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Theseus 24D: From Pilot to Commercial CCS MMV Programs

Lee Hunt, Carbon Alpha
Eric Street, Carbon Alpha
Graham Hack, Carbon Alpha
Jason Schweigert, BJV Design Inc.*
Matthew Allen, BJV Design Inc.

Introduction

Don Lawton is Director of Science of Carbon Management Canada (CMC), and in that role and others he has added tremendous value to our collective and growing understanding of carbon capture and storage (CCS). He has been involved in the early stages—the pilot stages—of numerous CCS projects. There is a real value in a pilot study, and likely a profound feeling of satisfaction in being involved in them. Pilots explore how things *can* be done, and sometimes even *if* things can be done. Perhaps most importantly they may also guide us all in the direction of how things *should* be done.

Theseus 24D is a seismic measurement monitoring and verification (MMV) method for onshore CCS that attempts to take key learnings from pilot studies such as those Don Lawton has been involved in and moves them into a more commercial footing. We believe these pilot studies have identified some critical information, and that this critical information can be used to conduct MMV in very *non-pilot* ways. We also developed elements of the Theseus 24D approach by considering how the construction of a pilot study—by certain elements within its very nature—drives the experiment in non-commercial directions. A pilot can do this, and perhaps it must do this, because a pilot is free to explore ideas without the burden of commercial, at-scale, economics. At least to some extent. While there are great advantages in this relative freedom, the commercialization step must consciously recognize this difference.

We do not bring up the relative bias differences in pilot studies versus commercial work lightly or in a pejorative way—this recognition is important. A big part of developing through pilot to commercial methods is the need to test and to learn. A pilot study is probably most successful if it leads to someone saying, “Well I wouldn’t do it that way again,” or even better, “I would do it this way now.” We need to look at what is done critically, as this is the intention of the exercise.

What is Theseus 24D?

The seismic elements of CCS MMV can cost as much as 50% of the entire MMV budget. The problem with this is that there are many other methods of performing MMV, and each of them require capital investment. Seismic is unfortunately the costliest of them. This amount of capital might be justifiable if seismic added sufficient unique value to the MMV problem. We could certainly draw justification for the capital that seismic uses if that capital level is necessary. But we argue that seismic MMV is profligate and wasteful. Too much of what is shot in repeat seismic MMV experiments is unnecessary. Theseus 24D addresses this.

Consider the Ship of Theseus thought experiment, which focuses on the sailing vessel of the mythical Greek hero, Theseus. After the passing of many years and adventures, one of the planks of Theseus’ ship rots and is replaced. Is the ship still the original Ship of Theseus? Many would say yes. Over the long and inexorable march of years, one by one, each plank is replaced until none of the original planks remain. Is this still Theseus’ ship? This question has been debated since the time of Plutarch. We can certainly deliberate on this ancient philosophical problem over identity, but what we probably will not argue about is that we only

ever replace the rotted planks. We do not replace the good planks; when one plank rots, we do not replace the whole vessel. And yet, seismic MMV for CCS does just this. We shoot a baseline 3D, then we shoot repeat seismic that images a CO_2 plume, and another repeat seismic program that images the same CO_2 saturated rock plus a little more (for the plume front has advanced), and then yet another seismic program which images once more mostly rock that has already been saturated by CO_2 and has already been imaged by seismic. Most of the repeat seismic did not need to be repeated; we replaced far too many planks, wasting capital, and unnecessarily disturbing the surface environment again and again.

Theseus 24D is more efficient (or wastes less planks in the Ship of Theseus analogy) through several key means, including:

1. By choosing seismic methods that are more pragmatic to onshore CCS projects and the primary goals of the seismic. As part of this line of thinking, we discard VSP surveys, which are commonly used to good effect in pilot studies.
2. By minimizing the excess amount of repetition, or redundancy, in the area covered by the repeat seismic surveys. We do this by redefining monitoring areas.
3. By integrating all seismic activities and their scheduling. This is principally through the integration of repeat 2D and 3D in a method we call 24D. The endpoint of 24D considers the minimization or even elimination of repeat 3D surveys, which is a stark contrast to the scheduling of some pilot studies.

Value

We show that the value that the Theseus 24D method might bring, in a relative sense, depends on many things, including the regulatory environment, nature of the storage complex, the injection volumes and how far we take the Theseus argument. We will explore two cases:

Case 1: We use the Theseus strategy to streamline scheduling and re-define repeat 3D design areas to minimize the replacement “planks” in repeat 3D surveys. We first derive an analytical formula describing the controls on efficiency, and next give an example where this saves 26% in capital and about 30% in environmental disturbances.

Case 2: We take the 24D aspect of Theseus to its extreme endpoint and eliminate repeat 3D surveys altogether. In our example case, this results in a capital savings of 57% and reduction in environmental disturbances of 96%.

We hope to use these examples to provoke a discussion over the validity of our arguments.

Experiment

Central to case 2, above, is the strength of the claim that a seismic MMV program that costs so little and has no repeat 3D surveys could still achieve the goals of MMV which are to assure the containment and conformance of the CO_2. We explored this problem through a series of 3D design evaluations followed by a 3D ray-tracing and processing experiment. This case study investigates the ability to use 2D and 3D in an optimal repeat seismic schedule. Further, the experiment evaluates the design of the baseline 3D in enabling this integration and assesses which baseline 3D is most appropriate for such an MMV program.

Connection to further work

This talk is an amalgam of three talks that will be given at the 2024 GeoConvention. Those talks are:

1. *Theseus Onshore CCS Seismic MMV Strategy*, which outlines the conceptual strategy of Theseus 24D.

2. *24D Onshore CCS Seismic MMV Tactic*, which explores the 3D design details of the 24D idea, a key tactic within the Theseus strategy.
3. *24D Onshore CCS Seismic MMV Experiment*, which summarizes the results of a model experiment in 24D seismic design.

What will separate this presentation from those talks given at GeoConvention is the concentration of information and ideas. Come ready to be provoked.

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