An Undersea Distributed Network System (UDNS) is defined as a warfighting system consisting of sensors, unmanned vehicles, and platforms, all networked together to provide an accurate perception of the underwater battlespace. A key question is: How can the UDNS community leverage these components to experiment with innovative concepts, while minimizing investment in interim hardware? This paper focuses on existing Boeing unmanned vehicles that can support UDNS sensor and network experimentation.

The underwater battlespace ranges from the sea floor to the sea surface, and from the deep ocean to the littorals. While manned platforms such as submarines are very capable over most of these regimes, unmanned vehicles operate capably over all these ranges and more. Unmanned vehicles offer additional benefits including force multiplication, covertness, and the ability to perform missions in areas denied to manned platforms.

Key requirements for unmanned vehicles supporting UDNS include:

- Fully autonomous behavior sufficient to perform planned missions and operate payload(s). Autonomy must handle both nominal and off-nominal conditions, without manned platform support.
- Accurate internal navigation with minimal reliance on external navigation resets.
- Communication and sensor payload support. Communication payloads include acoustic, laser, and/or RF communication link(s) to other unmanned vehicles or manned platforms. Sensor payloads include acoustic, ISR, and other sensors. Payload support includes volume and UUV operational considerations such as buoyancy/ballast/trim control, surfaced, and antenna extension/retraction.
- Battery Endurance and Power sufficient for vehicle range/mobility, sensor payload(s) and communication payload(s) that meets mission needs.
- Reliable launch, operation, and recovery from host platform (submarine or surface ship) that meets host compatibility (e.g. TEMPALT/SHIPALT) and supportability needs.

Unmanned vehicles have been in development for

Table 0-1 AN/BLQ-11 Capabilities as an UDNS Mobile Node

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<th>UDNS Key Requirement</th>
<th>AN/BLQ-11 Capability</th>
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| Full autonomous behavior            | Autonomous execution of high level mission plan  
|                                     | Autonomous SSN shadow & docking  
|                                     | Fault tolerant autonomy (redundant systems) |
| Accurate internal navigation        | Kearfott INU, Teledyne DVL  
|                                     | ACOMM or GPS reset (as needed or as planned)  
|                                     | Navigation error < 0.15% distance traveled |
| Communication and Sensor payload support | Existing UHF SATCOM on extensible mast.  
|                                     | Existing mine detection/classification acoustic sensor suite (FLA, SLS).  
|                                     | SAS and LPUMA capable. Alternate payloads could replace existing comm and sensors. Vehicle drop weight could be replaced with additional payload. If vehicle is extended > 240”, use an additional payload section. |
| Battery Endurance and Power        | Lead Acid secondary batteries: 4 KWH (4 nm @ 4 kts)  
|                                     | AgZn secondary batteries: 22 KWH (25 nm @ 4 kts)  
|                                     | Lithium primary batteries: 95 KWH (108 nm @ 4 kts)  
|                                     | If vehicle is extended > 240”, can use additional energy section. |
| Reliable launch, operation, and recovery | Demonstrated SSN full impulse (10 g) launch from torpedo tube  
|                                     | Vehicle acoustic C2 with sub-qualified SDE (TEMPALT)  
|                                     | Built-in vehicle maintenance and diagnostics SW  
|                                     | Complete mission planning, sim capability, and analysis tools  
|                                     | Demonstrated autonomous docking with SSN |
decades. The state of the technology is mature enough to conduct near-term UDNS demonstrations. For example, unmanned vehicles can support experimentations from surface, submarine, and air platforms. This allows the UDNS integrator to focus on sensor payloads, communications connectivity, and roles of vehicle mobility. By leveraging existing unmanned vehicles into fleet experiments, UDNS can be transition into U.S. Navy operational capabilities.

**AN/BLQ-11**

The AN/BLQ-11 is a sophisticated autonomous UUV

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_**Echo Ranger schematic (below) and Echo Ranger payload bay (above right).**_
UDNS Key Requirement | Echo Ranger Capability
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**Full autonomous behavior** | Autonomous execution of high level mission plan
Fault tolerant autonomy (redundant systems management)

**Accurate internal navigation** | Kearfott INU, Teledyne DVL, Simrad altimeters, depth sensors
Reset via Sonardyne ROVNAV LBL (as needed or as planned)
Reset via Linkquest acoustic modem (as needed or as planned)
Navigation error < 0.15% distance traveled (w/o resets)

**Communication and Sensor payload support** | Large bottom payload bay (20" H by 50" W by 60" L, 977 lb dry, 158 lb wet) is well-suited to store other sensors and multiple self-deploying/self-connecting nodes with minimal modifications.
Secondary battery pack can be replaced with up to 7.5 ft³ of additional payload, including extensible RF/ISR mast.
Nose section can provide 1.5 ft³ payload area. High capacity power subsystem can provide up to 300 W @ 48 V to the payload. 10/100 Ethernet interface to vehicle controller and communication payload. Serial interface to Linkquest high-speed acoustic modem.

**Battery Endurance and Power** | NMH batteries: 42 KWH total (78 nm @ 3 kts)
Li-Ion batteries: 136 KWH (252 nm @ 3 kts)

**Reliable launch, operation, and recovery** | Demonstrated over-the-side portable L&R on ship-of-opportunity.
Also capable of stern ramp and pier-side L&R.
Vehicle acoustic C2 using laptop PC and COTS acoustic modem.
Built-in vehicle maintenance and diagnostics SW.
PC-based mission planning, simulation capability, and analysis.
system designed to operate clandestinely from a U.S. Navy 688/688i submarine, with launch and recovery through the submarine’s torpedo tubes. It consists of a self-propelled 21-in. diameter autonomous UUV equipped with mine search and classification sonars for locating mine-like objects in a naval operational area of interest. The system includes hands-off launch and recovery, and is designed to operate from both Los Angeles and Virginia Class SSNs. Surface ship applications have been reviewed and can easily be implemented. Boeing has also begun evaluation to upgrade the system for Synthetic Aperture Sonar and Littoral Precision Underwater Mapping Sonar. The AN/BLQ-11 vehicle is 21-in. diameter by 240-in. long, weighs 2,800 lb. dry, and has a 1,500 ft. working depth with speeds up to seven knots. For use as a UDNS mobile node, AN/BLQ-11 meets all the key requirements as indicated in Table 0-1.

**Large Displacement UUV (Echo Ranger)**

Echo Ranger is a complete deep water AUV system with a large modular payload bay originally developed by Boeing for the commercial oil survey industry. It consists of a Large Diameter UUV (LDUUV), a portable Launch & Recovery (L&R) system that can be quickly installed (<1 day) on a variety of surface ships, and topside vehicle command and control (C2) equipment. The Echo...
Ranger vehicle provides the same complete autonomous capabilities as AN/BLQ-11. The L&R system releases the vehicle from a protective cage 100-150 ft underneath the air-water interface in up to SS4, and can recover the vehicle in the same way in up to SS5. The Echo Ranger vehicle is 50-in. high, 50-in. wide and 18 ft. long. It weighs 11,700 lb dry (including 977 lb. dry payload), and has a 10,000 ft. (3,000 m) working depth with speeds up to eight knots. While on deck, the topside C2 equipment downloads the mission plan to the vehicle over a detachable Ethernet cable. At the same time, the vehicle batteries are recharged for the next sortie. While deployed in the water, the vehicle and topside C2 communicate via a pair of COTS acoustic modems. A low speed acoustic modem is used for vehicle C2 (as needed), while a high speed acoustic modem is used for real-time payload data uplink. The deployed vehicle normally operates without topside intervention, and employs a high precision inertial navigation system with optional external LBL resets from pre-deployed bottom-moored Deep Ocean Transponders (DOTS).

For use as a UDNS mobile node, Echo Ranger meets all the key requirements as indicated in Table 0-2.

**Scan Eagle**

The Scan Eagle is a 40 lb. (18 kg) Unmanned Aerial Vehicle (UAV) designed for continuous mission of 15+ hours, cruising at speed of 50 knots at an altitude of 5,000 m. The system was designed for autonomous field operation. Scan Eagle is 7-in. diameter by 48-in. long with a one ft wingspan. It weighs 39.6 lb. with fuel, and carries a payload of 6 kg with an operating ceiling of 5,000 m for over 16 hours (gas) or 28 hours (JP-5). Maximum level speed is 70 knots. It can be launched and retrieved over any terrain, including naval operations. Scan Eagle C2 is provided by a Harris SECNET11 radio (802.11b + Type I encryption), with 5 nm range @ 500 ft.

The UAV is equipped with nose-mounted inertial-stabilized camera turret, designed to track an object of interest for extended periods of time. The gimbal carries either
zoom CCD or IR sensor. ScanEagle was designed with removable avionics bay and two expansion slots allowing seamless payload integration. Scan Eagle can easily provide high-bandwidth persistent communication linkage between UUV mobile nodes, maritime patrol aircraft (e.g. P-8A), surface ships, and submarines.

**UDNS Evolution Opportunities**

Since existing Boeing unmanned vehicle assets are well suited as UDNS mobile nodes, near term fleet UDNS experimentation is feasible. One candidate experiment would be a variant of battle space preparation. A notional CONOPS (Figure 0?1) might include an AN/BLQ-11 and an Echo Ranger, each configured with SECNET 801.11 RF communication and acoustic mine detection/classification payloads. The Echo Ranger would also be configured with a number of deployable acoustic sensors. Initially, the AN/BLQ-11 would be deployed in a littoral zone, while the Echo Ranger would be deployed in an adjacent deep ocean zone. A Scan Eagle would be maintained in high altitude orbit to provide Echo Ranger C2, mission tasking, mine detection/classification RF data uplink with an IRIDIUM OTH relay to a surface ship, submarine, or maritime patrol & reconnaissance aircraft (MPRA). AN/BLQ-11 and Echo Ranger could rendezvous underwater to exchange data and tasking assignments via ACOMM. After Echo Ranger completes the mine detection/classification task over its assigned area, it could be re-tasked by to transit toward shore and covertly deploy bottom-sitting or mobile sensors to provide an acoustic tripwire outside a harbor. Obviously, the key requirements identified previously for unmanned vehicles to support UDNS are important for this CONOPS to succeed. In particular, full autonomy, accurate navigation, and large payload capacity, and long endurance are critical.

UUVs have the ability to be deployed clandestinely close-in or at a stand-off range from submarine, surface ship, or shore base. When deployed at stand-off range, the UUV has the ability to clandestinely enter a denied area carrying organic sensors or deployable sensors. The use of Scan Eagle or another UAV as a high-bandwidth OTH relay node is essential to minimize UUV time on surface, away from its main tasking. In the future, we envision that the Boeing P-8A Poseidon, with its wide spectrum of FORCEnet-compliant communication interfaces, will provide the ASW command and control to manage multiple unmanned vehicles, sensors, and communications associated with UDNS. The P-8A would deploy an air-launched UAV from a stand-off range to provide the relay node function for submarine/ship-deployed UUVs and associated sensors. We envision that the P-8A could also air-launch UUVs having an Mk50 form factor to augment UUVs launched from submarine and surface ship. The P-8A provides conventional sonobuoy and ASW weapons (e.g. Mk54 torpedoes) to complete the UDNS ASW end-game.