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The Central Role and Challenges of Integrated Production Operations

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Abstract

This technical paper endeavours to describe the central role of Integrated Production Operations (IPO) in exploiting hydrocarbon reserves through the production phase of an asset. It provides definition of the key characteristics of IPO, sets out business case criterion for investment in IPO, challenges current industry positions and paradigms on future field management and provides a generic roadmap for operators seeking to be early adopters of IPO as a platform around which to organize their Digital Oil Field of the Future [1] (DOFF) initiatives.

Introduction

At the time of proposing this paper the price of a barrel of oil was around $60 and business sections of newspapers were bristling with news of record revenue and profits being posted by operators. Almost invariably the optimistic outlook for the Oil and Gas industry is hedged by analyst's concern about the respective operator's ability to meet and sustain production demands. As industry bodies host conferences, establish committees, and call for papers, many E&P firms are engaged together with industry partners on strategies and initiatives in various guises that are synonymous with the self same challenge. Conditions in the industry point to a convergence of the factors necessary for a paradigm shift. The status of technological maturity, market demands and commercial feasibility of solutions, lead those engaged in the relentless search for performance improvement to sense the emergence of a potentially disruptive technology capable of a transformational impact on the industry. The precise nature of this transformation - how and when will it be achieved - will be broadly determined by the strategies and investment decisions made by E&P firms, technology firms and service companies today. Can the technology adoption patterns of the industry be bucked in order to exploit this breakthrough in the near future?

Integrated Production Operations (IPO) can play a central role in exploiting hydrocarbon reserves to their fullest extent and can also provide a fulcrum point about which to organize strategies and initiatives for the emerging Digital Oil Field of the Future.

Integrated Production Operations

Integration of production operations can be simply understood as creating an operating environment wherein the various stakeholders are organized and collaborate around the key operational workflows with the common objective of optimizing the net present value and cash flow of the asset at all times.

In the past this objective may have been achieved to some extent and with variable success by having dedicated teams focused solely on the performance of a single asset. However the very nature of continuous production operations coupled with industry demographics, the increasing sophistication of many operations and the greater prize offered by system-wide optimization and concurrent asset management [2] increasingly render this teamwork centric version as necessary but insufficient.

Integrated production operations involve achieving integration in three distinct areas described as:

- technology integration
- workflow integration
- integration of the asset model

Correspondingly, the challenges in achieving integrated production operations are defined as technological, operational and organizational constraints. Furthermore, these challenges are considered more likely to be apparent in the case of brownfield assets where retrofitting to achieve integrated production operations will necessitate change to established operations. This paper will therefore discuss integrated production operations from the perspective of a brownfield retrofit.

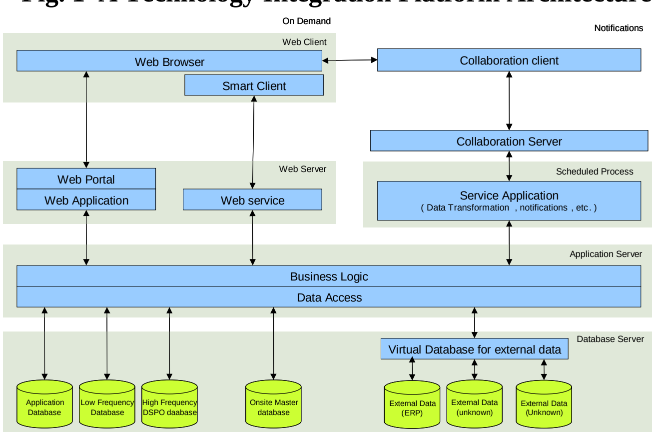
Technology Integration. The industry challenge with respect to technology is reportedly [3] not the absence of suitable technology but the need for automation and integration of available technology in order to realize promised benefits. Technology integration involves providing connectivity across the established technology infrastructure and enabling appropriate interfaces with operational workflows. The technology requirements reported as those necessary for Real Time Optimization [4] are broadly similar and a modified version is presented in this paper. Many assets already have instrumentation, controls, and SCADA systems. Communication and telemetry bandwidths may already be in place and enterprise systems including maintenance management systems and ERP's such as SAP are now commonplace.

As a result many assets are already data rich and have established production data historians, reservoir history, well, engineering and other databases. Collaborative environments may already exist with enterprise portals provided via internet and internet servers.

The initial challenge is one of understanding what technology is already available in order to make the most of existing technology infrastructure and investment and to identify any critical constraints to achieving IPO.

It is necessary to establish an integration platform that enables the various technology components to be connected and interfaced at appropriate points and preferably in order to accommodate expansion in a modular fashion. A methodology for integrating technology will ensure consistency especially across multiple assets for the purpose of concurrent asset management. Figure 1 described a suitable technology integration architecture.

Fig. 1 A Technology Integration Platform Architecture



Integrated technology platforms provide a mechanism for streamlining business processes and capitalising on the available technologies. A platform promotes consistency, robustness and efficiency through 5 main areas: Data access and management, data storage and analyse, Business Process Management (BPM), collaboration environment and abstract design.

Data Access through a generic library of adapters/providers to databases and repositories common to the industry or operator. These adapters are written based on predefined software patterns to maintain consistency, speed and ease in further developing custom and bespoke adapters.

A technology framework that enables integration of multiple legacy and disparate systems is necessary. This can be achived through implementing or adhering to an abstraction model where data and functionality of these integrated systems are captured in a consistent format. This prevents the platform from having to understand several potentially diverse protocols and/or programming models and techniques. Integration platforms maintain abstraction by implementing a loose coupling approach and service orientated architecture (SOA) where legacy and custom application are retrofitted with a common user interface.

The platform consists of a shared application database that stores shared repository metadata for all the integration touch points that will be managed and used within and by operations. A well defined data model and database supports and maintains uniformity when storing, reading and analysing data thus ensuring robustness and scalability.

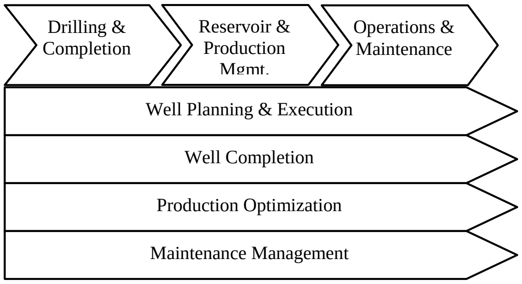
The platform facilitates the orchestration of business process management (BPM) through an embedded BPM engine. Workflows can be automated and processed through a platform generic messaging service that sends notification through SMS, email and IM. Workflows processes and rules are built and modeled using an integration graphic modelling tool, as previously described the data adapter library enables communication with any legacy party system. This feature of key in brownfield retro-fitting where various and disparate technologies are likely. In addition and complementary to BPM is collaboration services.

BPM technology capable of interfacing with the technology platform will provide the catalyst around which the various stakeholders involved in production operations are organized. A recent IT industry report [5] describes the trend toward 'Packaged Composite Applications' that use BPM technology to interface with disparate enterprise systems and applications using a services oriented architecture to engage with the organization and orchestrate work effectively through the workflows effectively connecting the people to the data via the processes. The report predicted the widespread adoption and availability of this technology in 3 to 5 years. BPM is already deployed widespread in many transactional oriented industries and various proprietary applications are available.

Workflow Integration. A recent oil and gas industry report [6] concluded that in order to realize the benefits of integrated operations (IO), 'a profound change to existing work processes are necessary offering that teams with decision-making authority and tools for real time collaboration and filtering of information are critical for successful implementation of IO'. Workflow integration is crucial to leveraging the integrated technology. Understanding the key production operations workflows and how data flows and how applications are applied at each step of the workflow enables the technology to be brought to life, to be interactive and dynamic.

The highest level definition of the operational workflow is the production value chain. Figure 2 identifies the key operational work flows i.e. those few processes that have the largest effect in value creation and cost.

Fig. 2 Operational Work Processes [vi].



Source: OLF Report [6]

Integration of production operations involves literally spanning and interconnecting the entire production value chain in order to maximize profitability by operating the asset consistent with optimal net present value and cash flow over its life. Traditionally, focus has understandably been on reservoir management. However, as production increasingly is viewed as critical to business success, E&P firms are increasingly realizing that the production value chain is only as strong as its weakest link.

Dissaggregation of these processes to the literal workflows practiced by operations is necessary if dynamic collaboration around automated workflows is to be introduced.

Causes of sub-optimization are the discontinuities and delays that result from fragmented workflows. Arguably, the degree of sub-optimization experienced is consistent with the degree of fragmentation. This begins to suggest criteria for the evaluation and quantification of a business case for moving toward IPO, discussed later.

Figures 3 a) and 3 b) are simplified representations of the workflow elements to be integrated and can be applied to any data set flow through a workflow. Table 1 identifies the key characteristics of both fragmented and integrated workflows.

Fig. 3 a) Fragmented Workflow

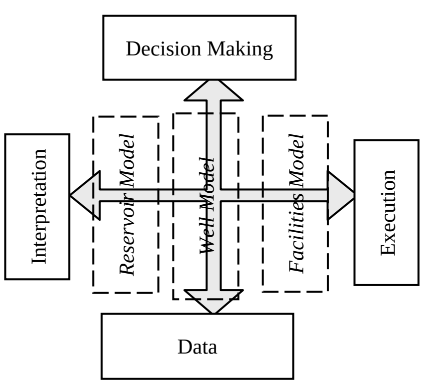
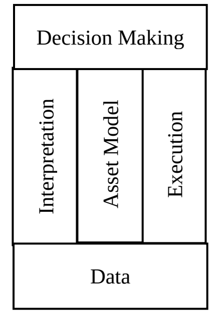


Fig.3 b) Integrated Workflow



Characteristic	Fragmented W/Flow	Integrated W/Flow
Data	undirected incomplete unused/undervalued not relevant	directed complete used/valued relevant
Interpretation	occasional adhoc reactive time consuming	Continuous Systematic responsive automated
Decision Making	ill informed adhoc ignores consequences tactical	ill informed by exception risk aware strategic
Execution	sub optimal independent of others poor visibility and accountability	optimal interdependent high visibility and accountability

Table 1 - Workflow Characteristics

Continuous and automated analysis of real time, aggregate and historical data with the application of artificial intelligence ranging from simple algorithms to complex networks and predictive sciences can allow work flows to be initiated as-required and to direct and orchestrate information and actions through the asset management organization, regardless of location. Collaborative technologies can enable a high degree of interaction and reduce time cycles from identification of an event to decision making, execution of appropriate action and importantly, validation that the action was in fact optimal.

Advanced Process Automation (APA) can in certain instances provide a closed loop system for the regulation and control of wells and production facilities. Production data can be literally be interpreted and acted on real time, removing the need for operator intervention and providing true remote control. In certain instances, the decision to adopt APA can be informed and validated only after a period of operating integrated workflows that can demonstrate the value and provide confidence to proceed to closed loop automation.

IPO creates a virtual operating environment where the various stakeholders are organized and collaborate around the key operational workflows, sharing real time data and acting on highly intuitive and automated analysis to provide consistent total asset awareness. Operators are able to manage-by-exception, making informed right-time decisions interpreted against an integrated asset optimization model, in order to realize production enhancement opportunities and mitigate potential loss.

Integration of the asset model. It is common for assets to be modeled. Typically reservoir, wells, networks and facilities models are maintained in disparate applications. Seldom are they synchronized, often they are poorly maintained and only occasionally are periodic offline optimization studies undertaken. The constraints of each model resolving its own conditions before comparison with the other models, the necessary computing resources and the resulting time required have proven a barrier to real-time or online optimization of the overall asset model. Given that any full field or system wide optimization application requires a model of all elements of the asset (reservoir, wells, networks, facilities), how does one construct such am Integrated Asset Model (IAM)?

Real-time history or tests on the asset are one approach. Since the objectives of the final application will exceed the limitations of the existing (or historical) performance these paradigms are insufficient. In others words the integrated asset model must be capable of extrapolating to a new, as yet unseen, operating regime. Therefore the model must be derived from another source. Two possible approaches are; 1) to somehow link existing full-physics models of each of the components or, 2) create simplifications of the full-physics simulations.

There are several potential challenges to linking the existing simulations:

- Multiple disparate (and potentially new) simulators must be linked.
- Each of these simulators has different time-domains.
- Multiple convergence criteria.
- Certain constraints must be mutually respected across multiple simulators.
- Can the linked model execute fast enough and in a robust manner to support closed-loop applications?
- How do the separate disciplines coordinate the individual simulator development with the knowledge that they must be linked?

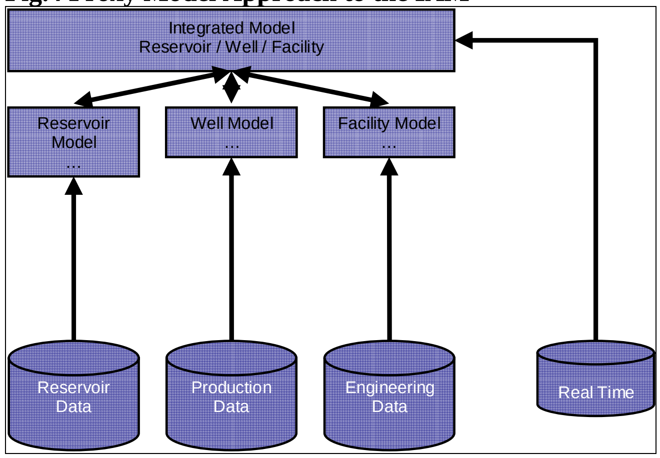
Obviously the simplified approach could yield a model which is insufficiently accurate to support the decision processes required.

This paper proposes using a procedure to copy the simulators with an advanced data modeling technology. Artificial neural networks (ANNs) have been proven for this type of applications in other areas and the authors have conducted prototypes that demonstrate they can do the same in this instance. ANNs have several advantageous properties for the IAM applications:

- Proven to be universal approximators
- Fast
- Parsimonious
- Continuous functions

The approach is depicted in figure 4.

Fig.4 Proxy Model Approach to the IAM



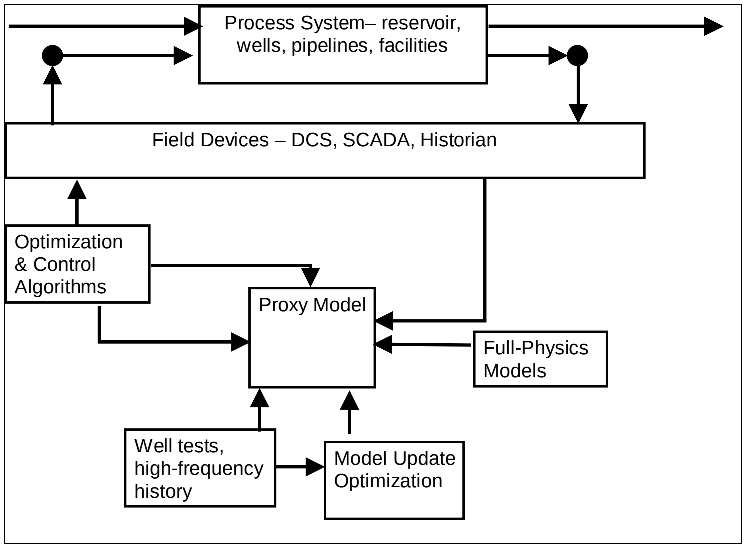
Through data generated from each individual simulation using a design-of-experiments, a proxy of each simulation is created with an artificial neural network. Once each individual proxy model is created, the proxies can be linked and made dynamic using high fidelity historical data (e.g.; well tests, etc.). The proxy model concept has many benefits:

- Accuracy consistent with the simulation model
- Nonlinear
- Very fast (less than a minute for the entire IAM)
- A single continuous function which can be robustly linked to feasible path nonlinear optimizers
- Does not require the individual engineering disciplines to modify their work practices.

Another challenge of using models in the IPO activities is to keep the IAM current in a simple manner. Changes to the asset (new wells, equipment, etc.) will require the simulators to be updated. This is an extremely tedious and infrequent task, however, one that is required to facilitate the IPO vision. The proxy optimization system can also be used to either assist or fully automate the simulator model update (history match for the reservoir simulations). This activity will be required periodically as the individual simulator model degrade.

The full IAM system in operation can be shown in concept in the block diagram figure 5.

Fig. 5 IAM Architecture



Appendix A details a case study of one example of the IAM concept applied to a real deepwater Gulf of Mexico asset.

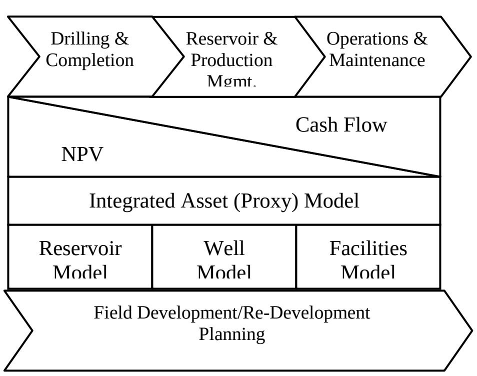
Appendix B details a case study of integrated production operations applied to gas production assets in the UK sector.

The Central Role of Integrated Production Operations

This paper proposes that IPO has two central roles: 1) Exploiting hydrocarbon reserves through the production phase of an asset in order to realize maximum NPV and cash flow. 2) Providing a fulcrum around which to organize Digital Oil Field of the Future (DOFF) initiatives.

Exploiting hydrocarbon reserves. The fundamental decisions around field development and reservoir management determine the reserves accessed and their potential recoverability. The exploitation of the asset is realized over the production phase of the asset lifecycle. The balance and inter-relationship between field development/re-development, reservoir management and production operations over the production phase is described in figure 6.

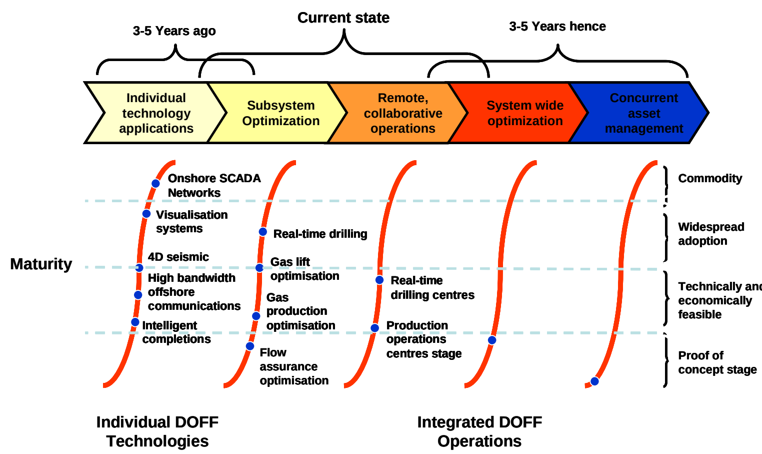
Fig 6 - Maximizing Asset Value Creation



Integration of the asset model offers the key to true, sustainable optimization throughout the production life of the asset. Real time optimization using existing modeling applications to bring the optimized modeling and scenario simulation into an online environment is central to integrated production operations being truly responsive to dynamic business and operational conditions. IPO enables relevant, accurate and total asset awareness and control of the few key operational workflows. The IAM sets the overall context for operations and is the basis for consistent, informed decision making consistent with maximizing NPV and cash flow over the life of the asset.

Mapping a Pathway to the Digital Oil Field. For some time the E&P industry has been engaged in a dialogue about emerging digital technology and its potential application and impact on the industry. Broadly defined as the Digital Oil Field of the Future, the industry forum on DOFF have defined the path towards the digital oil field [ii] shown in figure 7.0.

Figure 7 - Path to the Digital Oil field of the Future [ii]



Source: CERA

During the period depicted, adoption of simulation and optimization applications, visualization systems, real-time drilling and establishment of real time drilling and production operation centers have become reasonably widespread and are generally considered both technically and economically viable. These technologies have succeeded in enabling significant subsystem optimization and a greater degree of remote collaboration than previously possible. However, as figure 7 suggests, the real prize and opportunity for production operations lies in firstly achieving sustained *system wide optimization* and ultimately in enabling *concurrent asset management*. Establishing IPO can play a pivotal role in achieving both these objectives.

System wide optimization. IPO, as described previously, provides the means for achieving true system-wide optimization for complex and partially automated networks. This represents the majority of assets likely to qualify as candidates for investment in IPO (discussed later). The process of establishing real time monitoring, analysis and the ability to collaborate around the production critical workflows enables:

- Total asset awareness
- Right time operations
- Sustained Production Optimization

Total Asset Awareness. A previous industry transformation resulted from the introduction of reservoir simulation and visualization technologies. Involving transformation of massive amounts of data into highly representative images of the geological and geophysical properties of the reservoir allowed a greater level of understanding and improved decision making and reduced risk inherent in reservoir management. Bringing a similar level of transparency to across the complete production value chain likewise involves transformation of the (in many instances) data rich production environment to provide highly intuitive and readily understood representations of all production critical information. This will likewise improve decision making and reduce risk inherent in production operations by presenting; product characteristics, the operating envelope, the status and condition of equipment and the status of maintenance work on the asset.

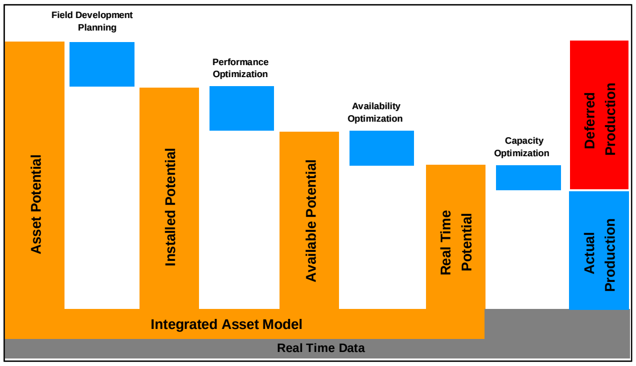
The performance, availability and configuration of the asset quite literally dictate how optimal production will be. All of these variables have to be monitored and managed on a 24/7 basis over the life of the asset with information frequently requiring to be shared across remote geographic locations and with third parties such as original equipment manufacturers.

IPO can establish 'the truth as it is commonly understood' across the asset regardless of location. Transparency of all critical information can permits levels of accountability and responsiveness that many operators have never before experienced.

Right-Time Operations. Assets are traditionally operated primarily in a reactive mode with decisions and actions based on historical information; this is a significant cause of sub-optimization. The ability to act on real time data in a responsive manner is the current ambition of many operators as is characterized by the many data-to-desktop pilot schemes currently being undertaken (Appendix B details a case study demonstrating the feasibility of real time production monitoring). The application of predictive technologies such a neural network and pattern recognition is gaining strength and may hold the key to enabling operators to act in an increasingly proactive mode, preventing loss and avoiding or mitigating performance problems before they are experienced. While many technologists have debated the concept and definition of real time, understanding the right time application of data as it applies to production operations and how it must interface and interact across the critical workflows is necessary if the industry is to realize pragmatic solutions to this challenge.

Sustained Production Optimization. IPO can enable optimization of an asset over the lifecycle of the asset. Figure 8 describes the key contributory factors of deferred production.

Fig 8 – Factors contributing to deferred production



The asset's full *potential* may be initially compromised during field development and during the design process. The as-designed asset may be further compromised during construction resulting in a sub-optimal installed potential. At completion and commissioning and thereafter, key production facilities may experience *performance* degradation. Due to inevitable down time or sub-optimal maintenance planning, the production facilities actually *available* at a given period are often sub-optimal and throughout the daily, *real time* production cycle, equipment set points and operating parameters are often not consistent with the optimal value production profile. Unforeseen events result in loss of production over and above the accepted operating envelope that informs production targets. Production targets are usually based on historical performance and not necessarily reflective of asset's true potential. The resulting level of deferred production is quite literally a constraint on the firm's cash flow.

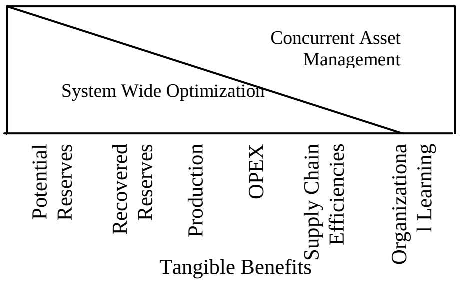
This represents a complex and dynamic operating environment with multiple interdependencies across the production value chain. While the causes of sub optimization are apparent, the reason for sub optimization can be seen in disintegration across operational workflows. This results in discontinuities and delays between the real time production data or history and the experts who are able to analyze and give it meaning, the decision makers who have authority to take action and the operatives who ultimately have to respond in order to restore the optimal condition. All of this in an environment where there is often no commonly accepted understanding of what 'optimal' is with disconnected decisions based on consideration of single or even out of date models. Operational workflow must cross and break down many silos.

It is these operational workflows that IPO focuses on. By overcoming the discontinuities and delays and monitoring and acting to maintain the integrated asset optimization model. Understanding how data, people and systems interact across these processes and how technology can improve that interaction is key to sustained production optimization which is simply operating as close as possible to the asset's true potential.

Concurrent Asset Management is the ultimate state of the digital oil field of the future. This is where multiple production assets are able to be managed and supported by a single asset management team.

Figure 9 identifies the respective benefits associated with system wide optimization (of an asset) and concurrent asset management (multiple assets).

Fig. 9 Tangible Benefits



While the tangible benefits of system wide optimization are more obviously realized at an individual asset level, by spanning multiple assets, the less tangible benefits of IPO are greatly increased. The objective of Concurrent Asset Management is to leverage the asset management and asset support resources as well as optimizing the supply chain and maximizing organizational learning across multiple assets. Real time drilling centers with a single group of highly experienced experts controlling multiple drilling projects and achieving tremendous learning that travels across multiple projects have quickly demonstrated their value. Likewise, real time operating centers have demonstrated the potential for greater collaboration between disparate, remote groups. However while such centers provide effective communication bandwidths and facilities for greater organizational interfacing and more open collaboration, especially on high intensity projects such as drilling, workovers and shutdowns, they have lacked the shared access to asset-wide real time and predictive data necessary for sustained collaboration over the routine 24/7 production environment. Indeed some such initiatives have failed to be maintained due to the demands that routine operations places on the operations team i.e. their routine operations simply don't leave the time to 'collaborate', which in this mode is often additional to the established routines.

Integrated production operations can provide total asset awareness and right time connectivity across multiple assets to enable successful collaboration around the routine operational workflows that are production operations. As operators seek to leverage their asset management and support resources using collaborative centers, IPO provide the missing link necessary for concurrent asset management.

In one ambitious project, a National Oil Company has engaged in a long term plan to firstly, integrate all their key production operations and then to interface the respective operations with a single databank and virtual asset management control center. The production of oil and gas is viewed as critical to the national economy and true optimization of their production network can only be achieved by an integrated approach to concurrent asset management.

Providing a fulcrum for DOFF. Integrated production operations are an increasingly feasible option, industry pilots and case studies have proven the concept. Proprietary technology platforms are emerging and the challenge broadly becomes one of establishing an industry execution capability. The technology available today is adequate for effective IPO. The ongoing development and increased sophistication of individual technologies will undoubtedly continue and as these are introduced into an IPO operating environment will improve the respective processes. Likewise, as computing resources and communication and visualization bandwidths increase, and as collaborative technologies improve, an IPO operating environment will benefit from upgrades. However the potential benefits from deploying IPO using existing technology should be embraced by the industry now. Adoption of IPO as a central fulcrum for the DOFF can provide the pragmatic solutions that operations management require now and also add impetus to the technology leaders of corporate E&P DOFF initiatives providing them with a framework for mobilization of individual breakthrough technologies to existing brownfield production assets, who will after all, remain the vast majority of their 'customers' for the foreseeable future. Proven IPO models and the drive for standardization of technologies are then more appropriate to new greenfield opportunities.

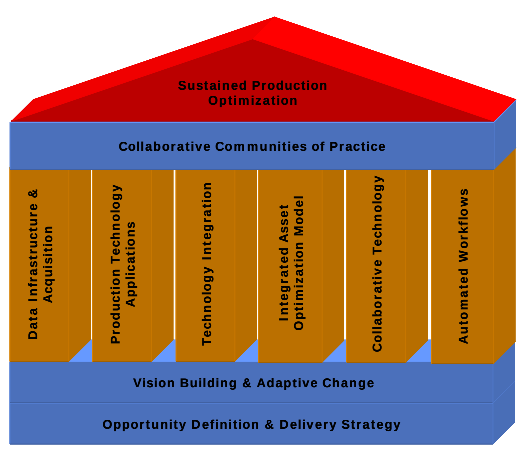
The Challenges of Integrated Production Operations

A case for deploying IPO on brownfield assets will necessarily require demonstrating to the operators that all the potential hurdles can be surmounted. These are likely to include:

- Demonstrating that a feasible solution is available
- Presenting the business case for investment
- Proving an execution strategy
- Management of change

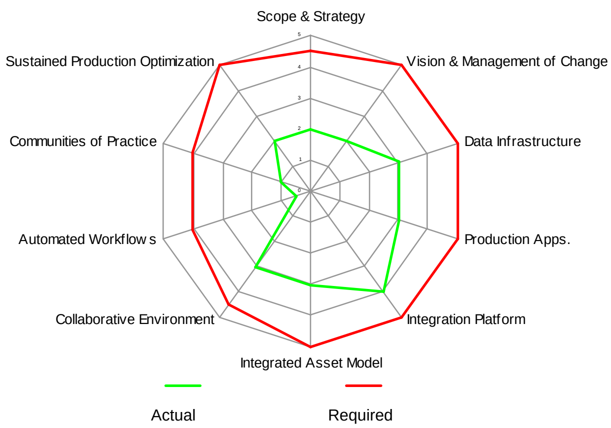
IPO Solutions. It should be apparent that establishing IPO is not solely nor primarily a technology issue. The technologies are available if not yet readily integrated. The design of an IPO solution will necessitate co-ordination of multiple disciplines and span multiple domain workflows as well as the integration of disparate technologies A solution is much less tangible than a 'product' and will encompass all the aspects of delivering the required outcome. Figure 10 identifies the key requirements and inter-relationships required for most IPO solutions to a greater or lesser degree (depending on the current state of the brownfield asset).

Figure 10 - Requirements of an IPO solution



By breaking down the individual components of an IPO solution, it becomes possible to evaluate each in its own right for any particular asset or group of assets providing the information for an execution strategy and defining a qualified and quantifiable scope of delivery. Figure 11 represents the evaluation of a specific solution for the case study appendix B.

Fig 11 Solution scope evaluation



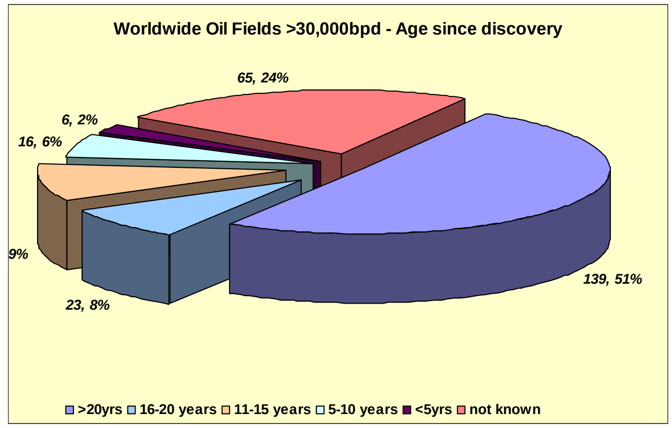
Operations management will seldom enter into an ill-defined project. The multiple-disciplined aspect of IPO is reflected in many of the alliances currently in place under the various industry DOFF initiatives. However, from published case studies their track record in execution and delivery of complex IPO/DOFF solutions remains to be proven.

To meet the challenges it faces and in order to realize the opportunity presented by IPO and the Digital Oil Field of the Future now, the E&P industry is seeking proven technology products that integrate easily with and harness the existing technology infrastructure, preferably with minimum intrusion. They require solution providers that can take the strain executing installation and supporting the inevitable change necessary for successful adoption of the new technology. These are non-core skills to the operator. Given the industries history where outsourced non-core skills are delivered much more efficiently by service providers on a competitive basis, it would perhaps suggest that the industry should be proactive in promoting and establishing an industry capability as opposed to attempting to co-ordinate IPO/DOFF projects internally.

The business case for IPO. Investment in IPO will require a compelling business case for investment and perhaps most importantly, operators must have confidence that the solution will succeed. IPO projects will be subject to return in investment, payback and cost/benefit criteria.

At a macro level, while the technological leaders have tended to focus on Greenfield assets assuming new build design will incorporate necessary technology possibly based upon a corporate or indeed industry standards (such as WITSML or the current PRODML initiatives). However, despite the difficulties of retrofitting, it should be apparent that the foreseeable global oil and gas production will be delivered predominantly by existing assets. Given the likely cost and the need to pass any return in investment hurdle, this paper assumed a reasonably conservative estimate of the global need based on assuming that only asset with production greater than 30,000 boe per day would be candidates for retrofitting of IPO. Figure 12 identifies the current opportunity for IPO in the brownfield arena. Furthermore, the management of these assets are currently under pressure to meet global production demands.

Fig 12 Brownfield IPO Opportunities



Source: Oil and Gas Journal Worldwide Production Report - 2003 Production Averages per Day. World Market Research Company Country Reports - Field Operators / Partner Information. [Does not include information on Brazil, Mexico and Malaysia]

It should be apparent that not all brownfield assets would qualify for such investment on an economic basis. The age of assets might provide a further indication of the likely state of technology but not necessarily so. Additionally many of the costs and benefits are less tangible but no less of a concern and impact on a potential IPO project. Table 2 identifies a set of broad screening criteria that can be used to evaluate a likely candidate for IPO. Initial IPO projects are likely to considered as pilots and therefore selecting a suitable pilot project with favorable outcome prospects is particularly important. This can enable a broad screening of an operator's asset portfolio in the first instance.

Table 2 - IPO Early Screening Criterion

Criterion		Aspect Evaluated
Culture	1	The operator's attitude to adopting new technology
	2	The operator's attitude to outsourcing technology projects
	3	Operator's openness about sharing production information
	4	Are Operations a learning organization?
	5	Operator's history & propensity for collaboration
Relationships	6	Operator's record/degree of success in working with the others (consultants & partners)
	7	How supportive the key buyers/decision makers in the organization?
	8	Degree of alignment between IPO and operators objectives
Demographics	9	Can location(s) be readily accessed and supported by core disciplines
	10	Is local/national culture conducive to success
	11	Health and safety, Security/stability at location
	12	Are multiple assets diversely located?

Opportunity	13	Potential benefits derived from success of IPO
	14	Potential costs of deploying IPO
	15	Probability of successful implementation of IPO
	16	Mode of operator organization (in growth, complacent or in trouble)
Suitability of Operations	17	Production history
	18	Completeness of Technology Infrastructure
	19	Definition of operational workflows
	20	Complexity of network and faculties
Power	21	Barriers (in-house initiatives, corp policies, strategies, etc)
	22	Disparate autonomous groups or strong central control
	23	Credibility of IPO project sponsor
	24	Complexity of commercial relationships affecting the operation (other stakeholders/partners)

The detailed costs and benefits are likely to be defined by a more detailed study of proposed operations likely to be suitable for IPO investment. This is the key to development of an appropriate opportunity definition and execution strategy.

Execution strategy. The key components of DOFF are well documented as people, processes and technology. This paper proposes a more accurate definition of these dimensions that can be considered as levers or constraints to achieving a successful outcome for IPO and wherein lies the detailed scope of work and challenges to be overcome during execution. These are; technological, operational and organizational levers and constraints. Definitions and individual criteria are offered for each.

Technological Constraints comprise the technological infrastructure and gingival technology components necessary for integrated production Operations. Categories and classifications were previously defined by the SPE technical interest group for Real Time Optimization [iv]. A modified version is proposed by this paper. The technology categories to be evaluated include:

a. Modeling
b. Measurement
c. Telemetry
d. Data
e. Analytics
f. Visualization
g. Controls
h. Workflow automation
i. Optimization
j. IT infrastructure

Operational Constraints comprise the physical asset and operating network, the operational workflows, the operators, the work and the work faces and interfaces. The categories to be evaluated include:

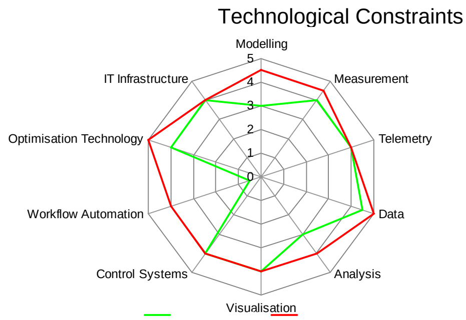
a. Operational Leadership
b. Key Performance Indicators
c. Facilities
d. Planning and Co-ordination
e. Competency & training
f. Operational Workflows
g. Safe System of work
h. Production optimization

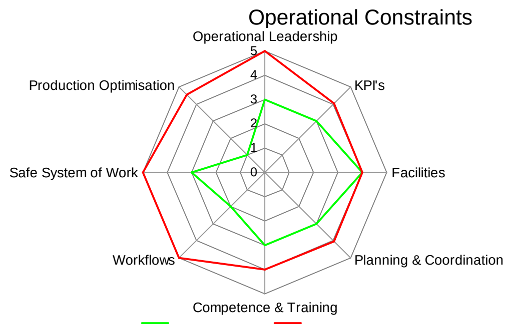
Organizational Constraints comprise the organization structure, organizational roles and interfaces, the operational policies and strategies, the management systems and the culture. The categories to be evaluated include:

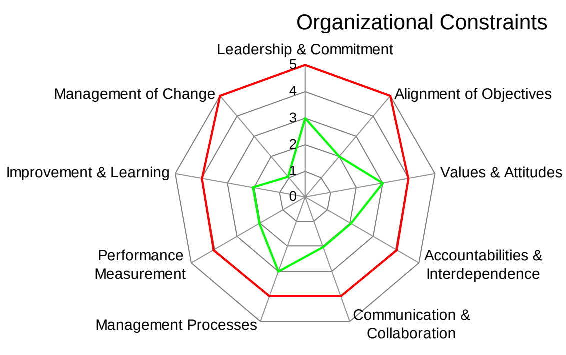
a. Leadership and commitment
b. Alignment of objectives
c. Values and attitudes
d. Accountabilities & Interdependence
e. Communication & collaboration
f. Management processes
g. Performance Measurement
h. Improvement & Learning
i. Management of Change

Evaluation of both the ‘importance’ and ‘actual findings’ of each to the specific IPO projects is necessary as these are relative to the context of a specific asset and organization. Figure 13 illustrates a gap analysis of the case study appendix B.

Fig. 13 IPO Gap Analysis







An execution strategy will include strategies for overcoming all the constraints and leveraging the appropriate levers. A phased introduction of IPO is the most likely scenario for purpose of engaging the organization, gaining confidence and competence and to realize early value be it tangible or intangible. The phasing is likely to be reflective of the level of maturity and readiness of the asset(s) and of the organization. One industry report [Vi] predicts the transition from traditional operational practices through two generations of workflow integration addressing firstly operational workflows and secondly supplies chain workflows, another operator's initiative [7] recognizes differing stages of transformation through levels of technology integration. However, generally the following progression is reasonable:

- Transition to integration of traditional disparate data, measurement and control technologies.
- Establish total asset awareness providing automated analysis of key data to desktop access across the organization in real-time.
- Engage organization though opportunity and alert notification
- Process automation.(where appropriate)
- Workflow integration and collaboration with logical and phased automation of each workflow.
- Extending IPO across multiple assets and establishing real time centers for the purposes of concurrent asset management.

This provides a logical path, each generating more or less tangible value in its own right. The management of change throughout each staged transition is of course critical to the likelihood of a successful outcome as well as an operational necessity.

Management of change. IPO will involve technological, operational and organizational change. Whilst many operators will have defined processes for the administrative management of such change, and this paper assumes that the legislative, technical and management system changes associated with change will be adequately addressed by these processes (although caution on such an assumption in practice). This paper focuses on the intentional facilitation and support necessary to effect the necessary adaptive change successfully which is undoubtedly a critical success factor in establishing IPO. This paper proposes three dimensions of change that can influence the successful adaptation of IPO, these are:

- A change process
- Soft change factors
- Hard change factors

Change processes abound and many such structured approaches will yield results if practiced intentionally, systematically and rigorously. Unfortunately it is more common for change to be imposed or executed as opposed to true adaptation being fostered amongst those affected by the change. Forcing the fit is a valid if risky approach to change and no one approach is appropriate across all cultural contexts. However, this paper proposes a structured approach. Table 3 identifies a three stage, eight step change process [8] with defined outcomes that has been implemented with reasonable success in field projects.

Having determined the scope of change and identified the constraints to be overcome, as part of step 1, the phased execution approach presented previously can be supported by this process. The key to effecting the necessary change for each phase of an IPO project lies in ensuring a successful outcome at each step is understood and actually achieved before moving on to the next step. This is an iterative process for each significant change introduced.

Soft change factors. Change agency is a specialist skill set requiring experienced and competent practitioners. External consultants may bring a perceived 'expert' power that internal personnel cannot and can also imbue a perceived importance and sense of commitment to the project. Proprietary change programs may have a valuable role to play in preparing the affected groups. Education on the nature of change and how to adapt to change can be a valuable preparatory investment.

The skilled co-ordination, facilitation and support of change in structured process can be a valuable tool to mitigate the risk of poor adaptation of IPO.

Table 3

	Change Process [1]	Outcome
1.Visualization	**1. Establish a Need for Change.**	• Understand the current reality • Recognize and define potential crisis • Identify significant opportunities • Agree Change
	2. Create a Coalition for Change.	• Establish a group to lead change • Enable the group to work as a team
	3. Develop a Vision for Change	• Create a vision of the changed state • Develop strategies for realizing the vision • Agree critical success factors
	4. Communicate the Change Vision	• Use every appropriate vehicle to communicate and reinforce the vision and strategies. • Intentionally role model behavior expected of operatives
2. Integration	**5. Empower Action**	• Create a pause for change and allocate resources • Identify and remove obstacles to change • Suspend processes or structures that undermine or oppose the change vision • Endorse processes or structures consistent with the change vision
	6. Generate Visible Wins	• Plan for early 'wins' that prove the vision • Facilitate and lead those 'wins' through their cycle • Visibly recognize and reward those involved in delivering 'wins' • Celebrate success across wider organization
3. Optimization	**7. Consolidate Gains & Accelerate Change**	• Confirm credibility of changes to deliver anticipated gains • Agree permanent changes to processes and structures • Promote people who can maintain the change vision • Re-invigorate change process with new actions, themes and people.
	8. Anchor Change	• Monitor changed processes, behaviors and structures against critical success factors • Leaders re-enforce and encourage changed behavior, processes and levels of performance. • Connect new behaviors etc to wider organizational success.

Hard Change factors. The apparent soft issues and soft skills associated with change, culture, leadership, motivation etc. are the subject of untold narratives and case studies and out with the practical scope of this paper. However there are also hard factors associate with change and understanding and managing these factors can significantly improve the probability of a successful outcome. A well defined project will permit the application of what has been called the DICE [9] framework after the four key hard factors:

- **Duration:** Contrary to popular misconception, projects with a long duration that are reviewed frequently are more likely to succeed than a short project that isn't reviewed frequently. The time between reviews is more critical to success than a project's lifespan. The probability that a project will run into trouble increases exponentially between reviews exceeding eight weeks. Effective milestones describing major actions, achievements and outcomes are the focus of review by senior management sponsors and of course, review implies agreement of recovery actions to get a project back on track.
- **Integrity:** The extent on which companies can rely on teams of managers, supervisors and staff to execute change effectively. The best people available should be committed to the project while making sure that day to day operations don't falter. These employees will go the extra mile to ensure the extra work arising from change, gets done. Team roles must be clarified and the project team leader, and team composition are critical and worth significant investment to get right. Often the responsibly manager is not the best team leader.
- **Commitment:** Visible backing of the most influential executives and of the people who must deal with the new systems and workflows is vital. Companies often underestimate the role of managers and likewise their ability to build staff support – provided the need for change can be communicated.
- **Effort:** Employees will be busy with their day to day responsibilities. dealing with change on top of these will create resistance. A realistic calculation of the work associated with change must be made. Anything over 10% additional work must be resourced or employee morale will fall and conflict arise. Feedback on additional efforts and employees coping capacity must be established and prioritization and elimination of unnecessary activities and other projects and initiative undertaken. Initiative overload is often the death knell of change.

Evaluation and scoring of the key activities of change projects to generate aggregate scores will provide a valuable indicator of the likelihood of a successful outcome. Analysis of the outcomes of project falling onto three scoring zones (win, worry and woe) provides compelling insight of the ability to predict the success of a project or otherwise using this approach.

IPO Projects should be well defined, scoped, phased and apply effective project and change management techniques. Tracking the DICE score as a project evolves will plot a trajectory for success as well as the project controls used for forecasting cost, time and resources. The execution strategy with clearly defined critical success factors and key performance indicators, together with a structured and systematically applied change process will provide qualitative assurance of the desired outcome.

Conclusions

The approach presented by this paper can inform the decision to adopt IPO and move toward the digital oil field of the future. The definition of a credible position to adopt on this potentially disruptive technology is set out. A pathway and methodology for execution is clearly mapped out and, based on the quantifiable value offered by system wide optimization and concurrent asset management, the basis for a qualified go/no-go decision can permit suitable opportunities to be realized in the near future. The focus on retro-fitting of existing assets being the majority producers in the foreseeable future offers a shift from the dominant paradigm around new technology and adoption on greenfield assets. The widely held concern about the intangibility of managing change and having sufficient confidence to proceed is addressed and operators should be placed in a much improved position to make a positive decision around integrated production operations.

Acknowledgements

The authors thank all the individuals including consutants, developers and operations management and personnel employed by operators, service companies and solutions providers, who directly or indirectly contributed to this paper. Although not listed as authors, their participation in the projects that have informed and shaped this paper are valued and appreciated.

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Appendix A. Integrated Asset Model Case Study

The intent of the IAOM application was to ascertain whether there was any opportunity to increase production within the constraints of the facilities. The objective formulation was as follows:

- Maximize oil production
- Maximize gas production
- Respect compressor BHP limits
- Respect maximum separator flows
- Modulate separator pressures (within 10%) to increase flows

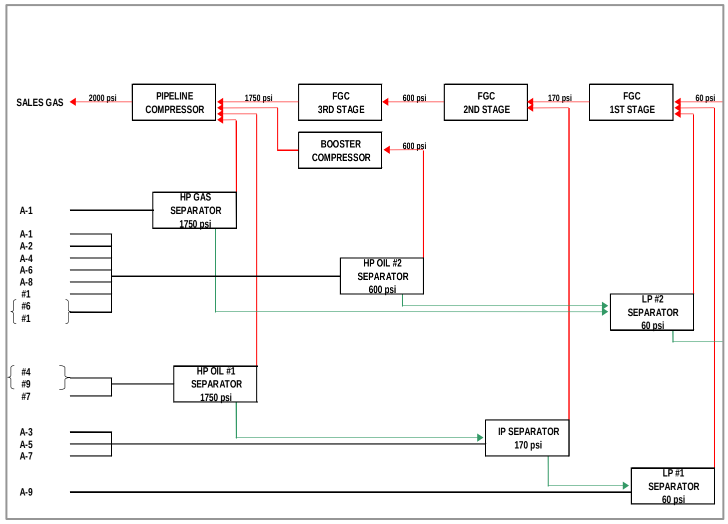
The optimization simulation showed that oil production could be increased by 1030 BOPD and gas production increased by 13 MMSCFD without adding any load to the compressors if the separator pressures could be slightly modified.

Process Overview

A generalized process flow diagram is shown below in the following figure A1. There are 16 total wells in 6 reservoirs which can produce into the facilities. Nine of these wells have dry trees with the chokes on the platform. Six wells are Sub Sea and produce into 2 pipelines with risers onto the platform. All wells have multiple completions but only produce from one at a time. The wells lie on about 4000 feet of water and most are completed at about 12,000 TVD. Once on board, the wells are manifolded so that all wells can be piped into the test separator and most wells can be piped into most separators. There are 6 separators on the platform. They are split into two trains. One train has a high pressure gas separator operating at about 1750 psig, a high pressure oil separator operating at about 600 psig and a low pressure separator operating at about 60 psig. The other train has a high pressure oil separator operating at about 1750 psig, an intermediate pressure separator operating at 170 psig and a low pressure separator operating at 60 psig. The oil from the separators is conditioned and pumped to a pipeline. The gas is compressed through three compressors to 1950 psig and sent into a pipeline. There is a flash gas compressor which has three stages to bring gas first from 60 psig to 170 then from 170 to 600 and finally from 170 to 1750 psig. The pipeline compressor then elevates the pressure to pipeline pressure.

The Asset currently averages about 24,000 BOPD and 188 MMSCFD of gas. One well, is not producing and one is close to watering out at 60% water. There are 2 primarily gas wells with the remaining wells producing oil and gas.

Figure A1



Available Full Physics Simulations, data and Proxy Modeling

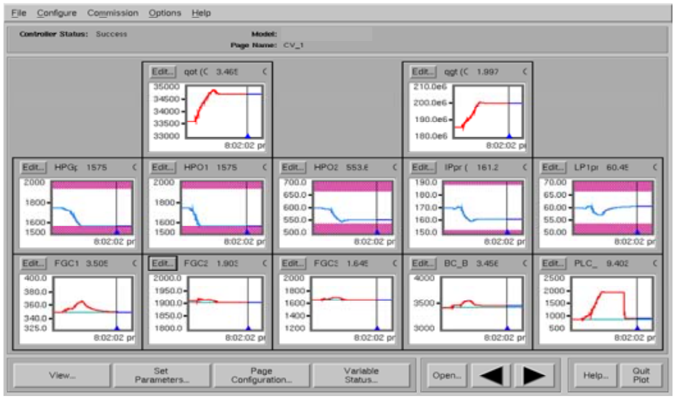
Eclipse reservoir simulations existed for 3 of the reservoirs which could model well delivery for 5 of the wells. The remaining wells were modeled via system analysis using IPR/VLP curves with Prosper. The pipeline and facilities were simulated with Pipesim. Daily reports with monthly flow tests on each well were available for approximately one year.

The first step was to match the existing simulations to the operating data and generate well models for the wells still requiring them. Next a design of experiments was run on the existing simulations to provide pseudo-historical data for the asset across a wide range of current and potential operating scenarios. This data was combined with the historical data and a full dynamic IAM was built with the ANN software. The dynamic model was linked with an optimization solver and simulated within a graphical user interface. Finally the objective function formulation was codified and case studies were executed.

The model takes about 2 seconds to complete in prediction mode and is capable of being connected to the SCADA system and running online. The optimization case scenarios took less than a minute to converge on a final solution.

The optimization model is online ready and has a graphical user interface for it. The following figure A2 shows the result of lowering separator pressures to maximize production and the affect on compressor BHP.

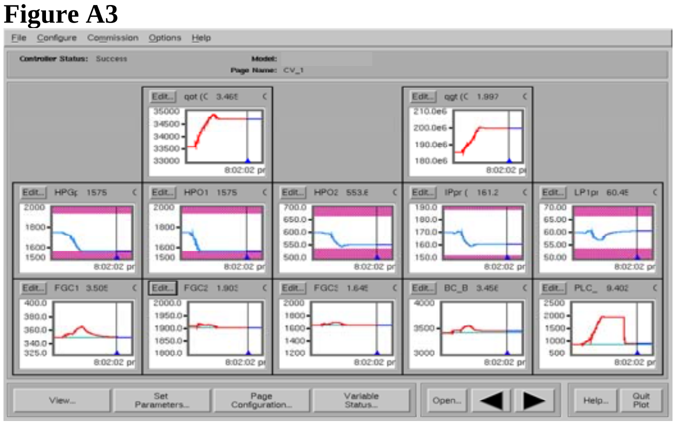
Figure A2



The oil production is shown in the upper left box, the gas production in the upper right box. The middle layer shows the separator pressure modification and the lower layer is the compressor BHP requirements. Note that the increase can be achieved without increasing load on any compressors except for the pipeline compressor which is currently under loaded.

The optimization model is online ready and has a graphical user interface for it. The following figure shows the result of lowering separator pressures to maximize production and the affect on compressor BHP.

Figure A3



The oil production is shown in the upper left box, the gas production in the upper right box. The middle layer shows the separator pressure modification and the lower layer is the compressor BHP requirements. Note that the increase can be achieved without increasing load on any compressors except for the pipeline compressor which is currently under loaded.

Appendix B. Integrated Production Operations on a Shallow Water Gas field Case Study

This case study details an engagement in the delivery of a real time integrated production operations solution, aiming towards concurrent asset management, for an E&P Major in Western Europe undertaken over the last three years.

Asset Overview

There is one primary E&P firm as operator with over 30 commercial partners, operating three main manned complexes, with nearly unmanned 30 satellites and 8 sub sea completions. There are over 180 producing wells only three of which have down hole sensors, producing over 800mmcfd, from good quality sandstone reservoirs which are in excess of 10,000 foot deep. SCADA and DCS control systems were already in place, there are 8 main compressors and 15 power generation systems. There are over 80 personnel permanently deployed on the offshore installations with approximately 200 providing full time onshore support and as required offshore support.

Project Scope

In the initial phase the project was focused on three main areas

- Asset Performance
- Production Optimization
- Maintenance Management

The primary driver for the partnership from the solution developer's perspective was to develop and deliver an industry leading solution, whilst the E&P firm's drive was to gain access to technology and expertise that wasn't available within their own organization. The initial project developed over three phases and further development is ongoing. Initially the requirement was to provide a highly visual data to desk top solution, this then moved forward to a phase of developing further value propositions with the final stage being value realization.

Underlying the solution from day one has been an aim of '*making best use of what is available'*. Whilst the operator had already deployed significant resource in terms of applications, systems and processes, as components the value delivered had not reflected the investment. The eventual solution brought together the legacy components from earlier investments, augmented these with state of the art offerings and wrapped it all together in a new, intuitive and highly innovative solution. Initially viewed as a pilot scheme, the solution underwent a proof of concept period whereby critical success factors were monitored. This concluded the solution was viable and subsequently went operational.

This web based solution, which is available on a secure 24/7 basis has delivered incremental and continuous value across the E&P firm's assets.

In the area of **Asset Performance**, the solution gives the end user clear and transparent status of overall production and all key equipment. Registered users, regardless of location or time zone, have up to the minute access to production data from field level down to individual wells which can be trended over time and presented in volume or value in a range of units and currencies. Key equipment performance can be similarly viewed and analyzed with a couple of 'clicks'. In addition to the ability to view and trend performance, the solution constantly monitors performance, looking for adverse trends. Where such a trend is recognized, the solution automatically generates an alert, and delivers the alert in an appropriate format (e-mail, SMS or system notification) to the stakeholder. The business rules and logic that facilitate this management-by -exception approach have been developed using expertise from the E&P firm, from the contractor and from a wide range of suppliers, maintainers and other domain experts.

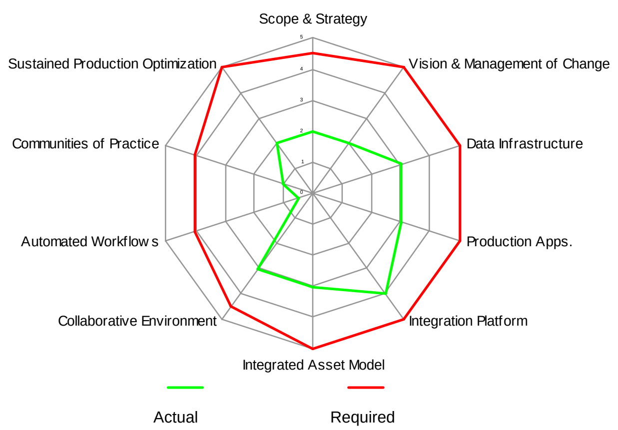
Within the **Production Optimization** area, the solution incorporated a standard industry modeling and optimization technology solution. Where it differs from the traditional approach is that, the models are continually fed with real time equipment performance data, the optimiser is run on an intraday basis and the feedback to the organization is in a highly visual and intuitive manner. Optimization opportunities are ranked by value and the operators are fed the choke and compression settings required to obtain the optimal production. A number of standard operating scenarios are built into the solution from Maximum Production, through various other scenarios to Minimum Compression. At any time the operators can view the scenarios and apply the appropriate set-up. Through the adoption of APC technology, it would be feasible to 'hard wire' these outputs to the installation control systems and effectively close the optimization loop – this is not a desired outcome for this client at this time. As with the equipment alerts in the Asset Performance area, these optimization opportunities can be managed on an exception basis through the adoption of an automated workflow.

In the area of **Maintenance Management** the solution takes raw data directly from the E&P Firm's CMMS (Computerized Maintenance Management System) and transforms it into useful and actionable information in real time. Simple drill down facilities are provided, from field level through asset to individual equipment, which deliver the ability to analyze cost, failure cause, efficiency and compliance. As with Production Optimization, these maintenance management issues can be managed on an exception basis through the adoption of the automated workflow technology used in the Asset Performance.

The solution delivered is technically mature, having been drawn from established components and developed using standard technologies and methodologies. The solution partner continue to provide support both for the solution itself in terms of 'bug fix', as well as providing domain expertise support where required to facilitate expansion, adoption and adaptation. Measures for success include the tangible benefits to the E&P firm of reduced chemical usage, steady production and enhanced maintenance performance, as well as a steady and continued uptake in access requests and modification requests. There has been absolutely no adverse impact on the operating environment through the development and deployment phase. Whilst there has been a requirement for some degree of training for a small number of key users, the vast majority of the end user population, require little or no training other than basic web browser familiarity.

It is recognized that this instance is a partial integrated production operations solution. Evaluation of the current solution is depicted in figure B1.

Figure B1 – IPO Solution status



Having substantially successfully tackled the technical issues surrounding an engagement of this nature, focus for the next phase of the project is primarily on addressing the operational and organizational constraints to adoption and realization of sustained production optimization. Figure B2 depicts an evaluation of the technological, operational and organizational constraints that remain.

This case reflects a phased development and introduction philosophy extending from proof of concept as a very early adopter through ongoing development of the solution. The next phase of the project has been approved by the key partners and will include an integrated asset model and collaboration around automated workflows as the means for value realization which is ultimately sustained optimization and concurrent asset management.

Figure B2 – IPO Current Constraints