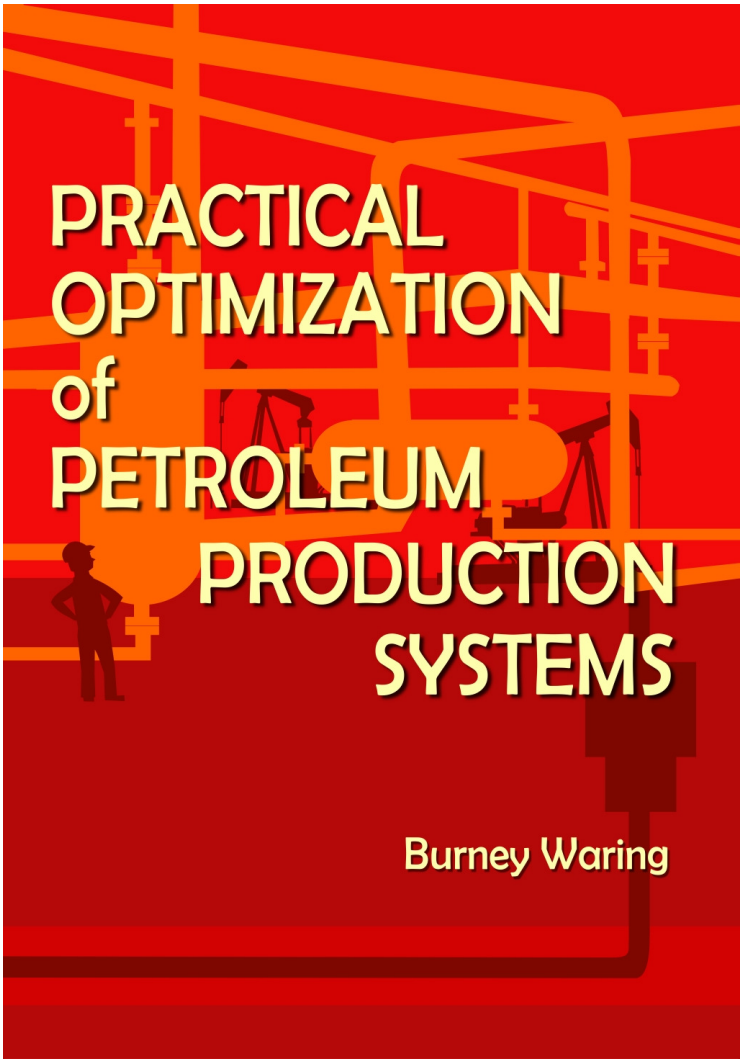

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PRACTICAL OPTIMIZATION of PETROLEUM PRODUCTION SYSTEMS

BURNEY WARING

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Dedicated to Debbie, who made it all possible.

CONTENTS

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This book is the result of 35 years of unique experiences that were only possible because of my mentors, friends and colleagues. I was incredibly lucky to have met them.

I'm indebted to my friends at Royal Dutch Shell. Thanks for giving me 29 years of amazing experiences. Halfway along I turned from student to teacher, but I never stopped learning because there were always plenty of brilliant, patient people around. Special recognition regarding the topic of this book goes to Pieter Kapteijn, inventor of the Value Loop. And to my friends in the WRFM team: Aimara, Fidelis, Harri, Semiramis, Clement, Frank, Frans, Marc, Reinier, Peet and Stuart. Working with you was a priceless education.

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Finally, thanks to Patricio Panichelli who suffered through my whole draft and provided countless helpful suggestions. You are a star, Patricio!

1

BEGINNING

"No, not that one!" Johnny is a smidge irritated. I'm more than a smidge ignorant and confused, so his irritation isn't unexpected. "I'm telling you, it isn't the surge vessel that's the problem," he says. He leads the way downstairs, away from the enormous, heavy and expensive steel pressure vessel, installed a few months earlier. I hope he is right. There is probably no way to fix that monster any time soon, or at a cost the company would be willing to pay. Walking downstairs, the sea breeze helps with the heat and humidity that is the Gulf of Mexico in summer. "There's the problem," Johnny says, pointing at the second stage separator that takes the liquid from the surge vessel. "That sucker has overflowed twice. That's why you have to keep them from putting on any more production. This platform is at CAPACITY!" I don't like people to scream at me, but I appreciate him making things clear to me, a very green engineer whose day got exciting at 6am on the tarmac at Lakefront airport as the Bell helicopter launched into the New Orleans dawn and headed south. The news about the problem separator, if true, is good. This second-stage vessel is much smaller than the monster surge vessel. The smaller vessel was reclaimed from the old equipment during last year's refurbishment, and is in a better spot, near the outside of the deck. So probably the whole vessel skid could be replaced. Still, it would be a very expensive upgrade, I thought.

I was wrong.

I stand in the breeze and consider this second-stage vessel, the one that seems to be restricting production from the new platform 29 miles away. Last year's project massively increased the capacity of this old platform and was brought in on-time and under-budget by Don, the Senior Facilities Engineer. I don't yet appreciate how rare this is. Don has already moved on to his next big project. My first real project, to

install a test facility and manifold on the new platform, has just been commissioned. The oil from the new wells on the new platform flows to this old platform. The surge vessel absorbs the big slugs in the 29-mile multiphase line and sends the liquids to this second-stage vessel. Don's masterpiece is working as expected, and is at capacity. Unfortunately. Well, not really unfortunate at all—the new wells are better than expected and their production rates are not yet at their full potential. The team asked me to see what could be done to find more capacity. They want more production and are wondering why we didn't provide even more spare capacity in the first place. Of course, if Don had done that then the same folks would have beat up Don with the over-expenditure stick. But I don't know that yet. As a one-year engineer, I'm trying to take it all in, but I really have no idea what I'm doing. Johnny, standing next to me, is not going to magically provide the answers. I have a camera and start to take pictures. [In those days, no one asked if the camera was explosion-proof or intrinsically safe. I'm sure it wasn't.]

The picture-taking is going well and I'm starting to think about the heli-ride home. I notice that the oil outlet nozzle of the smaller separator routes through some skinny-ish pipe. Since the liquid from the new wells is mostly oil, that pipe is carrying most of the new field's liquid production. And look, that's a small dump valve that it routes through. "Johnny, Is that a pretty small dump valve?" I ask, hoping for some help. "I don't know, but it is wide open," he says. We watch a while. The valve stays fully open. I think this means something. "If it is wide open then it can't do any more. The valve is at its capacity. Right?" Johnny agrees. "So that valve right there is the whole problem?" I ask. "You're the engineer," Johnny says unhelpfully.

I am surprised and happy. This will be a cheap fix. Some more pictures, then off into the wild blue and home.

With some help back at the office, I designed a few feet of 2-inch piping that would split the flow into two 2-inch control valves, doubling the oil outlet capacity. Three weeks later the assembly was fabricated in a construction yard then installed offshore. For a cost of $20,000, oil production was increased a couple thousand barrels per day for at least the next six months. That's about **6 cents per additional barrel**, maybe less. I was very pleased with myself.

Naturally, this was not a significant event in anyone else's life, but I remember it because it was the first time I had increased production from an existing field. It was also the first and only time in my brief Facilities Engineer assignment that I could see a direct connection between my own actions to the company's bottom line. Managers say, "You need to help our bottom line!" all the time. It is hard to see how attending the monthly meeting or making the weekly forecast help that line. But, adding barrels to the tank for the **lowest possible cost**, that was easy to see!

I didn't know at the time, but that was the beginning of my strange path-much-less-traveled, to the often-neglected area of ***Production System Optimization*** (PSO). While most of my colleagues fought for assignments in greenfield developments, I found plenty of low-hanging fruit and satisfaction in the brownfields.

Do you have an internal scorecard? I think many people do. Mine became 'cost per barrel gained'. My supervisors were more interested in the number of workover and completion proposals I could produce a month. Naturally, my performance reviews were, shall we say, 'variable' in those days. But, when they let me, I got to see the fruits of my efforts doing simple jobs that paid out quickly. On this path, I found plenty to learn and over time managed to invent a few things of my own.

And, after those first years, I never needed to fight for my next job.

The Joy of PSO

People often give me a blank stare when I mention 'Production System Optimization'. A few people are passionate about it. What about you? For example, remember how you felt when…

> You saw that only a dump valve was restricting your production, not the size of the separator.
>
> You found your well was gas lifting through a leaking valve, 3 mandrels too high.
>
> The zone you thought was completely watered-out was not producing at all.
>
> Your Operations Tech told you how to easily eliminate the platform's water overboard constraint.
>
> You found that those three wells that were shut down because of high GOR actually had normal GOR.
>
> You found the compressor scrubber inlet had been partially blocked with gloves and welding rods.
>
> You found twelve well chokes that were 'fully opened' but still causing 50 psi of extra backpressure.
>
> You realized you could put your high-pressure well in your low-pressure manifold.
>
> You found three wells that were choked back for sand production were not producing sand at all.
>
> That strange 70 psi of pressure drop turned out to be from a decommissioned 6- inch gate valve with a 4-inch port.
>
> You discovered that it was pretty cheap to relocate a small compressor to help out some good wells.
>
> You found a plugged gravel pack was causing a huge drawdown in a good well.
>
> You realized that adding a second pipeline would be better and cheaper than drilling a new well.

I know how you felt. You felt GREAT! VICTORIOUS!

It's because you had just found a valuable, low-cost optimization opportunity proving yet again that you are a heroically spectacular engineer!

If you have not had that special feeling of massively profitable, quick PSO success, that makes me sad. This book can help you.

How could PSO get any better?

The Society of Petroleum Engineers defines a Production System as

> *"The system that transports reservoir fluids from the subsurface reservoir to the surface, processes and treats the fluids, and prepares the fluids for storage and transfer to a purchaser."*

If your job is to help manage such a system, then of course you are interested in making the most of that system in the short and medium term. You know that good optimization opportunities can lead to a reduction in a field's cost per barrel. Right?

What could be better? Well, have you ever thought about how you might more ***consistently*** find optimization opportunities in your Production System?

Perhaps you are an outstanding optimizer but find it difficult to ***lead*** your team/division/company to more consistent PSO glory?

In this book, I describe common challenges in optimizing production systems. I explain a wide variety of techniques and tools that will help you maximize the value from your production system. These are methods I have successfully used and refined over the past 34 years as a practicing engineer and consultant. In only the last 5 years, I have helped companies find and create economic PSO projects totaling almost a billion USD (net present value).

Why I Wrote This Book

There are oil and gas fields producing right now that could produce an additional 10-20%, very profitably—perhaps with no additional investment at all. There are engineers working hard right now to do the best they can for these fields, so how can this be? They have not been taught how work together to find certain types of opportunities. In fact, although they have been taught a full range of petroleum engineering skills, it is not likely that they have been taught how to treat their entire asset as a system that can be systematically optimized. This really distresses me!

I define the work of finding opportunities in the production system and turning them into value, '**Production System Optimization**'. PSO is a deep and fruitful line of business. It is also quick and cheap. Other areas of the business (such as new wells, EOR etc.) require senior management approval of millions (in some cases billions) of dollars and take years to materialize. The best thing about PSO is that there is a direct link between your individual abilities and your asset's success. You can make a direct difference to your asset's bottom line. You can do more with less money than anyone else can. You can see results before the drilling department even gets their permits.

Doing PSO, you personally tap value that would otherwise be trapped in the production system. You do the most profitable work in the oil and gas business. You learn skills and gain experience that can be used in any E&P company. **You have the most fun an engineer can have at work!** I hope this book helps you, a new or experienced Reservoir, Production or Facilities engineer, or a team leader, have more fun, while increasing the value of your asset.

This book contains my personal philosophies, thoughts and stories. I enjoyed receiving the same from my teachers and mentors and often wish that they had written down their stories. Stories bring with them a context which helps people utilize and remember related information. I have included many of my favorite stories herein and I hope you will enjoy them. I hope my ideas and stories point you toward your own optimization solutions.

There are two ways that you can use this book:

The first is pick up some techniques that can improve your own asset PSO efforts. As you read the book, make some notes and begin a 'to-do' list of potential changes and new tools that you can incorporate. The Health Check at the end of each chapter can be used to prompt you to look at areas that might need improvement.

The second way you can use this book is to improve your team's, division's or company's way of managing the operating phase of asset life. Each chapter of the book contains suggestions on managing the PSO process. The chapter on Sustaining PSO provides information useful for changing organizational practices and sustaining new practices over time. Start making a list of changes that would add the most value and use the Sustaining PSO chapter of the book to draft an improvement plan.

The Value of PSO

Finding additional production gives me joy and I hope I can convince you to feel that way too. There are sound business and societal reasons for a sustained interest in and joy of PSO.

Business Value

The lack of an sustained, effective effort in optimizing existing assets leaves behind hidden, lowest-cost-per-barrel opportunities. As I write this, the oil price is around $30/bbl and the industry is going through another severe reduction in spending. If your company needs to borrow money to drill more wells, the bank might not want to loan them another $100 million. But, you might be able to find $50,000 and use it to clean out a flowline or install gas lift valves deeper in a well. That might be worth 200 bbl/d oil. Over a year, that might be worth $2 million of revenue. So, even when the oil price is low, you should be able to find that $50,000. Your company should retain some staff to work on PSO, no matter the oil or gas price.

My PSO reviews have typically found opportunities worth about 20%-30% additional production. A company that institutes a permanent PSO process should find a level of additional production sustained over time.

Imagine a medium-sized company that makes changes and institutes a permanent PSO process. A company that produces 2 million barrels of oil per day and could increase that by 20% will (at $50/barrel, after expenses), generate an extra $7 billion per year! That's 400,000 barrels per day of the cheapest possible oil.

Societal Value

My generation of engineers did not spend much time thinking about how our industry affected society. When we did think about it, there was probably an oil spill happening. Our industry has the reputation for being greedy and not caring about the rest of society. Perhaps we deserve that, in part. With all the bad press, it's hard to think otherwise. I mean, **what good do *you* do** by working in the oil and gas business?

No one quantified this for me, so let me help you.

Continue with the assumption a company might generate an extra 400,000 barrels of oil per day with sustained PSO. At a consumption rate of 60 barrels/1000 persons in the US, an extra 400,000 barrels of oil per day is enough to sustain the lives of **6.6 million people** (for example, the entire state of Indiana), every day! Using the UK's more efficient 26 barrels/1000, that is enough for **16 million people** (the population of London plus all of Scotland and Wales), every day, meeting all their oil needs.

I think I embarrass or overwhelm engineers when I bring up their value to society. It is as if they have never considered such a thing before and have no framework to take in this information. One engineer reminded me that it was all a big team effort, so he wasn't sure he deserved much credit. He was right about the team effort, but when you wonder if you are personally making a difference, you should try some quantification. I used the production rate (2 million bbl/d oil) and number of employees (19,000) from his company's annual report, and then calculated the barrel per day produced per employee (2,000,000/19,000=105). Using the consumption ratio of oil per US person, I calculated that **each employee in that company, on average, sustains the lives of about 1,750 of their neighbors** (105/(60/1,000)=1,750). The numbers for natural gas are even larger.

Hydrocarbons are a necessity in our society. By any measure, your personal contribution to a large number your neighbors' way of life is worthy of high praise, not condemnation.

Since we are all concerned about society and the environment, then where people get their oil and gas matters. PSO helps to minimize the negative impact our industry has on the environment by maximizing the profitable use of ***existing*** wells and equipment. PSO helps minimize the need for additional oilfield development in order to meet production demands. Whether you are a person or a company, it should be common sense to make the most of what you already have.

Structure of This Book

My explanation of PSO and how to improve it can be divided into 6 parts:

1. **Introduction to PSO**: A background on my philosophy toward managing and optimizing fields, explaining terminology and the basic structure of Production System Optimization
2. **Data Acquisition**: The purpose of data, types of data, value of information, how to ensure the right data is acquired, data error and error propagation, measurement tips, error reduction tips, and data acquisition planning
3. **Surveillance**: The purpose of surveillance, cycles of surveillance, methods of anomaly identification, modeling and calibration for surveillance, data visualization, examples of surveillance successes, exception-based surveillance
4. **Optimization**: Definitions of optimization, requirements for optimization, practicality of optimization in oil and gas fields, types of optimization and common mistakes, optimization techniques for teams, PSO meeting structure
5. **Implementation**: Prioritization and planning of opportunity implementation, scenario optimization, looking back at implementation performance, use of After Action Reviews
6. **Sustaining PSO**: The special difficulty of sustaining PSO, methods of sustaining PSO, designing an improvement plan

I have included health check questionnaires at the end of each chapter that you can use to create your asset's or company's improvement plans. I have also included some key performance indicators that you can use to manage your PSO process.

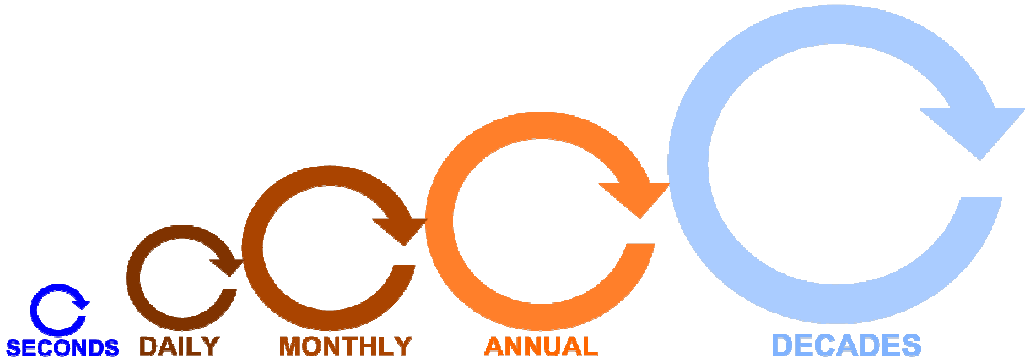
Defining PSO

Here is my definition:

'Production System Optimization' is the process of maximizing value in an existing production system by making changes in the short and medium term.

Why 'production *systems*'? Optimizing individual components in a system (e.g. improving the rate of one well) will not optimize the greater system (e.g. due to back-out effects, power constraints, or reducing lift gas from other wells).

Why restrict PSO to the *short and medium term*, i.e. daily to annual cycles?



PSO is thereby differentiated from ultra-short term Real-Time Optimization (RTO) tools such as distributed control systems and local control and optimization strategies that operate on the level of seconds. That cycle operates without human input.

PSO is thereby also differentiated from long-term optimization processes, which are mainly about Field Development and operate over years and decades. That cycle requires a huge team to be involved and operates without much feedback to team members.

The daily, monthly and annual cycles I call 'PSO' have the same small number of people involved and they benefit from many cycles of observing, changing and learning together.

The terminology used for PSO is inconsistent like it is for many other terms commonly used in the oil and gas business. Others refer to PSO as 'Production Optimization' or 'Production Enhancement' along with many other similar terms. But some of these terms lack the "system" context. Optimization of individual parts does not lead to an optimum system as a whole, so I think the word 'system', 'field' or 'asset' needs to be included. Others include the word 'integrated' instead of

'system'. 'Management' is sometimes included rather than 'optimization'. That's fine. No problem what you call it, as long as it gets done well and consistently by the right people.

An engineer contemplates PSO

However, this group of terms regarding PSO may refer to mathematical optimization techniques and/or to a broader definition of multi-discipline optimization of field production. It is important that you have both aspects in your PSO work. I will describe them in the sections below.

Mathematical Optimization of Production Systems

The petroleum industry technical literature most often uses the word 'optimization' to refer to the use of optimization algorithms acting on numerical models.[1]

In 1992, the first user-friendly commercial software to model and optimize whole fields was introduced by Petroleum Experts of Edinburgh, Scotland. The capability to model and optimize fields mathematically has continued to grow and evolve. Today there are several such tools available. I call these **Integrated Production System Models**. These are highly useful tools to help with PSO. They are amazing, but they are not omnipotent. It is very hard in real systems to find 'The Optimum'.

Consider the difficulty of optimizing a real production system. If you try to find the optimum arrangement of 50 wells into two production headers (for example a low-pressure header and a high-pressure one) there are 1125 million million combinations. If you try to also choose between 10 gas lift rates and 10 choke settings, the number of combinations is literally astronomical. Then there is the nonlinear nature of most of the system behaviors. And, there will be multiple constraints in any given system. If the calculation time of each system state was nearly instantaneous, then it still might be practical to explore the whole optimization space. Unfortunately, phase behavior, thermal flows, and multiphase flow correlations all take some time to calculate.

[1] Of course, PSO is not a new idea, but I did try to find its first use with the definition it has today.
Chu and Evans wrote a paper "Production system optimization for natural flowing water drive wells" in 1983 about system design optimization which includes inflow performance, outflow, choke flowline and separator.
Something close to this definition can be found in Kermit Brown's 1984, Vol. 4, section 4.9 as "Field-Integrated Oil-Production System" which refers to optimization of a whole production system.
The phrase is found in Jim Lea and Willie Iyoho's paper "Production System Optimization: Model Applications, Capabilities, and Pitfalls", 18220-MS SPE Conference Paper, published in 1988. PSO is "total production-system analysis useful for economical design of well inflow parameters, sizing of tubulars and accessories, and determining well flow constraints", as well as flowline and production separators sizing.
A master's thesis by JA Carroll, "Multivariate Production Systems Optimization", was published in 1990. It gives a background of prior optimization of sub-systems such as numerical pipeline and reservoir optimization and is itself focused on numerical optimization of wells.
Dale Beggs published a book in 1991 called "Production optimization using NODAL analysis" which has a chapter on 'Total System Analysis', and discusses reservoir models, well inflow, well outflow, chokes, and flowlines.

It is better to modify the goal from finding 'The Optimum', to a more practical goal of improving significantly from the current situation, perhaps by 5 or 10%. Wouldn't that be great? (My optimization teams have never found less.)

While the mathematical optimization of systems is a useful tool that can sometimes be applied, there is another definition of PSO that I think is more important.

Multidiscipline Optimization of Production Systems

As I said earlier, the industry technical literature most often explores mathematical optimization of production systems. The broader sphere about improving existing asset value (of which numerical optimization techniques are one small, important part) is less explored[2], and requires multidiscipline teamwork to truly be *system* optimization.

The following history is my own experience with multidiscipline optimization at Shell and my consulting business. I am sure that there have been parallel efforts in other companies, some that will have pre-dated these events. If you have similar stories, please let me know. I would love to hear them!

In 1993, Shell's leadership issued a series of Technical Challenges to its operating units. TC-3 was a 'barrel chasing' effort to boost production, primarily ad-hoc events by teams from Shell's international head office working with engineers from Shell's operating units. This challenge continued for 2-3 years.

In 1997, Shell began '***Produce-the-Limit***' , sometimes known as 'Producing-the-Limit' or simply 'PtL' events. Unlike previous production boosting efforts focused on wells and run by Production Engineering with help from Operations, these were formal multi-disciplinary reviews, usually organized by Production Engineering, with active participation by Reservoir and Facilities Engineering and often Production Planning, Petrophysics, and Geology. These two-week events were highly structured and very intensive. The teams were dedicated solely to the review effort for the entire two weeks. Each team was made up of discipline engineers from the asset under review and led by very experienced senior staff from Shell's head office. They simultaneously reviewed reservoirs, wells, and the related surface facilities. These reviews were very successful, **increasing production by 10-30% in most fields** and

[2] 'Less explored' if you want to read about how to do it. Many companies offer services to do it for you. An internet search for 'production optimization oil' turns up over 200,000 results, although many people/teams/groups are focused only on wells and artificial lift.

covered virtually the whole of Shell's portfolio of assets. PtL continued for about 10 years, finally stopping partially because the assets had been well-optimized so the gains were reducing (more on the Optimization Paradox in the last part of this book), and partially because organizations, like people, have limited attention spans. Ten years was an amazing run for such an effort in Shell. Thousands of engineers participated in these reviews. I was lucky to be a part of the first PtL event, participated in several more over the years, and later taught classes of engineers how to run their own PtL events.

PtL is widely recognized as a successful, broadly-applicable method to boost value in existing fields. Variations have been applied by ex-Shell engineers in several other companies. BP had its own version of PtL events imaginatively named "Production Technical Limit." I heard rumors of several other companies, and at least one service company running versions of PtL workshops.

While PtL was near its end in Shell, in 2006, Petroleum Development Oman, a joint venture company of Shell, invented a new term 'Well and Reservoir Management'. This was adopted by the Shell globally and changed to **'Well, Reservoir and Facilities Management' (WRFM)** in 2010.

> *"WRFM is the art of extracting maximum value from our oil and gas assets by understanding and optimising the performance of our reservoirs, wells, and facilities all the way from the oil and gas in the pores of the reservoir through the reservoir to the wells, through the wells to the flowlines and facilities and then on to the sales point where we get paid."*[3]

WRFM was rolled out globally in Shell, sponsored by the most senior management, with a VP managing the team. The multidiscipline team consisted of a dozen or more very senior engineers who were practitioners of optimization, plus various consultants and even a Change Management expert. As the successor of PtL efforts, WRFM added a continuous process and was designed to be a permanent process.

After retiring from Shell in 2010, I started my own consultancy. In 2011, I did my first PtL-type review for another company. This was based on principles I learned at Shell, but with a streamlined process. In 13 events, primarily for two medium-sized companies, our teams identified opportunities to increase production by 53% production (the median was 35%). In each event, we organized the opportunities into projects and got approval to proceed with them. The total net present value of

[3] From: http://www.ifea.no/wp-content/uploads/2012/02/R_Hellerud.pdf, downloaded 1/30/2016.
Also, see SPE-128834, "Well and Reservoir Management Project at Salym Petroleum Development" for a general description of time spans and more definitions.

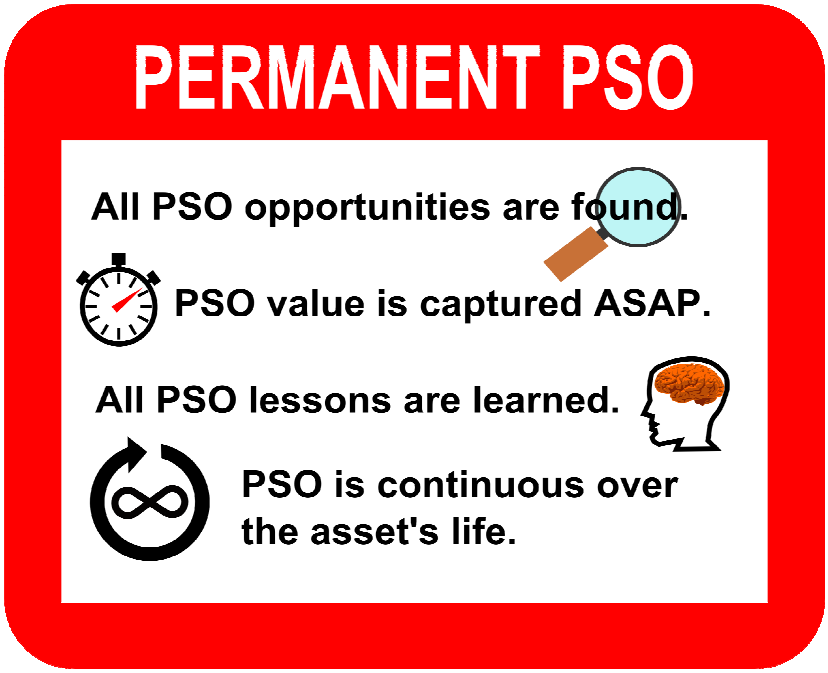
the resulting 13 optimization projects was about 1 billion USD and highly profitable. I taught one of these companies to perform their own PtL reviews and they continue to use PtL reviews for their optimization efforts.

By 2012, I was convinced that my customers would benefit from instituting some sort of managed, continuous PSO process, and so I developed and gave multiple classes on this topic. To me, this book was a logical next step.

Permanent PSO Defined

The topic of 'Production System Optimization' covers anything that tries to optimize system value, including single discipline efforts, as well as periodic, multidiscipline PtL-like reviews. WRFM is Shell's method to make this into a continuous process—that is something organizationally very different, and much better.

I find the term 'WRFM' too vague and a bit long. I call my process of getting and keeping existing assets optimized 'Permanent PSO'. In simple terms, it can be described as a system that meets these objectives:



Challenges of Permanent PSO

PSO is core engineering work of oil and gas producers. It is creatively challenging, valuable, and cheap. So, why might a defined, permanent PSO process not be implemented in every company?

Here are four reasons:

1. PSO Is Multi-disciplinary

This is work that requires deep, continuous, high-bandwidth connections between engineering disciplines. New engineers are trained to specialize in a given discipline so that they can generate value as soon as possible. Most mid-career engineers are doing or leading large engineering projects within a discipline. Even with the advent of multi-discipline teams of engineers working on assets, the communication skills and allotment of time required to focus on optimizing *across* all disciplines are not sufficient for Permanent PSO. True teamwork requires creating things together. In brownfield operations, the goals may be common but there are few common system-level activities that require Reservoir, Production, and Facilities Engineering teamwork. Well maintenance plans, facility maintenance plans, reserve calculations, forecasts; these are often accomplished with just one discipline, perhaps two. No one person gets the full view of the system.

2. PSO Is Overshadowed by Development

Think about these projects:

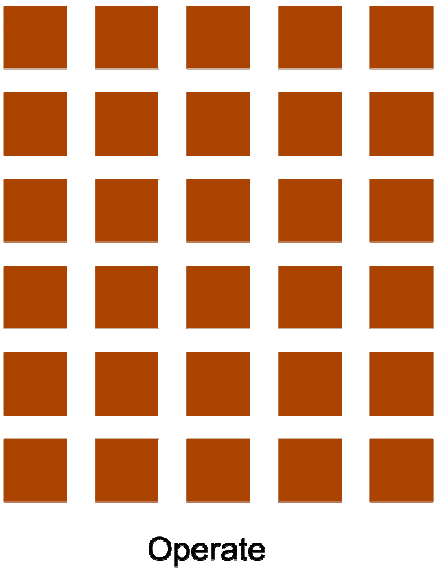
> Spending $4 billion on a new platform which has to come on stream in less than 3 years.
> Feeding new well plans to a drilling rig which costs $1 million per day on stand-by.
> Planning hydraulic fracturing work on 1500 wells over the next 5 years with an ever-evolving drilling schedule.

Development projects are scary enough to be exciting. They hold the full attention of the teams that work on them and, of course, of senior leadership.

Mixing Development projects with Production projects is a disaster for Production which, under normal circumstances, has lower urgency and smaller costs. The two exceptional circumstances are safety-critical projects (e.g. repair the pipeline before it leaks) and projects to restore production when things fail (e.g. repair the export pipeline that is leaking). Neither of these circumstances are about optimization. Optimization projects in Production teams can always wait a bit longer, and if they fail the consequences in terms of costs and production are small relative to Development projects. This was understood long before I first started working in the industry, and is why Shell Offshore had a Production Division separate from a Development Division. Talent and attention turns away from brownfield Production projects when there is an opportunity to work on Development projects.

It is a bit difficult to rationalize this thinking, however. Perhaps a Development project takes 7 years to get in place, including finding the field, designing the facilities and wells, installation of the equipment, then drilling, completing, and hooking up everything. These phases are where the big *costs* are.

But, consider the other part of a field's life:



All the *revenue* is produced in the next phase, Operate, which requires perhaps 30 years. Isn't it incredibly valuable to have high-quality, focused, systematic, well-funded data collection, surveillance, and optimization work during those 30 years? Given our industry's inherent uncertainty, perhaps it is even more valuable to be able to learn from operating a production system and to be able optimize this revenue stream than it is to develop the field initially. Those 30 years should be filled with thousands of small, coordinated projects across the production system to maintain maximum value (usually this means to optimize production levels).

3. Leaders Have Less Experience, Expectations with PSO

As a result of the previous point, it is entirely possible, perhaps likely, that your leader has not had a meaningful assignment focused on PSO. They very likely have not had any assignment as a part of a multi-discipline team with the primary focus on PSO. The faster the career path of leaders in our industry, the less likely it is that they spent much time on PSO tasks.

4. The Oil & Gas Industry Had It Too Easy

Other industries, for example auto manufacturing, airlines or grocery stores, optimize in the face of thin and narrowing profit margins. The successful companies hold on by virtue of their ability to optimize operations. They take over less efficient businesses and increase performance by applying their optimization techniques at a larger scale. They apply measurement tools, control systems, highly-structured processes, and statistical analysis to reduce costs and improve quality. Contrast this with any number of fields that can never seem to afford basic SCADA systems, outsource their artificial lift support, or have no Facilities Engineers working in the asset team.

When the price of hydrocarbons is high, the oil and gas industry chases new developments. When the price of hydrocarbons is low, the industry focuses on cost reduction and there is no appetite for trying new things. Overall, there has been enough profit to sustain the industry. So, why optimize?

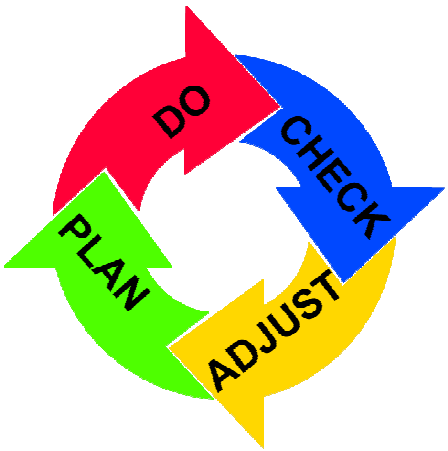
A few enlightened companies will consider changing their core processes to improve existing asset profitability. I hope this book might help the reader lead such efforts.

What Does It Take?

As with most everything, the ingredients for PSO can be broken into Process, People, and Tools.

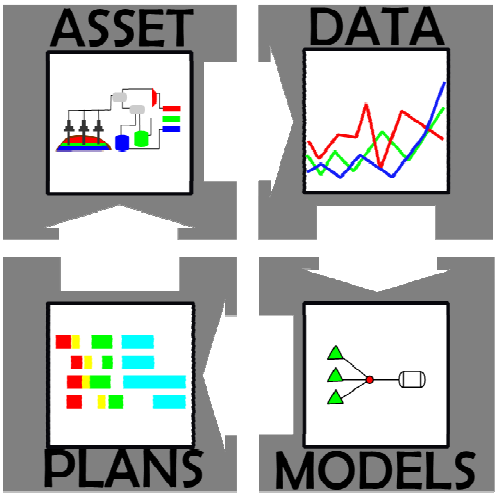
PSO Process

Every process is a cycle. If you want to improve a process, there is a whole field of study called Continuous Performance Improvement (CPI) dedicated to this. If you are familiar with CPI, then you are likely familiar with the Shewhart Cycle, also known as the Deming Wheel:



Some of us know this as the "Plan, Do, Check, Act" cycle or PDCA. I like the variation "**Plan, Do, Check, Adjust**" because I can never remember what 'Act' means. Permanent PSO is like a PDCA cycle.

What are the steps of the PSO process cycle? Let's start with *things* found in our field that are involved in Optimization: Assets, Data, Models, and Plans.



Assets, Data, Models, and Plans are *things*. What *actions* do engineers take on these things in the PSO process cycle? We take the following actions:

1. **Acquire Data** from the assets in sufficient quantity and quality to be able to make the correct optimization decisions

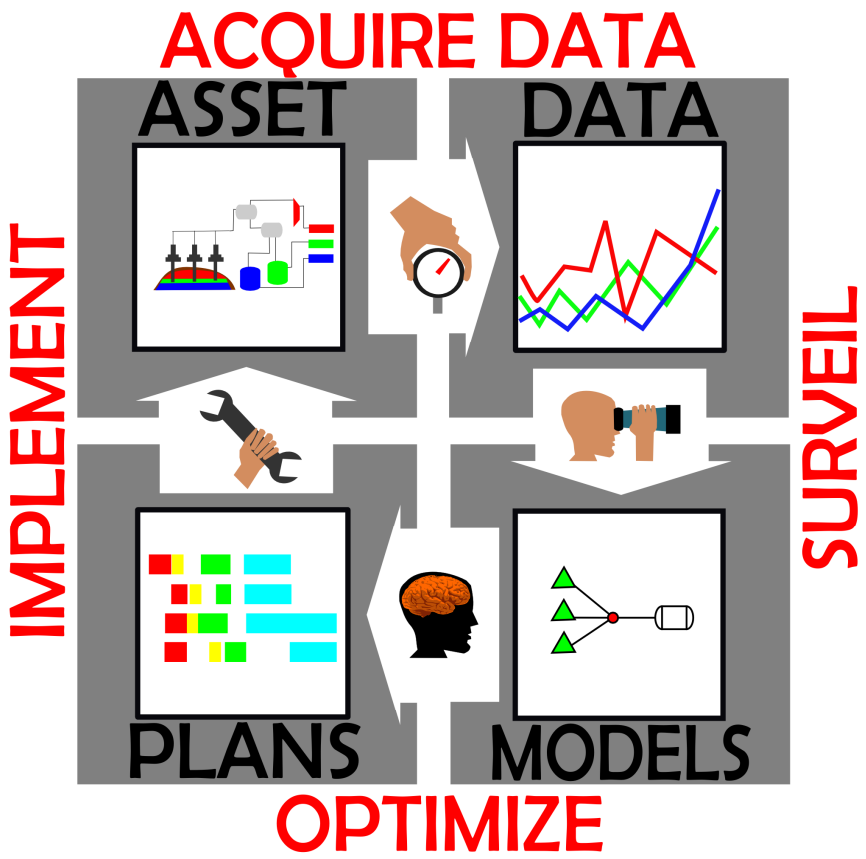
2. **Surveil** the Data to find anomalies that may lead to value and improve models

3. **Optimize** the asset, searching out and defining opportunities to add value, picking the best set of opportunities, and creating a plan

4. **Implement** the optimum changes in the asset by getting the best opportunities approved, being involved in the implementation, and collecting feedback to improve future implementations

The main focus of this book is on these four actions. They are the topics of the next four major chapters.

Let's add these actions to the diagram to get the **PSO Process Loop**.

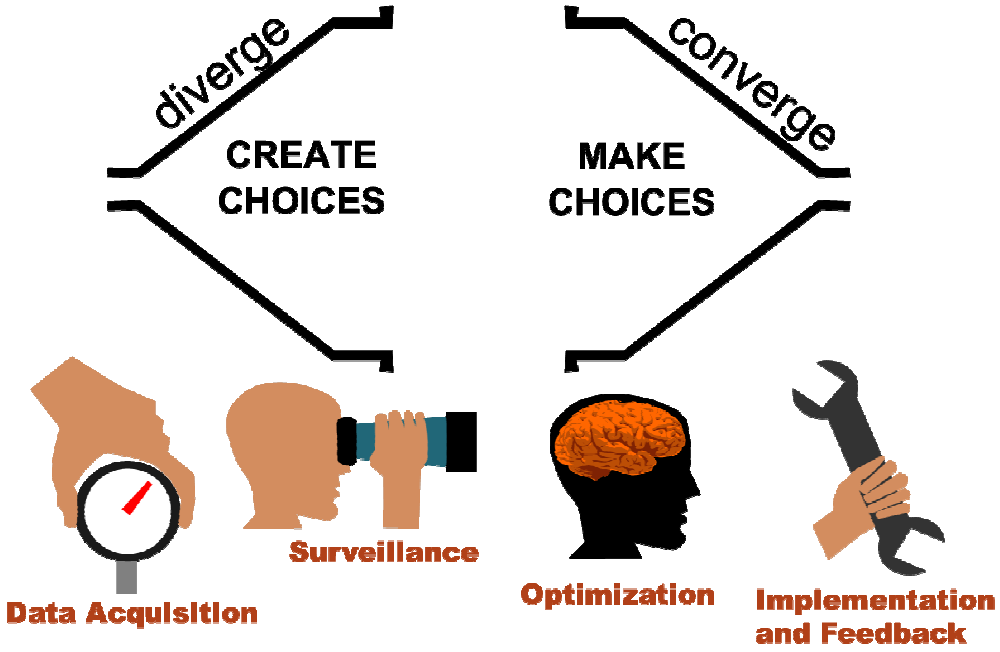


The PSO Process Loop[4]

[4] Circa 2001, Pieter Kapteijn created the idea of using a process loop to describe the production life of a field. This became Shell's 'Smart Field Value Loop'. The Value Loop was a multi-colored octagonal, overlaid with 49 words.

Sustaining Performance Improvement in PSO is the topic of the second to last chapter of this book.

The PSO process can be split into two parts, each with a different emphasis. The first two of our actions in PSO are **divergent**. In these actions, we are seeking to cover all ground, to maximize options, to create choices.



The second two of our actions in PSO are **convergent**. In these actions we are seeking to compare options, find the few best possibilities, to make choices.

You must balance your focus between these two sets of actions to succeed at Permanent PSO.

Tools for PSO

Engineers will be familiar with most of the tools used for PSO. These include:

Databases, e.g. production, reliability, petrophysical
Data Visualization tools, e.g. OFM, DecisionSpace
KPIs
Automation Systems (e.g. SCADA, DCS)
Economic Analysis
Project Reporting
Integrated Production System Models (IPSMs), e.g. IPM, ReO
Review Meetings
Standard Operating Procedures

Several of the above will be discussed later in this book. Three of the above tools merit a special mention here.

Standard Operating Procedures: As you will see throughout this book, I am an advocate of Standard Operating Procedures (SOPs). These are tools to help people certain business products. They are created, documented, agreed and maintained within the organization that will use them. The reason to have procedures standardized is that good procedures can then be shared, and the overall end-products can be improved. Also, by establishing clear expectations, SOPs prevent engineers from wasting time working to improve parts of the process that are already good enough. SOPs capture learning, and as learning changes the SOPs should change as well. This ensures that only the right methods are in use as circumstances and understanding change. SOPs allow new staff to come up to speed quickly and are invaluable as training materials. Finally, SOPs can be used as the basis for automating certain procedures as they explain step-by-step to automation software developers the best procedure to follow. More about SOPs in the chapter on Sustainability.

IPSMs: Remember I said that one of the problems with PSO was that true teamwork requires producing a common product together. IPSMs provide a common tool for the whole team. This is a very valuable mechanism for sharing not only work, but creating and agreeing on a common understanding of the asset.

Review Meetings: Many of you may not think of meetings as tools. Some of you spend half your week in meetings, perhaps with not much to show for the time spent. However, PSO is multi-disciplinary work and three types of meetings are necessary:

Daily Meeting

This is a meeting held every morning between Operations and Production Engineering to review the previous day's performance and identify short-term actions to protect production levels. The focus is on staying in the existing envelopes and adapting to changes. Most companies and teams use such a tool.

PSO Meeting

This is a meeting of Reservoir Engineering, Prod Engineering, Facilities Engineering, and Operations held monthly or quarterly to identify short- and medium-term opportunities to add value. The focus is on multi-discipline integration, optimization, and implementation planning. In my experience, these meetings are not very common in the industry. The PSO Meeting will be discussed further in the chapter on Optimization.

Annual Reviews

These are reviews of particular parts of the system, for example Well Reviews, Reservoir Reviews (or both together). Most companies and teams use such reviews. Facility Reviews are not as common, probably because most assets do not employ Facility Engineers on existing assets. (This is a mistake.)

Other tools that you might not know or might not recognize as related to PSO will be explained in detail later in this book:

Value of Information Analysis
Error Propagation Analysis
Interviewing
Deductive Reasoning
Root Cause Analysis
Experimentation
Exception-Based Surveillance
Paint-the-Picture
Limit Diagram
Scenario Optimization

People for PSO

At the core of PSO are people in these disciplines:

Reservoir Engineering
Production Engineering
Facilities Engineering
Production Operations

These disciplines should form the backbone of the PSO team. All require *dynamic* operational data in order to make their decisions. The necessity to work with a constant flow of dynamic data is what requires PSO to be a continuous process rather than a series of individual projects.

Other disciplines tend to be more project-focused and less involved in optimization of the production system, but they may still be important to certain optimization efforts. Of course, we would not have a field to produce without Drilling, Civil, Geophysics, Geology and Petrophysics! We would certainly have plenty of problems without Maintenance and Completions! We desperately need Human Resources—no, sorry, just kidding.

Aside from disciplines, it is necessary to have various roles within and supporting a PSO team: Leaders, organizers, modelers, creative thinkers, troubleshooters, and team players.

Conclusion

The purpose of this introduction was to give you a sense of why I feel PSO is so important and enjoyable, as well as to explain why I have written this book. I'm sure now you can understand how I define PSO, describe the PSO process and who is involved. I hope you appreciate why systematic PSO processes do not exist in many companies and some of the tools you can use to practice Permanent PSO.

You may want to read through and rate your team using the Health Check of PSO Concepts. Then, use the ratings to identify improvement areas. These can be used along with improvement areas in the other chapters to create a PSO Improvement Plan, which I will describe in the second-to-last chapter of this book.

A PSO Concepts Health Check

Use these health check questions to reflect on your company's or field's performance regarding PSO. This can help identify areas for improvement.

The higher number levels illustrate higher levels of performance. Level 1 is probably not acceptable. Level 2 and 3 may be acceptable, depending on the needs of your business. Level 4 illustrates a high level of performance.

Are the concepts of PSO known and used in your company?

1-No

2-These or equal terms and concepts are used

3-There is training for these concepts

4-There are designated Subject Matter Experts overseeing these concepts

Are people dedicated to PSO tasks?

1-Informally, occasionally

2-Periodically dedicated almost 100% of time

3-Major task, dedicating 50% or more of total time

4-Almost 100% dedicated all the time

Are multi-discipline teams working on PSO?

1-No, single disciplines if at all

2-Owned and managed actively by one discipline with plenty of help from Operations

3-Owned and managed actively by two disciplines with plenty of help from Operations

4-Owned and managed actively by three or more disciplines with plenty of help from Operations

Are tools specified and available for PSO tasks?

1-There are some tools, but perhaps not all, and/or not specified which ones should be used.

2-Most of the necessary tools are specified and used, including Integrated Production System Models

3-Almost all the tools are specified, widely used and users are provided training.

4-Tools include exception based surveillance and other automated workflows.

Are PSO processes in place?

1-No written process, but people are experienced and doing the work anyway.

2-Many standard procedures exist, and procedures are managed, but not in a coherent process.

3-Multiple standard procedures are managed in a complete process.

4-Multiple standard procedures are managed in a complete process, with continuous performance improvement.

Dear Production Optimizer,

I hope you enjoyed Chapter 1 of my book, where I defined and explained Permanent PSO. In next 6 chapters, I will provide you with methods and tools to complete the PSO loop, explain how to sustain PSO in your organization, and tell you a lot more stories about PSO. If you think that might help you, the links below will show you where you can purchase my book.

Cheers,
Burney Waring

Practical Optimization of Petroleum Production Systems

Available on Amazon: http://goo.gl/S3hr8e