In conventional reservoirs there are two main reasons for running a completion across the reservoir: to control sand production and/or to optimise inflow.

Inflow optimisation is so fundamental to field economics that in the FEED phase, long before a Final Investment Decision (FID) is made, evaluation and screening of a potential reservoir or advanced completions takes place.

Detailed planning of the optimal completion configuration occurs throughout the execution phase. However, final configurations are often only determined once the Logging While Drilling (LWD) data becomes available and the completion is lying on the deck of the rig. This reservoir completion is then expected to provide the functionality required for the life of the well. While top-hole workovers are common practice, but for reservoir completions this is where operations end, or at least, that used to be the case.

Retrofitting advanced completions
Inherently, as fields mature, the range of production and recovery challenges increases or becomes more apparent. This can range from unwanted fluids being produced, differential depletion occurring, and hydrocarbons are bypassed. On the flip side, innovation provides an increased range of solutions that can contribute to improved performance. Faced with such technical issues, there is now a growing trend towards retrofitting advanced completions into existing wellbores. This approach is not only aimed at improving production and optimising secondary and tertiary recovery projects, it can also be used to reduce well intervention requirements. Below is a selection of technologies that are enabling this trend:

- through-tubing autonomous and wireless technology that can be installed to manage inflow without linkage back to surface or mechanical manipulation
- advanced packer technologies that can compartmentalise the production zones
- chemical solutions that can access the existing wellbore annulus and high expansion swellable and mechanical options.

As with primary reservoir completions, the range of technologies is increasing with the latest systems now offering fully intelligent completion functionality.

Smart wireless technologies
To combat the limitations associated with the use of conventional control lines, the development and deployment of wireless completions equipment is now becoming more prevalent (figure 1).

From drill stem testing to multi-node intelligent completions, the shift from downhole equipment with no communication and/or actuation mechanisms to wireless technology represents potentially huge efficiency and performance savings, as well as improved safety. However, these solutions tend to be targeted towards new field developments where there are currently limited options for replacement of failed equipment, or applications for existing wells, other than to conduct a complete workover.

For instance, there are a variety of digital oilfield solutions on the market today for topside applications, which can be integrated into existing fields to manage data and automate processes. Unfortunately, the same cannot be said for downhole solutions. The limited scope of intelligent equipment available does not address the needs of existing...
assets and can therefore demonstrate limited value. Without these retrofittable, intelligent downhole systems, the full benefit of the digital oilfield is beyond the reach economically for many mature fields.

Well communication and data transfer
Tendeka, a global specialist in advanced completions and production solutions for the oil and gas industry, has developed a unique two-way pressure pulse telemetry system which can be applied to downhole devices for communication in all phases of flow from a well. The PulseEight system (figure 2) provides a versatile wireless alternative to existing data transfer and actuation methods within both production and injection wells.

Downhole, the flow regime is diverted through an infinitely variable choke system which permits the manipulation of the available flow area with which to illicit a pressure pulse response that can be observed at surface. Multiples of these pulses can be received and decoded by surface software examining the amplitude, duration and interval between pulses to deliver meaningful data from the tool.

A similar effect can be achieved at surface using a production choke for the reversal of the communication route. As this pulse is contained within the normal flow stream, it is possible to achieve this level of communication without the need for additional downhole ‘jewellery’ such as signal boosters or repeater systems. This provides the ability for the entire system to have an elegantly compact configuration with limited downhole footprint (figure 3). Additionally, surface equipment requirements can be reduced to almost zero by utilising existing pressure monitoring already in place which enables an easy to install solution.

Early development of the device focused on the need to address the significant challenges associated with ensuring pulse telemetry could be achieved in not only liquid flow but also gas, and all three phases of flow. Tool responses have been designed such that they can autonomously optimise the pressure response created downhole to illicit a robust surface signal. This has been demonstrated to be possible even within the changeable characteristics of ‘steady state’ flow regimes associated with any hydrocarbon production stream.

The PulseEight Wireless Gauge was first applied to a retrofit downhole pressure and temperature monitoring system. This significantly expanded upon the limited functionality of the traditional industry memory gauge by providing real-time data to surface. This has facilitated the capability of existing reservoir models to be simultaneously updated with the latest data in a timeframe that is unhindered by the need for well interventions to retrieve memory gauges to surface for download.

These benefits, coupled with the flexibility of the retrofit design, were exemplified over multiple deployments in the North Sea. This allowed valuable pressure and temperature monitoring to be regained in wells which experienced a failure of their permanent downhole gauge systems and wells which were never designed for gauge inclusion in the first place. In one example, declining reservoir pressure in a field had resulted in the requirement for more surface compression capability to drive production. It was therefore crucial that there was an accurate understanding of reservoir pressure and decline to meet contractual gas deliveries and achieve recovery targets. A long-term deployment of the gauge system secured the requisite information to facilitate these needs.

Reservoir to smartphone communication
The communication system capability has been further expanded to offer true cable-free access to wellbore data. A recent deployment of a flow control valve in an onshore well demonstrated the ability of the system to send data wirelessly from the tool all the way to a smartphone app.

In what is believed to be a world first, this wireless ‘reservoir to smartphone’ communication enabled easy access in almost any location with either cell phone or satellite link connectivity (figure 4).

Despite the obvious benefit of ease of access, this opens up a new data route capability for challenging wells and/or remote locations that would otherwise be unattainable.

The system’s additional ability to function autonomously in reaction to specific wellbore events, without the need of surface instruction, opens a new chapter in the digital oilfield delivery. It now brings aspects of data analysis downhole to illicit responses in a timeframe unachievable by traditional human analysis and action alone.

Storm Choke alternative
One such application currently being trialled in the North Sea sees this autonomous functionality being combined with downhole tooling to offer an alternative to Storm Chokes.

In wells with a failed sub surface safety valve (SSSV), the retrofit deployment of an insert valve would always be desirable. However, should the mode of failure be confined to the SSSV control line, it typically precludes the use of these insert valves. Storm chokes are traditionally selected as a temporary means of maintaining both production and safety
of a flowing well. However, it is often a difficult balancing act to maintain the desired production rates whilst ensuring the valve can effectively respond to safety critical events. The Electronic Ambient Valve (EAV) contains inbuilt intelligence within the downhole tool that is used to recognise characteristic changes in flow regimes associated with both loss of surface containment or emergency shut-ins.

By recognising not only the flow responses but also the time frames associated with them, the EAV can respond to a greater number of events than traditional systems. It can also provide considerably more longevity and production uptime as it is not reliant upon a narrow absolute pressure window as required by traditional ambient valves. Ultimately, the system can still be controlled from the surface with pressure pulse telemetry to request closure or opening of the valve as required. This gives the human interface override capability, so crucial in the acceptance of new autonomous technologies.

Advancing digital oilfield operations
As a minimum, intelligent wireless technology could simplify and confidently advance digital oilfield operations by removing the need for traditional hydraulic or electric control lines. The elimination of these items can positively impact overall system costs whilst delivering an improved design from a safety aspect. Moreover, the truly intelligent capability of modern tooling sees the absolute need of surface data analysis for key trigger points in the well lifecycle to be mitigated, leaving engineering time to focus on more complex aspects of the reservoir's production potential.

The future for this and other technologies should be to extend the operating envelope for intelligent completions and address its various applications. With advances in surface data analysis and autonomous completion tools, which can link both inter-tool and inter-well, should be considered as the next step for production optimisation over multiple wells and can deliver demonstrable value to both existing and new field developments.

Chemical technology
To maximise return on investment, reducing the time and cost to complete wells in unconventional shale plays is crucial, particularly given the increasing trend to pump more proppant per thousand feet as well as the associated increase in volumes of fracturing fluids.

One such way to reduce time and cost is during perforating in acid with plug and perf completions. This new patent pending process and technology eliminates the procedure of placing acid ‘after’ the guns are removed from the well. A spearhead acid stage is typically pumped prior to the main fracturing stage to clean cement debris and generally assist in reducing initial injection/fracture pressures. Taking a four well pad as an example, with 50 stages per well, with an average displacement volume of 250bbl and acid displacement time of 20 to 60 minutes per stage (based on pump-down method and rate), this would amount to over 50,000bbls of fluid and up to 200 hours of equipment time that could potentially be minimised.

The application of perforating in acid is not a new concept, but to date, its use has been limited in unconventional shale plays because of the corrosive properties of the hydrochloric acid (HCl) or urea-hydrochloride and the temperature limitations of urea-based products.

A new thermally stable Modified Acid™ system is now available to the market and is already in use by various North American operators. It shows far superior performance properties compared to hydrochloric or urea-based acids, without the extremely hazardous/negative exposure, transport, effluent, and corrosive properties associated with HCl. This system is a replacement for hydrochloric acid blends and can be utilised and exposed to perforating tools and wireline at high temperatures over long periods with minimal effect. This system allows operators to pump acid with the perforating guns and plug, reducing time per stage and saving considerable water per stage (a hole-volume per stage) where applicable.

In addition to the advantages of this system, it also achieves ultra-long-term corrosion protection on corrosion resistant casing widely utilised in industry, such as P110. Casing integrity issues have been observed by multiple operators due to spearhead acid placement (hydrogen embrittlement). This system will provide corrosion protection well below the industry standard of 0.05 lb/ft² for up to 96 hours versus the usual six hours provided by HCl based systems, virtually eliminating the risks of casing integrity.

The chemical solution is part of a new portfolio of applications which aims to reduce water use and pumping time during completion operations in unconventional shale plays in the USA. Unique to Tendeka, the MajiFrac Solution (figure 5) also includes the company’s field proven MajiFrac Composite Plug, which incorporates a pump down feature to minimise water by-pass, and MajiFrac, a range of high viscosity friction reducers (HVFR).