Land seismic node technology: Current capabilities and future directions

Tim Dean[1]* and Matt Grant[2] give an overview on the development of nodal acquisition systems and offer their opinions and suggestions on future systems.

Introduction

In 1996 Ian Jack published a summary of the specifications for a future land seismic recording system (Jack 1996). Ian Jack's system was based on what he called an SGR (seismic group recorder) but what we would now call a node. Back in 1996 the range of nodes available was limited and they were both heavy (> 5 kg) and expensive, restricting their use (Dean et al. 2018). The introduction of GPS timing and modern lightweight electronics has resulted in a boom in nodal acquisition and there are a wide variety of units currently available (Figure 1).

We have been tracking the development of nodal acquisition systems with much interest over the years and, similar to Ian Jack's paper, we decided that it was time we gave our suggestions on future systems. Many of the features we recommend are not new, and we have attempted to give credit to the originators accordingly, for those we have missed, we apologise. Obviously, we could have dreamt up some unlikely component, e.g. a tiny geophone with a low natural frequency and high spurious frequency, but we attempted to be realistic in the choices made.

The aim of the system design is to reduce time (i.e. cost) and HSE exposure whilst maximising the quality of the data acquired. A commonly accepted model of quality vs. cost is shown in Figure 2. Initially, we can make significant improvements in quality for little additional cost, but as the system improves additional improvements in quality become increasingly costly. Ideally, our system would appear near the inflection point of the graph (the green point on Figure 2), which represents the best value in terms of the trade-off between quality and cost.

The quality of the seismic data is not only related to the node itself (i.e. the sensor and its electronics) but also the coupling of the sensor. Similarly, the cost of the node is not only related to its purchase price but also its cost of use. In this paper we begin by describing the acquisition process. By examining this process in depth, we can then make decisions about how the node will be configured, which will be the subject of the second section.

Figure 1 A photo of just some of the modern nodes available on the marker (from left): Sercel Accel, Stryde, EarthPulse ANT-1C, Geospace Pioneer, INOVA Quantum Accuseis, AllSeis.

Acquisition process

When describing the acquisition process, we assume that the survey has already been planned, and the lines have been cleared (if required).

Scripting

The first stage in deploying the nodes (assuming they are fully charged of course) is to script them. Scripting the nodes involves setting their recording parameters such as the gain level, sample-rate, and any acquisition filters. Of particular importance is programming the recording periods – if we are limited in the times during which we can shoot, then there is no point wasting battery and memory by recording data outside these periods. For some systems this 'calendar' option is limited to simply setting the times at which the node will be operational. Although better than recording continuously, a superior option is to be able to individually set recording times by date as well. Although not applicable to every survey, often longer breaks during acquisition may be required, for example to allow the crew to have rest days.

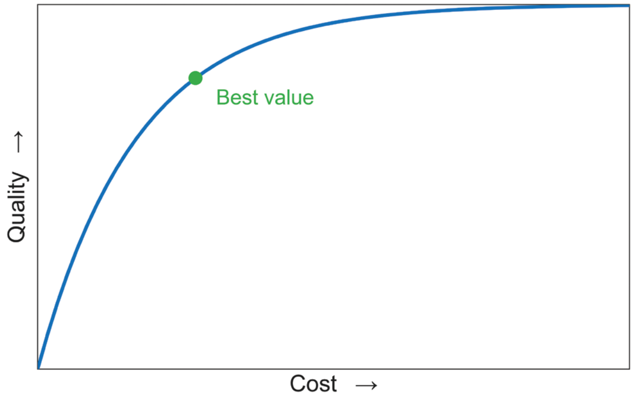

Figure 2 Theoretical quality vs. cost graph. Quality improves rapidly at the lower end of the cost axis but small improvements in quality become increasingly costly.

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Figure 3 Photo of a typical node system harvester. The nodes are placed into racks to script/download data/charge. Often there will be different download and charge racks as the former is considerably quicker (minutes vs. hours).

Figure 4 Stryde initialisation tool used to program the nodes with their acquisition parameters and positions during deployment. Courtesy of Stryde.

Figure 5 Photo of the Stryde positioning-with-layout system. The GPS antenna is mounted on the backpack with the nodes caried in a tray on the side. The operator is initiating a node by placing it upside down into the small initiation device. Courtesy of Stryde.

Figure 6 The 'Tiny Surveyor' autonomous survey robot. The can of spray paint can be seen mounted on the rear of the robot.

If we can set the nodes not to record during these days, then we can conserve additional memory and battery.

Scripting the nodes is typically done by running the nodes through the harvester (Figure 3). Although the scripting itself is quick (of the order of a few seconds) it still takes time to physically load the nodes into and out of the harvester. An alternative approach is to script the node during its planting, using an initialisation device, such as that employed by the Stryde system. (Figure 4), or by connecting to it wirelessly. This may appear to be desirable functionality but if this is the only operation required during deployment (note that the Stryde system also programs the node with its position at this stage) then it may be more efficient to do so before deployment. It also requires careful management – if one of the node programmers is incorrectly set up then all the nodes it initiates will be incorrect as well.

Survey

Once the nodes have been scripted (or will be scripted during deployment) we need to navigate to their position. This is conventionally done in one of two ways:

1. A dedicated survey team moving ahead of the layout team marking the receiver positions. There are multiple methods to do so. For closely spaced nodes the survey team can operate on foot with positions marked with spray-paint. Alternatively, a vehicle can tow a chain with multiple stations marked on it. For sparser positions surveying can be done from a vehicle. For example, markers (e.g. biodegradable plastic bags of sand) can be dropped out of the vehicle window at each station.
2. Positioning-with-layout: the layout team have their own integrated survey system that is used to navigate to each receiver position where the receiver is then planted. Such a set-up is shown in Figure 5, the GPS system including the antenna is mounted to the back of the backpack and the navigation tablet on the front. Once in position the user initialises the node (carried in the tray on their hip) with its acquisition parameters and position.

The positioning with layout approach may seem at first glance to be the most efficient as it removes the duplication of multiple passes down the line. With such approaches, however, the team progresses at the speed of the slowest activity. For example, it may take twice as long to plant the node as it does to navigate to the next position, thus the surveyor is left standing around waiting. Another alternative is to use a small robotic surveyor as part of the layout team. Such a unit is shown in Figure 6. This unit is capable of navigating between points autonomously, each one being marked with spray-paint, if the planned point cannot be achieved then the operator can adjust the position by manually steering the robot (Dean and Grant 2021).

Transportation

Once the position of each node has been identified, either in advance or during the layout process, the next stage involves placing the nodes in position. Again, there are multiple methods to do so, including:

1. The nodes can be dropped individually out of a vehicle at their required position. If done accurately then the nodes themselves become the survey markers.
2. Trays of nodes can be placed at regular intervals along the line and then hand-carried to their appropriate positions and planted.
3. The nodes can be carried within a vehicle that stops at each position or set of positions for the node/s to be planted.

For efficiency of transportation (not just during deployment but also during mobilisation) the nodes should be as light as possible but also be packed efficiently.

Planting

Now the node is at its correct position it needs to be planted into the ground. Typically, this has involved digging/scrapping a small hole using a pick or mattock, placing the node in the hole, and then stamping on it to get firm coupling. Obviously in soft terrain such as sand the stamping may be unnecessary. Rather than digging the hole by hand the hole can be created using a machine-mounted auger (Figure 7) which can also include a navigation system, removing the need for separate surveying.

Although coupling has been shown to be important, in some terrains, particularly in sand, coupling using a spike may not be effective, instead simply placing/burying the node on the ground may be sufficient. For soft/muddy terrains we have found that cylindrical-shaped nodes not only result in excellent coupling but can also be extremely easy to emplace if a tool is used to create the hole into which they are then inserted. The Stryde node can bridge both these scenarios as it has a removable spike that can be used when required (although the long cylindrical body may leave it susceptible to swaying if the body of the node is not partially buried as well).

Again, there is likely to be a trade-off between the time spent achieving perfect coupling and the resulting quality of the data (i.e. Figure 2). It may actually be advantageous to spend an equivalent period of time planting a large number of slightly poorly coupled nodes rather than a smaller number of perfectly coupled nodes.

Figure 7 Track-mounted auger used to create holes for planting nodes in.

Activation

Once the node is in place it needs to start recording. Nodes can be activated in a number of ways, using a magnet, a specialised tool (e.g. Figure 9), or the node can activate automatically when it is placed vertically.

Line and point assignment

Land seismic surveys typically employ a local grid coordinate system where positions are defined in terms of line and point numbers rather than their actual coordinates. This vastly simplifies acquisition (and processing) as the true (geographic) coordinates are often complex, particularly if the grid is not oriented north-south. Therefore, each node needs to be assigned a line and point number. This can be done directly during emplacement, either by programming the node before it is planted (Figure 5) or after it has been planted by connecting to it wirelessly. Alternately the position and serial number of the node can be recorded and the values assigned after harvesting. The final approach, and the most efficient as no field effort is required, is *self-assignment* where the line and point values are assigned post-acquisition based on matching the surveyed positions to the GPS positions recorded by the node. Obviously, this requires accurate internal GPS positions to be recorded by the node, but through the employment of an appropriate matching algorithm even relatively closely spaced nodes (~4 m) can be assigned correctly (Dean 2025).

Quality control

The options for quality control during acquisition currently vary from real-time data, intermittent/compressed data (neither of which are applicable for large channel-count systems), real-time QC, medium-range (hundreds of metres) opportunistic QC, short-range

Figure 8 Stryde node showing its removable spike (which is inserted into the base of the node).

Figure 9 Photo of the NuSeis 'bump' tool which is used to turn the nodes on. Courtesy of GT).

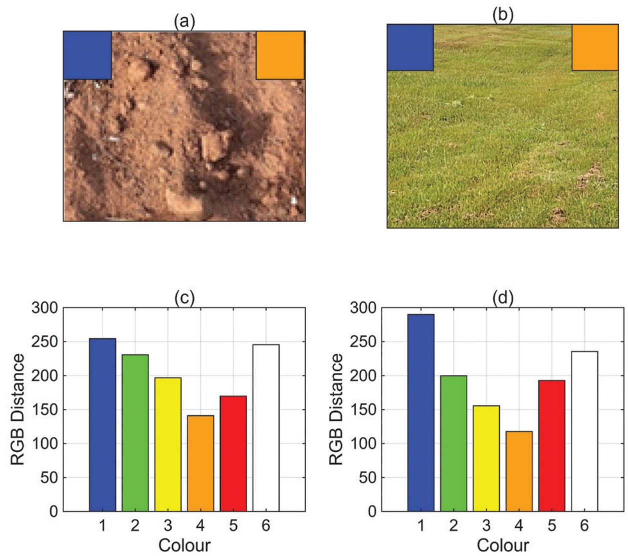

Figure 10 Examples of determining the most visible colour for a node. (a) and (b) show two different terrains whilst (c) and (d) show their RGB difference to six different colours. The largest and smallest differences are shown in the top left and top right of the photos respectively.

(tens of metres) opportunistic QC, and blind (Dean et al. 2025). Modern nodes are extremely reliable (Dean et al. 2021) so QC is not really required to confirm the nodes are operating, more so to make sure that they are still correctly planted (or in the location at all).

Retrieval

Once recording has been completed the nodes then need to be collected. One of the obvious issues with doing so is finding them. Unlike cabled systems where you simply follow the cable, nodes can become completely buried or disturbed by wildlife etc. One obvious way to help find the nodes is to make them a distinctive colour. The visibility of different colours can be tested by taking the Euclidean distance between the average RGB values in a terrain photo and the candidate colours (Miller et al. 2014). An example of the process is shown in Figure 10 which shows two different ground terrains, dirt (a) and grass (b) compared to six possible node colours. For both conditions blue has the largest contrast whilst orange has the lowest contrast (shown in the corners of the photos). Reflective coatings can also make nodes more visible (Dean et al. 2020).

If nodes do become lost, if they have some form of communication then the strength of the signal can be used to help locate their approximate position, with metal detectors being used to find them (Dean, Grant and Sweeney 2025). A nice alternative, not currently offered, would be to have a small buzzer in the node that could be activated remotely to help locate the node. Such buzzers can, however, by quite bulky (e.g. 10 x 30 mm) but still light (e.g. 6 g).

Charging and downloading

The two main choices for charging and downloading are wireless or direct contact. Wireless systems have the advantage in that there are no exposed contacts that can be damaged. An exception to this is the SmartSolo system that protects the physical contacts by placing them inside the two halves of the node meaning they are only exposed when the node is split in half for charging and/or downloading (Figure 11). Being able to split the node into two

Figure 11 SmartSolo node split into its electronics/sensor (left) and battery (components). The charging/power connectors are shown by the white boxes and the download connector by the black box.

components has additional advantages, as the download time (typically minutes) is much shorter than the recharge time (typically several hours). By employing additional batteries, you can utilise the recording section of the nodes for longer periods. You can also 'mix-and-match' different node components (Figure 12). The obvious disadvantage of such an approach is that it requires the nodes to be split apart for downloading/charging. This process can be improved using automatic machines (the spike at the base of the node acts as the head of a bolt which screws the two components together). Opening the node also risks introducing dirt/moisture into the internal components when it is reassembled.

Although wireless charging is less efficient, the charge times do not appear to be longer for these systems, for example, the Stryde and Pioneer node charge times are ~4 hours for 50 days recording, consistent with, if not better than, the charging time of other systems (Figure 13). Induction charging also creates heat, which may cause issues if a large number of nodes are being charged in an enclosed space.

Deactivation

The nodes have now been downloaded and charged ready for their next survey. One stage that is not always necessary/available is deactivation of the nodes. Some nodes, particularly those that are designed to activate automatically, continue to operate in a low-power mode. Although the battery usage is minimal, if the nodes are not redeployed in a short period they will need to be recharged before being reused. A better option is to be able to

Figure 12 A SmartSolo 3C IGU (top section of the node) attached to a base with external battery connection option.

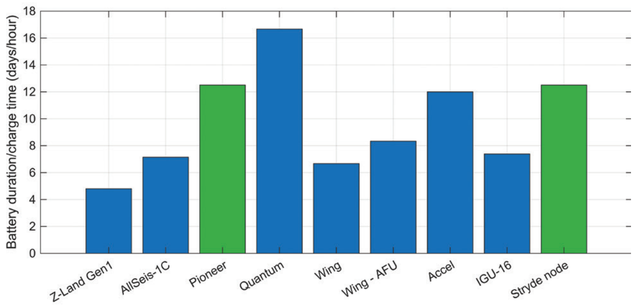

Figure 13 Battery duration/charge time for modern nodes, the higher the values the proportionally faster the node charges. The nodes with inductive charging are shown in green.

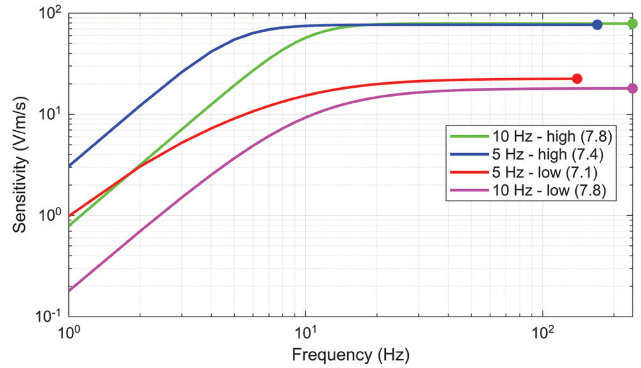

Figure 14 Geophone response curves for four typical geophones (in this case made by DTCC).

turn the nodes off completely. Although obviously this then requires an additional stage of turning the nodes back on (ideally during the scripting or deployment process), this is much quicker than having to charge them again.

System requirements and design

Now that we have the acquisition process described we will define the ideal system as we see it. We begin by addressing the sensor and the form factor and configuration, in our view the two most important features.

Sensor

A key component of any seismic node is the type of sensor that it contains. The choice of sensor is currently limited to the traditional geophone, MEMS (Sercel WiNG & Accel and INOVA Quantum Accuseis), or a piezo-electric accelerometer (Stryde). If a geophone is selected as the sensor, then there is a further choice between the element type, in particular its sensitivity and natural frequency. Most geophone-based nodes offer a choice between 5 or 10 Hz natural frequency geophones. The lower the natural frequency the better the low-frequency recording performance, but also the lower the spurious frequency. This can be seen from the geophone response curves for four typical geophones shown in Figure 14. The bandwidth in octaves (calculated between the natural frequency and the spurious frequency) for each geophone is shown in the plot legend; note that the 5 Hz geophones have a lower bandwidth than the 10 Hz geophones, something that is not immediately evident due to the logarithmic scales used on the plots. The tilt-tolerance of geophones decreases with their natural frequency (Dean and Grant 2024) so additional time and effort is required to ensure near vertical placement is achieved.

As well as the natural frequency of the geophones, there is also a choice to be made about sensitivity. For modern nodes, high-sensitivity geophones have become the norm (~80 V/m/s vs. standard sensitivity of ~28 V/m/s). The responses of high-sensitivity and standard sensitivity geophones are also shown in Figure 14. High-sensitivity geophones are preferred as they enable lower amplitude signals to be recorded if the dominant source of noise is system (electronic) noise. Theoretically this would, in-turn, allow the source energy to be reduced. For example, the 2.8 times larger sensitivity of a high-sensitivity geophone should allow the sweep-length to be reduced by a factor of ~7.8 (the SNR of vibroseis is proportional to the square-root of the sweep length (Landrum 1967)) but the dominant source of noise is typically ambient noise. Increasing the sensitivity of the geophone will increase the signal level but also the ambient noise level, and thus the SNR will not change.

When compared directly, high-sensitivity geophones tend to be larger and heavier mainly due to their larger internal coil. The Geospace GCL and Pioneer nodes (Figure 15) are unique in that they utilise a much smaller ('SMG') element that weighs just 43 g vs. 130 g for a standard element, at the expense of a small decrease in sensitivity (63 V/m/s, note that this is still higher than a 'standard' geophone). These small geophones enable the lightweight Pioneer and GCL nodes (Figure 16).

MEMS sensors have a reputation for greater power consumption. For example, INOVA offer a geophone and MEMs version of their Quantum node (Figure 17) – the MEMS version promises 23 days of usage and weighs 0.48 kg (48 days/kg, Figure 18) whereas the geophone version offers 50 days recording and weighs 0.65 kg (77 days/kg). The Sercel WiNG in both its analogue and digital forms claim the same battery life (40/50 days with pathfinder QC on/off, 53/66 days/kg) with only a nominal (<3%) difference in weight. The new Sercel Accel offers 30 days recording (97 days/kg). Even if the power consumption of MEMS nodes is higher, the battery lives of MEMS-nodes still compares favourably with geophone systems such as AllSeis (33 days/kg) and the SmartSolo IGU-16 (22 days/kg).

The only node with a piezo-based accelerometer (the Stryde node, Figure 20a) is also that with the best battery life (333 days/kg, Figure 18).

Although it is difficult to compare the relative sensitives of accelerometers and geophones (Goujon et al. 2021) our experience where side-by-side measurements have been made (Dean and Grant 2024, Dean, Grant and Sweeney 2025) suggests that they are broadly equivalent. Comparisons of different geophone-based systems have also shown little difference (Dean 2024, Dean and Hooi 2025). Concerns also been raised about differences in dynamic range, particularly with respect to clipping on near-offsets (Miller, Ivanov, Peterie, Bailey and Sloan 2014) but our work (Dean et al. 2021) shows that this is unlikely to be an issue. Modern systems also have dynamic ranges (typically at least 124 dB) that far exceed that previously suggested by Shirley et al. (1985) of just 80 dB. Care must be taken when directly comparing the dynamic range of accelerometer and geophone-based systems (Dean, Grant and Sweeney 2025).

Figure 15 Photo of a GS-One 10hz Geophone (left) and SMG 10Hz Geophone (right). Courtesy of Mike Dahl, Geospace.

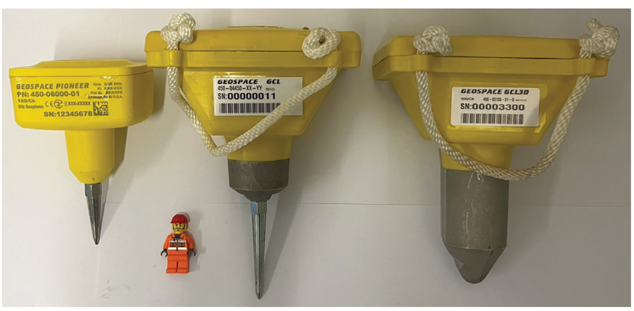

Figure 16 Geopace nodes (from left) Pioneer, GCL and GCL3 (a 3-component node).

We remain therefore relatively agnostic on which sensor to choose, although if a MEMS system is employed then it needs to have low power consumption and a low 1/f noise corner frequency. If a geophone is employed then it needs to be a modern, miniaturised element (e.g. Figure 15) to keep node weight down.

Form-factor and configuration

Although popular in early nodal systems, the use of systems with external sensors and batteries (Figure 19) has become increasingly unpopular. This is a result of both an acceptance that denser point-receivers are generally superior to sparser arrays of geophones (Ourabah 2024), and the significant improvements in nodal technology over the past 15 years. The first successful integrated node, the Fairfield Z-Land (Figure 20d) introduced in 2008, weighed 2.2 kg, had a volume of 1900 cc (excluding spike), but a battery life of only 12 days. In contrast, modern nodes are typically less than 1 kg, with the smallest, the cylindrical Stryde node (Figure 20a) being just 150 g with a volume of 170 cc (15 times lighter and 11 times smaller than Z-Land). Similarly, the more conventionally shaped Geospace Pioneer (Figure 20c) weighs just 450 g and the INOVA Quantum Accuseis (Figure 20b) 480 g. Despite these lighter weights, modern nodes typically have battery lives of between 20 and 50 days (Figure 18).

Modern systems specifically designed solely for use with external sensors are limited to the Sercel WiNG AGU and Smart-

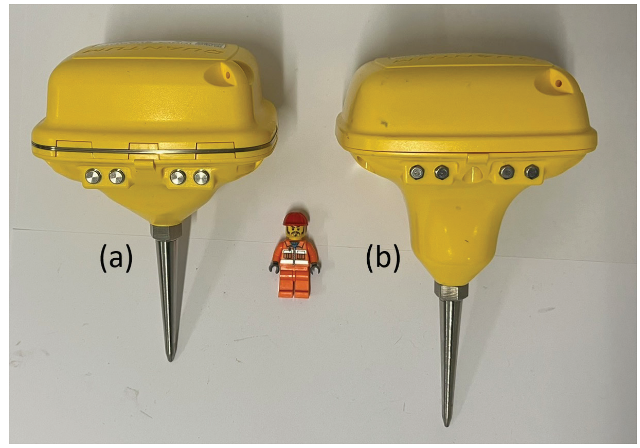

Figure 17 INOVA quantum nodes containing (a) MEMS, and (b) geophone sensors.

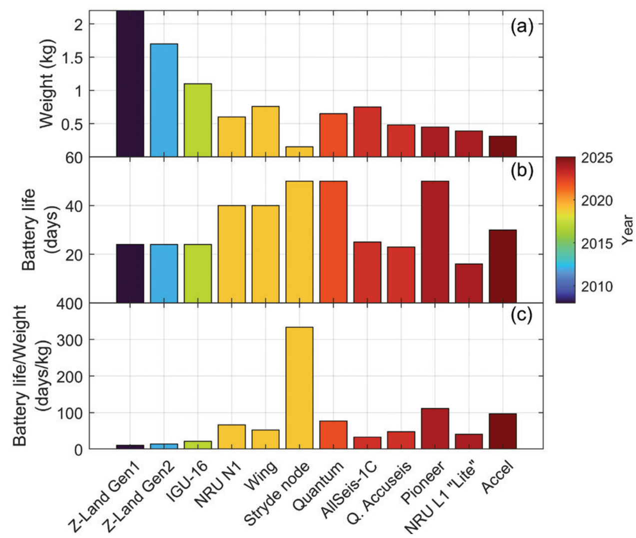

Figure 18 Weights and battery durations of different nodes.

Solo IAU-19 (Figure 21). Rather than force the user to choose between an internal and external sensor option, manufacturers tend to offer the option to 'override' the internal sensor of the node by attaching an external sensor (Figure 22), rather than removing the internal sensor completely and thus sacrificing the utility of the self-contained node.

Again, although some systems offer the option to connect of an external battery (Figure 12), no modern large-scale systems are designed with such a configuration in mind. The SmartSolo node offers several different configurations as the node splits into two sections, one containing the recording electronics/sensor and the other the battery (Figure 11). Components with different sensor configurations (1-component/3-component/external sensor) can then be combined with different capacity batteries or external battery connectors to create different nodes.

The NuSeis system (Figure 23) is designed so that the electronic components can be easily moved between different form factors. Even nodes that are not explicitly designed in this way may be reconfigured if required (Figure 24).

Bucking the trend of the conventional body and spike node and the cylindrical designs of NuSeis and Stryde is the new Accel node from Sercel (Figure 25). Accel is a drop-node, i.e. it is designed to be simply placed on the surface without being buried or coupled with a spike. This concept is instantly attractive as it is far easier to emplace and far more suitable for automation.

The first key consideration when designing our own node was keeping the weight as low as possible. Figure 26 shows a breakdown of the weight of the components in two popular commercial nodes, both of which have a conventional shape. Note how the battery, which we originally thought would be the heaviest component, is only ~30% of the weight of the node, less than the total weight of the case (~40%).

Design criteria

Our design criteria are summarised below. In terms of the physical characteristics of the nodes we recommend:

- Light and compact – the node should be a shape that minimises the size and weight of the case and other 'superfluous' elements (i.e. those that are not integral to recording seismic data). The weight should be consistent with other lightweight nodes currently offered (Figure 18a), ideally less than 0.3 kg (the target back in 1996 was 0.2 kg (Jack 1996), but this didn't include the battery).
- Adaptability – the node should be as adaptable as possible, in its simplest form, the node should be capable of being used with different sized spikes or no spikes at all. Ideally it should be able to be easily reconfigured if a different form-factor (e.g. a cylindrical body in muddy terrains) is more appropriate. If geophones are used then it should be easy to replace the elements if they become damaged, or if a different element or even an external sensor is desired (note that the ability to connect an external sensor (Figure 21) should not be a standard feature of the node design).
- Suitable for bulk handling – a key element in the efficiency of the system is to be able to handle the nodes in trays. The aim is that the only time the nodes are not in a tray is when they are planted in the ground.
- Battery life – There is a direct trade-off here with weight, increasing the battery life will increase the weight of the node although perhaps not as much as we originally thought (Figure 26). Given the ability to efficiently recharge the nodes due to their bulk handling, we believe a battery life of 25 days is sufficient (Figure 18b).
- Direct contacts for charging/downloading – We have extensive experience of using nodes with external connectors and have found few issues and thus ideally the node should use direct physical contacts – but only if this can be done without sacrificing the ability to bulk handle the nodes.
- The node should have a colour that makes it visible in the terrains that it is most likely to be used in. Although dark colours may be tempting (Figure 10), these may result in the node becoming too hot, so lighter, particularly fluorescent, colours are recommended.

In terms of the functionality of the node we recommend:

- There should be an option to script the node during its deployment, but this should not replace the ability to script nodes prior.
- The system should be compatible with a range of different survey options.

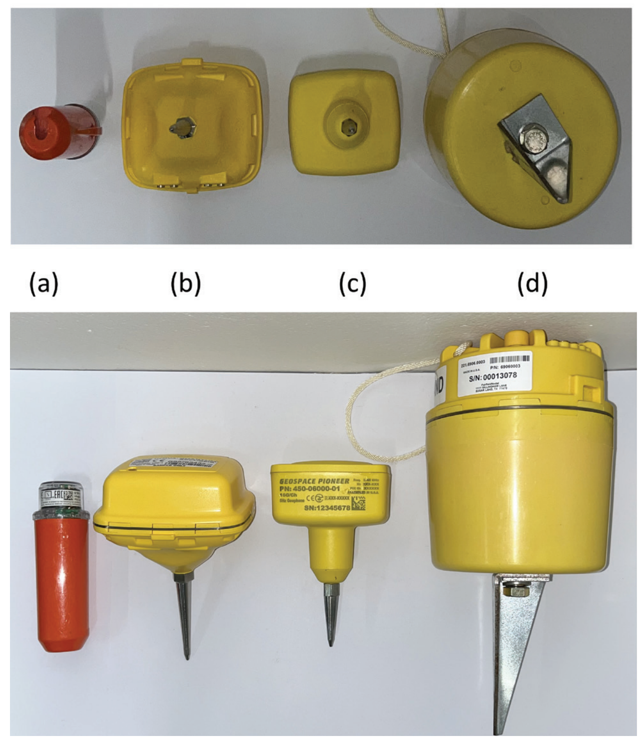

Figure 20 The first fully integrated node, the (d) Fairfield Z-Land with some more modern successors (a) Stryde, (b) INOVA Quantum Accuseis and (c) Geospace Pioneer.

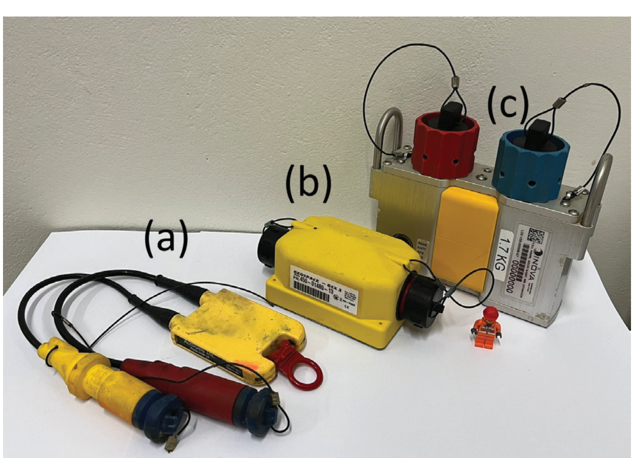

Figure 19 Photo of early external sensor/external battery nodes, from left: Autoseis HDR, Geospace GCL, and INOVA Hawk.

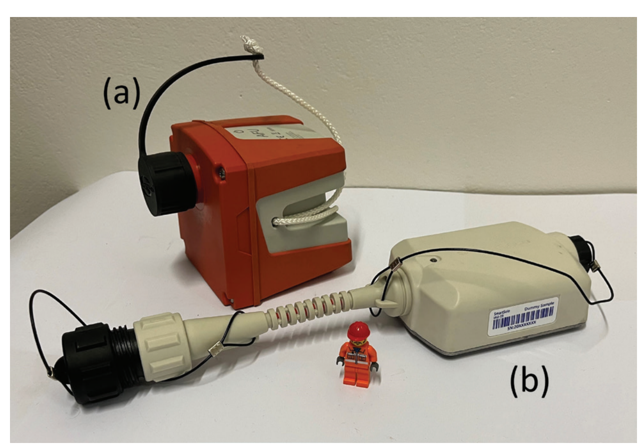

Figure 21 Photo of the (a) WiNG AFU and (b) SmartSolo IAU-19. The sensor is connected via the connector on the left of the nodes.

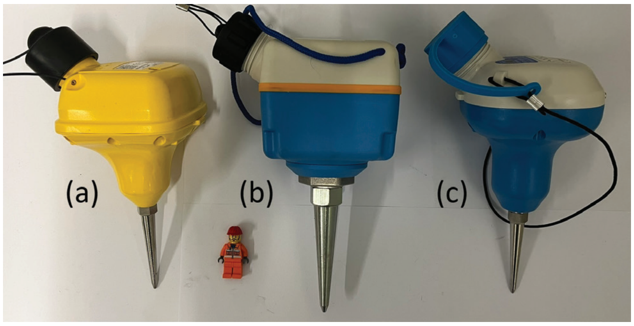

Figure 22 Modern systems with external sensor options, (a) INOVA Quantum, (b) AllSeis, and (c) SmartSolo IGU-16HR-IES.

Figure 23 Three different configurations of NuSeis nodes. Note that the electronic housing (under the transparent dome) is identical for all nodes.

Figure 24 A standard AllSeis node (left) that has been converted to a drop-node (right) using a 3D printed case that replaces the lower half of the original node case. The geophone is under the circular cover.

Figure 25 Photo of the Accel node from Sercel.

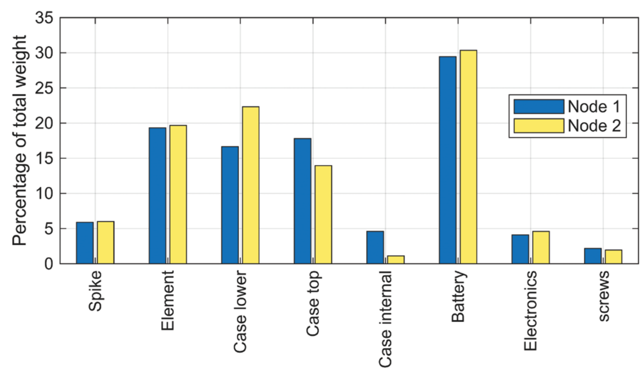

Figure 26 Break-down of the weights of the different components contained in two different nodes.

- The survey/layout systems need to be adaptable – no matter how good the plan is there are always issues encountered. Where encountered, these need to be overcome efficiently, for example by integrating offset rules (Dean 2024) into the navigation tablet.
- The node should automatically activate when turned vertically if this does not impact the ability to efficiently transport the nodes, but…
- The node should be capable of being turned completely off/on a the end/beginning of the survey.
- The internal GPS of the node should be accurate enough to enable self-assignment.
- The node should employ opportunistic QC, if short-range then it should be supported by mobile phone apps and/or a specific harvesting unit such as the Geospace line health recorder (LHR) which is compatible with a drone.

Discussion

When asked a question about geophysics we often make the 'joke' that the answer to every question is 'it depends'. The node design we have outlined here should also contain the same caveat, our design has been heavily influenced by our own recent acquisition experiences involving high-density, large channel count (>20,000 channels), high-productivity vibroseis (~4000 node moves per day with an average deployment time of ~5 days) in the Australian bush (Dean and Grant 2024, Dean, Grant and Pavlova 2021). The ways in which nodes are used, and the terrain within which they are employed, varies greatly around the world, and we have attempted to incorporate this into our design by making the node as adaptable as possible.

Although we have been primarily concerned with describing the node itself, the way in which it is employed is a key consideration (note that we have ignored many of the technical specifications given in Jack (1996) as they have either been met or are of no consequence anymore). Given the continued increase in channel-count efficiency of use is a key consideration and we feel that the future of efficiency is automation. Although not mentioned in the previous section, our ideal node design is therefore one that is suited to an automated deployment system, in both its form-factor and ability to be handled in bulk.

A clear analogy is farming or forestry, where labour-intensive tasks have been replaced by mechanised and/or automated operations. GTI introduced an automated deployment system for their NuSeis system several years ago that involved using a spike to create a cylindrical hole that the node is then inserted into. This is ideal but a simpler system could be to use a post-hole driver with a node-shaped tip that could be easily mounted on a variety of vehicles. The driver would create a node-shaped hole that the node could then be (manually) placed into (rather than an auger (Figure 7) that simply loosens the dirt thus still requiring excavation and effort to ensure tilt is within specification).

We also cannot discount the cost of the node itself and its associated systems. The target cost back in 1996 (Jack 1996) was <\$1000 (equivalent to \$2000 in 2025)). Even though this target has been far exceeded, given the large, and increasing, number of channels being used, the node should be as low cost as possible (<\$200). But when considering cost, the cost of use must be considered along with the cost of purchase. Again, this brings us back to adaptability, what works for one survey will not necessarily work in others, or be the most efficient, e.g. if the receiver spacing changes. For automation, we may need to accept that not every position may be suited to automated node deployment, but its use for a significant proportion of the survey is a huge advantage.

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