

# **The RangeNav™ Portable Underwater Tracking Range: A Review of the First Year of Operations**

Marco Flagg, CEO; Desert Star Systems LLC, 3261 Imjin Rd, Marina, CA 93933 USA  
Andrew Schwartz, CEHNC, U.S. Army Corps of Engineers, 4820 University Square, Huntsville, AL 35816  
Thomas Gray, Sales & Marketing Manager; Desert Star Systems LLC, 3261 Imjin Rd, Marina, CA 93933 USA

## **ABSTRACT**

Operations in littoral (near shore) waters have taken on increased significance for the U.S. and other Navy's since the end of the Cold War. With a multiplying number of adversaries and threat scenarios, much greater significance of Special Forces operations and a variety of potential operating theaters, there has been both a strong growth in both systems developments and specialized training to meet these threats.

This diversification has also meant that there are now many smaller and lower budget projects that require underwater testing. Further, operating conditions in shallow waters are varied and site specific, meaning that both system tests and military training has to be done in waters that match these conditions.

In 2004, the Naval Surface Water Center (NSWC) in Panama City (Florida) contracted our company to develop a tracking range that would be responsive to these requirements. From the outset, the clear demand was that this system should not be gold plated – it should be a Toyota perhaps, not a Mercedes. It should be deployable anywhere – offshore or in inlets, in harbor basins or in lakes. Deployment was to be from vessels of opportunity, and using local ship's crew rather than specialized technicians. Finally, the system operation too should be straightforward enough to not require a dedicated crew.

The NSWC system was delivered in early 2007, and deployed four times throughout the year in several locations around Florida and in water depths from 3m to around 100m. The tasks included Navy specific systems testing, but also less traditional work for a tracking range: A U.S. Army Corps of Engineers project to precisely map unexploded ordnance underwater for environmental clean-up of former military training sites.

The original design goal and the specific contribution of RangeNav™ to the field of underwater tracking ranges is that it provides a portable, rugged, user friendly and affordable capability that is well adapted

to work in littoral waters. RangeNav™ also offers significant performance. Accuracy for example has been demonstrated to reach 0.5 meters, area coverage can be small or reach up to 400 square miles, and up to ten targets can be tracked simultaneously.

This 'hands-on' paper reviews the capabilities, performance and practical use of RangeNav™ by drawing on data and experience from the field operations since 2007.

It discusses the system's architecture and components and explains how the system is configured and operated to serve a selection of representative tasks.

## **DESIGN GOAL**

RangeNav™ [1] was specifically designed for straightforward operation. The design blocks focus on making the system easy to use, operate, deploy, and understand.

For example, a small system can be transported in the back of a pick-up truck. A larger system may be transport via freight. You can physically carry the hardware from the truck to the boat by with a small forklift (or by hand) if that's all you have available.

The system was designed to withstand the majority of challenging operational environment conditions without the use of armored cables, metal housings, or other heavy gear. The listening stations, for example, are housed in light-weight and non-corrosive Delrin plastic housings. They experience rough handling and occasional drops in the field. Damage does occur at time, such as a cable or transducer gets caught on reef or wreckage. However, the overall ruggedness has been proven to be sufficient. The damaged parts are easily identified and replaced during an operation. Damaged inventory is swapped out and eventually sent to Desert Star for service or repair. Due to low component cost, this method of operation is cost effective and supports operation in high-hazard environments.

Deployment can be done on any vessel of opportunity. We deployed the system from as small

as a 24' pontoon boat up to a 100' working class ship. Different methods were utilized for each vessel. On the pontoon we used reels whereas on the working class ship we used a winch capable of holding one hundred 275m cable lengths and an equal amount of listening stations.

System calibration is simplified by an acoustic self-survey capability. The process takes a few minutes and is completely hands-off. Acoustic self-survey is sufficient for tracking range uses where only array relative positions are needed. For operation in earth coordinates (UTM, lat/lon), RangeNav™ provides a pinger pole survey capability. This survey determines the earth coordinates of the listening stations by comparing acoustic and GPS track data.

Our goal was to build a system that can be used by anyone, anytime, at any location. We achieved just that; Navy personnel are now the primary operators and no longer need Desert Star Systems' on-site support.



**Figure 1: Self Survey gives RangeNav™ a hands-off approach making it easier for anyone to use.**

## Portable

The running joke, in the tracking range community, is that any tracking range is portable...once. RangeNav™ has proven its portability over multiple deployments. Cable sections come in lengths ranging from 100m to 1000m. The listening stations are relatively small as well as the surface station and other mounting hardware.

The goal here is to have a system that can be easily moved from one location to another. A sizeable system can be deployed in a day, and it is not uncommon to start deployment and calibration of a smaller array in the morning and be done by lunch.

Therefore, RangeNav™ effectively supports a variety of small and large tracking requirements. This also opens up other opportunities for uses outside of the

traditional military applications, including resource constrained jobs.



**Figure 2: Spools of cable being loaded into the back of a pick-up truck.**

## Rugged

Ruggedness and ease of repair is of particular importance for RangeNav™ because hazards are high and varied in the littoral environment.

To date, deployed RangeNav™ arrays have encountered stresses including being trawled over by a shrimp boat and being dragged across the sea floor after the surface vessel's anchor broke free in a storm. The results included a mangled connector, broken cables (RangeNav™ cables have a working load of 1500lbs and a breaking strength of 3000lbs), and a few flooded listening stations. However, in all cases the damage was quickly diagnosed and repaired or worked-around. The most downtime the system has seen in all deployments has been half a day.

The software constantly monitors the power consumption and communication integrity of each station. Malfunctioning station or cable sections are easily identified; while rugged and simple underwater mating connectors make a swap straightforward.

Repairs can be made using a diver or small ROV. RangeNav™ listening stations include a pinger mode that allows the diver or small ROV to quickly locate the station immediately upstream of a failure point. The diver or ROV is equipped with a Desert Star DiveTracker homing device. The light-weight cable and listening station are easily lifted to a small boat at the surface for replacement, or a new station or associated sonar transducer can be splice in by a diver while underwater.



**Figure 3A:** In this picture the connector was destroyed. It was sent back for repair; however meanwhile, we swapped out stations.



**Figure 3B:** A severed section of cable. It was discovered by monitoring the health of the array.

### Deployment

We wanted to build a system that could be deployed from any vessel. So as our test platform we used a 24 foot pontoon boat. We spent several months in a reservoir deploying/operating the system and found that boat to be adequate enough.

With that said, the system has been used on various sized vessels. The system is scaled with the size of the operation; therefore, if a harbor needs to be outfitted with a RangeNav™ system then a larger vessel would be needed.

There are different methods that work when deploying the cable. On the pontoon boat and on other smaller boats we've used spools to hold the cable and a small winch to deploy the cable. We have also laid the cable out on the deck in a figure eight format.

On larger ships we have used a modified winch. The Navy uses the winch to hold up to one hundred stations. The cable occupies the center section of the drum, while the stations are mounted, already wired for operation, in brackets located on the side.

The system was developed to be adapted to any situation. Deploying a system should be a job that can be done on any vessel of opportunity.



**Figure 4A:** The Navy's winch, it holds 100 stations and 100 section of 275m cable.



**Figure 4B:** Using the figure eight method for mid-sized deployments.



**Figure 4C:** Smaller systems, shown above, can be easily deployed using spools and/or a small winch.

## FIRST YEAR OPERATIONAL EXPERIENCE

The design of the tracking range was commissioned by the Naval Surface Warfare Center in Panama City (NSWC-PC) under the name PLATS (Portable Littoral Acoustic Tracking System).

One requirement of the system is that it not be “gold plated”. This simply means that it needs to be functional first and foremost. The Navy wanted a system that could be operated by their own personnel and was straightforward and easily operated. They did not want a system that looked as though it was developed “by engineers for engineers.” We achieved this with RangeNav’s™ overall ease of operation, deployment, portability and ruggedness.

The ‘phase 1 system’ was delivered by the manufacturer Desert Star Systems LLC in late 2006. During 2007, PLATS was deployed four times at three sites around the state of Florida. This included the initial system acceptance test in St. Andrews Bay, two offshore deployments related to a Navy project, and a final very shallow water deployment testing the system’s capability to meet a requirement of the U.S. Army Corps of Engineers. We have seen one non-military application so far, the University of Victoria is using theirs for measuring ROV dynamics.

In 2008 and the years to come, the Navy anticipates using RangeNav™ between one to five times a year, primarily in shallow waters. The Navy is no longer requiring any direct support from Desert Star Systems in their deployments. This shows how over the course of the last two years RangeNav™ has transformed from a “science project” into an off-the-shelf system.

With RangeNav™ now a standard (COTS) Desert Star product, it is supported and continually updated by our R&D program. At this time, proposals for customer specific performance and feature enhancements are pending with both the Navy, U.S. Army Corps of Engineers, and the University of Victoria.

We are also developing a very small form factor RangeNav™ version with RF (radio modem) rather than cable communication links. Murphy and the weather gods willing, first field data from use ‘on the ice’ near McMurdo base in Antarctica will be available and reviewed during our presentation at UDT Pacific 2008.

The following discusses our experience of operating the system during the first four deployments for the U.S. Navy and the U.S. Army Corps of Engineers.

## Deployment

Prior to array deployment, the surface station must be established. In various cases, a near-shore building, a comfortable RV style trailer, and vessels moored at sea were used to house the surface equipment and operator.

Next, the deployment boat motors close to the surface station and a small boat transfers the ‘upstream end’ of the tracking cable to the surface station. The deployment vessel now follows a pre-determined course to lay the array. As the end of a cable section is reached and the attached listening station is dropped into the water, it is powered up via remote command by the surface operator. The surface operator verifies proper station operation (a process that takes about 30 seconds) while the deployment vessel motors further along its course. Exact station location is uncritical so it is OK for the deployment vessel to drift slightly off-course.



**Figure 5: A small boat transfers the feeder cable from the deployment vessel to the already moored surface station vessel.**



**Figure 6: It takes about 1 minute to deploy connect and ready a listening station.**



**Figure 7: The readied station is then lowered into the water and deployment continues.**

Experience has shown that it takes about 10 minutes to deploy one 275m cable section and associated listening station. This number held true independent of the size of the deployment vessel, method and sea state (within reason).



**Figure 8: The deployment vessel follows a pre-programmed course to place the array in the desired location.**

Consequently, about 48 stations can be deployed in a 8-hour shift. Including a 10% allowance for cable slack and course drift, this equals a linear listening station string length of 12km yielding a coverage area of 3 sq. km with a 250m x 250m station grid.

No deployment time data is yet available for larger systems, but an estimate can be ventured. For example, RangeNav™ was designed with a maximum coverage area of 1600 sq. km in mind. Such a large system would most likely be in deeper water and support a 1000m x 1000m station grid. It would consist of 1600 listening stations and an equal number of 1000m cable sections. Assuming 20 minutes to deploy each section, the deployment time would be about 22 days for a single vessel operating around-the-clock. It should be observed that such large systems would not be a single string of stations.

Instead, such a system would consist of one or more 'backbone cables' from which individual listening station strings fork off in regular intervals.

### On-site Repair



**Figure 9: A listening station and cable section is replaced after abuse during deployment led to a failure.**

Tracking ranges are subject to many environmental hazards and portability means the system must support rapid repair of faults as they occur. The design goal for the RangeNav™ hardware was a 'Toyota' rather than a 'Mercedes', i.e. hardware that was economical and easy to repair – or can simply be replaced. The cables for example are rugged but not steel armored, and the listening station housings are lightweight plastic instead of titanium. This approach has proven to be successful. While failures somewhere along a chain of listening stations might occur during deployment or operation due to environmental, human induced, or some early design issues (nodes sometimes experienced an unreliable power-up and were swapped out), the problems were always corrected in a matter of minutes and up to a few hours worst case.

In one dramatic and instructive example a shrimp boat trawled its seafloor gear straight through a deployed array at night despite a posted Notice to Mariners, radio warning by a guard boat and a subsequent chase and boarding of the intruder by the Coast Guard. During the next morning's power-up, a short circuit was localized at a specific point in the array. Consequently, the last 'live' station just before the failure point was instructed to ping. A diver equipped with a Desert Star manufactured DiveTracker™ homing device localized that station within less than one minute and attached a recovery line. The station was pulled to the surface from a small boat and we then worked our way down the

cable to the failure point. In fact, the connector on that station was damaged and subsequently burned out. The cable section and station were quickly replaced and the entire range was operational again before lunch.

In a few other cases a problem would be noted during deployment and a station or cable section was swapped by reversing the path of the deployment boat – a process of a few minutes.

During four deployments damage due to external events was encountered twice: one on account of the shrimper and the other when an approaching storm caused the surface vessel on the two point mooring to drag its anchor by about 100 meters and along with it the array. Several cables were broken.

Beyond that, quick repairs to replace a suspected unreliable station were needed once or twice during each deployment, mostly on account of the previously mentioned ‘power-up’ problem. The only operations down-time was experienced in the shrimp event.

In summary, the economic ‘Toyota’ approach of the system has resulted in good reliability because repairs of the array are very simple and fast and can be accomplished with small boats plus support by divers or small ROV for deeper waters. The economy and capability for rapid deployment has also allowed us to deploy redundant hardware. In the case of one project, RangeNav™ was a critical element of a large test involving an expensive sub-sea vehicle that would only be available for a few days. Tracking service therefore had to be assured with a very high degree of confidence. The team simply deployed two redundant loops of listening stations around the test site. Each loop could be operated independently. The capability was not ultimately needed but it was tested and available.

## **System Operation**



**Figure 10: A shore based operator monitors the tracking performance. Once tracking is in progress, only some occasional minor adjustments may be needed.**

Once the range is deployed and surveyed, operation is quite simple and tracking has proven to be robust. The operator mostly monitors the quality of the track and the various system health parameters displayed by the surface station software. An occasional adjustment of the pinger detection threshold might be needed if ambient noise rises or when the pinger signal gets weak as the target travels outside the coverage area. Simple to read displays for noise and signal strength are available to the operator for this purpose.



**Figure 11: A target pinger is placed in a special mounting bracket. Pingers are available in various sizes and operating at various frequencies from 8 kHz to 42 kHz**

## System Recovery

System recovery is a very simple process. The tracking range is powered down and then spooled back onto the winch. The winch can be used as the permanent storage location for the array, and a winch mounted array can be powered up and tested on shore prior to the next deployment. Bad stations are swapped out in the holder and bad cable sections are noted. During the next job, deployment is temporarily stopped when a bad section is reached. That cable section is removed from the winch and deployment continues. This 'running maintenance' technique removes components in need of service while continuously maintaining a healthy set of equipment on the winch. If hardware gets depleted, new cable sections and stations can be loaded onto the winch.

When not using a winch you can store them anywhere out of the elements. We wouldn't recommend storing them outside in the weather for example; although there is no immediate danger.

### **APPLICATION EXAMPLE: RANGENAV™ USE FOR THE UNDERWATER MAPPING AND RECOVERY OF UNEXPLODED ORDNANCE**

An instructive example of RangeNav™ use are the recent sea trials to develop a capability to map and recover unexploded ordnance from the sea floor, as part of the environmental clean-up of military training sites or operating areas [2].

RangeNav™ was chosen to provide positioning for the ordnance mapping function and for re-acquisition of mapped ordnance during the clean-up phase. The system provide these critical capabilities:

- RangeNav™ offers the required **portability**; the system may have to be deployed at a variety of clean-up sites ranging from small ponds or lakes, to near-shore ocean waters and harbor basins. RangeNav™ can be transported by pick-up truck for smaller configurations or shipped as freight.
- RangeNav™ offers **wide area coverage in shallow water**. Shallow water acoustics are limited by wave refraction (bending) due to water temperature and salinity variations. As a rule of thumb, an acoustic listening station or transponder may be effective for a horizontal range of 25x to 100x water depth. By deploying a grid of listening stations,

RangeNav™ can cover large areas even if the water is shallow.

- **Sub-meter accuracy** is a requirement during both the mapping and the re-acquisition phase. Small ordnance has a magnetic field that may reach only a few meters, and in order to produce a proper magnetic dipole map, the system must operate with sub-meter accuracy.
- **Accuracy at speed** is important because the magnetometer fish may be towed at anywhere from two to five knots, covering up to 2.5 meters in one second. RangeNav™ positions are based on a single ping of very short duration (1-4 ms), meaning that tow speed does not degrade accuracy.

The tests were done in a shallow water (10 foot) location with a gradually sloping sea floor. This is an environment similar to what might be encountered during a clean-up project. Small sections of steel rebar simulating ordnance were hammered into the

ground, and surveyed with centimeter accuracy using a GPS antenna fixed to the top of a pole which was placed on top of each target. The operating area measured about 300m x 100m.

For RangeNav™ operations, a single string of eight listening stations spaced 100m apart was deployed around this site.

During this series of tests, the RangeNav™ system was used to track the magnetometer tow fish, and to support re-acquisition of mapped targets with both divers and a small ROV.



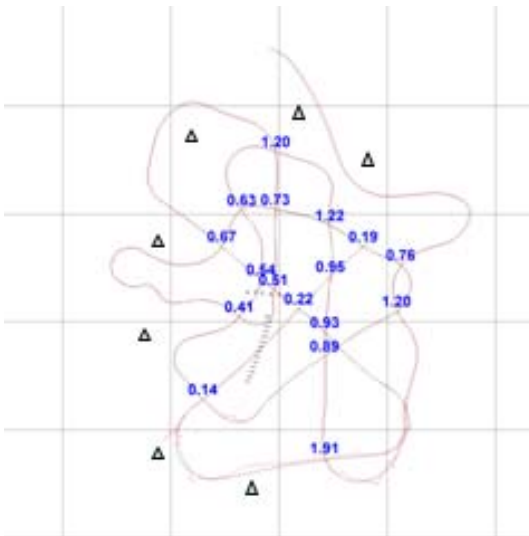
**Figure 12: A rebar target is mapped precisely using a pole mounted differential GPS.**

## Data Analysis

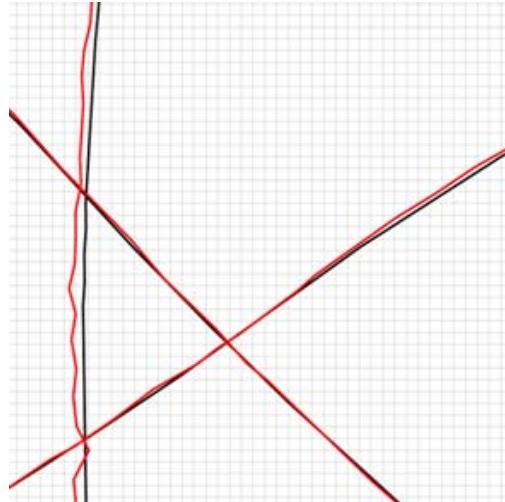
The tests showed the capability to conduct magnetometer tow fish surveys and diver and ROV target re-acquisitions in shallow water. It demonstrated a strategy of using the RangeNav™ portable tracking range to perform wide area mapping and extended clean-up

The pinger pole survey gives you the location of the GPS and the pinger's position in RangeNav™. In theory these should be exactly the same. We find this to never be the case as with any underwater tracking system as there are always acoustic factors that effect performance.

However, in operation our average error was .76m in 10 feet of water. This is illustrated in the two figures below (Figure 13 and Figure 14).

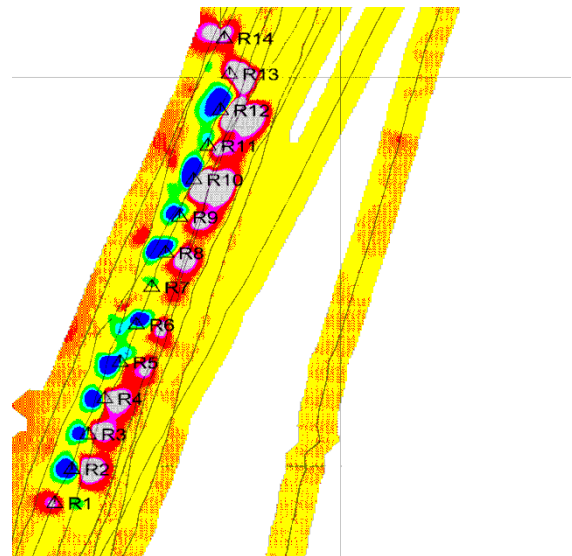


**Figure 13:** A screen shot of the RangeNav™ software illustrates a pinger pole survey. The triangle shapes are the location of the baseline stations. The blue numbers are the error difference between the GPS receiver and the pinger at the bottom of the pole. The average error was .76m.



**Figure 14:** A cross section of Figure 14 is shown above. This is a 1meter section of the entire track. The red trace is representative of the pinger; whereas, the black trace is the GPS receiver.

Figure 15 shows the magnetic signature of the steel rebar. This test was to simulate actual unexploded ordinances. The locations of the steel rebar are marked with the triangle shape and the corresponding R#. These locations are determined with the magnetometer towfish in conjunction with the RangeNav™ positions.



**Figure 15:** A magnetometer map showing four targets. It is obtained by combining magnetic field and RangeNav™ positioning data. The well defined shape of the magnetic dipoles (red/blue) demonstrates good survey accuracy.



**Figure 16: The Geometrics magnetometer towfish equipped with a RangeNav™ pinger is towed behind the boat.**

### RANGENAV™ ACCURACY AND POSITION AVAILABILITY REVIEW

This performance table shows results from the RangeNav™ system acceptance test in St. Andrews Bay, FL. Water depth was 24 to 44 feet. Listening station spacing was 250m nominal, which was appropriate for this environment. In general, denser station spacing can be expected to result in better precision and accuracy while looser spacing should produce greater errors. An analysis for a test with 100m station spacing is currently pending.

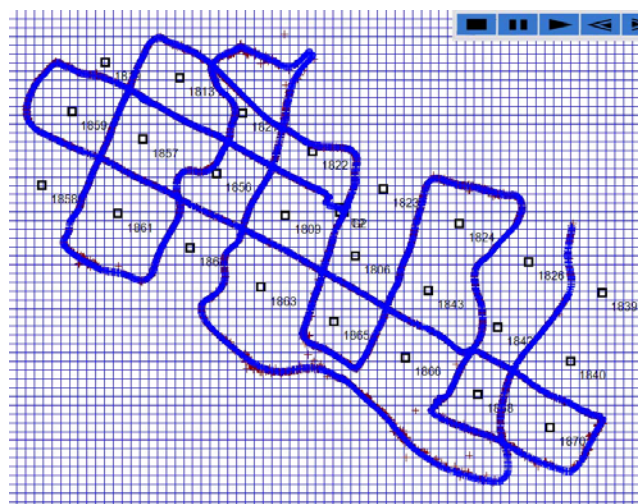
Parameter	Observation
Static target position precision (repeatability)	0.5m average precision
Static target geo-referenced position accuracy (using GPS reference positions)	1.2m average discrepancy between acoustic and GPS positions (note 1)
Track Accuracy vs. GPS track (from pinger pole runs at 2.5 knots)	1.8m average discrepancy between acoustic and GPS positions (note 2)
Position data availability at 10m error acceptance standard	97% of all theoretically available positions (1-sec update rate)
Position data availability at 1m error acceptance standard	95% of all theoretically available positions (1-sec update rate)
Track acquisition distance from array	Good track was available up to 500m-1100m from the boundary of the array, depending on location.

Station spacing	250m station spacing was used and found adequate.
Position update rate	Pingers were operated at 1 message per second, yielding 1fix per second.
Number of targets tracked	One target. Firmware upgrade to support simultaneous tracking of up to eight targets is pending.

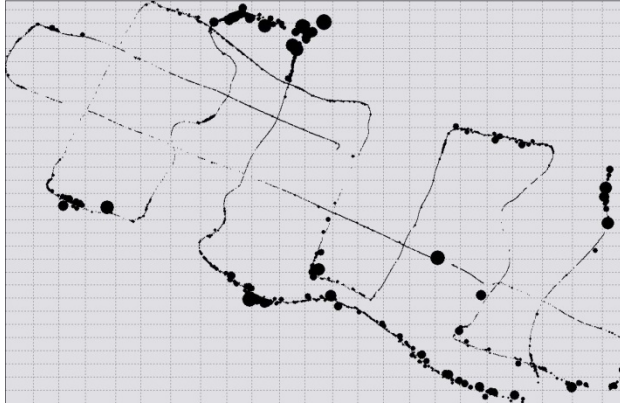
#### Notes:

1. The static position accuracy numbers includes an error due to sound speed variations estimated at 0.8m based on multiple CTD casts.
2. The track position accuracy includes an additional 0.4m boat speed related error. This is due to an average +/- 0.25 sec synchronization error between the GPS and acoustic data stream for a boat run speed of 2.5 knots.
3. The reference GPS system (differential GPS) has a stated accuracy of 0.01m

**Table 1: RangeNav™ performance observations**



**Figure 17: Overlaid GPS (blue) and acoustic (red) track for a pinger pole run at 2.5 knots and using a 16 kHz pinger. The grid is 30m x 30m. The black squares are the listening stations.**



**Figure 18: Error magnitude plot for the same pinger pole run. Each position fix appears as a dot, the size of which relates to the error vs. the GPS reference position. Larger dots indicate a bigger error. Notice that large errors generally are seen when tracking outside of the array.**

## CONCLUSION

The first year of RangeNav™ operations in 2007 has seen four successful employments at a variety of sites and projects. The work established a set of performance parameters for RangeNav™. During these field trials, the system and its operators coped successfully with a many adverse conditions, demonstrating the robustness of the technology. The operational deployments during 2007 showed the practical value of a portable tracking range for many applications. Furthermore, in 2008 the Navy has determined that RangeNav™ is self-sufficient. Thus, the Navy may only require remote support!

## ACKNOWLEDGEMENTS

The RangeNav™ development has been made possible through the cooperative efforts of a number of parties. NSWC-PC funded the development work and purchased a sizeable system under a 'SBIR Phase 3' contract. Earlier Phase 1/2 SBIR work for NOAA established the fundamental technology on which RangeNav™ is based. Other SBIR work for U.S. SOCOM helped establish the necessary signal processing capabilities.

## REFERENCES

[1]: RangeNav™ is a portable tracking range available as a standard product from Desert Star Systems LLC. For further information, see [www.desertstar.com](http://www.desertstar.com) and click on the Positioning tab.

[2]: This is an ongoing joint project between the U.S. Army Corps of Engineers, Huntsville AL (lead agency) and Desert Star Systems LLC sponsored by the Environmental Security Technology Certification program (ESTCP), a DoD activity. NSWC-PC contributed their PLATS (RangeNav™) system plus support for phase 1 sea trials.

[3]: AquaMap™ is a compact, commercial off-the-shelf acoustic long baseline positioning system. It is manufactured by Desert Star Systems LLC. For further information, see [www.desertstar.com](http://www.desertstar.com) and click on the Positioning tab.