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The ‘Meanings’ and ‘Enactments’ of Science and Technology: ANT-Mobilities’ Analysis of Two Cases

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Abstract

In this work I study two cases involving practices of science and technology in the backdrop of related and recent curricular reforms in both settings. The first case study is based on the 2005 South Asian earthquake in Muzaffarabad, Pakistan which led to massive losses including large scale injuries and disabilities. This led to reforms at many levels ranging from disaster management to action plans on disability, including educational reforms in rehabilitation sciences. Local efforts to deal with this disaster led to innovative approaches such as the formation of a Community Based Rehabilitation (CBR) model by a local NGO, which I study in detail. The second case study is based on the recent reform of science and technology curriculum in Ontario, which is related to the release of the 2007 Intergovernmental Panel for Climate Change (IPCC) reports. With climate change science driving this reform with curricular demands for students to learn 'what scientists do', my second case study details the formation of the Canadian CloudSat CALIPSO Validation Project (C3VP) and scientific practices which depict cutting edge science related to climate change.

Towards contending with the complexity inherent in these cases, I have developed a hybrid framework which is based on Actor-Network Theory (ANT) and the mobilities paradigm while drawing on some aspects of the Annales school of historians. The resulting historical sociology or historiography depicts how these various networks were formed via mobilities of various actor-networks and vice versa. The practices involved in both cases evolved over time and required innovation in times of crises and challenges, and are far more than simple applications of method as required by biomedical and positivist representations of science inherent in both educational reforms. Non-human agency in the form of crisis and disaster also emerges as a key reason for the formation of these networks. Drawing from both cases, I

introduce the concept of “transectionalities” as a metaphor which represent configurations of actor-networks in science and technology geared towards dealing with crisis and disaster scenarios. Based on these findings, I also extend the idea of “multiple ontologies” by Mol (2002) to “Epistemic-Ontologic-Techne-” configurations which is sensitive to considerations of time. Moreover, I also find that mathematics is a key mobilizing actor and material semiotic which mediates communication between humans and non-humans and term these dynamics as “mathematical mobilities.” Based on case study one, I also suggest the notion of “affective care” in clinical reasoning, which is based on enhancing the beneficial effect of human to human relationships in these engagements.

Keywords: Science and Technology Studies, Education, Rehabilitation Sciences, Community Based Rehabilitation, Crisis and Disaster Studies

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To all my human and non-human teachers

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Chapter 1

Introduction

Major disasters and crises leave deep impacts on those directly affected as well as on those beyond immediate regions of devastation. Such events also catalyze educational reforms to respond or adapt to the changed conditions and new levels of awareness. In this regard, my study addresses changes in two education curricula. On the one hand, the growing awareness of climate change as an ongoing crisis, and its (pending) catastrophic effects, has compelled revision to science and environmental curricula. Science education is to be relevant to the present world, engage the inter-relations of science, technology and society, and reflect what scientists 'really do.' Indeed, this demand to bring 'real science' to the classroom, in the absence of informed understandings of how 'real science' is enacted is one of the primary rationales for my study. And, on the other hand, crisis and disaster itself impacts and shapes how 'real science' is

done and how it is applied. My research examines two current enactments of science formed and informed by crisis and disaster.

Here, I think it would be pertinent to introduce some standard definitions for “crisis” and “disaster”. The definition of *disaster* by the United Nations Office for Disaster Risk Reduction is described as a blend of vulnerabilities, lack of measures along with hazards which leads to destruction and losses at various scales (UNISDR, 2009). *Crisis* is described as “a disruption that physically affects a system as a whole and threatens its basic assumptions, its subjective sense of self, and its existential core” (Pauchant and Mitroff, 1992, p. 15). It is notable that crises and disasters are interrelated.

The first case my research examines is set in motion with the 2005 Northern Pakistan disastrous earthquake. The large-scale impacts of this disaster led to crises and, subsequently, to adaptive strategies and changes in prior health-related practices. These changes included, in a disjointed manner, reforms in disaster management, reforms in disability policy and curricular reforms in rehabilitation sciences. At the level of practice, adaptive formations included multiple groups contending with the large-scale disabilities through the *application of rehabilitation sciences*.

In relation to my second case, several shifts occurred in the context of Ontario, Canada after the Intergovernmental Panel for Climate Change (IPCC) released its fourth assessment on climate change. Environmental education was introduced in the Science and Technology curriculum and more diffusely extended to all subjects across all grade levels. Concurrently, scientific research programs were also responding and operating especially in the context of climate change. In my second case, I examine how *atmospheric science is enacted* in a specific

scientific research program operated by Environment and Climate Change Canada at the King City Radar facility in Ontario.

Overall, my research illuminates how scientific knowledge and practices were and are mobilized and stabilized in crisis and disaster situations. It explicates on how scientific communities form and reform and mobilize scientific expertise in crises events; these formations and mobilizations produce new knowledge that is translated in/to disaster management practices. By showing how science and technology is practiced, this work then addresses (and challenges) the demands made in revamping of educational curricula with respect to the portrayal of 'real' scientific work and the *application* of science-based work. I also examine crisis and its role in disaster management via the findings of my cases.

Science education is undergoing an interesting transformation across multiple countries and regions. Several jurisdictions in Canada and USA have changed their curricula significantly (for US requirements see Kali et al., 2008). One prominent example is the 2007 revision of the Ontario Science & Technology curriculum (Ministry of Education), which introduced environmental education as a key theme in the syllabus. In the current context of responding to the scientific and social consequences of climate change, came new or renewed emphasis on teaching science and technology in relation to society and the environment. The three *new* learning objectives laid out in the Grades 1-8 curriculum are illustrative—students are:

> 1. to relate science and technology to society and the environment
> 2. to develop the skills, strategies, and habits of mind required for scientific inquiry and technological problem solving
> 3. to understand the basic concepts of science and technology
>
> (Ministry of Education, 2007, p. 3)

With the social and environmental focus, students are further expected to learn about the "nature of science," which is stated as:

- what scientists, engineers, and technologists do as individuals and as a community
- how scientific knowledge is generated and validated, and what benefits, costs, and risks are involved in using this knowledge
- how science interacts with technology, society, and the environment. (p. 4)

Regarding the study of technology, the students are expected to consider:

- what technology is, in its broadest terms (much more than the knowledge and skills related to computers and their applications)
- how technology and science are interrelated
- how thinking about technology's benefits, costs, and risks can contribute to using it wisely. (p. 4)

At first glance, these curricular expectations appear progressive and timely (see similar goals in Bloom, 2006; Aikenhead, 2006; Abruscato & DeRosa, 2010). Relatedly, one of the key motivations of the reform is the introduction of Environmental Education (EE) in the first goal which is "to relate science and technology to society and the environment" (p.3), which is explicated as follows:

> The overall expectation of relating science and technology to society and the environment (STSE) and the related cluster of specific expectations are placed first to better align the curriculum with the teaching and learning of science and technology, and to emphasize the importance of scientific, technological, and environmental literacy for all students. (p. 11)

Whilst the 2007 Ontario curriculum expresses a need for depiction of "what scientists, engineers, and technologists do as individuals and as a community," the *scientific approach/method* espoused in the document aligns with the long-standing, idealized hypothetic-

deductive model, with controlled experiments. Admittedly on the one hand, the curriculum (Ministry of Education, 2007) alludes to *multiple* scientific methods, as stated:

> Although there is no single scientific method, there are scientific methodologies – practices that are followed when investigating questions in a scientific manner. In scientific inquiry, students engage in activities that allow them to develop knowledge and understanding of scientific ideas in much the same way as scientists would. Like scientists, students must also develop skills in the two major components of scientific inquiry – experimentation and research. Experimentation involves conducting "fair tests" to determine whether changing one factor in the experimental set-up affects the results, and, if so, in what ways. In a fair test, the scientist/student identifies variables that may affect the results of the experiment; selects one variable to be altered (tested), and keeps other variables constant; measures all trials in the same way; and repeats tests to determine the validity of the results. (p. 12)

However, on the other hand, it is notably clear that the idealized *controlled* experiment represents the foundation of scientific practices.

Thus, upon inspection, these current curricular demands align with a positivist representation of scientific knowledge along with an emphasis on controlled experiments. Positivist epistemology, drawing from the group of intellectuals from the "Vienna circle," mainly aims to draw upon a certain verification criterion designed to distinguish empirically-testable doctrine from non-scientific doctrine. Schon (1983) critiques positivist epistemology as depending on three problematic dichotomies. The first division is the separation of means from ends, since instrumental problem solving is a technical procedure to be measured by its effectiveness in achieving a pre-established objective. The second separation is that of research from practice. It assumes practice as application to problems of research based theories, verified by control experiments. The third separation is of knowing from doing, with action only an implementation and test of technical decisions (1983, p.165). Positivism, thus, aligns well with the scientific orientation represented in the Ontario curriculum documents. Unfortunately, as I will illustrate in this thesis, this positivist representation is actually misrepresentation of how

science is done or enacted. A key rationale of this study is therefore to offer a more informed understanding of how science is enacted.

As a professional scientist and educational researcher working across disciplines, I wanted to analyze such demands for 'real world' science and the connections to social issues, given the dominant positivist representations of science and its applications in various disciplines present in the policy and curriculum documents. To this end, my research study contributes two thick depictions of science. The first is a means of highlighting the 'application of science' in rehabilitation sciences. The second represents a case of 'doing science' in the areas of cloud and climate sciences.

The impetus for carrying out this research was to present a detailed account of actual scientific practices and their formation over time. Hence, this work is based on empirical evidence, rather than on long running positivist idealizations of science. These disparate cases are linked as contending with crises situations. In the first case study, I present the post-2005 earthquake crisis and its fallout; in the second, I detail a scientific response to the crisis of climate change.

Positivist representations of applied sciences in professions

Professions that draw from Natural Sciences depend on scientific knowledge which significantly influences their practices. Schön (1983), in his chapter, "Reflective Practice in the Science-Based Professions" notes that,

> Medicine, agronomy, and engineering are prototypical examples of professions, which have a basis in scientific knowledge. Many others, such as dentistry, optometry, meteorology, nursing, management, forestry, are, in Glazer's words, "either based directly on science or contain a high component of strictly technological knowledge based on science in the education which they provide" (p. 51).

As another example of how certain representations of science take hold and become the material for curricular reform, representations of medical practice are also founded upon a positivist epistemology of science. Montgomery (2006), notes that,

> The positivist idea of science – science as the uninflected representation of reality - pervades our culture. It has a strong presence in education, the news media and the arts. Elementary schools introduce science as a realist and value-neutral endeavor, and most high school courses do little to alter the idea. In the media, journalists not only use "science" in this simplest way but take for granted in reporting on medicine: cost containment, technological breakthroughs, malpractice, and, especially, new therapies. Perhaps most important, the idea of medicine as a science is the desperate assumption of patients, including, I suspect, physicians, scientists and philosophers of medicine when they are ill. Just as the most convinced Copernican amongst us speaks of the sun rising and setting, so when we or those we love are ill, we find the body to be palpably, painfully real beyond all social construction. Then the body seems best known through science. No wonder that in practice physicians think of medicine as an exact and unmediated representation of reality (Montgomery, 2006, pp. 9-10).

The imposition of such representations is not limited to medicine. Holmes and colleagues (2006) also describe EBHS (evidence-based health sciences), which is about clinical practice based on scientific inquiry. They state:

> The premise is that if healthcare professionals perform an action, there should be evidence that the action will produce the desired outcomes. These outcomes are desirable because they are believed to be beneficial to patients. Evidence-based practice derives from the work of Archie Cochrane, who argued for randomised controlled trials (RCTs being the highest level of evidences) as a means of ensuring healthcare cost containment, among other reasons…While EBHS does acknowledge that healthcare professionals possess discrete bodies of knowledge, EBHS advocates defend its rigid approach by rationalising that the process is not self-serving because improved healthcare and increased healthcare funding will improve patient outcomes. Consequently, EBHS comes to be widely considered as the truth. When only one method of knowledge production is promoted and validated, the implication is that health sciences are gradually reduced to EBHS. (p. 141)

The role of EBHS as a key cornerstone and 'gold' standard has key implications for rehabilitation sciences as well; for example, the biomedically oriented discipline of physiotherapy is privileged over occupational therapy as was evidenced in my first case study.

Two cases as enactments of science and technology: An overview

To address the concerns in the representation and approach to science in schooling and professional practices, my thesis work started by investigating two seemingly disparate case studies. In my examination of how science and its application could actually be studied and depicted in all its complexity, I selected a hybrid combination of 'Actor-Network Theory' and 'mobilities' as the most appropriate approaches; I explain these approaches in the next chapter. My broad research questions are:

- How do scientists and related professions practice science and technology?
- Over time, how are such actor-networks built and what types of actors and mobilities are involved in such formations?
- How is science and technology mobilized across various actor-networks sustained or destabilized?

Using the case study and modeling simulations approach, the connection between science and technology education and practice has been made (Khan, 2008, 2009). Further, numerous ANT studies have been conducted in health sciences (see, e.g. Mol, 2000, 2002; Mol & Berg, 1994; Mol & Mesman, 1996; Singleton & Michael, 1993). The approach I propose will further complement and enrich existing literature. It is also meant to make problematic the new curricular requirements, which may be unrealistic or simplistic in their demands and have conflicting or contradictory recommendations in their proposed approaches. By studying ethnographic data and historical sources, the practice of science and technology inherent in the

first case involved considering how Spinal Cord Injury (SCI) is performed in association with various actors who are involved in mobilizing certain networks towards particular configurations both before and after the 2005 Northern Kashmir earthquake. Using a similar methodological approach, the second case involves looking at how clouds are being studied in the context of climate change, using CloudSat (a NASA satellite) and ground radars at a facility in King City, Ontario.

My study illuminates the conditions, processes, networks and movements that are inherent to each of these cases. As well, it documents the formation of the current practices, which necessitates *historical* as well as ethnographic excavation. The formation of actor-networks is therefore viewed historically. This aspect gives useful insights in observing shifts in practices and associated knowledge domains. Mapping such formations across time and space (not just geographical, but also, for instance, disciplinary regions) and the flow of science and technology is a crucial approach of this study.

To answer the research questions above, I constructed a hybrid of Actor Network Theory (ANT) (Law and Mol, 2005) and mobilities (as espoused by Urry, et al, 2000, 2007, 2009) as theoretical and methodological lenses terming it as "ANT-Mobilities". With this approach, I show how various networks and practices are conducted and how they shift across time. Considerations for the agencies of non-humans is key for both the ANT-mobilities and the Annales school of historians. In particular, Fernand Braudel, a leader and key historian in the Annales tradition considered the natural environment as a historical actor to be considered especially in the context of crises and disasters. In the process of analysis, a novel method of historiography and historical sociology emerged in my work, which assembles the sociological paradigms of ANT and mobilities sociological paradigms with the Annales approach to history.

While doing field studies of the first case, I encountered the massive 2010 Pakistani floods which led me towards further appreciating the interconnectedness of these cases. As I studied the satellite images taken by CloudSat (and other satellites) of this massive flooding disaster (due to my work in case study 2), I was 'acted upon' by this crisis event as well. Indeed, I was struck by my embeddedness in these distinct events via the networks in which I have participated and continue to do so. My participation in these events includes my involvement in relief responses to the 2005 earthquake, the 2010-2014 floods and the 2015 Baluchistan earthquake. The changes and mobilities I encountered in my enrollment in these various responses also influenced me during the course of this study.

The first case

In the first case, I describe the formation of responses to the large incidence of disability arising from the 2005 South Asian Earthquake. The historical account of the earthquake disaster and resulting crises to the present rehabilitative work in a rural setting in Muzaffarabad are presented first. Next, I present ethnographic accounts of those living with Spinal Cord Injury (SCI), their caregivers and health practitioners alongside the non-human actors, which are involved in the stabilization (or lack thereof) of the network. This distinct "practice network" coordinates a network of actors in which a Community Based Rehabilitation (CBR) program is run by a local NGO, Subh-e-Nau (SN). I lead the R&D (Research & Development) department of this NGO. This practice network links into other actor-networks involved in contending with disabilities, particularly SCI, post-2005 earthquake. My empirical analysis builds accounts of particular mobilities within the CBR actor-network, which represents both the daily functioning and its overall formation with various actor-networks.

With historiography and associated historical sociology, I show how this particular network has formed. I map the first year and a half of post-crisis by following the work of the SN NGO, which worked in a distinct biomedical "practice network" within governmental hospitals and makeshift centers. After explication of how certain actor-networks were instituted in this practice network (which involved particular deployments and movements of human and non-human actors), I describe how a shift from this network to the rural CBR program occurred. The aim of this explication is to show how the current CBR program (practice network) descends from a particular practice network formed through encounters with the crisis and its devastating effects. Viewing the latter as an innovation, the links between these two "practice networks" is made, especially through noting the shift in knowledges and practices (of science and technology) in each of these domains and how both epistemological and ontological formations occurred in and through events and times.

Highlighting the role of the earthquake as an event which triggered many actors and networks, the case study documents the proliferation of policy documents out of this event. The emergence of rehabilitation sciences is highlighted as a distinct means to mobilize and make more patient-centered practitioner practices more readily acceptable to those running the dominant biomedical actor-networks, including the approaches used by the Army and governmental organizations, such as the Pakistan Medical and Dental Council which trains physicians with this model.

The second case

In this case, the present practice of a scientific research study focusing on clouds is presented. From an ethnographic orientation, the notions of 'weather' and 'climate' take on particularly interesting valences in the lives of those working at this radar facility. 'Weather' is

related to everyday practice in reporting of such conditions, whereas 'climate' centers the research concerns of this validation project (termed the C3VP validation project) between NASA and Environment Canada. One task is to map this "practice network," which involves detailing the project and more specifically how a research paper is produced (in the context of climate) out of this network; a second task is to historically map the formation and consolidation of this network.

By tracing the formation and evolution of the weather radar network across Canada, and King City Radar, climate change (and its formal identification) is postulated as an ongoing crisis which triggered certain actor-networks and associated movements. Noting the historical presence of ground radars as a basis for the validation project, enabling sources, such as funding and expertise, as well as resistances including political expedience, are represented in a former "practice network," which catalyzed the present network to conduct climate change research, in particular, as the study of clouds.

The case study also discusses the formation of the global Intergovernmental Panel on Climate Change (IPCC) which established climate change in relation to local networks that are implementing science and technology towards "solving" this crisis.

Thesis outline and summary

In summary, I examine two distinct cases where science and technology is understood, applied and practiced using Actor-Network Theory and mobilities paradigm. These cases challenge the (pseudo) positivist curricular representations and professional practices that draw from dominant representations of science. They present more empirically-based and nuanced understandings of science and technology, in fundamental and applied science.

In the second chapter, I discuss alternative representations of science beyond positivism. I elaborate ANT and mobilities as sociological sensibilities. I illustrate various and interrelated ways in which both epistemologies and ontologies of these approaches are related and compatible, while differences complement each other in the constructed ANT-mobilities hybrid detailed in this chapter. The emergent historiographic method and historical sociology that arises from the assemblage of ANT, mobilities and borrowing of some aspects from the Annales frameworks is demonstrated to be a novel innovation applicable to both cases in the study. The methods used in collecting data are also explained.

With the application of this novel historiography and historical sociology, the first case study of the Pakistani earthquake is presented in the third chapter, The CBR network, including its historical network formation and its SCI practices and mobilizations in the present functioning of the actor-network, is detailed. The fourth chapter presents the findings of the ethnographic study depicting the performances of SCI.

The fifth chapter presents the second case study of the Canadian involvement in the CloudSat validation project, with key historical network formations and mobilizations which led to the Canadian CloudSat CALIPSO Validation Project (C3VP). The sixth chapter presents the findings detailing how validation studies were performed in various domains of atmospheric science.

In the concluding chapter, I present practice theorizations of the two cases. These include three new concepts derived from the studies, namely, “transectionalities,” “epistemic-ontologic-techne- configurations” and “mathematical mobilities.” These ideas are situated in the existing literature in the domain of Science and Technology Studies (STS) and History of Science domains. At the level of practice, these ideas are further explicated in relation to science

education and rehabilitation sciences. In the context of clinical reasoning, I discuss the notion of "affective care." I further address the various demands of each associated curriculum to the case studies, and provide reasons as to how some of these are problematic. This chapter also provides suggestions, based on the findings in this study, for science and technology education especially in the context of the ongoing climate change crisis.

Chapter 2

ANT-mobilities: Theoretical Framework and Methodology

In this chapter, I provide an overview of alternative representations of scientific practice including Actor Network Theory (ANT). For this thesis study, I also detail the assemblage of ANT with the mobilities paradigm, indicating the junctures where both these theoretical frameworks connect and enhance each other. This approach is termed 'ANT-mobilities' sensibilities. Using a case study approach, I use various data sources within the ANT-mobilities framework. I also propose a novel historiographic approach alongside this framework. My case study method draws on Bruno Latour's (1993b, 2005) "We have never been modern" and "The Pasteurization of France" as sources of inspiration, as well as John Urry's (2012) "Sociology Beyond Societies."

Beyond positivist epistemology

Karl Popper stands out as a figure who powerfully challenged the positivist representation of scientific practice. In contrast to positivist logic, Popper (1999) states that

falsification is the means to seek the verification of scientific theories; hence, for a phenomenon under study, tentative theories are systematically subjected to rigorous falsification procedures. In this process of verifying scientific knowledge, elimination of error occurs, and theories that survive are representations of the 'best fit.' In terms of their application, these theories can now be applied to other situations, given their passing of falsification strategies. The process can be depicted in the following manner:

Situation 1 → Theories →Falsification and error elimination →fittest from 1 applied to Situation 2

More radically, using History of Science, Kuhn (1970), was amongst the first to posit that the natural sciences themselves are historically and socially situated as communities of practice. He states that:

> Scientific knowledge, like language is intrinsically of a group or else nothing at all. To understand we shall need to know the special characteristics of the groups that create and use it (Kuhn, 1970, p. 210).

By emphasizing group practices of science in terms of functioning "paradigms," Kuhn introduced the sociology of the production of scientific knowledge. While instrumental rationality underlies the production of specific knowledge, scientific communities, according to Kuhn (1970), are also in "subjective" positions of theory choice (Kuhn, 1977) and deploy practical rationality in conducting their everyday practices.

Kuhn (1970) opened the possibility that if science is indeed a human construction, there is no reason why it cannot be studied by sociologists. David Bloor (1976) in "The Strong Programme in the Sociology of Knowledge" argues that the sociology of knowledge should treat science as any other knowledge to investigate its content and nature. He argues that sociologists should not limit themselves in studying only the institutional framework and external factors regarding scientific growth but examine the practices as a community.

Kuhn (1977) furthers the idea that theory choice by a scientific community is not limited to simple application of the scientific method and validation by data. Each scientific community applies and perform certain "epistemic values" which are meshed out over time; particularities and their relative importance vary from one member of the community over another. These values, as proposed by Kuhn, are not a complete set and vary over time and across the context of "theory choice." He categorizes these epistemic values as follows:

- Adequacy: this value indicates agreement with empirical observations. For a good theory this means good accord with existing experiments.
- Consistency: this value indicates agreement with existing theories as well as with itself. A good theory would demonstrate internal consistency as well as reduction to limits/findings of other established theories.
- Broadness of scope: this value indicates the range of applicability of the theory. A good theory extends its immediate scope of existing laws and makes predictions other than just explaining the current phenomena under study.
- Simplicity: this value indicates the nature of the theory. A good theory will demonstrate simplicity and straightforwardness in its nature.
- Fruitfulness: this value indicates the ability of a theory to lead to advancement in current understanding, as well as potential for predictability of new phenomena. A good theory will predict new phenomena that will indicate its advantage over existing and limited theories.

(Kuhn, 1977, p. 325)

In the same vein, Feyerabend (1993) argued that there are no strict or prescriptive methodological rules at the disposal of scientists for the generation of scientific knowledge. A strict adherence to such methods would limit the activities of scientists to narrower purposes, and halt genuine scientific progress. In his position, rather, science would benefit most from an acknowledgement of theoretical disorder. By imposing less rigid rules on scientists, this

alternative representation is more human and humanitarian, and connected to broader values of the society than specific systems of organization.

> For is it not possible that science as we know it today, or a "search for the truth" in the style of traditional philosophy, will create a monster? Is it not possible that an objective approach that frowns upon personal connections between the entities examined will harm people, turn them into miserable, unfriendly, self-righteous mechanisms without charm or humour? (1993, p. 154).

Imre Lakatos, on the other hand, attempted to resolve the perceived disagreement between Popper's falsification and the revolutionary structure of science described by Kuhn. Given that Popper's view required an immediate giving up of a theory as soon as it was falsified, Kuhn depicted science as mostly periods of normal science within "paradigms." In these periods, it is observed some scientists persist with falsified theories in the face of anomalies, even when conceptual change is required. To resolve this disagreement, Lakatos (1977) emphasized that the collective of theories that are slightly different from each other, in so-called 'Research Programmes,' remain unified by a certain theoretical "hard core." Using auxiliary hypotheses, a certain 'research programme' and its adherents will defend this theoretical core from attempts to falsify it. Hence for Lakotas, the verification criteria were not applicable to individual hypotheses – rather it was to verify whether certain research programmes fared better than others over a period of time. A so-called "progressive research programme" leads to a great deal of novel ideas, predictions of phenomena as well as experimental support. On the other hand, a "degenerating research program" is marked by a decline in its enterprise or at least stagnation due to its protection leading to auxiliary hypothesis that lead to no further growth or expansion of the theories defended.

The development of Science and Technology Studies (STS)

The aforementioned intellectuals employed various methods that borrowed from philosophy and history of science; however, anthropological based studies of scientific practices have also been conducted extensively. From 1975 to 1977, Bruno Latour was stationed at Professor Guillemin´s laboratory for a two-year study of the Salk Institute which was published first in 1979. Using ethnomethodology to further his study, he asks:

> How are facts constructed in a laboratory, and how can a sociologist account for this construction? What, if any, are the differences between the construction of facts and the construction of accounts? (Latour and Woolgar, 1986, p.40)

Playing the role of a participant observer (Latour and Woolgar, 1986), he found a way to understand the existence of a laboratory – which, according to him exists due to literary inscription. Latour's study concluded that scientists, who claimed that they were discovering facts, were convincing others and being convinced. Hence, according to Latour and Woolgar (1986) scientific facts are actually constructions, and by means of rhetorical persuasion, participants are convinced that the facts are not constructed. Credentials and credibility make possible "the operation of black-boxing." This is a practice in which the inner workings of any laboratory actant is shut and only its inputs and outputs matter, thereby this object becomes a black box. They conclude,

> Scientific activity is not "about nature," it is a fierce fight to construct reality. The laboratory is the workplace and the set of productive forces, which makes construction possible. Every time a statement stabilizes, it is reintroduced into the laboratory (in the guise of a machine, inscription device, skill, routine, prejudice, deduction, programme, and so on), and it is used to increase the difference between statements (Latour & Woolgar, 1986, p. 243)

Latour and Woolgar (1986) further argue that their account of the laboratory is "no more than fiction" (p. 257). It is "neither superior nor inferior" to those produced by the scientists themselves. The crucial difference is that the scientists have a laboratory but according to Latour

and Woolgar, they only have a 'text.' These views provide an insight into the political as well as cultural factors drive the scientific enterprise, and not merely facts or nature as scientists or science education claims. This study illustrated key aspects of scientific practice in a laboratory and according to Law (2008) led to the formation of Science and Technology Studies (STS). Later in his landmark work, "Science in Action," Latour (1987) developed a more nuanced representation of scientific practice which includes non-humans involved as significant considerations, which I utilize in this thesis in Actor-Network Theory (ANT), which was seen as another key development in STS.

If scientific knowledge is influenced by politics and other factors, then there are deep implications for its study: firstly, there are impacts on how it is taught, given that certain representations, such as that put forth by the Ministry of Education (2007) are dominant. This implies that certain understandings will be propagated across various levels, starting from an early stage in schooling. Secondly, scientific activity and society are not represented within the curricular activity of the practice of science itself, thereby calling for more nuanced depictions that show these practices or applications in relation to these considerations. Finally, education related to science and technology not only requires a grasp of a certain set of skills, methods and knowledge but also requires ethical and broader considerations which require an appreciation of not only humans directing all activities, but also inclusion of these so-called "non-human actors" within the depiction and in connection to the scientific "knowledge-activity" in question. There are extensive mobilities involved in these practices as well, which happens both within certain scientific groups and from external networks that moves scientific work ahead. It is further contended in this work that mobility is not only an effect produced by networks, but also what

allows relationalities to expand and build actor-networks in turn. With these aims in mind, I intend to contribute to the STS community with this work.

Actor-Network Theory

According to Law (2007) Actor-Network Theory is,

> … a disparate family of material-semiotic tools, sensibilities and methods of analysis that treat everything in the social and natural worlds as a continuously generated effect of the webs of relations within which they are located. It assumes that nothing has reality or form outside the enactment of those relations. Its studies explore and characterize the networks and the practices that carry them. Like other material-semiotic approaches, the actor network approach thus describes the **enactment** (emphasis added) of materially and discursively heterogeneous relations that produce and reshuffle all kinds of actors including objects, subjects, human beings, machines, animals, 'nature', ideas, organisations, inequalities, scale and sizes, and geographical arrangements. (Law, 2007, p. 2)

This approach emerged in Paris between 1978 and 1982, with Bruno Latour as a key proponent (Law, 2007). The term "Actor-Network" itself appeared around 1982, however the general approach extends beyond a given starting time and place. The next two sections will explicate the terms "Actor" and "Network" in relation to ANT and then define it using four qualifications put forth by Law (2007). Afterwards, the mobilities paradigm will be explicated.

Beginning with very basic ideas in regard to ANT, an 'actor' or 'actant' is anything or being that can effect, affect or induce change. I take both of these concepts to be equivalent as in Harman (2008). What is quite unique about Actor-Network Theory studies is that they incorporate and describe both human and non-human actors as they are assumed to be related with one another, and as such ANT is likened to a 'post-humanist' approach. Instead of assuming objects as passive and in the background, this frame allows the material world to enter as non-human actors who "pushes back on people" (Latour, 1992). In the ANT frame, these nonhuman

actors can be anything that cause change. For example, the flashing or beeping cell phone signal that informs you of an incoming call could be termed a nonhuman actor. This is probably one of the most defining characteristics of ANT - the inclusion of non-human actors and is quite relevant for both my case studies.

Hence, the activity of acting is spread widely and it is not only humans that act. For example, in the context of CloudSat and King Radar research on clouds, actors might include instruments, equipment, policies, and institutions along with technicians, administrative personnel, scientists and the clouds themselves. Potentially each could be an actor in the proposed study and ANT grants them agency with respect to their roles.

This is not to say that intentionality is ascribed to non-living objects, but rather that action itself loses any humanistic suppositions. The same idea of agency is used to describe objects on either side of the traditional dichotomy between things that belong to nature and things that belong to society (Latour, 1993b). It is the "…underdetermination of action…the uncertainties and controversies about who and what is acting when 'we' act" (Latour, 2005, p.45).

This is where ANT's connections to ethnomethodology are most apparent. Rather than imposing the analyst's frameworks and theories onto the participants, ethnomethodology aims to figure out the frameworks and theories that the members possess for understanding their own behavior. Latour has described ANT as "…a very crude method to learn from the actors without imposing on them an *a priori* definition of their world-building capacities" (in Law & Hassard, 1999, p. 20).

This symmetrical inclusion of non-human actors has been a target of critics, especially from the Sociology of Scientific Knowledge (SSK) view. For example, Yearly and Collins

questioned how, as humans, we can speak for non-human agents who cannot speak for themselves. They have criticized Latour for what they called his "absence of methodological control over fantasy" (1992, p. 320). Here, they call into account these ideas as beyond application of systematic methodology which is contentious as ANT considers effects of non-human actors as observable and accountable. Moreover, they were concerned about the essentialist implications of taking non-human actors too far:

> If non-humans are actants, then we need a way of determining their power. This is the business of scientists and technologists; it takes us directly back to the scientists' conventional and prosaic accounts of the world from which we escaped in the early 1970s (1992, p.322).

Thus, Yearly and Collins, along with Bloor (Bloor, 1999) and those in the Edinburgh school, prefer to adopt a purely human-based approach to represent scientific practices. Jensen recapitulated Yearly and Collins's position and stated:

> On the one hand the epistemological realist position of science is granted, but it is then doubled by the position of the sociologist who is able to really point to how realism is the result of the open and negotiable work of scientists (but notably not the open and negotiable work of natural entities) (Bruun Jensen, 2004, p. 239).

Hence, according to this frame, it is only the *sociologists* who are able to provide an account of science and how it works. However, as stated earlier, ANT is quite different in contrast, where the idea is to trace networks between human and non-human actors, all of whom have agency in terms of their enrollment in the network.

Latour calls for a principle of symmetry as a key feature of ANT, which is to start a study without privileging any of the actors, be it human or non-human (Latour, 1993b). This principle has been misunderstood and criticized by various authors, by stating that ANT attempts to equally symmetrize both humans and non-humans. However, this 'issue' with ANT is addressed by Latour as follows:

> This is because the principle of symmetry aims not only at establishing equality – which is the only way to set the scale at zero – but at registering differences - that is in the *final analysis, asymmetries* [emphasis added] – and at understanding the practical means that allow certain collectives to dominate (Latour, pp. 107-108, 1993b).

In regard to implementing such a principle of symmetry in ANT, it is therefore key to *start* by an equal consideration of both human and non-human actors; however, as the analysis proceeds, asymmetries and differences may emerge. As such, ANT was most appealing for me in this regard as it attempts to be as least affected by grand narratives/ideologies or pre-established prejudices embedded within research approaches, yet as the analysis happens asymmetries and findings emerge from observation and analysis, rather than confirming pre-established bias(es).

Pickering (1984, 1995) has portrayed the practice of science as a "mangle" in which "the dance of agency…takes the form of a dialectic of resistance and accommodation" (1995, p.22). He elaborates on this concept by noting that from this perspective science is seen as an "…evolving field of human and material agencies reciprocally engaged in a play of resistance and accommodation in which the former seeks to capture the latter" (1995, p.23).

Thus, contrary to the Edinburgh school, which, for the most part, obfuscates the role of non-human agency in science, Pickering (and Latour) calls for a view that incorporate both human and non-human agency simultaneously. In this way, actor-network theory described by Latour and the dialectical mangle invoked by Pickering, occupy a space "…in which human actors are still there but now inextricably entangled with the nonhuman, no longer at the centre of the action and calling the shots" (1995, p.26).

Black-Boxing

Black boxing is a process in which ideas or knowledge is rendered "distinct from the circumstances of its creation" (Latour, 1986, p. 259). This process of black-boxing is also

referred to in the ANT literature as 'punctualization'(Akrich, 1992). One of the obstacles with following actors is that many actors quickly become black-boxed once a controversy is resolved or an innovation is taken for granted.

When this phenomenon happens, the ANT researcher aims to unpack those boxes and recover all the important actors. As stated previously, this framework does not assume a division between humans and non-humans when discussing agency. Latour describes an article written by Louis Pasteur in 1857 on lactic acid fermentation. He raises the question of how many acts happen and who acts when a scientist is conducting an experiment in a laboratory. Writes Latour, "Pasteur acts so that the yeast can act alone" (1993a, p. 141). At times Pasteur details the activities of the scientist working in the laboratory, trying to make the lactic fermentation:

> The liquid, a complex solution of albuminous and mineral material, is carefully filtered. About fifty to one hundred grams of sugar are then dissolved in each liter, some chalk is added, and a trace of gray material I have just mentioned from a good ordinary lactic fermentation is sprinkled in; then one raises the temperature to 30 to 35 degrees centigrade (Latour, 1993a, p. 143)

The quote above describes the work that Pasteur is doing. However, Pasteur continues "…the very next day a lively and regular fermentation is manifest…In a word, we have under our eyes a clearly characterized lactic fermentation" (Latour, 1993a, p. 143).

In this later account, fermentation is seen by the reader to appear independent from the process done by Pasteur the day before. Latour concludes that depending on which actors were emphasized, the human scientist or the lactic fermentation, different epistemological positions were established. In the first quote, a constructivist approach was used, however in the next statement a realist epistemological position is taken. In this regard, two seemingly opposing epistemologies are drawn together, whereby the actor is not explored in isolation. Rather, actors act in relation to other actors within a network, which leads us to the concept of 'network' itself.

Networks

Latour has reconsidered the term ‘network’ in ANT and its common association with the internet. “Network” is a commonly used word today and has lost the meaning that was intended when actor-network theory was first named. Specifically, Latour explains:

> At the time, the word network, like Deleuze's and Guattari's term rhizome, clearly meant a series of transformations - translations, transductions - which could not be captured by any of the traditional terms of social theory. With the new popularization of the word network, it now means transport without deformation, an instantaneous, unmediated access to every piece of information. That is exactly the opposite of what we meant (in Law & Hassard, 1999, p.15).

The work by Mort (2002) on the development of the Trident network of a submarine and missile system in in the United Kingdom offers a better view of a network. Two of the key attributes of the ANT network, ambiguity and instability, are shown when these authors map the networks of ‘missile-making’ which included various and diverse actors such as technicians, scientists, workers, laboratories, government agencies, and defense officials.

The stabilization of this defense based network was enabled through active management of uncertainties and risk factors by government officials who enrolled various actors for this project. With workers getting dissatisfied, this study highlights the formation of a counter network which advocated for alternative technologies against those planned in the Trident project. Thus, the network which seemed to have stabilized on the outside, had to face actors which threatened to disrupt it down with disciplinary measures taken by those in charge which led to delivery and production.

Thus, networks in ANT are changing and ambiguous. Actors can have multiple ties to many networks simultaneously (Singleton & Michael, 1993). Unlike a network of highways, which is stable and transports vehicles from one place to another without any change, the

network in ANT is often very unstable. Moreover, in ANT, actors are also modified by their involvement within a network. In the example, above, a genetic test as an actor is modified into a commercial resource within the network.

ANT: a definition

With definitions of actors and networks, as well as some assumptions stated here, overall, ANT is qualified in four simplistic ways by Law (2007). Contrary to initial assumptions, Law (2007) notes that it is possible to describe actor network theory in the abstract. However, ANT is not an abstract approach, but rather grounded in empirical case-studies. According to Law (2007), a first qualification of this approach is that it is "embedded and extended in empirical practice" (p. 2).

Secondly, Law describes ANT as an approach and not a theory in the usual use of the term. Theories typically try to explain why something happens, but this approach is descriptive rather than foundational in explanatory terms – it tells stories about 'how' relations accumulate or do not. More deeply, it is a sensibility to the muddled and messy practices of relationality and materiality of the world (Law, 2007, p. 2).

In this regard, ANT has been labeled as an exercise in "material-semiotics." Mol and Mesman explain, "semiotics treats language as a system of related signs. The value of any one sign depends on that of the others to which it relates…what words mean can be found out...by digging out their mutual relations" (1996). ANT extends semiotics beyond the world of language and texts to the matter and material world as well. So, materials …(finish)

Thirdly, Law (2007) further characterizes the actor network approach as a "diaspora." The nature of ANT as a diaspora overlie with other intellectual traditions. Accordingly, "the

network of activity is located in many different case studies, practices and locations" (Law, 2007, p. 2) and done in many different ways, drawing on a range of theoretical resources.

Finally, Law asserts the following as a fourth qualification of ANT: "If all the world is relational, then so too are texts, coming from somewhere and telling particular stories about particular relations" (2007, p. 3). In this regard and beyond, the concept of "translation" in the context of ANT becomes multiply relevant.

Translation

Translation is a key concept of actor-network theory, through which actors find conversion into particular forms which render some meaning to them. According to Law (1999): "Translation is the process or the work of making two things that are not the same, equivalent. But the term translation tells us nothing at all about how it is that links are made" (p.8). What Law is pointing out is the rich processes through which translation takes. In this section, I will attempt to draw the pieces together (and introduce a few more terms) to offer the reader an account of how translation happens in a certain framework grounded in ANT by Callon (1987).

Callon (1987) outlines four components or 'moments' of translation. These are problematization, interessement, enrolment, and mobilization. I will briefly outline what each of these moments means as they are explored through Callon's study of scallops, fishermen and scientists. He points out that his framework relies on three basic principles: 'agnosticism' (impartiality between actors), 'generalized symmetry' (allowing explanation of conflicting viewpoints in the same terms), and 'free association' (no distinction between natural and social aspects).

His work depicts fishermen and scientists who align aims in an attempt to increase production of scallops in St. Brieuc Bay. Oblivious to the relationship between adult scallops and their larvae, the scientists offered a technique for cultivating scallops borrowed from Japan. These dynamics between the various actors are told with four moments of translation.

The first moment, *problematization*, refers to the process by which a particular actor attempts to define the nature of a problem and thus calls for its resolution. Translation, thus, involves a particular way of defining a problematic situation for others. The scientists set themselves up by defining the problem, and they want to know if the techniques used in Japan for cultivating scallops can be applied in France. Through problematization, a network alliance between actors gets assembled which includes fishermen, scientist colleagues, and scallops.

The second moment, *interessement* describes how attempts to capture particular roles for actors happen. Now that the problem is defined, the scientists have to convince other actors to adopt specific roles and identities.

Enrolment, being the third moment, depicts when the actors themselves accept the roles assigned to them and they can refuse these roles as well. This moment highlights the negotiations that take place such that actors take on certain roles and accept their identities in a network.

Lastly, *mobilization* encompasses strategies used to ensure that spokespersons for related collectives, are not betrayed by competing spokespeople. For example, it is not the fishermen themselves but their official representatives that sanction the research project proposed by the scientists. With the actors enrolled, the scientists are now able to speak on behalf of all the fishermen and scallops. They may go to a conference and present graphs and figures with numbers to a small group of experts.

These diagrams and tables represent different populations of silent actors, but have been mobilized, displaced, and translated into certain representations, such as a graph. Without built alliances these representations would not have happened. The following section explains additional ANT concepts.

Strategies of Co-ordination, Modes of Ordering and Multiple Ontologies

Law (2002), in his study of the TSR 2 aircraft describes two concepts that are also relevant for the work proposed here. In the passage below, he talks about the brochure designed for its potential buyers, which depict certain "strategies of co-ordination."

> But why be naive? To answer this question I need to talk about *strategies of coordination* (italics added). In particular I will identify a series of mechanisms that work to connect and coordinate disparate elements. The TSR 2 brochure, or so I want to suggest, embodies and performs a number of these. (Law, 2002, p. 15)

Law (2002) then goes on to describe the table, showing syntax, tables, structure "...and its deferrals produce a hierarchy that generates a subject that has focus but also a coordinated object, one that hangs together because it has been constituted as a set of hierarchically related parts or aspects that combine to produce a unitary whole." (p. 21)

Mol and Law (date) offer another depiction of strategies of coordination,

> ...it can also be argued that the different knowledges (clashing at some points, ignoring each other at others) all know their own "body." If this is the case, then it becomes important to understand how these different bodies hold together in hospital practice. It appears that this requires a lot of coordination work: files that go from one building floor to another, routines, conversations, memos, case conferences, operations. In practice, if a body hangs together, this is not because its coherence precedes the knowledge generated about it but because of the various **coordination strategies** involve succeed in reassembling multiple versions of reality. (emphasis added, p. 10)

Thus, an important feature of 'strategies of coordination' is the intention and strategy to create unity or coherence out of multiple versions of reality.

In this regard, the concept of "multiple ontologies" (Mol, 2002) becomes relevant. In her work, "The Body Multiple: Ontology in Medical Practice", documents how the problem of lower-limb arteriosclerosis is practiced in three different ways. Rejecting these as different perspectives on a single disease, she states that each practice generates its own reality or in other words, there are 'multiple ontologies' generated by the various practices. Here "ontologies" are realities that are constructed through practice, rather than the usual meaning of term as in the nature of being. She states that,

> This is the plot of my philosophical tale: that *ontology* is not given in the order of things, but that, instead, ontologies are bought into being, sustained, or allowed to wither in common, day-to-day sociometric practices. Medical practices among them. Investigating and questioning ontologies are therefore not old-fashioned philosophical pastimes, to be relegated to those who write nineteenth-century history. Ontologies are, instead, highly topical matters. They inform and are informed by our bodies, the organization of our health care systems, the rhythms and pains of our diseases, and the shape of our technologies. All of these, all at once, all intertwined, all in tension. If reality is multiple, it is also *political* (italics added) (Mol, 2002, pp. 6-7).

Mol's study thus looks at how the body is "multiple and its diseases done well" (Mol, 2002, p. 7). Informing such "ontological politics" (Law & Hassard, 1999) and "multiple ontologies" are "modes of ordering" which depicts the various 'interferences' that these various realities create. Law (2000) states that

> …Haraway's optical diffraction metaphor allows us to ask how the different modes of ordering interacted with one another to generate complex patterns of interpellative interference. To make subjects, readers and authors, places of illumination where the wave patterns were coherent, but also with dark places where they were not because they cancelled one another out (p. 24).

Such "modes of ordering" are frameworks that allow multiple realities to co-exist and strategies of co-ordination, alongside translation, allow a single unity to emerge as a result (Law, 2002).

The Mobilities Paradigm

The Mobilities paradigm, situated in the social sciences, is a contemporary framework which studies the movement of people, ideas and things, as well as the broader societal consequences of those flows.

The "mobility turn" started in the 1990s, by giving due importance to movements of individuals and groups, basing itself as a critique of sedentarism and deterritorialisation in the social sciences at the time. Since the social sciences traditionally had a static take on the social, the mobility turn raised the significance of travel in everyday life to leisure travel amongst other types of movements (Sheller and Urry, 2006). This paradigm utilizes novel ways of understanding how these mobilities can better explain formation of identities, networks and everyday life which features greater movement than ever before (Cresswell, 2011). Like ANT, mobilities research has taken seriously ‘the material turn’ and ‘the spatial turn’ in the social sciences. Influenced by social studies of science and technology, in particular actor-network theory and Bruno Latour’s (1987) analyses of ‘immutable’ and ‘mutable mobiles’, mobilities theorists pay close attention to the infrastructures, technical objects, prostheses and embodied practices that assist or disable flows or mobility (Büscher et al., 2010; Latour, 1993a). Everything from shoes and bikes, mobile phones and motor vehicles, passports and satellites, software code and embedded sensors, are part of the sociotechnical assemblages or human/material hybrids that perform as mobile systems and support specific mobility regimes.

One of its founder and leading proponent, John Urry (2007) defines five interdependent types of mobilities as follows:

- Corporeal Travel: Travel of people for work, leisure, family life, pleasure, migration, and escape.

- Object Travel: Physical movement of objects to producers, consumers, and retailers; also sending/receiving of presents.
- Imaginative Travel: Images of places and peoples appearing in one's mind from interaction with media and associative objects.
- Virtual Travel: Travel to virtual spaces
- Communicative Travel: Travel through person-to-person messages via email, SMS, telegraph, and telephone.

Actor-Network Theory and Mobilities: Beyond the "social" and "society"

Moving beyond Science and Technology Studies, Bruno Latour, one of the key founders of ANT, has described that the present state of sociology confines the "social" within its own narrow definitions. In his landmark work, "Reassembling the Social", he calls for a holistic relational consideration which takes sociology beyond its typical and asymmetrically as human-centered. The proposal to expand contemporary conceptions of the social views non-humans and humans in a relational manner

In a similar vein, John Urry in his work, "Sociology beyond societies", calls for a move to a "borderless" notion of sociology which has been hampered by the confining construct, "society." In an increasingly mobilized world, he calls for an accounting of various mobilities which proliferate now. Law (2005), one of the key proponents and developers of ANT, has suggested researchers using this approach to embrace mobilities, in order to transcend a narrow scope put forth by description of networks and to be able to describe changes and instability, as well as network formation. Moreover, both these approaches have the ability to probe beyond traditional notions of the "social" and "society" simultaneously, while providing new insights which are not available to each in isolation. In this work, I not only take both approaches and apply them to two case studies to provide insights into the practices that are

mobilized within networks, but given the temporal aspect of network formation, develop a novel historiography using the ANT-mobilities approach.

ANT-mobilities: A productive and complementary union

To address research questions presented in the introductory chapter, I contend that Actor-Network Theory (ANT) (Latour, 2005; Callon, 2007) and the mobilities paradigm (Urry, 2002; Creswell, 2011; Sheller, 2011) approaches are appropriate and responsive to concerns stated earlier. ANT has emerged both as a new representation of science in bringing materiality into knowledge and framing knowledge as materially embodied in and between diverse human and non-human actors such as computers, apparatus, and texts and so on. Thus, the term "actors" are also termed collectively as "actants" because … A key element of an actor is its ability to act and modify other relationalities and actors in the network. In addition, the ordering and patterns of these heterogeneous materials should also be studied. In other words, not only people form networks, but also all the other heterogeneous materials including non-humans constitute such networks.

A key assumption present in ANT is the notion of "generalized symmetry." Extending from the sociology of scientific knowledge (SSK), the researcher accounts for social, technical as well as natural elements that makes up a network. Actor-Network theorists refuse to accept certain types of reductionism; they reject ontologies that separate the human and the technical into distinct categories and also refuse to assume that the human drives the other. The relationship is instead a complex one, according to ANT researchers as Callon (1980); for example, even the elements bound together in networks are, at the same time, constituted and

shaped in and by those networks. This perspective implies complex chains of actions and interactions, shaping and reshaping among various heterogeneous elements.

Technologies, as Latour (1987) claims, do not have a momentum of their own that allow them to pass through a neutral social medium. Rather, technologies are shaped and reshaped by human and non-human interactions. Technological changes are therefore contingent, evolving and emergent. He uses the example of the door to illustrate how the human element is part of the network.

In general terms, Actor-Network theory is a relational and process-oriented "sensibility" (Mol, 1987) that examines the interactive effects and relational identities among human and non-human actors. The objective is to explore how a pattern, an organization or an order is generated. It is known as the sociology of associations because it implies transformation and the possibility of replacement, the possibility that one thing (for example an actor), may stand for another (for instance a network). The emphasis is on the relational effects and the mapping of the conditions and materials that generate these effects.

Complementing ANT, the study of mobilities (Sheller, 2011) is a recent approach which involves "…research on the combined movements of people, objects and information in all their complex relational dynamics" (p. 1). According to Sheller,

> Mobilities research combines social and spatial theory in new ways, and in so doing has provided a transformative nexus for bridging micro-interactional research on the phenomenology of embodiment, the cultural turn and hermeneutics, postcolonial and critical theory, macro-structural approaches to the state and political-economy, and elements of Science and Technology studies (STS) and new media studies.

Since science and technology involve movements, and also transform in such displacements and enactments, the mobilities approach, alongside ANT is relevant, especially where and when

radical situations are involved. Mobilities are also important in tracing how actants move in certain networks and also connect to different actants, furthering mobility or network building. The combined approach has strengths in terms of providing a better depiction as to how networks come together and transform, with a better accounting of those involved and as to how particular networks are stabilized (or not) as a result.

The ANT-mobilities Assemblage: Some exemplary studies

The use of ANT along with mobilities has been used by a number of scholars and researchers. This bricolage has informed a diverse array of work on particular networks and spaces of mobility ranging from driving and roads (Urry, 2004; Merriman, 2007; Beckmann, 2001) to flying and airports (Adey, 2007, 2010). In this regard, it is notable that no educational studies have been done using both approaches (see e.g. Fenwick & Edwards, 2010 for a collection of ANT based educational studies). Hence, this thesis is a first-time application of the ANT-mobilities approach in educational studies.

A historiography and historical sociology using ANT-mobilities sensibilities

The inclusion of temporality is key to understanding network formation and disruptions, as well as various mobilizations that happen in the network. Hence, the historical study of both cases is a necessary element for my present study. Coming from the ANT-mobilities sensibility used to describe practices in one segment of this thesis, also opens a novel approach which has not appeared in literature as far as my knowledge is concerned. A similar approach, namely ANTi history was conceived earlier by Gabrielle Durepos in 2009 which is applied to organization studies (Durepos & Mills, 2012). However, her approach is different than mine as she has not

taken the mobilities approach, and unlike her social constructionist approach using the sociology of knowledge (SSK), my deployment of ANT-mobilities is not founded upon these modernist notions which take nature and culture as separate and purified.

It is notable here that the link of historical events with social sciences is vital. Braudel (1980) concurs in stating that,

> History seems to me a dimension of the social science; they are aspects of one and the same thing. In fact, time, the passage of time, history impose them, or should impose themselves on all the human sciences. Their tendency is not to oppose, but to coalesce. (p. 69).

This visionary statement, led to a new branch of study known as historical sociology. According to Smith (1991, p.2), ". . . historical sociology is the study of the past to find out how societies change and work and change." He further clarifies the application of this branch by "historians and sociologists who investigate the mutual interpretation of the past and the present, events and processes, acting and structuration. They try to marry conceptual clarification, comparative generalization and empirical exploration. Given the precepts of ANT and mobilities outlined above, I apply additional considerations towards outlining this new approach which can be interpreted as both a historiography and a historical sociology. In particular, drawing from "We have never been modern" (Latour, 1993b), the construct of "modernity" is challenged by Latour, who views that the "purification processes" associated with such a period have not happened. Rather, there have been a mass creation of hybrids or assemblages which defy reduction to modernist categories. As a result, the historical approach is "amodern" (Durepos, 2005) which coincides with the ANTi approach. However, neither Latour nor Durepos take a mobilities view into how the "modern" myth was built, along with the various actors involved and the various obstructions involved in carrying out certain purification processes to stabilize.

Another key influence for my approach is "The Pasteurization of France" by Latour (1993a; 1993c), which describes how Louise Pasteur was also acted upon by a non-human actor which led to a discovery and ultimately the formation of a network. Here, the presence and the agency of the non-human actor is acknowledged, as well their influence which led to a historical event. However, Latour does not take into account the various mobilities that were afforded to Pasteur at the time of his discovery and afterwards, which enabled the growth and mobilization of the spread of his network. While this study is beyond the scope of our work, it is an incentive to build a historiography which accounts for actors, mobilities along with various network formations as well as network shutdowns.

Hence, the historical formation of networks will be seen relationally and the mobilities of various actors (both human and non-human) will be traced across time. Using the approach of generalized symmetry, asymmetries and mobilities are then drawn through study of historical sources.

Connections to the Annales School

This historical approach also has ties to the Annales school of historians, who did not believe in specialized history, arguing that to understand the realities of the past, a historian needed to have a relational underpinning in their approach. This view has a direct bearing on the belief expressed by Febvre and later by Braudel (1980) about the need for interdisciplinary historical research. In particular,

> While Annales historians have had to learn to regard production as part of the overall communications system, their conceptions of territoriality as part of the communications system has been of the long duration. ***It is based on their long-standing in the interest between people and environment and on their image of people as a function of their situation on a dynamic Earth, at once acting upon them and acted upon***. It has the

> origins of “possiblist” geography of Paul Vidal de La Blanche, as reinterpreted by Febvre, Bloch and Braudel. (emphasis added, Stoianovich, 1976, p.77)

Stoianovich (1976), in “French Historical Method: The Annales Paradigm”, claims that this view of history is fundamentally different from that of the established academic community, and that a paradigm shift involving its becoming acceptable constitutes a revolution in the field. Braudel, who represents a very key figure in the second phase of the Annales, is described to work “Under the notion of the “the dialectic between space and time (geography and history),” which he once called “geohistory,” Braudel subsumes both ecological and temporal-territorial continuities and transformations” (Stoianovich, 1976, p. 77).

Certainly, the history outlined earlier in this chapter reflects the path that Kuhn (1970) would predict, and constitutes fully a different “paradigm” as explicated by Fulbrook (2002). The beginning period corresponded to the nineteenth century attacks on positivism. Precursors such as the philosopher Henri Berr provided early avenues of communication and publication. The new ideas of Febvre and Bloch generally failed to win converts among the established historical community, but rather relied on gaining young supporters.

The conflict, which this implies, it is relevant to bear in mind the nature of the opposed viewpoints. Braudel (1976) emphasizes that Febvre and Bloch were in opposition mainly against the purely political and narrative histories (later termed "*recit evenementiel*" or recitation of events) of the Sorbonne. The identification of "the enemy" as political history led the Annales group to underplay the role of the political sphere in their analyses, undertaken during the period of establishment and battle for recognition.

Another key objective of Annales work is to “…construct a history of every group and subject whose investigation has been suppressed or neglected. It thus aspires to bring antique, up to date, and future history (but a prospective future, not a projective or futurological history

deprived of foundations in the past or with a basis in the recent past only) into its focus of concern" (Stoianovich, p. 158). Accordingly,

> It aims similarly at the "demasculization of history" and at the development of a history of women, of youth, of childhood, of oral cultures, of voluntary associations..." (Stoianovich, 1976, pp. 158-159).

Under the notion of paradigm stated earlier, Febvre, Bloch and Braudel argued, for a structural view of history. This is where there is a distinct departure from our approach, which is does not abide by structuralism, as both ANT and mobilities frameworks are not based on these ideas. Nevertheless, our new approach does draw from aspects of the Annales approach to historiography. Sheller and Urry (2006) also clearly note the connections of ANT, mobilities and the Annales approach in a striking passage,

> The mobilities paradigm indeed emphasizes that all places are tied into at least thin networks of connections that stretch beyond each such place and mean that nowhere can be an `island', as Braudel (1992) showed in the case of the complex trading and travel routes that constituted the Mediterranean world over many centuries. From the ships, sea routes, and interconnectivity of the Black Atlantic (Gilroy, 1993) to the complex mobilities of diasporas and transnational migrants in the modern world (Cohen, 1997), multiple interacting mobilities have long been significant. (p. 209)

The Importance of Crisis

In the study of the structure of society and sociology within the temporal framework mentioned earlier, the role of the crisis is seen as of great importance to Annales historians. In the Annales language, climate change can therefore be viewed as a crisis. What, then, is its nature and significance? Interestingly, Ladurie (1981) draws towards the metaphor of the earthquake to underlie this aspect of the Annales. Being the product of subterranean surface tensions, an earthquake is a release that is accompanied and followed by a terrifying readjustment. It further reveals underlying forces, lays waste to existing superstructures and "(gives) builder/s freedom ...in their choices and design for reconstruction" (p. 288).

An event such as the climate change crisis or the earthquake, leading to action in reorganizing entire school systems and policy is itself an indication of deeper tensions in the social fabric. These stresses are in turn brought about through transformations and disruptions in the economic as well as material worlds, which of course play a crucial role.

Analytical framework for thematic analysis and quality

I invoke the application generalized symmetry in ANT and mobilities as a complementary practice to define and detail themes insofar as to how main themes will be determined. Various asymmetries were drawn from the data and participant observations.

The overall data collected is considered as an assemblage, which was analyzed keeping the process of mobilizing symmetry and then mapping out asymmetries in the process happens. In other words, the entire data set is considered as a 'research data assemblage' for each case study and guided by the research questions, as well as generalized symmetry and mobilities, themes and other key features are drawn out.

An important aspect of a good ANT study is that it captures the movements and explanations of the people being part of certain social and natural worlds lived relationally. In this regard, my drawing from ethnomethodolgy is warranted from its similarity to ANT's goals.

As in ethnomethodology, the ANT researcher is encouraged to follow the actors as they will make their own frameworks, theories, and contexts. While this does seem to be at odds with ANT's use of specialized vocabularies, Callon (1987) has qualified this as a criterion for quality including keeping the considerations of generalized symmetry. In a footnote, he brings the researcher as a writer with a chosen vocabulary back into the spotlight:

> The argument developed here is similar in some respects to that advanced by Weber (1965). For Weber, the sociologist is guided by his own values (Wertbeziehung) and selects the problem to be studied and the elements of reality that seem to him to be most important. It is only once this reduction of an infinitely complex reality has been undertaken that the proper work of the sociologist can begin. The principle of generalised symmetry endows the sociologist-observer with analogous discretionary powers. In principle the choice of repertoire is entirely free. The only restriction is that it must relate both to nature and society (Callon, 1987, p.24)

The key point for Callon is that the vocabulary chosen remains consistently applied and indifferent to the actors being studied, whether they are human or not.

Methodological Concerns: The Researcher as Mobile Actor in Networks

Networks do not just apply to the human and non-human actors brought together by the members of the groups we study. In a particular ANT account, the researcher has been typically situated outside the network being described (Schwartz Cowan, 1987). However, how do the networks of the researcher and the networks of the field site interact in the study itself? Given that part of the account is that I am already part of the networks that I am analyzing, how do I locate myself in relation to the networks being traced? In this regard, and in ANT, the researcher may be thought of as a network builder among network builders. Latour has stated, "…the text, in our discipline, is not a story, not a nice story. Rather, it's the functional equivalent of a laboratory. It's a place for trials, experiments, and simulations" (Latour, 2005, p. 149).

Another great concern is that of knowing when the network has been fully traced and when to stop. Strathern (1996) looked at this issue at detail in terms of "cutting" the network. She states:

> …the power of such analytical networks is also their problem: theoretically they are without limit…one can always discover networks within networks; this is the fractal logic that renders any length a multiple of other lengths, or a link in a chain of further links.

> Yet analysis, like interpretation, must have a point; it must be enacted as a stopping place (p. 523).

A myriad of network-cutting possibilities does exist. "Ownership" is one means offered by Starthern. "…belonging divides and property disowns. So, where technology might enlarge networks, proprietorship can be guaranteed to cut them down to size" (p. 531). In her article, a consideration of the example of an invention is cited. The academic paper detailing the invention include up to fifty authors, however, while the patent contains only six. Here, due to ownership, the network is cut down and boundaries are established. Thus, ownership and authorship are a means of truncating a network, which will be used here to set initial boundaries for the networks under study.

While this demarcation is of significant use, Neyland (2006, p. 43) has also ascertained that "promoting incompleteness and ambiguity [are] positive aspects of a theoretical strategy." Hence, the research study remains open towards these unexplored networks, and keeping the present analysis open to further change. Also, to keep the first consideration stated above, my own implication and relations in these case studies will be described in detail as well. In other words, I have not considered myself as "outside" of these networks in consideration.

The case study approach

Network formation, various practices and actant mobilizations within and beyond the network under study will be described using the case study approach. Collection of data for these two studies, first of all draws from the notion of case studies itself. Taking the cue from Law (2007) who views ANT studies as particular types of case studies, a pertinent definition is,

> Case studies are set in temporal, geographical, organizational, institutional and other contexts that enable boundaries to be drawn around the case; they can be defined with

> reference to characteristics defined by individuals and groups involved; and they can be defined by participants' roles and functions in the case (Hitchcock & Hughes, 1995, p. 319)

This definition is suitable for both the case studies in my PhD dissertation, as the actors, which involve both human and non-human ones are relationally linked to each other within a network and various mobilities are involved in both their functioning and operation. The communication of knowledge and depiction of practice will be a key objective of this study, whose aim will be to theorize networks present in both cases.

Three methodologies will be employed inspired by ethnomethodological and newly devised historiography (described earlier) in drawing data from each case study. To theorize networks and various mobilities relating to their formation, and in creating "thick descriptions," these methodologies are:

- Analysis of documents and historical sources
- Participant observations (their interaction with non-human actors involved)
- Interviews

The overall methods of "depicting networks" are inspired by ethnomethodological methods. The term "depiction" does carry intentions in the study towards describing as well as using imagery-based techniques such as observations and interviews from actors to "draw and paint" such accounts and theorizing of networks. Drawing from ethnomethodology and having termed as "alternative sociology" by Harold Garfinkel, a central figure in its development, this area as a rich and pertinent source is described as follows:

> As a first approximation, one can say that 'ethnomethodology' is a special kind of social enquiry that is dedicated to explicating the ways in which collectivity members create and maintain a sense of order and intelligibility in social life.

This definition is quite compatible with the ANT notion of actors and networks coming together and maintained. Classical sociology, in contrast has different notions of study. According to Ten Have (2004, p. 14),

> For the Durkheimian strand in classical sociology, and social research generally, the ultimate goal is to investigate 'social facts' have the twin characteristic of being both 'external' and 'constraining' to the actions of the individuals. In ethnomethodology, on the other hand – to adapt the phrase from Melvin Pollner (1974) – 'facts are treated as accomplishments', that is, they are seen as being produced in and through members' practical activities. In other words, while classical sociology is in the business of *explaining* social facts, the effort of ethnomethodology is the explication of their *constitution*.

This again speaks to ANT's overall goals in describing *how* the networks come together and explaining 'what happened' over essences and reasons such 'what is and why'.

Analysis of documents

Drawing from one aspect of Law's interpretation of ANT insofar that texts are interrelated (2007), document analysis will be involved in both case studies. The texts involved are interpreted as "non-human" actors and/or intermediaries in each network, and the relevant ones studied will be connected to practices, or those that are related secondarily to these practices. Thus, a term "enactor text" is used to denote the connection of specific texts under analysis that are enacted, or practiced along with historical sources. This is also drawn from "Natural Document Analysis" within the ethnomethodology approach which is practice-focused (Ten Have, 2004), where documents related to practice are deemed as pertinent to the study.

In both case studies, the first level of entry and complexity is the overarching network as well as the overarching policy for each system in each case study. This usually reflects the overall scheme of things and structure of the institutions and actors involved. These policies can be a very revealing guideline in terms of the political and social outlook of the authorities that designed it and the people for which it is intended for, as well as the "intended network." The relevant documents for the first case will be policy documents by Ministry of Environment and Environment Canada for meteorological activities to be conducted by King Radar facility. In the second case, these documents will be the medical education policy documents set out by the Ministry of Health, Pakistan as well as the guidelines for medical professionals by Pakistan Medical and Dental Council, which is applied nationally. On the end of implementation of Community Based Rehabilitation (CBR) the World Health Organization (WHO et al, 2004) will be studied in terms of its policy definitions of disabilities. The policies set up by Subh-e-Nau in regard to its organizational structure and overall aims are also included at this level of analysis.

The texts that are used for technical sources as well as those that set guidelines for practice are the second level of document analysis. In the first case, these documents will be the technical protocols setup by the administration at the King Radar facility, the policies and agreements with NASA in regard to exchange of information and also the job qualifications and written expectation for the personnel involved in the validation studies project. In the second case, medical curriculum which mediates between national policy and medical teaching will be studied. The texts related to technical practice and ethics set by Subh-e-Nau personnel for dealing with the SCI population, their job descriptions, related documents that point towards relevant qualifications, will also be included at this level.

Since the actual and relevant subject matter is interrelated with policies, and since this involves manuals and textbooks, hence I consider this as the next level of complexity in terms of the analysis. These are, for the first case, the technical manuals related to operation of the King Radar facilities and the standard textbooks employed by the personnel, which includes textbooks related to undergraduate and postgraduate degrees, as well as current and state of the art ones.

In the second case, this level will incorporate analysis of texts related to community medicine, disabilities especially those in relation to treatment of SCI within Rawalpindi Medical College (RMC) and also those employed by the SN personnel. This will also include texts related to instructions involved in dealing with SCI patients and the training of their caretakers, which also involve deployment of non-human actors such as wheelchairs, surgical rods, ergonomic readjustments, etc.

While the layered analysis of texts is done in a systematic manner, themes were drawn from these texts in relation to the practice as well as the broader topic at hand. These themes will vary from each level, however, in both cases, an "initial center" will be made. In the first case study, this means, a start will be looking for themes related to clouds at all levels, however, this will subsequently facilitate the decentering of this non-human actor in various texts and link towards interrelated practices. In the second case study, this "initial center" will be the Spinal Cord Injury disability and its decentering will be mapped out in terms of intended practice methods and related knowledge.

In terms of the depiction and description of actual practice, as well as the lived experiences of human actors involved in each network, two methods will be incorporated towards honing in on the material-semiotic relations involved in networks, ordering both

constructions of clouds and SCI in certain ways, namely 'historical sources,' and 'observations of actants.'

Historical Sources

A vital question that remains is the research material amenable for the historical analysis mentioned above. Historical methodology divides sources as evidence at two levels, namely primary and secondary sources. According to Berkhofer (2008),

> Primary sources are those documents and other things both from and the times that are being investigated. Secondary sources are those referring to matters and times earlier than their own time of production. In that sense all history books are secondary sources (except for a history of history-writing), but so too are historical enactments, documentary films, simulated artifacts, and virtual computer images of past texts, artifacts, peoples and places (p. 19).

In terms of the research question posed, as well as the methodology employed, both primary and secondary sources as well as historical accounts during interviews are used to map out network formation and mobilities of various important actors involved.

Observations of Actants

The naturalistic account of the actors, both human and non-humans will be a crucial part in depicting the materiality of the practices that they encounter in each case. Observations which are based on being a participant will be employed in providing "thick descriptions" of the lived experiences of both human and non-human actors involved. In the first case study, participant observation is employed in order to fulfil such thick descriptions. According to Cohen et al (2007, p. 258),

> There are two principal types of observation – participant and non-participant observation. In the former, observers engage in the very activities they set out to observe.

I undertook data collection and interpretation activities with the King Radar facility group, hence will be a participant observer. In the second case study, I was be partly a non-participant observer, insofar as not conducting any medical or rehabilitation effort, but would be involved in observing the activities of the SCI patients as well as the medical and rehabilitation experts involved in the program. However, I was also a participant observer in depicting the operations involved in the program, where my role as an administrator will be ascertained as being part of the group. The collection of all this data was done by both structured and unstructured note-taking at field sites.

According to Cohen et al (2007, p. 405)

> Participant observation is often combined with other forms of data collection that, together, elicit the participants' definitions of the situation and their organizing constructs in accounting for situations and behaviour.

In this regard, I will also focus on interviews with various actors in each network.

Interviews

The lived experiences of human actors in the both networks are also investigated using interviewing techniques. The questions posed were done in open-ended manner. Cohen et al (2007) state that

> The interview is a flexible tool for data collection, enabling multi-sensory channels to be used: verbal, non-verbal, spoken and heard (p. 349).

The questionnaire was designed such that it is also dependent on the actor as well as the practice they are involved in, which includes interaction with non-human actors. The lived relationality of these experiences is drawn out in these interviews in both cases. For the first case study, 40 interviews were conducted, while for the second case 15 such enquiries were done. Topics

explored in the open-ended interviews are provided in Appendices B.1-B.3, including the question guides used in both cases.

Chapter 3

Case Study 1: The (re)formation of Rehabilitation Sciences and a Local CBR Network

Introduction

The crisis unleashed by the 2005 Northern Pakistan earthquake caused dramatic shifts and mobilizations not only in a geographical sense, but also across multiple human practices, such as of disaster management. To contend with the damage and massive displacements related to this crisis, a large number of local and international networks mobilized 'outside their relations' (Latour, 2005) to adjust to physical seismic shifts and associated 'reality failures' (Law, 2010).

This chapter describes the events which occurred and the actors involved after the earthquake in relation to the formation of rehabilitation sciences and to the current Subh-e-Nau (SN) CBR network. Here, my aim is to historically explicate network actors who could mobilize themselves to contend with disability issues. In this chapter, I describe how the initial networks changed to particular types of 'practice networks' over time which enacted SCI distinctly. Here, I analyze key policy documents as historical, including those related to disability and

rehabilitation sciences present before and in the aftermath of the 2005 Northern Kashmir earthquake. These documents are deemed relevant as they are referred to within various interviews and by participants observed in the field studies, which will be elaborated in the next chapter. Another aim of this chapter is to describe the formation and current functioning of the CBR program. To begin, an overview of the health system in Pakistan in the context of disability issues is presented.

Background

The 2005 South Asian earthquake sent waves of destruction across Northern Pakistan, Afghanistan and India. Most of the damage occurred at the epicenter of the 7.6 magnitude earthquake, which was Muzaffarabad city located in the Azad Jummu Kashmir (AJK) region, Pakistan. Other provinces such as the Khyber Pakhtunkhwa (KP) and regions such as Gilgit-Baltistan were also deeply affected. However, a near complete breakdown in the Muzaffarabad region happened, where hospitals, schools, homes, and police and military buildings and infrastructure literally collapsed. The earthquake unleashed devastation on many levels, most notably with more than 75,000 people killed and at least 125,000 people injured; about 3.5 million people were initially displaced due to this crisis. Seventy percent of the total losses are said to have occurred exclusively in Muzaffarabad itself. There was considerable aid, both local and international, to address the devastation, which is estimated to be around $6 billion. Under the military rule of General Musharraf, the National Disaster Management Authority (NDMA) was formed, which was a first of its kind. An institution was designated to oversee the post-earthquake rebuilding efforts and is termed the Earthquake Reconstruction and Rehabilitation Authority (ERRA) which has worked alongside Turkey, Japan and Saudi Arabia and United Arab Emirates (UAE) in a long-term basis. Directing the flow of aid into projects, they also conducted rebuilding

and reconstructions efforts. The United Nations (UN) and associated wings, Canada, U.K. and the U.S.A. also provided various relief aid packages and conducted interventions in the region.

In terms of my theoretical framework, the material agency of the earthquake disaster exceeded any human expectation or mechanisms in place to contend with its effects, which are too many to elaborate in this work. In terms of ANT-mobilities (Latour, 2005; Urry, 2008) sensibility, the earthquake represents a major and heterogeneous non-human actor that affected and displaced various terrains at a multitude of levels, including the way disability was treated previously in the country. Various networks were built and mobilized to deal with this catastrophe. Hence, the historicity of this case under study is crucial. As an exemplar actor network, the Community Based Rehabilitation (CBR) instituted in Muzaffarabad evolved from a crisis event instigated through a non-human actor in the form of an earthquake.

In other words, the CBR program and this case study can be viewed from a historical aspect to have emerged from a 'crisis' event. With the ANT-mobilities sensibility, the earthquake, a heterogenous non-human actor allowed for the proliferation of a CBR network over time and allowed for mobilities of various networks in responses to the disaster in order to resolve major crises. This case study is similar to other ANT studies done on health-related issues, however, in these studies temporality or historicity was not considered (for example, Mol, 2002 and Mol, 1999). The development of a functioning CBR in Muzaffarabad grew out of these challenges into a network that exists today. Its services as well as current functioning are described in detail in the following sections. The formation, functioning and maintenance of this CBR network required significant innovations, changes and local adaptation of standards, materials and practices from abroad and within Pakistan.

Disaster Management: A shift in paradigm

The 2005 Northern Pakistan Earthquake and the consequences lead to a major shift in the practice of disaster management in the country. The earthquake in 2005 highlighted Pakistan's vulnerability to disaster risks and motivated a shift in paradigm from the former response-focused to the current, more proactive approach. Hence, the resulting systematic framework developed in response to this disaster replaced former "reactive" measures. One major shift in this regard was the formation of National Disaster Management Agency (NDMA) and a shift in disaster management practices. Key policy documents that emerged include "Ordinance XL of 2006: No. 2(1)/2006-Pub. B" which laid the legal foundation of NDMA in 2006. A National Five-Year plan followed in 2007, which detailed the multidisciplinary role of this agency and the financial resources dedicated towards various disaster management sectors for priority areas identified in these documents. Accordingly, four crucial areas of disaster management: preparedness, response, recovery and prevention/mitigation were addressed. Both documents assign only a vague role to mitigation and prevention strategies, however do contain clear directives to address health impacts due to disasters at a high priority.

The Health System in Pakistan: An overview

As a background, Pakistan has a mixed health system, with both private and public health institutions providing health care (Nishtar, 2010). A 'mixed health system' is more precisely defined as, "…a health system in which out-of-pocket payments and market provision of services predominate as means of financing and providing services, respectively in an environment where publicly financed government health delivery co-exists with privately financed market delivery" (Nishtar, 2010, p. 40). Citing 73.38% of the population paying out of their pockets, a large proportion of Pakistan faces the economic burden of disease on their own – as such Nishtar

(2010) classifies these health problems under a "Triad of Determinants" which are a cause for chaos in the system (p. xxi), which are:

1. Low public funding for health
2. A poorly regulated private sector and differences in incentives
3. Lack of transparency in governance

The amount of health expenditure by the private and public health sector in 2005/6 was 2.9% of the total Gross Domestic Product (GDP). This percentage amounts to USD $22.06 million, with1.16% was spent by public sources, whereas a higher 1.73% by private sources (ibid., p. 81).

Another pressing concern in the midst of this challenging environment is the lack of medical personnel. Julio Frenk (Nishtar, 2010, xv) states "…the most pressing problem, as in most health systems in developing nations, is related to the availability of human resource. In Pakistan, there is a reasonable supply of doctors but a shortage of nurses, dentists, midwives, and other health personnel such as rehabilitation specialists." Additionally, the lack of material sources and technology are also significant barriers, and in particular with disability, the low amount and relative absence of an alignment of medical rehabilitation science personnel (physiotherapists, occupational therapists, etc.) within governmental health provision is indeed a significant gap as well (Rathore, 2007). With rather limited resources, Subh-e-Nau (SN) attempted to partially fill this gap in order to contend with the large scale and severity of disabilities that arose from the earthquake.

With a disability rate estimated at 10-12% of the current population, a "systematic care of persons with disabilities" was nevertheless initiated in the "1980s" (Ministry of Women Development, Social Welfare and Special Education, 2002). Most recently, Pakistan is a signatory to the "Biwako Millennium Framework for Actions (1996) required to achieve an

inclusive, barrier-free and rights-based society for persons with disabilities in Asia and the Pacific," and has outlined specific actions in policy documents to meet this framework's targets by 2025.

As is evident, Pakistan's health care system was and is still not fully equipped to deal with the 2005 earthquake disaster, which had more than 4 million people displaced and affected. In the earthquake-affected regions, experts warned that the disability rate was higher than the estimated 10-12% due to the local impact of the disaster. With the immense scale of disabilities encountered, the existing health care system was unable to address basic medical rehabilitation issues, which continue to this day.

Disability and Spinal Cord Injury: An earthquake's consequences

One of the fallouts of the earthquake was an "epidemic" of disability as a direct result of physical injuries, and this epidemic was a most challenging aspect in the rebuilding phase. The challenges arose from the lack of infrastructure in the region and the reconstruction work itself in the difficult mountainous terrain. Hence, in the first year and a half most of the injured were bought to Islamabad and Rawalpindi. These are the nearest urban centers hosting various hospitals and medical institutions with some capacity to deal with those severely injured by the catastrophe. Many people sustained a Spinal Cord Injury (SCI) and its long-term nature made it difficult to treat as various rehabilitation sciences were not available or prepared for this condition, when the crisis struck.

As one of the many collectives involved in this process, Subh-e-Nau (SN), a local non-governmental organization (NGO) started working on such disability issues. As the head of research and development of this organization, my own locality in the organization and in Islamabad provided a means of setting up of and working with medical rehabilitation teams. For

the first one and a half years, SN assisted in meeting these needs in the hospitals and makeshift centers where the victims were flown in by the Army rescue teams. The teams, which included local and international experts, worked to address the gaps exposed in the wake of the earthquake, which literally and figuratively had shaken the country to its very roots.

Policy documents played a key role in the practice of contending with disability; as stated in earlier chapters, in terms of Actor-Network Theory (ANT) these policy documents represent significant non-human actors (Law, 2007) as well as 'intermediaries' (Latour, 2005) that are influential in defining, standardizing and negotiating the practice of those involved in rehabilitation of disabled people, including trained professionals in the medical and health sciences areas. Next I examine the relevant policy documents produced before and after the earthquake.

National Policy for Persons with Disabilities, 2002

At the outset, this policy document indicates that "systematic care" for Persons With Disabilities (PWDs) in the country started as early as the 1980s, with the "observance of 1981 as the United Nations International Year of Disabled Persons" (p. 1). It is interesting that the whole movement of responding to disability is referenced to an annual United Nations observance. However, efforts in the national policy included "education, rehabilitation and care" and a "National Policy for Special Education" (p. 1) still did not happen for a couple of decades. This policy, which claims to be the first ever document on PWDs in Pakistan, has materialized after more than twenty years, which is duly stated in the first paragraph of the "Introduction." The process of formalizing this policy occurred after a consultation between the Ministries of Education, Health, Labour and Manpower, Housing and Works, Science and Technology and Planning and Development, as well as provincial Social Welfare and Education departments,

alongside NGOs. Accordingly, this "…team realized the importance of international focus on care, education and rehabilitation of persons with disabilities, which demands a *multi-disciplinary approach* [emphasis added]" (p. 1, 2002). As such, this recognition is important, as such approaches were largely absent during and after the 2005 earthquake, which speaks as a lack of implementation of such policy documents. The "Introduction" is written by Ms. Parveen Qadeer Agha, who was at the time, the Secretary for the Ministry of Women Development, Social Welfare and Special Education. Interestingly, this 12-page document was released under this ministry. In terms of its aims and vision, this policy aims to address the issue of disability through various means, including special education. The vision and goal of the documents are in line with the religious and national identity building objectives found earlier in education policy documents related to mathematics education (Chishtie, 2007). In the "Preamble," the policy document's starting statement is notable, which is "The need to make special provision for those members of the community who suffer from the effects of disability has long been recognized in Pakistan" (Ministry of Women Development, Social Welfare and Special Education, p. 3, 2002). To reach these goals, "…creation of special facilities for the education, training and rehabilitation of disabled persons is regarded as being of central importance…" (p. 3). It is also stated in the document that equal rights for PWDs, "… make Government of Pakistan a partner in the global movement for the betterment of this segment of society (p. 3). The Ministry also recognizes that comprehensively dealing with these issues is beyond its capacity and scope. As such, "The provision of a comprehensive range of facilities for persons with disabilities from pre-natal care through education, vocational training, employment and support during adult life cannot be a matter for a single government department or agency" (p. 3). Rather, the document notes that a large number of organizations at the federal, provincial local and at the NGO level

alongside professionals, families and communities, would be needed to provide sufficient services towards meeting the goals stated in this document.

The vision of this policy document is:

> The overall vision of the National Policy for Persons with Disabilities in keeping with our Islamic way of life, is to provide by 2025 an environment that would allow full realization of the persons with disabilities through their inclusive mainstreaming and providing them full support of the government, private sector and civil society (2002, p.4).

The overall goal, which follows is:

> Empowerment of persons with disabilities, irrespective of caste, creed, religion, gender or other consideration for the realization of their full potential in all spheres of life, specially social, economic, personal and political (2002, p.4).

These very first pronouncements reveal a tension between insertion of religious ideology in the vision and secular nature of the goal provided. It is also notable that the implementations of these goals are to be achieved by 2025 and no firm targets with timelines are mentioned in this particular document. The mission statement is the "Optimal development of persons with disabilities for the realization of their full potential in all walks of life, especially in the areas of health, education, economic and vocational needs, for the fulfillment of their present as well as future requirements" (p. 4). Within the "Guiding principles" of carrying out of such a mission, the document upholds "…accession to international instruments on human rights, as the reiteration of Islamic principles of justice and equality" (p. 5). Another such principle is adherence to non-discrimination and gender equity at all levels, while a so-called "holistic approach" as another principle is to be directed to cover all aspects of PWDs in their communities. Further, the document espouses another principle, which is a "…rights-based approach rather than welfare concepts in program planning and implementation." The last

principle acknowledges active participation from individuals, institutions from both the private and the governmental level.

Eight "Aims and Objectives," are stated in the document; I offer a summary here of the relevant components. Access to facilities and involvement in planning for education, as well as health related choices, and guarantees of having equal rights are cited within various objectives. Three objectives worth mentioning verbatim are as follow:

> To persons with disabilities: …
>
> - ensure that they have equal opportunities and access to medical, education, social, psychological, vocational training, employment and rehabilitation, without any discrimination;
> - expand service infrastructure which is adequate to accommodate and cover all persons with disabilities both in urban and rural areas;
> - harness modern technology, tools and skills to streamline national policy, planning, programming and service delivery for effective redressal of disabilities;
>
> (p. 5)

These policy objectives *did* exist before the 2005 earthquake; nevertheless, little was done to implement these objectives at any level. Hence, there was practically little or no effort towards the materialization of eight "Strategies," which include ensuring the provision of "quality services to all segments of age groups for Persons with Disabilities," or towards expansion to "…coordinate and monitor a comprehensive network of services for Persons with Disabilities in Pakistan" (p. 6).

It is indeed quite relevant to note that amongst the "Areas of focus and Special Attention," are entire sections termed "A. Early intervention, assessment and medical treatment" and "B. Education and training," which address these rather broadly, but also reveal a lack in

acknowledging a full umbrella of rehabilitation sciences as a part of the services needed (pp. 6-7). Accordingly, the

> "…prevention of disabilities, to a large extent, is the domain of medical profession, family counselors, psychologists and social workers and has its basis in research and training within those disciplines. However, educational services have a role to play through the provision of courses of study in schools/colleges for students in the area of health, education and child development. This would supplement information provided to the families and could improve their knowledge and skills for prevention of disabilities" (p. 6).

In terms of early diagnosis of disabilities, it is recommended, "a reliable and accessible diagnostic system is a pre-requisite for the development of preventative and intervention strategies" (p. 6). This diagnostic system is conducted with the recognition that delays in early identification lead to problems later for children. The proposed intervention would be a referral to a "multi-professional team" at district level which is also envisaged alongside with "Counseling," "Genetic Counseling" and "Family Guidance." The document states "Counseling" is "an area which cuts a number of concerned disciplines such as anthropology, sociology, genetics, psychology, social work, religious instructions, etc." (p. 6). finish the paragraph by commenting on the quote.

Within section B, namely "Education and Training," various institutions created earlier in the eighties are mentioned, such as the Directorate General of Special Education (DGSE) and the National Trust for the Disabled (NTD). These institutions are named, alongside the National Institute of Special Education (NISE) as key actors in the delivery of "special education" and training of school teachers (p. 7). Further, there is promise of building medical and rehabilitation services towards treatment of disabilities. In a key passage, the document forecasts that

> Training of doctors, pediatricians, and other related specialists in the diagnosis of disabilities will be arranged at medical colleges or at relevant departments at the university level, in order to build up a well qualified professional team. The number of training institutions available for *occupational therapy* [emphasis added] and

> *physiotherapy* [emphasis added] will be increased along with training centers for *speech therapists* [emphasis added] and other relevant professions (p. 7).

In this passage, it is clear that the Ministry understands the importance of medicine as well as rehabilitation sciences. However, what also emerges is the lack of assignment of these recommendations to any particular institution, except a vague mention to medical colleges, university departments, "training institutions" and "training centers." The last two educational sources are mentioned in connection to three areas of rehabilitation sciences, namely occupational therapy, physiotherapy and speech therapy. This recommendation is stated without any connection to the training carried out in the medical colleges or universities marking them lower in terms of status. It is also quite clear in the above passage that medicine is first in consideration before any other disciplines in relation to treatment of PWDs. This hierarchies is further noted in the recommendations provided in "D. Research and Development," where research, "academic and applied" are to be utilized towards findings that work for the benefits of PWDs. As such, the document states that,

> Efforts will be made to enlist the interest and support of the universities and other organizations particularly in the area of medicine, social work, psychology, vocational training, engineering and technology. These Institutes/Centers will function as focal points for research, central record and information (p. 10).

Most of these plans and recommendations had not been implemented when the earthquake arrived, as there was a dearth of expertise and trained professionals amongst many other gaps at that time. I contend that it took this tragic event and a large disabled population, as well as contributions from Handicap International, a French NGO also contributed to the formulation of the "National Plan of Action" in 2006,to mobilize the Ministry to meet the aforementioned targets. Some of the plans are still pending, but there is mobilization in certain areas from the 2002 policy document.

National plan of Action, 2006

After the earthquake, the "National Plan of Action, 2006: To Implement the National Policy for Persons with Disabilities," was issued by the Ministry of Social Welfare and Special Education, headed by Ms. Zobaida Jalal. On the upper left corner of the front cover, the French International NGO "Handicap International" logo is printed while the Ministry's name, logo and address are on the lower left corner. On the back cover, both the Ministry's and the NGO logo appears on the lower part, centered, with the statement, "Joint initiative of Handicap International & Government of Pakistan." Throughout the document, and this includes the foreword by the minister, there is no mention of "Handicap International", the mobile actor-network which played a key role in this policy. However, it is clear that they were an important set of actors that mobilized immediately following the disaster, in producing this document, and possibly induced certain types of "implementation networks". For example, Aid workers and experts from this foreign NGO arrived as soon as the earthquake happened and their main aim at the time was to provide emergency relief services, including caring for the disabled population. As the head of research and development in SN, I met their representatives as they were helping with the injured and disabled in the hospitals in 2005. This meeting led to a four-year collaboration with SN and this partnership extended into the CBR program in Muzaffarabad. These issues are further expounded in Chapter 4 where the professionals I interviewed in the CBR program also attest to the first ever presence of this actor-network after the disaster to this day and its influence over initiating various policy initiatives including this document which I am describing now.

Strikingly, there is only one mention of the earthquake throughout the document. This heterogenous non-human actant, the earthquake, is referred in exclusive focus on SCI, while it is stressed that

> After the massive earth quake that has led to creation of a large disabled population in the country, it is of utmost importance that establishment of paraplegic centre for care and rehabilitation of paraplegics be taken up on an urgent basis. This should include their physical, vocational and social rehabilitation (Ministry of Social Welfare and Special Education, p. 10, 2006).

This exclusive mention of paraplegics (SCI PWDs), is under the section, "Escalating the Medical Rehabilitation Services," pointing to an exclusive attention to both the disaster and its damage in the form of a severe disability the form of SCI, which opened and exposed a wide gap, which the document admits in a muted manner. It is indeed striking that the large number of a particularly difficult disability as a result of an earthquake, namely SCI, led to the realization, as stated in this document, of the near absence of rehabilitation services, not only for their management, but for the entire population of PWDs in Pakistan. The silence over a catastrophe that literally overwhelmed the government's medical and professional expertise and institutions is understandable, as they clearly lacked in various capacities to deal with the large amount of PWDs. This lack of reference further points to relative amount of inaction over the course of about four years after the 2002 document emerged, without any firm timelines.

In the foreword, the minister focuses solely on the plan towards meeting the goals set out by the 2002 document, without any mention of Handicap International or the earthquake. According to her, the National Plan of Action (2006) includes several areas are to be targeted by 2025, which remain a challenge at an institutional level, let alone at provincial and national levels for the government. The 2006 document states timelines for targets to be achieved in the next six

years, however recommendation up to 2025 are given in the document (p. 1). These areas (following from the 2002 document) are:

- early intervention, assessment and medical treatment
- education and training
- vocational training, employment and rehabilitation
- Research and development
- Advocacy and mass awareness
- Sports and recreation
- Barrier free buildings, parks and public places
- Strengthening of institutional mechanisms
- Adequate funding

It is notable that while there are slight changes in wording from the 2002 document, a vital area, namely, “monitoring” is left out in the 2006 document. While the term does appear in various forms in the 2002 document, it is interesting to note its absence from the 2006 document. The document bases its recommendation upon a situational analysis conducted between March to May 2004, with over 100 organizations, which were from the government, NGO and private sector. The document reaffirms the 2002 policy document, which is based “on the philosophy that access, inclusion and equalization of opportunities for Persons with Disabilities (PWDs), which form 2.49% of the population in the country, according to 1998 census, cannot be achieved by isolated interventions.” Therefore, the services are designed in “an integrated manner with the goal of full inclusion” (p. 1). In this regard, the document sparingly uses the term “special education” which is kept at a minimum, unlike its sporadic usage in the National

Plan of Action. To achieve these goals, the document states that funding would have to be allocated from various sources, and by extending the services to rural areas, where about two-thirds of PWDs reside, and "that are currently neglected" (p. 1).

Addressing the areas outlined by the earlier document, requires certain "Actions" (pp. 1-2) espoused by this policy document, which are seventeen – the document has implications on the practice of professionals as well as PWDs, hence it is an example of an "enactor text" conceptualized earlier in Chapter 2. I will address certain ones that are relevant to the case study at hand. These numbered "Actions" are detailed in two to three tables for each in the policy document, one that has "Goal/Outcome," "Identified Barriers" and "Performance Indicators," while the second table has the headings, "Short Term Steps," "Responsibility" and "Timeframe" and relevant information indicated. A third table with the heading "Long Term steps," "Responsibility" and "Time Frame" appears associated with certain Actions. A "short term step" is defined to take place in the period between July 2006 - June 2009, whereas a "long term step denotes the time between July 2009 – 2025.

Actions, actors and implementation: mobilization of "regimes of truth and promise"

Amongst various strategies that are recommended to be carried out from June 2006 to July 2025, **Action 1**, is, "Determining the extent of disabilities and distribution of causes." The Goal/Outcome as "Accurate assessment of magnitude of the problem and the causes of disabilities at district level for efficient planning and implementation of disability services," as the "Identified Barrier" is lack of accurate data on PWDs. The "Performance Indicators" are "reliable mechanisms" at the level of the district. This is relevant as the SN CBR program authorities lacked information and systematic knowledge of PWDs, especially in the

Muzaffarabad. Thus, SN had to make its own mapping tools, which were then implemented in the field by experts working with community members. In stark contrast with many of the "Short Term Steps," which for example, rather advanced initiatives, even basic information about PWDs is unavailable. These advanced "short steps" includes,

> 1.1 Design and adapt WHO's "International Classification of Functioning Disability & Health" (ICF) for measuring disabilities and propagate the same at all levels i.e. from federal policy levels to service delivery points in the community (p. 3).

This is the "responsibility" of Ministry of Health (MoH) and Ministry of Social Welfare & Special Education (MoSW&SE), with technical support from WHO with the timeline between July 2006 to December 2006. To my knowledge, no such exercise has happened nor is any such information of ICF classification available about PWDs in Pakistan so far. It is also stated in Action 1.5 to "Carefully designed modules on ICF to be introduced in National Population Census and other public sector household surveys," from January 2008 onwards. The imposition of a framework on a national level has interesting implications towards how allocation of services is also mediated by an international framework such as the World Health Organization's ICF – these classification standards are also discussed in Chapter 8 and 9. It remains to be seen whether these steps will be actually be put in place.

Action 2, is "Improving prevention of injuries, deficiencies, diseases and other factors to disability," with the Goal/Outcome as reduction in disabilities through primary and secondary prevention and the identified barrier being, "The current programme has no role or linkage with prevention programmes" (p, 3). The "Performance Indicators" is the establishment of inter-sectoral links "at all programme levels." Such a strategy is pertinent as the strategy employed by SN CBR program is reliance on early detection and preventative treatment such that the impact of disability is limited at first contact. While the policy states actions to be adopted in this category are to occur from July 2006 onwards in short-term and July 2009 onwards for the

longer term, very little implementation of the proposed have happened in both such demarcations. In the policy document, preventative strategies are to be done in collaboration with ministries – for example, partnerships are to be made in areas of "measles immunization," "IDD control," "Iron Supplementation," Training of skilled birth attendants," and "Genetic Counseling at Teaching and other Hospitals." Another area of intervention is public transportation, whereby these areas are chosen in collaboration with Ministry of Commerce, Ministry of Commerce and Traffic Police. A select few of these "short steps" are,

> 2.14 Local manufacturers of automobiles should be asked to make specialized vehicles/three wheelers for all four categories of the PWDs these vehicles should be available in the market. In cases where a specialized vehicle by the PWD the manufacturer should possess the requisite facility to make it (p. 5).

And, while the document claims to support service in rural regions, there is a complete lack of provision of roads in rural regions, as the following "short step" indicates:

> 2.16 Improve roads condition for the benefit of PWDs and public at large and specific arrangements like wheel chair crossing point, special signal for Persons with Disabilities crossing shall be made at busy intersections in urban areas.

In field findings, a significant challenge turned out to be transportation for PWDs in rural Muzaffarabad, and even the city region had none of the amendments that are recommended in this action – notably, however, is the lack of transportation concerns in a rural setting where it is significantly more challenging. In the findings that will appear in the next chapter, these challenges affected and proved to be burdensome for SCI PWDs, especially towards gaining access to health and education. Hence, the SN program had to rely on creating and maintaining a mobile and active outreach program in order to meet such gaps.

Action 3, is "Mobilizing Early Detection and Intervention," whose Goal/Outcome is "minimize the incidence and impact of disabilities" (p. 7). With "Identified Barriers" as being lack of early

detection and intervention for PWDs, both at the government and NGO levels, the "Performance Indicators" are increased rate of early detection in these sectors.

This proposed action, has relevance, again due to early detection and prevention being an underpinning in the SN CBR program. For the "short term steps," the "Responsibility" lies mostly with the Ministry of Health and the provincial health departments. Amongst these steps, the following are pertinent due to their relative lack of implementation and being related to the SN CBR network.

> 3.2 Arrange increased access to Health facilities, especially in the rural areas.
>
> (p. 7)

This is implemented to a limited extent in Muzaffarabad, whereby the villagers have easier access to NGOs such as SN and other foreign medical services. This action also calls for the development of multidisciplinary approaches and explicitly calls for development of medical rehabilitation sciences, in particular, at the DHQ [District Headquarters] hospital level, which leaves out development and delivery of such services in the rural regions a challenge not fully addressed. These policy actions are,

> 3.4 Increase in the number of team of specialists (eye, ear orthopedics, etc.) to foster a multi-professional approach and also to improve screening measures.
>
> 3.7 Expand training opportunities for multi-disciplinary teams (like speech, occupational, physiotherapy, clinical psychology and learning disorders, etc.)
>
> 3.8 Develop rehabilitation centers at DHQ [District Headquarters] hospitals with services like speech, occupational, physiotherapy, clinical psychology and learning disorders.
>
> 3.11 Establish Rehabilitation Medicine Departments in every teaching hospital.
>
> (p. 8).

Interestingly, the document also seeks to support NGOs that are active in early detection and prevention of PWDs. As such,

> 3.13 NGOs who have demonstrated successful implementation of out-reach and mobile services in early detection and intervention, finding difficulty to reach such areas should be financially supported for further expansion (p. 8)

Despite various collaborations with governmental agencies and departments, SN failed to find any such governmental support, throughout its service delivery in Phases I to III in the Muzaffarabad region. This brings to an Action which points to a most missing aspect, especially in the context of SCI treatment in Pakistan.

Action 4, is "Escalating medical rehabilitation services," the Goal/Outcome is "Provision of timely and effective medical rehabilitation services for people disabled by disease, injury or congenital impairments" (p. 9). The "Identified Barrier" is an admittance of a lacking in the present setup. This is stated as, "At present, mainstream government led system is not fully geared and hence does not contribute its full potential in addressing this issue." The aim or "Performance Indicators" is the establishment of "A specialized network of medical rehabilitation services is established at district level in next ten years" (p. 9). The SN CBR program has been addressing these gaps for a vast range of PWDs, however, its focus on SCI cases is also due to the relative incapacity of the governmental capacity and capability in this regard. This is explicitly stated and an obstacle to be overcome in the "Short term steps," whereby, the earthquake is mentioned for the first and only time exclusively in relation towards dealing with PWDs, and in particular the SCI disability.

> 4.1 Criteria for various levels of rehabilitation services (Basic and Comprehensive) should be established in consultation with professionals in the field. After the massive earth quake that has led to creation of a large disabled population in the country, it is of utmost importance that establishment of a paraplegic centre for care and rehabilitation of paraplegics be taken up on urgent basis. This should include their physical, vocational

and social rehabilitation.

(p. 10)

The departments made responsible for this include collaboration of the policy-producing ministry with Mayo Hospital (located in Lahore, Pakistan), AFIRM (Armed Forces Institute of Rehabilitation Medicine), National Institute of Handicapped, Islamabad (NIH). The full implementation of this policy objective is stated to take place between July 2006 to December 2006. To this day, the suggested criteria for the various rehabilitation services has not materialized, nor the establishment of a "paraplegic centre." The SN CBR program delivery of medical rehabilitation services to PWDs, in particular to the SCI condition in Muzaffarabad meets some of the gaps stated in the document.

Also demanded in the policy is "4.2 Departments of Orthopedic at DHQ Hospitals be expanded to minimally provide basic medical rehabilitation services," required from January 2007 onwards. This has started to happen, albeit partially, as is attested by formation of physiotherapy units mostly in urban government-run institutions such as the Holy Family Hospital in Rawalpindi. However, such services are far from being mobilized towards rural regions such as Muzaffarabad.

A "long term step" under this "Action" is "4.5 Steps should be taken to establish "Rehabilitation Medicine" departments in all public and private teaching hospitals," with the timeframe given between July 2009 till December 2020. These can be seen in various accredited four-year Bachelor of Science (B. Sc.) programs in physiotherapy – a prominent example is the provision of such a program by the Rawalpindi Medical College (RMC) in Islamabad.

Next, **Action 7**, addresses issues and strategies related to "Women with Disabilities," with the "Goal/Outcome" being that "Women with disabilities have a role to play for their betterment, through s[up]port services." Identifying that there are "…presently no access to the existing

programmes/services, both in the public and private sector," the "Performance Indicators" of recommendations is inclusion and consideration such that "Programmes are prepared/implemented associating women with disabilities at every stage of development, preparation and implementation" (p. 14). Such gender issues emerged in the field studies of the SN CBR program, where women PWDs and the health practitioners, as well as caregivers had to contend with various gender-specific obstacles regarding service delivery amongst various cultural, social and political issues embedded in their localities.

The document takes on various "short term steps," which are all to be implemented from July 2007 onwards. These are to be carried out by Ministry of Social Welfare and Special Education, Ministry of Women Development, NGOs and Self Help Organizations (SHOs). Some of these relevant to the SN CBR program are,

> 7.1 Take measures to uphold the rights of women with disabilities and to protect them from discrimination. Measures in particular to be taken to ensure equal access of them to health services, education, training and employment. Also to implement programmes to raise public awareness at consequences of violence against women and children that leads to disabilities.
>
> 7.2 Implement programmes to raise the public awareness of the situation of women with disabilities and promote positive attitudes, role models and opportunities for their development.
>
> 7.12 All agencies, including Governments, NGOs, self-help organizations, donors and civil society must promote and uphold at all times the rights of women with disabilities to choice and self-determination (pp. 15-16).

While these actions are still to be implemented at any level, to cope with the gender issues, the SN CBR program practiced with full considerations regarding the rights of people of whatever gender with disabilities, including women. The practice aspect of health delivery was challenged by existing norms in the society regarding both disability and women in particular that have such

a condition. As explicated later, this aspect emerged prominently in the field findings alongside class, ethnicity, religion and other considerations.

"Expanding and reinforcing vocational training, employment (including self-employment) and economic rehabilitation" is termed as **Action 9**, with the Goal/Outcome towards the upgrading and enhancement of skills that lead towards economic empowerment of PWDs (p. 19). The lack of vocational training and vocational rehabilitation is the "Identified Barriers," in this regards, and the "Performance Indicators" are stated to be the fraction of PWDs gaining employment towards reaching the same levels as the "general population" (p. 19).

Vocational rehabilitation has been a part of SN CBR program in the latter phases of the program, as SCI PWDs gained a healthier status and were able to proceed with daily living without any major challenges. This included evaluation as well as facilitation of proper skills after the SCI condition and its treatment. This includes arranging for loans and micro-financing, as well as materials for self-employment in Muzaffarabad. The governmental institution responsible in this aspect, namely Vocational Training Centers for Disabled (VTCDs), which are located mostly across urban centers of the country, is missing in terms of training on the rural front, although the document regards implementation in the rural regions as important. Pertinent actions suggested are, "9.14 Work done on Community Based Rehabilitation Programmes be supported for successful implementation in rural areas and urban slums" (p. 21).

Beyond stating the relevant organizations responsible for this action (namely the Directorate General of Special Education, National Trust for the Disabled and Community Based Organizations), or the timeline, which is July 2007 onwards, there are no details given as to what these CBR programs are, or what needs to be done in a rural setting. The SN CBR program faced considerable difficulty in procuring financing for self-employed for PWDs, however, it was the International Commission of the Red Cross (ICRC) that came through in Muzaffarabad who

facilitated loans for PWDs wanting to set up shop. These challenges can be gleaned from the lack of any local banks that provide loans for PWD during the first three phases of the SN CBR network.

In regard to such issues, the only "long term step" which was planned to happen after July 2009, makes the provision that "All micro credit institutions and banks should develop and promote a special micro credit product with simplified procedures for PWDs" (p. 22). Till now none of such products for PWDs have materialized.

Along similar lines, **Action 10** is "Poverty alleviation through capacity building, social security, and sustainable livelihood programmes," whose Goal/Outcome is that "PWDs have an access to developmental activities leading to poverty alleviation," as the identified barrier for this is that opportunities for becoming "economically independent" do not exist. The "Performance Indicators" are steps taken that lead towards becoming "earning members of the family and society" (p. 22).

- Raising public acceptance and improving social integration and environment
- Creation of Barrier-free physical environment
- Boosting capacity for production and supply of prosthetics, orthotics and assistive aids and other supporting items and facilitation in duty free imports

The Pakistan Medical and Dental Council's National Curriculum

Medicine and health sciences education are provided in various institutions across the country. In this regard, the Pakistan Medical and Dental Council (PMDC) sets national standards for medicine, dentistry and all allied disciplines, as well as provides accreditation to institutions towards providing recognized certificates, diplomas and degrees. Constituted by the Federal Government in 1962, under the Pakistan Medical & Dental Council Ordinance, the PMDC has the following function:

- Prescribe a uniform minimum standard of courses of training for obtaining graduate and post-graduate dental qualification.
- Prescribe minimum requirements for the content and duration of courses of studies for the degree of MBBS.
- Prescribe condition for admission to courses of training for the degree of MBBS.
- Prescribe the standards of examinations method of conducting the examination.

(PMDC, 2007, p. 3)

In terms of medicine, a qualification towards a practicing physician requires undergoing a five-year training program after Grade 12, which results in a degree termed as M.B.B.S. ('Medicinae Baccalaureus et Baccalaureus Chirurgiae' translated as Bachelor of Medicine and Bachelor of Surgery). This designation is practiced in the UK, as well as various other countries and is distinctly different from the North American designations. After a one-year house job training, the M.B.B.S. doctor is qualified to practice professionally.

The latest national curriculum (PMDC, 2007), places an emphasis on problem-based learning. The appearance of disability as a biomedical concept appears in the third year of medicine, when students are taking Community Medicine. This concept is housed under "epidemiology and disease control" (PMDC, 2007, p. 48). Rehabilitation science or any associated profession is not independently mentioned in the curriculum, and its mention only exists under a subsection of "ORTHOPAEDIC SURGERY & TRAUMATOLOGY" (4th year requirement. The objectives of this course are:

> After successful completion of the course, the students are expected to demonstrate knowledge and exhibit skills regarding preservation, investigations and treatment of common affections of the upper and lower limb and the spine. The students should be able to give emergency care to patients with limb injury, all kinds of injuries to the limbs and spine and demonstrate holistic approach in managing patients inclusive of safe transportation of patients to tertiary care centres (PMDC, 2007, p. 83).

Within section 2.2, termed as "Necessary Applied Basic Sciences with reference to Orthopaedics," concepts of physiotherapy appear (in italics below) within the context of orthopedic surgery. These are:

> • pathophysiology of trauma and shock.
> • mechanical properties of bone & Soft & tissue.
> • biomechanics of Fracture.
> • healing & Repair (Bone & soft tissues).
> • healing principles of fracture.
> • *principles of physiotherapy, (orthotics & prosthesis).*
> • *(Orthotics – Orthopaedic appliances to support and correct deformities).*
> • *(Prosthesis – artificial substitute for missing body parts).*
>
> (PMDC, 2007, p. 85).

Injuries to the spine are classified under section 3, titled, "Systems and the diseases" (PMDC, 2007, p. 86), and in section 3.7, titled "Neck Pain, Low Back Pain and Sciatica" where typical SCI PWDs are to be classified and treated:

> • Deformities (C3) of Scoliosis, Kyphosis.
> • Spinal Injury (C3), Soft tissue injuries (Sprains, Strains etc.)
> • Fractures (stable, unstable), Neurological Damage (partial, complete) Paraplegia (C3).
>
> (PMDC, 2007, p. 86)

The "Specific Required Skills" for treatment are:

> • Examination of patient with: low back pain/sciatica (P3), neck pain (P3).
> • Management.
> • Application of Cervical Collar (P2), cervical Traction (P1).
> • Application of Lumbosacral corset (P2).
> • Internal fixation of spinal fracture (P1), log rolling, prevention of Bed sores, bladder Care/Catheter Care and rehabilitation.
>
> (PMDC, 2007, p. 87)

Within "Clinical Teaching" in the 4th year, the following spinal disorders are placed under "Neurology and CNS":

> **Spinal cord disorders**
> • Spinal cord compression, paraplegia, quadriplegia
> • Myelitis.
> • Spondylosis.
> • Syringomyelia and Syringobulbia.

(PMDC, 2007, p. 102)

The National Physiotherapy Program

Under the PMDC, the University Health Sciences (UHS) was formed to provide a framework for inclusion of rehabilitation sciences in Punjab, Pakistan. Since all the professionals in the CBR program while working in the AJK region were trained in various regions in Punjab, this document is an important aspect of the type of practices conducted.

As voiced in the "Foreword" by the Punjab Governor (retired Lieutenant General Khalid Maqbool), the UHS (2007, p. 2) sets out with the following goals, amongst which medical education is the foremost in terms of improvement of quality.

> The establishment of University of Health Sciences is a milestone in the efforts of the Government to ensure quality medical education in the province… with a view to bring about further improvement in medical education, the undergraduate programmes are being reviewed on a continuous basis so as to improve their quality and to bring them at par with international standards.

Next in line is the focusing on "components of health sciences" amongst which a four year degree program in "Allied Health Sciences" is introduced (p.2, 2007). This is introduced in "Considering the rapid technical developments in the health systems around the world, the Allied Health Sciences programme is a step forward to fill up the gap in the prevailing health systems in the province" (p. 2). The acknowledgements of these gaps in education have led to a formal introduction of a "comprehensive programme covering 17 disciplines in the Allied Health Sciences."

In the "Preface" section of the Physiotherapy curriculum, the vice-chancellor (Prof. M. H. Mubbashar) indicates that 15 disciplines have been started so far. Emphasizing the gaps that the Allied Health Sciences will fill, he first acknowledges the gaps in the current lack of professionals in these areas. He states that,

> Allied Health Sciences is a field in medicine which has been completely neglected up till now so that there is absolute dearth of trained Allied Health personnel who are the actual service providers to the patients. As a matter of fact they form the connecting link between the doctors and the patients which is missing altogether in our health care system. (UHS, p. 3).

He claims that this initiative is a first of its kind, and introduces the fifteen disciplines, which also includes areas in the rehabilitation sciences. These are

> Realizing all this UHS Lahore for the first time took the lead to organize education and training at B.Sc Honors level in all disciplines of Allied Health Sciences. Fifteen disciplines have been identified…Medical Laboratory Technology, Medical Imaging Technology, Emergency & Intensive Care, Physiotherapy, Optometry and Orthoptics, Orthotic and Prosthetic Sciences, Respiratory Therapy, Cardiac Perfusion, Dental Technology, Occupational Therapy, Speech & Language Pathology, Operation Theater Technology, Nutrition, Audiology and Biomedical Engineering. This is going to be a remarkable development in the field of medicine in our country and will fill up the existing gaps in the health delivery system (UHS, p. 3, 2007).

The implementation of these programs is forwarded and supported by the Ministry of Health, Punjab, Higher Education Commission (HEC) as well as PMDC (p. 3, 2007). The vice-chancellor concludes that the Physiotherapy curriculum "will certainly produce competent Physiotherapists to fill in the gap in the system which is main objective of this programme" (p. 3, 2007).

The aims of the four-year degree in physiotherapy are broadly stated as, "Physiotherapy is to equip the students with relevant professional knowledge, skills, techniques and ethical values to enable them to apply their acquired expertise at level between the doctors and the patient for efficient health service delivery" (UHS, p. 1, 2007).

In regards to SCI, Neurology is addressed in the second, third and fourth year of the curriculum. The topics are as follows:

> **The Spine: Acute Problems**
> Review of the structure and function of the spine, general guidelines for treating acute symptoms, inter vertebral disk and flexion load lesions, facet joint lesions in the spine.

Muscle and soft tissue lesions, strains, tears, and contusions form trauma or overuse, selected conditions.

The Spine: Sub Acute, Chronic And Postural Problems

The dynamics of posture, characteristics and problems of common faulty postures, procedures to relieve pain from stress and muscle tension, procedures to increase the range of motion of specific structures. Procedures to train and strengthen muscle function and to develop endurance for postural control (stabilization exercises). Procedures to retrain kinesthetic and proprioceptive awareness for posture correction, procedures to teach management of posture to avoid recurrences of the problems.

The Spine: Traction Procedure

Effects of spinal traction, definitions and description of traction, indications for spinal traction, limitations, contraindications, and precautions, general procedures, cervical traction techniques, lumbar traction techniques.

Certain traction techniques are specified in detail in the third and fourth year of study. These are:

- The Spine: Traction Procedure
    - Effects of spinal traction
    - Definition and description of traction
    - Indications for traction
    - Limitations
    - Precautions
    - Contraindications
    - General procedures
        - Cervical traction techniques
        - Lumbar traction techniques

Historical account of a local-international response to disability

Besides the governmental response, many local efforts were started. These initiatives included a Disability Reduction and Rehabilitation strategy (SNDRR) which was devised soon after the earthquake struck and SN started work with the earthquake victims as soon as they arrived in Islamabad and Rawalpindi hospitals. As SN officials, the Chief Executive Officer (CEO) and I apprised and advised the public and private sector regarding emergent disability issues from this earthquake. These consultations were concrete steps required for rehabilitation, which were also locally implemented in the organization's efforts to contend with these issues.

In the initial one and a half years following the disaster, when the victims were mostly in the Islamabad and Rawalpindi region, SN expanded its Rehabilitation program with the assistance of international and national volunteers. This included assistance from visiting Canadian medical and rehabilitation experts from Toronto Rehab, Lyndhurst Institute and University of Toronto, upon which SN managed to build a specialized team. This team was equipped with a much more sophisticated view to treat injuries and disabilities. These teams consisted of physicians, physical therapists, psychologists and other providers to attend to the social, psychological and physical needs of the seriously disabled population in five major hospitals in the "twin cities" region (Islamabad and Rawalpindi). For example, this work extended into the H11 Camp City, Islamabad, which housed more than 10,000 people. The team also worked in convalescence/nursing centers housing more than 200 spinal cord injured persons.

The Pakistan Working Group at the International Centre for Disability and Rehabilitation (ICDR), University of Toronto, provided the main technical assistance in this period. I currently chair this working group at the Rehabilitation Science Institute, University of Toronto and Toronto Rehab's Lyndhurst Institute for Spinal Cord Injury (SCI) Rehabilitation. Early in the formation of the CBR network there was a greater dependence on such international sources. Over time, the CBR network has become mostly run by local sources and experts.

The Community Based Rehabilitation (CBR) approach

The program developed by SN in Muzaffarabad draws from the CBR approach, mainly arising out of decisions towards working in a resource constrained setting with an equity-based and social justice approach towards disability. WHO (2004, p.1), defines this approach succinctly as "Community-based rehabilitation (CBR) promotes collaboration among community

leaders, people with disabilities, their families, and other concerned citizens to provide equal opportunities for all people with disabilities in the community." In 1994, International Labor Organization and WHO formalized finding a common ground in a "Joint Paper on CBR." While being active for the past three decades, in various forms, this was a standardization of this approach. The WHO document states that,

> Despite the progress made since then, many people with disabilities still do not receive basic rehabilitation services and are not enabled to participate equally in education, training, work, recreation or other activities in their community or in wider society. Those with the least access include women with disabilities, people with severe and multiple disabilities, people with psychiatric conditions, people living with HIV, persons with disabilities who are poor, and their families (WHO, p. 2, 2004).

However, WHO posits, that "following the CBR Strategy, efforts must continue to ensure that all individuals with disabilities irrespective of age, sex, type of disabilities and socio-economic status, exercise the same rights and opportunities as other citizens in society - "A society for all"" (WHO, 2004, p.2).

Malcom Peat, a key figure in the development of CBR (1997, pp. 2-3) contends that,

> Community based rehabilitation (CBR) has emerged as a primary contender in the search for a practical and successful means of providing appropriate health care to a greater percentage of the disabled population…As a component of social policy, CBR promotes the rights of individuals to live within their communities and participate fully in its economic, social, political and cultural life. CBR is appropriate and applicable both economically advantaged industrialized societies and developing, economically challenged regions.

The 2004 document describes that the concept of CBR as evolving, however remaining firm on human rights aspects and incorporates to bring action against poverty of those affected by disability. The document does make universalizing assumptions insofar as claiming that "WHO, ILO and UNESCO view CBR as a strategy that can address the needs of people with disabilities within their communities in all countries" (2004, p. 4).

The concept of CBR is centered on a strategy "within general community development for the rehabilitation, equalization of opportunities and social inclusion of all people with disabilities." The implementation of the strategy is declared to depend upon the work put forth by not only PWDs, but their families, and all associated stakeholders, including relevant NGO and governmental organizations and allied services.

The major objectives of CBR (2004, p. 12) are:

> 1. To ensure that people with disabilities are able to maximise their physical and mental abilities, to access regular services and opportunities, and to become active contributors to the community and society at large.
>
> 2. To activate communities to promote and protect the human rights of people with disabilities through changes within the community, for example, by removing barriers to participation.

The 2004 document, as stated earlier, defines an evolution within the conception of CBR, which is pointed towards shifts in the notions of "disability" and "rehabilitation" themselves. Defining disability around the social model, it is stated (2004, p. 11),

> Disability is no longer viewed as merely the result of impairment. The social model of disability has increased awareness that environmental barriers to participation are major causes of disability. The *International Classification of Functioning, Disability and Health* (ICF) includes body structure and function, but also focuses on 'activities' and 'participation' from both the individual and the societal perspective.

The notion of rehabilitation is also revised as follows.

> Rehabilitation services should no longer be imposed without the consent and participation of people who are using the services. Rehabilitation is now viewed as a process in which people with disabilities or their advocates make decisions about what services they need to enhance participation. Professionals who provide rehabilitation services have the responsibility to provide relevant information to people with disabilities so that they can make informed decisions regarding what is appropriate for them.

Further, there is greater emphasis on human rights and actions towards addressing inequalities including poverty, as well as recognizing the role of DPOs (Organizations of Persons with Disabilities).

The Community Based Rehabilitation (CBR) Program in Muzffarabad

SN continued its work towards those affected by the earthquake disaster, when the disabled persons were relocated to shelters and homes in the Northern Kashmir in late 2006. With partnership, funding support and shared goals with the International Development Relief Fund Canada (IDRF), the organization instituted a Community Based Rehabilitation (CBR) program aimed to reintegrate the disabled population in the Muzaffarabad region. This IDRF funded project was founded on a holistic approach to the disability of the population: aligning medical services with community development, emphasizing the 'mainstreaming' of the disabled, and providing an enabling environment for the disabled to become active partners in the program. For all the phases conducted, a total of CAD 100,000 funds were provided, which ended in 2010. Part of the reason the funding stopped was due to the 2010 super flood in Pakistan which lead to a change in funding priority for the organization. Now the program runs on donations from local businesses and organizations including and has recently expanded to Karachi where the services are being provided in a metropolitan setting.

Lack of basic services to the disabled continues to this day. Recommendations are not carried through. There remains a dearth of medical services to barriers to access at all levels in the society. The World Health Organization (WHO) defines Community-based rehabilitation (CBR) as a comprehensive strategy for involving people with disabilities in the development of their communities (WHO, 2004). The objective of the CBR program is to ensure that people with disabilities have equal rights with all members of the society and access to health support,

education and a means of living. Moreover, the basis of this choice was made in consideration to population needs, existing government policies, and lack of proper medical and rehabilitation services, especially for the Spinal Cord Injured affectees.

SN's funding support from the IDRF was divided into different phases. The first joint project (Phase I) was conducted between December 2006 to November 2007. This phase focused on medical rehabilitation services for the disabled while they relocated back to their homes. A major portion of this phase was dedicated to locating and enrolling PWDs. Phase II (from Dec 2007 to September 2008) continued with medical rehabilitation, with a dedicated focus on forming a Community Based Rehabilitation (CBR) Model in consultation with national and international partners, that could work in these remote, resource constrained settings.

Phase III & IV (from December 2008 to January 2011) developed and delivered a holistic approach to the disability of the population, with an alignment of medical rehabilitation services with community development, as well emphasis on 'mainstreaming' the disabled people, and providing them with an enabling environment to become active partners. Functional independence was the mainstay of the program throughout the phases, with greater emphasis in the later phases. The funding agreement with IDRF ended after Phase IV and the program is now run through local donations and sponsors.

In the implementation of CBR and over the course of the four phases, SN was not only able to achieve substantial medical rehabilitation of the disabled population, but also attempted at their re-integration within the community, which was gradually addressed as the CBR network evolved. The project also reached a vast spectrum of PWDs beyond persons with SCI, totaling more than 4,000 persons and their families. These have been affected men, women, children affected with various problems, which, besides SCI include stroke, cerebral palsy, arthritis, fractures, amputation, sciatica, muscular dystrophy and various other disabilities.

The challenges still faced by these populations range from lack of basic medical services, stigmatization and marginalization in mainstream able-bodied communities, lack of vocation and subsequent poverty, gender discrimination, lack of a barrier-free environment and little or no legislative support for their rights. As stated earlier, the CBR program was set up initially to address basic medical and rehabilitation aspects of PWDs, with a special focus on those affected by SCI, so these challenges remain further attention.

However, what initially started as an emergency response has been built up into a comprehensive rehabilitation longer-term network that has been geared towards active community involvement and development. The current CBR project has achieved significant milestones against the challenges faced by those experiencing disability in Muzaffarabad. The services offered in the program are detailed in the following section.

CBR Project Services

The major project services of the CBR Rehabilitation Program offered presently are:

A) Outreach services to Persons with Disabilities (PWDs) at their homes

B) Attendant services to PWDs and

C) An Out-Patient Department (OPD) Rehabilitation Clinic for adults and children with disabilities.

D) Specialist referral services

I describe each of these services in the upcoming sections.

Outreach Services: Locally mobile network of services

Outreach services are provided to PWDs with SCI, and the seriously disabled. These mobile services are a combination of PT (Physiotherapy), OT (Occupational Therapy), medical

advice and treatment, provision of assistive devices, training in functional independence, progressive building Activities of Daily Living (ADLs), psycho-social counseling and referrals related to specialist interventions. The team includes a medical doctor, a psychologist, two PTs and an OT, working in both outreach and the OPD center.

Since the program's main component was to target SCIs, this outreach service envisages visiting PWDs at their homes for assessment and follow-up. The team members' visits are made as per need, with more visits to PWDs who need close follow-up as determined by the medical staff. To facilitate travel, the following map (see Fig 3.1) was designed by administration staff members in the CBR team to coordinate the timely provision of services. This mobility mapping can be seen as a way to enhance movement (Urry, 2008; Sheller, 2011) and was done to save resources in a geographically challenging terrain and provided services in a timely manner.

Fig. 3.1: A map depicting travel times and geographical mobilities to PWDs across Muzaffarabad

Counseling regarding Disability

In the outreach program, PWDs with SCIs were offered counseling about their respective condition and disability in general. These included aspects such as functional limitation, prognosis, rehabilitation options, services in the region, and services provided by the SN IDRF program. Psychological counseling also focused on motivation, and specifically targeting depression.

Skin and Wound Care Services and Training

Wound or skin care is an extremely important aspect of services for PWDs with SCI. Failure to promote skin care results in bed sores that cause much morbidity and mortality.

PWDs are administered services, and enquired about this aspect, at each visit as they were trained in self-care for wounds. Additionally, their caregivers were also trained, are also enquired.

Mirror use for checking of pressure sores is taught, and recommended checking for pressure sores on a daily basis. Postural change for avoiding of pressure sores is a major strategy, and is also part of the training program to both the PWDs and caregivers alike.

Bowel Care Management and Training

Bowel care is important as PWDs with an SCI are predisposed to constipation, leading to a variety of complications. This is also a recurrent problem. Bowel care management services and training is also offered during Outreach Visits, both to PWDs and caregivers. In this regard, they are taught the importance of having a daily voiding routine. It has been observed in the area

that improper training on equipment provided, and use of inappropriate equipment such as tires as a commode chair have also been common practices. To accommodate for this gap includes the provision and use of the commode chair by the SN Program, with appropriate trainings.

Nutrition advice is another aspect of bowel care management, which includes prescribing use of fiber as a long-term laxative for bowel movement, and is also provided to SCI PWDs.

Bladder Care Management and Training

Bladder care is important for PWDs with SCIs as they are predisposed to recurrent Urinary Tract Infections (UTIs). The SCI PWDs are being offered bladder care as part of Outreach Services. These services generally focused on proper intake of fluids and catheter care. Caregivers are also provided training to make sure that infections are prevented.

Increasing mobility and Activities of Daily Living (ADLs) for PWDs with SCIs

PWDs are trained to get out of home, using a wheelchair, if applicable. They were taught the actual use of a wheelchair in getting out of home, while some could actually get out of home, as the physical conditions allowed it, with or without the use of a wheel chair. By devising alternate ways to be mobile, (Sheller, 2011) rehabilitation sciences and related non-human actors such as these trainings within this network have also allowed for the PWDs to move better and form further collaborations and networks.

Transfers for increasing ADLs

“Transfers” between different surfaces, for the use of equipment and personal needs is an essential part of Occupational Therapy (OT) care needed for PWDs with an SCI. The Program

focused on transfers so that functional independence of these persons can be achieved, while they could use mobility aids such as a wheel chair (WC).

These included transfers between bed and toileting facility, such as a commode chair or seat, while transfers between wheelchair and toilet, transfers between wheelchair and bed, while between the wheelchair, ground and mat activity are also provided. These strategies were aimed to prevent any injuries that can result from misalignment or transfers that can potentially lead to further injuries.

Postural Care Training and Other Activities

Postural care for activities and during the use of the wheelchair is also offered by the program.

Home Care Training

Home training services for the PWDs and their caregivers was also an important component of the Program.

Attendant Services Training Program

The attendant training program consists of education and provisions related to preventative care for SCI PWDs. The main areas of focus in the trainings are:

1. Wound Care
2. Bladder Care
3. Skin Care
4. Nutrition
5. Teaching Activity of Daily Living (ADLs)
6. Mobility trainings

7. Bowel
8. Exercise training including Posture related
9. Dressing training
10. Transfers

Integrated training sessions occur at home and both at the OPD center and during outreach visits to their homes. As different aspects of the training were offered by different personnel, e.g. wound care training is carried out by the doctor. Sessions include the PT, the combination of PT/OT, PT & doctor and the PT/OT/doctor combination towards their training. Typical sessions range from 30-120 minutes for the PWD caregivers.

In terms of both postural care in bed and chair, these were combined with skills taught towards mobility. The taught skills as well as findings are summarized as follows,

- Moving from Bed to Wheel chair (locking WC, lifting foot rest, removing arms, Lifting feet)
- From wheel chair to ground
- Bed to Toileting facility
- Balance Training
- Gait Training
- Stair Management
- Indoor Mobility
- Outdoor Mobility (on uneven terrain)
- Turning
- Mat Activities

Out-patient Rehabilitation Services

An Outpatient Rehabilitation Clinic was also set up in Phase I of the Project that continues to serve PWDs with medical, as well as training services to the targeted PWDs. Using this Clinic as a base station, the team reaches out to the PWDs at their homes and in other settings, most specifically with PWDs having an SCI.

Specific services included Medical and surgical consultations, PT and OT, and referrals. The Clinic also provided trainings to PWDs and caregivers in self-care, management and building up of their Activities of Daily Living (ADLs).

Specialist Care Services

Specialist care services were provided at hospitals and other institutions, such as Shifa Hospital, Islamabad and Abbas Institute of Medical Sciences (AIMS) hospital in Muzaffarabad. These collaborations help in aiding services that exist beyond what is offered by the CBR program, which includes detailed neurological exams and spinal surgeries.

Patient records and assessment tools

As part of the program, PWDs are enrolled and each patient has a record assigned. Designed with the help of local and foreign experts, the 'patient file' consists of the following forms compiled in a booklet:

- Form 1: Registration Form
- Form 2: SCI assessment and plan (contains Pressure Ulcer scale)
- Form 3: Management Plan
- Scale: American Spinal Injury Association (ASIA) scale
- Scale: Spinal Cord Independence Measure (SCIM) scale

- Scale: Berg Balance Scale
- Scale: Home assessment
- PT daily consultation form

Besides forms (see Appendix D.1-D.5) for the copy of all the Forms stated above), these patient records contain assessment tools which are indicators of the type of rehabilitation sciences being performed in the CBR network, and these are thus explained briefly for the sake of explicating another aspect of the program.

Description of assessment tools

Pressure ulcer scale

Pressure ulcers are one of the leading cause of deaths amongst patients with spinal cord injury (SCI), with mortality rate as high as 10% (Holtz & Levi, 2010). About one-third of those newly injured develop pressure ulcers, and pressure ulcer incidence during the first and second years after SCI is 10% (Holtz & Levi). The risk of recurrence is high for those who lack of sensation, which would normally provide warning signs such as pain or discomfort. Therefore, those with complete or high-level injuries are at an even greater risk of developing pressure ulcers (Holtz & Levi).

The National Pressure Ulcer Advisory Panel (NUPAP) defines a pressure ulcer as a "localized injury to the skin and/or underlying tissue, usually over a bony prominence, as a result of pressure . . . shear and/or friction" (Black et al, 2007, p. 347). As such, clinicians use the NUPAP classification system (Black et al, 2007), which is based on a score of 0 to 4, where 0

indicates least amount of damage to 4 indicating life-threatening conditions due to a pressure ulcer. These scores are recorded in the SCI Assessment and Plan form of the records.

The ASIA Scale

The American Spinal Injury Association (ASIA) was the first to develop International Standards for Neurological Classification. This led to the formation of the ASIA scale, which is used widely for the SCI condition (see Appendix D.2 for a copy of the ASIA assessment). This scale was introduced by the visiting Canadian team. The main motivation was to use standardized physical examination and classification, which facilitates where the injury has happened and how much neurological damage has occurred.

SCIM: The Spinal Cord Independence Measure

A main outcome of medical rehabilitation is functional independence. This construct is deemed relevant in regard to how well the PWD is doing in term of Activities of Daily Living (ADLs), especially in the context of SCI and further those who have Spinal Cord Lesions (SCL). Before the CBR program and into the Phase 2, the Barthel index was used as a means to assess this construct.

As suggested by foreign and local experts during Phase III, the SCIM version 3 (see Appendix D.3 for the scale), is used towards measuring this construct. In this version, total SCIM scores range from 0 to 100, and there are 19 items which are assessed in three domains. These are “Self Care” (involving 6 items, with scores ranging from 0-20), “Respiration and Sphincter Management” (involving 4 items, scores ranging from 0-40) and “Mobility” (involving 9 items with scores ranging from 0-40).

From its original form (Catz et al, 1997) till the latest version, SCIM is deemed relevant for acute and chronic as well as traumatic and non-traumatic SCI. The SCIM version 2 was analyzed through clinical input and Rasch modeling (Catz, et al. 2002), leading to a much improved SCIM version 3. Three sub-scales were introduced in this version, as mentioned above, namely, 'Self care'; 'Respiration and sphincter management'; and 'Mobility'. Further, the mobility subscale has two subscales: a particular one assigned for 'indoors and outdoors, on even surface' and another for 'room and toilet'.

In its latest version, SCIM has been established as a valid and reliable instrument from studies conducted. For the SCIM version 3 test, a multi-center, international study by Itzkovich et al. (2007) involving 425 participants in 6 countries in 13 rehabilitation units in 3 continents namely North America, Middle East and Europe. This formed a justification towards using this in Pakistan, whereby the Barthel index, which was used earlier, is typically used for stroke patients and does not have such validity and reliability research backing its use for SCI.

The current SCIM version was recommended as a valid and reliable instrument typically used by OT professionals, which justifies its usage to the present context with some careful considerations. A key element required in conducting is that at least to some extent, the therapist and the client must know English at a high proficiency level in this present usage. This is usually not a problem in Muzaffarabad across the practitioner population, where most healthcare professionals speak and work in English.

Berg Balance Scale

The Berg Balance Scale is a test which measures standing balance during functional activities (Berg, 1992). Since many with SCI cannot walk, this test is applicable to those PWDs

who have incomplete SCI identified and who can walk with some support (see Appendix D.4). The patient is scored on fourteen different tasks and this is typically carried out by a doctor or a PT.

Patients are asked to complete fourteen tasks while an examiner rates the patient's performance on each task. Elements of the test are representative of daily activities that require balance, such as sitting, standing, leaning over, and stepping. Some tasks are rated according to the quality of the performance of the task, while others are evaluated by the time required to complete the task. Each item in the score can range from 0 (cannot perform) to 4 (normal performance). Overall scores can range from 0 (severely impaired balance) to 56 (excellent balance).

Home assessment scale

The home assessment scale was devised by physicians, PTs and OTs as a novel feature which aimed to help devise home adaptation for the SCI and other PWDs. This form appeared in the second phase of the CBR program when the outreach services were reaching homes, and OT as a rehabilitation science was being incorporated through incorporation of ADLs and home adjustment strategies with the PWDs and their caregivers.

The main idea of this form is to firstly assess what is available and acts as a possible obstacle in maintaining mobility and functionality within a home setting (see Appendix D.5 for details). So, for example, the type of home within a local context is first determined, which includes whether the home is a new or old construction, as well as which level the PWDs lives on. Accessibility to various locations using wheelchair are also assessed such as stairs and ramps.

Further, transfers of the PWD are noted, and accessibility to the bathroom, clothes, laundry etc. are also noted; some idea about the daily functioning within homes are recorded.

Conclusions

This chapter outlines key policy documents, including those related to medical and health sciences education present before and in the aftermath of the 2005 earthquake. These documents are deemed relevant as they are referred to within various interviews and participant observations involved in the field studies conducted, which will be elaborated in the next chapter. As stated in earlier chapters, in terms of Actor-Network Theory (ANT) these policy documents are interpreted as significant non-human actors (Law, 2007) that are influential in defining, mobilizing, standardizing and negotiating the practice of those involved in rehabilitation of the disabled, including trained professionals in the medical and health sciences areas. The chapter also provided a detailed historical development of the Subh-e-Nau Disability program including its movement from initial delivery of services from the twin cities of Rawalpindi and Islamabad to rural Muzaffarabad in CBR network setting.

Chapter 4

(Im)Mobilities of SCI practices in a CBR network

Introduction

The Subh-e-Nau (SN) CBR program is a rich, mobile network which performs Spinal Cord Injury in multiple ways via the intermingling of human and non-human actors. The aim of this chapter, informed by Actor-Network Theory (ANT) and mobilities sensibilities, is to explicate the rich practices of actants that relationally constitute and stabilize this network. These includes Persons With Disabilities (PWDs) with SCI, their caregivers, the health and administration staff as well other organizations both in Muzaffarabad and beyond. In this chapter I first introduce multiple actors enrolled in the CBR network and discuss the themes and enactments which emerged from the interviews and participant observations. I conducted field work for a period of nine months during the 2010-2011 period of the program. The findings of the fieldwork are arranged in sections according to emergent themes from the analysis of data. Firstly, I introduce the participants in the study and the later sections are main themes which

emerged from the interviews and observations with various actants in the network. The second section contains accounts of four practice settings which typify SCI enactments, showcasing how outreach SCI practices are conducted through application of an assembly of sciences and services. I then draw out relevant practice themes which are noted from observations and involvement in field visits during the study period.

Brief introductions of members/actants in the study

Patients and associated caregivers

Amna

Amna was an earthquake victim, flown into Islamabad, and one of the PWDs (partial SCI) who remained with the SN program from the start. She kept in touch after relocating with the SN team to Muzaffarabad. Amna first used a wheelchair; now she can walk with the help of walking aid. Presently, she takes care of the entire household and cooks, cleans as well as maintains a small coup of chickens in her home. She got married in 2006 after Firdous, her fiancé at the time, did not give in to the social pressures to leave her. She also had a failed pregnancy, but is hopeful to have children in the future.

Firdous – Caregiver

Engaged to Amna before the earthquake, Firdous and his family lived in the same region as her. He is employed at a local hotel where he takes care of tourists and visitors at the front desk and also acts as a tour guide at times. He has supported Amna in all stages of her SCI condition, and has been able to convince his family to visit them as well, after their initial

disapproval of the marriage. He has taken SN trainings and is able to help with the range of motion exercises and transfers when Amna has difficulties.

Alia

Aged in her mid-20s now, Alia is part of an 11-member household. She is the youngest, has two sisters and a brother. She was attending her school classes when the roof collapsed on her, leading to partial SCI. At the time she was in Grade 7. She was enrolled in the program in 2007 after the program personnel found her through an outreach program trip. She has received various spinal stabilizing surgical procedures, which were mediated by the SN programs, and has resumed her studies at home and also through occasional visits to the school.

Sabah and Jehangir - Caregivers

Alia's older sister, Sabah and Jehangir, her father, are her primary caregivers, who have received SN trainings to better engage with the SCI condition. Sabah attends college. Jehangir is a local businessman who manages a local auto parts store and also owns land that farmers work for him.

Arshad

In an immediate family of five, Arshad was the eldest, with two younger brothers and a mother and father. He used to paint advertising billboards before the earthquake. To learn his craft, he went to a formal teacher. He used to paint large billboards, which earned him a living. He then switched over to smaller canvases and started to paint beyond the commercial ads that are placed on these billboards. He enrolled in the SN program in 2006 where he was identified as a deserving PWD. The program supported his art work by provision of supplies. Arshad passed

away early 2011; complications related to Urinary Tract Infections (UTI) and a heart problem were cited as reasons for his death.

Waqas - Caregiver

Arshad's younger brother, Waqas, aged in his mid-20s, primarily took care of him after the SCI condition. He would do transfers and helped in the Activity of Daily Livings (ADLs). He was given training in these areas by the SN staff. He was learning to paint from Arshad both before the earthquake and after Arshad's condition improved. Further, he was pursuing his matriculation exams for graduation.

Basit

Aged in his mid-50s, Basit was an earthquake victim, and was enrolled in 2006 in the SN program. Before the onset of SCI, he used to do farming and support his family which consists of a wife and two children. After two years in the program he was able to move from being in a wheelchair to walking using crutches. The SN program helped set up a shop which helped provide sustenance for him and his family.

Amna – Caregiver

Amna supported Basit, her husband and provided care primarily in his household. She also took care of the two sons, while he worked at his shop. She received training in helping him perform exercises as well as transfers around the home.

Dildaar

He was an earthquake victim flown into Islamabad immediately after the disaster. Aged 30, he is one of the PWDs who remained with the SN program from the very start of the program

in 2005. Before the disaster he was a farmer working in rural Muzaffarabad. He was enrolled in the Cantonment General Hospital (CGH) program and maintained contact with the SN program until the CBR program started, and he was one of the first PWDs to join. In 2006, SN facilitated a grant which allowed him to set up a small shop where he supports himself and his family which consists of a mother, two younger brothers and an elder sister.

Jamshed and Hina - Caregivers

Dildaar's primary caregivers are his younger brother, Jamshed, and Hina, his sister. They received training in range of motion (ROM) exercises and wheelchair transfers. Dildaar is often not motivated to do his exercises, so he is motivated by his sister, while his brother helps with the transfers. Hina also cooks and takes food to his shop, typically during lunch hours. Jamshed, who has taken over farming duties, helps him whenever needed.

Fareed

Fareed, is in his late 30s and belongs to a family of five. He was a truck driver and was enrolled in the program after getting admitted to the AIMS hospital in Muzaffarabad due to a bad back injury after getting into a traffic accident. After being classified as having SCI by SN experts, he and his primary caregiver were provided with outreach services, medical supplies and related trainings to manage his condition at home. He remains without a vocation and is supported financially by his brother who is a manual laborer.

Nida and Jamshed – Caregivers

Fareed's elder brother, Jamshed, who stays with him and his wife, is able to provide care for his SCI condition after undergoing trainings by the SN staff. He is a manual laborer who is

able to maintain a job and supports Fareed and his family as a result. Nida also provides support on the household front but is not able to help much with the SCI related duties.

Muneeza

Muneeza, is in her early 30s and belongs to a joint family of seven where she is the youngest with two brothers. Before this, she used to take of household chores, including taking care of livestock. In 2006, she fell from a tree while picking apricots and was taken to AIMS immediately after she was found. There is an existing population in Kashmir who injure their backs due to falling from apricot and walnut trees (Tabish et al, 2004; Nabi et al, 2009). The SN team located her in their campaign to locate post-earthquake victims, and enrolled her in the program. Her partial SCI condition led to a series of operations. Initially, she was on a wheelchair but is now able to walk using supports.

Ghazal – Caregiver

Muneeza is primarily taken care of by her sister-in-law Ghazal, who is married to Waleed. They have a daughter. After the SCI, she has taken trainings from the SN team to help with the exercises and transfers. Further, she has taken on a lot of the household duties previously done by Muneeza. With gradual improvement of her SCI condition, Ghazal does get some support from her now in some chores as well.

Health Care Providers in the CBR program

Dr. Waqas

As the project director and Chief Executive Officer (CEO) of Subh-e-Nau, Dr. Waqas has managed this initiative to the current CBR level. He has been a pioneer in regard to the initiatives

taken and his background in medicine (as a physician) and public health professional has been part of this process.

Farrukh

As part of the network, I have been flanking Dr. Waqas and other rehabilitation specialist in setting up the initial services, ensuring that we have all the professionals and updated research needed required for provision of services. This process has been gradual as I was basically helping at the level of conducting meetings and facilitating collaborations when the program was operating in Islamabad. Setting up the CBR program with Dr. Waqas and Canadian experts, I have also facilitated in updating our services through latest research initiatives. My background is a doctorate in Theoretical Physics, but I have been interdisciplinary in my approaches throughout the program.

Dr. Bakhtiar

Before the earthquake, Dr. Bakhtiar helped provide physiotherapy to injured tennis players. He was part of the rehab team when the program started in 2005 and also during the start of the 2006 CBR program. After the disaster, he now is overseeing the provision of rehabilitation services in the current CBR program. He has also learned Occupational Therapy (OT) aspects of managing SCI from visiting foreign experts. Located in Rawalpindi where he is working in Holy Family Hospital, he divides his time between these duties and also managing the program in Muzaffarabad. He is currently enrolled in a graduate program in physiotherapy which he is completing through weekend classes.

Dr. Tariq

The day-to-day operations with respect to provision of medical care in Muzaffarabad are overseen by Dr. Tariq, an experienced physician. He joined the program in 2007, and his duties include doing medical checkups, especially for the SCI in the outreach program and referrals to allied departments and hospitals in Muzaffarabad and beyond.

Farhan

Graduating from a physiotherapy school, Farhan joined the program in 2006, where he is part of the health professionals who reside in Muzaffarabad. He is involved in provision of care at the OPD center and is also involved in the outreach program. At the time of the interviews, he was enrolled in a graduate program in physiotherapy which he is completing through weekend classes.

Afridi

With a degree in physiotherapy, Afridi also previously worked in occupational therapy at Shifa International which is valuable to the program in various ways. He joined the program in 2006, and was instrumental in bringing practices such as home adjustments and splinting, as well as teaching other rehab specialists about conducting the “Home Assessment” in the program.

Farheen

Having a diploma in reproductive health and maternal child care from Muzaffrabad, Farheen joined the program in 2006. She was deployed mainly in the outpatient department where she learned to perform physiotherapy exercises for visiting females. This included SCI

PWDs, who found it culturally inappropriate for males performing, especially on certain parts of the body.

Usman

As a local who has lived in Muzaffarabad all his life, Usman joined the CBR program as a field coordinator. His job is to locate and enroll SCI and other PWDs, where he is able to mediate between various cultural differences between the local community and the team which hails mainly from urban centers. He also maintains records, data taking, facilitating patient mobility across various health institutions, planning and conducting field visits and also maintaining contact with PWDs registered in the program.

Nadim

Having muscular dystrophy, Nadim, a Muzaffarabad local, joined as program staff in 2006, where he became part of the OPD and outreach services as a peer-to-peer counselor. He has provided training at centers in Islamabad in counseling techniques and was involved in these processes with PWDs who required these services. He also helps maintain the OPD and is able to help in mobilizing those visiting to this unit.

Kazmi

As a former truck driver, Kazmi joined the program in 2006, where he is mainly responsible for transporting the outreach team and PWDs to various locations. These range from within Muzaffarabd to the twin cities. He drives a refurbished 1994 4X4 Toyota Prado, which has been a mainstay since the CBR program started.

Enacting SCI: themes and findings

The initial shock

In the interviews, a key theme across all the participants was how the incidence of SCI led to the loss of a previous life and personhood. I felt that the interviewees relayed the initial shock of the injury with particular emphasis, regardless of the cause. Arshad, a billboard painter recounted his encounter.

> I returned from the morning prayers around 5 am and went to sleep at the roof top. I was awakened by the loud thunder of the earthquake hitting our house. Before I knew it, I lost my *charpai* (bed) and I fell through the roof. Next, I woke up in intense pain in a hospital with my family around me. I tried to talk, but I fell unconscious again. I can never forget that day and event, this just is so…[takes a deep cigarette puff]

Arshad's caregiver, his brother Kazmi, also recounts how he escaped the terrible encounter, as he did not return back home from the mosque.

> It was Ramadan those days, and we had competitions as to who would keep most days of fasting. I was walking home and I decided to just spend time outdoors after the *Fajr* (morning) prayers. When the ground was literally moving under my feet, I ran to my home, where all my family was standing outside the rubble except Arshad, who was injured beyond recognition. We rushed him to the AIMS hospital for help. It was a horrible scene and it affects all of us to this day…in fact Muzaffarabad is still recovering from that day.

Alia, a young girl was attending school when its rooftop fell. Her father recalls the tragedy:

> We were at home when the earthquake struck. Alia had gone to attend school, which is near our house. After the shaking subsided, we rushed to her, only to find that there were stones and cries of help from the school which had fallen on innocent children. We [were] able to bring Alia out of the rubble but when we reached her she was unconscious so we rushed her to a nearby doctor. The Army personnel helped us transport her to Rawalpindi where she got proper help.

All Alia stated was, "…the roof fell and I do not recall much afterwards."

The non-earthquake victims also recounted their encounters with tragedy. Muneeza recalled this as:

> The earthquake was devastating indeed, but I did not get injured from that. In 2006, I was supposed to pick up apricots from a tree, and I am quite good at climbing. Little did I know that this climb would be my last. That day, it was quite sunny, so I was in a good mood. Right near the top of the trunk I lost my balance and fell. Next, I woke up and was being carried away to the AIMS hospital. I was in a lot of pain, and I still remember those days.

Dr. Waqas recalls feeling the earthquake shocks in Islamabad. He stated that as soon as the news happened, he was concerned at the vast scale of tragedy that was ahead.

> I felt the shocks of the earthquake as they reverberated across Islamabad. We ran outside but it was alright after a while. The immediacy that was across the news and the initial information was quite grim, and I was very concerned that this will lead to a large amount of injuries, disabilities and casualties. Once the victims were brought to the hospitals, we were there, but it was just too much to witness.

Dr. Bakhtiar, the physiotherapist assigned to the first trips to hospitals recalls the first encounter as horrifying.

> I wanted to help with the injured that were arriving in the hospitals; however, I still cannot help but recall how overwhelmed I felt when I saw the disabilities and the condition of the victims as I visited these places in Rawalpindi and Islamabad.

As someone embedded in this event, I witnessed the event in Karachi at the time the earthquake struck. Flying into Islamabad the next day and joining the aid efforts with Dr. Waqas, I also saw and was deeply affected by the devastation and the heavy flow of injured in the hospitals caused by the earthquake.

Self in relation to human and non-human actors: changes to this day

Most participants relayed how their lives, including their bodies and self-knowledge changed from the day they were first injured and traumatized. Amna, who was heavily injured in the earthquake, shared some of her views about the various changes she faced.

> Without Allah, of course nothing is possible and he has blessed me such that I can walk today. My family and fiancé played a great role in helping me through this nightmare and I find myself much more hopeful about life. Sure, a lot has changed, my body is different now. But I am happy to be free from just confined on the bed back then. There were a lot of challenges which are there, but I am glad that I am now well-adjusted and improving now.

Firdous, now her husband and main caregiver resonated with these views and shared some of these shifts which were not without struggle.

> At the beginning when we realized that Amna was going to be paralyzed, my family got on my case to leave her and marry someone else. I was appalled at all of this as I really had given my vows to her and her family earlier. Why should we let an earthquake come in the way? She is the same person to me! It was indeed quite heartening that after the first surgery, she recovered considerably and was on the wheelchair. With all the surgeries, exercises and care came through and now she can walk using crutches, which we are grateful for.

Arshad shared his views in a much more different tone. He found the adjustment to the disaster much more difficult.

> In the beginning, I was going mad at what had happened to me. I used to jump through rooftops and was so physically active before…and then this… It was seriously a lot of physical pain, and mental pain to realize what had happened to me. I just lost my body, my control and did not know where to start! It took me months to accept that I cannot walk again, or paint billboards. You can say that now I have this acceptance, but still I wish that something happens and I go back to being the *old* Arshad again.

Then again, Arshad, appreciated how his various supports helped him move differently. Besides his family, he noted how his first transfer from the bed to the wheelchair was transformative. He states that, "Lying in the hospital was very difficult for me, as it felt like I would never *move* again. When they put me into the wheelchair and I was able to get away from that state, it was like I was born again…I move differently than before, but I am thankful that there are things like this for people like me."

Strikingly, Dildaar shared a similar view. He recalls how when being confined to the bed at the Combined General Hospital (CGH) felt like forever.

> I was in a lot of pain and then would phase in and out of consciousness, I thought that I was going to Allah, my maker. When I was able to sit up, I regained hope and then when I was put into my wheelchair, I felt like a newborn baby. This wheelchair has been part of me ever since then, as it gets me to live this new life in a better way.

Caregivers were also quite aware of the changes, especially in relation to the PWDs. Ghazal, noted how Muneeza's body and its mobility had undergone a radical shift. She shared these views in relation to how she had to adjust her activities as a result of this transformation, which also included adjustments to various non-human actors.

> Before Muneeza's fall, I used to mostly take care of my baby, while she used to do most of the household work such as cooking and cleaning. After the injury, I also have to tend to these chores and also make sure Muneeza is being looked after. It is striking to see her go from a girl who used to run around the house to seeing her walk on crutches. These things are very helpful, but still she is not the same person that I knew for quite some time. She does have the will to get better and so she helps with washing dishes and tending to our goats.

In regard to the health care workers, most recall their changes since dealing with SCI as transformative. Dr. Bakhtiar notes that his own professional practice has changed after this encounter.

> If you'd ask me before the earthquake, that I would be learning occupational therapy and going through a graduate program in physiotherapy now, I would laugh it off. The disaster changed my practices considerably. I learned a lot from the visiting physios from Canada or being part of this CBR program. I never knew that I would learn and practice so much about SCI too.

Dr. Waqas recounts how he knew very little about disability in general. He conveyed how his training as a physician and foray into rehabilitation sciences in relation to SCI were life-changing.

> As someone who set up this program, I had no idea how much effort and alignment it takes to manage a chronic condition like SCI. Professionally, I have a much more holistic view about disability and this encounter has changed me considerably as I had not engaged rehabilitation sciences nor been involved in such situations.

Similar changes in professional shifts were also shared by other health staff as well.

Sources of support and mobility in and through human and non-human actors

Most participants attributed their management and adaptation to dealing with the SCI condition in relation to other actors, especially family members and caregivers. Participants stated that a combination of various supports led to improved mobility. Mohammad Fareed shared that, "…my wife and brother are sources of support in dealing with all of this, every day. I thank Subh-e-Nau for visiting me and providing me with a wheelchair and a commode chair which facilitate my movement around the house."

His brother noted that after receiving training in Range of Motion (ROM) exercises, Fareed is able to move better even across the bed:

> Fareed can now shift himself better after getting stronger with exercises that I was taught which I regularly conduct. This has helped him to turn in the bed without assistance more regularly which is good for his skin and also his mindset as he can get stuff closer to him such as a glass of water or food. With the wheelchair he feels even more better knowing that he can do many things together.

Not only does his wife help him around the house, cleaning and cooking for him Basit also credits able to walk with the aid of crutches, which he stated as "his new friend". Previously he was on wheelchairs, so his mobility was somewhat restricted.

> It is remarkable that I am able to move around in crutches. Back then, moving from the bed into the wheelchair felt so good. Now, my wife helps me get up at times and when I am on these crutches, I walk to my shop and manage things from there. My friends also visit at times, and the mobile phone also helps in regard to communicating if I need anything.

In my observations, mobile phones emerged as being quite useful for contact between the PWDs and caregivers, as well as the keeping in touch with the health staff. All of the PWDs kept in touch with the SN staff mostly through mobile phones and these were used to initiate outreach visits too (explicated later in the next section). Arshad relayed how this was particularly helpful for him.

> I am quite a social person and I love to talk. So, when I am at home and my siblings and friends are away at work, I call them at the lunch hour. They are able to bring me sweets and cigarettes on the way back. Also, when I am extremely bored, they leave me at a friend's shop where I get to be around him and customers who visit. It helps me stay socially active and stay away from depressing thoughts. When I want them to pick me up, I call them and they are there. Similarly, if I have some pressing medical issue, or I am feeling depressed I use my mobile phone and connect to Farhan, Dr. Tariq or Dr. Waqas for advice and encouragement.

Alia was able to relate her father and sister as very helpful in supporting her. She also relayed that after a recent spinal surgery, she feels much better than before.

> My father and sister have been there for me. I used to be in a lot of pain even after taking the pills, and had a surgery recently where they took out the rod in spine put in there earlier by surgeons at Shifa.

Alia's father, also agreed with the surgical intervention which stabilized the spine as a key change in her life getting better. The rods are now removed.

> Thanks to the surgeries arranged at Shifa, we were able to get a very difficult problem out of the way. She is able to sit properly now, and without much support can move about much better without pain.

All PWDs declared their belief in Islam and cited Allah as a guiding support. Muneeza shared that,

> "I am thankful to Allah for supporting me towards getting better. I am regular in my prayers and ask for betterment in my condition. It is improving, and after all we have to accept whatever that has happened as the will of Allah."

Affect and embodiment as stabilizing actants across the CBR network

Affect within various actors and embodied engagement of SCI was communicated as an important mediator within the CBR network, which, for the most part seemed to stabilize the CBR program. All PWDs interviewed relayed how pain and fatigue, as well as psychological trauma figured a great deal in their enactment of SCI.

Amna shared how her back pain and inability to control her bodily functions such as bladder and bowel movement caused embarrassment and frustration at times.

> I feel a lot of pain at times, especially when I move into the bed or out of it. Some of the days I feel very tired to do anything because of this. The painkillers help, but I have to thank my husband for being so tolerant regarding my condition. When I am unable to control myself […] he helps me and then encourages me to get out of bed.

Firdous, her husband conveyed how affection for Amna helps him too, yet in a different manner.

> Here is someone who I love and have seen her go through so much pain. It is frustrating and difficult to not do enough for her at times. We are able to console each other on most days and it helps me too, because I feel I am doing my duties as a husband in a sincere manner and she supports me. And, it is not all about her body but also about her soul.

Many caregivers like Firdous were confident that their attention helps those related and dealing with SCI. Fareed stated how his brother would sometimes go to work late in order to take care for him. Jamshed, his brother stated that,

> We are family and how can you see or let your own suffer in front of you. He is already going through a lot, and with lots of pain in his upper back, I do the exercises that were taught by the physios, which help.

Tariq, the peer to peer counselor at the SN outpatient expressed how some of the PWDs were able to relay their emotions better with him.

> I have muscular dystrophy and it is visible as to how my body moves, as you can see. Many patients I meet actually start by asking me about my condition first, as they see someone that they can relate to. I am able to tell them how it all happened, and then we become good friends after sometime. Many are still quite angry and depressed at what has happened, but I try to let them vent these feelings as it is what I have to do in order to remain sane.

SCI Enactment and mobilities: network mobilization of Rehab Sciences in relation to other practices

The outreach team constitutes most of the services offered to the SCI group, as transport is difficult for these PWDs. While some do visit the outpatient unit, this is usually done when

they have some intermediate treatment to be done before going to a hospital for an intervention such as surgery or a required consultation.

In order to conduct the participant observations, I spent a couple of weeks traveling with the outreach team on various occasions in following the actors, as a form of a mobile method. While I was able to interview the participants above, I also enquired how they were enrolled in the program and what types of services were provided.

The four practice scenarios which I depict here are drawn from following the actors during various field visits, which offer but snapshots of the myriad of SCI enactments in place. However, they do partially illustrate how various practices and sciences move and "hang together" (Law, 2007; Mol, 2005) and multiple enactments constituting SCI in the CBR network.

Practice Setting 1: Enrolling a New PWD

Fareed recalls that he heard about Subh-e-Nau's services at the local AIMS hospital from the local staff. After locating Usman's phone number, Fareed called Usman (field coordinator) as a new SCI PWD. As stated earlier, Fareed had been treated to stabilize his spine at this local Muzaffarabad facility after a bad road accident. He was discharged after this treatment was completed at this health facility.

Usman stated that during the phone call, Fareed complained of extreme back pain and explained that he could not visit the SN outpatient clinic; he requested the team to visit his home. Usman added him to the outreach visitation list, where coordination with the main office is required before each outreach trip is made. This produced a set of calculations around geography, time and resources in the enactment of (practices of) SCI.

Time and location within practice: A crucial element in SCI enactment

Upon discussing the criteria with Dr. Waqas and Dr. Bakhtiar, these outreach trips were developed first and foremost based on the nature of the medical condition and priority was given to those needing utmost attention first. Then, mobilizations for other geographically nearby and reachable regions are planned each week. Dr. Bakhtiar, the lead physiotherapist, stated that time was of utmost importance for SCI PWDs as their condition could worsen if delays happen, so this planning was of great importance. Hence, the first priority of the outreach services is to visit as quickly as possible, especially in the case of an emergency situation. Follow-up visits happen later within the trip or when there are no emergencies present.

A map which denoted the geographical regions and associated time needed to reach from the center proved to be an efficient means to mobilize services in a timely manner (see Figure 3.1 from Chapter 3). This was devised in Phase 2 of the program when most of the SCI PWDs had been traced and enrolled in the Muzaffarabad region. This non-human actant hence played a key role in planning and delivery of services, even as a reference during times of inclement weather and adverse driving conditions where delays were estimated based on this map.

Field translations: Usman as a network mobilizing actor

The team assembled for the trip included Dr. Tariq, Dr. Bakhtiar and Afridi. Since Fareed's condition was deemed critical, the plan was to visit him first and then travel to other PWDs. As is usual in all outreach visits, Usman told the team to wait outside Fareed's home and then called the new PWD. After receiving confirmation, he went in first and made sure that the team had consent to visit them. We followed this routine in all the outreach visits. It is quite remarkable that Usman, a local Kashmiri, played a key role in mobilizing the team's entry in a culturally acceptable manner. This aligning and translating across various actors as an initiation

of enrolment of the response team members highlighted the key role of the field coordinator in enacting SCI in the field.

Enrolment of PWD and Assessments of SCI through aligned rehabilitation science practices

At the start of this enrollment, Usman filled out the first part of the patient record by taking verbal consent from Fareed. Upon discussing with the staff, I found out that Dr. Tariq took Fareed's body temperature and assessed that no fever was present, which is standard practice in enrolling new PWDs. Given the AIMS hospital reports, Dr. Tariq and Dr. Bakhtiar then located the current source of his pain and first checked to see the location of the SCI trauma. Dr. Tariq also looked at X-Ray radiograph where was able to 'locate and align' where the spine fracture was assessed at the hospital. The treatment done there was 'spinal fixation.' According to this, they were able to confirm and add that the "vertebral/radiological level" of this incomplete SCI, classified as 'cauda equina' at the L3 level. Next, Afridi conducted the ASIA scoring test on him, hence finding the level of neurological damage caused. According to him, this test takes about half an hour to 45 minutes. This assessment led to finding all sensations intact except for the lateral side of the left foot. The motor and sensory scores of ASIA led to grade D of partial SCI assessment. All these findings were noted in the patient record.

At the time, Afridi wanted to conduct the Spinal Cord Independence Measure (SCIM) to assess functional independence in activities of daily living (ADLs). However, since the wheelchair was not available, this measure was planned for the following visit. Nevertheless, he inquired Fareed about self-care, respiration and condition of his bladder and bowel movement, which were again recorded in the patient record. The house was also inspected using the home assessment tool which indicated how much adjustment was needed. He did not have a wheelchair during this first visit, so that was assigned to be donated coordinated through the

Muzaffarabad Physical Rehabilitation Center (MPRC). Usman facilitated these exchanges. These wheelchairs are given for free to PWDs after they are assessed at this facility, under an agreement of this organization run by the International Commission of Red Cross (ICRC).

Enrolment of caregivers and treatment planning to a 'newer' enactment of SCI

After these tests were conducted, then family members were asked to volunteer to care for Fareed. His elder brother, Jamshed, agreed to transport him to MPRC to get a wheelchair. A treatment plan was devised, which included painkillers alongside daily exercises and routines, including ROM physiotherapy exercises. Afridi and Bakhtiar, the PT/OTs noted that certain portions of the house had entrances which would pose difficulties to wheelchair movement. These obstacles were made out of wood, so were sawed off by Afridi. He noted that the bed was not level with the standard wheelchair provided, so the wooden base supports were sawed off.

Given the level of pain which Fareed faced, and the unavailability of a wheelchair, the team decided to do a follow-up visit next week, for training sessions that would involve both Fareed and his elder brother. When the team conducted a follow-up visit, Fareed was in much less discomfort and the wheelchair was also made available. At this time, Afridi conducted the SCIM before the trainings. When I asked why he did this before the trainings, he stated that at this point conducting an assessment was necessary to helped establish an aligning 'baseline', which includes mobility amongst considerations of self-care and respiration and sphincter management. He scored a 'low' 39/100, which was expected, but this helped Afridi establish the ADLs and mobility issues that needed to be addressed.

Next, trainings were provided by the team to both Fareed and his caregiver. The following trainings were conducted by both Dr. Bakhtiar and Afridi: maintaining a specific posture; self-care trainings on ADLs including feeding and self-grooming; ROM exercises

involving both Fareed and help from his brother; transfers taught from bed to the wheelchair and the bathroom; preventative management of pressure sores through turning every two hours; wheelchair mobility, both within the house and outside; bathing, skin management and activities for maintaining cleanliness. In terms of mobilizing other non-human actors towards enacting SCI, Afridi had to 'modify' certain utensils by bending them at a certain angle, such as spoons and forks such that Fareed could eat in bed without help.

Dr. Tariq explained that he came in later and, along with Bakhtiar and Tariq, performed the following trainings: management of bladder and bowel movement; nutritional advice including foods containing fiber was also given to the brother and to the mother who cooked for the family. A locally available natural laxative 'Isphagol', was provided and recommended for usage if Fareed encountered constipation. Dr. Tariq also taught regular water intake to prevent Urinary Tract Infections (UTI). A follow-up was planned in two weeks. However, the team, and in particular Usman, assured their availability to Fareed and his family, in case of emergency.

Practice Setting 2: Spine stabilization surgeries

While interviewing Alia, I was pleasantly surprised to hear that she had no back pain after her three spinal stabilization surgeries. These stabilization surgeries are quite common in the program, as well are complications post-surgery. Thus, I enquired further about Alia's condition with associated health care staff. They explained that her spine stabilization rods which were inserted in the lumber region were finally removed in a third surgery, as her bones had fused into a stable structure.

Alia had received a first spinal surgery at the Shifa International Hospital immediately after the earthquake in November 2005. This involved the insertion of rods and bolts to stabilize her spine by Dr. Suhail, an expert neurosurgeon.

After informal discussions and getting some references from him, a key consideration in these surgeries is spinal biomechanics and using appropriate supports with proper material properties. The surgery's main aim is to create a support via a rod or some fixture to stabilize the spine by considering a bending moment which is given by the following equation (Benzel et al, 2006):

$$\vec{M} = \vec{F} \times \vec{D}$$

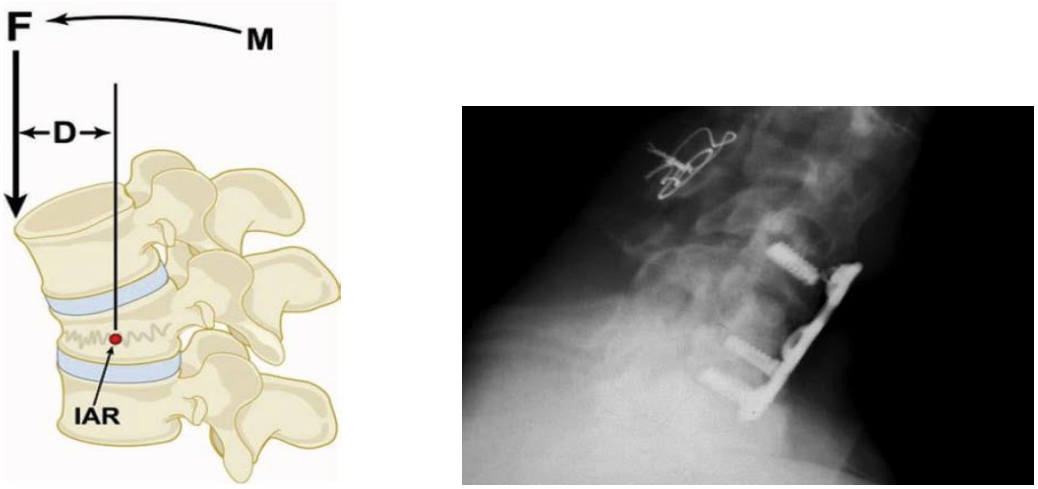


Figure 4.1: (a) Representation of a spine wedge compression fracture that failed about an axis termed the instantaneous axis of rotation (IAR, red dot). The bending moment (M, curved arrow) is the product of the load applied (force, F) and the distance from the IAR at which it is applied (D) (b) Implant for a fracture at a vulnerable point, with stress application on the implant is maximum at this point.

This is a 3-dimensional vector equation with a cross product. Figure 4.1 (a) describes the bending moment *M* which is due to a compression fracture about an axis termed as the IAR (Instantaneous Axis of Rotation) which is a cross-product of the applied force *F* and distance *D* shown above. This is a key equation which allows neurosurgeons to determine the point of maximum stress and it helps in inserting the location and type of implant which can then stabilize this bending moment.

Upon locating Subh-e-Nau in Muzaffarabad in 2007, Alia's family enrolled her in the program. In December 2008, Usman, the program coordinator received an emergency call from her father, as she was suffering from severe fever which was not going away. The outreach team assembled quickly and planned to exclusively visit Alia. Upon a two-hour drive from the outpatient department, the team arrived at their house. The team consisted only of a doctor and a PT.

Dr. Tariq recalled a high fever and an elevated blood pressure, and enquired about various other aspects of her condition. With Amir conducting certain mobility tests of the spine, he noted that pain tended to increase in the region during certain types of muscle flexes in the region of the prosthesis. It was decided that the condition may require another surgery and Usman called in Shifa International Hospital in Islamabad, where such operations are conducted with an understanding with Subh-e-Nau.

Mobilization of the CBR Network with the Shifa International Hospital Network

The team, alongside Alia and her father, drove directly to Islamabad, which took about 5 hours. Usman recalls that during the transport, he had been informing, arranging and coordinating with the Shifa Hospital. This included active communication with Dr. Suhail. He then further probed into her condition through mobile phone exchanges with the SN team doctor, and concurred that a replacement surgery was required, but that further tests were needed.

Upon arrival at Shifa hospital, Usman recalled that he was able to go into the emergency section, where Alia was checked by attendant physicians. She was given painkillers on the spot. Her patient record was pulled out, and tests were conducted, which included X-ray radiography. After these radiographs were made available, the team took them to Dr. Suhail, who inspected these with Dr. Tariq. After visual and tactile confirmations of where the pain was originating, the

X-rays revealed that the fixation was in place, but the area around was swollen. Blood and culture tests indicated an infection. This led the team to clinically judge that local infection in and around the area of the prosthesis was causing discomfort and pain. Dr. Suhail decided that it was best to admit Alia into the hospital for next-day surgery.

The following day the rods were removed, sterilized and re-inserted. Usman handled the paperwork with the administration, including the payments. Upon an agreement, Shifa provides a 40% discount for such surgeries for SN PWDs on humanitarian grounds. The team departed for Muzaffarabad, whereby it was understood that it would take a week for Alia to recover in the hospital before returning home.

Unfortunately, the infection reappeared in 2009, and the same team attended with the result of repeating the sterilization and reinsertion of the rods. With variations in certain details, the infection reappeared yet again in three months. At this time, Dr. Suhail decided that removal of the rods was possible as the vertebral bones in the affected region had fused sufficiently enough to provide support. A final surgery was conducted and Alia was given a three-month intravenous dose of Vancomycin, an antibiotic which was put in place to kill any infection present in the region of injury.

In this scenario, the CBR network, utilizing its outreach services continually mobilized a PWD with another connected network in Shifa International towards stabilizing her SCI-health condition through spine-related surgeries and drug treatments.

Practice Scenario 3: Pressure Sore Management

When we visited Dildaar, relayed to the team regarding the darkening of skin on a patch near his right trochanteric (hip) region. Alongside the usual routine checkup, Dr. Tariq inspected

this alongside Dr. Bakhtiar, and both arrived at the conclusion that a pressure sore is happening in this region. The sore was classified as a Grade 2 pressure sore according to the NUPAP classification scheme.

Trained in using a mirror to find bony prominences not directly visible, Dildaar had noted this problem earlier in the month. He complained that the team did not arrive early enough. Dr. Bakhtiar talked to the caregiver and asked whether they were monitoring the two-hourly turning that is advised towards preventing pressure sore development. Jamshed and Hina reported that they had difficulty maintaining this regimen during the night time, given they had to sleep as well. Dr. Tariq and Dr. Bakhtiar surmised that this may have been the reason behind this sore. They then proceeded to show Dildaar how to use his mobile phone as an alarm clock which could help maintain this routine during night time. Dr. Bakhtiar also checked out his bedding and found out that it was clean and moisture free.

Dildaar also reported that he had been sitting for hours on the wheelchair in his shop, without much change in posture. Dr. Bakhtiar reminded Dildaar and Jamshed how he was taught to shift his weight and change posture on the wheelchair. He also recommended moving to a different seat while working in the shop and also to make sure that the bedding was clean.

Dr. Tariq recommended a moisturizing lotion; he further discussed diet and recommended more protein (as meat and lentils) in Dildaar's diet. He also recommended more fiber to avoid constipation and provided the laxative Isabghol. Towards the end of the session, both recommended Laiqat to follow these routines and to keep them updated about the progress of his sore. A follow up visit, two weeks later, indicated that the sores had lessened after these preventative approaches were followed.

Practice Setting 4: Urinary Tract Infections in SCI

Arshad faced a lot of urinary tract problems including infections. These problems required periodic treatments at his home, at the outpatient unit and also at Shifa International Hospital (SIH). The department of Urology helped considerably, from providing training to surgical care. Both the caregivers and Arshad were trained in self-catheterization, but these were not carried out in a proper and timely manner. There were consistent issues with his smoking and drug addiction habits which oftentimes hampered his routine and overall treatment. In my encounter with him, he explained how the entire routine was difficult. He admitted that he did drugs earlier, but under severe pain and stress.

When I discussed UTI management with the healthcare providers, they stated that trainings are given at home as well as the outpatient department. Water intake is stressed and proper cleaning and sterilization of catheters. These practices were sometimes followed by Arshad and Usman reports that at times he even tried quitting smoking beyond doing drugs.

After Arshad passed away due to UTI complications (which also affected his blood circulation condition), the notion of death and 'failure' of the CBR network loomed large in the face of complications at several levels. The complications not only lay at the level of the individual, but also at the level of society. It also provided a sobering look at how these assemblages of services not only do not cohere at times, but also cannot fully contend with the impact of SCI despite various enactments towards its stabilization and management. The services could not fully address the addiction and emotional state of Arshad who tried his level best to end them, but struggled despite support provided both by caregivers and health providers.

Key Practice Themes

Based on practice observations and being part of field visits, I noted several key relevant themes relevant to the enactments of SCI in the CBR network under study.

Different knowledges and practices mobilized in the CBR network

Most participants were quite involved in the practice of Islam, which is considered a key metaphysical actor. Islam influenced not only the PWDs and their caregivers, but also the health care staff. This religion, as practiced, for example, prayers require a certain level of cleanliness, had an intimate link with the enactment of SCI. Dildaar shared that, "…the day I could pray without having to lose control of my bowels or bladder, I was very happy. I knew that I was on the way towards healing." The healthcare providers were well aware of certain prohibitions of praying when deemed 'unclean.' Amir, a PT, noted that

> I think one of the most difficult thing is to make the patients realize that in their circumstances, prayer is allowed without ablution (washing before prayer). It is a milestone when they are able to pray without the guilt of being 'unclean.'

The healthcare staff also had religious views and most shared that it was their duty to help those afflicted by the tragedy. For example, Dr. Bakhtiar stated that he prays for their healing every day.

Patient knowledge of SCI and related practices was also facilitated through training sessions. Several would speak in rehabilitation terms for their condition which was shared with their caregivers and the SN staff. However, some stated that the caregiver would never really understand their situation. Arshad noted that, "…while you are trying to help, you have no idea what I am going through right now."

The interplay of medicine and rehabilitation sciences between the staff was showcased in the daily practices detailed earlier. The staff engages in multidisciplinary conversations with each other, however, there is a lack of coherence. Dr. Tariq states,

> I mostly let the rehab staff do their bit and let them do my job. In the patient record, there are sometimes difficulties when we fill out the 'Management plan'. It is divided into 4 sections ("MEDICAL/SURGICAL", "PSYCHO-SOCIAL", "PT/OT" and "TRAININGS"). We discuss with each other why certain treatments are necessary, so there is some engagement there.

Afridi, the PT stated that they were a team in handling various disabilities every day. SCI stood out because it demanded so much from the practitioners at all levels.

> It is after all a chronic condition, and as such, no one as the 'right' answer. We have to let our experience and judgment guide us when the situation is extremely difficult some days. Doctors are sometimes hard to reach out to, but Dr. Tariq has learned a lot with us and us from him.

So, non-coherence and lack of translations between the health care providers usually occurred when they saw certain disciplinary and practice boundaries which they chose to respect. This was not only out of professional courtesy, but due to lack of knowledge. Nevertheless, exchange of knowledge happened within practice, as the scenarios partially indicate.

Gender also emerged in practice as a deciding factor in some of the rehabilitation practices. Certain family members and female PWDs did not like being touched, especially in sensitive parts. So, in these cases, Farheen helps with both the SCI PWDs as well as those in the outpatient clinic.

> The PTs teach me relevant exercises which I then apply to female patients or their family members who are sensitive to these issues. They supervise me when I am conducting these. This helps ease any tension between certain local and religious traditions and what we do, so I see myself doing something important.

Knowledge and related practices weres facilitated through non-human actors who were also part of these practices. Wheelchair mobility training, Activities of Daily Living (ADLs) and

other trainings led to lively exchanges between the health care providers including the staff, caregivers and the PWDs.

Enacting and Learning to enact SCI: views from actants

The health care staff relayed that learning was a big part of practicing in the program. Amir, who is pursuing a graduate degree in physiotherapy, indicates that his learning was difficult when he joined as he had no prior experience with SCI.

> The first two months were extremely difficult as I had read some of this material in my undergraduate years, but actual practice is different! I would just get material from the Internet and tried to learn from the existing staff here, but it took time to understand and apply what was being relayed.

The PWDs also relayed how much time it took to accept this gap as a reality and then deal with it on a daily basis via various sources. For example, for the proper use of wheelchair and its mobility, required some foundational knowledge and skills to gain proper positioning. Dildaar relayed that the amount of effort required to even get his wheelchair positioned for mobility was a difficulty, often hampered due to the pain and fatigue it could bring on.

> Well, you're in this new situation! You have a wheelchair – this thing is part of you and moving it about requires listening to one of these folks who know how it works. I tell you, I could not get this moving right. One day, you find yourself moving around, but it took me time to adjust to so many things together.

Most caregivers were mostly grateful that they were able to contribute towards the well-being of the PWDs. However, a few did express their dissatisfaction at having to learn and do a lot too.

(Im)mobilities in and from the geography and environment

Muzaffarabad is a difficult region in terms of geography as it is hilly and many outreach locations required the 4X4 as a means to reach the SCI PWDs. In this regard, the geographic

mobility of the team was facilitated by the driver who is an expert in handling the vehicle. Kazmi the driver cautioned that,

> We have to watch out for dangerous weather and road conditions at times. I am very cautious in regard to this as there are many landslides that can happen, especially during the winter and rainy summer days here.

This caution meant that service delivery to various PWDs was often difficult and delayed especially during the summer monsoon and winter season where extreme rainfall caused all kinds of adverse driving conditions for the driver. This included closed roads due to landslides and active threats of these events due to inclement weather.

Health care providers also noted that getting around required plenty of stamina and coordination. Amir noted that some places require plenty of walking to reach as the jeep can only reach to a certain point. I accompanied the team in several of these outreach visits and can attest to the challenge to mobility the environment and geography provides.

The team has had to contend with this as a part of practicing SCI through a unique type of geography and type of movement needed to perform. The geography and the environment do appear as strong actants which can change practice patterns. The 4X4 jeep and the driver act by building and maintaining mobilities within and beyond the network as also demonstrated in the scenarios described earlier.

Within and beyond the CBR network

Location within the CBR program and mobilizations/treatments done towards SCI – lacks and dislikes

The PWDs placed themselves as a deserving segment of the CBR network and also provided some insights into how they can benefit. Some PWDs were quite critical about the

frequency of services provided. Dildaar voiced his views about how there should be more visits by the outreach team.

> I understand the limitations this program has, but you should come here to me more often. It is not enough that you show up when I call you and even then, the staff gets delayed by a few days. They should follow up on us more often, as I do need physio attention.

Basit viewed the issue of provision of medical supplies as problematic and regarded a more frequent follow-up so he would not run out. And a steady supply of care as well is also implicated in the process.

> I am usually out of pills which lessen pain. These are not so easily available and the staff can do better if they visit me more often. Using my mobile I call them, however, they are sometimes not as regular as I would like them.

In a separate interview, Usman (field coordinator), offered reasons for delay and lack of frequency in service provision. He stated that each field trip is made according to various weather conditions, priority in relation to PWD condition and also how the number of PWDs reached in a trip can be maximized.

> We have to watch out for the amount of gas we have, the funds available. Sometimes there are difficult road conditions. I know in my position I get a lot of angry people when we are not able to reach them. However, what can I do? We are limited in so many ways and sometimes the expectations are too high.

Usman stated his position in the program as that of arranging logistics and these were done in a challenging, resource constrained, rural environment. Dr. Bakhtiar also agreed and noted that within the movement of the services provided, the position of the health care staff was important and this was well coordinated with Usman. This contradicted the statements of the PWDs who had expressed their dissatisfaction and spoke more towards lack of certain resources and limited mobility of the CBR services especially in its outreach program.

In contrast, some of the PWDs also regarded their position as somewhat surprisingly privileged. Amna stated that, "…we are quite grateful that you visit us and provide service for free. If I was to go the AIMS (local hospital), they would charge me and the cost for transportation is high."

Fareed (truck driver), too noted that

> I am impressed by the consideration of the staff. They are polite, and it is remarkable that they travel for hours to reach me. Then there is provision of these items which would be so difficult to get since I cannot drive anymore.

Overall, the CBR network involved certain actors in situations where they required further needs and some of these gaps were stated as unsatisfactory by some. The health staff relayed that they were performing satisfactorily, however, this revealed lack of resources in the program.

SCI as a site of Discrimination and lack of access to various networks and decreased mobilities

While many PWDs reported a smooth relation with the staff and appreciated the quality of the services provided, they raised the concern that the CBR program was easier to be 'mobile' in or being more integrated. Arshad stated in relation to work mobility:

> When your staff arrives, I can joke with them and they make me feel like I am important as they try to listen to me. But when I step into my neighborhood, people call me names and also tease me…I cannot get a job as a painter as I cannot climb up billboards. I pleaded and begged that I can still paint while sitting on this wheelchair, but some of these idiots are so narrow minded! You cannot imagine the discrimination I face each day, it is very depressing at times.

The limited scope of the CBR network was also noted by Dildaar, and related how his social mobility alongside geographic mobility is compromised. This also shows the wider context in which medical sciences/rehab work in such that 'health and wellness' is much bigger with many social factors (as discrimination) which affect how the 'applied science' intervention happens and its success.

> I cannot walk out there without one of my relatives treating with pity or sometimes they make fun of the way I struggle with this thing. The improvement provided by the program and the support is there, but we are also facing a world where there are no opportunities for us.

Muneeza lamented how even basic education was difficult and lack of access to other networks. She stated that,

> Because we are poor, we cannot afford transport. I wanted to study and finish matriculation at least. There is no way I can afford to reach the nearest school which is at least an hour away. Then I tried to find a place where I can work, as in wash dishes or cook and people turned me away saying I cannot do anything!

Fareed shared his encounters where his sexuality was questioned. He felt humiliated at such comments that are commonplace when his friends and family visit, where he often gets angry at their remarks about his relationship with his wife.

> I do not go about questioning other people's lives. Why do they have to some here and be so insulting to me and my wife? I am sure that they do not understand what this is all about, but I get impatient at their remarks which can be rather rude at times.

As a caregiver, his wife notes that this also adds on to his frustrations to not being able to work.

> He feels that his manhood is lost after the accident. I try to console him but there are times where he is very angry at remarks made by close relatives. They laugh it off, however, he is unable to get a job and is also unable to take his mind off these petty remarks and insults.

Arshad was quite vocal about the lack of support from the government. Insofar as his interaction went, he found it extremely frustrating to get any support.

> The Pakistani government should do something about us. They should include us in the mainstream, and provide us with the support we deserve as regular citizens. It is great what this program is doing, but how much can you do? Once the government backs us up we will be respected in the community. They have just given up on us, that is why no one allows us in.

From these views, social mobility and community acceptance seemed like the most difficult aspect which the program had difficulty to directly address. While some of the immediate mobility issues have been addressed through provision of wheelchairs and other rehabilitation services, limitations in geographic mobility as well access to other networks remain limited.

Present and future aspirations

Beyond the current reach and limitations of the CBR program, all participants shared their aspirations towards the future. Dildaar, for example, wanted a bigger shop with an assistant to help him around. Arshad expressed his need to display the art he was developing after the earthquake. He shared some of these works during the interview.

> I am quite grateful for the art supplies the program provided. These works need to be displayed at an art exhibition, don't you think? I am looking for someone to finance this so I can get these noticed in a big city like Islamabad. There are a few people who are interested and I hope they can set this up for me.

Sadly, Arshad did not get his hopes fulfilled.

Amna and Firdous wanted children immediately. They shared that "…a home with a child would feel so lively and we would have a bigger purpose to fulfill." Similarly, Basit wanted to get over some of his SCI issues and add another child to his family.

Fareed wanted his condition to improve to the extent that he could earn a living for his family. He stated that while he misses driving, he hopes to set up a shop where he can sell items just as other PWDs (like Dildaar and Basit) have been able to do.

Muneeza wanted to find opportunities towards improving her condition such that she could eventually walk without crutches. She wanted to get an education and improve her and her family's socioeconomic status considerably. Alia wanted to also continue with her education and wanted to continue education beyond matriculation.

> I am not alone in this world; I have Allah and my family to help me through this. Though a wheelchair helps me move these days, I am going to get good education and a life that will be better than it is now. It is sometimes difficult to see friends jump around who I want to play with, but at least I can join them and have some fun.

The medical staff also wanted to expand their horizons. Both Farhan and Bakhtiar wanted to continue their graduate work and finish their Doctor in Physiotherapy degrees. Afridi wanted to continue working in the region and secure a part-time position in a local hospital. Usman, Javed and Tariq stated that they wanted to improve their job efficiencies such that the program itself can expand towards other regions in Kashmir such as Bagh, where SCI PWDs have been identified.

Conclusions

In this chapter, I have, using ANT-mobilities approach highlighted the various themes that emerged during my study and practices related to SCI in the CBR network. The participants in this study are involved actants in a network whose positioning, mobilities and relationalities amongst each other as well as non-human actors are not only complex, but also eye-opening in the various glimpses of their multiple enactments I have relayed here. What is singularly referred to as the management of SCI is not only depicted within existing practices, but I also found the limitations of the program in addressing social immobility and discrimination faced by the PWDs in a wider societal context.

Chapter 5

Formation of the Canadian CloudSat-CALIPSO Validation Project

Introduction

Climate change is a global crisis, which threatens to dramatically disrupt various cycles and adversely impact all life on the planet. Clouds play a key role in maintaining and facilitating many atmospheric processes on Earth. They are key actants for the regulation of water cycles, mobilizing and delivering water through precipitation. They are also responsible in maintaining radiation budgets. Earth's radiative balance is maintained by reflecting short wave radiation back into space, and through capturing longwave radiation back to the surface.

These feedback loops are currently not well understood; they and related mechanisms need further study towards comprehending our climate system (Stephens, 2005). Moreover, alongside such feedbacks, precipitation and related qualities of clouds are leading sources of uncertainties in climate models (Stephens and the CloudSat Science Team, 2002; IPCC, 2007). In the context of global climate change and resulting changes in weather patterns, cloud

dynamics need to be understood better, especially to improve cloud parameterization schemes and resulting accuracy of climate modeling efforts.

To examine clouds in greater detail, CloudSat, a Low Earth Orbiting (LEO) satellite was launched on April 28, 2006 by National Aeronautics and Space Agency (NASA), as part of the "A-train constellation." With a 94 GHz, near-nadir pointing, W-band Cloud Profiling Radar (CPR), the focus is on range resolved cloud and precipitation characteristics.

The *validation* of CPR's observations and products is a scientific endeavor taken on by the Canadian CloudSat-CALIPSO Validation Project (C3VP). I studied C3VP; itis primarily a collaboration between Environment and Climate Change Canada (ECCC) and NASA and most activities for validation were conducted in King City Radar facility which is located in Ontario, Canada.

In this chapter, I provide a historical account on the formation of C3VP through an evolution of various networks and mobilities. Beginning with the brief history of the Intergovernmental Panel of Climate Change (IPCC) and its role in establishing climate change a human induced phenomenon, I then outline the historiographies of various collaborating networks in NASA, Canadian Space Agency (CSA) and Environment and Climate Change Canada (ECCC) which led to the formation of C3VP. Next, I discuss the development of weather radar and the events which led to the formation of the present ground radar capabilities at ECCC and those developed for CloudSat. I then delve into the formation of C3VP, as well as various experiments and outputs which involves scientists, technologists, human weather observers inter-connected to a myriad of non-human actors, including NASA's CloudSat and CALIPSO satellites and the validating dual polarization King City Radar operated by Environment Canada.

A brief history of IPCC

In 1988, The United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) (Bolin, 2008) formed the Intergovernmental Panel on Climate Change. In 1990, The IPCC put out its First Assessment Report, which included the "Working Group I – Climate Change: The IPCC Scientific Assessment", "Working Group II – Climate Change: The IPCC Impacts Assessment", "Working Group III – Climate Change: The IPCC Response Strategies)" with supplementary releases in 1992. In 1995, the Second Assessment Report was released which led to the formation of the famous Kyoto Protocol in 1997, which was ratified in 2005. The Third Assessment Report was released in 2001 and the Fourth Assessment Report was published in 2007. The latest Assessment reports were released in 2013 and 2014.

The Working Group One (WG1) report, titled "Physical Science Basis of Climate Change," was released on 2nd February 2007, which detailed the scientific evidence for the current climate crises. Based upon extensive scientific research and peer review, one of its main conclusions is

> Warming of the climate is unequivocal, as is now is evident from observations of increases in global average air and ocean temperatures, widespread melting snow and ice, and rising global average sea level.
>
> (IPCC: Summary for Policymakers, 2007, p. 5)

The main reasons cited are the burning of fossil fuels and clearing of land for agriculture. The evidence is further solidified in the Fifth IPCC reports whereby results are reported at a higher certainty level—science is confirming these anthropogenic activities at a higher resolution. The resulting abnormal rise in temperature across the planet, also termed as "global warming," is contributing adversely to all the known natural cycles as a result.

Despite scientific advancements, clouds and aerosols continue to provide significant challenges in understanding a perturbed climate system. The latest IPCC WG1 reports indicate that,

> Both clouds and aerosols are a major source of uncertainties in the climate system. Clouds respond to climate forcing mechanisms in multiple ways and individual cloud feedbacks can be positive or negative. The representation of cloud processes in climate models has been recognised for decades as a continuing source of much of the uncertainty surrounding climate change.
>
> (Boucher et al, IPCC: WG1 Report, 2013, p. 5)

Various initiatives are underway in understanding cloud and aerosol dynamics including monitoring from space by satellites which provide observations globally. CloudSat and CALIPSO satellites are one of the first space dedicated missions to study clouds and aerosols from space, especially in the context of climate change. In the next section I will detail the historical background, formation and mobilities of actors and networks which led to the launch and operation of the CloudSat mission.

The NASA EOS program: Climate vs. Weather dynamic

The CloudSat mission is a part of the Earth Observation Science (EOS) program whose legacy is the NASA's Meteorology Program that started in 1960. As the phenomenon of climate change became more evident, the EOS was substantiated. According to Conway (2008),

> NASA's part of this effort was the formulation of a space-based research infrastructure for studying global climate processes, drawing on its expertise in remote sensing and planetary studies. It commissioned its first study of what a comprehensive climate observing system should include in 1979; it launched the first piece of hardware for its Earth Observing System (EOS) in 1999, twenty years later.
>
> (p. 156)

EOS is comprised of a series of coordinated satellites designed to monitor and understand key components of the climate system and their interactions through long-term global observations. The EOS mission focuses on the following climate science areas: radiation, clouds, water vapor, and precipitation; the oceans; greenhouse gases; land-surface hydrology and ecosystem processes; glaciers, sea ice, and ice sheets; ozone and stratospheric chemistry; and natural and anthropogenic aerosols.

Towards studying clouds and aerosols, CloudSat and CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) were designed as complementary missions. Both these missions were selected in 1998 under competitive bids for opportunities released by the NASA's Earth System Science Pathfinder program (ESSP). This program is managed by NASA's Science Mission Directorate, and sponsors missions which support Earth science research. Both CloudSat and CALIPSO fit the requirements to address clouds and aerosols exclusively in a highly focused scientific manner in providing vertical profiles of clouds and aerosols which was unprecedented.

Given the bipartisan division on climate change as real, funding was allocated to the EOS but also cut, since its inception. With Republicans in the White House, these cuts have been significant. NASA has had to adapt to these pressures by declaring certain missions as related to "weather" as compared to "climate change" in order to secure approval for funding. An example of this strategizing is the Tropical Rainfall Measurement Mission (TRMM) which was motivated as entirely a weather based satellite as compared to CloudSat which was motivated by studying clouds towards understanding climate change. The latter mission hence faced challenges from administrations of both George Bush Jr. and George Bush Sr., while most of its funding was secured during the intermediate Bill Clinton terms in office.

The Canadian Space Agency: Key Supporting Network for NASA satellite programs

The Canadian program in upper atmosphere and space has its beginning around the end of Second World War. For defense purposes, Canada undertook several small launcher and satellite related projects between 1945 and 1960. This included the development of the Black Brant rocket in a series of advanced studies which also involved studies in orbital dynamics. Headed by the Canadian Defense Research Telecommunications Establishment (DRTE), this lead to the S-27 project (later known as the "Topsider Project"). A key outcome of this was the development of the first Canadian satellite named “Alouette 1.” Canada became the third country in the world at the time to launch a satellite into space with the support of NASA, when the satellite was launched in September 1962. The main area of research done with this satellite was ionospheric studies and the mission lasted for 10 years, instead of a one year expected life span. This led to further collaboration on the International Satellites for Ionospheric Studies (ISIS) series of satellite missions with the US which started in 1993. In 1999, CSA helped with the Fine Error Sensor in the Far Ultraviolet Spectroscopic Explorer (FUSE) satellite, an astronomy-research based mission. That same year, the Space Science Division funded and developed the MOPITT (Measurements of Pollution in the Troposphere) sensor which was launched by NASA in their Terra satellite which is still in orbit. It also marked a key collaboration with NASA that continues to this day.

Environment and Climate Change Canada (ECCC): Continuing Collaborations with the US

Based on the legal incorporation as the “Department of the Environment” under a 1985 Act, the ECCC is a Government of Canada organization. It shares various responsibilities

between the federal and provincial governments. It was formerly named as Environment Canada and this was changed recently by the Justin Trudeau government in November 2015 to including "Climate Change" in its title signifying an explicit acknowledgement of climate change being a real issue.

The ECCC involvement and collaboration with NASA via the C3VP project is based in its "Atmospheric and Climate Science" under the Science and Technology Branch. This is not the only ongoing collaboration with the US. It has a history of productive collaborations with the US, which includes an International Joint Commission (IJC) cooperation which was established as part of the 1909 Boundary Waters Treaty. This was enacted in order to resolve differences and promote international cooperation. Another such cooperation is the 1972 Great Lakes Water Quality Agreement which has led to joint control over trans-border water pollution, with ECCC playing a key role in monitoring the situation.

With scientists on both sides observing and establishing the "acid rain" effect caused by US industrial air pollution, the Brian Mulroney government pressed the Reagan administration for a treaty in 1986. Initially this was met with resistance by the US, however, given the scientific evidence an "Acid Rain Treaty" was agreed upon. The result was the ratification the Air Quality Agreement of 1991 by the first Bush administration. Under this treaty, the two governments consult semi-annually on trans-border air pollution. This has led to reduced acid rain and given these successes, in 2000 an annex dealing with ground level ozone was also added to this treaty. This collaboration was facilitated and operationalized by the ECCC. Trans-border air pollution remains a problem especially during summer due to coal-fired power stations, with a majority in the Midwestern United States.

Another key area of collaboration is during the creation of North American Free Trade Agreement (NAFTA), Canada, Mexico and the U.S. ratified the North American Agreement on

Environmental Cooperation. This created the Commission for Environmental Cooperation which monitors environmental issues across North America. The North American Environmental Atlas is one key publication as one part of the joint monitoring duties.

Presently neither Canada nor the US support the Kyoto Protocol, which set out time scheduled reduction of greenhouse gas emissions to reduce climate change. However, Canada has ratified the agreement, however due to political divides on the issue, the government does not enforce the Kyoto Protocol. This has received criticism from environmental groups and from other governments following substantive plans to reduce greenhouse gas emissions. In January 2011, under the Stephen Harper government, the Canadian minister of the environment at the time, Peter Kent, explicitly stated that the policy is to wait for the United States to act first, and then try to blend with their approaches. After the shift in government in 2015, in April 22, 2016, Prime Minister Justin Trudeau signed the Paris agreement on climate change during a ceremony at the United Nations in New York City, thereby committing Canada to utilize renewable energy as a way of reducing greenhouse gas emissions.

NASA, Canadian Space Agency, Environment Canada: Mobilization of networks

In 1998, Dr. Graeme Stephens of Colorado State University, began an initiative for CloudSat as Principal Investigator (PI) which was housed in NASA's Earth System Science Pathfinder (ESSP) program (Walter et al, 1998), which was part of the broader Earth Observing System (EOS) started in the 1980s.

The NASA Jet Propulsion Lab (JPL) and Ball Aerospace along with support from US Air Force and US Department of Energy were tasked with building the satellite, while Colorado

State University provided scientific guidance. Funding cuts to the EOS program began in mid- to late-1990s during the George Bush Sr. era, which led to the mobilization by Dr. Stephens and the NASA EOS to seek financial, scientific and technical support from the Canadian Space Agency (CSA) and (then named) Environment Canada (EC). This coordination led to the formation of a collaboration between NASA Jet Propulsion Lab, CSA and PI Graeme Stephens' team in February 1998. This partnership led to a support via funding of the development of the Cloud Profiling Radar by the CSA (see Figure 5.1 for details) which was crucial for the overall success of the mission. The Atmospheric Environment Service (AES) of Environment Canada followed suit later in August 1998 and three scientists were assigned by Prof. Gordon McBean, who was Assistant Deputy Minister and heading AES at this time. The diagram shows the technological and hardware contributions from both NASA and CSA teams for the building of the satellite. This diagram shows both the front-end electronics and the Cloud Profiling Radar (CPR) which is the only instrument on board. Besides developing these non-human actors by the CSA, Canadian scientific co-investigators were also brought into this collaborative effort mainly via the C3VP. The overall cost of the CloudSat mission is estimated at USD 185 million of which 15 million of which was provided through the development of CPR by the Canadian Space Agency. This radar is the main instrument onboard the satellite performing measurements on clouds.

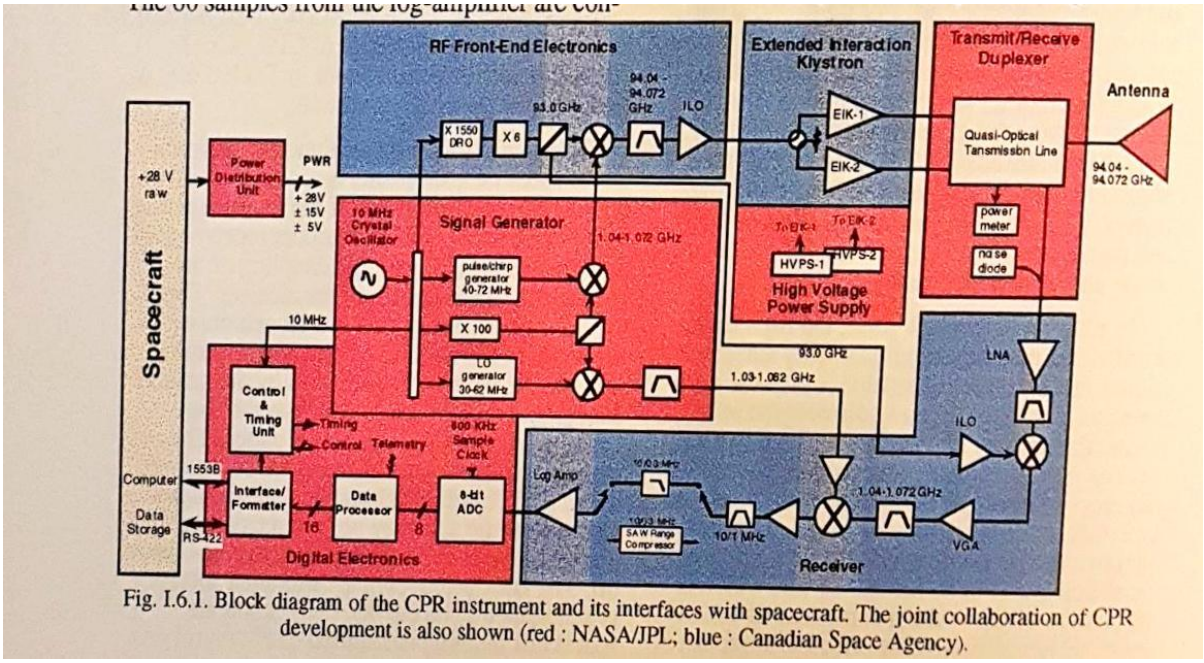


Fig. I.6.1. Block diagram of the CPR instrument and its interfaces with spacecraft. The joint collaboration of CPR development is also shown (red : NASA/JPL; blue : Canadian Space Agency).

Figure 5.1: Division of development of various components between NASA Jet Propulsion Lab (JPL) (red) and Canadian Space Agency (CSA) (blue). The Cloud Profiling Radar (CPR) and front-end electronics were developed by CSA.

Launch of the CloudSat and CALIPSO satellites

While the CloudSat project was originally planned to launch in 2003 (Walter et al, 1998), technical, funding and a worker strike in 2005 by Boeing employees delayed its launch until 2006. The launch was conducted on April 28, 2006 using a Delta II rocket, which also carried the CALIPSO satellite. It released them into the A-train constellation orbit around earth in a two-

stage process as depicted in Figures 5.2 and 5.3.

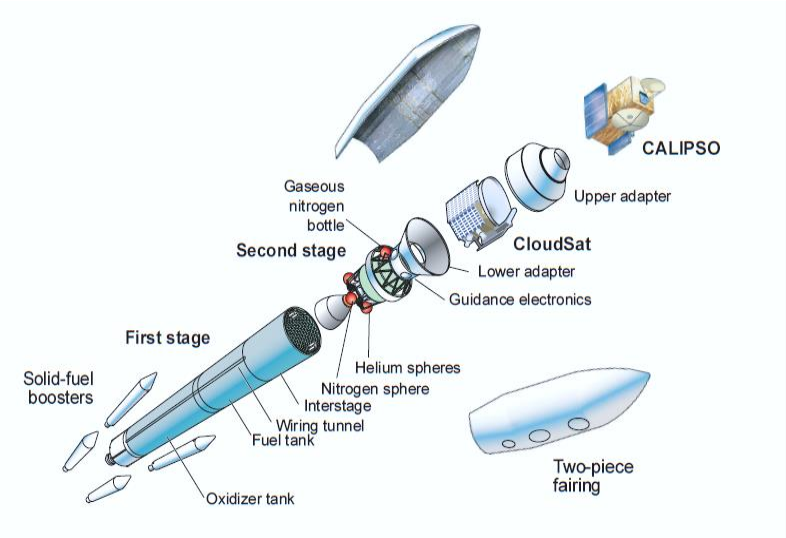


Figure 5.2: The two-stage Delta-II rocket carrying the CloudSat and CALIPSO satellites for launch into a stable orbit.

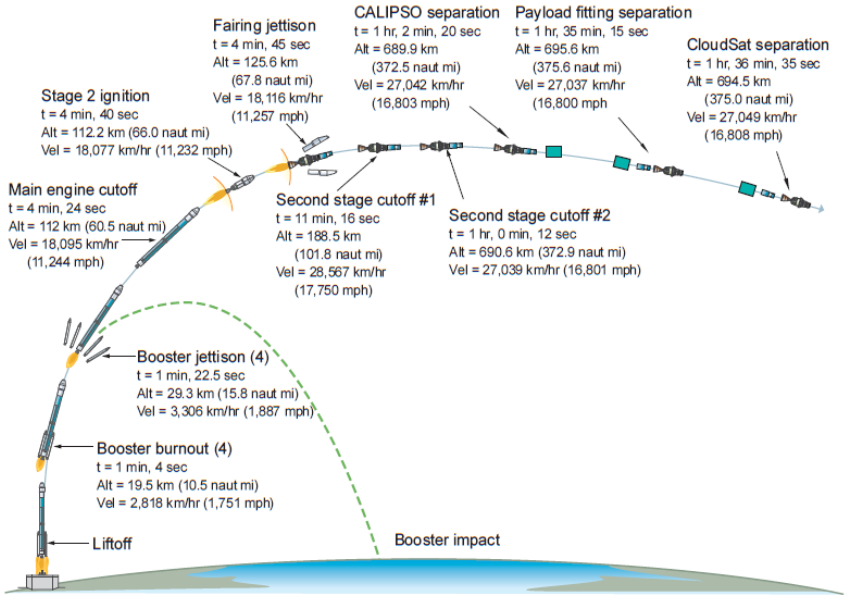


Figure 5.3: Key steps and stages involved at planned times and location for the launch of both CloudSat and CALIPSO satellites

Weather Radar: Some Basics

The term “Radar” is shorthand for “Radio Detection and Ranging”. The instrument Radar is termed as a key technological innovation, with applications ranging from military defenses to weather observations (Buderi, 1996). As the shorthand implies, the radar has its “…roots in the radio” (Reinhert, 1996). The stabilization of radio as a technology in 1892 by Marco Moriconi led into various events and mobilizations in the development of the radar (Buderi, 1996), and this instrument was extensively used in various major wars for early detection of aircraft.

In Canada, weather radars and their development started after the Second World War. Major developments were done in "Project Stormy Weather" and McGill University became a key network in this regard. The resulting Canadian National Radar Program (NRP) has evolved and by 1997 had 19 radars installed (Paul & Lapczak, 2002) which increased to 31 by 2004 with major upgrades in technology. This included the installation of the King City Radar facility which hosts a dual polarization Doppler radar. In February 2017, the ECCC, announced the contract with Selex ES to buy 20 additional radars at the cost of $83-million. These are expected to have the latest technology to date and to enhance present coverage of the NRP.

Weather Doppler Radars

Typically, radar consists of four components. These are a transmitter, antenna, receiver and a display system. The transmitter is used for producing a high-frequency signal which is sent out using an antenna. Then, upon getting scattered from solid object, the receiver picks up this signal, amplifies it and gives the output on a display system. Noting the time-of-flight from this radar leads to the distance of the scattering object. The radar sends electromagnetic pulses which are partly reflected back, having receiving energies and certain other qualities from encountering objects.

Weather radars measure raindrops and snow (also termed “hydrometeors”) are distinct in that they are designed for meteorological objects such as rain. Doppler radars, a sub-type of weather radars is commonly used in weather applications. They were first devised in 1953 by Ian Browne and Peter Barratt to demonstrate the use of Doppler techniques to calculate motion of a vertical rain shower. They are a technological advancement which not only allows radar ranging, but also provides quantitative aspects of movement of hydrometeors. Figure 5.4 illustrates this principle in some detail.

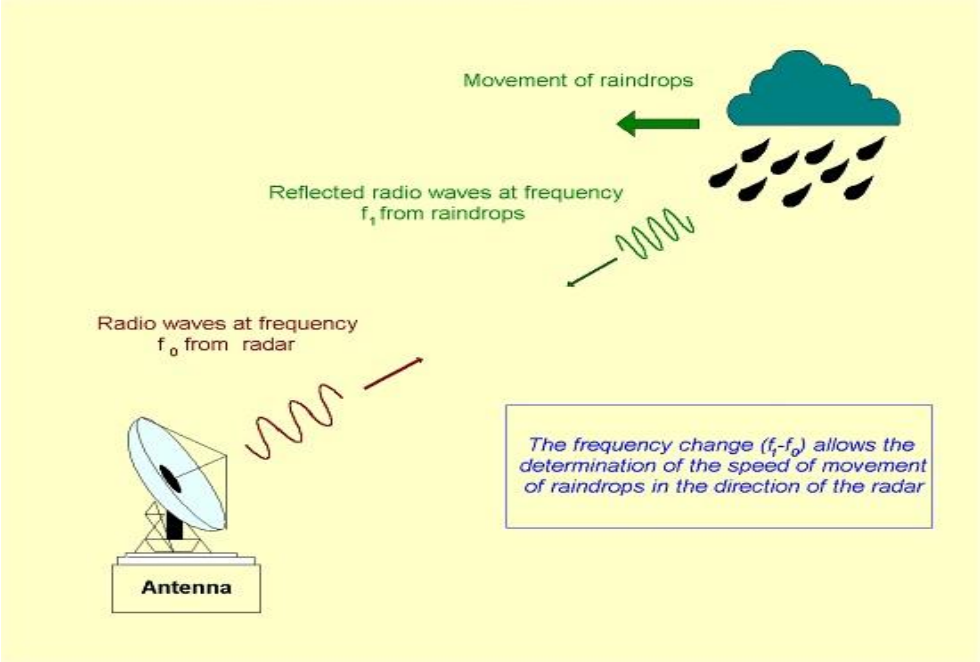


Figure 5.4: Doppler radar and its application for precipitation processes

Dual-Polarization Doppler Radar

A scattered polarized light wave (see Figure 2) has components at both horizontal and vertical polarization. Detection capability of such polarizations is possible with dual polarization radar. The King City Radar facility is a dual polarization or a polarimetric Doppler radar. Conventional Doppler radars emit and receive horizontal pulses of energy which provides a one-

dimensional view. While the detection of precipitation is possible with this type of technology, , the *type* of precipitation such as snow, rain or ice pellets is not. Dual Polarization radars (see Figure 5.4) are able to identify different types of precipitation, as well as other species present in the atmosphere. This type of capacity is thus a significant improvement in meteorological observations and related forecasts.

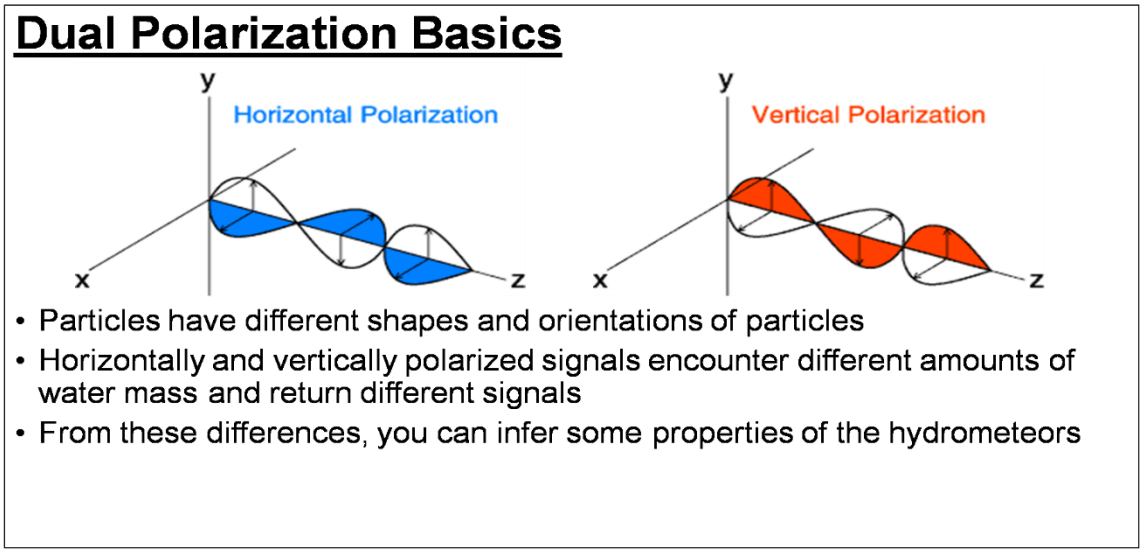


Figure 5.5: Dual polarization radar waves and their utility in meteorological applications

King City C-Band Dual Polarization Radar

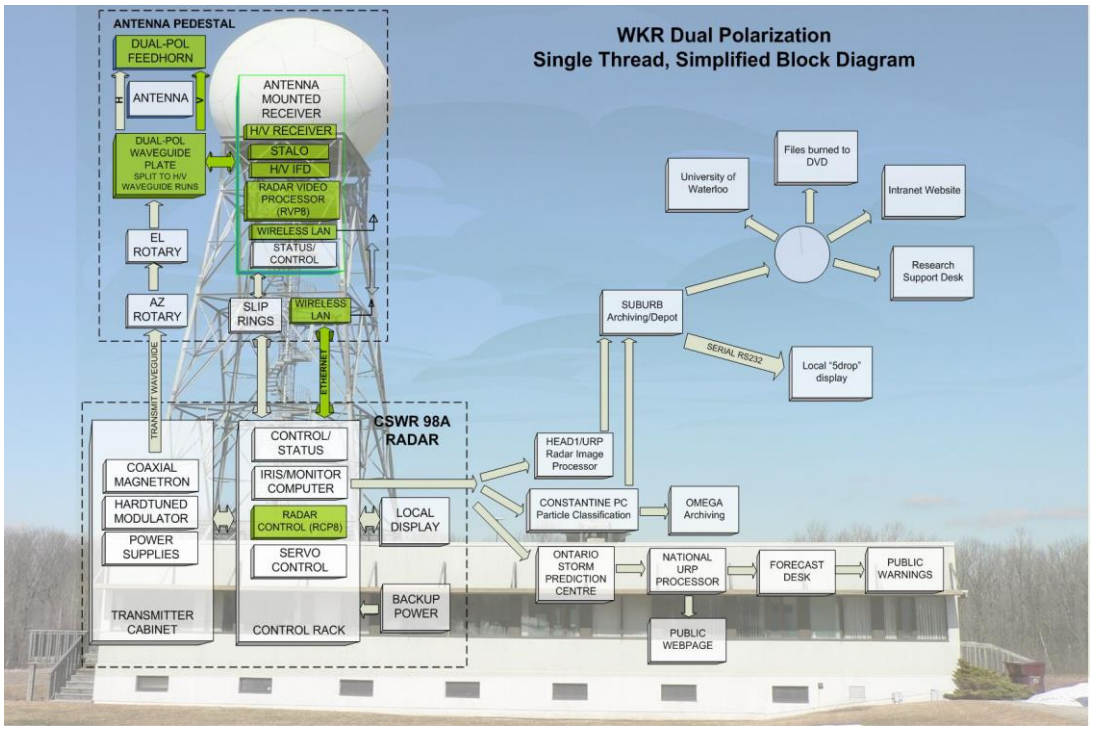


Figure 5.6: A block diagram showing schematic operational organization and data flows within the King City Radar. The various blocks represent observation from radar hardware (top left) to power supply and processing output (bottom left) which is then related to various organizations ranging from Ontario Storm Prediction Center to the public.

The King City Weather Radar facility is situated just north of Toronto and is used for research and operational activities. Operated under Environment Canada, the station collects data to fulfill those observational requirements, which are utilized by various networks. It is a frontrunner regarding ground-based meteorology in Canada, as it is geared "…to providing national leadership on radar meteorology research applications" (Environment Canada, 2008). Within the weather observational framework, the Dual-Polarization C-Band collects data for the Golden Horseshoe and the Greater Toronto Area. This data is typically used for weather reporting and forecasts.

The Cloud Physics and Severe Weather Research Section of EC operates the dual polarization radar to collect data for research and related applications. Current research projects include the C3VP initiative, quantitative precipitation estimation, winter precipitation, detection and short-term forecasting of high-impact weather events and classification of type of precipitate.

The Canadian Radar Network

The King City Radar facility is part of the 31 C-Band Doppler Radar Network (See Fig. 5 below) deployed by Environment Canada (EC) network across Southern Canada (see Barker et al 2008 for operational details). Networked C-band radars operate on a ten-minute scan cycle, with volume scans of reflectivity obtained on 24 tilt angles. This is within a range of 256 km with 1 km resolution as gate spacing.

Such tilt angles can be put together to produce vertical cross sections within the coverage area. Four Doppler scans are done additionally from tilt angles of 0.2 to 3.5 degrees, within a range of 113 km and at a 0.5 km resolution.

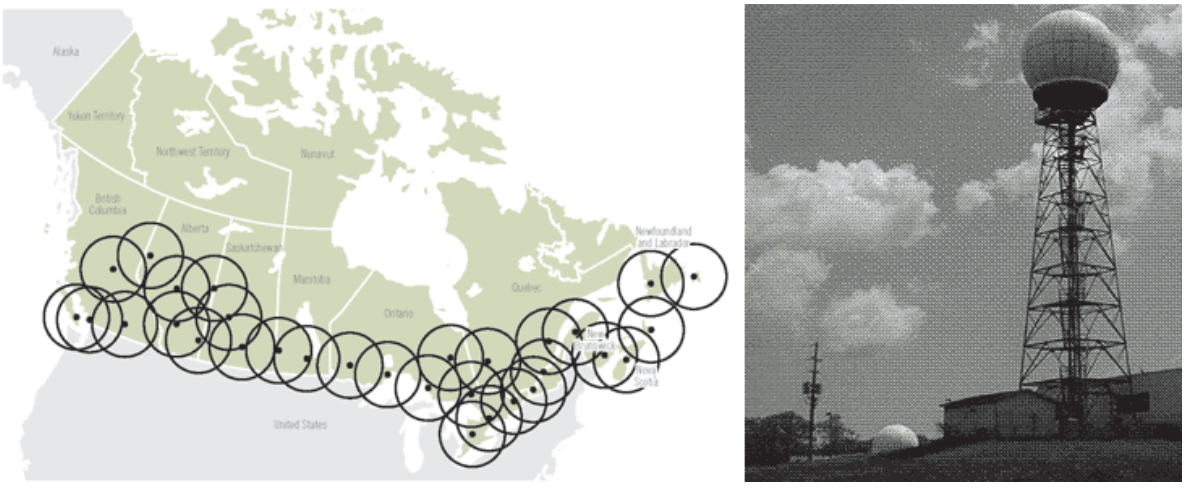


Figure 5.7: Left: The 31 Canadian C-Band Radar network. Right: The King City Radar

In relation to the C3VP, the A-train constellation satellites overpasses happen over only a few radars in this network because of the narrow CPR swath and CloudSat's return cycle of 16 days. Typically, it is estimated that there are four ascending and descending overpasses per day over at least one of the EC Radar network.

The A-train: An alignment of mobilized transecting observational networks

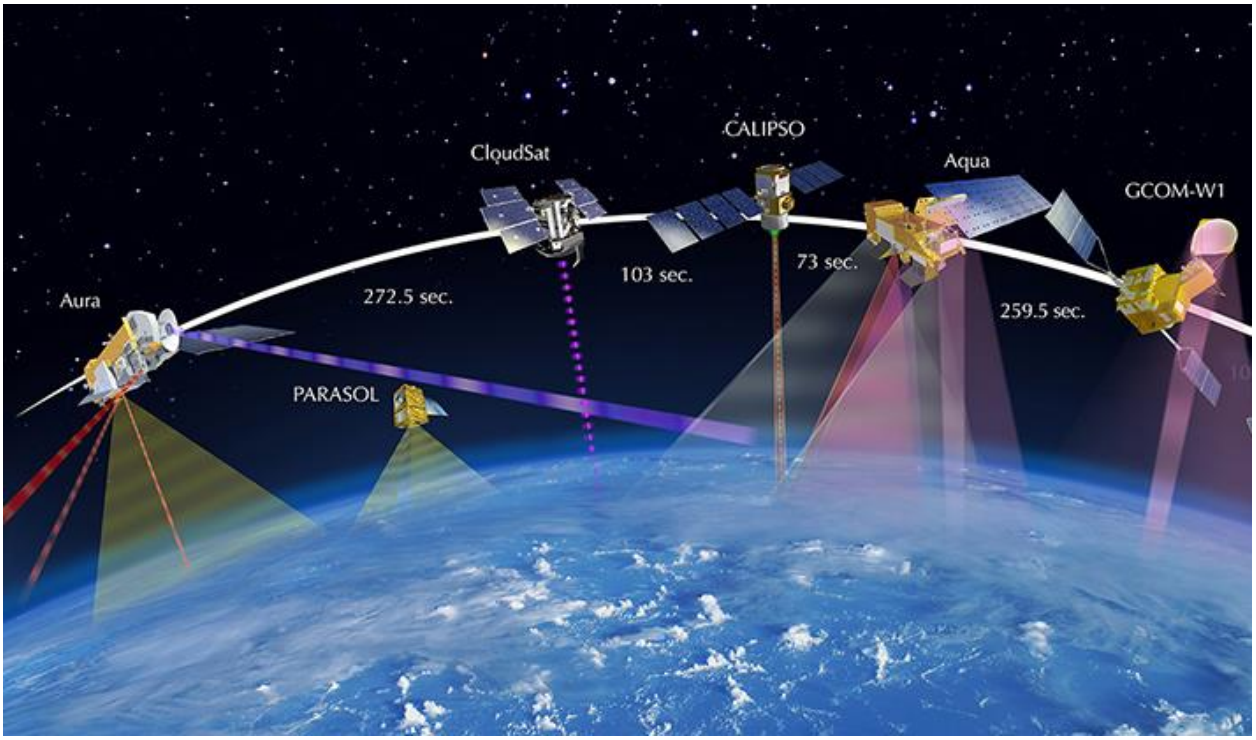


Figure 5.8: The five A-train constellation satellites with lag times between each instrument (PARASOL used to be on this track but lowered in 2009 below this track and CloudSat was also lowered due to technical issues in early 2018)

The "A-train" constellation consists of five operational satellites with a sun-synchronous track. These satellites are flying in tandem and mobilized on one track like a train, hence they are termed as the "A-train constellation." Another term used for such a type of constellation flying is

also “formation flying”. This set of satellites crosses the equator around 1:30 p.m. local solar time. Since these cross the equator in the afternoon (and in the night around 1:30 am), they are termed an Afternoon constellation. With an orbit period of 99 minutes, a ground track is repeated every 16 days.

The leading satellite is the GCOM-W1, followed by Aqua, CALIPSO, CloudSat and finally Aura. The time difference between the leading satellite and the last is about 15 minutes. In the context of C3VP, the difference between CALIPSO and CloudSat is roughly 20 seconds, which also means that observations on clouds and aerosols from both of these different instruments can be collocated.

This mobilization in a constellation form allows the instruments on all the A-Train satellites to function as if they were on a large platform together. This synchronicity means that scientists can use instruments on several different satellites in the constellation to study particular atmospheric phenomena of interest—e.g., clouds, aerosols, greenhouse gases—and learn more than they could have with any one satellite by itself.

Combining data from these different satellites enables scientists to gain a better understanding of a variety of Earth-system processes, including processes relevant to climate. Data collected synchronously gives more-complete answers to important scientific questions than would be possible with satellite data collected at different times. CloudSat has remained in the A-train till recently when it was lowered due to technical issues in February 2018.

CloudSat: Observing vertical structure of clouds in the context of climate

Amongst the five operational satellites in the A-train constellation, CloudSat started observing in June 2006, (Stephens et al., 2008) with its Cloud Profiling Radar as the only instrument onboard. Originally planned with a 22-month mission lifetime, CloudSat has far

exceeded its goals establishing satellite based cloud climatology for over a decade, though not without some technical problems. In April 2011, the battery for providing enough current to power spacecraft systems started to malfunction, especially during part of its orbit which on the dark side of the globe when solar panels are not illuminated. To remedy this situation, Ball Aerospace engineers developed a mode that enabled during the sunlit part of each orbit by the satellite. More recently, due to the damage of one of its reaction wheels, which control its orientation in orbit, the satellite was lowered away from the A-train constellation.

The instrument is still delivering and has established the first survey of cloud profiles globally. These measurements also include cloud physical properties that are sensitive to seasonal and geographical variations. This instrument was ultimately needed to evaluate the way clouds are parameterized in global models. Hence, these measurements are meant to improve predictions of weather, climate and the cloud-climate feedback problem (Stephens et al, 2008) and data pertaining to these issues is collected for over a decade. The instrument provides measurements which are one-of-a-kind vertical structure of clouds. Further, precipitation is also detected from space through the 94 GHz radar reflectivity measurements. These measurements are enhanced through the mobilization of data within this network using a combination of observations from other satellites in the A-Train.

Broadly speaking, the science objectives of the CloudSat mission are:

- Evaluating the cloud representation in weather and climate prediction models.
- Evaluating relationships between radiative properties of clouds in relation to liquid water and ice content
- Evaluating properties retrieved using existing satellite measurements and towards promoting development of new remote sensing methods for observing clouds.

- Contributing towards investigations of indirect effect of aerosols on clouds by exploring the effect of aerosols on cloud formation.

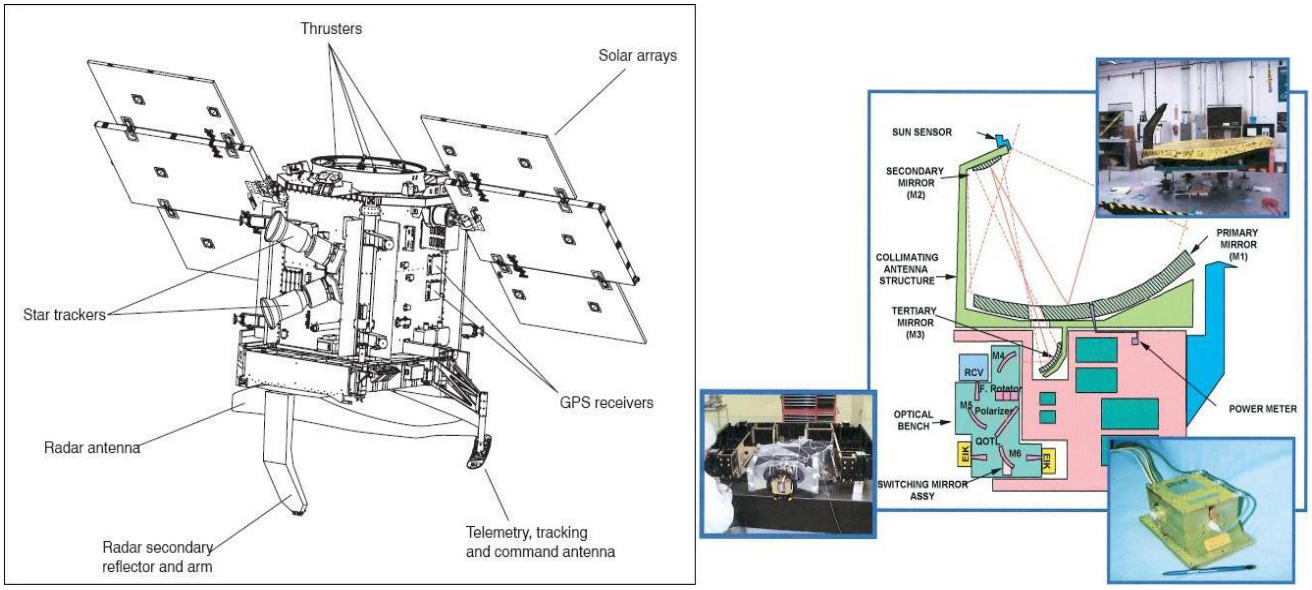


Figure 5.9: (Left) CloudSat satellite instrumentation. (Right) On-board schematic diagram of Cloud Profiling Radar (CPR)

METAR Observations

Human weather observations are taken by trained experts at airports or permanent weather observation stations. These are usually in the Meteorological Aerodrome Report (METAR) format. METAR is a format for reporting weather information, which is used by pilots predominantly, but this information is also used by research weather stations such as the King City radar facility. The former use it as a means to plan and discuss a pre-flight weather meeting, while the latter use it in weather forecasting.

The METAR format was introduced internationally on the 1st of January 1968 and has been modified a number of times since. North American countries continued to use a Surface

Aviation Observation (SAO) for current weather conditions until 1996, when this report was replaced with an approved variant of the METAR agreed upon in a 1989 Geneva agreement. The World Meteorological Organization's (WMO) publication No. 782 "Aerodrome Reports and Forecasts" contains the base METAR code as adopted by the WMO member countries. METAR is a standardized code recognized by the International Civil Aviation Organization (ICAO). It is the most frequently used format in the world for the transmission of weather data, and in particular, North America. The standardization helps in the translation of the reports across the globe, making it an “immutable mobile” (Latour, 2005).

Weather observation sites generate findings and reports every 60 or 90 minutes. A special (SPECI) report may be issued if the conditions are out of the ordinary. These observations are also encoded by automated airport weather stations, which can be at airports, military bases, and other sites. Some observation sites use a combination of digital sensors which encode via software. These are then checked and reviewed by certified observers before being transmitted. Observations taken by trained weather observers also happen. Typically, they observe manually and encode their observations prior to relaying it to wider networks.

Station Name and ID	Distance from King City Radar (km)
Borden – CYBN	43.5
Eliot Lake Municipal Airport – CYEL	354.3
Kingston Airport – CYGK	238.7
Hamilton Airport – CYHM	93.73
Buttonville Municipal Airport –CYKZ	19.50

Windsor Airport – CYQG	332.3
Niagara District Airport - CYSN	91.13
Trenton – CYTR	163
Wiarton Airport – CYVV	149.8
Petawawa Airport – CYWA	280.8
London Airport – CYXU	164.6
Toronto Airport – CYYZ	31.96
	Totals

Table 5.1: A list of METAR observation locations, distance from the King radar, the number of observations of the Environment Canada observing weather station used in the thesis study.

The C3VP Project

To validate CloudSat and CALIPSO satellite products, a field campaign in the Great Lakes area of North America, termed the Canadian CloudSat-CALIPSO Validation Project (C3VP) deployed aircraft, surface, and radar observations towards independent validation of space borne observations from January to March 2007. The campaign took place near the Centre for Atmospheric Research Experiments (CARE) run by the Meteorological Service of Canada in ECCC. Studies that focused primarily on physical validation studies from C3VP were 27 in number in peer-reviewed journals to this date, making it a highly productive experiment with respect to contributions to the scientific community. Overall, three key experiments have been carried out in partnership with various universities and research organizations across collaborative networks including McGill University, Colorado State University and University of Massachusetts including the NASA Global Precipitation Mission (GPM) team. The latter became

a key partnership as the GPM Project and the Precipitation Measurement Mission (PMM) Science Team participated in C3VP as well as the The Light Precipitation Validation Experiment (LPWEx) held in Helsinki, Finland in 2010. This further led to The GPM Cold Season Precipitation Experiment (GCPEx) in 2012 prior to launch of the GPM satellite in 2014. Later, in 2016, the OLYMPEX experiment was conducted for validation of GPM satellite observations. The collaboration of ECCC with the NASA GPM team continues to this day and C3VP was indeed a key meeting point for both teams.

One of the scientific objectives of observing precipitation in the C3VP was to advance better simulations in the winter season and mixed-phase cloud systems for the development of high-latitude and mid-latitude remote sensing products.

There are two aspects of the validation process. The first is called ground truth (GT) aspect which deals with the independent verification of the products from the algorithms. This activity assumes there is more confidence in the ground measurements than in the product being validated. The measurements in the C3VP were envisaged to be analyzed on a statistical basis to identify egregious errors in the products, both random and systematic, and set the meteorological context of the observations.

GT was also planned to be used to assess the overall uncertainty of effects not directly measurable but that affect the retrievals. The second aspect, physical validation (PV), is concerned with verification of the physical basis of the algorithms. In this case, testable assumptions in the forward model of the individual algorithms were examined. Specifically, the C3VP activities in the overall validation were planned to involve:

1) Assessment of random errors, biases, a priori errors, and measurement errors and their effects on the final derived products

2) Identification of conditions under which the retrieval algorithms do not work

3) Testing of steps in the retrieval algorithms

4) Refinement or development of new retrieval algorithms.

In the C3VP Science Plan (2005, p.5) it is noted that

> When validating satellite measurements and the resultant data products from ground-based or aircraft platforms, there are a number of complicating factors. For instance, ground-based remote sensing equipment, such as radar or lidars, are below cloud looking up, but corresponding satellite sensors are above clouds looking down. Signal attenuation by atmospheric constituents needs to be explicitly taken into account. Also, the vertical resolution and horizontal footprint size of data will be unique for each instrument. This is not only a factor in comparing ground-based and satellite data but also radar and lidar data from a common perspective. For aircraft measurements, huge sampling volume discrepancies with remotely sensed data (e.g. 8 orders of magnitude) need to be accounted for.

The main sources of error that require consideration are, retrieval algorithm errors, precision of measurements, sample volume mismatch, space/time offset in the measurements, and representativeness of measurements. A key aspect in the error analysis employed in the C3VP experiments is "their relative importance, and whether they are dominated by a random or systematic component, needs to be determined" (C3VP Science Plan, 2005).

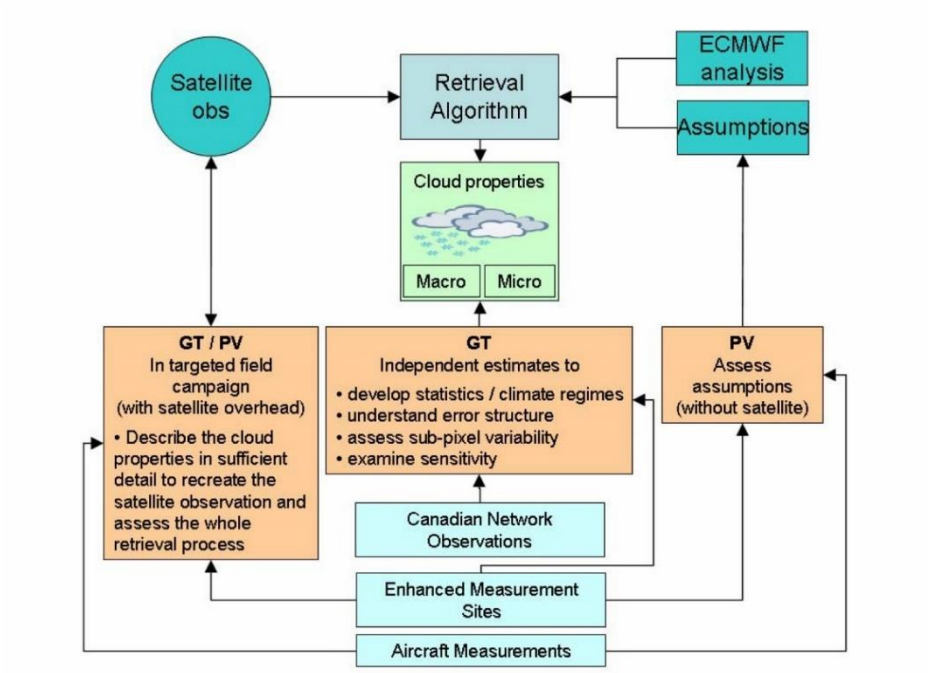
Types of C3VP studies conducted

The planned C3VP data collection strategy involved three types of observational studies in order to achieve project objectives (Barker et al, 2004). These consisted of

1) surface MSC network observations (radar and surface measurements)
2) enhanced measurement sites (EMS) with advanced surface and remote sensing instrumentation
3) targeted field campaigns involving cloud physics research aircraft

Basic field experiments were carried in early 2007 at the CARE site (see Figure 5.10) while aircraft studies were also carried out (see Figure 5.11). In the next phase, long term

measurements from the network and EMS, which include human observations were used in GT



A summary of the validation strategy for C3VP incorporating ground truth (GT) and physical validation (PV).

Figure 5.10: A summary of the validation strategy for C3VP incorporating ground truth (GT) and physical validation (PV)

studies to develop cloud statistics, understand measurement error structure, assess sub-pixel variability and sensitivity issues, and describe various climate regimes. The EMS and research aircraft measurements were used to evaluate the algorithm retrieval assumptions.

Figure 5.11: The Centre for Atmospheric Research Experiments (CARE) site for C3VP experiments

Figure 5.12: Instruments aboard and outside the NRC Convair-580 Research Aircraft for C3VP

Mapping the Ground Radar Validation

As part of the C3VP program stated above, a statistical validation approach using ground-based observations was envisaged using the network of C-band radars in the Canadian environment. A study of such validation efforts was conducted by scientists at the King City Radar facility. It focused on a winter season (from September 2006 to April 2007) with 1456 profiles analyzed using the King City Dual-Polarization Radar as a frame of reference for the validation of the CloudSat precipitation occurrence product. For this limited data set, the results of this study were that the CloudSat precipitation product for winter precipitation performed well with a 94.7% probability of detection, critical success index of 88.6% and a false alarm ratio of 6.7% (with a positive bias of 2%).

Using a similar approach, the aim of my collaboration in C3VP was to provide a long-term analysis of the data taken by CloudSat from 2006 to 2010, using the same radar facility as a reference. A prior study was conducted by the C3VP group which involved extensive manual quality control of the ground-based radar precipitation product prior to its comparison with the CloudSat product and only one winter season was considered.

In the study to be detailed in this thesis, this process was automated and generalized in order to derive more extensive statistics considering year-round precipitation over a five-year period. In addition, a second method of validation is also conducted using automated and trained human observations from METAR reports taken from various weather observing stations within the Environment Canada network. The scientific aims of this collaborative addressed issues such as the dependency of ground-based radar range on the accuracy of validating precipitation measurements. It will also serve as a point of comparison of precipitation measurements between the instantaneous point measurements of the CloudSat CPR satellite sensor (a narrow swath ~1.4

km) with the subjective, larger area perspective of a manual observation by a trained weather observer.

Conclusions

The C3VP collaborative network involves local and international collaboration which was formed due to various historical ruptures, including the substantiation of climate change and its causes. This scientific network, formed primarily through the mobilization of networks resulted in productive collaboration between NASA CloudSat team and Environment Canada. It has moved towards conducting research studies related to satellite retrievals and validation of these products, and has further extended to other ongoing satellite based precipitation missions like the GPM. Assembling instruments and related scientific and technical staff, there were three types of validation experiments which were based on both ground and aircraft based observations. Having different objectives, in particular, I provide details of the ground radar based validation which also includes human observations which are mobilized alongside the C-Band Radar data from the King City as well. CloudSat's precipitation occurrence algorithm is validated from these established networks. The details of these collaborative practices are presented in the next chapter. This includes the scientists, technicians and observers as key actants which mobilized C3VP towards meeting its scientific objectives and outcomes.

Chapter 6

Practices in assembling validation of CloudSat observations

Introduction

The interactivity between human and non-human actors in a particular scientific effort for validation studies of CloudSat mission is detailed in this chapter. Various actants, mobilities and processes are outlined in the network, which lead to scientific results. To tell my story of how atmospheric science is enacted with at least some degree of precision, I have been compelled to describe a wide terrain, that describes the network and its formation (see Chapter 5), that describes the instruments used and the measurements that are taken and interpreted and mathematically manipulated and analyzed and digitized and interpreted again and again. At times these details might be too specific, but I attempt to provide enough detail so that the reader can begin to see the complexity and expansiveness involved in this case of an enactment of cloud science. Some parts may be scanned.

As documented in the previous chapter, the Canadian CALIPSO CloudSat Validation Project (C3VP) was assembled to conduct studies which validate the data products related to CloudSat and CALIPSO satellites. This type of research work involves a positioning of various ground instruments within the swath of particular satellite observables. This instrumentation includes in-situ and remote sensing measurements from both ground-based and airborne platforms. Many processes are needed to validate the satellite products with other instruments, once observations are made and properly aligned. In this chapter, I aim to describe such processes in the context of the scientists involved in the C3VP project. It will involve a comparison of the CloudSat measurements of the occurrence of precipitation and cloud types in relation to the Environment and Climate Change Canada (ECCC) King City Radar and human weather observations. As part of this scientific study, I first begin with an account as to how I am enrolled in this scientific project and ultimately in this study

Clouds and then Cloud Physics

I am quite fascinated by clouds and precipitation, especially since I am from Karachi, Pakistan, a city which experiences an annual monsoon season. This was turned into an even deeper curiosity after having studied physics and noting that reports from the Intergovernmental Panel for Climate Change (IPCC), state~~s~~ explicitly that clouds and aerosols are one of the leading sources of uncertainty (IPCC, 2007a, 2007b).

When the earthquake rehabilitation work subsided somewhat in 2007, I took a break and began a PhD in Education at Western in August of that year ~~and then~~ I approached Environment Canada where I met Sebastian who was heading the C3VP project at the time. Without much initial in-depth knowledge of the subject, I worked with him and Larry in subsequent years. We were able to identify a research problem which would also be used to portray how CloudSat, a

satellite dedicated to the study of climate, is being studied by the C3VP group. To begin highlighting this process, I first present brief profiles of the main scientists involved in the study.

Brief introduction of human actants

Dr. Sebastian

Sebastian is a research scientist under the Cloud Physics and Severe Weather Section in Environment Canada. His current focus is the use of weather radar and high-impact weather forecasting and climate studies. He holds a PhD in Physics from the Atmospheric Group at the University of Toronto and has passed an internal course in Environment Canada on weather forecasting. He is also a certified consulting meteorologist for the American Meteorological Society and is a member of the Committee of Meteorology and Oceanography. He is primarily an expert on ground and space-based weather radars having conducted many research studies using these instruments.

Larry

Larry is a Physical Scientist Level 2, and is a Weather Radar Applications scientist. His expertise is data mining, handling data and assembling various work efforts within the King City Radar and Environment Canada network. He works both individually as well as in a team especially in the deployment of ground instruments including smaller portable ground radars. He holds a bachelor's degree in Earth Sciences with Mathematics as a double major from York University.

Martin

Martin is a weather radar research technologist. On-site he is responsible for the maintenance and upkeep of the C-Band radar and other instruments, dealing with contractors and other infrastructure. He went to a trade college where he took a course in Electronic Engineering Technology. He was a lead technician in the dual polarization radar upgrade of the King City radar in 2004 along a team of other technicians and engineers.

Brian

As part of a dwindling manual weather observation team at Environment and Climate Change Canada (ECCC), Brian carries out direct measurements of precipitation, cloud types and heights. He is not a part of the C3VP or King City Radar network but observes at a station in London, Ontario. He has a Bachelor of Science degree and received specialized training from Environment Canada at their weather technician training site in Kingston. Recently, ECCC is getting out of the human based observations as these are being replaced by automated stations.

Farrukh

I joined in 2007 as part of the C3VP scientific collaboration with dual aims of contributing towards the project and presenting how scientists are contributing towards addressing the climate change issue. My background is a doctorate in Theoretical Physics and Applied Mathematics, alongside two engineering degrees and a Master’s in Education.

Formulation of the C-Band radar and human observations validation project

While I was completing my coursework in the PhD program and getting through qualifying exams, I was able to meet Sebastian and the associate members of the C3VP project in late 2007. During these two years, I had to learn quite a lot about weather radar and satellite meteorology in order to comprehend the project underway by the group.

In mid-2009, alongside Sebastian and Larry, we assembled what seemed like a promising study plan for using the C-Band radar network as a validation source. This would be a five-year statistical assessment of the CloudSat observation of precipitation and classification of cloud types based on King City Radar and METAR human observations as ground validating sources. We completed the study and compiled results in 2012 and in this thesis activities and results related to precipitation occurrence are focused upon as an exemplar of scientific practices in this study. Before I move on to the project, its workings and how we obtained certain results, some definitions are in order.

Reflectivity: A key radar observable

A key observable in any kind of radar measurements is "reflectivity". This is a measure of the fraction of electromagnetic energy which is reflected on a material interface. It is typically measured on a logarithmic scale in decibels or dBZ in shorthand. For the purposes of the C3VP study reported here, this variable figured largely in the algorithms of various data products. In terms of Actor-Network Theory (ANT), this physical observable, which is related to the electromagnetic radio wave, is translated in a manner using mathematical relations to connect weather phenomena such as precipitation and cloud types. Most radars emit pulses of

electromagnetic (EM) energy which involves scattering and reflection from incident targets such as hydrometeors. Here, it is notable that mathematics is itself an actor which enables, via reference to Maxwell's laws of electromagnetism, the conversion of electromagnetic pulses received by the radar's antenna into a meaningful geophysical observable like "reflectivity".

A mathematical expression of this phenomena is given via the Probert-Jones (P-J) radar reflectivity equation. This relationship quantifies physical aspects of pulsed EM energy with the associated limitations of target detection. In this case, precipitation of various kinds determines such limitation. It is given as:

$$P_r = \frac{P_t G^2 \theta^2 H \pi^3 K^2 L}{1024 \ln(2) \lambda^2} \times \frac{Z}{R^2} \tag{1}$$

Here P_r = returned power to radar from a target, P_t = peak transmitted power, G = antenna gain, H = pulse length, K = physical constant (depending on the physical characteristics of the target), θ = angular beamwidth, π =3.141592654…, L = signal loss factors associated with attenuation and receiver detection, λ = wavelength of transmitted energy, Z = target reflectivity and R = target range. In the above equation, power is expressed in watts.

The term "equivalent reflectivity" in radar meteorology refers to using certain assumptions which allow computations to become easier within physically valid regimes. For example, within the assumption of smaller sized spherical droplets, equivalent reflectivity (Ze) can be computed within the Rayleigh scattering regime (see a detailed derivation of reflectivity using these assumptions in Appendix E).

Reflectivity is expressed in decibels (dBZ), which allows a compression of an extensive range of values this observable can take on by using equation 4 This allows operational ease of

use avoiding large ranges of values in the usual units. This conversion to dBZ is done by using the relation

$$dBZ = 10 \log_{10} Z \tag{5}$$

Assessing data quality of Remote Sensing products: Validation of Satellite Products

Assessing data quality of products from any satellite typically involves four aspects, namely, calibration, monitoring, validation and verification. According to the Committee of Earth Observation Satellites (CEOS), calibration involves quantitatively defining the system responses to known, controlled signal inputs (CEOS). It includes routinely checking the quality of the measured reflectance or transmittance with respect to possible changes in instrument behavior. Applied calibration functions usually take changes of the instrument into account. Monitoring is the process of routine analysis of specific quality parameters to detect instrumental, processor or auxiliary data problems.

Validation is defined by the Committee on Earth Observation Satellites (CEOS) as the process of assessing, by independent means, the quality of the data products derived from the system outputs. The International Organization for Standardization (ISO) guide of metrology vocabulary (VIM) (ISO, 2007) further defines validation as verification where the specified requirements are adequate for an intended use. Validation therefore addresses the fitness for-purpose of the data products via comparisons.

This exercise should result in an estimate of the bias and the uncertainty. The ISO guide 99 Vocabulary for International Metrology (VIM) (ISO, 2007) defines the bias as the systematic

error of indication of a measuring system, and the uncertainty as the parameter that characterizes the dispersion of the values that are being attributed to a measured quantity, based on the information used. The bias therefore is a measure of the total systematic errors, and the uncertainty of the total random errors. Validation of a data product results in an estimate of the bias and the uncertainty, which may depend on geographical, algorithmic and instrumental parameters.

Verification is defined as the provision of objective evidence that a given data product fulfills specified requirements. Data products are checked for internal consistency, out-of-bound values, geographical distribution, and statistical behavior. The comparison of retrieval methods and the comparison of experimental data with predictions from models are also called verification. Verification identifies errors in the retrieval software or auxiliary data. Validation and verification help to optimize the retrieval algorithms.

In the case of CloudSat, the path from observation towards how the data is mobilized involves inputs from various networks towards forming products which can then be validated. These processes and the various actors are detailed in the next section.

CloudSat Measurements and flow of data to the CloudSat Data Processing Center (DPC)

The observations conducted by CloudSat are first sent via telemetry to the United States Air Force (USAF) Research Development Test & Evaluation Center in New Mexico. In Figure 1, the flow of data towards other Colorado State's Data Processing Centre (DPC) is indicated and as to how further data is aligned from other networks is shown. This includes data from other satellites in the A-train constellation such as CALIPSO and Aqua. Further, data which is aligned with the CloudSat track from the Moderate Resolution Imaging Spectroradiometer (MODIS) on

AQUA and the CALIOP lidar on CALIPSO and the various atmospheric parameters from the model analysis of European Centre for Medium-Range Weather Forecasts (ECMWF) are also added. This data is written to DVD media, stored in online systems which are accessible via internet web based access or via a direct File Transfer Protocol (FTP) to dedicated users. This data consists of various CloudSat products shown in Table 2. These are mostly cloud related observables.

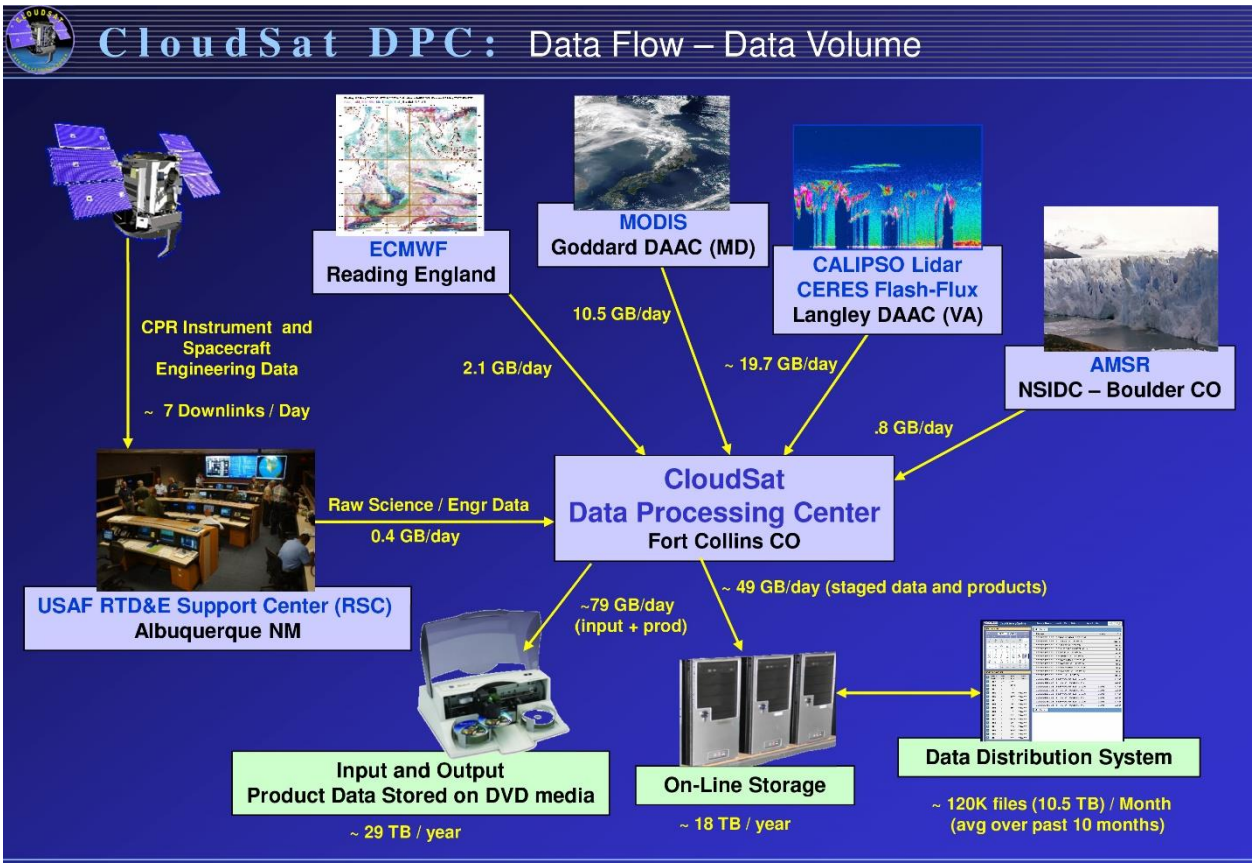


Figure 6.1: CloudSat data flow across various networks

CloudSat Data Products

The data from CloudSat available is in the form of various "satellite products". According to conventions set by NASA Earth Observation Sciences (EOS) protocols, there are different levels of data products. In the case of CloudSat, these are:

- Level 0 – observation
- Level 1 – calibrated reflectivities
- Level 2 – data products
- Level 3 – monthly or aggregated statistics.

These are typically processed information which are relevant to various types and Table 5.1 provides a brief overview of some of these standard products. These are named in a standard manner, such as Calibrated Radar Reflectivities are termed '1B-CPR'. The '1B' denotes a Level-1 product while others in Table 5.1 are Level-2.

Based on algorithms which process the observed data, these data products are also dependent on versions which are updated as soon as some improvements in the algorithm or errors are noted.

Product	Description
Calibrated Radar Reflectivities (1B-CPR)	Radar power with appropriate calibration factors
Cloud Geometric Profile (2B-GEOPROF)	Cloud mask applied to Z profile based on SNR and Spatial and vertical continuity considerations; Convert to cloud top classification using ECMWF pressure and temperatures; assigns MODIS Scene Variability designation
Cloud Type (2B-CLDCLASS)	Cloud type is determined using the cloud mask and is based upon empirical relations of Zmax vs temperature for different cloud types height above ground, spatial persistence, height of Zmax, cloud thickness, cloud top temperature
Cloud Liquid Water Content	Uses Z profile to estimate LWC and cloud droplet effective radius In daytime portion of orbit, uses Z profile and optical depth to estimate LWC, cloud droplet number density, and cloud droplet effective radius Assumes Rayleigh scattering and lognormal distribution of droplets
Cloud Ice Water Content	Uses Z profile to estimate IWC and cloud particle effective radius In daytime portion of orbit, uses Z profile and optical depth to estimate IWC, cloud number concentration, and cloud particle effective radius Assumes a modified gamma distribution of ice crystals

	Accounts for Mie scattering and ice density
Precipitation Occurrence (2B-CLDCLASS)	Zmax in lower radar gate and path integrated attenuation Z max threshold for precipitation (note in polar region it is acknowledged that this does not work effectively)

Table 6.1: CloudSat products at various levels

CloudSat Precipitation Algorithm

Data gathering and processing in CloudSat is done based in forming various "geometric profiles" through the 2B-GEOPROF product. This is done in a hierarchical manner with the 1B-CPR product first converting the CPR observations to calibrated values. This process involves noise level estimation and standard deviation, surface clutter bin identification and its removal with a further identification of its impact on the four bins above the surface.

Further conversion into calibrated reflectivities is done through an algorithm termed as the 2B-GEOPROF, which generates a profile through the backscattered power received by the radar, and this product decides whether the signal is significant (Mace et al., 2007; Marchand et al., 2008). The profile is reported in equivalent reflectivity factors (Ze) alongside a mask which indicates significance for each radar bin. A scoring procedure allows a determination of this procedure, with values assigned to each mask ranging from 6 (low echo) to 40 (high echo). When ground clutter contaminates a radar range bin, this mask value is set to 5. Broadly speaking, these scores can be interpreted as each echo indicating the probability of the presence of hydrometeors. With the filtering of noise and ground clutter, the mask and reflectivity profiles from 2B-GEOPROF are the main inputs into the 2B-CLDCLASS products which make cloud classifications, ground precipitation occurrence and associated phase (Sassen and Wang, 2008). Towards determining the phase of precipitation, the ECMWF-AUX product is deployed

(Stephens et al., 2008). This product is derived from the European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis data, and provides temperature, pressure and humidity profiles which are matched to the ground track of CloudSat and interpolated vertically to its resolution. Figure 6.2 indicates various flows of internal processing which leads to the various satellite products given in Table 6.1.

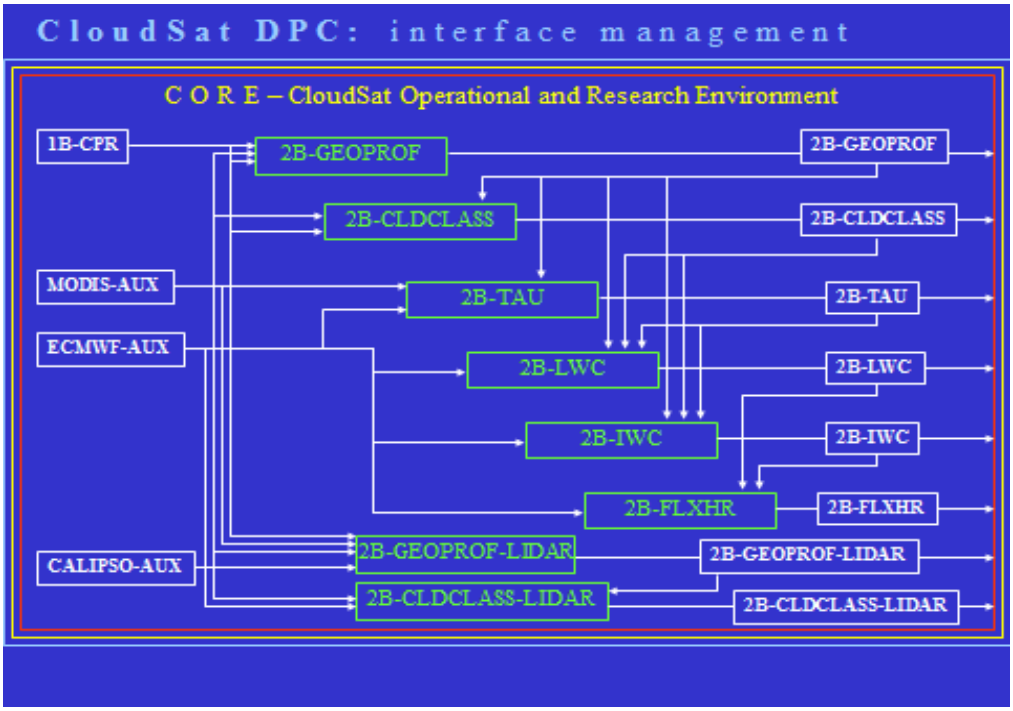


Figure 6.2: CloudSat product data dependencies and flows towards final products

Such profiles are then used to determine the phase of precipitation. Using the reflectivity at the fifth range gate as a proxy (due to ground clutter contamination in the lowest four bins) above ground, precipitation occurrence occurs if reflectivity Z is greater than a threshold value, Z_thresh (dBZ), where Z_thresh = -18 dBZ if temperature T (at the fifth range bin)

< -10 °C or equals to T if temperature is found between 0 and -10 °C, and

it is zero if temperature is greater than 0°C.

The occurrence of precipitation is also found if the difference between the regional clear sky reference signal at the surface and the measured surface reflectivity is more than 6 dB, which

would also indicate strong attenuation. Precipitation is classified as liquid based on finding a bright band in the vertical reflectivity profile or if the surface temperature is greater than 2°C. If these criteria are not satisfied, the phase is declared as solid. Further, if a cloud type of low stratus or stratocumulus is found, and the maximum reflectivity is greater than -18 dBZ, then the type of precipitation is classified as drizzle.

In an earlier validation study conducted by the C3VP group in 2008, the most frequent false detections were due to an incorrect precipitation threshold in the CloudSat algorithm, while misses were identified due to ground clutter removal of valid echoes. Additionally, a more effective ground clutter filtering of CloudSat data was recommended in the lowest four range bins by the C3VP group study conducted in 2008.

King City C-Band Dual Polarization Radar

King City Radar is part of the networked C-band radars within the National Radar Program (NRP) across Canada. These operate on a ten-minute scan cycle, with volume scans of reflectivity obtained on 24 tilt angles. This is within a range of 256 km with 1 km range resolution and a 1° azimuthal resolution.

Such tilt angles can be put together to produce vertical cross sections within the coverage area. Four Doppler scans are done additionally from tilt angles of 0.2 to 3.5 degrees, within a range of 113 km and at a 0.5 km range resolution and a 0.5° azimuthal resolution. Once the data is collected, it is transmitted and mobilized within and beyond King City. Figure 4 from Chapter 5 illustrates the data flow and provision towards other connected network which includes the Ontario Storm Prediction Centre that incorporates the radar information into their forecasting activities for public dissemination which can be located at http://weather.ec.gc.ca.

NRP precipitation algorithm

Precipitation classification as detected by the King City radar followed a certain set of criteria performed through an automated algorithm which follow a North Reference Pulse (NRP) protocol designed for timing pulses in a standard manner. These were

- Echo had to be at least 480 m in vertical extent
- Echo within 180 km of King radar (beyond 180 km the radar beam due to earth curvature is above 2 km and deemed too high to be useful as a surface precipitation validation tool).
- Within 120 km Doppler information is used to distinguish precipitation echo from ground clutter. Beyond 120 km, beam is sufficiently high that ground clutter is not an issue.
- Minimum Reflectivity threshold of -5 dBZ applied – this is the MDS at 120 km. From 120 to 180 km MDS increases to 0 dBZ – the loss of sensitivity in this range interval is not expected to significantly affect the results.

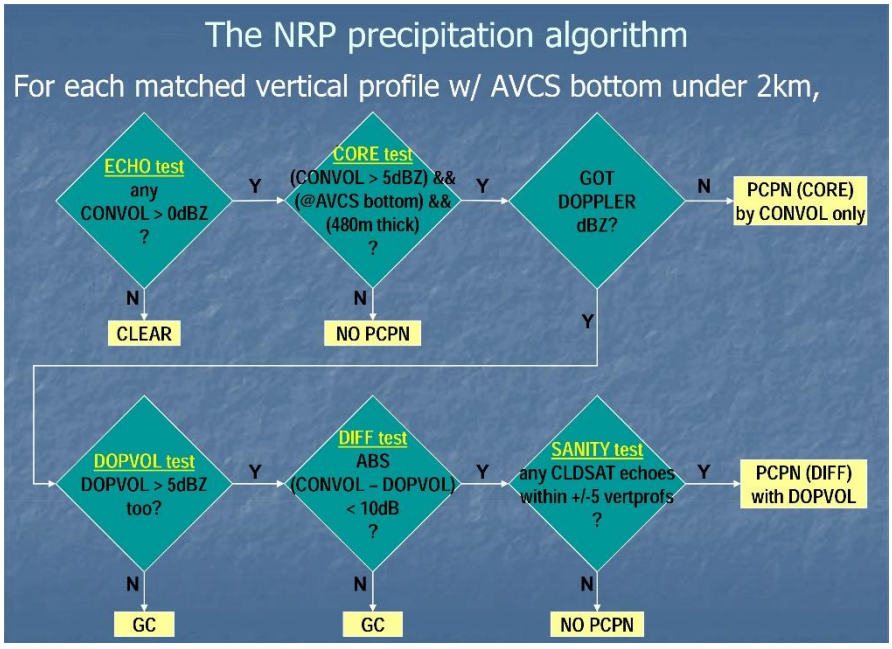


Figure 6.3: The NRP Precipitation Algorithm

Themes from interviews

Given some background on the various CloudSat products and also the C-Band Radar processing flows, I now introduce findings based on the interviews conducted with these team. The following themes were found to be salient.

Sources of Knowledge and Non-Human Actants involved in practice

Given the involvement of satellite and remote sensing technology all participants in the C3VP network offered their own learning about the various technologies involved. Sebastian shared that,

> I am trained professionally as an atmospheric scientist and have worked in deploying weather ground radars, which is also my usual work at the King City radar facility. However, the advent of a space based radar required a lot of learning and especially from our NASA colleagues. I had to get a good grasp of the hardware along with the algorithms in order to see how this will connect with the ground based instrumentation. Larry had to learn new software and orbital mechanics related to satellite mechanics in order to get our bearing right.

Larry also relayed a similar experience though he had to contend more with both the deployment of ground based instrumentation and data retrieval and processing software. He noted that

> Given my background as having an undergraduate in Physics, I recognized that it was going to be an enriching experience for me. So, when the CloudSat experiment was being formulated with us, I learned relevant tools from NASA colleagues and other sources such as the Internet. I had to figure out the satellite overpass times and had to get into satellite orbital mechanics, while I also self-learned the Interactive Data Language (IDL) for data processing purposes.

As a weather radar technologist, Martin stated that he was excited to provide support to both Sebastian and Larry by making sure that the instrument remained functional and he was on site to ensure that the measurements were done as the satellite overpasses occurred. This involved learning about the CloudSat mission further from both Sebastian and Larry.

> They explained to me how this whole thing works and I thought it was so incredible that such measurements are possible from space. Sebastian gave me all the scientific basis and Larry laid out the timings when radar measurements were ensured according to specification for this experiment.

Brian, who is not part of the C3VP network shared his surprise as to how his observations are being used in the experiment.

> I had no idea that human observations are being used for a satellite based mission. Come to think about it our eyes have a much wider scope of vision especially for spotting precipitation and cloud types, and I am glad that these METAR observations are of use in this advanced technology.

Perceived role in the network and in mobilizing various actors

Sebastian saw his role as a project manager as well as a scientific mentor to junior staff, while Larry noted that he had various interests in both setting up instruments and also ensuring that data was processed. Martin saw his role as a supportive actor who had to be mobile and available for the maintenance of the radar across various sites. All actors noted that involvement in the C3VP required movement outside their usual work which was far more routine as compared to their work in this project.

Scientific Practices in C3VP as lab and field mediations

Sebastian observed that his efforts were spent on ensuring ~~quality~~ measurements on the ground and air campaigns were of research quality while also keeping abreast with the latest happenings in the larger scientific community. A key notion expressed by Sebastian regarding scientific practices was regarding "anomalies" in the observations:

> Sometimes we find discrepancies in the data or that certain amount of observations simply does not account for the phenomenon. In that regard, field visits and time itself are important. Mulling over the data and going to the sites takes time and then some satisfactory explanation is reached, though of course this is not guaranteed.

Sebastian's work therefore involved mobilities across various field sites to international workshops and research conferences. Larry aligned his efforts with Sebastian as supportive of his mobilities including field instrument installations as well as data analysis in the office and lab environments. Martin ensured that the instruments were maintained and his mobilities remained between the field sites and the workshop lab at ECCC, where instruments and various parts were repaired.

Role in Society and impacts of research and scientific practices

All participants relayed that they were playing a key role in being part of a project which was anticipated to have large scale implications on understanding weather and climate. Sebastian noted that, above all, measuring snowfall rate from space would be of great interest with everyday implications.

> With the latest Global Precipitation Mission (GPM) moving in the direction of measuring snowfall rate, the validation studies from CloudSat will provide the baseline for better measurement from space which would be valuable for both weather and climate services.

> Overall, CloudSat is also valuable as it provides a new window into clouds which helps better climate modeling and an overall understanding about their role.

Funding also played a key role in conducting research and Sebastian pointed out how key political approvals had been required before this entire project took off.

> From the Canadian Space Agency supporting NASA to Environment Canada taking on a key role in support the validation efforts, which do tie in having the proper funding to conduct these experiments, the various officials involved in this approval had the vision and acceptance of climate change as a key issue for our (Canadian) society and beyond which is key.

Larry saw that the role of ECCC has been to engage with the public in matters of weather, but with the onset of climate change such engagements are getting better via missions like CloudSat. He noted that

> With this study we have purchased Cloud radars and are ever more interested in how precipitation happens in the context of both weather and climate change. Given how extreme weather events are becoming the norm, including snowstorms, we are hopeful that our efforts are contributive towards better forecasting and related mitigation efforts.

Martin noted that the team efforts are indeed well motivated and he felt that it was time that more work be done to understand and address climate change.

> Though I am not a scientist, I understand the overall impacts of climate change across Canada and the globe. I am happy that we are doing our part and more efforts must be poured into further research and understanding of climate change. CloudSat is a key yet one effort in this direction and I am glad to be part of this team.

Data mobilities: alignment for scientific analysis

Once Sebastian decided the boundaries of the project, Larry was assigned towards getting the relevant data in an 'analysis ready' form. Using Interactive Development Language (IDL) as a primary tool, he could arrange, download and extract data from three sources, namely CloudSat, the ground radar and METAR. These were aligned together in Comma Separated file format, which could be manipulated using Excel and SPSS software. After informing me of his approach, Larry shared that he has devised his own code in IDL which automates certain operations for large data sets. In participant observations, I was able to map out his overall approach which is summarized in four stages in Figure 4.

Stage 1, which geared towards getting the satellite tracks for the time of the study, involved three steps. These were collecting all the two-line elements (TLEs) which are an encoding of each satellite and their relevant tracks in space. The second step in this stage was to use a C-program which uses these TLEs in a satellite tracking model by Dr. T. S. Kelso. The third step was to find granule numbers of satellite tracks all within 256 kilometers with respect to the King City Radar facility.

In the second stage, Larry could use a PERL script which, using the File Transfer Protocol (FTP) had the data associated with these granule numbers that representation data over a complete satellite orbit extracted from the CloudSat Data Processing Center (DPC).

In the third stage, Larry used IDL to "trim down" these tracks to just Canadian limits. This approach led to saving data space, and the files were done in the IDLSAV data format. To sum up his entire strategy, Larry summarized his approach as: "The emphasis is that within IDL, I've made each sensor, product and result portable as a data structure that can be IDL saved, restored and exported at will." Take note of Fig 6.4.

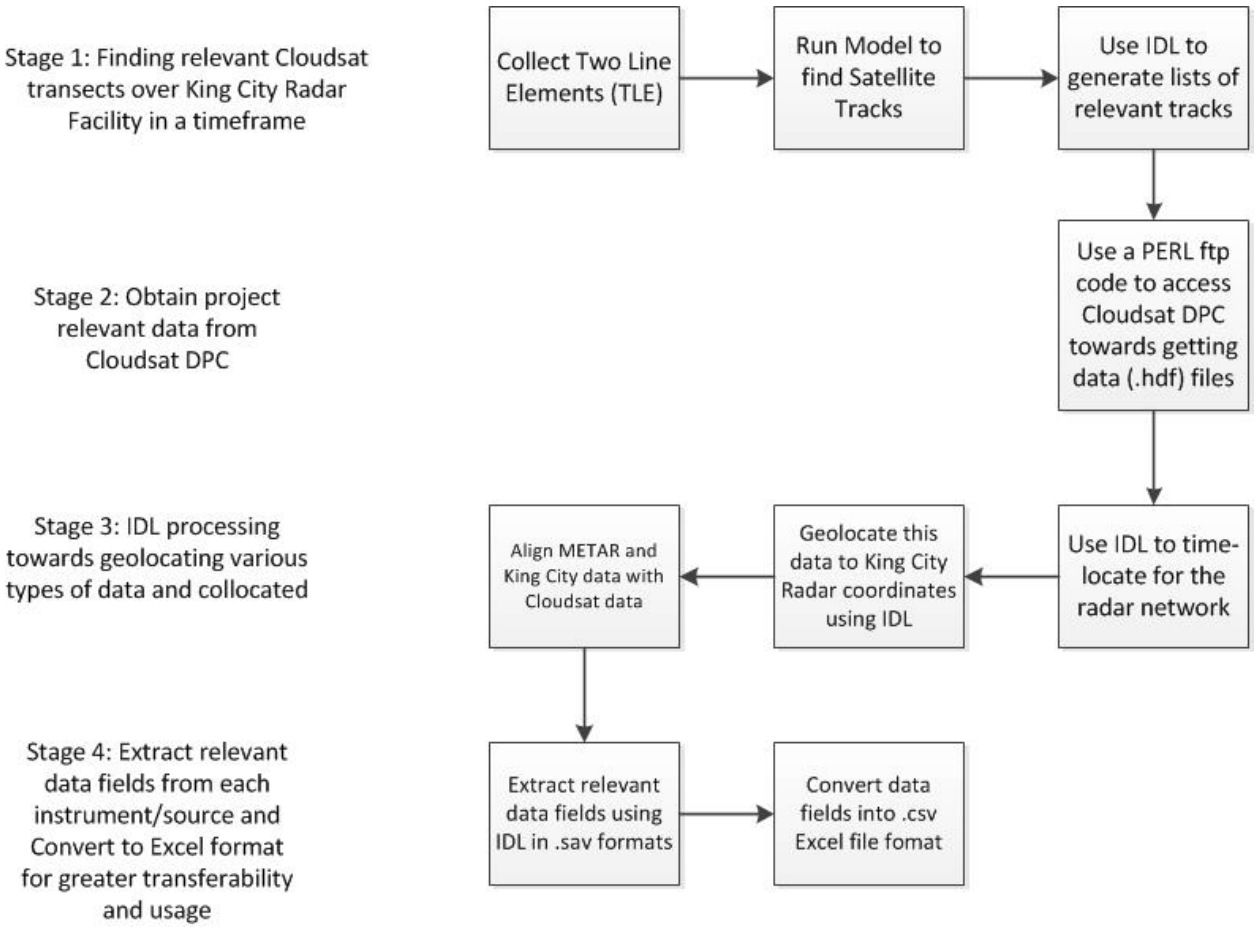


Fig 6.4: Data conversion workflow designed and assembled by Larry

Following Larry's processing, I compiled data files which were given in daily formats into single Excel files, while separating the data into specific years. Next, I separated the data into two streams: Precipitation data and Cloud Type Data. I then used SPSS software towards extracting specific data fields for further analysis. Towards understanding the results in a better manner, I used Google Earth to map the CloudSat transects (blue, green, red and orange lines) with respect to the various human observations as depicted in Figure 5. The King City Radar is depicted as a red marker in this figure.

Figure 6.5: Transects of CloudSat overpasses (red, orange, green and blue lines) over King City Radar (red marker) facility and various METAR observation sites (blue markers).

Skill Score Calculations

Towards establishing the accuracy of CloudSat's precipitation occurrence algorithm, we computed contingency tables relevant for categorical data (Wilks, 2011). A graphical depiction of this table is given below.

Contingency table		Observation = NRP or human observations	
		Yes	No
Forecast = CloudSat	Yes	Hits	False
	No	Misses	Negatives

Table 6.2: A contingency table used to determine CloudSat Precipitation Occurrence performance

Here, the various measures used from the information from this table are as follows:

Critical Score Index (CSI), which is the overall accuracy when the negatives are excluded which is mathematically equivalent to

$$CSI = Hits / (Hits + Misses + False)$$

A second skill score is Bias, which is comparison of the forecast by CloudSat with repect to actual observation

$$BIAS = (Hits + False) / (Hits + Misses)$$

The Probability of Detection (POD) is the measure of when CloudSat and ground radar measure the rain events together correctly. It is defined as

$$POD = Hits / (Hits + Misses)$$

The False Alarm Rate (FAR) measures when CloudSat detects precipitation while the ground observations do not. It is mathematically expressed as

$$FAR = False / (Hits + False)$$

Analysis: Iterative attempts at translations to Scientific Findings

I sent in the accumulated statistics for 5 years to Sebastian for both the CloudSat and the King City Radar data (NRP), which also included the number of hits, misses, false and negatives, he firstly computed skill scores of the entire data set as he and his collaborators had done earlier in a paper. This resulted in the table where there was moderate agreement with the previous results. The overall CSI score was for CloudSat was indeed significantly lower for five years as compared to previous study as only one winter season was studied earlier by the C3VP group. An improvement of this approach was its restriction of radar range to 113 km, and the analysis was done on a case by case basis for just one winter season. In the present approach, this range was extended, while the analysis was conducted across five years and the entire process was automated as compared to the previous approach taken by C3VP.

Sebastian first suggested an analysis across the entire dataset, which is shown in Table 5.3 below:

CloudSat		**NRP**	
		PCPN	NO PCPN
	PCPN	11481	2460
	NO PCPN	9562	51736
Scores	**%**	2008 study	
CSI score	48.85	88.6	
BIAS	-33.75	2.0	
POD	54.56	94.7	
FAR	17.65	6.9	

Table 6.3: The contingency table and skill scores for the CloudSat and NRP precipitation classifications for 5 years (75239 observations)

The overall accuracy scores such as CSI and POD were much lower than the earlier C3VP study and this was attributed to five years of all-season study in this present approach, as compared to only one winter season studied in the prior effort.

Range-from-Radar Analysis: Clearing out the ground clutter

After an overall statistical indication of scores, in an email exchange, Sebastian then suggested to look at the ground radar range dependence of the CloudSat results as compared to the King City Radar range which was up to 181 kilometers. I was able to arrange the data in 10 km distance bins and then calculated the skill scores for each bin, whose frequencies are depicted in the table below.

Range	no of data points	% precipitation events (CloudSat)	% precipitation events (NRP)
0-10 km	855	15.6	99.5
10-20 km	1718	18.1	93.1
20-30 km	1166	20.3	87
30-40 km	2504	27.1	78.4
40-50 km	3003	24.4	48.4
50-60 km	2634	22.3	36
60-70 km	2710	22.6	27.2
70-80 km	2910	22.7	25.5
80-90 km	6417	19.5	20.9
90-100 km	5555	17.7	19.5
100-110 km	5322	15.1	18.2
110-120 km	7050	14.6	23.3
120-130 km	6091	17	22.1
130-140 km	5754	16.9	21.1
140-150 km	5520	17.3	19.8
150-160 km	5389	19	19.3
160-170 km	5290	17.6	19.3
170-181 km	5357	18.7	18.4

Table 6.4: The range bins for the CloudSat and NRP precipitation classifications and related frequency of observations

Range	CSI Score	Bias	POD	FAR
0-10 km	0.156286722	-0.843713278	0.156286722	0
10-20 km	0.191396509	-0.805625	0.191875	0.012861736
20-30 km	0.225048924	-0.766502463	0.226600985	0.029535865
30-40 km	0.333838384	-0.653924567	0.336901121	0.026509573
40-50 km	0.472053872	-0.494490358	0.482782369	0.044959128
50-60 km	0.573770492	-0.379746835	0.5907173	0.047619048
60-70 km	0.717948718	-0.181818182	0.759837178	0.071310116
70-80 km	0.683073229	-0.110512129	0.766846361	0.137878788
80-90 km	0.640278657	-0.068605518	0.753914989	0.190552442
90-100 km	0.6528	-0.090573013	0.754158965	0.170731707
100-110 km	0.632258065	-0.168562565	0.709410548	0.146766169
110-120 km	0.449023861	-0.374695864	0.503649635	0.194552529
120-130 km	0.597454789	-0.232023721	0.661230541	0.138996139
130-140 km	0.5546875	-0.199835526	0.642269737	0.197327852
140-150 km	0.532233883	-0.126489459	0.650779102	0.25498426
150-160 km	0.531504818	-0.013461538	0.689423077	0.301169591
160-170 km	0.50038432	-0.090019569	0.636986301	0.3
170-181 km	0.506434519	0.018255578	0.678498986	0.333665339

Table 6.5: The skill scores for range bins with CloudSat observations referenced to NRP precipitation observations

The range analysis scores and the percentage of precipitation events indicated that there is an overestimation by the King City (NRP) algorithm due to ground clutter within 70 km. This is

indicated in Table 6.5 and graphically in Figure 6.6, whereby there are poor skill scores below 70 km. Hence, we also accounted this inherent 'bias' in the instrument and used this finding to conduct a fairer accuracy assessment of CloudSat with the ground-based radar observations beyond this range.

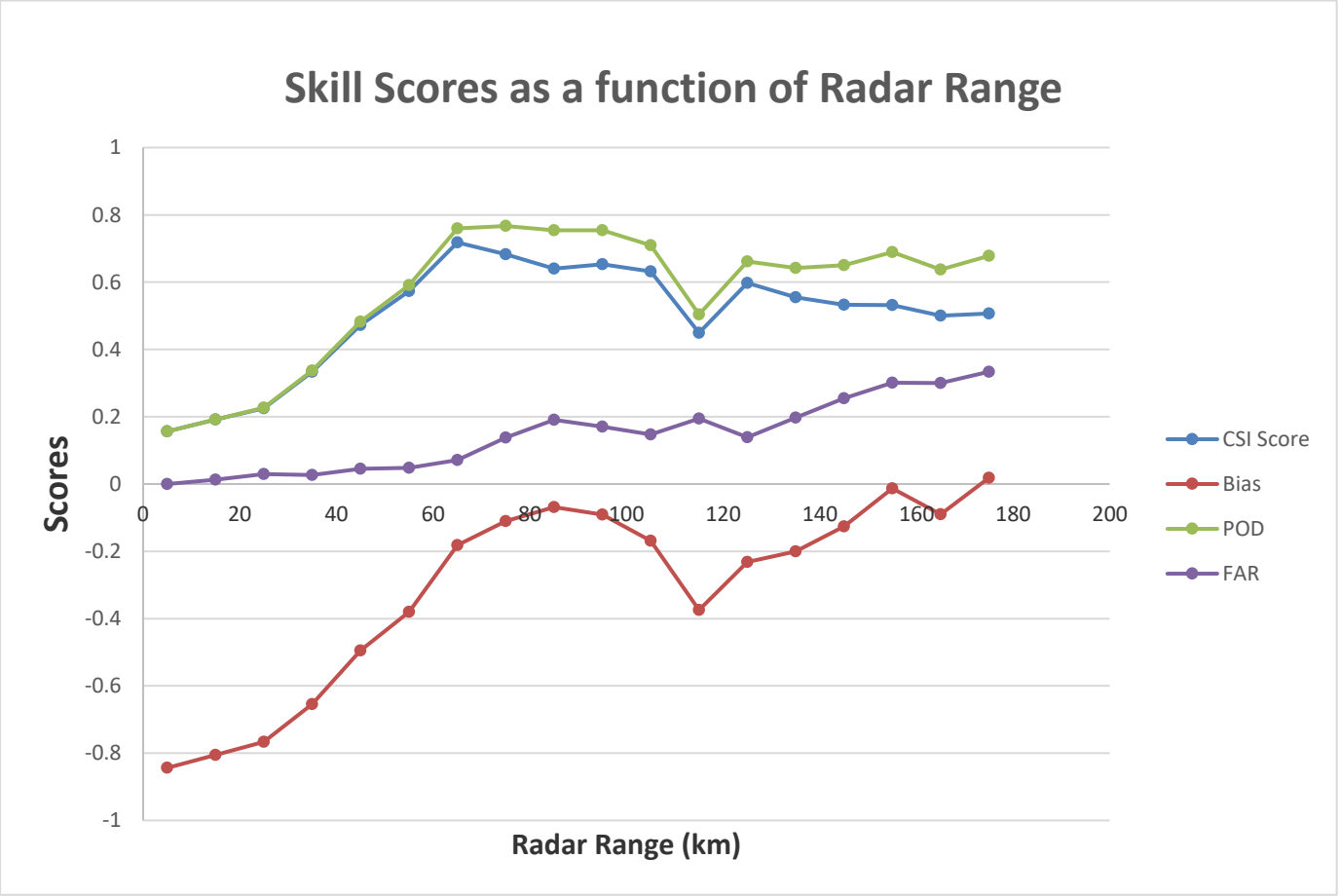


Figure 6.6: CloudSat Skill scores as a function of Radar Range (km) indicating best performance beyond 70 km

We then decided to have a distance threshold beyond this range towards calculating skill scores which took such errors within this domain from the ground validating instrument into account. As a result of this adjustment, the skill scores, in particular the critical score index (CSI) were much improved for CloudSat.

Given that we determined the ground clutter present below the 70 km range, we then looked the performance for radar observations which are shown in Table 6.6 below. We found that the performance of CloudSat then increased due to elimination of effects from ground clutter.

CloudSat		NRP	
		PCPN	NO PCPN
	PCPN	8329	2317
	NO PCPN	4149	45854

Scores	%
CSI score	56.30
BIAS	-14.68
POD	66.75
FAR	21.76

Table 6.6: The contingency table and skill scores for the CloudSat and NRP precipitation classifications for 5 years for radar ranges beyond 70 km (60649 observations)

Non-humans acting on humans to an "Aha" finding for us

After recognizing the lower threshold of CloudSat's detection capabilities, I checked on how well it did below this threshold and found that the results actually worsened considerably below -10 dBZ. These results are shown in Table 6.7:

CloudSat		NRP	
		PCPN	NO PCPN
	PCPN	197	569
	NO PCPN	485	2937

Scores	%
CSI score	15.75
BIAS	12.32
POD	28.89
FAR	74.28

Table 6.7: The contingency table and skill scores for the CloudSat and NRP precipitation classifications for -18 dBZ < Z (CloudSat) < -10 dBZ (4188 observations)

Taking the above findings into account, more specifically, in the low reflectivity range from -18 dBZ to -10 dBZ (near the CloudSat precipitation threshold) I found lowered skill scores as compared to the scores found after the NRP range adjustment was made. This indicated increased errors of the precipitation occurrence within the CloudSat algorithm which starts classifying precipitation after -18 dBZ. Upon increasing the CloudSat threshold precipitation threshold to -10 dBZ, the scores improved considerable within this range. Extending this to the entire range adjusted data set led to an overall increase in skill scores as indicated below. I chose a reflectivity threshold above -10 dBZ together with radar range greater than 70 km. This lead to the best performance for CloudSat which are shown in Table 6.8 below. Sebastian was excited at these findings and these indicated 'optimal' settings for CloudSat measurements for precipitation occurrence to the wider scientific community and for improving the present CloudSat precipitation algorithm. We both recognized this as a significant "Aha" moment in the study enabled by various non-human actors such as the instruments involved who acted on us as well as various failures in translation encountered earlier during the study.

CloudSat		**NRP**	
		PCPN	NO PCPN
	PCPN	8078	1288
	NO PCPN	4400	46883

Scores	**%**
CSI score	58.68
BIAS	-24.94
POD	64.74
FAR	13.75

Table 6.8: The contingency table and skill scores for the CloudSat and NRP precipitation classifications with Z (CloudSat) > -10 dBZ (indicating precipitation) and 70 km NRP Radar thresholds (60649 observations)

Accuracy: from the human eye

Using the available human METAR observations, CloudSat performed well and above the radar based observations and these were consistent as compared to the skill scores obtained via ground radar observations. The results are compiled in Table 6.9 and do indicate that the number of human observations were quite less as compared to ground based radar observations in the period of 5 years. According to Sebastian, the approach is methodologically innovative and results are worth reporting to the broader scientific community.

CloudSat		**NRP**	
		PCPN	NO PCPN
	PCPN	218	22
	NO PCPN	173	106
Scores	**%**		
CSI score	62.43		
BIAS	-30.38		
POD	65.19		
FAR	6.36		

Table 6.9: The contingency table and skill scores for the CloudSat and METAR precipitation classifications for 5 years (519 observations)

Conclusions

In this second case I consider a validation project which is one scientific network where actants are 'doing' science. To even make a sense of a small scientific endeavour within this project (itself – just one node in the assemblage of networks engaged in cloud/atmospheric science). I have to describe the network and its formation, in order to contextualize the enactment of science in this one small endeavor. The various scientific activities in the C3VP network involved intricate assembly of ground observations and mobilities of data by actants through various networks towards CloudSat validation studies. In this chapter, the various aspects of human involvement with non-human actors are outlined. This data acted on the

various scientists and this was depicted in a particular instance of assessing CloudSat observations from both ground and human based observations.

Indeed ‘doing science’ is not solely a human activity. Rather mathematical algorithms, core theories founding stable constructs (i.e. reflectivity), triangulating instruments are all acting to interpret across level from ‘raw data’ (which is barely visible in the complex digitized network) to high-level knowledge claims. The contingencies of physical geography, mobilities, information highways are also in play.

Chapter 7

Practices in Science and Technology: beyond method-centrism

Introduction

The main objectives of this thesis were to examine two cases of how scientists and related professionals practice science and technology. Further, I sought to find historical events and conditions which led to the formation of the networks and related actor-networks upon which these cases of science depended. To achieve these objectives, I developed a historical sociology based on an ANT-mobilities hybrid and the Annales school of history. The enactments of science and stabilization of networks are presented in the previous chapters. In this final chapter, I discuss key findings from both studies and propose new theoretical concepts.

To begin, I return to the problem of positivist science and the related dominant biomedical model in medicine and allied disciplines. Given that practices of science and

technology, in both cases, were far more complex than positivist representations, I deduce that postivist representations of science are simplistic, method-centric and ultimately insufficient to understand practices of science. Method-centric representations are reductionist, narrowly privileging method over broader conditions, actual processes and intricate practices; they also ignore the significance of crisis events.

In this work, crisis and disaster emerge as key mobilizing actors that lead to the formation and reformation of networks and their associated mobilities, which in turn also leads to innovative practices and new approaches of and for science. The key idea expressed is that the crisis itself leads to the formation of new networks as well as to the detriment of older networks; in parallel, new mobilities emerge as modes of stasis or breakdown happen. In both cases, significant is the non-human aspect and its contribution in both establishing and destroying actor-networks, and in fostering scientific and technological innovation, as in the Community Based Rehabilitation Model (CBR) in case one and the CloudSat satellite in case two. Based on these findings, I propose that practices of science and technology are spatio-temporally constituted, and I present a novel concept of "transectionalities" to denote their unique features in contrast to more typical "steady state" network practices.

Next, in a complementary manner on the basis of this study, I reconsider the concept of "multiple ontologies" proposed by Mol (2002), which is applicable to steady networks. To address less stable networks, I present the notion of "epistemic-ontologic-techne formations" as a concept drawn from the two case studies of this research. I also identify mathematics as a key mobilizing actor and a material semiotic which connects human and non-humans via what I term as "mathematical mobilities."

My findings emerge via the historiography and historical sociology developed alongside the assemblage of the ANT and mobilities approach. I emphasize the importance of historical time and crisis as key features driving scientific practices and applications, both within the timeframe of the crises and well beyond its occurrence. I then present the implications of these findings for education, both for rehabilitation sciences and science education, as well as their contribution to future crisis and disaster management. This includes the notion of "affective care" in clinical reasoning to better involvement of education in addressing environmental crises including climate change and disasters.

Method-centrism in representations of science and associated disciplines/professions

The practice of science and its associated professions are often represented as a *method* via positivism and related models in professions. In my two cases, I find that actual practices in both cases are far more complex and nuanced than just following a predetermined recipe or algorithm. While there is a narrow range of problems and associated problems that are addressed by positivist approaches, such regions are typically in closed and controlled environments. Many enactments of science feature challenging and large-scale issues which are not amenable to a positivist methodology. Rather, and as was described in prior chapters, science enactments enroll human and non-human actors into much wider levels of politics and disaster and rely on existing and newly forming mathematical-technological-material networks and mobilities.

The first case study depicts a post-earthquake practice scenario with the Community Based Rehabilitation (CBR) model as operationalized in an evolving actor-network in Muzaffarabad for SCI patients. Here, medical/rehabilitative practices went well beyond

institutions care; and while biomedical approaches played a role in the form of surgeries, etc., rehabilitation sciences and community in treatment and management of the SCI PWDs played a much greater role in a holistic fashion. These practices were constituted by adjustment, modification and innovation rather than the application of set procedures.

The second case featured validation studies for the CloudSat satellite where atmospheric science efforts were conducted in an open experimental design. Beyond the usual controlled lab conditions, scientists and technologists assembled various instruments in an innovative manner to address the nature and scale of the *evolving* problem at hand.

Both cases amply demonstrated the complexity, adaptability and ingenuity of actors and related practices which went far beyond the prescriptive practices inherent in positivist and related biomedical representations. Hence, I term practices derived from positivism as method-centric, which can be severely limiting to being non-applicable in several real-life scenarios as in cloud science or rehabilitative science. It is notable these practices and innovations were also shaped and molded by the type of crisis (and the material responses) faced by the actors in each case study.

Crisis as Actor: Potential destroyer and progenitor of (new) networks and mobilities

A key finding of this thesis is that while crises not only create destruction and immobilization at a vast scale, they also expose gaps in, and opportunities to improve, the status quo. In the first case, it is indeed concerning that the currently estimated 10% of the Pakistani population was disabled prior to the 2005 earthquake, and still faces challenges daily. They not only lack effective support on the medical front, but they also face numerous barriers to integration as fully functioning members of society.

The earthquake inflicted an immense amount of disability in Northern Pakistan, with more than 75,000 injured. As a non-human actor, it exerted an agency whose effects led to the formation of various networks and mobilities, not only for those affected by the disaster, but also the existing population in the country. When I began this research, I was also quite ignorant of the challenges faced by the disabled. Working with foreign experts and representatives of social organizations, I heard their concerns at the lack of proper medical facilities and expertise across the country. Of course, this lack not only affects those tragically injured by the earthquake, but also the existing disabled population that survives with little support. All experts voiced their concern that the disabled face a 'race against time' and the authorities need to shift their focus from mere application of surgical treatments towards comprehensive care strategies informed by current rehabilitation sciences. Thus, a key step towards making the disabled productive members of the society is through a proper introduction and integration of missing rehabilitation sciences such as occupational and vocational therapy; the 2005 earthquake played a key role in catalyzing this transformation.

In the past, hospitals in Pakistan had not adopted modern methods of medicine, which indeed involves care beyond surgery. The current level of rehabilitation sciences can be gauged from the fact that, after the earthquake, from scattered centers for rehabilitation a tiny population of physiotherapists and a non-existent amount of vocational and occupational therapists, came full units that have been introduced across the country (Rathore, 2011).

To begin to address these gaps, Subh-e-Nau (SN), a NGO devised a Community Based Rehabilitation (CBR) program in rural Muzaffarabad with an outreach program. It found that these clients need modern medical care including surgery, psychological support for their shocked state of mind, and other therapies such as occupational and vocational therapy to help

resume their lives. This thesis work showed but a slice of SN's practices and functioning. Sufficient care, however, is a long-term task, which may need decades. Again, older practices would have likely persisted without the earthquake fully exposing the limitations of the biomedical model dominated practices. This transformation developed from grassroots to policy levels which mobilized practices towards implementation in hospitals and communities by both non-governmental actors and prominent internationally mobile such as Handicap International.

On a broader level, being disabled in Pakistan typically means being a source of shame from the start, as parents or family members overprotect or hide them from the broader community. Disabled people are therefore immobilized from reaching out to possibilities that can improve and maximize their potential and this includes extending their own relations and networks, as was shown by the data collected in the first case study. I thereby recommend that family members be provided education by the media or the school system to gain better understanding, as they are influential actors in local networks. People with disabilities also face negative behavior outside the home, which can be overwhelming. This can be partly overcome by providing accessibility, including making better physical facilities like ramps and special lifts, and using media for education to increase tolerance for the disabled amongst the public. In addition, access to information poses a great challenge for the disabled. The job quota in the constitution of Pakistan is a mere two percent, however, Pakistan ratified the United Nation Convention on the Rights of Persons with Disabilities on July 5, 2015 with the commitment to translate it into the domestic statute. The ultimate purpose was to create a favorable environment to ensure the social inclusion of persons with disabilities by engaging them in all policy and legal matters and decision making related directly to them. Unfortunately, this gesture failed to deliver the persons with disabilities at required level in keeping the existing domestic statutory cover

intact. The existing legislative framework (Disability Ordinance) was formed and promulgated in 1981 in response of the first disability decade (announced by UNESCAP). The said, the legal framework only focuses on medical, welfare and charity models, and does not fully fulfil the needs of persons with disabilities. The existing legal framework excludes not only persons with disabilities, but also restricts the organizations of persons with disabilities to perform the medical, welfare and charity jobs. In contrast, South Korea has fully developed an anti-discrimination campaign and implemented related laws on a national scale. Following such examples, Pakistan must amend its constitution to address all such barriers.

In regard to application of science and therapy, a key lesson yet to be implemented is that rehabilitation sciences are not limited to physiotherapy but encompasses multidisciplinary and interdisciplinary approaches designed according to every specific individual need. It is an essential step needed in relieving the plight of the disabled in the country. Alongside, the barriers that they face towards proper functional and social integration must be removed, which are on their way to improvement due to rehabilitation sciences have played a key role in filling a key gap at various levels building proper layers of care. These evolving services can redress existing gaps, towards improving the quality of life in the existing disabled population.

In the second case study, climate change is by far a most dangerous and evolving crisis in the making, which is requiring scientists to adapt and innovate in order to understand its impacts on the earth systems and processes. With the IPCC establishing this crisis and its impacts, with increasing levels of precision, the formation of various networks and mobilities in response has been staggering. The assembling of CloudSat by NASA and CSA to map out a key uncertainty of clouds and the formation of C3VP to validate and verify the satellite's measurements is enhancing understanding of clouds and their impacts across the globe. As such, without the

climate change crisis exerting its non-human agency in unanticipated and destructive ways, these network formations and mobilities would not have formed and evolved in the manner which are presented in this dissertation.

'Transectionalities' towards (partial) translations: practices for resolution of crises and disasters

Humans and non-humans align in various ways in order to contend with crises and disasters. Besides utilizing Science and Technology, other ways were found in Case 1 whereby most earthquake affectees used Allah and religion to deal with their situation, both individually and as a community. These non-human and metaphysical resources are allowed in my analysis as ANT allows inclusion of all types of actants. Another way to contend with the earthquake and SCI condition was noted via using various artistic expressions and also by using drugs by Arshad, a participant using paints and related materials that allowed him to cope with post-earthquake trauma and his SCI condition to an extent.

For the case of Science and Technology, I introduce the concept of 'transectionalities', which are defined as the various alignments of humans and non-humans in configurations acting in order to contend, manage and solve crises and disasters. As stated above, there are many ways in which such relations form and develop to contend with such events, and actor-network and interrelated mobilities via Science and Technology based-human endeavors is a distinct mode to enable translation and resolution of crises. As shown in the two cases in preceding chapters, contention and management of crises and disasters are often a time sensitive processes with various alignments of human and non-human configurations and networks. Further, embedded in these transectionalities are politics, funding and practice cultures which makes them distinct

spatially as well. These actant-networks adapt, mobilize and change over time as the crisis also acts on them.

This concept is drawn from the term "transection" which is intended to be a hybrid material-semiotic metaphor (which involves both humans and non-humans) drawing from its meanings related to repeated observation in alignment and surgical invasive procedures, which is in contrast with light-based metaphors such as 'reflection' or 'diffraction.'. Both these latter metaphors are also anthropocentric as they are focused on human vision-centered practices, while 'transectionality' is a post-humanist concept which stems from an appreciation for non-humans (such as trained instruments) and their agency along with human actants geared towards contending with crises and disasters.

As is evident from both cases, reaching a level of management and developing some results which is of use is also fraught with error, learning and failure. Hence, full translation is never guaranteed in 'transectional practice;' typically due to the scale and nature of crisis itself, the usual model of translation by Callon (1987) is not typically applicable as there are various failures ensue due to the high level of complexity and lack of proper understanding of the phenomenon by the humans. Hence, in contending with earthquakes, chronic conditions such as SCI and the climate change crisis present formidable challenges to any straightforward solution thereby partial translations are invoked via transectionalities in order to attempt more nuanced understanding of these crisis and disasters in order to manage them to some extent.

In the first case, the key outcome of transectionality in contending with disability and SCI, enabled by the trained non-humans, was *durability* which provided physical support in the form of equipment such as spinal support, wheelchairs, leg supports, medicine, stints, etc. In the second case, the trained non-humans (instruments) provided observations which had the agency

to disrupt and change presuppositions in present understandings of clouds. For example, the ground validation using a weather radar was initially thought of as the "ground truth", however, during the study CloudSat's performance disrupted this assumption; it is now considered to be valid within only a certain range where ground clutter was not affecting ground observations.

While transectionalities may run into failures and challenges, scientists and practitioners typically learn via the agency of non-humans towards building better approaches towards better translations and actions oriented to resolving and managing crises.

Beyond Multiple Ontologies and Steady State Network assumptions: Epistemic-Ontological-Techne- formations as evolving and (im)mobilizing modes of ordering in practice networks

As explained in Chapter 2, Mol (2002) introduces the notion of "multiple ontologies" as a concept drawn from ANT, which points to the various realities which various practitioners bring to a practice network. In both cases, it is notable via ethnographic methods, that indeed within a relatively stable period of the functioning of the networks, multiple ontologies can describe how such differences are mediated. However, as Mol herself concedes, "time is left out of [her] study" (p. 3, Mol, 2007). In and around the presence of crisis enhances temporality to a great extent as unpredictable events and disasters rupture, reorder and reshape networks in a manner which is typically not foreseeable during times of stable functioning of networks. Considering Mol's assumption of the practices as nested within a "Steady State Network," I do regard it valid for a hospital in Netherlands, which was largely functioning in a smooth manner during the course of her study. Secondly, another assumption exists in her approach in that she considers epistemology as a "partially connected ontology" (quoted from Law, p. 5, 2008), which I consider a reduction of the usual meaning of the concept. In the same vein, the ideas of Law

(2006) regarding various "modes of ordering" (explained in Chapter 2), is also quite a handy means to understand the complex manner of a network, however, yet again this notion of practice rests on a network in a steady state. It is also notable that in both cases, temporality is important especially due to each specific crisis, which lead to sharp distinctions, disruptions and disjunctures in various practice epistemologies, ontologies and technologies which led to their clear distinctions during such periods. For example, in the first case, the period from the onset of the earthquake disaster in 2005 till the middle of 2006 featured practices in hospital settings where the biomedical model was dominant which featured particular epistemologies, ontologies and technologies. In the shift to the CBR program in late 2006 and resulting change (which was gradual) in practices led to different configurations which are inclusive of rehabilitation sciences. Similarly, in the second case the shift from ground based measurements to space based cloud observations with CloudSat at C3VP required shifts in various epistemological, ontological and technological practices.

To address these assumptions, and inspired by Barad's (2007) "epi-ontic" description of scientific practices, I extended this notion based on the findings of this thesis in arriving at the concept of "Epistemic-Ontologic-Techne- formations." They include network formation and mobilities as key elements of scientific practice and its applications. I base my ideas on such formations as they are amply present and demonstrated in both studies in this dissertation. For example, in the first case, practices involved technology and sciences such as enabling wheelchair mobility led to a differing ontological frame of SCI and the body, as compared to use of implants for spine stabilization surgeries which required a different ontological, epistemological and technological configuration. In the second case, clouds were observed as multiple in being across a satellite, ground and aircraft-based instruments constituting differing "epistemic-ontologic-techne" formations. Hence, my concept extends and describes crisis-based

practices better than prior concepts and ideas, including those put forth by Barad (2007) in the form of agential realism. In this regard, I include the notion of "Techne" to highlight the key presence of trained non-human actors, which includes instruments and the contribution of technology and its spatio-temporal evolution, as was detailed in both cases. I attach a hyphen at the end of this concept to keep the reader aware that my concept too will be limited given additional aspects which might drive scientific practices and networks. In the context of crises and disasters, these network formation and mobilities are theorized to be present and are vital in the scientific and technological mode of transectionalities.

In regard to Barad's agential realism, which is based on Niels Bohr's interpretation of quantum mechanics, I contend that while it is indeed via direct measurement that objects are stabilized and given the status of being real, there are counterexamples which refute this approach. So, based on both case studies in this study, the measurements taken are based on classical, deterministic observables such as stresses on spine (based on Newtonian mechanics), or "reflectivity" (in Case 2) for radars, which depends on the laws of Maxwell's Electromagnetism. Moreover, there are many objects which are inferred, but have yet to be measured directly, such as quarks (Gell Mann, 1995), which are bounded in the nucleus of atoms and yet to be directly detected dark matter. The latter is indirectly inferred from galaxy rotation curves (Corbelli & Salucci, 2000), yet it is considered to exist. Overcoming these limitations, I propose that scientific practices, as in "Epistemic-Ontologic-Techne-" formations contact phenomena to be studied experimentally via the context of what is to be measured and then these non-human actors are trained via the most relevant theory (which could be classical and deterministic, unlike Barad's quantum mechanical based assumptions). At the level of ontology, I further argue that her approach does not consider realms of relativistic kinematic regimes which are covered by quantum field theoretical considerations, as quantum mechanics is an

approximation in such regimes. Hence, quantum mechanics and its implications for measurements and scientific practice cannot assume an ultimate “epi-ontic” description; nor is the model of agential realism fully representative of the diversity of scientific practices that presently exist. How will these practices evolve, what new knowledges will be forged and how technology will evolve remain open questions, and the consideration of time is an important element in all these considerations.

Mathematical mobilities

Both cases feature a diversity of non-human actors involved in transectionalities such as rehabilitation equipment and scientific instruments. While science and engineering are responsible for designing these instruments from the level of physical structure to their functioning for human interaction, mathematics plays a crucial role as a material semiotic as well as a mobilizing actor across related disciplines and in such transectionalities. For example, the durability of the spinal support and related surgery is enabled by materials which are based in range of disciplines with many non-human actors designed via a range of scientific and engineering disciplines which in turn rely on mathematics in their design. Hence, the design of the spinal support required materials, science and engineering to ensure its durability, which is based in various types of mechanics expressed via mathematics. The spinal surgical procedures require attention to biomechanics which require attention to mathematical equations as shown in Chapter 4, I have also explicated the ways in which a radar signal depends on various mathematical relations to relate to weather phenomena such as rainfall as being based in classical electromagnetism. In this study, mathematics emerges as a key design material semiotic while its functioning allowed mobilizations for various human and non-humans. Inspired by the mobilities paradigm, I conceptualize these features in the form of a new type of mobility which is termed as

"mathematical mobilities." Hence, within the context of scientific and technological transectionalities, mathematical mobilities play a key role in both design and mobility of non-human actors.

'Affective Care' in Clinical Reasoning

Clinical reasoning is a key aspect of healthcare delivery and requires a thorough understanding of various skills and types of knowledge which are then typically translated into practice. In contemporary times, with the advent of client centered approaches, the simpler setting of a healthcare professional leading this process are further challenged. Stewart (2003) states that within client centered care "…the hierarchical notion of the professional being in charge and the patient being passive does not hold…" (p. 4-5).

Clinical reasoning processes can potentially incorporate and range from scientific and evidence based knowledge to social science (Higgs & Jones, 2008). These processes can further entail a multidisciplinary engagement where several notions of knowledge and techniques are brought together through collaborative reasoning. Thus, a vast span of knowledge types, practitioners and types of various reasoning processes are potentially incorporated, oftentimes depending on the context of the client and nature of the clinical issue itself (Croker, Loftus & Higgs, 2008). To systematically incorporate these seemingly diverse and divergent aspects in clinical practice, the notion of "affective care" is outlined next which is drawn from the findings of Case 1. This recommendation is an attempt to view clinical reasoning as a complex and contextualized process which requires assembling of various services, and may hold a potential for translation into better decision making and healthcare delivery. The notion of "affective care" also highlights the importance of human to human relationships in the clinical decision-making processes which are increasingly subsumed via introduction of technologies and interventions

such as “self-care” approaches which oftentimes are highly reliant on technology (Mol, 2008). Borrowing from ANT-mobilities approach, consideration of non-human interventions involved in each treatment assemblage, whereby their agencies and movements are taken into account in order to better understand how much technology and non-human agency can actually take over human to human relationships.

Based from Case study 1, the concept “affective care” aims to explicate certain processes and aspects for healthcare professionals which are important towards guiding assessment and treatment of clients. Drawing from the data from Case Study one, I noted that ‘affect’ by caregivers enabled better healing and health outcomes. This is also in line with the notion of ‘client-centered care” is a basis for the model and draws attention to the unique situation surrounding each individual (Fearing, 2000) and the community they belong to. As such, it is thus a move beyond the conventional biomedical model of practice as “…it is crucial to understand a patient’s illness within a broader biopsychosocial framework that acknowledges the importance of health promotion” (Atkins & Ersser, 2008, p. 78).

Here, the client includes context and their values, beliefs, assumptions as well as knowledge and meaning of disability (Higgs & Jones, 2008). The notion of context is of importance as it is a characteristic feature of clinical reasoning. In a bid to extend the process view of clinical reasoning, Higgs & Jones (2008) themselves “…expand our interpretation of clinical reasoning from a process view, to explore clinical reasoning as a contextualized phenomenon” (p. 3).

As was shown in Case 1 and in the context of the CBR program network, there is an overlap of the ‘client’ with key human actors, namely the therapist, family/caregivers, teams and organizations which illustrates a collaborative network between these groups (Crocker, Loftus &

Higgs, 2008). While these positionalities are all involved in clinical reasoning, a key assumption is that the 'therapist' is involved in a particular mode of reasoning and these processes are further explicated as the therapist's beliefs, values, tacit knowledge, professional and evidence-based research knowledge (Fleming & Mattingly, 2008). Clinical reasoning as explored from a therapeutic point of view is assumed to have feedback loops seen as a means towards further refinements of the application of clinical reasoning. In these considerations, it is recommended that the therapist is able to understand how certain relationships affect the client's situation towards facilitating an environment whereby healing and care are made optimal. This is evident in case one where affective support from caregivers and community enabled healing and well-being. Additionally, consideration of the agency exerted by non-human interventions such as technology are recommended for better consideration of the client's situation.

As a typical start of a clinical reasoning process, the therapist uses 'deep listening' (Frank, 1998) in order to gain some bearing of client issues. Employing and accessing both propositional and non-propositional knowledge alongside 'reflection-in-action', the determination of a proper intervention is done collaboratively (Driscoll & The, 2001; Fearing, 2000; Higgs, Jones & Titchen, 2008). Application of this therapeutic intervention is assumed to lead to an 'outcome', whereby 'reflection-on-action' is also used. This approach is used to shed further light on the entire process, and gain further knowledge (Fleming & Mattingly, 2008; Schön, 1987) including the quality and quantity of affective relationships available for support. This process is deemed potentially useful towards further refinements of clinical reasoning and its application, including the actions taken and the outcome obtained. Further, it also suggests that this mode of reasoning is not a pathway, but rather a continuing process whereby the client and allied actor play a central role in determining its mobility. During this process, the key

reasoning processes involved are those which have an influence on the reflective practice of the health professional. These processes are 'active judgment', 'narrative reasoning', 'scientific reasoning', 'conditional reasoning', 'ethical reasoning', 'procedural reasoning', 'pragmatic reasoning' and 'interactive reasoning' (Chapparo & Ranka, 2008; Fleming & Mattingly, 2008).

Within the context of the client centered approach, the key underlying epistemology of practice applied by a therapist using "affective care" is reflective practice (Driscoll & The, 2001; Schön, 1987). These two ideas are compatible since health care practitioners are dealing "…with people who because of their individual nature require us to be responsive and reflective instead of simply carrying out the routine tasks or rituals…" (Driscoll & The, p. 96). Thus, "affective care" acts differently and along with reflective practice is geared towards balancing the dominance of 'technical rationality' in healthcare practice.

Such a rationality is described by Schön (1987, p. 21) as "…instrumental problem solving made rigorous by the application of scientific theory and technique" and as "…an epistemology of practice which leaves us at a loss to explain, or even describe, the competencies to which we now give overriding importance" (p. 20). Towards addressing these concerns, "affective care" combines approaches including consideration of both propositional and non-propositional knowledge combined with scientific reasoning in a balanced manner with other aspects such as client context and voice, as well as consideration of non-human actors and their agencies. Thus, the application of this model entails clinical reasoning that avoids an oftentimes narrow framework which is involved in simply using a 'technical rational' or biomedical model to address clinical issues.

"Affective care" is also geared towards appreciating client values, assumptions and situation, incorporating 'deep listening' as put forth by Frank (1998). By incorporating narrative

reasoning as an ally to this process, this would facilitate "…attending to the stories which patients reveal the meaning to their suffering" (p. 198). Further guided by reflective practice these narrative exchanges have the potential for highlighting the unique context of the client through their voice. A cyclical approach in this model is further required, as "…many stories do need to change. Letting people tell their story repeatedly, gently noting changes in that story, can help. Most significant to the process of change, the person who is attended is no longer alone" (Frank, p. 210). This is in stark contrast to "self care" approaches for chronic conditions (such as SCI) which have the potential to isolate and diminish the benefits of human relationships as a result.

Given that reforms in the introduction of education of rehabilitation sciences after the 2005 Northern Pakistan earthquake, I note that Physiotherapy is well developed now and has a national curriculum designed. In contrast, other disciplines such as Occupational Therapy are still under curricular development to this day. Hence, the bio-medical model still persists in institutional practice across most governmental and private, I recommend the introduction of clinical reasoning with "affective care" and alternative models such as Community Based Rehabilitation (CBR) as a means to expand present approaches which are still restricted in their scope. In this regard, the notion of "Community", which is a human-centered concept can become more holistic with due considerations of non-humans (such as technological actants) as well. In this manner, a better understanding of how non-humans contribute can be taken into account especially when clinical reasoning is involved and "affective care" is ascertained.

Climate Change and shifts in Ontario educational policies: (en)countering ontological politics

While climate change is well established scientifically, politically there have been movements in both Canada and the United States as well as other regions of the world by climate sceptics and political leaders to declare it as a hoax. It is indeed one major example of "ontological politics" (Mol, 1999) whereby the reality of climate change is denied altogether. Meanwhile, for upcoming generations, with climate change impacts increasing, education, and especially science education, can play a key role in addressing such grave concerns. Science education can enable students to engage in "matters of concern" rather than "matters of fact" (Latour, 2004), whereby the former concept indicates issues that are of ethical and political value. It is crucial that short term political gains do not sweep away such concerns, as was witnessed in the era of Prime Minister Stephen Harper in Canada, as well as the ongoing assault on climate change science and related policies by the Trump administration in the United States.

The impact of climate change science on the Ontario educational system is further discussed here as to how it influenced a curricular reform of science education through inclusion of environmental education in various domains. Playing a key role in educational reforms are scientific reports from the Intergovernmental Panel for Climate Change (IPCC), which have made it known that climate change is happening and for a large part, due to human intervention. In terms of awareness and action, how does one deal with these issues such that human attitudes towards treatment of the natural environment are changed. In this context, schools are typically envisioned to form a component in providing knowledge needed to bring about such change and contend with this crisis by creating awareness and students who can pursue scientific careers in related fields. One answer is the inculcation of "Environmental Education" (EE) within

educational policy, curricula and textbooks as was seen in the recent reform of Ontario in 2007. Thus, this educational reform can be seen as a genuine reform in contending with the increasing impact of climate change.

Canada has played an active role in environmental education since the 1960s, "…often with a background in areas such as nature study or natural history, conservation education and outdoor education" (Palmer, 1998, p. 173). While world conferences in relation to environmental awareness were held in the 1970s, the Canadian focus was to associate solely with the North American Association for Environmental Education in the United States. Hart (quoted in Palmer, 1998) notes a departure from this earlier focus in the 1990s.

> It was not until the 1990s that a Canadian network was established: the Canadian Network for Environmental Education and Communication (p. 174).

It is important to note that education in Canada is a jealously guarded provincial responsibility. The Council of Ministers of Education, Canada (CMEC), launched a Pan-Canadian science curriculum document initiative in 1993 (Hart, 2002). Hart notes that this was "…most likely in response to the 'nationalization' of curricula in countries such as the USA (in terms of national standards), Australia and the UK" (2002, p. 1240), considering that Canada is a provincial jurisdiction, rather than a federal one. This initiative resulted in the Pan-Canadian Science Curriculum, which was released in 1997. Amongst the four foundational statements, Foundation 1: Science, Technology, Society and the Environment was stated as the 'driving force of the framework' (CMEC, 1997, p. 9). This document however, did not constitute an implemented curriculum. It was, however, a framework upon which individual provinces could develop their own curricula.

The initiative by Ontario to introduce environmental education in schools at a comprehensive level is notable. This reform is expected to lead to significant transformations in all subject areas, with science and technology curricula and pedagogy, as well as the nature as to how environmental education is implemented in the Ontario curriculum and classrooms.

This reform initiative, which started in March 2007 by the Ontario Ministry of Education, was not too far from the launch of the 4th IPCC Assessment reports. Headed by Dr. Roberta Bondar, the Working Group on EE, released its recommendations in "Shaping Our Schools, Shaping our Children: Environmental Education" (June 2007) in which a top need is a proper policy formulation of environmental education policy for the province. Immediately after this, the Science & Technology curriculum, Grades 1-8 was revised (Ministry of Education, 2007), a resources guide developed (Ministry of Education, 2008) and a policy was formulated (Ministry of Education, 2009). I will detail findings in relation to science education and will center itself on the first two documents, namely the Bondar report (2007) and the Science and Technology Grades 1-8 document (2007).

The gaps posed by the recommendations in the report (Bondar et al, 2007) are inspected in the case of the Grades 1-8 science curriculum from its earlier formulation in 1998 to the latest 2007 document from both of these frameworks. The current role of EE is discussed, especially in light of the recommendations formulated by Bondar et al (2007) as well. The increasing precision of the production of knowledge, scientific research in relation to the natural environment and climate change is considered one of the driving influences in these curricular reforms and shifts as well. The influences of the EE working group report as well as the possible role of IPCC reports on this reform initiative are discussed.

In June 2007, the Ontario Ministry of Education released a report, “Shaping Our Schools, Shaping Our Future: Environmental Education in Ontario Schools.” In this document, the Working Group on EE (headed by Dr. Roberta Bondar) declared the unsatisfactory state of affairs in regard to environmental education in the province. In this regard, the report highlights some of the practices of other jurisdictions, such as Alberta, which has a multidisciplinary approach to environmental education involving outdoor investigation starting from Grade 2. Further, British Columbia has an interdisciplinary guide for teachers for cross-subject environmental learning in all subjects and guidance on perspectives for creating lessons. Additionally, the report cites provinces such as Quebec, states from the USA such as California, as well as the UK and Israel that have much more well-defined and comprehensive EE (Bondar et al, 2007, p. 7). Thus, a clear motivation is to keep up with the leaders in the EE arena. Overall, the proposed EE Policy Framework is expected to consider aspects of Leadership and Accountability, Curriculum, Teaching and Resources within EE, with the overall aim to be integrated in a policy framework.

The report, in its opening paragraph states that, “Over the past decade, changes in the Earth’s environment and its natural systems have emerged as a matter of increasingly urgent concern around the world” (Bondar et al, 2007, p. 1). The above sentence is based out of a better understanding of the environmental science as well as its increasingly felt presence in detailing climate change as a phenomenon and its impacts. The IPCC reports and related scientific research, indirectly, if not directly have contributed to this motivation.

The document states the importance of institutions in bringing about change and awareness, especially the schooling system in this regard. It states that

> Schools have a vital role to play in preparing our young people to take their place as informed, engaged, and empowered citizens who will be pivotal in shaping the future of our communities, our province, our country, and our global environment. (p. 1)

The report seeks to move EE to the center of the curriculum; claiming that knowledge of the environment is to be considered as vital and important as that of literacy and numeracy (Bondar et al, 2007, p. 10 & p. 17). Thus, EE has to be introduced at all levels and in all possible subjects, not just in science, geography, history and social science.

The document states that the presently formulated Ontario policy is not fully up to mark in terms of EE. According to the document,

> For many years, promising elements of environmental education have been reflected in Ontario's curriculum, and supported by innovative programs and partnerships developed by school boards and schools across the province. In the absence of a comprehensive framework for environmental education however, these efforts remain fragmented and inconsistent.

In its "Vision and Intended Outcome" chapter, a common definition is formulated for the Ontario education system.

> Environmental education is education about the environment, for the environment, and in the environment that promotes an understanding of, rich and active experience in, and an appreciation for the dynamic interactions of:
> • The Earth's physical and biological systems
> • The dependency of our social and economic systems on these natural systems
> • The scientific and human dimensions of environmental issues
> • The positive and negative consequences, both intended and unintended, of the interactions between human-created and natural systems.
>
> (Bondar et al, 2007, p. 6)

This recent report by Bondar et al (2007) deals with climate change and the policymaking effort is helped by contributions, from both natural and the social sciences and experts who lead in identifying and solving such issues in the first place. The possibility of collaboration with the

Ministry of Education with the Ministry of Environment is raised as having potentially good outcomes, as is it has worked in, for example, Israel (Bondar et al, 2007, p. 8).

While the formulation of a comprehensive EE policy happened later (Ministry of Education, 2009), the change in the Grades 1-8 Science and Technology Curriculum is a direct manifestation of recommendation #2, of which will be detailed in comparison to the former 1998 document. The policy document is analyzed and will be presented in a subsequent work while the current Grades 9-10 Science & Technology curriculum was updated in light of these recommendations in 2008 document and will be studied in forthcoming studies.

The IPCC Reports and their influence

The increasing precision of the IPCC reports and their findings ring the bell on the crisis of climate change, mobilizing reforms and forming networks for implement EE – it may also point to why education policymakers have chosen to implement a reform, based on its timing (first report released in February 2007) to action taken by the Ontario Ministry of Education in March 2007. The first action taken by the Ministry was to reform the Science and Technology curriculum and, as the analysis points above, significant shifts both science as well as environmental education were made in a relatively short time scale. The role of IPCC and its reform as a related driving force are not too farfetched, as Dr. Roberta Bondar herself quoted reading IPCC reports as an educational goal for children in schools. In a newspaper article, Bondar, "…said documents such as the UN's latest report, which warned the world was approaching a "tipping point" of irreversible damage to its environment, should also be presented to students to raise awareness…Hopefully when people present it to a classroom setting, they would start deploying what's called critical thinking, which is what we need in order to assess

these documents” (Canwest, 2007). "For kindergarten kids, it may not be appropriate. But I think that we sell students short these days if we don't think they can understand this by Grade 4 or 5.”” This comment points towards a view that may have played a role in structuring the Ontario Science Curriculum, with understanding the IPCC reports as an educational goal.

Hence, the 2007 revised Science and Technology curriculum takes EE to a new level and meaning as compared to the 1998 document. In this context, it is clear that the direct driving force behind this is the EE recommendations report (Bondar et al, 2007). However, it is also contended that other factors may have played a role, such as greater level of scientific certainty in relation to climate change, which was reflected in the 2007 IPCC reports. The formulation of the provincial EE policy happened later on Ministry of Education, 2009).. With support from leading scientists and experts as well as potential collaborations between various ministries, the goal for an effective and comprehensive environmental education, especially in the context of Science and Technology subject area, is filled with possibility and potential towards substantial transformation in learning about, in and actions for the environment. It is also clear from this perspective in regards to the demands in the reformed science education curricula for students to understand what scientists and technologists do, such that areas such as climate science are not seen as ‘fake news’ or a conspiracy by students and the general public.

Educational reforms arising from crisis and disasters: recommendations from findings

As demonstrated earlier, climate change and the 2005 earthquake played key roles in catalyzing educational reforms, the curricular requirements need to be understood in this light as well. In the case of Pakistan, the physiotherapy discipline and its education has emerged as a dominant

discipline in the rehabilitation sciences sector. The national curriculum remains largely focused on the biomedical medical of clinical reasoning to this day though spaces for other disciplines are opening up including having official curriculum for other disciplines such as occupational therapy. Here, as stated above, beyond the institution models of rehabilitation such as the CBR model can further increase the scope of care and service delivery to the underserved especially in the rural and hard to access regions.

In the case of Ontario's educational reform at primary and secondary levels, whereby science education was first changed with requirements such as students getting to know what scientists actually 'do.' This requirement, beyond what is required at the primary and secondary levels can be traced to the reasons such as climate change and IPCC reporting as helpful for creating an informed students and community at large. As McBean notes,

> Educators and scientists must work together more effectively to address these barriers through improved access to comprehensible and quality information, and to foster a learning environment of critical thinking amongst students studying climate change (McBean and Hangefeld, 2000, p. 9).

As a practicing scientist, while there are certain established exemplars that can be described to students at sufficient detail, the horizon of this present requirement is precisely at the juncture of contemporary scientists encountering the various complexities and unknowns inherent in crises and disasters. Hence, in contending with a crisis requires scientific efforts at the edges of our present knowledge and requires a considerable amount of learning time and skill (such as at least an undergraduate or a graduate degree); meeting this requirement in the curriculum for primary and secondary students is not particularly realistic. While meeting this requirement at the practice level is challenging, students can be exposed to approaches in various scientific disciplines that proceed beyond the usual hypothetic-deductive model which is done in closed experimental designs. Case 2 in this thesis is an example of atmospheric science done in

an open design experiment in which sampling of observations is done in an uncontrolled environment. Rather than limiting students to science as application of method, exposing them to more real-world approaches will also enable meeting objectives set out by environmental education requirements which include better understanding of how earth and its various processes are being studied in various disciplines. Along with a better understanding of analytical processes, a better integration of Mathematics with Science and Technology is also recommended.

Summary

In this thesis I have studied two cases by developing a hybrid ANT-Mobilities historical sociology approach which led to multiple insights and concepts. Practices in science and technology are indeed complex, and there is much more involved than human agency and ingenuity. In both cases, crisis and related failures, disasters were featured in evolving networks which required actor-networks that mobilized to establish collaborative and cooperative scientific and technological practices towards understanding and managing such ongoing ruptures.

The so-called ‘scientific method’ is oftentimes far from the actual conditions and practices of a particular scientific endeavor and is often acted upon by the crisis or disaster it purports to solve and/or manage. In the first case, via the initiation of a CBR program from the wake of an earthquake, the limitations of institution-based and biomedicine were remedied using a wider network of humans and non-humans to manage a chronic disability. Further, and as illustrated in the second case, the complexity and the integration of technology and mathematical models are so entangled that humans can only engage some very small part embedded in a large web of expensive measurement devices, computer storage and communication flows across

political and disciplinary borders, device maintenance, study, calibration, error analysis, networks of scientists and political parties and funding agencies.

In closing, I do want to acknowledge that this work was an ambitious task that covered a lot of ground literally (physically) and also in a disciplinary sense, where many practice communities were reached. My task was challenging both to the complexity of science and technology as well as its representation. This study has increased my awareness and has also helped in the various disciplinary engagements I am presently involved in, which includes scientific practices in disaster preparedness, response and management. With the approaches and concepts developed in this thesis, I intend to contribute back to various communities of practice, towards learning and improving from both anticipated and oftentimes surprising, exciting exchanges.

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Appendices

Appendix A

THE UNIVERSITY OF WESTERN ONTARIO
FACULTY OF EDUCATION

USE OF HUMAN SUBJECTS - ETHICS APPROVAL NOTICE

Review Number: 1005-2
Principal Investigator: Allan Pitman
Student Name: Farrukh Chishtie
Title: *The 'Meaning' and 'Enactment' of Natural Sciences: An Actor-Network Theory Depiction of Two Cases*
Expiry Date: September 30, 2011
Type: Ph.D. Thesis
Ethics Approval Date: June 2, 2010 Revision #:
Documents Reviewed & Approved: UWO Protocol, Letters of Information & Consent.

This is to notify you that the Faculty of Education Sub-Research Ethics Board (REB), which operates under the authority of The University of Western Ontario Research Ethics Board for Non-Medical Research Involving Human Subjects, according to the Tri-Council Policy Statement and the applicable laws and regulations of Ontario has granted approval to the above named research study on the date noted above. The approval shall remain valid until the expiry date noted above assuming timely and acceptable responses to the REB's periodic requests for surveillance and monitoring information.

During the course of the research, no deviations from, or changes to, the study or information/consent documents may be initiated without prior written approval from the REB, except for minor administrative aspects. Participants must receive a copy of the signed information/consent documentation. Investigators must promptly report to the Chair of the Faculty Sub-REB any adverse or unexpected experiences or events that are both serious and unexpected, and any new information which may adversely affect the safety of the subjects or the conduct of the study. In the event that any changes require a change in the information/consent documentation and/or recruitment advertisement, newly revised documents must be submitted to the Sub-REB for approval.

Dr. Jason Brown (Chair)

2009-2010 Faculty of Education Sub-Research Ethics Board

Dr. Jason Brown	**Faculty (Chair)**
Dr. Elizabeth Nowicki	**Faculty**
Dr. Jacqueline Specht	**Faculty**
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Dr. Robert Macmillan	**Assoc Dean, Graduate Programs & Research (*ex officio*)**
Dr. Jerry Paquette	**UWO Non-Medical Research Ethics Board (*ex officio*)**

Karen Kueneman, Research Officer Faculty

Copy: Office of Research Ethics

Appendix B.1

The 'Meanings' and 'Enactment' of Natural Sciences: An Actor-Network Theory depiction of two cases

LETTER OF INFORMATION

Introduction

My name is Farrukh A. Chishtie and I am a Ph.D. candidate at the Faculty of Education at The University of Western Ontario, London, Ontario, Canada. I am currently conducting research into how scientific practice is carried out in two case studies, for my thesis dissertation work. One of these cases examines how Spinal Cord Injury (SCI) is being treated in a population with a Community Based Rehabilitation (CBR) model in Muzaffarabad by the organization, Subh-e-Nau. As a person receiving treatment in this regard or a caregiver of this person, I invite you to participate in the study.

Purpose of the study

The aims of this study are to illuminate how scientific knowledge is understood and carried out by medical practitioners.

If you agree to participate

If you agree to participate in this study you will be interviewed regarding your experiences and participation in the CBR program for SCI patients in Muzaffarabad. The length of the interview will be about 45 minutes, at a mutually agreed upon place and will be audio taped, which will be transcribed later. I am also asking you to allow me to observe your participation in the CBR program, with caregivers and with medical practitioners in instances where adjustments for your functional independence are made. I will take notes of my observations. These observations will be carried out for a few hours on a weekly basis from June to August 2010 in medical facilities, and your home, wherever you feel comfortable, insofar as where adjustments for functional independence are made. If you do not agree to participate in the study, no observational notes will be made of your activities. As well, only those caregivers who have agreed to participate in the study will be observed.

Confidentiality

I am not a medical practitioner by profession and the information collected will be used for research purposes only, and neither your name nor information which could identify you will be used in any publication or presentation of the study results. All information collected for the study will be kept confidential. I will make sure that your name is not used in order to ensure confidentiality. The interviews recorded will be destroyed within 2 years of the completion of the study while all written records, including transcripts and my written notes will be kept

indefinitely after the study is completed. However, all materials that are kept will contain no information that could identify you.

Risks & Benefits
There are no known risks to participating in this study.

Voluntary Participation
Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time. Refusing to participate will have no effect on the medical care provided. Even if the person under your care has decided to participate in this study, you should not feel obligated to participate.

Questions
If you have any questions about the conduct of this study or your rights as a research participant you may contact the Manager, Office of Research Ethics, The University of Western Ontario (London, Ontario, Canada) at ---. If you have any questions about this study, please contact me at --- or my PhD supervisors, Prof. Allan Pitman (---) and Prof. Paul Tarc (---). This letter is yours to keep for future reference.

[Signature]

Appendix B.2

The 'Meanings' and 'Enactment' of Natural Sciences: An Actor-Network Theory depiction of two cases

LETTER OF INFORMATION

Introduction
My name is Farrukh A. Chishtie and I am a Ph.D. candidate at the Faculty of Education at The University of Western Ontario, London, Ontario, Canada. I am currently conducting research into how scientific practice is carried out in two case studies for my thesis dissertation work. One of these cases examines how Spinal Cord Injury (SCI) is being treated in a population with a Community Based Rehabilitation (CBR) model in Muzaffarabad by the organization, Subh-e-Nau. As a member of the team I invite you to participate in the study.

Purpose of the study
The aims of this study are to illuminate how scientific knowledge is understood and carried out by medical practitioners.

If you agree to participate
If you agree to participate in this study you will be interviewed regarding your practices and participation in the CBR program for SCI patients in Muzaffarabad. The length of the interview will be about 45 minutes, at a mutually agreed upon place and will be audio taped, which will be transcribed later. I am also asking you to allow me to observe and take notes of your everyday practice at the CBR program. These observations will be carried out for a few hours on a weekly basis from June to August 2010 in medical facilities as well as during patient interactions in homes. If you do not agree to participate in the study, no observational notes will be made of your activities. As well, only those patients and caregivers who have agreed to participate in the study will be observed.

Confidentiality
The information collected will be used for research purposes only, and neither your name nor information which could identify you will be used in any publication or presentation of the study results. All information collected for the study will be kept confidential. I will make sure that pseudonyms are used in order to ensure confidentiality. The interviews recorded will be destroyed within 2 years of the completion of the study while all written records, including transcripts and my written notes will be kept indefinitely after the study is completed. However, all materials that are kept will contain no information that could identify you.

Risks & Benefits
There are no known risks to participating in this study.

Voluntary Participation
Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time. Refusing to participate will have no effect on your employment status. You should not feel obligated to participate in this study even though I am a member of the team.

Questions
If you have any questions about the conduct of this study or your rights as a research participant you may contact the Manager, Office of Research Ethics, The University of Western Ontario. If you have any questions about this study, please contact me at --- or my PhD supervisors, Prof. Allan Pitman (---) and Prof. Paul Tarc (---). This letter is yours to keep for future reference.

[Signature]

Appendix B.3

The 'Meanings' and 'Enactment' of Natural Sciences: An Actor-Network Theory depiction of two cases

LETTER OF INFORMATION

Introduction
My name is Farrukh A. Chishtie and I am a Ph.D. candidate at the Faculty of Education at The University of Western Ontario. I am currently conducting research into how scientific practice is carried out in two case studies for my thesis dissertation work. One of these cases examines the practice of cloud physics of the NASA and King City Radar collaboration. As a member of this team, I would like to invite you to participate in this study.

Purpose of the study
The aims of this study are to illuminate how scientific research is carried out by scientists.

If you agree to participate
If you agree to participate in this study you will be interviewed regarding your scientific practices and participation in the collaboration between CLOUDSAT and King City Radar validation studies. The length of the interview will be about 45 minutes, at a mutually agreed upon place and will be audio taped, which will be transcribed later. I am also asking you to allow me to observe your everyday work / scientific practices and take notes of your practices. If you do not agree to participate in the study, no observational notes will be made of your activities. Please do not hesitate to let me know if you are uncomfortable when I am doing my observation of your scientific practice. I will stop observing if you ask me to do so at any time.

Confidentiality
The information collected will be used for research purposes only, and neither your name nor information which could identify you will be used in any publication or presentation of the study results. All information collected for the study will be kept confidential. I will make sure that pseudonyms are used in order to ensure confidentiality. The interviews recorded will be destroyed within 2 years of the completion of the study while all written records, including transcripts and my written notes will be kept indefinitely after the study is completed. However, all materials that are kept will contain no information that could identify you.

Risks & Benefits
There are no known risks to participating in this study.

Voluntary Participation
Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time. Refusing to participate will have no effect on your employment status.

Questions
If you have any questions about the conduct of this study or your rights as a research participant you may contact the Manager, Office of Research Ethics, The University of Western Ontario at ----. If you have any questions about this study, please contact me at --- or my PhD supervisors, Prof. Allan Pitman (---) and Prof. Paul Tarc (---). This letter is yours to keep for future reference.

[Signature]

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The ‘Meanings’ and ‘Enactment’ of Natural Sciences: An Actor-Network Theory depiction of two cases

Principal Investigators Name	Dr. Allan Pitman, Dr. Paul Tarc
Title & Position	Associate Professor, Assistant Professor
Student Name	Farrukh Chishtie
Course / thesis / project	PhD thesis project

CONSENT FORM

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Name (please print):

Signature: Date:

Name of Person Obtaining Informed Consent:
Farrukh Chishtie

Signature of Person Obtaining Informed Consent:

Date:

Appendix C.1: Interview topics and guides

The following topics were explored in open-ended interviews:

Case Study One (topics)

For SCI patients:
Sources of support, knowledge of condition and practices employed for everyday living
Their perceived role and particular expertise in the CBR network
On their medical treatment and Spinal Cord Injury
Views on their specific goals and their role in the family
Their view of family support and caregivers
Overall role in Society and Community

For caregivers:
Sources of support, knowledge of condition of patient under care and practices employed for their everyday living
Their perceived role and particular expertise in the CBR network
On their medical treatment and Spinal Cord Injury
Views on their specific goals and their role in the family
Their view of family support and caregivers
Overall role in Society and Community

For Medical Staff:
Sources of knowledge and tools employed for practice
Their perceived role and particular expertise in the network
Medical practice and Spinal Cord Injury
Views on their specific practice and their role in the organization
Overall role in Society and Community

Case Study Two (topics)

For Scientists/Technicians:
Sources of knowledge and tools employed for practice
Their perceived role and particular expertise in the network
Cloud Physics and Climate Change
Views on Scientific Practice and their role in the organization
Overall role in Community and Society

Appendix C.2: Interview guide, Case Study 1

For SCI PWDs:

- How did the injury happen? What non-human elements were involved in the initial and subsequent events: Earthquake, accident, etc,
- Ask questions about Family, etc., local sources for treatment, SN program, what equipment is available there both from the SN and other sources?
- What are their views about their SCI condition? Perspectives granted from sources such as Biomedlcine, Religion, Family, Equipment, etc.
- How did introduction of help equipment such as wheelchairs/implants help their sense of being/perspective?
- Hospitals, etc. availability, and their contributions, both In terms of human expertise an equipment? How have they added or taken from their issues?
- Transportation, how ls it done to the SN team, local hospitals? Distance traveled for each treatment?
- Are they providing peer support to other PWDs? if so, are non-human actors such as training for wheelchairs, etc, involved?
- What other help are they providing or see themselves in such or similar roles in the future? Will this also involve training for equipment, medical treatment or moral support, etc?
- What improvements do they themselves perceive as important? Medical treatment, etc.
- How do they themselves, their caregivers and implants/wheelchair help their condition?
- What ADLs have they achieved? How much of this is done independently?
- how do they see themselves change over time? What factors according to them, are the key roles?
- What is their role/family position and place in the community?
- How are they related to the caregiver and how does the usage of equipment take up a place within the family or daily usage?
- How do they see themselves and SO in relation to overall family support as well as the taught/dedicated caregiver? What services do the caregivers and other family members provide? How much does non-human help also contribute?
- Are there other emotional, psychological sources/reserves, such as religious beliefs, etc that help beyond/with the family? V.
- If applicable, does the SN CBR program help with their family relations? Does improvement in condition lead to better relations? How do non-human actors such as wheelchairs, etc. help?
- How does society and their community view them and the disabled population? Do they see themselves connecting with the mainstream society?
- If not, what will get them there? Equipment, treatment, family and community supports as suggestions.
- What are the present barriers they face?
- Are they making a living? If so, what was their job before SCI and now? What change in human and non-human actors does this involve? Occupational identities?

- If applicable, how has this program helped and what can be improved?
- How can the barriers be removed?
- What are they envisioning in the future?

For caregivers:

- How are they related to the PWD and how did the SCI happen?
- Ask questions about family, the patient etc., local sources for treatment, SN program, what equipment is available there both from the SN and other sources?
- What do they think about the SCl condition and what services and supports do they perform? Perspectives granted from sources such as Biomedicine, Religion, Family, Equipment, etc.?
- How did introduction of help equipment such as wheelchairs/implants help their sense of helping and seeing change in patient's condition?
- Hospitals, etc. availability and their contributions? How have they added or taken from their issues?
- Transportation, how is it done by the SN team, local hospitals? Distance travelled for treatments?
- Are they providing support to other PWDs other than their own in the family? If so, are non-human actors such as training for wheelchairs, etc, involved? What other help are they providing or see themselves in such or similar roles in the future? Will this also involve training for equipment, medical treatment or moral support, etc?
- What improvements do they themselves perceive as important for the management/treatment of SCI? How do they themselves as caregivers help them?
- What ADLs have they helped achieved or help the PWD with?
- What role/family position? How are they related to the patient and how does the equipment take up a role within the family or daily usage?
- How do they see themselves and SCI patient in relation to overall family support as being the "taught" dedicated caregiver? What services/support do other family member provide?
- Are they also providing financial support? If so, how are they earning?
- Are there other emotional, psychological sources/reserves, spiritual sources such as religious beliefs that help (beyond/with) the family?
- Does the help cause them emotional/psychological/physical toll and take away from their lives? Why are they helping the patient?
- If applicable, how does the SN CBR program help with family relations? Does improvement in condition lead to better relations? How do non-human actants such as wheelchair help?
- How does society and their community help their own and the population in general?
- Do they see the PWDs connecting with the broader community or stigmatized? If so, what will get them there? Equipment, treatment, family and community supports as suggestions.
- What are the-social barriers they themselves face in taking care of the PWD?
- If applicable, how has this program helped them as well? How can the barriers for SCI be lowered and what do they want out of their lives, in a broader sense, after taking on the role of a dedicated SCl caregiver?

- How do they see their roles in the future?

For medical staff:

- What is their designation in their particular organization? What is their professional expertise and how were they trained or educated to achieve this?
- What type of non-human actors (such as technology, etc) are involved in their daily practice?
- In their area of expertise, what are the educational sources? What textbooks and other sources help them in practice, including other possible non-humans?
- How do they see themselves in relation to the SN program? What are their views, and in general with other professionals and how does non-human actors help facilitate their position in the program/their organization?
- For SCI, what types of patients have they treated? What is the role of non-human actors here and how does their help facilitate the treatment of SCI?
- How does their professional practice play a role in their sense of being and reality? How do they see the patient in their particular field of expertise (e.g. PTs looking at the body as a biomechanical being, etc. "practice generating ontology")?
- How do non-human actors add or shift their views towards this condition?
- How are other services/disciplines aligned in their organization and how do they perceive this?
- How do they see themselves contributing to society and the community, disability and SCI in particular?
- How are they also contributing to their profession and societies as such and how are they monitored, both in the program as well as outside licensing agencies, etc.?

Appendix C.3: Interview guide, Case Study 2

For the CloudSat study:

- What is their designation in Environment Canada? What is their professional expertise and how did they get/earn it?
- When did the King City Radar project begin?
- When did the C3VP project begin, some history? Who were the main people behind this initiative? Why was the mission started collaboratively?
- What type of non-human actors involved in daily practice in treatment of the validation project?
- In their area of expertise, what are the education sources? What textbooks are used, manuals, etc?
- What technology are being used in daily work? Computers, software, hardware and the importance of these non-humans in practices.
- How do they see themselves in relation to the validation project? What are their views, and how do they work with other professionals in this regard and generally as well.
- How do non-human actors help facilitate the program/their organization?
- What types of clouds have they studied? What about the particular data that this study is focused on?
- What is the role of non-human actors here and how does their help facilitate the validation?
- How does their professional practice play a role in their sense of being and reality?
- How do they see the weather and clouds in their particular field of expertise (e. g. CLOUDSAT looking at it differently)? How do non-human actors add or shift their views towards this condition?
- How are other weather/climate services aligned in their organization and how do they perceive this?
- How do they see themselves contributing to society and the community, Climate Change and the validation project in particular? How are they also contributing to their profession and societies as such and how are they monitored, both in the program as well as outside licensing agencies, etc.?
- Future of the Collaboration with NASA GPM: what has Environment Canada done and planning to do in the future?
- Any other upcoming collaborations in the future?

APPENDIX D.1

SUBH-E-NAU CBR PROGRAM

FORM 1: REGISTRATION FORM

(Primary Responsibility: Center Admin Staff)

Name:_____

s/o, d/o, w/o
_____

NIC:_____

Age: _____Sex: M / F_____

Address:
Current:
_____
_____

Permanent
_____
_____

Village: _____

UC: _____

Contact Details:
Cell: _____
Email: _____
Other: _____

PC:
_____
_____

Diagnosis *(to be filled in by Dr/ Head PT):*
_____
_____

Summary, if form is being used for pre-op/post-op needs assessment and referral:

SUBH-E-NAU IDRF CBR PROGRAM
FORM 2: SCI ASSESSMENT AND PLAN

(Primary resp: in order > Physician, senior PT/OT, junior PT/OT, technical staff assigned)

NEEDS 80. Tech	0 None Req 1 WC 2 Orthotics 3 Prosthesis 4 Walker	5 Elbow Crutches 6 Axillary Crutches 7 Stick 8 Commode chair	9 Reacher 10 Theraband 11 Working Counter 12 Self Help Devices	**Pt ID/Serial Number** **Date _____**
81. Ref	0 None Required 1 Urological 2 Neurosurgical 3 Wound care	4 Spinal Surgery 5 IBR 6 Medicine 7 Gen Surgery	8 Orthopedics 9 Psychology 10 Other	
82. Ref to: Master code list!	0. CMH 1. AFIRM 2. DHQ 5. PIMS	3. HFH 4. ICRC 5. RGH	RGH 7. Melody 8. other	

Name:
_____

Age (completed years):
_____

Sex: 0 – M 1 – F

Address:
Current:_____
_____

Permanent:_____
_ _____

Contact:

Home: _____
Cell: _____

Occ: Pre-Injury:_____

Occ: Post-Injury:
0 – Unemployed 1 – Student 2 – Office Work
3 – Laborer 4 – Farmer 5 – Self-employed
6 – H.wife 7 – Teacher 8 – Other
9 – Skilled Laborer

Marital Status:
0 – Single 1 – Married
2 – Divorced 3 – Widowed

No of children: _____
8 – More than 7

Education:
0 – Illiterate 1 – Primary
2 – Middle 3 – Matric 4 – Intermediate
5 – Graduate 6 – Literate 7 – Quranic

Cause of Spinal Cord Injury:
0 – EQV 1–RTA 2–Fall 3–Other:

Sensory Level
0.T4, 1.T5, 2.T6, 3.T7, 4.T8, 5.T9, 6.T10, 7.T11, 8.T12, 9.L1, 10.L2,
11.L3, 12.L4, 13 L5, 14.S1, 15.All sensations intact, 16.C2, 17.C3, 18.C4, 19.C5, 20 C6
21.C7, 22 C8, 23.T1, 24.T2, 25.T3, 26.S2, 27.S3, 28.S4-5

Anal Sensations: 0. Intact 1. Not intact

Motor Level:

0. No power in lower limbs
1. L1
2. L2
3. L3
4. L4
5. L5
6. S1
7. C5
8. C6
9. C7
10. C8
11. T1

Voluntary anal contraction: 0 - N 1- Y

ASIA Scale:

0. A
1. B
2. C
3. D
4. E

SCI Type/Clinical Sy:

0. Cord Tran-section
1. Cord Compression
2. Anterior Cord Sy
3. Brown Sequard Sy
4. Central Cord Sy
5. Cauda Equina Sy
6. Conus Medullari

Complete or Incomplete Injury? 0-Complete 1-Incomplete

Disability Type:

0. Complete Paraplegia
1. Incomplete Paraplegia
2. Incomplete Quadriplegia
3. Complete Quadriplegia
4. B/L Foot Drop

Vertebral/Radiological Level:

0.C8; 1. T1; 2.T2; 3.T3; 4.T4; 5.T5; 6.T6; 7.T7; 8.T8; 9.T9; 10.T10; 11.T11; 12.T12; 13.L1; 14.L2; 15.L3; 16.L4; 17.L5; 18.C1; 19.C2; 20.C3; 21.C4; 22.C5; 23.C6; 24.C7

Mode:

0. Fracture
1. Dislocation/Subluxation
2. Fracture + Dislocation
3. SCIWORA

Management:

0 – Conservative
1 - Spinal Fixation

Implant In-situ: 0 - N 1 - Y

Implant Status:

0 - Intact 1- Dislocated/broken 2 - Pain full

H/O Implant Failure: 0 - N 1 - Y

Cause of Failure: 0 – Infection 1- other

Spinal Deformity: 0 - N 1 - Y

Zone of Partial Preservation: 0 - N 1 - Y

Acute care Facility/s: _____

Rehab facility/s: _____

Co-morbidities:

0. HTN
1. DM
2. Asthma
3. TB
4. Stroke
5. Other

Associated Injuries:
0. Limb/s
1. Chest
2. Head
3. Abdominal
4. Other

Type: 0 - Fracture 1 - Laceration
2 - Perforation

COMPLICATIONS:
0 – Current 1 - Documented H/O 2- Reported
3- Suspected

Spinal Shock:_____

Autonomic dysreflexia:_____

Heterotopic ossification_____

DVT:____

UTI:____

Pressure Ulcers:____

Location/s:

0. Sacral
1. Ischial
2. Trochanteric
3. Heels/Ankles

Grade: 0 1 2 3 4

Status: 0–Healed 1–Healing 2-Non-Healing

Nutritional Status (available Last Hb/Protein/Albumin) whether: 0 – Low 1 – Normal 2 - High

CURRENT HEALTH ISSUES

Pain: 0 - none 1 - present

Pain Site relative to spinal level:
0- Above 1 –At 2 -Below

Type:
0. Neuropathy
1. Nociceptive
2. Psychogenic
3. Visceral

Severity 1–10:_____

Effective Management: 0 - N 1 - Y

Bowel: 0 - Continent 1 – Incontinent
2 - Paretic

Toilet Trained: 0 - N 1 - Y

Pampers: 0 - N 1 - Y

Toilet:

0. Commode chair
1. English
2. Indian
3. Bed pan

Adequate Dietary Fiber: 0 - N 1 - Y

Bladder:

0. Voluntary
1. CISC
2. ISC
3. IDC
4. Ext-Catheter
5. Credes
6. SP

Leakage: 0 - N 1 - Y

Respiratory Symptoms: 0 Absent 1 Present

Cardiac Symptoms: 0 Absent 1 Present

Sexual difficulties: 0 Absent 1 Present

Family History:
0. HTN
1. Diabetes
2. Asthma/COPD
3. IHD
4. TB
5. Tumor
6. M. Dystrophy

SOCIAL HISTORY

MENTAL STATUS: 0 - Poor; 1 – Satisfactory; 2- Good

Participation: _____

Interaction:_____

Behavior:_____

Outlook:_____

Appetite:_____

Sleep:____

Smoking: 0 – N 1 - Y

No of dependents: 0 - N 1 - Y

Financial dependence: 0 - N 1 – Y

Current Medications:

_____
_____
_____
_____
_____

Radiological Record Available: 0 - N 1 - Y

Health Facility Access:

Type: 0.Dispensary 1.Primary Care Hospital 2. Basic Health Unit

Public or Private Facility: 0.Public 1. Private 2.NGO _____

Care available:

0. Medical
1. Surgical
2. Physiotherapy
3. Med + Surgical
4. Urology
5. Trauma/Wound Ca

Traveling Time: No. of hours…..

0. 0-30min
1. 30min-1hr
2. 1-2 h
3. 2-3 h
4. more than 3h

Mode of Travel: 0 – Walk 1 - 2x4 Vehicle 2 - 4x4 Vehicle

Tertiary Care

Hospital where tertiary care is sought: (same master codes):

Ambulance available: 0. N 1. Y

Needs: Tech

Referred for

Ref to (Inst) ***Fill 82 to 84 on front of form!***

MANAGEMENT PLAN

(Primary Responsibility: in order > Physician, PT, OT, Psych, Peer)

Site:
Center/OPD
Outreach/ at home
Outreach/other facility e.g. school etc_____
Combined (both at center and outreach-home/facility). Mention facility *(if applicable)* _____

MEDICAL/SURGICAL

Goals: Short term	Mid term	Long term

Spine Mgt/Review:
Conservative
Fixation
Surgery
Implant removal
Implant review from NS
Other_____

(Mention facility in the referral box)

Wound mgt:
Debridement
Dressing
Plastic surgery

Drug Therapy:
Antibiotics_____
Analgesic_____
Pain management_____
Others_____

Sexual rehab:
_____
_____

Bladder regime:
_____
_____

Bowel regime:
_____
_____

Nutrition:
_____
_____

Respiration:
_____
_____

Cardio pulmonary:
_____
_____

PSYCHO-SOCIAL

Goals: Short term	Mid term	Long term

(Any social assistance, including counseling for psychological problems, vocational therapy, vocational advice, switching occupations according to functional limitations, skills imparted, etc)

Counseling by:

Peer
Doctor
PT/OT
Psychologist

Counseling areas:

Motivation
Depression
Other_____
_____
____

PT/OT

Goals: Short term	Mid term	Long term

Plan or progression monitoring only:

Postural care
ROM
Strengthening
Mobilization
Stretching
Transfers

Exercise Regime:

ROM
Strengthening
Stretching
Mobilization
Positioning
Postural care
Traction

Gait training:

Walking bars
Walker frame
Balance board
Wooden stair
Stick

Cervical traction:

Manual
Mechanical

Lumber traction:

Manual
Mechanical

Cryotherapy:

Moist hot pack

Electrotherapy:

Ultrasound Sound therapy
Nerve Stimulation
Infrared radiation
TENS

Post operative rehab (Orthoplasty) :

Sexual rehab:

Neuro rehab:
Stroke rehab
CP rehab
ADLS
Myopathy
Neuropathy

1. **Home modification according disability:**

2. **Occupational therapy:**
   Self help devices
   Adaptation designing/training

Equipment provided:
WC
Orthoses
Walker frame
Working counter/table
Elbow crutches
Axillary Crutches
Stick
Theraband
Theraballs
Ramp
Transfer board
Air ring
Toilet seat
Air rings for skin care
Self Help Devices _____

Trainings + Vocational Therapy (VT)

Goals: Short term	Mid term	Long term

Caregiver training:
_____
_____

Vocational therapy:
_____
_____

Home session:
_____
_____

Home care program:
_____
_____

Referred for labs/consults: Pathology/labs Radiology Surgery Medicine Plastic surgery Urology Spinal Surgery IBR Orthopedics Psychology/psychiatric Microfinance Other: _____ _____	**Referred to *(use master code)*:**

_____ _____	

APPENDIX D.2

Form 3: ASIA scale

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Patient Name _____

Examiner Name _____ Date/Time of Exam _____

ASIA
AMERICAN SPINAL INJURY ASSOCIATION

STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

MOTOR

KEY MUSCLES (scoring on reverse side)

	R	L	
C5	☐	☐	Elbow flexors
C6	☐	☐	Wrist extensors
C7	☐	☐	Elbow extensors
C8	☐	☐	Finger flexors (distal phalanx of middle finger)
T1	☐	☐	Finger abductors (little finger)

UPPER LIMB TOTAL (MAXIMUM) ☐ + ☐ = ☐ (25) (25) (50)

Comments:

	R	L	
L2	☐	☐	Hip flexors
L3	☐	☐	Knee extensors
L4	☐	☐	Ankle dorsiflexors
L5	☐	☐	Long toe extensors
S1	☐	☐	Ankle plantar flexors

Voluntary anal contraction (Yes/No) ☐

LOWER LIMB TOTAL (MAXIMUM) ☐ + ☐ = ☐ (25) (25) (50)

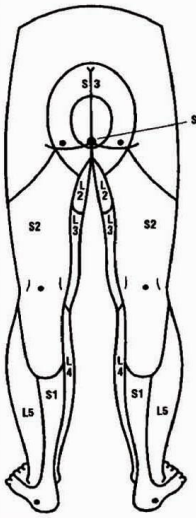
	LIGHT TOUCH R	LIGHT TOUCH L	PIN PRICK R	PIN PRICK L
C2				
C3				
C4				
C5				
C6				
C7				
C8				
T1				
T2				
T3				
T4				
T5				
T6				
T7				
T8				
T9				
T10				
T11				
T12				
L1				
L2				
L3				
L4				
L5				
S1				
S2				
S3				
S4-5				

TOTALS { ☐ + ☐ (MAXIMUM) (56) (56) (56) (56)

SENSORY

KEY SENSORY POINTS

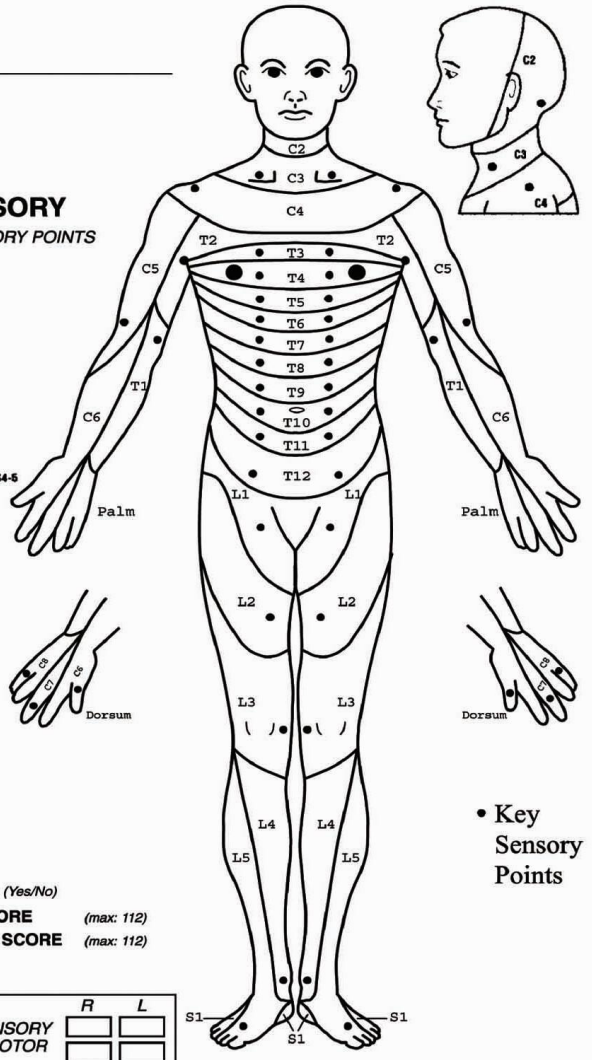
0 = absent
1 = impaired
2 = normal
NT = not testable



Any anal sensation (Yes/No) ☐

PIN PRICK SCORE ☐ + ☐ = ☐ (max: 112)

LIGHT TOUCH SCORE ☐ = ☐ (max: 112)



• Key Sensory Points

NEUROLOGICAL LEVEL		R	L
The most caudal segment with normal function	SENSORY	☐	☐
	MOTOR	☐	☐

COMPLETE OR INCOMPLETE? ☐
Incomplete = Any sensory or motor function in S4-S5

ASIA IMPAIRMENT SCALE ☐

ZONE OF PARTIAL PRESERVATION		R	L
Caudal extent of partially innervated segments	SENSORY	☐	☐
	MOTOR	☐	☐

REV 03/06

APPENDIX D.3

FORM 4: SCIM

Patient Name: _____MR. No._____ Examiner Name: _____
(Enter the score for each function in the adjacent square, below the date. The form may be used for up to 6 examinations.)

Date					

SELF-CARE

1. Feeding (cutting, opening containers, pouring, bringing food to mouth, holding cup with fluid)

0. Needs parenteral, gastrostomy, or fully assisted oral feeding
1. Needs partial assistance for eating and/or drinking, or for wearing adaptive devices
2. Eats independently; needs adaptive devices or assistance only for cutting food and/or pouring and/or opening containers
3. Eats and drinks independently; does not require assistance or adaptive devices

2. Bathing (soaping, washing, drying body and head, manipulating water tap). A-upper body; B-lower body

A. 0. Requires total assistance
1. Requires partial assistance
2. Washes independently with adaptive devices or in a specific setting (e.g., bars, chair)
3. Washes independently; does not require **a**daptive **d**evices or **s**pecific **s**etting (not customary for healthy people) (adss)

B. 0. Requires total assistance
1. Requires partial assistance
2. Washes independently with **a**daptive **d**evices or in a **s**pecific **s**etting (adss)
3. Washes independently; does not require **a**daptive **d**evices (adss) or **s**pecific **s**etting

3. Dressing (clothes, shoes, and permanent orthoses: dressing, wearing, undressing) A-upper body; B-lower body

A. 0. Requires total assistance
1. Requires partial assistance with **c**lothes **w**ith**o**ut **b**uttons, **z**ippers or **l**aces (cwobzl)
2. Independent with cwobzl; requires **a**daptive **d**evices and/or **s**pecific **s**ettings (adss)
3. Independent with cwobzl; does not require adss; needs assistance or adss only for bzl
4. Dresses (any cloth) independently; does not require adaptive devices or specific setting

B. 0. Requires total assistance
1. Requires partial assistance with **c**lothes **w**ith**o**ut **b**uttons, **z**ipps or **l**aces (cwobzl)
2. Independent with cwobzl; requires adaptive devices and/or specific settings (adss)
3. Independent with cwobzl without adss; needs assistance or adss only for bzl
4. Dresses (any cloth) independently; does not require adaptive devices or specific setting

4. Grooming (washing hands and face, brushing teeth, combing hair, shaving, applying makeup)

0. Requires total assistance
1. Requires partial assistance
2. Grooms independently with adaptive devices
3. Grooms independently without adaptive devices

SUBTOTAL (0-20)

RESPIRATION AND SPHINCTER MANAGEMENT

5. Respiration

0. Requires tracheal tube (TT) and permanent or intermittent assisted ventilation (IAV)
2. Breathes independently with TT; requires oxygen, much assistance in coughing or TT management
4. Breathes independently with TT; requires little assistance in coughing or TT management
6. Breathes independently without TT; requires oxygen, much assistance in coughing, a mask (e.g., peep) or IAV (bipap)
8. Breathes independently without TT; requires little assistance or stimulation for coughing
10. Breathes independently without assistance or device

6. Sphincter Management - Bladder

0. Indwelling catheter
3. Residual urine volume (RUV) > 100cc; no regular catheterization or assisted intermittent catheterization
6. RUV < 100cc or intermittent self-catheterization; needs assistance for applying drainage instrument
9. Intermittent self-catheterization; uses external drainage instrument; does not need assistance for applying
11. Intermittent self-catheterization; continent between catheterizations; does not use external drainage instrument
13. RUV <100cc; needs only external urine drainage; no assistance is required for drainage
15. RUV <100cc; continent; does not use external drainage instrument

7. Sphincter Management - Bowel

0. Irregular timing or very low frequency (less than once in 3 days) of bowel movements
5. Regular timing, but requires assistance (e.g., for applying suppository); rare accidents (less than twice a month)
8. Regular bowel movements, without assistance; rare accidents (less than twice a month)
10. Regular bowel movements, without assistance; no accidents

8. Use of Toilet (perineal hygiene, adjustment of clothes before/after, use of napkins or diapers).

0. Requires total assistance
1. Requires partial assistance; does not clean self
2. Requires partial assistance; cleans self independently
4. Uses toilet independently in all tasks but needs adaptive devices or special setting (e.g., bars)
5. Uses toilet independently; does not require adaptive devices or special setting

SUBTOTAL (0-40)

MOBILITY (ROOM AND TOILET)

9. Mobility in Bed and Action to Prevent Pressure Sores

0. Needs assistance in all activities: turning upper body in bed, turning lower body in bed, sitting up in bed, doing push-ups in wheelchair, with or without adaptive devices, but not with electric aids
2. Performs one of the activities without assistance
4. Performs two or three of the activities without assistance
6. Performs all the bed mobility and pressure release activities independently

10. Transfers: bed-wheelchair (locking wheelchair, lifting footrests, removing and adjusting arm rests, transferring, lifting feet).

0. Requires total assistance
1. Needs partial assistance and/or supervision, and/or adaptive devices (e.g., sliding board)
2. Independent (or does not require wheelchair)

11. Transfers: wheelchair-toilet-tub (if uses toilet wheelchair: transfers to and from; if uses regular wheelchair: locking wheelchair, lifting footrests, removing and adjusting armrests, transferring, lifting feet)

0. Requires total assistance
1. Needs partial assistance and/or supervision, and/or adaptive devices (e.g., grab-bars)
2. Independent (or does not require wheelchair)

MOBILITY (INDOORS AND OUTDOORS, ON EVEN SURFACE)

12. Mobility Indoors

0. Requires total assistance
1. Needs electric wheelchair or partial assistance to operate manual wheelchair
2. Moves independently in manual wheelchair
3. Requires supervision while walking (with or without devices)
4. Walks with a walking frame or crutches (swing)
5. Walks with crutches or two canes (reciprocal walking)
6. Walks with one cane
7. Needs leg orthosis only
8. Walks without walking aids

13. Mobility for Moderate Distances (10-100 meters)

0. Requires total assistance
1. Needs electric wheelchair or partial assistance to operate manual wheelchair
2. Moves independently in manual wheelchair
3. Requires supervision while walking (with or without devices)
4. Walks with a walking frame or crutches (swing)
5. Walks with crutches or two canes (reciprocal walking)
6. Walks with one cane
7. Needs leg orthosis only
8. Walks without walking aids

14. Mobility Outdoors (more than 100 meters)

0. Requires total assistance
1. Needs electric wheelchair or partial assistance to operate manual wheelchair
2. Moves independently in manual wheelchair
3. Requires supervision while walking (with or without devices)
4. Walks with a walking frame or crutches (swing)
5. Walks with crutches or two canes (reciprocal waking)
6. Walks with one cane
7. Needs leg orthosis only
8. Walks without walking aids

15. Stair Management

0. Unable to ascend or descend stairs
1. Ascends and descends at least 3 steps with support or supervision of another person
2. Ascends and descends at least 3 steps with support of handrail and/or crutch or cane
3. Ascends and descends at least 3 steps without any support or supervision

16. Transfers: wheelchair-car (approaching car, locking wheelchair, removing arm- and footrests, transferring to and from car, bringing wheelchair into and out of car)

0. Requires total assistance
1. Needs partial assistance and/or supervision and/or adaptive devices
2. Transfers independent; does not require adaptive devices (or does not require wheelchair)

17. Transfers: ground-wheelchair

0. Requires assistance
1. Transfers independent with or without adaptive devices (or does not require wheelchair)

SUBTOTAL (0-40)

18. TOTAL SCIM SCORE (0-100)

APPENDIX D.4

FORM 5: BERG BALANCE SCALE

Name: _____ **Age/Sex:** _____ **Dt:** ____**Score:** _____
Mr. no: _____ **Dt:** ____**Score:** _____
Disability Type: _____ **Dt:** ____**Score:** _____

SITTING TO STANDING
INSTRUCTIONS: Please stand up. Try not to use your hand for support.
( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or stabilize
( ) 0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED
INSTRUCTIONS: Please stand for two minutes without holding on. If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Precede item #4.
( ) 4 able to stand safely for 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
( ) 4 able to sit safely and securely for 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

STANDING TO SITTING
INSTRUCTIONS: Please sit down.
( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assist to sit

TRANSFERS
INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.
( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cuing and/or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding on.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
( ) 4 can reach forward confidently 25 cm (10 inches)
( ) 3 can reach forward 12 cm (5 inches)
( ) 2 can reach forward 5 cm (2 inches)
( ) 1 reaches forward but needs supervision

( ) 0 loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up the shoe/slipper, which is in front of your feet.
( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 2-5 cm (1-2 inches) from slipper and keeps balance independently
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try/needs assist to keep from losing balance or falling

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: Turn to look directly behind you over toward the left shoulder. Repeat to the right. (Examiner may pick an object to look at directly behind the subject to encourage a better twist turn)
( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
( ) 2 turn sideways only but maintain balance
( ) 1 needs supervision when turning
( ) 0 needs assist to keep from losing balance or falling

TURN 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.
( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps in > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/ unable to try

STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO PWD) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width)
( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

STANDING ON ONE LEG
INSTRUCTIONS: Stand on one leg as long as you can without holding on.
( ) 4 able to lift leg independently and hold > 10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold L 3 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently.
( ) 0 unable to try of needs assist to prevent fall

PT: _____
Total SCORE: **56**
1.
SCORE: _____
SCORE: _____
SCORE: _____

APPENDIX D.5

FORM 6: HOME ASSESSMENT

MR. no: _____
Name: _____
Age/Sex_____

Assessment PT/OT: _____

2. Type of home:

1. House
2. Tent
3. Camp
4. Apartment
5. Shelter

3. New or old construction:

6. New: Walls and roof made of Wood
7. New: Walls and roof made of Mud
8. New: Walls and roof made of Tin roof
9. New: Walls and roof made of Cement Blocks
10. Old: Walls and roof made of Wood
11. Old: Walls and roof made of Mud
12. Old: Walls and roof made of Tin roof
13. Old: Walls and roof made of Cement Blocks

4. Lives on:

14. Ground floor
15. First floor
16. Higher than first floor

5. Uses all floors of home:Y/N

Entrance to the building or home

6. Entrance used frequently or easily:

17. Front

Back

Side

7. Whether on W/C: Y/N

Environmental assessment: Accessibility on WC

(Only ask PWDs using WC; If not using WC, skip this section)

8. Electric outlet: Y/N

9. Open/close windows: Y/N

10. Open/close doors: Y/N

11. Non-slippery mat on floor spread out in WC area: Y/N

12. Patient can manage TV/radio/videogames: Y/N

Activity Inside Home

(For ALL PWDs)

13. Prayer:

18. Bed

WC

Table

14. Stairs inside home: Y/N

15. Climbs stairs:

(if yes in prev Q): Y/N

16. Hallway (lounge, get together area)

in home: Y/N

17. Doorsills in home: Y/N

18. Bedroom available?: Y/N

19. Bathroom available: Y/N

20. Separate kitchen: Y/N

21. Open space for using WC (Ground): Y/N

WC Patient: Safe movement on/around:

22. Loose rugs: Y/N

23. Faulty floor: Y/N

24. Highly waxed floor: Y/N

25. Sharpe edge furniture: Y/N

26. Heater: Y/N

27. Hot water pipe heater: Y/N

Doors

28. Number of doors (only mention used by PWD): ___

29. Width of doorway: ___

30. Material:

19. Wood

Iron

Curtain

31. Door with ramp: Y/N

32. Locks/unlock door/s: Y/N

Stairs/Ramp

33. Outside ramp: Y/N

34. Inside ramps: Y/N

35. Width of ramp: _____

36. Angle of ramps: _____

37. Stairs outside house: Y/N

38. If yes, Number of stairs: ____

39. PWD using stairs for getting outside and inside house: Y/N

40. Side railing on stairs: 1. R 2. L 3. B/L

41. Side railing on ramp: 1. R 2. L 3. B/L

Hallway

42. Ramp for w-chair: Y/N

43. Width of ramp: _____

44. Angle of ramp: _____

Bed

45. Height: _____

46. Width:_____

47. Both sides accessible: Y/N

48. Footboard: Y/N

49. Wheels: Y/N

50. Night table within reach: Y/N

51. Telephone or bell attached: Y/N

Independently transfer

52. Bed<>WC: Y/N

53. WC <> Toilet chair: Y/N

54. Toilet chair with bar: Y/N

55. WC Accessible Bath tub: Y/N

Kitchen: Things Available

56. Working counter: Y/N

57. Stove: Y/N

58. Sink: Y/N

59. Shelves: Y/N

60. Stove on:

20. Floor

Bench/short stool

Dining

61. On bed: Y/N

62. D table accessible: Y/N

Bathroom

63. WC accessible: Y/N

64. Walker frame acc: Y/N

65. Uses toilet seat?: Y/N

66. Sink (Knee sp beneath): Y/N

67. Mirror on WC height: Y/N

68. Sponge use (with cord): Y/N

69. Shower hand or top: Y/N

Clothes

70. Cl area near bedroom: Y/N

71. Can get cl from storage/dr: Y/N

72. Uses reacher to get cl: Y/N

Laundry

73. Separate space av: Y/N

74. Washing machine: Y/N

75. WM> can load/empty: Y/N

76. Laundry basket av: Y/N

77. Clothes hanging area: Y/N

78. Ironing:

21. On bed
22. On counter
23. Separate area

House Cleaning

79. Uses:

24. Mop
25. Broom
26. Vacuum

80. Pail from storage: Y/N

Emergencies/Other

81. In Case of fire: 1. Will call for help
2. Will escape on own

82. Fire Extinguisher: Y/N

83. Owns cell phone: Y/N

84. No of children at home: Y/N

85. Taking care of children: Y/N

86. Help av for child care: Y/N

87. Can shop on own: Y/N

88. Family has vehicle: Y/N

89. Neighbors helpful: Y/N

90. Physician av on phone:Y/N

91. PT av on phone: Y/N

92. Police av on phone: Y/N

93. Fire brigade av on phone: Y/N

Appendix E: Derivation of reflectivity for the Rayleigh scattering regime

For the radars in this study, *everything* is fixed except the following variables: returned power, P_r, reflectivity, Z, attenuation factor L, and range R. All the fixed variables can be denoted by a radar constant, C_r. Hence, in terms of this radar constant, equation (8.1) is now re-expressed as,

$$P_r = \frac{C_r Z L}{R^2} \tag{8.2}$$

Now, the returned power for a point target is proportional to the backscattering cross section, σ and inversely proportional to the fourth power of range,

$$Pr = C\sigma / R^4 \tag{8.3}$$

For a distributed target, the summation of σ is made over the entire resolution volume ($\Sigma\sigma$) and the relation becomes proportional to R^{-2}. The reasoning is that the resolution volume itself is a function of R^2. This introduces the "radar reflectivity" which is the average cross section of the target per unit volume (η).

Assuming homogeneous spherical particles and Rayleigh scattering, which is derived from Maxwell's laws of Electromagnetism, σ is equal to

$$\sigma = (\prod^5/\lambda^4) \, abs(K)^2 D^6 \tag{8.4}$$

Hence η is also a function of D^6 integrated of over the entire particle size distribution. And it is this integral that defines Z, the reflectivity factor. Here, through measurement of the returned power from distributed targets such as raindrops and range, which can be estimated through time-of-flight measurements, calculation of the reflectivity factors of various targets is made possible.

The radar equations are valid for computing reflectivity for one channel, which could be either due to horizontal or vertical returned power. Since the King City Radar uses both channels, reflectivity for the horizontal channel is referred is referred as Zh whereas Differential Reflectivity (ZDR) means reflectivities whereby returned power from both horizontal and vertical channels are used.

VITA

Name: Farrukh Ahmed Chishtie

Place of birth: Karachi, Pakistan.

Post-secondary education and degrees:

California State University, Long Beach
Long Beach, California, USA
1990-1995 Bachelor of Science (B.S.)
Chemical Engineering.

California State University, Long Beach
Long Beach, California, USA
1996-1997 Master of Science (M.S.)
Mechanical Engineering.

New Jersey Institute of Technology
Newark, New Jersey, USA
1997-1998 Master of Science (M.S.)
Applied Mathematics.

The University of Western Ontario
London, Ontario, Canada
1998-2001 Doctor of Philosophy (Ph.D.)
Applied Mathematics (Theoretical Physics).

The University of Western Ontario
London, Ontario, Canada
2002-2007 Master of Education (M. Ed.)
Applied Mathematics (Theoretical Physics).

The University of Western Ontario
London, Ontario, Canada
2007-2018 Doctor of Philosophy (Ph.D.)
Education (Environment and Sustainability).

Honors and Awards:

NASA SERVIR-Global 2017 Global Team Impact Award as Team Leader on “Enhancing Drought Resilience and Crop Yield Security Service Team”

International Centre for Integrated Mountain Development (ICIMOD) first prize for journalists

on media reports on climate change and its effects on the Himalayas.

National Sciences and Engineering Research Council of Canada (NSERC) Postdoctoral fellowship (2002-2004) conducted at Department of Physics and Astronomy, Cornell University, USA

Scholarship for CERN- Accelerator Physics School at Loutraki, Greece (2000).

Robert and Ruth Lumsden Graduate Student Award (1999-2000).

University of Western Ontario Special University Scholarship 1998-2001.

Related Work Experience

Jul 2017 – present	**Science and Data Lead**, SERVIR-Mekong, Asian Disaster Preparedness Center (ADPC), Bangkok, Thailand.
Jul 2016 – present	**Senior Associate**, Theoretical Research Institute, Pakistan Academy of Science (TRIPAS), Islamabad.
Oct 2013 – June 2016	**Head of Department**, Professor, Department of Space Science, Institute of Space Technology, Islamabad.
Oct 2012 – Sept 2013	**Founding faculty member**, Associate Professor, Department of Space Science, Institute of Space Technology, Islamabad.
Jan 2005 – Sept 2012	**Collaborating Scientist,** Theoretical High Energy Physics Group, Department of Applied Mathematics, University of Western Ontario.
Jan 2004 - Jan 2005	**Postdoctoral Fellow and Lecturer,** Theoretical High Energy Physics Group, Department of Applied Mathematics, University of Western Ontario.
Jan. 2002 - Jan.2004	**Postdoctoral Fellow,** Newman Laboratory of Elementary Particle Physics, Cornell University, USA.
June - July 2002	**Member Physicist**, Canadian B-Physics Theory Group, NSERC International Opportunity Fund Grant and the Japan KEK theory group.
Jan.1998 - Dec.2001	**Research and Teaching Assistant,** Department of Applied Mathematics, University of Western Ontario.
Jan 1997 - Jan 1998	**Research and Teaching Assistant**, Department of Applied Mathematics, New Jersey Institute of Technology.
Jan 1996 – Aug 1996	**Chemical Engineer**, Measurements of fugitive air pollution and calculation of fines as directed by the Air Quality Management District California, at Avanti Environmental, Irvine, California, USA.

ADDITIONAL WORK EXPERIENCE

Jan 04 – present **Head**, Research and Development
Subh-e-Nau: An Environment and Public Health Concern
Completed various public health and environment related projects focusing on disability (in regard to 2005 Northern Pakistan earthquake) and communicable disease due to flooding and displacement (in regard to 2010-2014 flooding across Pakistan).
Editor, The Monthly Subh-e-Nau
Pakistan's first magazine on Environment and Public Health

Jan 2012 – Sep 2012 **Consultant, Medical/Public Health Education**
Department for International Development, UK, (Technical Resource Facility), Islamabad, Pakistan.

Sep 2007 – Sep 2011 **Research Assistant**, Faculty of Education, University of Western Ontario Research on Education Policy and Curriculum in Pakistan and Canada; INSPIRE (Interdisciplinary Network for Scholarship in Professions' Research in Education) an interdisciplinary initiative between Rehabilitation Sciences, Schulich School of Medicine and Dentistry, and Faculty of Education.

ADDITIONAL CURRENT DESIGNATIONS

Jun 2009 – present **Chair**
Pakistan Working Group, International Center for Disability and Rehabilitation (ICDR) Department of Rehabilitation Sciences, Faculty of Medicine, University of Toronto, Canada.

Sept 2012 – present **Visiting Scientist**
King City Radar Facility, Weather Radar Research Station, Environment and Climate Change Canada, King City, Ontario, Canada.

Oct 2012 – present **Collaborating Scientist**
High Energy Physics Group, Department of Applied Mathematics, University of Western Ontario, Canada.

Jan 2015 – present **Visiting Professor**
Theory Group, CERN, Geneva, Switzerland.

Jul 16 – Jul 2017 **Adjunct faculty**
Geospatial Research & Education Laboratory (GREL), Institute of Space Technology, Islamabad