Summary

The Challenge
As one of the world’s largest oil companies, the number one priority for Shell’s Exploration and Production is to at least replace produced reserves each year by new additions from exploration, commercial deals or improving recovery efficiency. So maturing reserves from existing discoveries is also Exploration’s number one priority. A significant volume of future reserves will still come from Exploration for new reserves, and as a large company we cannot do this by only exploring near existing fields. We need new material, or large, exploration opportunities. It has become clear that these will not come from our long-established ventures, but rather from new plays, mostly in geological basins new to Shell. This is driving our strategy away from near-field exploration towards these new plays. So our strategy is to renew our portfolio by screening basins that have the right potential for hydrocarbons, and focusing on these areas. Within a basin we then consider which plays are the best and this will direct our efforts to obtain new acreage. Of course such plays may still be present in our conventional heartlands. This change in strategy towards material discoveries has profound implications for the development and implementation of technologies that will help executing this strategy. This is in particular true for new areas in on-shore areas in the Middle East and Russia including Arctic areas, but also in the high grading of exploration portfolios in Deep Water areas. As a result we have been developing new technical capabilities to screen basins that have the right potential for hydrocarbons, and then focus on these areas. The challenge is to provide optimal technologies that would both allow us to rapidly screen for exploration potential in large on-shore areas, as well as allow for a rapid appraisal and production of newly found discoveries. Of course, such capabilities would apply as well to our conventional heartlands that will important to Shell for some time to come.

A Physics-Based Approach
In order to move fast in the de-risking, Shell uses a number of technologies before starting projects requiring more time, such as acquisition of new seismic data. These technologies range from field geology, using satellite or other remote sensing methods, mapping geology regionally and evaluating the various aspects of the hydrocarbon system such as modeling basin and charge. When these techniques have provided the focus, we can use 2D and possibly 3D seismic to perform a more detailed evaluation. Thanks to recent advances in so-called ‘non-seismic’ technologies Shell has developed and integrated a state-of-the- art Frontier Exploration capability, built around various complementary technologies. Since absolute certainty will never be achieved the remaining uncertainty is best reduced by measuring several non-related parameters of the sub-surface which when put together in a consistent frame work produce a ‘most likely’ sub-surface scenario.
In the past this concept was not so extensively exploited, as in most cases structural information about sub-surface geology was seen as most important and indeed seismic based technologies were often seen as entirely adequate for this. In a few situations even the quantitative interpretation of seismic amplitudes in terms of rock and fluid properties were very successful in predicting the presence of Hydrocarbons in those imaged structures as well. However, these days the emphasis is shifting towards understanding more subtle traps for which seismic imaging is no longer enough for successful
exploration. Indeed, the question becomes not only whether a possible quite subtle trap is present (which often calls for innovative seismic technologies), but in addition the question if and to what extend these traps could hold commercial quantities of hydrocarbons. This shift towards understanding more subtle traps is one the main reasons other parameters based on different physical measurements become relevant.

These non-seismic technologies make possible measurements of other than just linear elastic rock properties that are the basis of the conventional seismic method. In addition, and very important as well, is that the assessment of possible exploration opportunities need to become much faster. This has lead to renewed interest in for example airborne and sometimes space-borne measurements of surface features which although indirectly may point towards attractive exploration opportunities in the underlying sub-surface. In this talk I will focus on two areas of recent developments in particular namely new uses of high resolution of airborne and satellite potential field data and developments in surface based Electromagnetic Prospecting techniques.

**Satellite/ Airborne Potential Field Technologies**

The first technology to produce 3D structural geology images of the subsurface (made already some 100 years ago) was based on the variation of densities due to varying lithology in the subsurface. These measurements were made with sensitive gravimeters exploiting a simple consequence of Newton’s gravity theory. Similarly, measurements of the earth’s paleo or induced magnetic field were already measured long ago as well, which has lead for example to the discovery of the reversal of the Earth’s magnetic field. Both gravity and magnetic measurements are based on simple consequences of potential field theory. At the time these measurements were of low spatial resolution, but recently these measurements have become so accurate that application on airborne platform allows for high-resolution structural images of the subsurface. Indeed, geologists have used aeromagnetic surveys for many years to tell them about basement features. However, new high-resolution techniques and evaluations can now reveal much more than in the past. These are now being used in more advanced, plate tectonic reconstruction techniques relevant at basin scale as well as well as for high-resolution structural information at sub-basin scale and sometimes prospect scale. For example, by analyzing frequency bands of high-resolution magnetic data, Shell geoscientists have revealed the structure of potential oil-bearing basins in the Atlantic Ocean, previously hidden beneath basalt layers.

![Figure 1. Vertical gravity gradient $T_{zz}$ measured with a marine gravity gradiometer (right) has much higher spatial resolution than $T_{zz}$ derived from observed gravity $T_z$ (left).](image)

Spectral analysis of high-resolution aeromagnetic data reveals depth interfaces and sedimentary basins that cannot be seen on seismic below basalt. Another development of Potential Field technology, the gravity gradiometer survey, is being used by Shell in the Gulf of Mexico, North Sea and Middle East. Gravity gradients can be recorded quickly over large areas using aerial techniques, and, when combined with magnetic data, can also show structures across a potential hydrocarbon basin, helping to narrow down the search. A combination of magnetic and gravity inversion has also been used successfully to map the base of salt, matching the best seismic pre-stack depth migrated images. Such
quick-look tools can be used to obtain a more accurate seismic picture faster, or even substitute for seismic in some cases.

![Figure 2](image1.png)

**Figure 2.** Conventional High Resolution Aeromagnetic data using Novel depth estimation techniques reveal subtle detail.

**Surface-Based Electromagnetic Prospecting Techniques**

Important new developments enabling much deeper and with higher resolution of Electromagnetic properties of the subsurface have lead to renewed interest of these technologies in exploration. Of course various different EM technologies are possible: passive EM technologies, for example self potential and magnetotelluric measurements exist, the latter exploiting naturally occurring EM fields in the sub-surface driven by the variations of the Earth’s magnetosphere. For example 3D Magneto-Telluric technology has improved significantly and through a recent breakthrough can now be applied also in ice-covered permafrost regions. Important active, or controlled source technologies are now possible as well, both on-shore as well as off shore. In the latter case a new controlled source EM prospecting technology has been developed which allows us to obtain 3D subsurface interpretations that would not be possible using just seismic technology. All EM technologies are of course sensitive to variations in the subsurface conductivity or resistivity, both parameters not measured in a seismic survey, and which may be directly indicative of the presence of hydrocarbons due their relative high resistivity compared to brines. Indeed exploration discoveries offshore in the Far East in 2005 have been made where EM directly demonstrated the presence of hydrocarbons.

![Figure 3](image2.png)

**Figure 3.** Seismic section and interpreted resistive body (red and yellow colors) from a marine Controlled-Source EM survey in Southeast Asia.

**A Comprehensive Geological Interpretation**

All these different geophysical technologies fit into an approach we have called ‘Play-Based Exploration’, in which the regional geological context is the starting point. The regional approach,
looking at the plays within an entire basin, is essential if we are to understand the whole petroleum system, the relative timing of elements such as the generation and expulsion of hydrocarbons, migration paths and structuration, as well as the distribution of potential reservoirs and seals. Only by doing this can we identify new plays and the possible large hydrocarbon volumes we can explore for. This approach also needs the integration of specialties and disciplines, and a globally consistent evaluation methodology and this we can supply with our global organization and processes. It is this holistic approach, rather than pursuing ever smaller opportunities on a fragmented country-by-country basis, that will give us an exploration business we can sustain in the future, with more upside and value.

**Impact**

Recent Shell Exploration successes have come from integrating seismic and non-seismic technologies in the way explained above, leading to improved sub-surface interpretations not possible with any single technology. This will be of direct relevance for exploration in Russia including in Arctic regions, where it is unlikely that a single geophysical data set will adequately reduce the sub-surface risk. Recent examples of this approach are Deep Water West Africa, Deep water Borneo in the Far East, where have tried earlier applications as well as onshore Middle East and on-shore United States.