity. Therefore this study possibly provides an appropriate starting point for the exploration of possible solutions for the identified challenges experienced in complex control room environments, more importantly it contributed to narrowing the socio-technical gap, between the engineering and research departments of a leading international optical telescope, SALT.

List of Reference

3LCD 2015. Projector Basics. *3LCD Business Centre*. [Online]. Available: http://www.3lcd.com/find/basics.aspx. [28 July 2015].

AFSCME 2015. Injuries Caused by Poor Ergonomics. *AFSCME.* [Online]. Available: http://www.afscme.org/news/publications/workplace-health-and-safety/safe-jobs-now-a-guide-to-health-and-safety-in-the-workplace/chapter-7-ergonomics-preventing-strains-sprains-and-back-injuries/injuries-caused-by-poor-ergonomics. [28 July 2015].

Altheide, D. 1987. Ethnographic Content Analysis. In: Pacific Sociological Association. *Draft Proceedings of the 1987 Annual Meeting of the Pacific Sociological Association, Albuquerque, 17—20 April 1985*. Edited by: R. Emerson, & S. Reinharz. *Arizona State*: SATI: 65-77. [Online]. Available: http://www.public.asu.edu/~atdla/ethnographiccontentanalysis.pdf. [20 October 2015].

American Museum of Natural History 2007. The Shining Star of South African Astronomy. *American Museum of Natural History*. [Online]. Available: http://www.amnh.org/explore/science-bulletins/astro/documentaries/salt-imaging-the-southern-sky/the-shining-star-of-south-african-astronomy. [15 June 2013].

Arbesman, S. 2014. Human Ingenuity has Created a World that the Mind Cannot Master. Have We Finally Reached Our Limits? *Aeon Media Ltd*. [Online]. Available: http://aeon.co/magazine/technology/is-technology-making-the-world-too-complex/. [21 July 2015].

Bachynskyi, M., Palmas, G., Oulasvirta, A., Steimle, J., Weinkauf, T. 2015. Performance and Ergonomics of Touch Surfaces: A Comparative Study Using Biomechanical. *Aalto Comnet Users.* 1-10. [Online]. Available: http://users.comnet.aalto.fi/oulasvir/pubs/pn2629-bachynskyiA.pdf. [17 July 2015].

Baskerville, R.L. & Myers, M.D. 2015. Design Ethnography in Information Systems. *Info Systems*. 25: 23-46.

Baxter, G. & Sommerville, I. 2009. Socio-Technical Systems: From Design Methods to Systems Engineering. *Interacting With Computers.* 1-30. [Online]. Available: http://archive.cs.st-andrews.ac.uk/STSE-Handbook/Papers/SociotechnicalsystemsFromdesignmethodsto systemsengineering-BaxterSommerville.pdf. [15 July 2015].

Bergsteiner, H., Avery, G.C., Neumann, R. 2010. Kolb's Experiential Learning Model: Critique from a Modelling Perspective. *Studies in Continuing Education*. 31(1):29-46. [Online]. Available: http://eds.a.ebscohost.com/eds/pdfviewer/pdfviewer?vid=3&sid=ad8cc07f-124f-4bdc-a2c3-90de2f3ccead%40sessionmgr4001&hid=4110. [17 August 2015].

Bhalla, M.R. & Bhalla, A.V. 2010. Comparative Study of Various Touchscreen Technologies. *International Journal of Computer* Applications. 6(8): 0975 – 8887. [Online]. Available: http://ijcaonline.net/volume6/number8/pxc3871433.pdf. [24 July 2015].

Blomberg, J. 1993. *Ethnographic Field Methods and Their Relation to Design.* [Online]. Available: http://scholar.google.co.za/scholar?cluster=2669370986154375444&hl=en&as_sdt=0,5. [28 September 2013].

Brumitt, B., Meyers, B., Krumm, J., Kern, A., Shafer, S. 2000. EasyLiving: Technologies for Intelligent Environments*. Handheld and Ubiquitous Computing.* [Online]. Available: http://www.eecs.wsu.edu/~holder/courses/cse6362/pubs/brumitt00.pdf. [17 July 2015].

Buckley, D. Lombard, M. Lomberg, M. Meiring, K. and Theron, R. 2005. *Africa's Giant Eye.* South Africa: SALT Foundation (Pty) Ltd.

Buckley, D., Schindler F., Gajjar, C., Levequed, S., Menzies, J., Sändig, K., 2008. A Novel Optical Sensor for Mirror Edge Sensing. *European Organisation for Astronomical Research in the Southern Hemisphere*. [Online]. Available: https://www.eso.org/sci/libraries/SPIE2010/7739-128.pdf. [01 August 2015].

Burmeister, O.K. 1999. Usability Testing: Revisiting Informed Consent procedures for testing Internet sites. *Swinburne Computer-Human Interaction Laboratory*. [Online]. Available: http://crpit.com/confpapers/CRPITV1Burmeister2.pdf. [17 August 2015].

Butscher, S., Mueller, J., Reiterer, H., Schwarz, T. 2012. Content-aware navigation for large displays in context of traffic control rooms*. Proceedings of the 2012 International Working Conference on Advanced Visual Interfaces, Germany, 2012.* Edited by: Tortora, G., Levialdi, S., Tucci, M. New York: SATI: 249-252.

Canada, Government of Ontario, 2004. *Computer Ergonomics: Workstation Layout and Lighting.* Ontario: Queen's Printer. [Online]. Available: http://www.labour.gov.on.ca/english/hs/pdf/gl_comp_erg.pdf. [28 July 2015].

Chamorro-Koca, M., Popovica, V., Emmisonb, M. 2009. Human experience and product usability: Principles to assist the design of user–product interactions. *Applied Ergonomics*. 40(4): 648-656. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0003687008001026. [17 July 2015].

Clair, R. 2003. *Expressions of ethnography*. Albany, NY: State University of New York Press.

Cocilova, A. 2013. Live la vida wireless with Windows 8-optimized keyboards and mice. *PC World*. 31(11): 73-79. [Online]. Available: http://eds.b.ebscohost.com.ezproxy.cput.ac.za/eds/pdfviewer/pdfviewer?vid=2&sid=888beb7c-2b96-484b-8d97-c009a646fc60%40sessionmgr110&hid=111. [17 July 2015].

Cotytech 2015. Expandable Dual Monitor Desk Mount Spring Arm Quick Release. *Cotytech*. [Online]. Available: http://www.cotytech.com/content-product_info/product_id-2020/expandable_dual_monitor_desk_mount_spring_arm_quick_release.html. [28 July 2015].

Cruickshank, L., Coupe, G., & Hennessy, D. 2015. Co-Design: Fundamental Issues and Guidelines for Designers: Beyond the Castle Case Study. *Swedish Design Research Journal*. 2(13)48-57. [Online]. Available:

http://svid.se/upload/Forskning/Design_Research_Journal/Design_Research_Journal_nr_2_2013/Forskningsartiklar%20DRJ%202/10.3384svid.2000-964X.13248.pdf. [10 August 2015].

Davis, Z. 2015. Microsoft Kinect for Xbox 360. *PCMag Digital Group*. [Online]. Available: http://www.pcmag.com/article2/0,2817,2372069,00.asp. [28 July 2015].

De Bono, E. 1970. *Lateral Thinking*. London: Penguin Books Ltd.

Deane, P. 1979. *The First Industrial Revolution.* Cambridge University Press. [Online]. Available: http://books.google.co.za/books?hl=en&lr=&id=eMBG_soDdNoC&oi=fnd&pg=PA1&dq=the+1760+industrial+revolution&ots=t1HSaCMxwI&sig=kLAx9wU0TbURbOXtP70rtitlfmg#v=onepage&q=the%201760%20industrial%20revolution&f=false. [30 November 2014]

Design Council 2015. Design Methods. *Designcouncil.* [Online]. Available: http://www.designcouncil.org.uk/news-opinion/design-methods-step-1-discover. [19 July 2015].

Design for humans 2007. Affordances in Product Design. *Design for humans*. [Online]. Available: http://www.designingforhumans.com/idsa/2007/11/affordances-in.html. [17 July 2015].

Digital Design Standards 2015. Why Designing for Accessibility is Simply Good Business. *Digital Design Standards*. [Online]. Available: http://digitaldesignstandards.com/standard/accessibility/designing-accessibility-simply-good-business/. [17 August 2015].

DirectShop 2011. Up to 24" 10kg Tilt Swivel Arm Single LCD Screen Monitor Wall Mount VESA. *Selby Acoustics*. [Online]. Available: http://www.selby.com.au/monitor-wall-mount-dual-monitor-height-adjustable-wmm020.html. [20 October 2015].

Dudek A. 2011. What is a Design Ethnographer?. *Thinking about the future & ethnography*. [Online]. Available: https://aliciadudek.wordpress.com/what-is-a-design-ethnographer/. [19 April 2016].

E.S.R.C 2015. Framework for Research Ethics (FRE). *Economic & Social Research Council*. [Online]. Availablehttps://www2.le.ac.uk/departments/archaeology/documents/ESRCETHICS%20revised%202010.pdf. [17 August 2015].

Echtler, F., Huber, M., Klinker, G. 2008. *Shadow Tracking on Multi-touch Tables Interfaces.* [Online]. Available: http://dl.acm.org/citation.cfm?id=1385640. [25 October 2013].

Elizabeth, B.N., Sanders, E., & Stappers, P. 2008. Co-creation and the New Landscapes of Design. *CoCreation in Design and the Arts*. 4(1):5-18. [Online]. Available: http://www.tandfonline.com/doi/abs/10.1080/15710880701875068. [30 August 2015].

EnchantedLearning 2015 b. Enchanted Learning All About Astronomy. *Enchanted Learning*. [Online]. Available: http://www.enchantedlearning.com/subjects/astronomy/glossary/indexo.shtml. [08 August 2015].

EnchantedLearning 2015. Enchanted Learning All About Astronomy. *Enchanted Learning*. [Online]. Available: http://www.enchantedlearning.com/subjects/astronomy/glossary/indexo.shtml. [08 August 2015].

Epec Engineered Technologies 2014. The Technology within Touch Panels. *ApplianceDesign*. [Online]. Available: http://eds.a.ebscohost.com.ezproxy.cput.ac.za/eds/detail/detail?vid=2&sid=212e 20be-c2bd-4802-a287-5e429df00aa5@sessionmgr4004&hid=4113&bdata=JnNpdGU9ZWRzLWxpdmU=#db=f5h&AN=95422444. [24 July 2015].

Erasmus, S. 2015. New Horizons for SALT. *SALT*. [Online]. Available: http://www.salt.ac.za/news/new-horizons/. [01 August 2015].

Ergodirect 2015. Ergotron LX Wall Mount Notebook Arm, ED-NB-LXWM. *Ergodirect*. [Online]. Available: http://www.ergodirect.com/product_info.php?products_id=16147. [28 July 2015].

Evenson, S., Forlizzi, J., and Zimmerman, J. 2007. *Research through Design as a Method for Interaction Design Research in HCI.* [Online]. Available: http://dl.acm.org/citation.cfm?id=1240704. [01 October 2013].

Fast Company 2016. Infographic: The Intricate Anatomy Of UX Design. *Fastcodesign.* [Online]. Available: http://www.fastcodesign.com/1671735/infographic-the-intricate-anatomy-of-ux-design. [30 March 2016].

Fast Company 2015. What Good Does Design Do For Business? *Fastcodesign*. [Online]. Available: http://www.fastcodesign.com/1665471/what-good-does-design-do-for-business. [20 July 2015].

Fischer, G. & Herrmann, T. A. 2011. Meta-Design Perspective. *Socio-Technical Systems.* [Online]. Available: http://l3d.cs.colorado.edu/~gerhard/papers/2010/journal-socio-ts.pdf. [10 May 2015].

Francis, R. 2015. Our Place Guide to Co-design. *Mycommunity*. 1-13. [Online]. Available: http://www.opm.co.uk/wp-content/uploads/2015/07/Our-Place-guide-to-Co-design-FINAL.pdf. [10 August 2015].

Friedman, V. & Lennartz, S. 2015. What Is The Most Underrated Word In Web Design? *Smashing Magazine*. [Online]. Available: http://www.smashingmagazine.com/2014/06/affordance-most-underrated-word-in-web-design/. [17 July 2015].

Harrison, S., Tatar, D., & Sengers, P. 2007. The Three Paradigms of HCI, *The Three Paradigms of HCI*. [Online]. Available: http://people.cs.vt.edu/~srh/Downloads/HCIJournalTheThreeParadigmsofHCI.pdf. [10 May 2015].

HDCabling 2015. 8x8 HDMI True Matrix Switch. *HDCabling*. [Online]. Available: http://www.hdcabling.co.za/8x8-ultrahd-uhd-4k-x-2k-3840-x-2160-resolution-hdmi-true-matrix-powered-switch-splitter-with-ir-remote-control-and-edid-management-hdmi-v14-3d-p-698.html. [28 August 2015].

Health and Safety Executive 2015. Control Systems. *Health and Safety Executive*. [Online]. Available: http://www.hse.gov.uk/comah/sragtech/techmeascontsyst.htm. [20 July 2015].

Health and Safety Manager 2015. Lighting in the Workplace. *Health and Safety Manager*. [Online]. Available: http://thehealthandsafetymanager.com/health-safety-help-support/healthandsafetyreferencesection/75-lighting-in-the-workplace. [01 August 2015].

Hendrickse, C. 2012. [*Notes from a conversation with Amanda Gulbis on 25 April 2013*]. Southern African Astronomical Observatory, Cape Town. (Unpublished).

Hendrickse, C. 2013. [*Notes from a conversation with Paul Rabe on 09 September 2012*]. Southern African large Telescope, Sutherland. (Unpublished).

Hendrickse, C. 2014. [*Notes from a conversation with Brent Miszalski on 26 August 2014*]. Southern African large Telescope, Sutherland. (Unpublished).

Hoey, B.A. 2014. A Simple Introduction to the Practice of Ethnography and Guide to Ethnographic Fieldnotes, USA: Marshall Digital Scholar. [Online]. Available: http://works.bepress.com/cgi/viewcontent.cgi?article=1022&context=brian_hoey. [28 October 2013].

Hsiao, S., Hsu, C., Lee, Y. 2012, An Online Affordance Evaluation Model for Product Design. *Design Studies*. 33(2): 126-159. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0142694X1100041X. [17 July 2015].

Huang, P. & Chiu, M. 2016. Integrating User Centered Design, Universal Design and Goal, Operation, Method and Selection Rules to Improve the Usability of DAISY Player for Persons with Visual Impairments. *Applied Ergonomics*. 51:29-42. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0003687015300107. [17 August 2015].

is.theorizeit 2016. Socio-technical theory. *is.theorizeit*. [Online]. Available: http://is.theorizeit.org/wiki/Socio-technical_theory. [20 April 2016].

Johanson, B., Hutchins, G., and Winograd, T. 2002. PointRight: Experience with Flexible Input Redirection in Interactive Workspaces. *Dl.acm.* [Online]. Available: http://dl.acm.org/citation.cfm?id=572019. [25 October 2013].

Kaptelinin, V. & Bannon, L.J. 2012. Interaction Design Beyond the Product: Creating Technology-Enhanced Activity Spaces. *Human–Computer Interaction*. 27(1):227-309. [Online]. Available: http://eds.a.ebscohost.com.ezproxy.cput.ac.za/eds/pdfviewer/pdfviewer?vid=2&sid=e2aba952-1bb5-4f2a-98e0-3ae3a5b3ab4e@sessionmgr4005&hid=4205. [22 July 2014].

Karray, F., Alemzadeh, M., Saleh, J.A., Arab, M. N. 2008. Human-Computer Interaction: Overview on State of the Art. *Smart Sensing and Intelligent Systems*. 1(1):137-159. [Online]. Available: http://www.s2is.org/issues/v1/n1/papers/paper9.pdf. [01 July 2015].

KaYuk Chan, C. 2012. Exploring an Experiential Learning Project through Kolb's Learning Theory Using a Qualitative Research Method. *European Journal of Engineering Education*. 37(4):405-415. [Online]. Available: http://eds.a.ebscohost.com/eds/pdfviewer/pdfviewer?vid=3&sid=ad8cc07f-124f-4bdc-a2c3-90de2f3ccead%40sessionmgr4001&hid=4110. [17 August 2015].

Kelly, J. & Matthews, B. 2014. Displacing Use: Exploring Alternative Relationships in a Human-Centred Design Process. *Design Studies*. 35(4): 353-373. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0142694X14000167. [17 August 2015].

Kensing, F., and Simonsen, J. 1997. *Using ethnography in contextual design.* [Online]. Available: http://dl.acm.org/citation.cfm?id=256190. [28 October 2013].

Kneelingofficechairs 2015. 5 Negative Side Effects of Bad Posture on Your Health, *Kneelingofficechairs*. [Online]. Available: http://kneelingofficechairs.com/understanding-back-pain/5-negative-side-effects-of-bad-posture-on-your-health/. [01 August 2015].

KOS Ergonomics 2015. Health and Safety Tips for Laptop Users. *KOS Ergonomics*. [Online]. Available: https://www.kos.ie/blog/health-and-safety-tips-for-laptop-users. [20 July 2015].

Koskinen, H., Laarni, J., and Norros, L. 2009. Activity-Driven Design Approach to the Novel Control Room Environments. *ACM.* [Online]. Available: http://dl.acm.org/citation.cfm?id=1690542. [5 September 2013].

Krishna, G. 2012. The Best Interface is no Interface. *Cooper*. [Online]. Available: http://www.cooper.com/journal/2012/08/the-best-interface-is-no-interface. [20 July 2015].

Krug S.2006. *Don't Make Me Think*: *A Common Sense Approach to Web Usability*. USA: Peachpit

Land, F. 2000. Evaluation in a Socio-Technical Context. *Organizational and Social Perspectives on Information Technology*. 41:115-126.

Leydesdorff, L. 2000. Complexity and Technology. *Science & Technology Dynamics*. [Online]. Available: http://www.leydesdorff.net/compltech/. [22 July 2015].

Lina, C., Yennc, T., Jouc, Y., Hsiehb,T., Yangb, C. 2013. Analyzing the Staffing and Workload in the Main Control Room of the Advanced Nuclear Power Plant from the Human Information Processing Perspective. *Safety Science*. 154(1): 161-168. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0925753513000441. [17 July 2015].

Lina, C.J., Hsiehb, T., Lin, S. 2013. Development of Staffing Evaluation Principle for Advanced Main Control Room and the Effect on Situation Awareness and Mental Workload. *Nuclear Engineering and Design*. 265(1): 137-144. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0029549313004196. [17 July 2015].

Linkqage 2013. *Premium Products Catalogue*. Cape Town: Lindy Connection Perfection.

Luttersa, E., van Houtena, F.J.A.M., Bernardb, A., Mermozc, E., Schutted, C. S.L. 2014. Tools and Techniques for Product Design. *CIRP Annals - Manufacturing Technology*. 63(2):607-630. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0007850614001929#. [17 July 2015].

Maguire, M. 2014. Socio-technical Systems and Interaction Design 21st Century Relevance. *Applied Ergonomics*. 45(2014): 161-170. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0003687013001233. [17 August 2015].

Mandela, N. 1995. *Long Walk to Freedom: The Autobiography Of Nelson Mandela.* South Africa: Back Bay Books.

Martin, D., & Sommerville, I. 2004. Patterns of Cooperative Interaction: Linking Ethnomethodology and Design. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 11 (1): 59-89. [Online]. Available: http://www-ist.massey.ac.nz/Plyons/Papers%20(by%20others)/HCI/Ethnography/Martin%20Sommerville%202004%20Patterns%20of%20Cooperative%20Interaction%20-%20Linking%20Ethnomethodology%20and%20Design.pdf. [14 July 2015].

Merino, G.S.A.D., Teixeira, C.S., Schoenardie, R.P., Merino, E.A.D., Gontijo, L.A. 2012. Usability in Product Design - The Importance and Need for Systematic Assessment Models in Product Development. *USA-Design Model (U-D).* 41(1): 1045-1052. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0007850615000438. [17 July 2015].

Merton, R.K. 2013. Focus Groups: Research Design, Limitations and Potential. *dostoevskiansmiles.* [Online]. Available: http://dostoevskiansmiles.blogspot.co.za/2013/04/focus-groups-research-design.html. [19 July 2015].

Mintaka 2002. The Control Room of the 40" Telescope at Mt. Laguna Observatory. *Mintaka*. [Online]. Available: http://mintaka.sdsu.edu/faculty/wfw/CLASSES/MLO/controlroom.html. [20 July 2014].

Miszalski, B. (brent@saao.ac.za) 10 June 2015. *Feedback.* [E-mail/ Online]. E-mail to Hendrickse, C. (freakylinks@mweb.co.za).

Mullen, L. 2011. It Takes More Than One Kind Of Telescope To See The Light. *NASA*. [Online]. Available: http://science.nasa.gov/science-news/science-at-nasa/1999/features/ast20apr99_1/.[20 July 2015].

Naito, T., Takano, N., Inamura, E., Hadji, A. 2011. Control Room Design for Efficient Plant Operation. *Yokogawa Technical Report English Edition*. 45(1): 33 – 36. [Online]. Available: https://www.yokogawa.com/rd/pdf/TR/rd-te-r05401-008.pdf. [21 July 2015].

National Institute of Environmental Health Science 2015. What is Ethics in Research & Why is it Important? *National Institute of Environmental Health Science.* [Online]. Available: http://courses.washington.edu/bethics/Homepage/What%20is%20Ethics%20in%20Research%20&%20Why%20is%20it%20Important_.pdf. [17 August 2015].

Norman, D.A. 2002. *The Design of Everyday Things*. New York: Basic Books, Inc.

Obal, D., & Stojmenova, E. 2013. Experience to Understand: a Methodology for Integrating Users into the Design for Kitchen Interactions. *Springer Science+Business Media*. 71: 97-117, May 2013.

Osuwomeninphysics 2013. Observing the Dark. *Osuwomeninphysics.wordpress.* [Online]. Available: https://osuwomeninphysics.wordpress.com/tag/astronomy/. [20 July 2014].

Oxlade, C. 2005. *Lighting and Sound.* (2nd edition). Great Britain: Hodder Wayland.

Pak, R. 2015. Scroll Direction, Touch Screens, Trackpads. *Thehumanfactorsblog*. [Online]. Available: http://humanfactorsblog.org/2011/03/02/scroll-direction-touch-screens-trackpads/. [20 July 2015].

Pfautz, S.L., Ganberg, G., Fouse, A., Schurr, N. 2015. A General Context-Aware Framework for Improved Human-System Interactions. *Ai Magazine.* 36(2): 42-49

Pink, S. 2001. *Doing Visual Ethnography.* London: SAGE Publications

Pink, S. 2013. *Doing Visual Ethnography.* (3rd edition). London: SAGE Publications

PriceCheck 2015. Projector lamp. *PriceCheck*. [Online]. Available: http://www.pricecheck.co.za/search?search=projector+lamp. [28 July 2015].

Quesenbery, W. 2001. What Does Usability Mean: Looking Beyond 'Ease of Use'. *Wqusability.* [Online]. Available: http://dostoevskiansmiles.blogspot.co.za/2013/04/focus-groups-research-design.html. [19 July 2015].

Rabe, P. (paul@salt.ac.za) 24 August 2015. *Feedback.* [E-mail/ Online]. E-mail to Hendrickse, C. (freakylinks@mweb.co.za).

Ramirez, R. 2009. *An Epistemology for Research Through Design Africa.* [Online]. Available: http://www.icsid.org/education/education/articles987.htm. [25 October 2013].

Ropohl, G. 1999. Philosophy of Socio-Technical Systems. *University of Frankfurt on Main*. 4(3):59-71. [Online]. Available: https://scholar.lib.vt.edu/ejournals/SPT/v4n3/pdf/ROPOHL.PDF. [28 July 2014].

Rottman, M. 2009. McDonald Observatory - Outreach and Research. *Ramblings Of An Astronomer Named Matthew*. [Online]. Available: http://mattastro.blogspot.com/2009_07_01_archive.html. [20 July 2014].

SAAO 2015. Home. *South African Astronomical Observatory*. [Online]. Available: http://www.saao.ac.za/. [08 August 2015].

Salo, L., and Savioja, P. 2006. *Practises of Process Control in Digital Control Room: Possibilities and Threats.* ACM. [Online]. Available: http://dl.acm.org/citation.cfm?id=1274916. [25 October 2013].

SALT Foundation 2015 b. Home. *SALT Foundation*. [Online]. Available: http://www.salt.ac.za/. [08 August 2015].

SALT Foundation 2015. About the Telescope, *SALT*. [Online]. Available: http://www.salt.ac.za/telescope/#telescope-control-room. [01 August 2015].

Schwarz, T., Kehr, F., Hermes, K., Harald, K. 2010. Holistic Workspace: Future Control Room Design. *Proceedings of the 2010 IADIS International Conference on Interfaces and Human Computer Interaction (IHCI 2010), Germany, 2010*. Freiburg: SATI: 305-308.

Selby Acoustics 2011. Up to 24" 10kg Tilt Swivel Arm Single LCD Screen Monitor Wall Mount VESA WMM020. *Selby Acoustics*. [Online]. Available: http://www.selby.com.au/monitor-wall-mount-dual-monitor-height-adjustable-wmm020.html. [28 July 2015].

Shimomura, Y., Nemoto, Y., Kimita, K. 2015. A Method for Analysing Conceptual Design Process of Product-Service Systems. *CIRP Annals - Manufacturing Technology*. 64(1): 145-148. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0007850615000438. [17 July 2015].

Smith, R, L. 2012. Adventures in Ground-based Astronomy: An Inside View (Part I). *Naturalsciencesresearch.wordpress.* [Online]. Available: https://naturalsciencesresearch.wordpress.com/page/15/. [20 July 2014].

Speier, C., Valacich, J.S., Vessey,I. 2007. The Influence of Task Interruption on Individual Decision Making: An Information Overload Perspective. *Decision Sciences*. 30(2):337-360. [Online]. Available: http://onlinelibrary.wiley.com.ezproxy.cput.ac.za/doi/10.1111/j.1540-5915.1999.tb01613.x/epdf. [17 July 2015].

Spinelli, G., Perry, M., O'Hara, K. 2005. Understanding Complex Cognitive Systems: The Role of Space in the Organisation of Collaborative Work. *Cogn Tech Work*. 7: 111–118.

Starizona 2014. Which Telescope is best for me? *Starizona Adventures In Astronomy & Nature*. [Online]. Available: http://starizona.com/acb/basics/equip_whichisbest.aspx. [01 August 2015].

Steen, M. 2012. Human-Centered Design as a Fragile Encounter. *Design Issues*. 28(1):72-80. [Online]. Available: http://eds.a.ebscohost.com/eds/pdfviewer/pdfviewer?vid=7&sid=714076c4-3db3-4299-8b66-a5ff25230385%40sessionmgr4003&hid=4203. [14 July 2015].

Strobel, N. 2015. Types of Telescopes. *Astronomy Notes*. [Online]. Available: http://www.astronomynotes.com/telescop/s2.htm. [20 July 2015].

Swart, G., Bester, D., Brink, J., Gumede, C., Schalekamp, H. 2004. Facing Software Complexity on Large Telescopes. *Proceedings of SPIE5496 the 2004 Conference of Advanced Software, Control, and Communication Systems for Astronomy, Bellingham, 15 September 2004*. Edited by: H. Lewis. Washington: SATI: 260-270.

Szeto, G., Chan, C., Chan, S., Lai, H., Lau, E. 2014. The Effects of Using a Single Display Screen Versus Dual Screens on Neck-shoulder Muscle Activity During Computer Tasks. *International Journal of Industrial Ergonomics.* 44. (2014): 460-465. [Online]. Available: http://ac.els-cdn.com.ezproxy.cput.ac.za/S0169814114000092/1-s2.0-S0169814114000092-

main.pdf?_tid=d7687e24-369b-11e5-b119-00000aacb35e&acdnat=1438248046_a958b6f3d5915ed0ab41382cf46987ed. [30 July 2015].

Ta Neter 2011. Early Africa (140,000 - 20,000 BC). *Ta Neter Foundation*. [Online]. Available: http://www.taneter.org/earlyafrica.html. [15 June 2013].

TechRepublic 2015. Universal Design and Usability: Accessibility Issues and How to Address Them. *TechRepublic*. [Online]. Available: http://www.techrepublic.com/blog/web-designer/universal-design-and-usability-accessibility-issues-and-how-to-address-them/. [17 August 2015].

Telescopes 2015. Telescope Glossary. *Telescopes.com*. [Online]. Available: http://www.telescopes.com/blogs/helpful-information/18967044-telescope-glossary. [08 August 2015].

The Human Solution 2015. Calculate the Ideal Height for Your Ergonomic Desk, Chair and Keyboard. *The Human Solution*. [Online]. Available: http://www.thehumansolution.com/ergonomic-office-desk-chair-keyboard-height-calculator.html. [01 August 2015].

The University of Texas McDonald Observatory 2015. HET Control Room. *McDonald_Observatory*. [Online]. Available: https://mcdonaldobservatory.org/news/gallery/het-control-room. [20 July 2014].

The University of Texas of Austin 2008. Hobby-Eberly Telescope. *Hobby-Eberly Telescope.* [Online]. Available: http://www.as.utexas.edu/mcdonald/het/het_gen_01.html. [02 October 2013].

Trent University 2012. Online History Workbook. *Trent University.* [Online]. Available: http://www.trentu.ca/history/workbook/theoreticalframeworks.php. [10 May 2015].

Trist, E. 1981. The Evolution of Socio-Technical Systems. *Occasional Paper*. 2:1-67. [Online]. Available: http://sistemas-humano-computacionais.wdfiles.com/local--files/capitulo%3Aredes-socio-tecnicas/Evolution_of_socio_technical_systems.pdf. [15 July 2015].

Tse, E., Shen, C., Greenberg, S., and Forlines, C. 2006. *Enabling Interaction with Single User Applications Through Speech and Gestures on Multi-User Tabletop.* [Online]. Available: http://dl.acm.org/citation.cfm?id=1133336. [25 October 2013].

UNISA 2007. Policy on Research Ethics. *UNISA University of South Africa*. [Online]. Available: http://www.unisa.ac.za/contents/research/docs/researchethicspolicy_apprvcounc_21sept07.pdf. [17 August 2015].

UX Magazine 2015. The Practical and Legal Reasons Behind Designing for Accessibility. *UX Magazine*. [Online]. Available: https://uxmag.com/articles/the-practical-and-legal-reasons-behind-designing-for-accessibility. [18 July 2015].

van Eijka, D., van Kuijka, J., Hoolhorstb, F., Kima, C., Harkemac, C., Dorrestijnd, S. 2012. Design for Usability; Practice-Oriented Research for User-Centered Product Design. *ResearchGate*. 41: 1008-1015. [Online]. Available: http://eds.b.ebscohost.com/eds/pdfviewer/pdfviewer?sid=cebc9197-2883-426c-8dd6-a0f9fe51e7dd%40sessionmgr111&vid=0&hid=114. [17 July 2015].

Viller, S., & Sommerville, I. 2000. Ethnographically Informed Analysis for Software Engineers. *International Journal of Human-Computer Studies*. 53: 169-196. [Online]. Available: http://archive.cs.st-andrews.ac.uk/STSE-Handbook/Papers/EthnoAnalysisForSE-Viller.pdf. [14 July 2015].

von Bertalanffy, L. 1968. *General System Theory.* New York: George Braziller

Wells, R. 2013. Startups, This Is How Design Works. *Startupsthisishowdesignworks.* [Online]. Available: http://startupsthisishowdesignworks.com. [01 Novemberr 2013].

Whitehead, T.L. 2004. *What Is Ethnography? Ethnographically Informed Community and Cultural Assessment Research Systems (EICCARS)*. 1-29, March 2004. [Online]. Available: http://www.cusag.umd.edu/documents/workingpapers/epiontattrib.pdf. [20 October 2015].

Whitelock, P,A. 2011. Astronomy in Post-apartheid South Africa. *The Role of Astronomy in Society and Culture Proceedings IAU Symposium*. 260(2469):587-594.

Whitelock, P. 2004*. Optical Astronomy in Post-Apartheid South Africa: 1994 to 2004.* Netherlands: Kluwer Academic Publishers

Whitelock, P. 2011*. Astronomy in post-apartheid South Africa.* In: The Role of Astronomy in Society and Culture*. Proceedings of the 2009 IAU Symposium of the International Astronomical Union, Cape Town, 2009*. Edited by: D. Valls-Gabaud & A. Boksenberg. Cape Town: SATI: 587-594

Whitworth, B. 2006. Socio-Technical Systems. *Encyclopedia of Human Computer Interaction*. 533-541. [Online]. Available: http://brianwhitworth.com/hci-sts.pdf. [28 July 2015].

Whitworth, B., & Ahmad, A. 2002. Socio-Technical System Design. *Interaction Design Foundation.* [Online]. Available: https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/socio-technical-system-design. [16 July 2015].

Wiles, R., Prosser, J., Bagnoli, A., Clark, A., Davies, K., Holland, S., Renold, E. 2008. Visual Ethics: Ethical Issues in Visual Research. *National Centre for Research Methods*. [Online]. Available: http://eprints.ncrm.ac.uk/421/1/MethodsReviewPaperNCRM-011.pdf. [17 August 2015].

Winsted Corporation 2015. Human Factors Planning & Design of a Control Room. *Winsted Corporation*. [Online]. Available: http://www.winsted.com/files/9813/9413/7804/human_factors.pdf. [20 July 2015].

Younga, J.G. Trudeaub, M.B. Odellc, D. Marinellid, K. & Dennerlein, J.T. 2013. Wrist and Shoulder Posture and Muscle Activity During Touch-screen Tablet use: Effects of Usage Configuration, Tablet Type, and Interacting Hand. *Pictorial, Research, Tables/Charts.* 45(2013): 59–71. [Online]. Available: http://eds.a.ebscohost.com.ezproxy.cput.ac.za/eds/pdfviewer/pdfviewer?sid=b2b2618d-dca7-4313-a0de-16f2cc8b027b%40sessionmgr4002&vid=2&hid=4210. [24 July 2015].

Zornoza, E., Garcés, P., Climent, M.A., Sánchez, I. 2013. The Best Method for The Evaluation of Master Students: Co-Evaluation, Peer-Evaluation or Professor Evaluation. In: *INTED2013 Proceedings.* Valencia. 6622-6626. [Online]. Available at: http://library.iated.org/view/ZORNOZA2013BES. [30 August 2015].

Bibliography

Abras, C., Maloney-Krichmar, D., Preece, J. 2005. User-Centered Design. *In Bainbridge, W. Encyclopedia of Human-Computer Interaction*. USA: Sage Publications. Draft: 1-14. [Online]. Available: http://www.e-learning.co.il/home/pdf/4.pdf. [17 July 2014].

American Association for the Advancement of Science 2015. Artificial Light Impacts Astronomy as Well as Human Health, The Environment, and World Views, Experts Say, *American Association for The Advancement Of Science*. [Online]. Available: http://www.aaas.org/news/artificial-light-impacts-astronomy-well-human-health-environment-and-world-views-experts-say. [01 August 2015].

ArchiExpo 2015. Light Switch / Automatic / Contemporary / with Motion Sensor. *Archiexpo.* [Online]. Available: http://www.archiexpo.com/prod/gira/product-51212-1575243.html. [19 July 2015].

Berg, O. 2012. The Digital Workplace: The Need for Good Practices in a Complex Work Environment. *cmswire*. [Online]. Available: http://www.cmswire.com/cms/social-business/the-digital-workplace-the-need-for-good-practices-in-a-complex-work-environment-017327.php. [21 July 2015].

Berker 2015. Switch-History-Switched on. *berker*. [Online]. Available: http://www.berker.com/downloads-service/switch-history/1024-168.htm. [19 July 2015].

Binder, T., Nilsson, J., Sokoler, T., Wetcke, N. 2000. *Beyond the Control Room: Mobile Devices for Spatially Distributed Interaction on Industrial Process Plants.* [Online]. Available: http://space.tii.se/spaceweb2001/publications/pdf/jorn_BeyondTheControlroom.pdf. [24 October 2013].

Bonnivard, D. 2004. Home Theater Cinema Paradiso with Video Projectors. *A Purch Company*. [Online]. Available: http://www.tomshardware.com/reviews/home-theater-cinema-paradiso-video-projectors,900-3.html. [28 July 2015].

Bowen, J., and Reeves, S. 2007. *Using Formal Models to Design User Interfaces: Case Study.* [Online]. Available: http://dl.acm.org/citation.cfm?id=1531316. [24 October 2013].

Bowers, J., and Martin, D. 1999. *Information Collaborative Information Visualisation Through an Ethnography of Ambulance Control.* [Online]. Available: http://link.springer.com/chapter /10.1007/978-94-011-4441-4_17#page-1. [20 September 2013].

Bowers, J., Martin, D., and Wastell, D. 1997. *The Interactional Affordances of Technology: an Ethnography of Human-Computer Interaction in an Ambulance Control Centre.* [Online]. Available: http://link.springer.com/chapter/10.1007/978-1-4471-3601-9_16#page-1. [25 October 2013].

Boy, G.A., Schmitt, K.A. 2013. Design for safety: A Cognitive Engineering Approach to the Control and Management of Nuclear Power Plants. *Annals of Nuclear Energy*. 52(1): 125-136. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0306454912003477. [17 July 2015].

Buckner, K., Laurier, E., and Whyte, A. 2001. *An Ethnography of a Neighbourhood Café: Informality, Table Arrangements and Background Noise.* [Online]. Available: http://eprints.gla.ac.uk/23/. [25 October 2013].

CAP 2006. Workplace Ergonomics Reference Guide (2nd Edition). *CAP.* [Online]. Available: http://www.cap.mil/SearchResults.aspx?cx=005013612145503756586:su25sn3_r88&cof=FORID:10&ie=UTF-8&q=Ergo_Guide%20&sa=Search. [30 July 2015].

dos Santosa, I.J.A.L., Teixeirab, D.V., Ferrazb, F.T., Carvalhoa, P.V.R. 2008. The Use of a Simulator to Include Human Factors Issues in the Interface Design of a Nuclear Power Plant Control Room. *Journal of Loss Prevention in the Process Industries*. 21(3): 227-238. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0950423007000447. [17 July 2015].

Education.vic 2007. A "Critical" Reflection Framework. *Reflective Practice*. [CD-ROM/Online]. Place of publication: Publisher Available: http://www.education.vic.gov.au/Documents/childhood/professionals/support/reffram.pdf. [28 August 2015].

Eishsa 2015. South African Road Traffic Signs. *Eishsa*. [Online]. Available: http://www.eishsa.co.za/minisites/traffic.html#control. [28 July 2015].

Fajen, B.R. 2007. Affordance-Based Control of Visually Guided Action. *Ecological Psychology*. 19(4): 383-410. [Online]. Available: http://panda.cogsci.rpi.edu/resources/papers/Fajen2007_EP.pdf. [17 July 2015].

Filmer J, 2014. Bortle's Dark-Sky Scale. *Quarks to Quasars.* [Online]. Available: http://www.fromquarkstoquasars.com/dark-sky-scale/. [08 August 2015].

Gellersen, H. and Thomas, P. (2000). *Handheld and Ubiquitous Computing*. Berlin: Springer.

Glodek, M., Honold, F., Geier, T., Krell, G., Nothdurft, F., Reuter, S., Schüssel, F.,Thilo Hörnle, T., Dietmayer, K., Minker, W., Biundo, S., Weber, M., Palm, G., Schwenker, F. 2015. Fusion paradigms in Cognitive Technical Systems for Human–Computer Interaction. *Neurocomputing*. 161: 17-37. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S0925231215002155. [17 August 2015].

Goldsmiths, W. 2012. *What Should We Expect from Research Through Design?* [Online]. Available: http://dl.acm.org/citation.cfm?id=2208538. [25 October 2013].

Greenhouse, E. 2012. Human-Centered Design. *Livable New York Resource Manual.* [Online]. Available: http://www.aging.ny.gov/LivableNY/ResourceManual/DemographicAndSocialTrends/I9.pdf. [10 May 2015].

Johansson, S. 2011. *Considering Context: Integrative Design of Graphical User Interfaces.* [Online]. Available: http://sirijohansson.com/writing/sider.pdf. [2 November 2013].

jnd 2016. Signifiers, not affordances. *Don Norman: Designing For People.* [Online]. Available: http://jnd.org/dn.mss/signifiers_not_affordances.html. [30 March 2016].

MacKenzie, I. Scott. Amsterdam : Morgan Kaufmann,. 2015. Human-Computer Interaction. *Nuclear Engineering and Design*. 265(1): 137-144. [Online]. Available: http://eds.a.ebscohost.com.ezproxy.cput.ac.za/eds/detail/detail?sid=d55cc7ac-5b92-4854-8c31-

1912fda799ba%40sessionmgr4003&vid=3&hid=4111&bdata=JnNpdGU9ZWRzLWxpdmU%3d#. [17 July 2015].

Norman, D. 2005. *Emotional Design: Why We Love (or Hate) Everyday Things.* New York: Basic Books, Inc.

Obrenovic, Z. 2011. *Design-Based Research: What We Learn When We Engage in Design of Interactive Systems.* [Online]. Available: http://dl.acm.org/citation.cfm?id=2008189. [24 October 2013].

Pao-Yen Wu, P., Fookes, C., Pitchforth, J., Mengersen, K. 2015. A framework for Model Integration and Holistic Modelling of Socio-Technical Systems. *Decision Support Systems*. 71: 14-27. [Online]. Available: http://www.sciencedirect.com.ezproxy.cput.ac.za/science/article/pii/S016792361500007X. [17 August 2015].

UC Berkeley Extension 2013. *Interior Design and Interior Architecture.* [Online]. Available: https://www.uop.edu.jo/download/research/members/intdes.pdf. [15 August 2015].

Wang, C. 2012. Automotive Usability: Human Computer Interaction in the Vehicle. *HCI Symposium*. 1-8, 30 November 2012. [Online]. Available: http://homepages.rpi.edu/~gricer/symposium/papers/Automotive_paper.pdf. [17 July 2015].

Woods, D. D., & Dekker, S. W. A. 2000. Anticipating the Effects of Technological Change: a New Era of Dynamics for Human Factors. *Theoretical Issues in Ergonomics Science*. 1(3):272-282. [Online]. Available: http://csel.eng.ohio-state.edu/woods/foundations/dynamicHF_proof.pdf. [30 August 2015].

World Mysteries 2015. 127 Years of Modern Automobile Evolution. *World Mysteries*. [Online]. Available: http://blog.world-mysteries.com/science/127-years-of-modern-automobile-evolution/. [17 July 2015].

Appendix A *Consent form from SAAO*

NRF National Research Foundation | SAAO South African Astronomical Observatory

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Observatory 7935
South Africa
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Int. Code: +27
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I, Dr Lisa Crause, in my capacity as Staff Astronomer at the South African Astronomical Observatory give consent in principle to allow Christopher Justin Hendrickse, a student at the Cape Peninsula University of Technology, to collect data in this company as part of his/her M Tech (IT) research. The student has explained to me the nature of his/her research and the nature of the data to be collected.

This consent in no way commits any individual staff member to participate in the research, and it is expected that the student will get explicit consent from any participants. I reserve the right to withdraw this permission at some future time.

In addition, the company's name may or may not be used as indicated below. (Tick as appropriate.)

	Thesis	Conference paper	Journal article	Research poster
Yes	X	X	X	X
No				

Dr Lisa Crause

12 November 2013

Appendix B *Consent form Structure*

Consent form for masters research project

Thesis title: Development of the user input system for the control room upgrade of Southern African Large Telescope (SALT)

By: Christopher Justin Hendrickse

Project Description: The thesis project, in the field of Design, is focusing on the interaction of the users and their environment in the SALT control room. This project aims to improve the work practice of the user and the telescope by creating a user centred work space.

I, __________________________________, in my capacity as _______________________________ at the South African Astronomical Observatory give consent in principle to allow Christopher Justin Hendrickse, a student at the Cape Peninsula University of Technology, to collect data in this company as part of his masters' research. The student has explained to me the nature of his research and the nature of the data to be collected. I reserve the right to withdraw this permission at any future time.

(Tick as appropriate.)

Yes	No	
☐	☐	I will allow the researcher to; voice record any informal interviews with me as long as I am aware the researcher is doing so.

I will allow the researcher to; take photos of:

Yes	No	
☐	☐	The control room with nobody in it.
☐	☐	The control room with me in it.
☐	☐	The control room with me in it yet keeping my identity concealed.

I will allow the researcher to; take video footage of:

Yes Yes (but with no audio) No

☐ ☐ ☐ The control room with nobody in it.

☐ ☐ ☐ The control room with me in it.

The data collected within the above mentioned categorise may be used with my permission in the following

	Thesis	**Conference paper**	**Journal Article**	**Research Poster**
Yes				
No				

Participant:

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study

Name: ________________________________

Signature: _____________________________ Date _________________________________

Researcher:

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Name: _________________________________

Signature: ______________________________ Date _________________________________

Appendix C *Event log Extract*

Date: 12 Feb 2013 **Time: 20:15**

Participants: A1: Current Astronomer 1 **A2: Next Astronomer 2** **TO: Telescope Operator**

20:27 A1 is showing A2 what she has done, with some tips and tricks on one of the features on the programme and points out that she must be careful with having too many tabs open. A2 is pointing at the screen, A1 says it's easy to cut and paste and A2 says its not easy. A1 reminds A2 to remember to close a particular function that gives problems if not closed. A2 uses the desk to move back to her space on the desk (1.5m). TO is aligning the mirrors during this time.

20:31 After the mirror alignment was completed the telescope is moved to its first position. The telescope movement sound is audible over radio system and throughout the building.

20:36 This is a standard star observation, which continues for ten minutes, A1 is observing the procedure on the third screen. A1 is happy with the quality of the observation, focus and alignment looks good.

20:38 A1 is now leaning over to the left to work on a forth monitor. The Alignment for the tracker is on this screen. Both A1 and TO are working together on the fourth screen. A1 and A2 check the two monitors above the astronomer and operator to monitor outside weather conditions and telescope parameters.

20:40 Voice over speaker: 'Procedure complete'. This is for the procedure the telescope is running on the particular target so A1 and A2 know when it's complete instead of having to look at the screen all the time. She can therefore continue with other work while the procedure is running.

20:49 TO is constantly monitoring that the telescope is holding the focus on the star, and they are ready to move the telescope to a new target and move onto science research.

20:55 The TO and A1 are under time constraints as the next priority target is coming into the telescopes field of view. While waiting on the telescope to move to the next target. A1 uses many tabs on a single screen which she has to constantly move around, notice signs of frustration.

21:00 Telescope moved and is having problem with the focus. A1 can't work until the focus is better as per the requirement on the proposal. She is looking at the fourth screen trying to help the TO focus the telescope. The TO is working on two screens, extended desktop mode, and a private laptop, while trying to focus the telescope. A1 explains that she keeps a manual typed log of all problems encountered during the night, for her own reference even though the computer saves the problems automatically.

20:08 Things are quiet. The telescope is running three exposures of a star that cannot be seen yet they are using a close target as reference to locate the desired star.

Side note: The telescope was closed for Saturday and Sunday past, due to bad weather. The staff stays at the telescope and does other work while they are wait for the weather to hopefully clear up.

21:25 The astronomer an TO are still waiting on the computers while they run the exposures on the star.

A1 says the keyboard and mouse setup is a real pain, and the fact that the screens are so far apart is less than ideal (horizontally 5m). A1 is short in stature.

21:36 A2 is typing on the end of the desk to the right, she is sitting in a reclined position as her arms rest on the slanted desk, she seems comfortable, however A1 complains about the desks but she is smaller in stature than A2. A1 uses the Lip of the desk to move herself along as she switches her focus from the SALT screen to her laptop, which are next to one another.

21:41 'Procedure complete' on the voice over, which is a soft unknown female voice. A1 askes the TO to please place a cyan UV filler in the telescope instrument, which she does from her computer.

21:46 A1 is checking to see if the telescope mirrors need aligning, TO and A1 have agreed to do an alignment as they have 10min until the next target is in the telescope's field of view. Rotating telescope to its home position. Feel the building vibrating. Sound over radios also monitored.

22:03 TO is still aligning the mirrors.

22:07 Alignment of the mirrors are complete, now pointing the telescope to a new target.

22:14 Problem with mirror, the target is running in a gap of the mirrors.

22:20 New target in sight, focus is out. A1 is leaning over to screen 4 to help fine tune the lining up of the new astronomical target, while TO works on improving the focus.

22:22 Procedure started.

22:30 Procedure still running.

22:34 Researchers note: The chair that I'm sitting on is killing me, the back rest is so straight up and it only has height adjustments. The TO is using the same model and make of chair as mine.

22:43 A1 moves across to the first monitor and while moving she knocks her knees on the support for the desk, this support is a wooden sheet running perpendicular out from the wall to about 100mm from the end of the table. These supports are placed every 1200mm and are black, however one can clearly see the paint has been rubbed off at the bottom where the feet and chair wheels meet with it, and where the users' knees would be. This shows that this is a common problem over a long period of time with multiple users.

22:50 PCON is still running procedure.

22:58 The TO moves over to look at the 4th screen as she needs to check the focus. This screen is parallel to the desk and cannot be rotated as both A1 and TO who sit on either side of the screen need to be able to view it.

A1 says the names of the tags disappear off the page, as she tries to adjust the screen resolution to create space for the tabs to have a less cluttered screen.

23:02 The procedure is complete and both A1 and TO moved back to the primary work stations.

Note: on A1 side there is very little desk space for paper documents.

23:07 Moving the telescope to a new target, while they monitor the sound in their peripherals.

Both A1 and TO are relying on the sound that the telescope makes while it moves, as one cannot physically see the telescope and its position.

23:16 New target acquired, focusing optics, lots of time is spent on setting up the telescope compared to the time spent doing procedures of data collection on the star, however this is not always the case.

23:22 Running procedure again, A1 and the TO are checking emails and conducting other work in the meantime.

23:30 the 1st procedure is complete, now moving onto the next procedure, which was a short second procedure on the same target. This is completed swiftly and they move onto the next target.

23:31 One can hear the telescope moving, lights are dimmed while the telescope moves as it draws a huge amount of current.

A1 types into the night-log as there is a problem with an instrument that's not cooling properly.

23:40 A1 jumps up from her seat to show the TO something. The A1's action appears to be much quicker than trying to move on the chairs.

A1 rotates screen 2 towards her and accidently knocks her coffee mug, which she had placed on the desk earlier on. The coffee mug slides down the desk but A1 stops the mug in time as it was heading for the keyboard.

23:50 A2 and A1 are standing while discussing the problem of the overheating instrument, they are looking at A1s laptop screen.

00:00 A2 leaves as she has gained enough information from A1 for her shift, which will start the following night.

00:05 I am informed that one of the other astronomers gets annoyed with the voice over from the computer procedures and wishes to turn it off when he is on shift however that option is not available.

A1 uses her left hand to work on the computer to her left while working on the computer to her right with her right hand, she is right handed. She explains that it is easier than trying to move herself so that her right hand could access the mouse on the left.

00:10 Acquiring a New target, telescope moved to new position.

00:20 A1 and the TO are setting up new guiding star, they ae sharing a computer screen.

00:31 A1 and the TO are waiting for procedure to run. A1 has left the control room to go and eat in the kitchen, which is the adjacent room.

00:45 While waiting, the TO turns on some music on from her laptop. A1 returns and they continue with other work.

01:10 The procedure is complete.

01:11 Acquired new target and they continue to set up the telescope. There is lots of communication between A1 and the TO while they focus on the 4th screen, which is shared.

01:31 I am informed that they will continue with the same sequence for the remainder of the night.

My shift ends as my lift back to the hostel is ready to leave, an alternate arrangement will be made for the following nights so that I can stay with them for the entire night.

End of session

Appendix D *Additional Information*

1. Types of Telescopes

Different kinds of telescopes include; atmospheric Cherenkov which are used to detect gamma rays, infrared, radio, submillimetre, ultraviolet, x-ray, and finally optical (Mullen, 2011). The research will focus on the optical telescope, like SALT. An optical telescope is a visual device, which makes distant objects appear closer with the use of lenses, or lenses and curved mirrors, by collecting and focusing light rays (Mullen, 2011).

All telescopes; from the ones in orbit around the earth, the large telescopes built at astronomical observatories, or the small bedroom telescope, fit within two groups of telescopes, refractors and reflectors (Strobel, 2015). Refactor telescope, Figure A.1, has many disadvantages and is not ideal for star gazing unlike the reflector type telescope, Figures A.2 – A.4. Currently reflector type telescopes are used in almost all optical telescopes, with different variations in design and build yet adhering to the basic principle of reflector type (Strobel, 2015). The SALT telescope is based on the Prime Focus Design with the payload instrument detectors in the place of the eye; see Figure A.2, yet one key difference is the primary mirror that is segmented instead of one single large mirror.

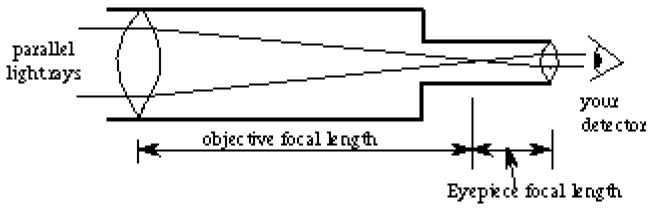


Figure A.1, Refractor Telescope
(Strobel, 2015)

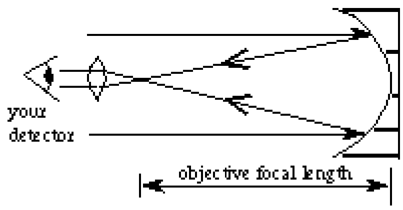


Figure A.2, Prime Focus Reflector Telescope
(Strobel, 2015)

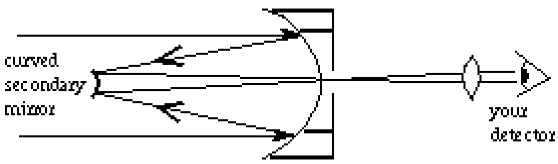


Figure A.3, Cassegrain Reflector Telescope
(Strobel, 2015)

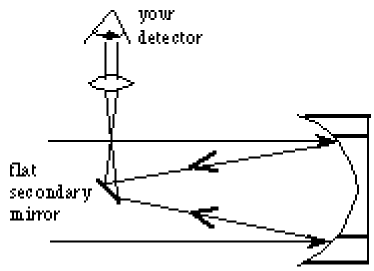


Figure A.4, Newtonian Reflector Telescope
(Strobel, 2015)

2. Design Framing From Literature

The following section will explore different ways to overcome the use of multiple keyboards and mouse from separate computers. Due to the technical limitation of the telescope operating system the separate computers will still be maintained.

Figure A.5, *Single Adjustable Monitor Stands* (Directshop, 2011)

Figure A.6, Dual Adjustable Monitor Stands (Cotytech, 2015)

Figure A.7, *Adjustable Laptop Stand* (ErgoDirect, 2015)

Figure A.8, *Digital Light Processing Projector* (Bonnivard, 2004)

2.1 Computer Monitor Sizes

It was reported by more than one of the astronomers that they would like to eliminate having to flip between the different tabs of a programme on the same screen. However, in a separate study at SALT, which was tested on a larger 52 inch full HD monitor, there was little improvement, see the male user in Figure 5.1, because the resolution of the text became difficult to read and the user had to search the screen for the mouse on multiple occasions. The users also reported excess head and eye movement while scanning across the large monitor, which put strain and discomfort on the user’s neck. They reported that the large monitor would be useful for images but not much else as it starts to scale-up everything and not adding more screen real-estate.

Medium displays (19 to 32 inch); these computer monitor sizes were ideal as the cost was affordable and the resolution was enough to read the fine text and numbers, however it did not solve the problem of having to switch between multiple tabs in a program. The switching between programs was manageable according to the users interviews (Hendrickse, 2012) and far outweighed the advantages of having these multiple computer screens. The 19 and 32 inch screens were more versatile in many ways in comparison to the larger 52 inch screens. They could be mounted on brackets allowing for customisation of the positions within the limits of the mountings, according to the user's needs. The smaller size screens took up less space and meant there could be more medium sized screens in the allocated space. From one of the co-design sessions with two of the astronomers and one telescope operator they mentioned the desire for duplicating some of the displays as they work at different computers and still wished to see what is displayed on one of the screens on the other end of the work space. Another advantage to having so many displays allows the user to be able to view more information quicker as there is initially more HD screen real-estate. Looking at the case study by Szeto, Chan, Chan, Lai and Lau (2014: 460), on *The effects of using a single display screen versus dual screens on neck-shoulder muscle activity during computer tasks.* It was believed that using multiple screens would worsen the fatigue and discomfort in the users neck and shoulders, however the study found that the regular movement of the subjects head helped reduce the muscles load of the neck and shoulders, compared to the use of a single screen where the muscles had no elevation from the load resulting in greater discomfort (Szeto, Chan, Chan, Lai, & Lau, 2014). These findings further supported the use of multiple monitors in the control room.

2.2 Digital Projectors

The exploration of the DLP projectors, Figure A.8, which could be mounted overhead to project a large display onto a screen, was discussed with the users as a display option. The DLP technology also called DMD (Digital Micro mirror Device) has advanced greatly with regards to display quality and resolution (Bonnivard, 2004). When taking the limited workspace into account, it would be impractical to mount a large screen.

According to *Projector Basics*, the recommended environment for a digital projector is an area with low ambient light situations (3LCD, 2015). This is because of the manner in which the projector operates. A DMD projects light onto a screen, which reflects the light into the users' eyes, unlike LED or LCD displays, which emits light directly into the users' eyes (Oxlade, 2005: 14). Therefore the projector device needs a dark environment as the reflecting light is weakened by ambient light sources (3LCD, 2015). This would not be a problem for the astronomers while they work, as some of the users choose to dim the overhead lights, however it would be a problem during the day as the blind on the large window is opened to let in natural light and energy, which would dull the reflecting light from the projector.

Another drawback to the DMD projector is the limited lifespan of the projector lamp, which normally ranges between 1,000 and 4,000 hours. This would give 3 years of normal home cinema use. However the displays at SALT are active most of the time and this would only allow for 6 to 23 weeks of lamp life and a high replacement cost. The cost to maintain this setup would be fairly high compared to a LED monitor, which does not require this type of maintenance. The users were presented with the relevant research on DMD projectors, it was discussed and agreed upon that the disadvantages of the DMD projector system far outweighed the advantages as a suitable display option for the control room.

2.3 Touch Navigation

Touch navigation also known as a touch screen is a visual electronic display that can sense the position and presence of something touching it; this could be a finger, hand or stylus (Bhalla & Bhalla, 2010). There are two parts to most touch screen systems, a display (LCD, LED, CRT) and the technology that reads the touch input (Epec Engineered Technologies, 2014). There are many different touch technologies available for the computer, such as; Resistive, Capacitive, Surface Acoustical Wave (SAW) and Infrared (IR). These all have advantages and disadvantages (Epec Engineered Technologies, 2014). For the use of the control room, the most optimal touch screen technology would be based on the LCD or LED displays. While discussing the touch screen technology with the users; roleplaying ideas of how it would work in the control room brought about the following advantages and disadvantages.

2.4 Advantages of Touch Screen Technology

Advantages of touch screen technology; the elimination of all the mouse and keyboards would be a viable reason to consider this technology. It will therefore remove the confusion with the multiple keyboards and mouse, without adding another step to the users work flow. The technology does not require additional work space as there is no extra input hardware required, helping with the limited space in the control room (Epec Engineered Technologies, 2014).

One of the foremost disadvantages with this navigational approach is the data that the users work with. The data is not ideally suited for clumsy fingers or a stylus, as it mainly consists of text and numbers. The software is also not designed for touch displays and requires the precision and accuracy of a mouse to work efficiently and effectively. The highly complex computer software has been specifically designed for SALT, and it requires large amounts of computing power. Therefore adding additional software to the computers for the touch displays is not advisable, according to the software engineers, due to the limited computer resources. Concerns were raised by the night staff regarding the engineers who use the computers during the day. Some of the staff had greasy hands as they worked on the telescope and touch displays are easily dirtied with fingerprints, which reduces clarity of the displays (Bhalla & Bhalla, 2010: 12). There would also need to be a redesign of the workspace layout as the touch display screen would need to be placed at an angle from the desk as the current vertical position of the displays would create great discomfort and fatigue to the users (Younga, Trudeaub, Odellc, Marinellid, & Dennerlein, 2013: 61). The advantages are far outweighed by the disadvantages of touch screen technology in the control room; it was concluded, with the agreement of the users that touch screen technology is not a viable option for the Improvement of the work practice in SALT control room.

2.5 Switches

Switches; these devices allow for the user to use more than one computer yet still having one display, keyboard and mouse and allowing the user to choose which computer they would like to access by making a selection on the device, see Figure A.9 and A.10, (Linkqage, 2013: 37). There are many types of switches for different applications, nevertheless for this project the most appropriate one is the *KVM Switch Quad*. This device allows for different modes; full screen, picture in picture (pip) and quad screen mode, see Figures A.10 to A.13. This was presented to the astronomers and they were initially keen on it, yet the drawbacks were quickly mentioned, for example, the quad view setup with hotkeys changing between the screens or mouse capture between them would be most efficient.

Figure A.9, *KVM Switcher* (Linkqage, 2013)

Physical switches on the desk or chairs or keyboards would have too high a latency and interrupt workflow. The full screen would be ideal yet the information on the ‘other’ computers would not be as quick to access. From research observations, users moved between screens to view data and progress of procedures. Finally, this device adds an extra step into the work flow for the astronomer as they astronomer will have to pause and select the computer they would like to proceed with, nevertheless the concept behind the device was explored further and automatic switching was investigated.

Full Screen Mode, only the active accessed computer video signal is displayed in full screen, Figure A.11 (Linkqage, 2013: 37). Picture in Picture Mode, the recently active computer is displayed in full screen. Each small window can be displayed or switched off. The window size of the small windows can be scaled from 3% to 50%, Figure A.12 (Linkqage, 2013: 37). Quad Screen Mode displays all video signals in equally sized windows. Mouse (or hotkey) commands between the windows, Figure A.13 (Linkqage, 2013: 37).

2.5 Automated Switches

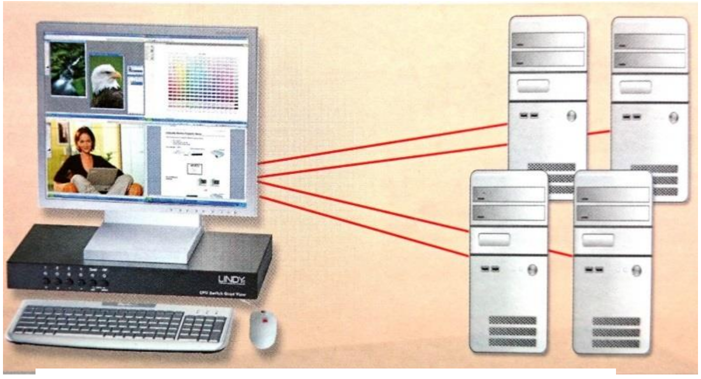


Figure A.10, *KVM System Overview*
(Linkqage, 2013)

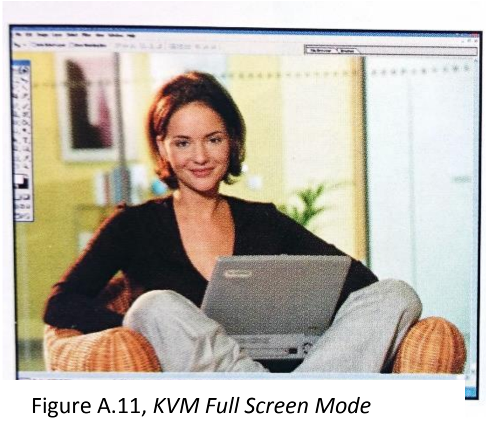


Figure A.11, *KVM Full Screen Mode*
(Linkqage, 2013)

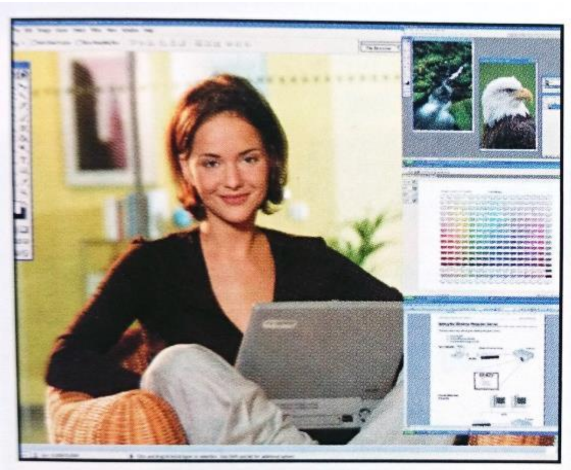


Figure A.12, *KVM Picture in Picture Mode*
(Linkqage, 2013)

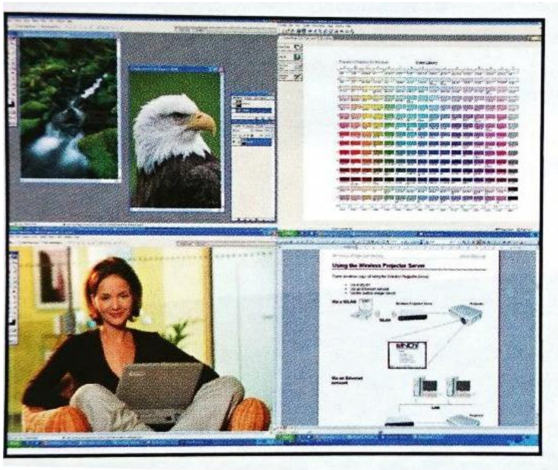


Figure A.13, *KVM Quad Screen Mode*
(Linkqage, 2013)

As previously discussed in the section on manual switches, the setup of the automated switches would be the same, with the addition of the switching part being automated through different methods. Physical switches placed in different locations were discussed with the users. For example, if a switch was placed under the chair, one for each screen, so that when the user rotated on the chair to face the appropriate screen, the corresponding switch would be activated. The keyboard and mouse would become operational for that computer and display. This removed the step of the user having to remember to press a button to switch between computers, however this would require the development of a chair with the switch or an attachment for the switches to be activated from. There are many complications with this option, such as the limited chair movement as a result of electrical cables joining the switches to the switching device. The chair would have to be correctly positioned for it to operate effectively, and the user would need to rotate the chair accurately to activate the correct screen.

The use of a Kinect setup might be a feasible option (Microsoft Kinect for Xbox 360) where the users' movements and position are tracked in three dimensional space without the connection of a physical control by the device. This setup consists of one colour and two black and white cameras (Davis, 2015). With some software modification one would be able to track the user's movements. When they turn to face a different screen, the Kinect camera will allow the computer to automatically switch the keyboard and mouse to the correct computers and its respective screen. There are no extra cables or steps to the users work flow, which is an advantage, however there needs to be good contrast with the user and the background. There is the risk of the camera not picking up the users movements and not switching to the correct computer and display, which could become problematic. Another major drawback with this concept is the setting up of the workspace, if the user has one keyboard and mouse he or she would not need to move to face a different screen as the screens could be mounted closer together. This would only require slight head movement, which could be problematic for the camera to track. It was concluded that this idea could possibly work in other environments yet it was not deemed suitable for the SALT control room.

The STS information levels, as seen on Table 2.1, represents a hierarchy of levels of an individual system (Baxter & Sommerville, 2009: 2). The satisfaction of the higher levels is based on the completion of the lower levels when one considers STS as related to communities. Therefore improving the user interaction would directly affect the STS. This would acknowledge the role of the individual and Information Technology (IT), and that improving it would affect the levels above and inevitably improve the STS (Whitworth & Ahmad, 2002).

As mentioned in the previous section, there are four identified improvement areas in the control room, consisting of; adjustable display mountings, laptop mounting systems, the feedback timer and reduced confusion of multiple inputs. The adjustable display mountings, laptop mounting systems, and feedback timer were all accepted by the users as areas that they predicted would improve their work practices. These areas could not be tested in the control room as the environment is very sensitive and the computer screens could not be moved or changed. Only the technicians could do this and it would have been too time consuming for the testing of these ideas. The ideas are discussed and mocked up with paper as imaginary screens; the ideal height, location and what was displayed on each screen. By focusing on these areas, and designing improved solutions at this level, it is hypothesised that the STS is positively influenced.

3. Co-Design

3.1 Control Room Display Layout

The following, Figure A.14 and Table 5.1, represent the co-designed layout of the screens and their displays. Figure A.14 is a front view of the control room work space and each numbered box with a number represents a computer monitor. Each number in Figure A.14 corresponds with a number on Table 5.1 and represents; the screen number, the allocation of the screen, and a description of the information displayed on the screen.

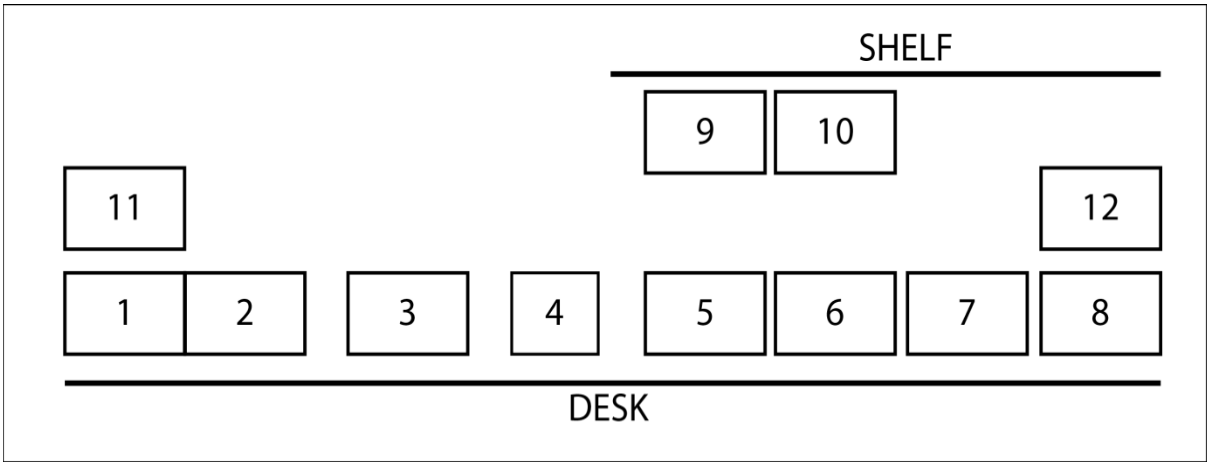


Figure A.14, Co-designed Layout of Control Room
(Author, 2014)

Screen No.	User	Description
1	Telescope Operator	Controls for Operating the Telescope
2	Telescope Operator	Extended desktop from screen No.1
3	Astronomer and Telescope Operator	SALTICAM
4	Astronomer	Personal Laptop
5	Astronomer	SAMMI VGA
6	Astronomer	Extended desktop from screen No.5
7	Astronomer	PCON
8	Astronomer	PDET
9	Astronomer and Telescope Operator	SALT Environment Display System
10	Astronomer and Telescope Operator	SALT Event Logger
11	Telescope Operator	Duplication of display 9
12	Astronomer	Duplication of display 3

Table A.1, Description of Screens Respectively
(Author, 2014)

The users indicated their preference of a duplication of certain displays as they would find it useful to be able to view it closer to their work space. For example, the telescope operator, who sits in front of screens 1 and 2, would like to see the SALT Environment Display System from screen number 9. It was up to them to make the decision to close the telescope if the weather was not suitable for its safe operation, and they were required to continually monitor screen 9. The astronomer stated that the placement of the weather display screens were difficult to view because they, the astronomers, sat out of range of the displays viewing angle, see Figures 5.8 and 5.9. The two screens are too high and the user had to stand to view the information on display. The astronomer also wanted a duplication of screen 3 to the far right at the end of their work space, as they sometimes needed to refer to it while working on screen 8, which is the last computer. The duplication of the selected screens can be achieved with a DVI or VGA splitter box, which can be purchased at a low price, yet create valuable improvement to the users work flow in the control room (Linkqage, 2013: 23).

Using the information from the co-design session, a suitable representation of the space was created using WELS4 software, see Figures A.15, A.16, and A.17.

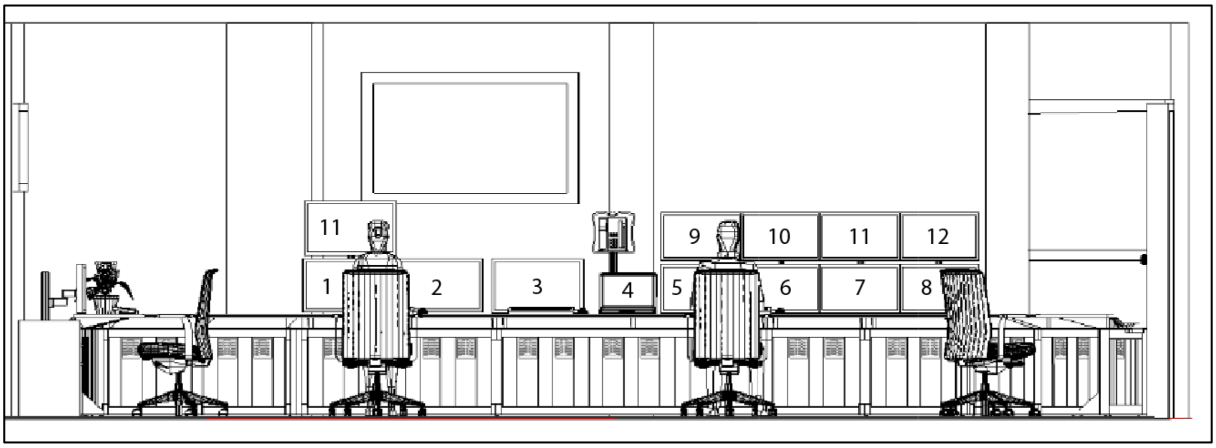


Figure A.15, Designed Layout of Control Room Screens
(Author, 2015)

Figures A.16 and A.17; represent the appearance of the control room. The monitors have been replaced with medium sized HD LCD screens while keeping the existing desks. 24” (60cm), 27” (69cm), and 30” (76cm) screens have been used according to the volume of information needing to be displayed. All monitors are mounted on adjustable stands and are set to the default position for clarity in the Figures below. This will allow the users to tilt and rotate each screen for the best ergonomic position and according to their preferences.

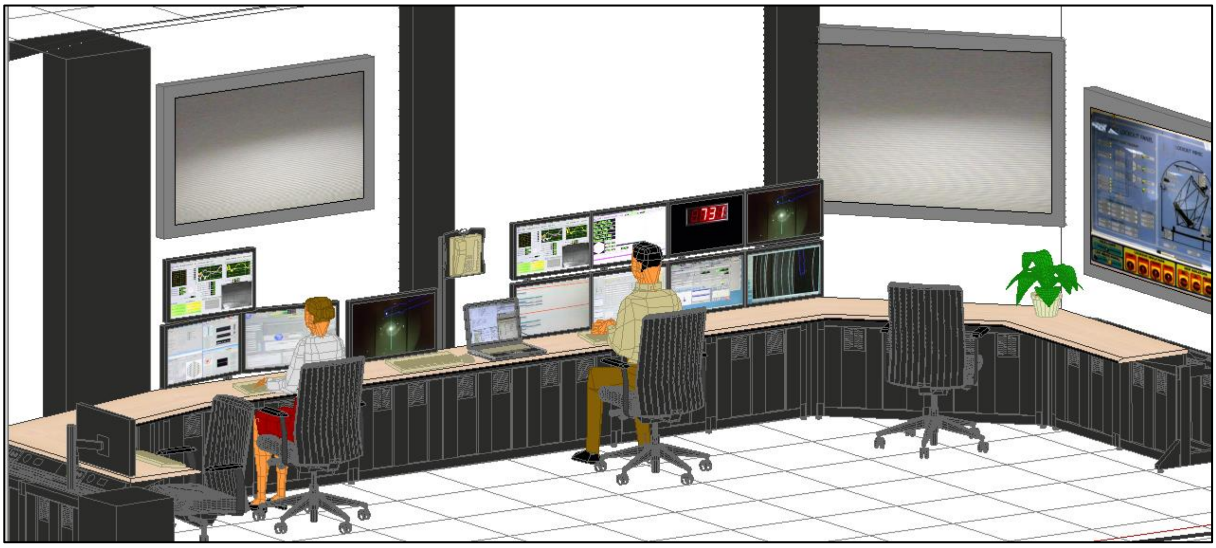


Figure A.16, View of Control Room and Screens
(Author, 2015)

Figure A.17, Top Front View of Control Room and Screens
(Author, 2015)

4. Additional Features

4.1 Audio Notification

Throughout the research observations the audio feedback of the status of the computer programs progress was a common complaint. The telescope would be aimed at a chosen space target for a specified period of time to collect information and run experiments, this is called 'taking science'. These procedures have different durations and are automatic once started. The Audio notification was a voice, which had different phrases to playback for different events during the taking of science. A user pointed out that the volume of audio could be adjusted however they would have appreciated an optional choice of voice.

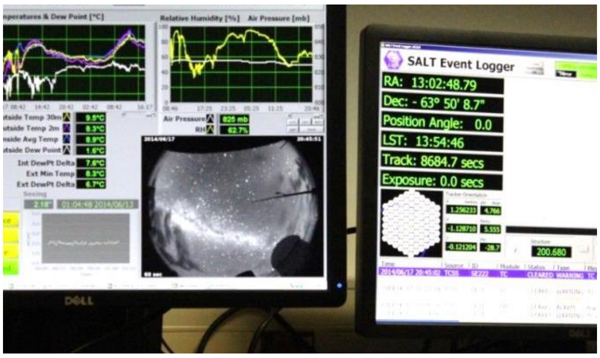


Figure A.18, SALT Event logger
(Author, 2014)

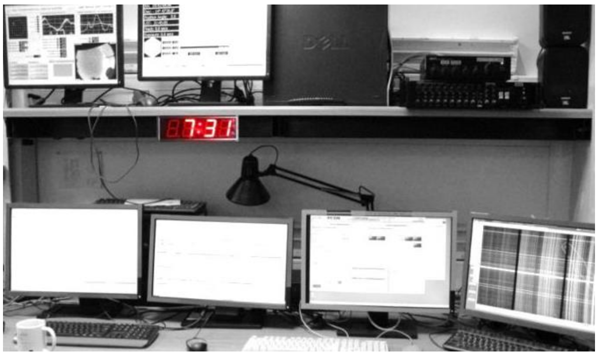


Figure A.19, Feedback Timer Highlighted In Colour
(Author, 2015)

The audio notification was monotonic as it was always repeating the same lines throughout the entire night, which became an irritation for most of the users. The users could however check on one of the computer displays, which showed the status of the events that the audio was referring to, however it was small and inconvenient to view at, Figure A.18. The audio notifications were implemented to alert the users if they left the room for refreshments in the kitchen, or if they were busy with other work on their computers while the programme was running. The audio notification works for some users and is hated by others, therefore by adding a larger digital timer the staff can keep track with ease if they dislike the audio. This timer can use a digital number display with four digits, as it runs in seconds, which can be mounted in an easy to view position Figure A.19. This feedback timer does not have to be limited to a digital clock as other display devices can also be investigated such as an LED monitor.

4.2 Power Outlets

It was observed and found in the interviews that there was difficulty in accessing the power outlets for laptops and other electronic equipment. Most of the users had their own laptops and iPads, which they used in the workspace and needed to power them. Figure A.20, clearly shows the outlets behind the computer screens and amongst a network of tangled cables. This was improved when the control room had a preliminary upgrade, however there was a problem with the switches as users could firstly, not find the switch next to the power outlet and secondly, the users were unsure of the position of the on and off switch. They were not clearly marked nor was there any indication on the outlet itself. There needs to be feedback from the power outlets such as a LED light indicating that it is active. It will also help save power as the users can switch off outlets that are not in use. The relocation of the power outlets would be ideal with an upgrade of the socket and switch, however, if this is not feasible because of safety regulations or the building restrictions, users could use extension leads to allow for easier and safer access to power.

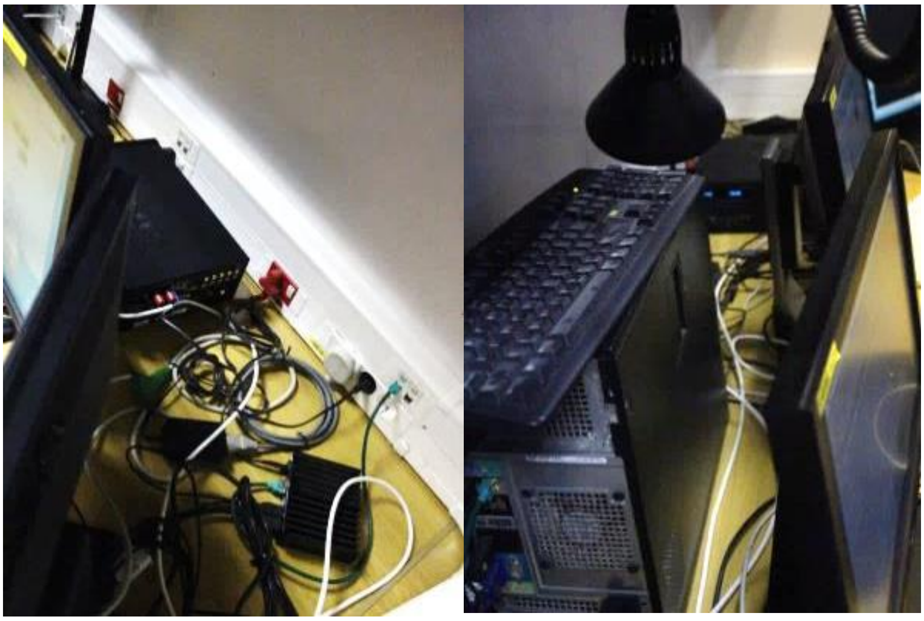


Figure A.20, Power Outlet Locations
(Author, 2014)

5. Design Analysis

5.1 Description of Samples

5.1.2 Adjustable Display Mountings

For an optimised work space which involves computer monitors, the user should have them positioned at the correct height. As the SALT control room has different users from week to week, the display screens should be adjustable to some degree for the best ergonomics for each user. It is suggested that wall mounted adjustable screen brackets are installed. These are adjustable through the X, Y, and Z axes, which allow each astronomer to customise its position accordingly. This improvement will directly affect the user's posture while working throughout the night, and a better posture results in less discomfort of the neck, shoulders, arms and back. As a result a user with less discomfort will work more efficiently and have higher productivity.

5.1.3 Laptop Mounting

As previously discussed, the users are placing their laptops on books to raise it to the correct working height for them. This also gives them more desk space to work on however the method is makeshift and not stable for their equipment. It is recommended that a wall mounted laptop stand be installed. It is adjustable through the X, Y, and Z axes, which allows each astronomer to customise the position of the laptop to their liking for the week. This is a safe and relatively low cost option to solve this problem.

5.1.4 Feedback Timer

The telescope runs an automatic science procedure for approximately 30 minutes. During these procedures the astronomer can continue with other work or take a tea break, while being conscious of the procedures progress. There is a very small count down timer displayed and various audible digital sounds to notify the astronomer when the procedure is complete. By feeding this information to a larger digital clock, the astronomer can keep track of the time with ease as he or she continues their other work, and customise it to their taste, colour, size, etc.

5.2 Description from Respondents

5.2.1 Adjustable Display Mountings

The respondents agreed that this would provide an excellent improvement to the users work practices. One of the respondents stated that they are 186 cm tall and they find it a constant struggle to maintain good posture in poorly constructed computer room environments such as the SALT control room. They understand that having the monitors at the correct eye-level height will help reduce neck and back stress while observing information on the screen. Another respondent noted that removing the computer monitors from the desk would not only improve the ergonomics of the setup but it would give more space for keyboard and mouse, and it would allow for easier access to the power sockets too. The engineer stated that this is definitely going to be implemented in the near future as the advantages are clearly noted.

5.2.2 Laptop Mounting

The respondents agreed that this would provide an excellent improvement to the users work practices. One of the respondents was enthusiastic about the laptop holder however slightly concerned about the reach of the holder, saying that they hope the laptop holder would be able to extend far enough from the wall to be accessible by the user without having to lean forward over the desk. The respondents reiterated that this is an essential improvement to improving the work environment. Another respondent did not make use of any make-shift laptop elevation techniques nevertheless they stated that they would use such a holder if available. The laptop holder could be easily and safely adjusted to the correct height for the user and they understood that it would improve their posture significantly. In an email received from one of the astronomers, he said that he really loves the idea of the laptop holder, especially in conjunction with the adjustability of all the other monitors too, as it would definitely have a great positive influence on all the users of the control room (Miszalski, 2015). The engineer noted that this was a good idea that would be an excellent addition to the adjustable monitors, completing the systems adjustability according to the different users' needs.

5.2.3 Feedback Timer

The respondents highlighted that this would provide an excellent improvement, and would provide some improvement to the users work practices respectively. One of the respondents thought it was a fantastic idea to have a large display of the procedure times as the audio was good yet for those who might be sensitive to noises like themselves; they would really appreciate having an alternative. They also suggested that the timer should have colour options and brightness adjustments as to customise it further to the individual user's needs and preferences. Another respondent pointed out that there are different feedback methods for the multiple instruments. The RSS spectrograph is the audible one with a voice informing the user of procedure complete or configuration complete, SCAM is quiet and HRS has different beeping sounds. They were concerned that the timer would only work for the RSS. The engineer was concerned about the placement of the timer as they want to install large high definition screens. The engineer suggests that the timer be virtualised on the screen when a procedure starts as it could still be displayed the same size. By doing this it would also eliminate the need for special interfacing to external units, as the less interfacing there is in the control room the less chance of the system experiencing problems.

5.3 Analysis of Design

Analysing the designs using the feedback received and the research conducted is discussed systematically in each of the key areas. This is discussed under the following sections; idea, goal, strengths and weakness, and appropriate further developments or directions of the concept.

5.3.1 Adjustable Display Mountings

This is achieved with a product which can be purchased from a specialised supplier. There are various types of brackets, and they can be either mounted onto the back of the desk or bolted to the wall. The desk mounted brackets would take up very little space, however access to the back of the desk would be required and the desk would need to be secure and stable in order for it to carry the weight of the monitors. The wall mounted brackets would require a solid wall within close proximity to the desk. The wall mounting would render the desk and monitors separately, freeing desk space. The wall mountings would be able to carry larger computer monitors as the weight would not be an issue if mounted correctly and securely. The mounting height of the brackets would need to be carefully selected as to accommodate the maximum adjustability for the computer displays.

By having easily adjustable displays it would be effortless when the users do their weekly swop to adjust it to the correct working height and position, according to their own ergonomics. The users spend one night handing over to the next user, and as a result there is an opportunity to share each other's settings. This may lead the users finding new and improved positions for the screens which they might not have discovered by themselves. The different user's preferences would be communicated through technology, allowing for the indirect collaborative customisation of the space. The continual adjusting of all monitors at the start of a weekly shift could become a weakness in the handing over procedure. Or worse they would have to do it nightly, if the technical staff adjusted the screens during the day. They currently have to do this for the new chairs they have and it's really irritating (Hendrickse, 2014). The user would have to adjust up to 10 displays, which will only be in that position until the next user arrives. The user uses the space for long enough periods for the adjusting of the displays to be worthwhile. If the user only used the space for a single night, it might not have been feasible to adjust all the displays, but instead only adjust the main one or two, which are used more or less 80% of the time. The weekly adjusting of the displays may eventually become tiresome, and it is possible that the users might stop adjusting the displays after an extended period of time. Therefore it is of utmost importance that the adjustability of the displays is quick and easy to reach the optimal positions for each user.

5.3.2 Laptop Mounting

The laptop mounting bracket would contain similar results as the adjustable computer display mountings. The key difference here would be the display. Instead of having a fixed display the adjustable mounting would require a stable platform which can accommodate various laptop sizes and weights. It has been noted that all the users of the control room have their own laptops, which they use while working in the control room, however the extent of usage varied from user to user, where some did not feel the need to raise theirs at all. The users who did not raise their laptops stated; that if there was an appropriate holder they would use it.

The holder would not be ideal for extended typing as the users arm position would be incorrect nevertheless the user would have better access to the display and they could add an external keyboard to the laptop which could be used on the desk, below the laptop. This is essential according to one of the users (Hendrickse, 2014). Figure A.21 clearly shows the improvement of the users' posture by raising their laptop to the correct height and adding an external keyboard for optimal use. A correct computer posture consists of; the top of the screen being at eye level, correct back support allowing for an upright body position (users not hunched forward), elbows at sides of body with a ninety degree bend at the elbow, forearms supported on a flat surface with the keyboard slightly raised for correct writs position, and feet comfortable flat on the floor or appropriate floor rest (KOS Ergonomics, 2015).

A generic keyboard can be left in the control room which would save the users from having to carry extra equipment. The nature of portable computers combined with the duration of the device being used, would require access to a power socket as they would need to be charged. The mounting of the laptop bracket against the wall would free up access to the wall power sockets.

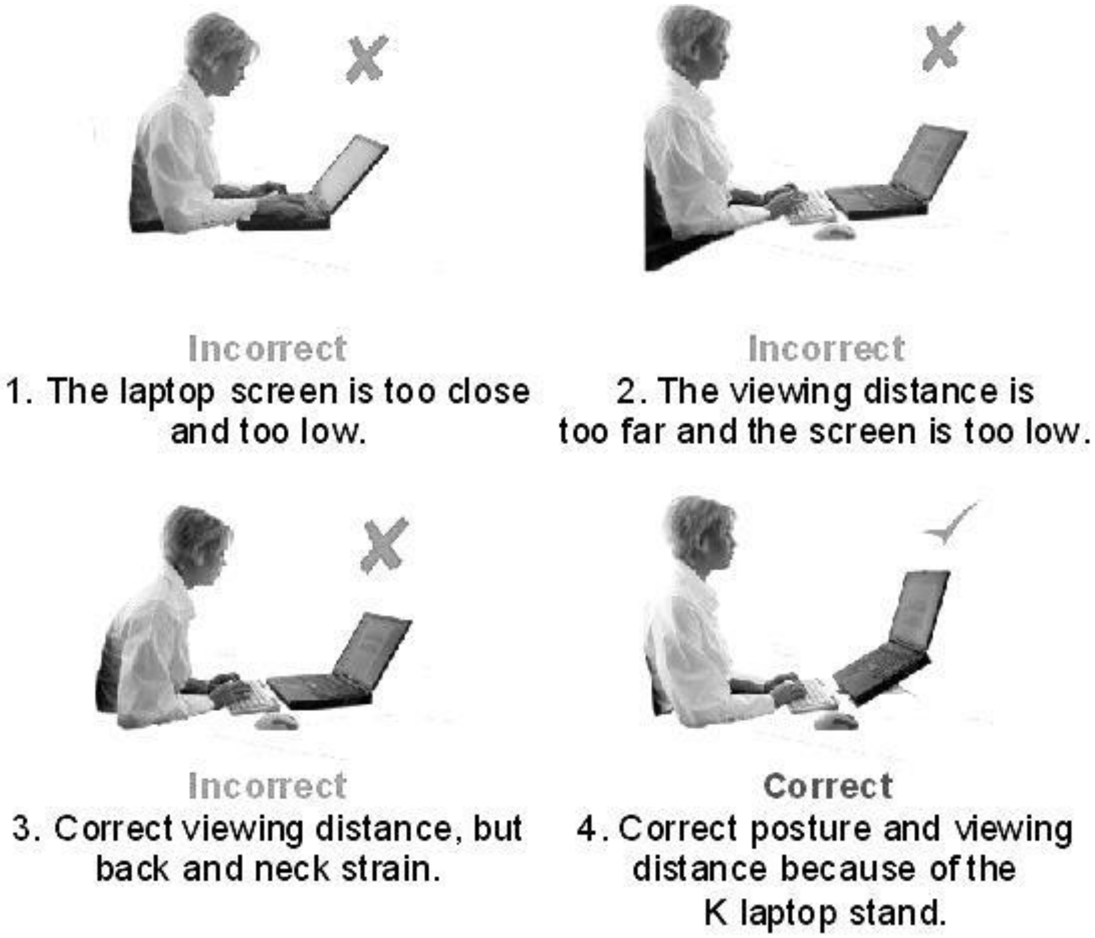


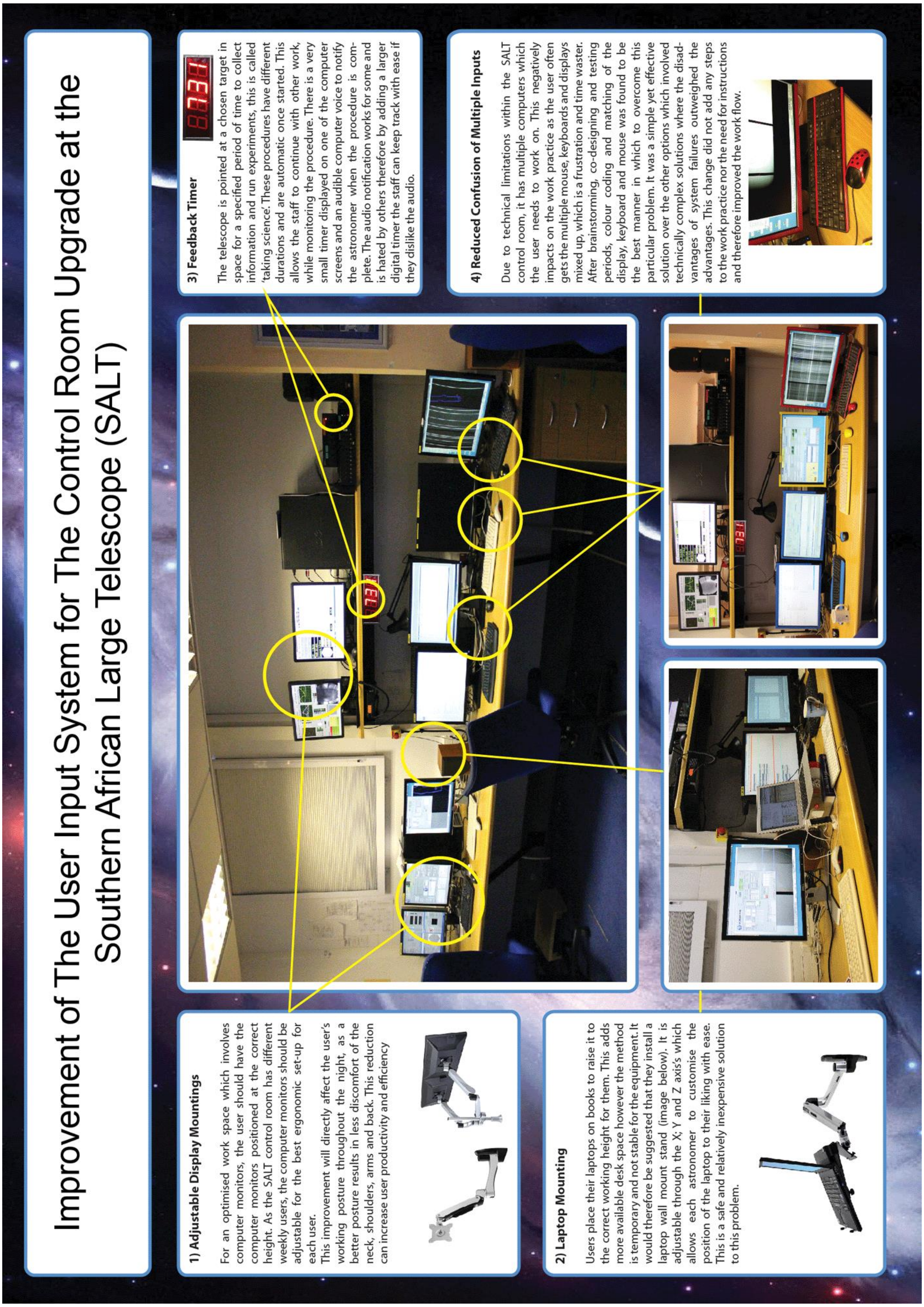
Figure A.21, Ergonomic Guidelines for Laptop Users
(KOS Ergonomics, 2015)

5.3.3 Feedback Timer

The feedback timer was an auxiliary addition to the system as it would add to the customisability of the control room to the different user's preferences. The idea was liked by the users and suggestions were made to improve it. The addition of this feedback timer would need easy customisations with an intuitive interface. The design of this timer in a digital platform could mean that the users could each have a present configuration. The digital feedback timer also allows for it to be placed on any display screen, giving the user control over where they would like to have it, whether it is at the very end of their work space or close to their main working area. Each user has a pre-set number where they can customise the feedback to their preferences; what feedback to display, whether it is visual or audio, colour, size, brightness, volume, etc.

These settings can be saved and each time the user arrives for their shift they can select the appropriate present number, saving them time, reducing frustration, and improving the comfort of the control room environment. This will help the user to focus on the task at hand while receiving feedback in a non-intrusive manner.

Appendix E ***Control Room Poster***



Appendix F *Evaluation Survey Feedback*

PAGE 2: 1) Adjustable Display Mountings

Q1: How would you rate this proposed idea as an improvement to work practice?

- **(no label)** Strongly agree

Q2: What are your thoughts and opinions on this proposed improvement, and do you have any suggestions?

I'm 186 cm tall and it's a constant struggle to maintain good posture in poorly constructed computer environments. I fully support this change so that monitors are at the correct eye-level height. It will help reduce neck/back stress while observing and is an excellent initiative!

PAGE 3: 2) Laptop Mounting

Q3: How would you rate this proposed idea as an improvement to work practice?

- **(no label)** Strongly agree

Q4: What are your thoughts and opinions on this proposed improvement, and do you have any suggestions?

Fantastic idea to have the laptop holders! I hope it can extend far enough from the wall to be accessible without having to lean forward over the desk. Again, this is an essential improvement!!

PAGE 4: 3) Feedback Timer

Q5: How would you rate this proposed idea as an improvement to work practice?

- **(no label)** Strongly agree

Q6: What are your thoughts and opinions on this proposed improvement, and do you have any suggestions?

This is a fantastic idea to have a large noticeable display like this. The audible voice is good, but for those sensitive to noises like me I also really appreciate the option to have it dimmed (or perhaps change colour?). Another great idea!

PAGE 5: 4) Reduced Confusion of Multiple Inputs

Q7: How would you rate this proposed idea as an improvement to work practice?

- **(no label)** Agree

Q8: What are your thoughts and opinions on this proposed improvement, and do you have any suggestions?

Having used this for the past few months it has helped significantly. The improvement is modest but definitely useful.

PAGE 2: 1) Adjustable Display Mountings

Q1: How would you rate this proposed idea as an improvement to work practice?

- **(no label)** Strongly agree

Q2: What are your thoughts and opinions on this proposed improvement, and do you have any suggestions?

Getting the monitors off the work surface will give more space for keyboard and mouse too. Getting to plugs behind monitors will also be easier.

PAGE 3: 2) Laptop Mounting

Q3: How would you rate this proposed idea as an improvement to work practice?

- **(no label)** Agree

Q4: What are your thoughts and opinions on this proposed improvement, and do you have any suggestions?

I don't raise my laptop on books, but my posture will improve if it's elevated to the correct height.

PAGE 4: 3) Feedback Timer

Q5: How would you rate this proposed idea as an improvement to work practice?

- **(no label)** Agree

Q6: What are your thoughts and opinions on this proposed improvement, and do you have any suggestions?

Multiple different instruments all have their own timers. The RSS spectrograph is the audible one with a voice informing the user of procedure complete or configuration complete. SCAM is quiet. HRS goes doodlidoo beepitybeep. The proposed solution sounds to be RSS only.

PAGE 5: 4) Reduced Confusion of Multiple Inputs

Q7: How would you rate this proposed idea as an improvement to work practice?

- **(no label)** Strongly agree

Q8: What are your thoughts and opinions on this proposed improvement, and do you have any suggestions?

The colour coding has worked very well. Thanks!

Appendix G *Evaluation Email Feedback*

From: brent@saao.ac.za
Sent: 2015/08/10 07:51:25 PM
To: freakylinks@mweb.co.za
Cc:
Subject: Re: Feedback

Hi Christopher

I really love the idea of a holder for my laptop and especially the adjustable heights for all monitors; it will be a huge improvement for our sore backs and necks!

Brent.

From: paul@salt.ac.za
Sent: 2015/08/24 03:58:25 PM
To: freakylinks@mweb.co.za
Cc:
Subject: RE: Re: Feedback

Hi Christopher

Thanks for the feedback.

I haven't had time to continue with control room upgrade although I have ordered some minor items as part of the original proposal of implementing large UHD screens. This will enable a single operated unit for SA and one for SO to customize how they want to see the various subsystems on which screen and will be loaded as a user profile for each of them.

See: http://www.hdcabling.co.za/8x8-ultrahd-uhd-4k-x-2k-3840-x-2160-resolution-hdmi-true-matrix-powered-switch-splitter-with-ir-remote-control-and-edid-management-hdmi-v14-3d-p-698.html

1. This is on the cards to do.

2. Good idea.

3. The position of this timer will not work for the big screens we would like to put on those desks. I would advise this timer be virtualised on the screen when a procedure does start. It can be displayed the same size. This will also eliminate the need for special interfacing to external units. The less interfacing we have, the less chance of problems that we will experience.

4. The colour coding was a fabulous idea. This will change if the above unit is installed and proves to work. We have installed 2 layers of trunking on top of the existing ones which will carry HDMI data over Ethernet. The trunking will have a HDMI port where screens will plug in. We have done a similar thing by install a USB over Ethernet which proves to work well. This will enable all those PCs on the desks to be installed in the server room and you would only plug in the screen, keyboard and mouse into the trunking adapters.

Kind Regards

Paul Rabe

SALT Software Engineer

South African Astronomical Observatory (SAAO)
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