INTERNATIONAL DEFENSE REVIEW - MARCH 01, 2002 **Date Posted: February 14, 2002**

Submarines to cast off their shackles, take on new roles

Mark Hewish

The US Navy, in collaboration with industry and government research laboratories, is taking the initiative in expanding undersea warfare, writes *Mark Hewish*

Submarines today are working harder than ever. Although the US Navy (USN) fleet of nuclear-powered attack **submarines** (SSNs) has been nearly halved since 1989, the number of intelligence, surveillance and reconnaissance (ISR) missions that they perform has almost doubled. **Submarines** are fast, stealthy and have very long endurance. They can arrive on the scene of a potential or actual conflict, unannounced, and perform missions ranging from covert long-endurance ISR to deep strike against targets far inland. A carrier battle group carries impressive firepower, and its high visibility may help to defuse a threatening situation, but it takes a very long time to transit the 11,000nm from San Diego to the Arabian Sea at 14kt.

Nuclear **submarines** are the most effective means of providing assured physical access to a denied littoral region. They are largely invulnerable to coastal cruise missiles, tactical ballistic missiles, and biological or chemical weapons. As a result, they will take on a greater role in intelligence preparation of the battlespace and in power projection. In 1996, the US Congress mandated that the USN develop and demonstrate technologies to make successive generations of **submarines** both more capable and more affordable than their predecessors. Despite their many advantages, **submarines** have traditionally suffered from deficiencies in terms of the weapons and sensors that they carry. In the former case, this is evident both as the limited number of types available and the comparatively small number of rounds that can be embarked. For example, the USN's present SSNs carry only Tomahawk cruise missiles, Mk48 ADCAP (Advanced Capability) heavyweight torpedoes, and mines.

Submarines operating in littoral areas may face increased threats from small patrol craft, helicopters and maritime-patrol aircraft. Shallow water, often containing obstructions (the existence of which may not be known), poses further constraints. When operating under these conditions, the natural inclination of an SSN commander is to keep his boat at a greater distance from target areas than if he were maneuvering in deep water.

In such cases, operations against intelligence and combat targets may better be conducted using **submarine**-launched payloads such as manned mini-**submarines**, unmanned underwater vehicles (UUVs) and autonomous sensors and weapons. The last of these could include a new class of non-lethal device capable of incapacitating surface ships and **submarines**. This would allow **submarines** to participate more effectively in sanctions enforcement and other low-intensity conflict, as well as providing decision-makers with a wider range of options during periods of heightened tension.

The US Naval Sea Systems Command's **Submarine** Future Studies Group (FSG) has addressed these questions when assessing potential roles for **submarines** in 2020.

The FSG developed two concept statements designed to provide long-term guidance for **submarine** research and development. The first says that "current and future SSNs should be able to transport and deploy an order of magnitude [ie, tenfold] increase in payload capacity over existing designs. [They] should not achieve this goal by increasing hull displacement, unless technologies improve affordability".

The second concept statement focuses on ISR. This says that the **submarine** force "should develop the capability to deploy, process and report information from a variety of offboard distributed sensors in order to greatly enhance its ability to contribute to battlespace preparation".

Accordingly, the FSG concentrated on four key areas for innovation:

- Improved connectivity with the battle group, joint forces and the National Command Authority;

- The introduction of innovative technologies and payloads, drawing on expertise from outside the traditional **submarine** community;

- Extending modularity to permit a more 'tailorable' approach; and

- Incorporating integrated electric-power systems.

In the short term, the USN continues to upgrade its in-service SSNs as it reduces force levels to the 55 hulls called for in the 1997 Quadrennial Defense Review. The AN/BQQ-10 Acoustic Rapid COTS [commercial off-the-shelf] Insertion (ARCI) program is a four-phase effort to provide the SSN force with a common sonar that is far more capable and flexible than earlier designs. An open-systems architecture based on the Multi-Purpose Processor (MPP) developed by Digital System Resources, which exploits commercial developments, permits the use of complex algorithms that could not previously be accommodated. MPPs and COTS workstations communicate with each other via a local-area network.

The ARCI program is already being implemented aboard Los Angeles-class **submarines** and will be extended to the Seawolf, Virginia and Ohio (Trident) classes. Phase I enhanced the narrowband and spatial vernier-processing for the towed-array sonar aboard two Los Angeles-class boats, which have since been further modified under Phase II. This significantly upgrades all aspects of towed-array processing. Phase III improves the processing for the spherical and hull arrays, while Phase IV addresses that for the high-frequency sonar. The AN/BQQ-10 equipment resulting from these upgrades is planned to provide a common COTS architecture for all USN **submarine** sonars by 2005-07.

The massive increase in onboard processing resulting from programs such as ARCI permits a fundamental change in how **submarines** collect and process acoustic intelligence (ACINT). At present, acoustic data gathered by USN **submarines** are stored on tapes that are sent to the Office of Naval Intelligence when the boat returns from deployment. The ACINT 21 program will introduce new software that allows ARCI-equipped **submarines** to play back the data immediately, eliminating much of the requirement for post-mission processing.

Other enhancements focus on Special Operations Forces (SOF). USS Dallas is the first SSN to carry the Dry Deck Shelter (DDS), a deck-mounted cylinder large enough to house a SEAL [Sea, Air, Land] Delivery Vehicle (SDV) or a complement of rubber raiding craft. This modification allows **submarines** to launch and recover SOF without detracting from their traditional missions.

The first two Seawolf-class **submarines** are now operational. The third, USS Jimmy Carter, is due for delivery in mid-2004. It is being modified during construction - including lengthening the hull by 30m - so that it can act as a testbed for new special-warfare and other applications.

SOF enhancements

The USN hopes to acquire 30 examples of the new Virginia class, which is optimized to perform multiple missions during littoral operations while retaining its deep-water capabilities. It will replace the Los Angeles class with a design that is comparable in most respects to Seawolf, but in a more affordable configuration. The Virginia class is the first designed from the outset to support special operations. In addition to carrying DDS and the new Advanced SEAL Delivery System (ASDS), it will contain a lock-out trunk that allows nine SOF team members at a time to deploy with their equipment.

The 1994 US Nuclear Posture Review recommended a force of 14 nuclear-powered ballistic-missile **submarines** (SSBNs) - all carrying the Trident II (D5) weapon - as being sufficient to meet national security requirements. As a result, four of the 18 operational SSBNs are surplus to requirements. The USN plans to convert these boats - USS Ohio, Michigan, Florida and Georgia - into cruise-missile platforms (SSGNs) for tactical strike missions and special operations. The **submarines**, which are due to be withdrawn from service as SSBNs over the next two years, each have 22 years of hull life remaining. The Fiscal Year 2002 (FY02) budget includes US$116 million for further studies, initial design work and advance procurement, augmenting the US$14 million appropriated in FY00 and US$38 million in FY01. The FY03 budget request includes US$1 billion to begin development and integration.

The SSGNs are expected to include:

- Up to 154 vertically launched Tomahawk Land Attack Missiles (TLAMs) and/or Tactical Tomahawks (TacToms) - seven each in 22 of the 24 launch tubes of 2.25m diameter that at present accommodate Trident C4 missiles. All could be fired within 6min. In January 2002, the USN's Strategic Systems Programs (SSP) office awarded Northrop Grumman Marine Systems a US$16.6 million contract for the demonstration and validation phase of the SSGN Multiple-All-Up-Round Canister (MAC). The work is due to be completed by July 2003.

- An enhanced communications suite to provide greater connectivity in real time;

- Quarters for 66 SOF personnel, with a surge capability to accommodate 102;

- Dedicated command-and-control space for enhanced mission planning;

- Two lockout chambers providing SOF with access to and from the **submarine** while it is submerged;

- Space for two externally mounted DDSs or ASDSs; and

- A dedicated SOF command, control and planning center.

An SSGN carrying 154 Tomahawks would provide a strike power almost equal to that of the 120-180 rounds normally carried by all the ships in the typical carrier battle group deployed to the Arabian Gulf. As a consequence, Vertical Launch System (VLS) installations on surface combatants could be tailored to include more rounds for theater missile defense and counter-offensive air operations. Similarly, SSNs could focus primarily on anti-ship and undersea-warfare missions rather than being constrained by land-attack requirements.

SSGNs could operate covertly in close proximity to an enemy coast to perform multiple surveillance and intelligence-gathering missions, using onboard sensors and by deploying SOF personnel, for 90 days or more. The proposed deployment cycle, based on experience gained in SSBN continuity-of-operations exercises, is intended to maximize in-theater presence while continuing to meet the existing maintenance plan. A force of four SSGNs could provide US Central Command (CENTCOM) with 154 available Tomahawks, while at the same time meeting global SOF commitments, continuously (365 days a year). Any given boat would typically alternate between a CENTCOM strike capability and one for SOF support of European or Pacific Command.

The overall SSGN Payloads and Sensors Study being conducted by the SSP includes the examination of packages optimized for power projection that could enter service in 2010. The SSP, with assistance from the US Naval Surface Warfare Center (NSWC) Dahlgren Division, is studying candidates supporting two key mission areas: Joint Suppression of Enemy Air Defense (JSEAD), and Interdiction Operations during a Major Regional Conflict. Options being assessed include weapons, decoys and unmanned aerial vehicles (UAVs).

The quest for new roles and missions fundamentally affects all aspects of **submarine** design. General Dynamics' Electric Boat subsidiary established its Concept Formulation Group (CFG) in 1996 to assist the USN in its efforts to continuously improve the capabilities of future **submarines** while reducing their cost.

As part of this work, the CFG has developed what it calls its "revolutionary **submarine** vision". Electric Boat has adopted a three-pronged approach to implementing its future vision. The first involves the insertion of new technologies into the Virginia-class design. The second focuses on increasing the number and variety of payloads, whatever the hull form involved. In many cases, these two aspects are interlinked. The third approach relates to potential new uses for additional Trident hulls that might become available as a result of future reductions in strategic forces.

The USN has significantly altered its acquisition plan for the Virginia class, placing much greater emphasis on 'spiral' development. More than 25 major enhancements are planned, including the introduction of conformal arrays. These comprise the Conformal Acoustic Velocity Sonar (CAVES) Wide Aperture Array, and the Integrated Bow Conformal Array (IBCA). The latter is intended to introduce affordable technologies for active transducers with high-energy densities, operating at high and mid-frequencies (HF and MF). This eliminates the need for MF spherical and HF sail/chin arrays, permitting implementation of the Advanced Sail concept.

The US NSWC Carderock Division is working with industry and other government research laboratories to develop the Advanced Sail, which could equip Virginia-class boats authorized from FY06 onwards. The canopy-like sail has a double-curvature, low-drag shape that provides about four times the enclosed volume of conventional designs. This permits the internal mounting of large payloads, and provides an increased surface area for external attachments (which would usually be fully or semi-recessed).

Kollmorgen, which has developed the Universal Modular Mast (UMM) to equip the Virginia class (see IDR 8/2001, pp48-55), is studying new applications of the design. A 'mission mast' member of the UMM family could accommodate small UAVs, with folding wings and control surfaces, carrying ISR sensors. The Naval Undersea Warfare Center (NUWC) Newport Division is working with Northrop Grumman to develop such a concept for the detection of 'time-critical' targets (TCTs), such as mobile ballistic-missile launchers. UAVs would act as sensor platforms and data relays. Candidate sensors include thermal imagers, and those employing laser vibrometry to detect moving targets by means of the vibration that they induce in the ground.

Innovative weapons

The UAVs could also deploy unattended ground sensors (UGSs) equipped with acoustic or seismic devices to provide measurement and signatures intelligence about TCTs. Alternatively, the UGSs may be emplaced by SOF personnel operating from the **submarine** itself or from other platforms. The **submarine** would act as a 'systems administrator' that receives and processes intelligence information, then relays it to command-and-control centers in real time.

Kollmorgen, in collaboration with Electric Boat, has also studied the possible installation of a M242 25mm Chain Gun in the single unallocated UMM (of the eight in total) planned for the Virginia class. The weapon, together with its ammunition and feed system, would be stowed vertically in the mast and then elevated for normal operation over the upper hemisphere. Potential roles include self-defense and/or engagement of surface/helicopter targets. The gun would be operated from the same console as that employed with the AN/BVS-1 Photonics Mast.

Other options that have been studied for novel **submarine** weapons are as diverse as a 127mm (5in) gun mounted vertically in a Trident D5 missile tube, firing rounds such as the Extended-Range Guided Munition; members of the Multiple Launch Rocket System family; supercavitating underwater weapons; directed-energy systems employing high-energy lasers or high-power microwaves; and equipment able to impart a pressure pulse of sufficient strength to detonate mines.

The USN plans to adopt an integrated electric propulsion system for Virginia-class boats authorized from about 2010. Although modern nuclear reactors provide enough stored energy to power the **submarine** throughout its lifetime, their use of mechanical-drive propulsion systems results in 75-80% of the useful reactor-power output being allocated exclusively to propulsion.

If this arrangement is replaced by an integrated electric power system, large amounts of reactor output can be fed to a common electrical bus. This can then be allocated as determined by tactical requirements, resulting in greatly enhanced operational flexibility. This will allow **submarines** to make greater use of rechargeable off-hull vehicles, payloads and sensors to extend their tactical reach and to safeguard operations in high-risk or restricted areas. With larger quantities of electrical power available, hydrogen and oxygen can be manufactured from seawater for use in fuel cells. This approach also offers the prospect of regenerative rather than expendable weapons and countermeasures.

Other potential advantages for **submarines** include greater stealth. The adoption of an integrated electric power system will afford designers more flexibility in equipment selection and location, and allow the use of other silencing methods. An all-electric **submarine** would also permit the elimination of hard-piped connections between hull modules, which would be linked only by power and fiber optic cables. This approach could allow major upgrades to be conducted in weeks, rather than the months or years taken today.

In a break with recent US design philosophy, Electric Boat sees its future revolutionary **submarine** as employing a double-hull arrangement in which the pressure hull is enveloped by a free-flooding outer hull. This follows the lead set by the VLS for Tomahawks adopted for the Los Angeles- and Virginia-class **submarines**, which is installed outside the pressure hull. As a result, the weapon payload of these boats has been increased by 50% without extending their length.

The baseline double-hull design is shorter than the Virginia class (just under 100m, compared with 115m), but has a greater displacement (8,600t submerged, rather than 7,830t), while retaining the same pressure-hull diameter of 10.35m. The Chief of Naval Operations' Strategic Study Group has also examined a double-hulled behemoth, 156m long by 12.8m in diameter, displacing 10,200t. This could carry up to 280 weapons of 21in diameter, or 1,056 of 10in, or 2,400 5in munitions. Other postulated payloads include 20 UUVs attached to external clips, 20 micro-UAVs, and six unmanned combat air vehicles in vertical tubes.

A double-hull design also allows the traditional shape of a right circular cylinder -which is inherently inexpensive to build - to be retained for the pressure hull, while at the same time exploiting an outer shape that is optimized for hydrodynamic efficiency and maneuverability. This latter aspect becomes more important as **submarines** are required to operate at or near the surface for long periods in shallow waters, where maneuverability is at a premium.

The shaping that is possible with an external fairing additionally contributes to signature reduction. A double-hull arrangement provides two external surfaces for acoustic coatings, and the space between the hulls can be filled with absorbent materials. Further advantages come from the ability to recess sonar arrays. A combination of these approaches may allow a reduction in isolation measures such as complex mountings, permitting the use of commercially available auxiliary equipment.

Versatile payloads

Standardization on 533mm (21in) torpedo tubes and 635mm (25in) hatches constrains not only the payloads available, but also determines which should even be considered. Accordingly, designers are turning to alternative solutions. The **Submarine** Payloads and Sensors effort has spawned many futuristic ideas. This began as a study, sponsored jointly by the USN and the Defense Advanced Research Projects Agency (DARPA), focusing on potential applications running from variants of the Virginia class through to radically new designs that could enter service in about 2020.

Two groups - Forward PASS (Payloads And Sensors for **Submarines**) and Team 2020 - conducted the initial 18-month studies. Many of the members have not historically been associated with **submarine** technology, allowing the teams to consider non-traditional approaches more easily. Electric Boat is a member of both consortia, enabling it to contribute its design expertise and to ensure that all proposed solutions are technically feasible.

The studies, completed between August and November 2000, continued into early 2001 under bridge contracts. The USN has since assumed responsibility for follow-on risk-reduction efforts, which involves demonstrations lasting about two-and-a-half years.

These include analytical work, augmented by testing, to pave the way for development of selected systems. These could potentially enter service as early as 2007-10, although the USN has not yet allocated funding to implement the results.

The goal of the program is to avoid ever having to develop another specialized payload for **submarines**. By adopting different methods of packaging and delivery, payloads from a variety of sources - including those originally developed for other services - can be employed without 'submarinizing' them. This greatly expands the number of roles that a **submarine** can perform, while also reducing payload costs. A modular approach permits reconfiguration of the devices to be deployed, according to the tactical situation, without returning to port.

The Forward PASS consortium consists of 12 member organizations from industry, academia and government research laboratories. Raytheon acts as team leader, although each has equal status in terms of its design inputs and recommendations. The other member companies are BBN Technologies, Boeing, ERIM International, Foster-Miller, General Dynamics, Oceaneering, Sarcos, Sensis, and Systems Planning and Analysis. These are complemented by the Applied Research Laboratory at Penn State University, and by the NUWC Newport Division.

Forward PASS is developing technologies in two main areas: a Broaching Universal Buoyant Launcher (BUBL) to accommodate payloads in a capsule that can be released from a submerged **submarine** or other vehicle, then rise to the surface; and a Multi-Payload UUV (MPUUV), together with the interfaces that would enable it to be launched from (and recovered back into) a **submarine** and deploy a variety of payloads.

BUBL is intended to be cheaper than present methods of encapsulation, and to be capable of launch at greater speeds and depths. It could be mounted externally in 'clips', stored in a free-flooding cargo bay, or carried within the pressure hull. Control of the ascent would allow the **submarine** to leave the area before the encapsulated weapon is launched. The demonstration program includes construction of prototype items for the capsule structure, electronics/sensor and power subsystems, and is expected to involve launches of representative missile airframes.

The other main approach being pursued by Forward PASS is one of ’cascading’ delivery vehicles and their payloads, thereby providing the greatest flexibility. Cascading permits the gradual step-down in size from the **submarine**, via a smaller vehicle, to payloads that may be as small (and therefore stealthy) as UGVs, UGSs and ’meso’ UAVs. At the center of this chain is the MPUUV, which the Forward PASS team sees as a lengthened derivative of the OSIRIS commercial vehicle being developed by Boeing.

The MPUUV is stored within the boat, allowing it to be loaded with the appropriate payload and fueled before a mission. It is then deployed into the water via a ’flexible ocean interface’, following which it transits to the payload-delivery area either autonomously or under control from the parent **submarine** or another platform.

The baseline MPUUV design is 10.7m long by 2m on each side. An adaptive interface allows it to accommodate standard payload modules in a free-flooding bay, each with a cross-section of 1.2x1.8m and in various lengths: 60cm for electronic-warfare or information-warfare payloads, and for energy packages; 1.2m for underwater maintenance devices; 1.8m for deployable caches; and 6m for torpedoes or cruise missiles. These would be assembled in different combinations, according to the mission. For example, a package intended for long-term ISR would devote some 90% of the available volume to energy storage. One allocated to deployment of an undersea network, however, would typically divide the space almost equally among a cache of communications nodes, a cable reel and a manipulator.

An SSN outfitted in such a way could stand off by up to 200nm from an enemy coastline, controlling both its own MPUUVs and those launched from other platforms. It could also be replenished by UUVs delivered from surface ships up to a further 400nm to the rear. Alternatively, upgrading earlier SSNs with ARCI ’Phase X’ capabilities would allow them to assume the responsibility for longer-term operation of payloads and sensors that have been put in place by new-generation boats.

The Forward PASS team believes that its overall system concept would expand the reach of a **submarine**’s weapons and sensors by a factor of 10 to 100, permitting a concept of operations that emphasizes monitoring rather than search. The ability to carry at least twice the payload percentage of current designs is predicted to double the number of kills achieved against TCTs while reducing damage to friendly forces by 33%.

Cost benefits

Non-traditional ways of engaging targets can also bring cost benefits. A **submarine** performing a strike mission against a land-based anti-access threat to naval forces could employ a combination of weapons. Directly launched TacToms carrying penetrating warheads (at a unit cost of approximately US$500,000) would attack hardened and/or deeply buried targets, with the remaining 80% of the total being engaged by 250nm-range Loitering Attack Munitions (LAMs) costing less than US$50,000 each. The LAMs, which are being developed under the joint US Army/DARPA NetFires program, could be launched from MPUUVs that had traveled to within 5nm of the enemy’s coastline.

Team 2020, headed by Lockheed Martin, is developing a Flexible Payload Module (FPM) and a Stealthy Affordable Capsule System (SACS) that together perform a similar function to the BUBL design being pursued by Forward PASS. The FPM is a box, 2.4m square and 7.6m deep, that could be stacked in free-flooding areas or in a missile tube. Towed modules could accommodate additional facilities, such as cruise or ballistic missiles, a hub for acoustic and electronic sensors, a habitat for special forces, and a UUV refueling station. Team 2020 is also working on the information-management aspects of such an approach, and on UAV applications.

The Manta Unmanned Undersea Vehicle Initiative that NUWC Newport Division has been pursuing since 1996 employs self-contained vehicles that can be carried externally by a **submarine**, then released to perform their own missions. Each can accommodate a variety of weapons and sensors, augmenting those of the parent vessel. This allows the **submarine** itself to have a smaller torpedo room, reducing the cost of the boat.

A typical arrangement would involve four Mantas grouped around the parent **submarine**’s forward hull, being semi-recessed into divot-shaped depressions in the outer casing. While attached, they could fire their own weapons to augment the **submarine**’s defensive or offensive armament. Following release, they would operate independently or under control from a remote platform (which may include the parent vessel). Various sizes of Manta have been studied, with lengths ranging from approximately 15m to more than 25m and typically weighing 50t. A 90t ’Super Manta’ would have a range of 1,000nm.

In support of its initiative, NUWC has built a Manta Test Vehicle (MTV) at approximately one-third scale. The center has worked with industry partners - including Boeing, Draper Labs, BAE Systems, Raytheon, General Dynamics, Kearfott, SenSyTech and Sensors Unlimited - to install and test subsystems aboard the MTV. Trials during August and September 2000 included operation of a basic ISR and communications payload consisting of a visual imager employing inexpensive commercial cameras (one forward-looking and two side-looking), a radio-frequency direction-finder, and a communications link. The last of these allowed the MTV, running in shallow water off Newport, to transmit imagery to the **submarine** USS Providence docked at Groton. In return, the SSN was able to control the UUV's sensors.

Testing of the MTV during 2001 included operation of a thermal imager provided by Threshold Unlimited, a SenSyTech Bobcat radar intercept receiver, a bottom bathymetric mapping package for 'non-traditional' navigation, and a modified commercial wireless Ethernet link able to handle data at 11Mb/s. The MTV has also deployed REMUS mini-UUVs from its wingtips.

Submarines will increasingly act as nodes within a network that also includes other surface and underwater platforms, both fixed and mobile, which will require sufficient communications bandwidth for them to function as an equal player in joint and combined operations. This demands a comprehensive fit of radio-frequency and acoustic communications equipment for use in different tactical situations, including new capabilities such as expendable buoys that accommodate modems for acoustic and satellite communications.

USS Providence was the first boat to be fitted with the **Submarine** High Data Rate (SubHDR) system, which it received in mid-2000. SubHDR, which replaces the current periscope-mounted Navy EHF System, uses a significantly larger antenna (the OE-562/BRC) and additional radio-room equipment to provide high bandwidth (up to 256kb/s) for EHF transmission and reception. It also provides SHF satellite communications and can receive the Global Broadcast Service. At the other end of the frequency scale, the ELF On-Hull Antenna system is intended to provide full access to ELF broadcasts, with a significant increase in maneuverability and flexibility, while conducting stealthy operations at depth in littoral waters.

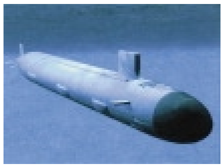
In April 2000, a prototype **Submarine** Super High Frequency (SHF) Phased Array Antenna demonstrated two-way communication over the Defense Satellite Communi-cations System, using an electronically scanned phased-array antenna that is designed for use in **submarines**. Data rates of up to 256kb/s were achieved by the array, which incorporates the first transmit/receive modules derived from DARPA's High Density Microwave Packaging technology.

NUWC's Communication at Speed And Depth program is examining technology developed by industry, including that funded by DARPA, in the areas of buoyant cable systems, towed bodies and tethered arrangements. Equipment under study includes the BAE Systems AVXD antenna, which can handle a wide variety of traffic, as a potential back-up to the present BR-34 or OE-538 aboard Los Angeles-class SSNs. DARPA has directed the Massachusetts Institute of Technology's Lincoln Laboratory to demonstrate an advanced UHF Buoyant Cable Antenna (BCA) that will fit within space now occupied by the OE-315 BCA. The Retrievable Tethered Optical Fibre (RTOF) buoy developed in the UK is a candidate for UHF, SHF, ESM and video links.

*n The US Navy's force of Ohio-class SSBNs carrying Trident fleet ballistic missiles will remain in service until at least 2040, following the service's 1988 decision to extend their lives from 30 to 44 years. In January 2002, the USN awarded Lockheed Martin Space Systems a US$248 million contract for follow-on production of Trident IIs and to begin the D5 life-extension program. The new rounds will replace C4s aboard the four Ohio-class **submarines** that are being retrofitted to accept the new weapon in 2004. A further four are expected to be converted to SSGNs. Trident II D5 is the only strategic ballistic missile in production in the US. It also arms the UK Royal Navy's four Vanguard-class SSBNs.*
(Source: Findler & Winter)

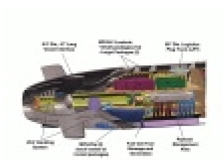
*The USN's attack **submarines** could evolve from the conventional Virginia-class design (bottom left) to ever-more innovative approaches, potentially including multihull layouts such as that illustrated top right.*
(Source: Electric Boat)

US **submarines** will increasingly take advantage of commercial off-the-shelf (COTS) electronics in major applications such as the AN/BLQ-10(V) electronic support measures system, seen here aboard the Los Angeles-class boat USS Annapolis. A similar process is under way in the sonar field with the implemen-tation of the Acoustic Rapid COTS Initiative.
(Source: USN)



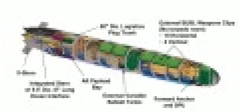
The USN's baseline Virginia-class boats are being fitted with 12 Vertical Launch System tubes and four conventional forward-firing 21in torpedo tubes. They will carry up to 38 Tomahawk cruise missiles each, together with Mk48 ADCAP torpedoes and mines.
(Source: USN)

The USN will convert four Ohio-class SSBNs to SSGNs, allowing them to perform missions including deep strike and deployment of Special Operations Forces (SOF - partially replacing the decommissioned USS Polk and USS Kamehameha in the latter case). Swimmers are seen in this artist's impression departing from a Dry Deck Shelter (right), with an Advanced SEAL Delivery System (ASDS) mini-**submarine** docked alongside it. The ASDS, now entering service, is nearly 20m long by approximately 2.4m wide and displaces 55t when surfaced. It can carry up to 16 SOF personnel, in addition to its two-man crew, in a dry compartment. The ASDS is reported to have a range of 125nm at 8kt, and can stay on station for several days.
(Source: Electric Boat)

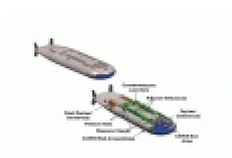


The proposed new-generation **submarine** incorporates an aft-mounted payload bay. This increases the available payload weight to 268t, compared with 88t for a baseline Virginia and 173t for the proposed Virginia variant.
(Source: Forward PASS)

The proposed Virginia variant with its ocean interface, providing dry access to the MPUUV for maintenance and payload installation. The cylinder connects via a 2m-diameter transfer trunk with a 14m-long payload bay within the pressure hull. The last of these can hold 24 payload packages, each measuring 1.8x1.8x1.2m, for loading into the MPUUV.
(Source: Forward PASS)

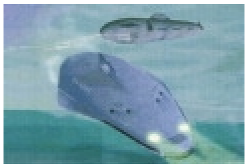


This is not your grandfather's **submarine**. The Forward PASS consortium has studied this next-generation design, with inner and outer hulls of 10.35m and 12.8m diameter respectively, having no sail and an integrated X-stern. Other features include external electric drive, conformal arrays and advanced signature control. The design could accommodate 72 Tomahawks (one-third of them launched vertically), 12 ADCAP torpedoes, 225 NetFires rounds, 90 UAVs, two MPUUVs and four self-deploying sensor nodes.
(Source: Forward PASS)

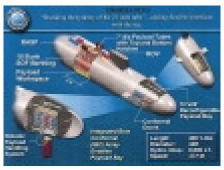


A multihull design considered by the Forward PASS consortium, which maximizes the payload space while minimizing hydrodynamic impacts. The design employs Conformal Acoustic Velocity Sonar (CAVES) technology for both the flank-mounted Wide Aperture Array (WAA) and the Integrated Bow Conformal Array (IBCA).
(Source: Forward PASS)

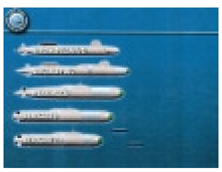
NUWC Newport Division is using its Manta Test Vehicle (MTV) to prove technologies and operating concepts for the full-size Manta. The vehicle can also carry heavyweight torpedoes, as illustrated here.
(Source: NUWC)



*Artist's impression of a full-scale Manta leaving its parent **submarine**. Another example is firing its on-board weapons while still attached to the SSN (background).*
(Source: NUWC)



*The family of platforms studied by Team 2020 under the **Submarine** Payloads and Sensors program includes the baseline Virginia class (115m long by 10.35m in diameter, with a submerged displacement of 7,900t); Virginia Plus, with a hull of the same diameter but extended to 124m and displacing 8,800t; and three designs with a diameter of 12.8m: Merrimack (116m, 12,000t), Renegade 1 (102m, 11,500t) and Renegade 2 (90m, 9,900t).*
(Source: Team 2020)



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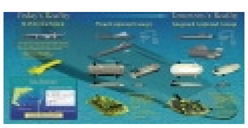

*Electric Boat and the US Naval Undersea Warfare Center's Newport Division are examining several candidate concepts for the Manta unmanned underwater vehicle, which would allow a **submarine** to carry much of its armament externally and permit weapon delivery from stand-off ranges.*
(Source: NUWC)

*Electric Boat and the US Naval Undersea Warfare Center's Newport Division are examining several candidate concepts for the Manta unmanned underwater vehicle, which would allow a **submarine** to carry much of its armament externally and permit weapon delivery from stand-off ranges.*
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*Electric Boat and the US Naval Undersea Warfare Center's Newport Division are examining several candidate concepts for the Manta unmanned underwater vehicle, which would allow a **submarine** to carry much of its armament externally and permit weapon delivery from stand-off ranges.*
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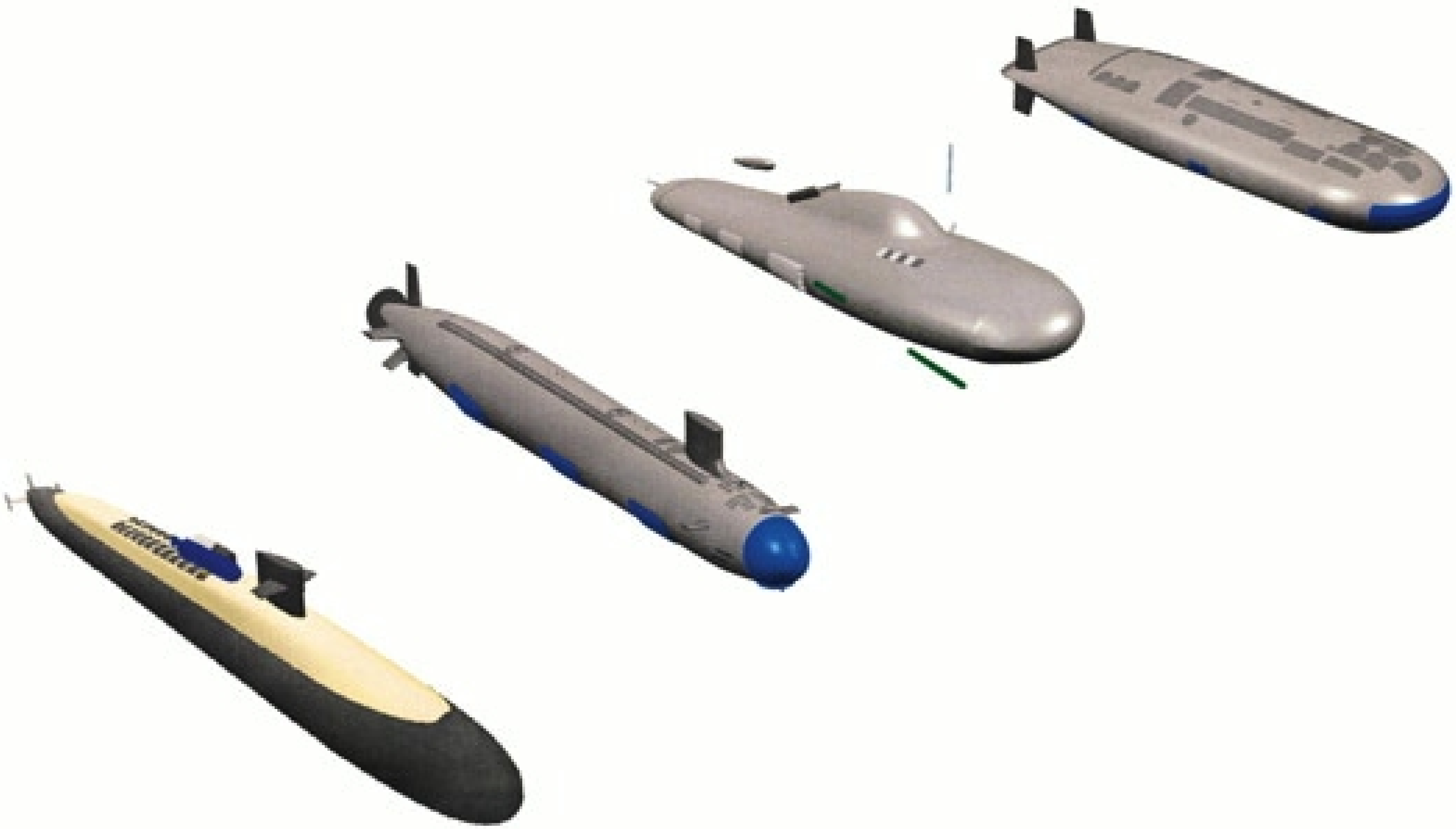
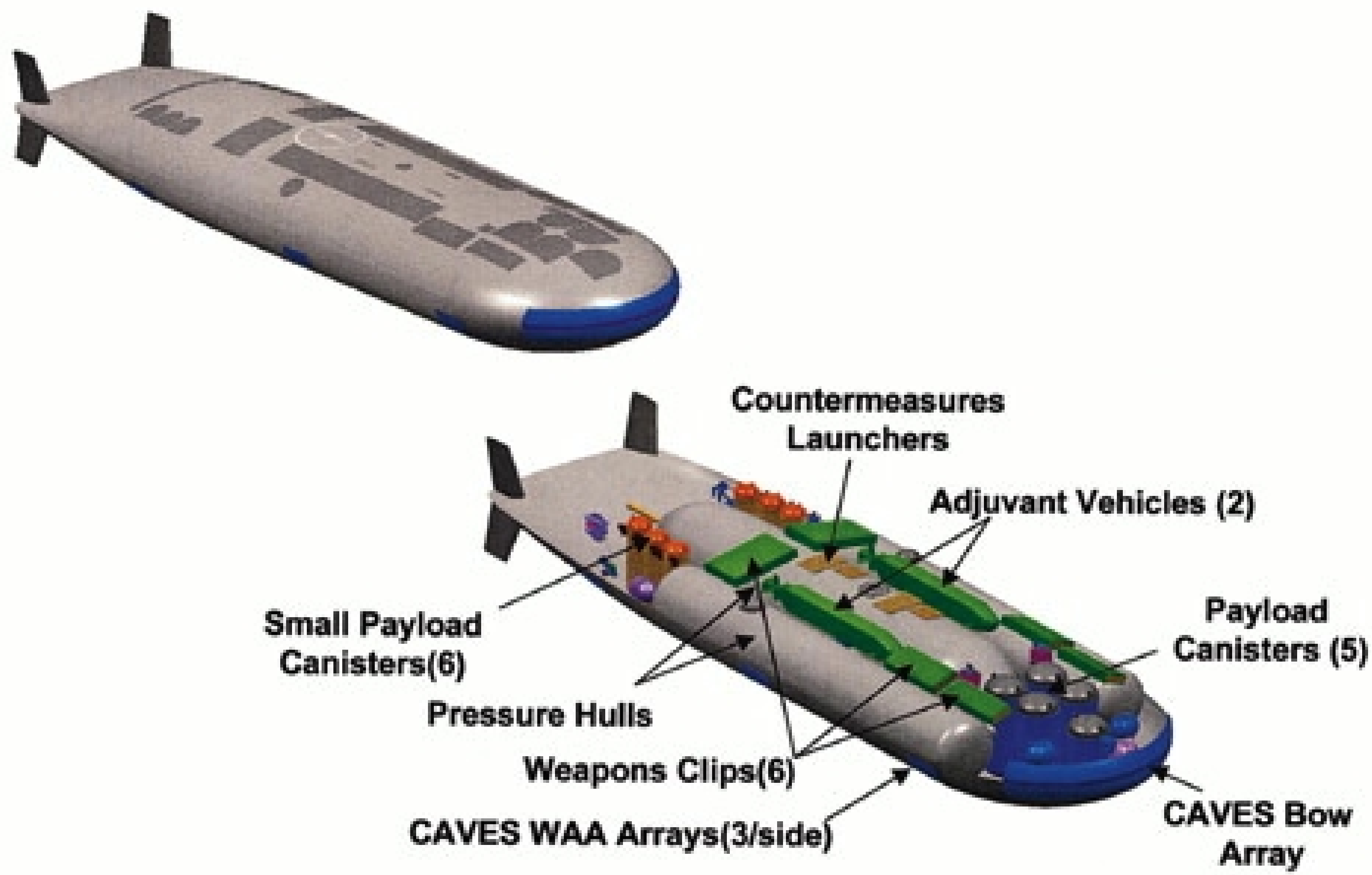
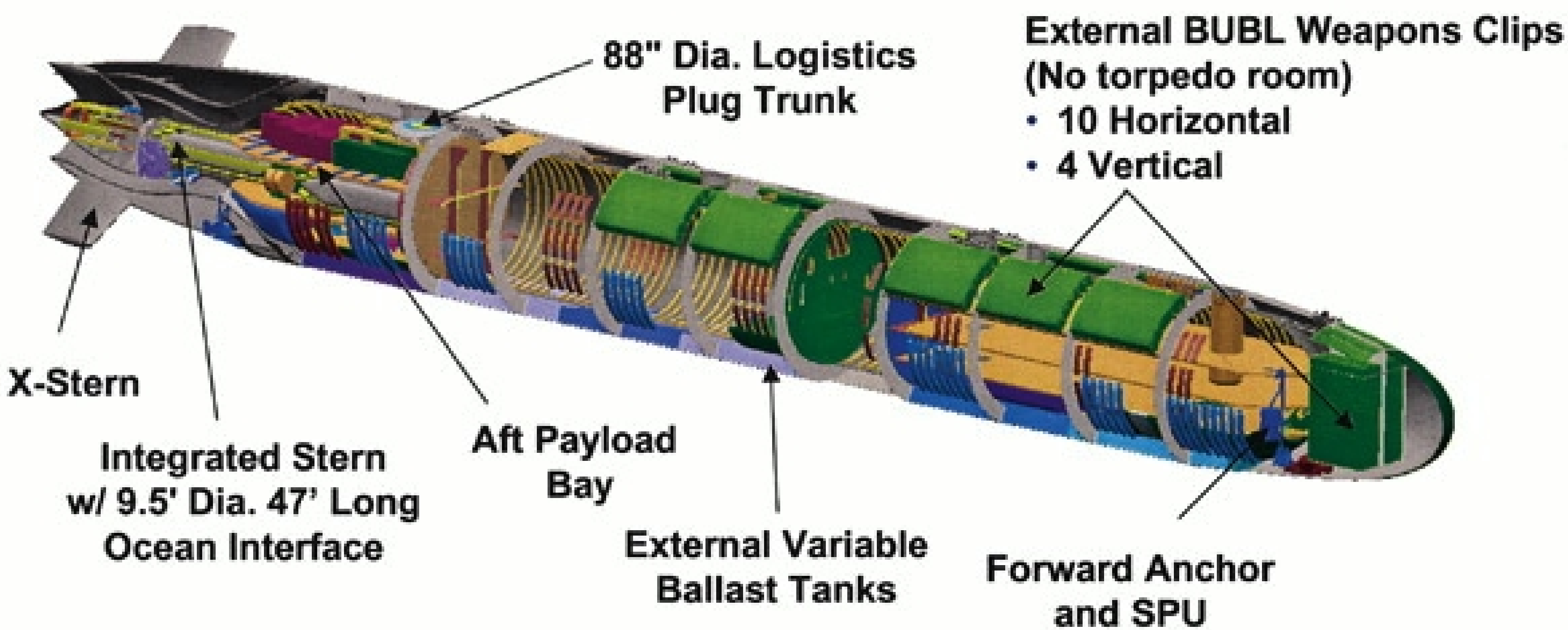
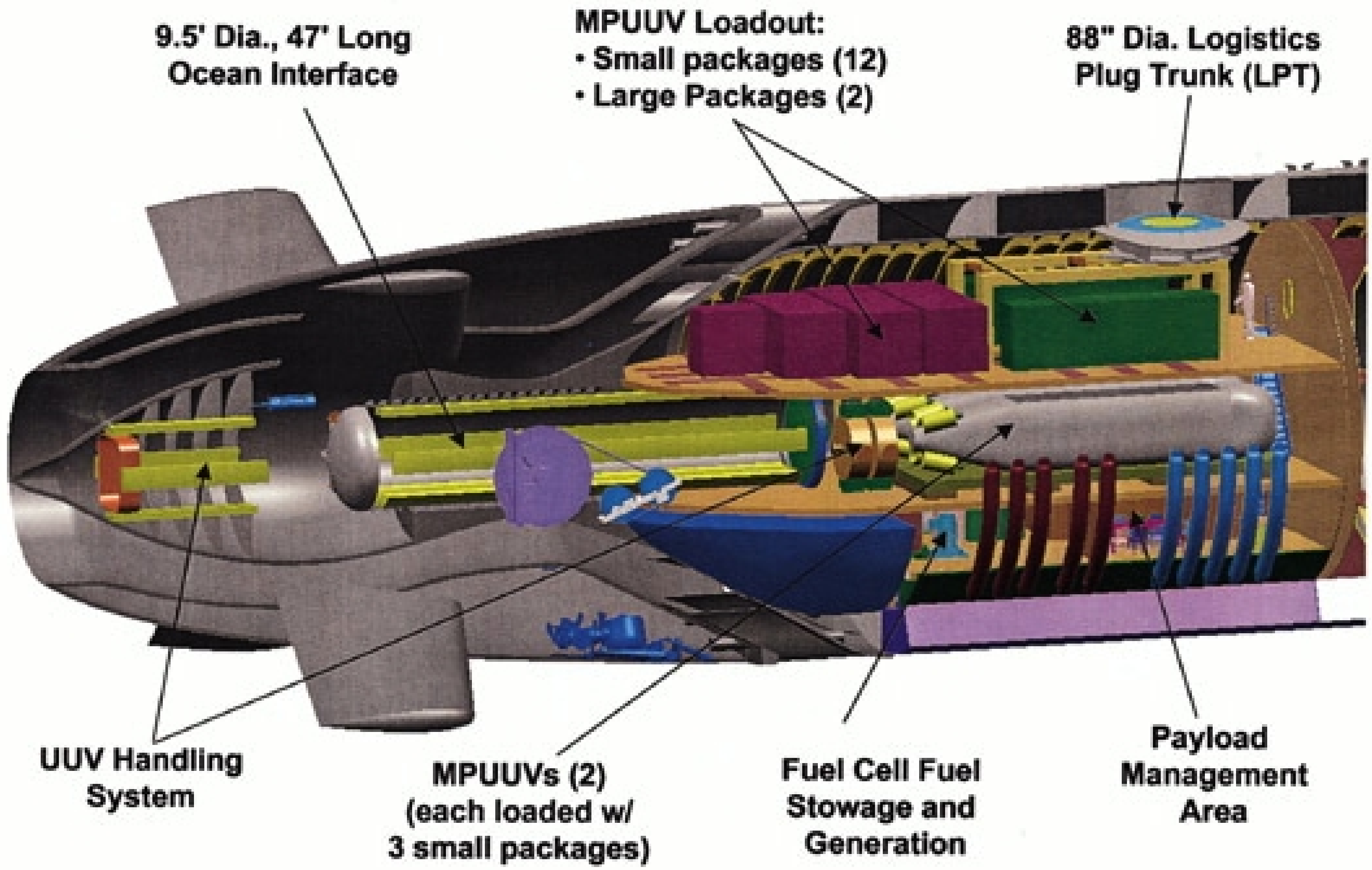
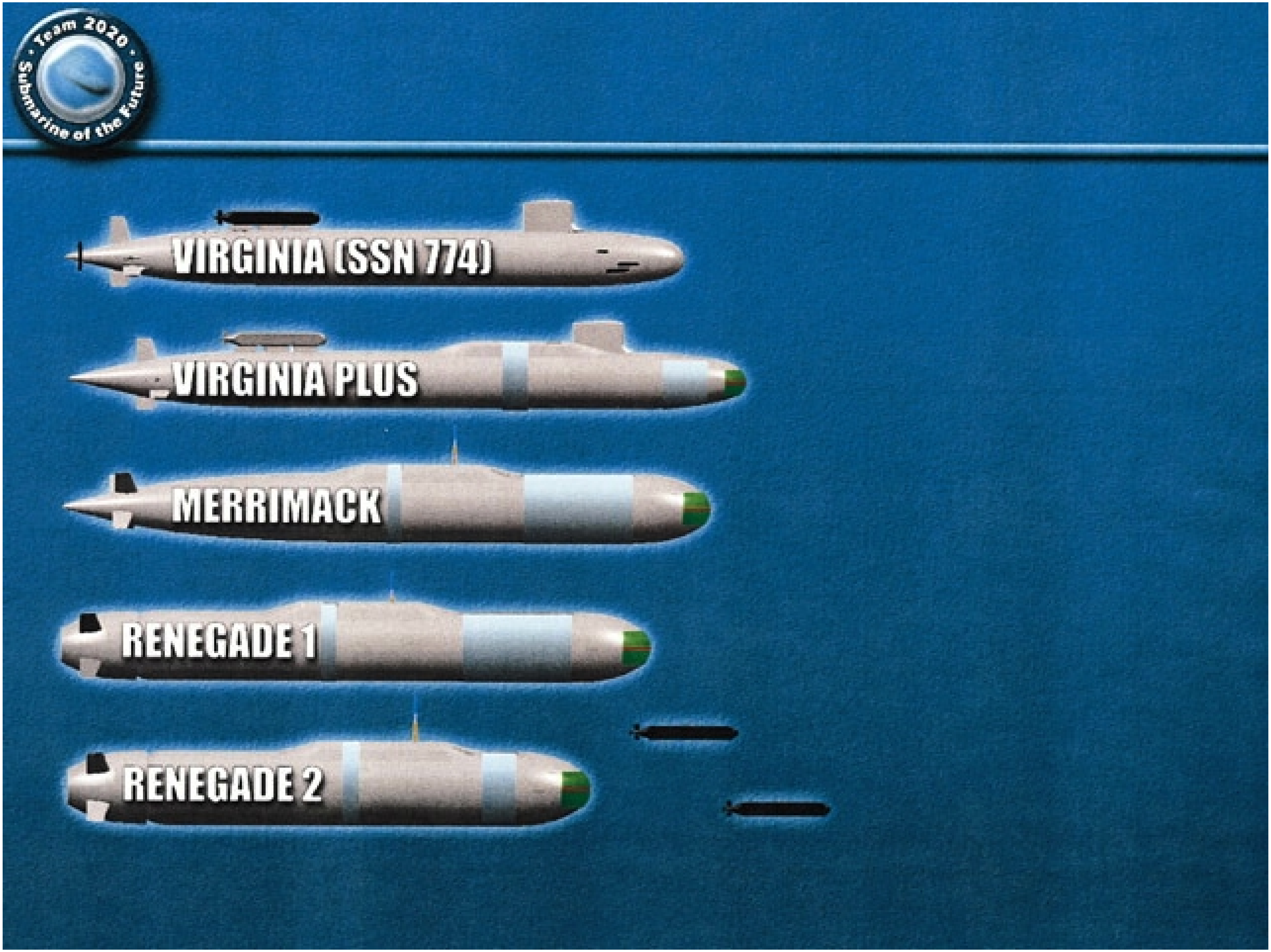
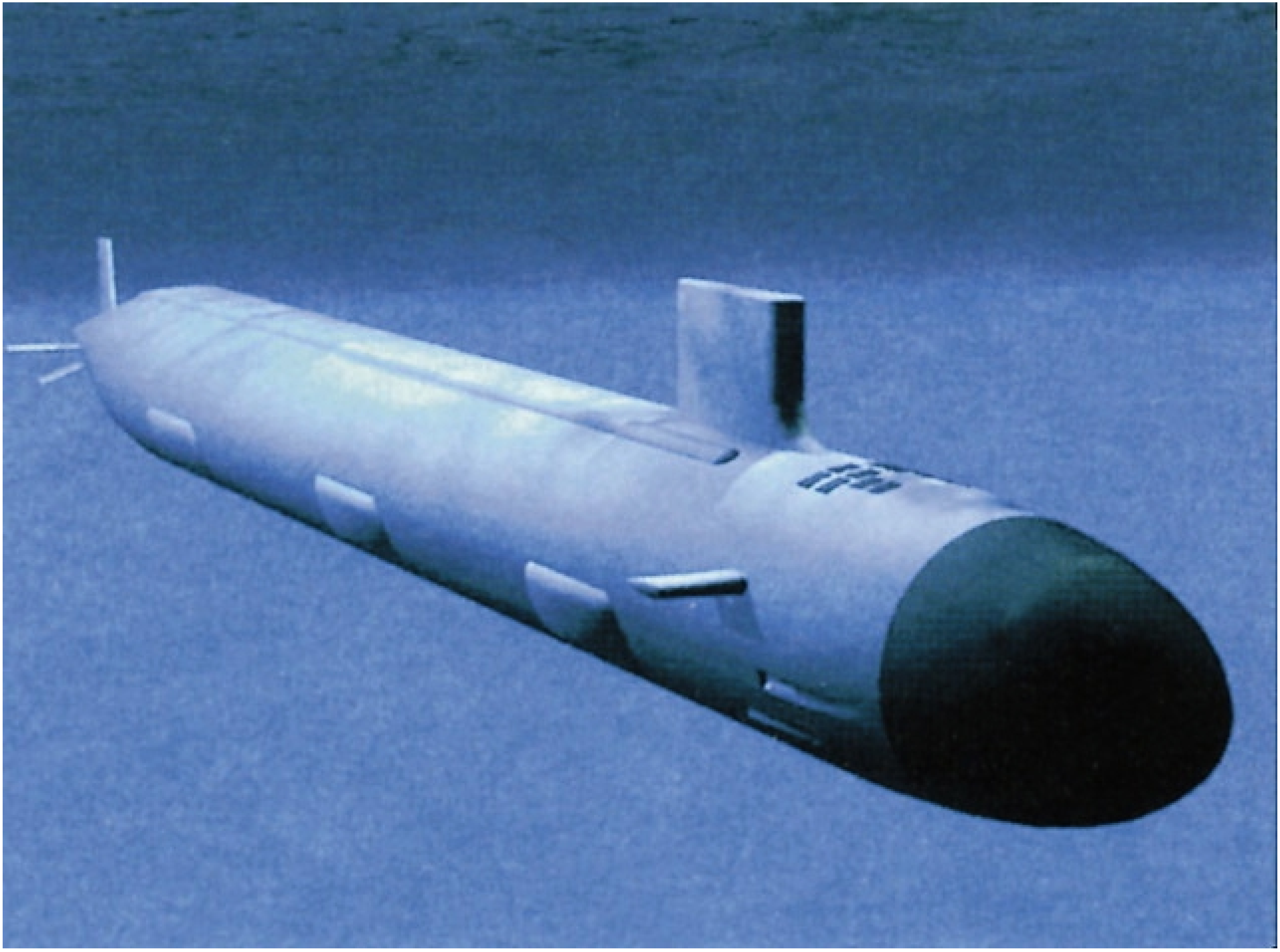


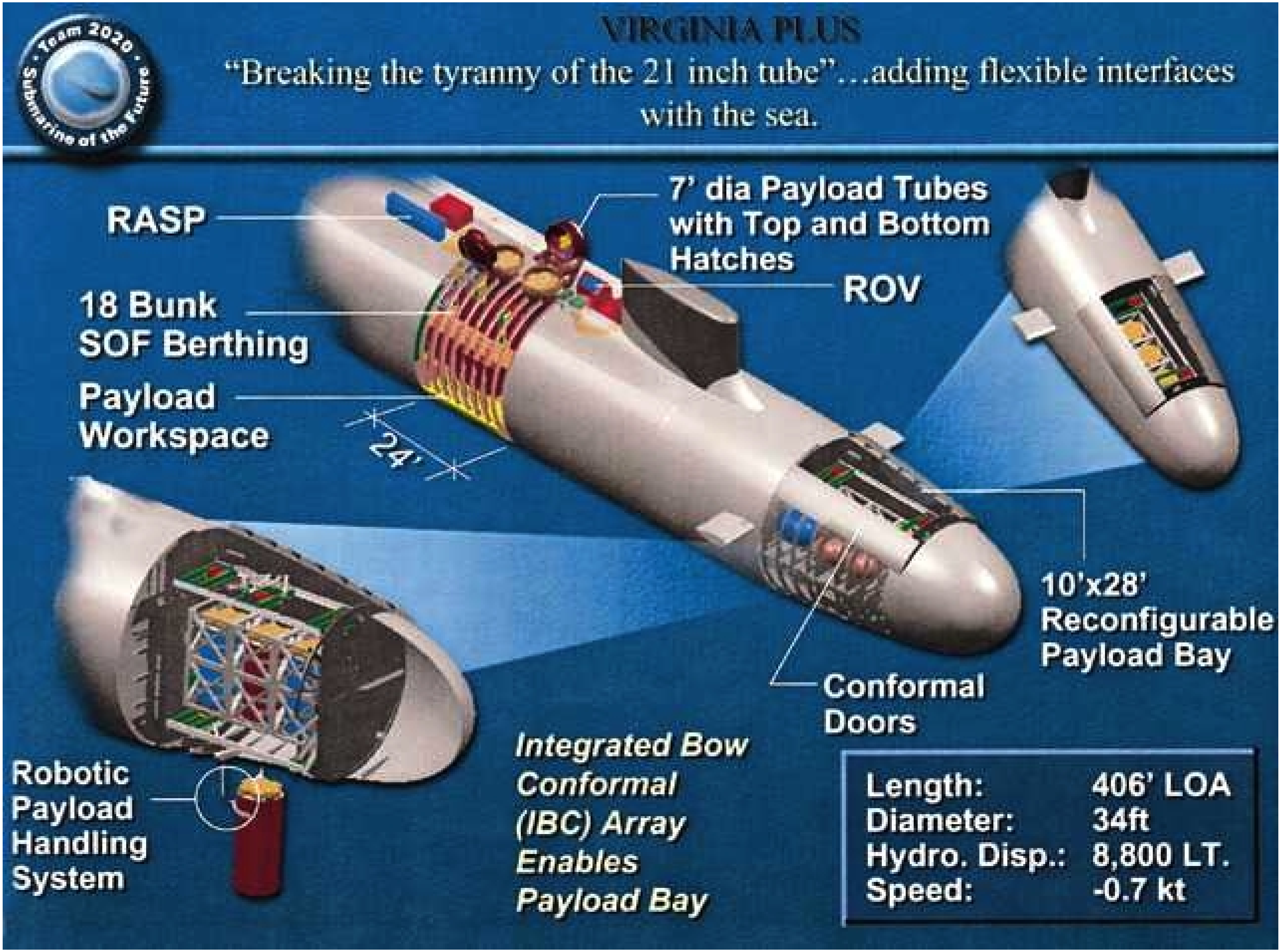

Countermeasures
Launchers
Adjuvant Vehicles (2)
Small Payload
Canisters(6)
Payload
Canisters (5)
Pressure Hulls
Weapons Clips(6)
CAVES WAA Arrays(3/side)
CAVES Bow
Array

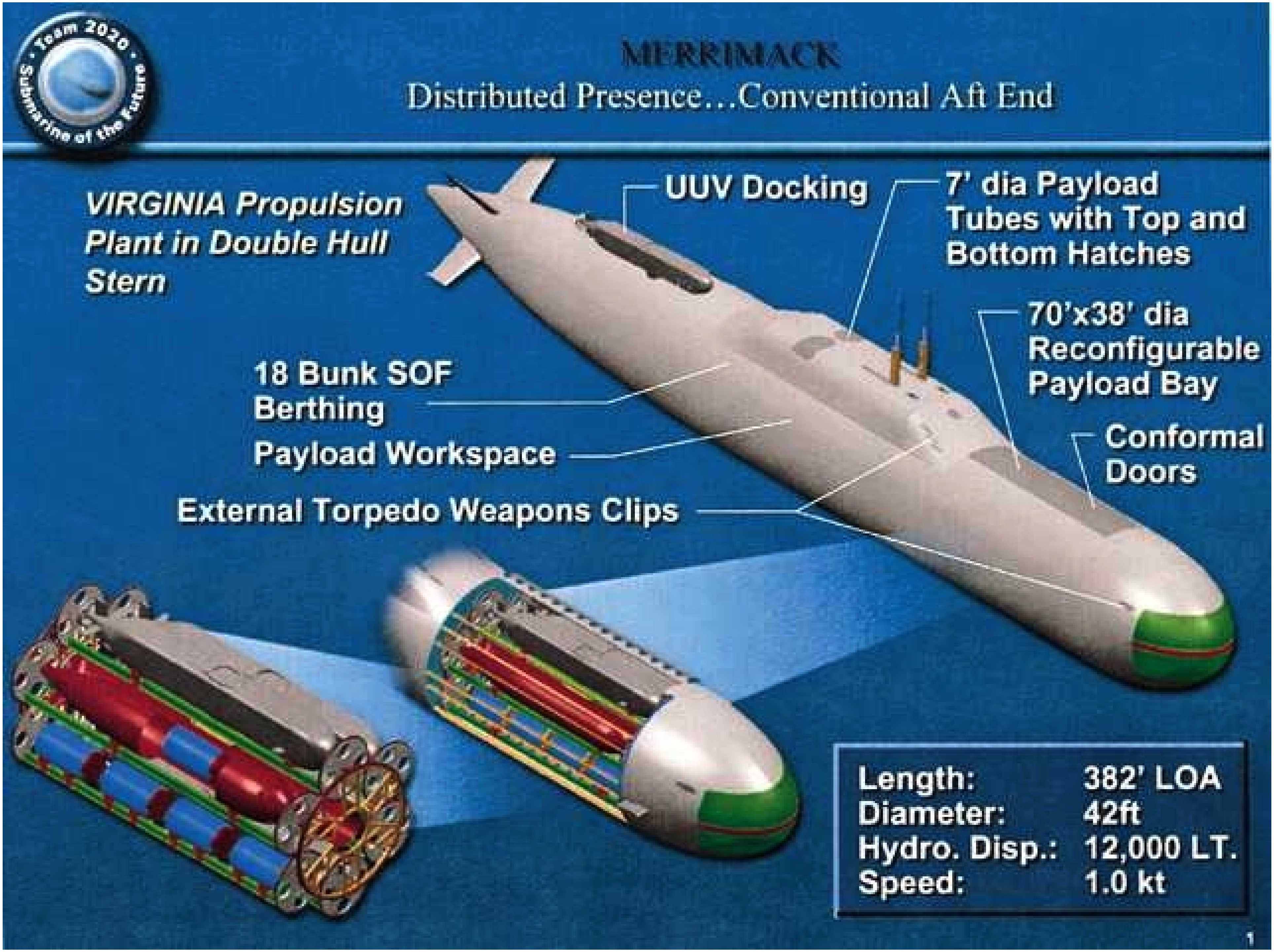

External BUBL Weapons Clips
(No torpedo room)
• 10 Horizontal
• 4 Vertical
88" Dia. Logistics
Plug Trunk
X-Stern
Integrated Stern
w/ 9.5' Dia. 47' Long
Ocean Interface
Aft Payload
Bay
External Variable
Ballast Tanks
Forward Anchor
and SPU

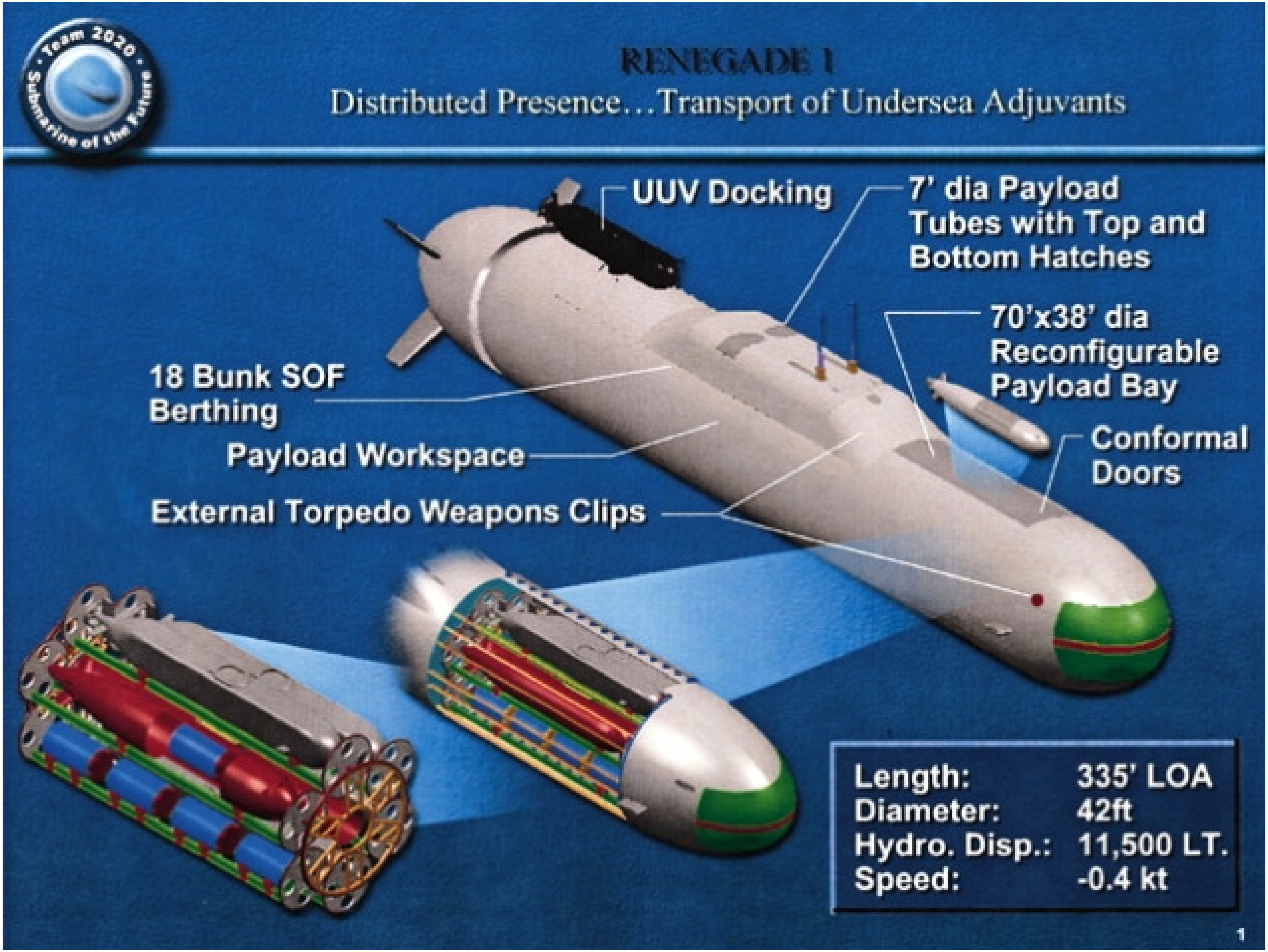

9.5' Dia., 47' Long Ocean Interface
MPUUV Loadout:
• Small packages (12)
• Large Packages (2)
88" Dia. Logistics Plug Trunk (LPT)
UUV Handling System
MPUUVs (2) (each loaded w/ 3 small packages)
Fuel Cell Fuel Stowage and Generation
Payload Management Area


Team 2020
Submarine of the Future
VIRGINIA (SSN 774)
VIRGINIA PLUS
MERRIMACK
RENEGADE 1
RENEGADE 2

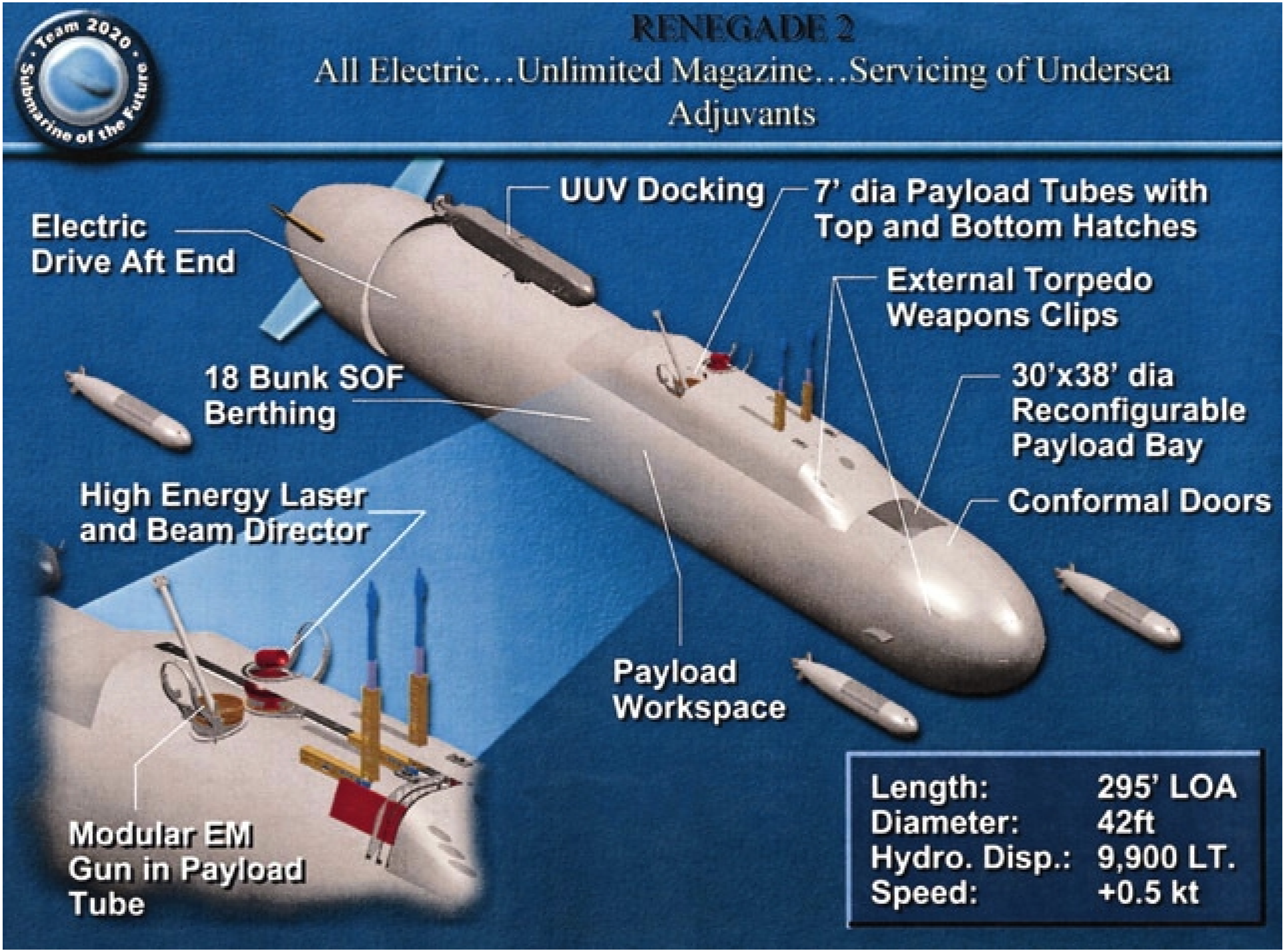



Team 2020
Submarine of the Future
VIRGINIA PLUS
"Breaking the tyranny of the 21 inch tube"…adding flexible interfaces with the sea.
RASP
7' dia Payload Tubes with Top and Bottom Hatches
ROV
18 Bunk SOF Berthing
Payload Workspace
24'
10'x28' Reconfigurable Payload Bay
Conformal Doors
Robotic Payload Handling System
Integrated Bow Conformal (IBC) Array Enables Payload Bay
Length: 406' LOA
Diameter: 34ft
Hydro. Disp.: 8,800 LT.
Speed: -0.7 kt

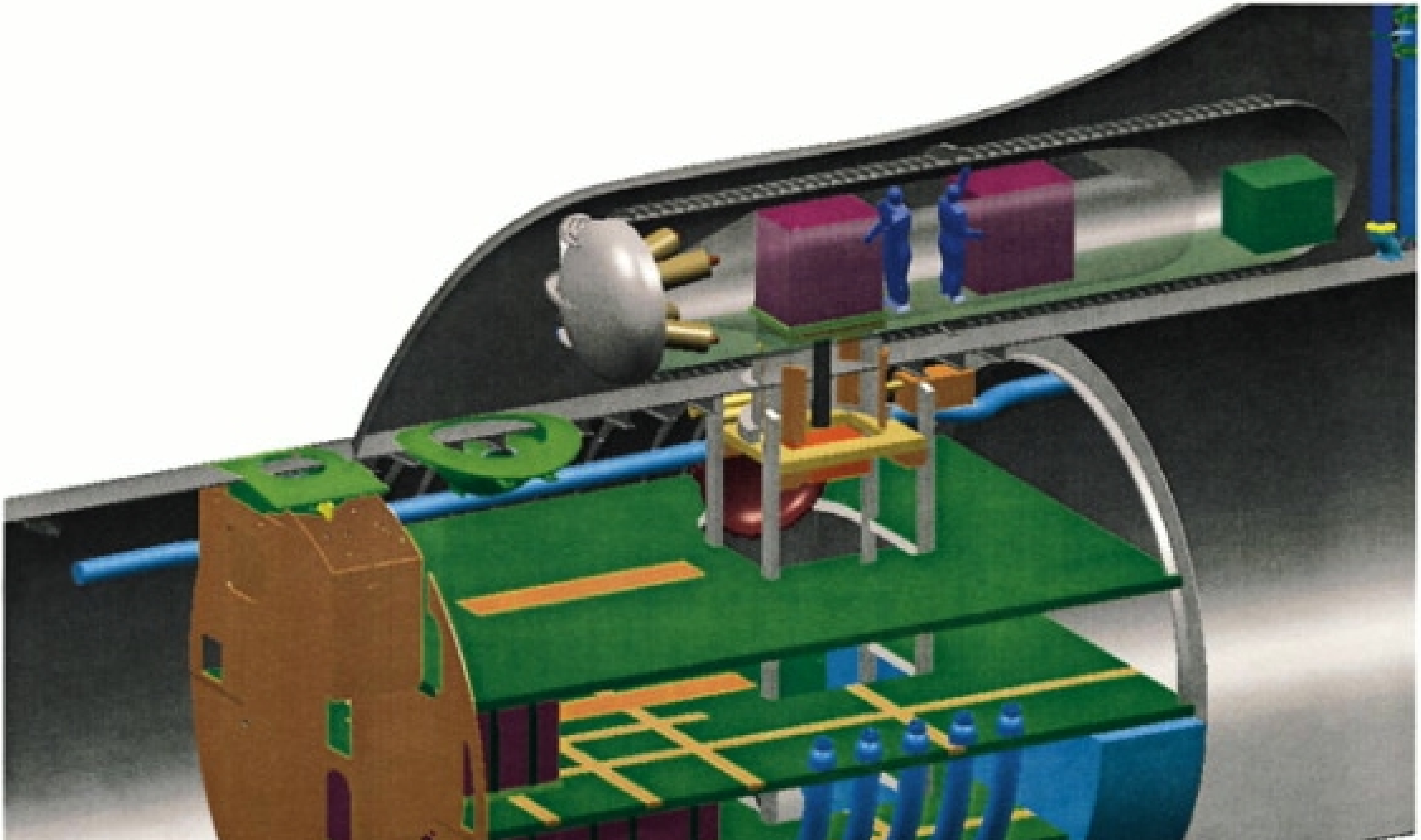

Team 2020 · Submarine of the Future
MERRIMACK
Distributed Presence…Conventional Aft End
VIRGINIA Propulsion Plant in Double Hull Stern
UUV Docking
7' dia Payload Tubes with Top and Bottom Hatches
70'x38' dia Reconfigurable Payload Bay
18 Bunk SOF Berthing
Payload Workspace
Conformal Doors
External Torpedo Weapons Clips
Length: 382' LOA
Diameter: 42ft
Hydro. Disp.: 12,000 LT.
Speed: 1.0 kt
1

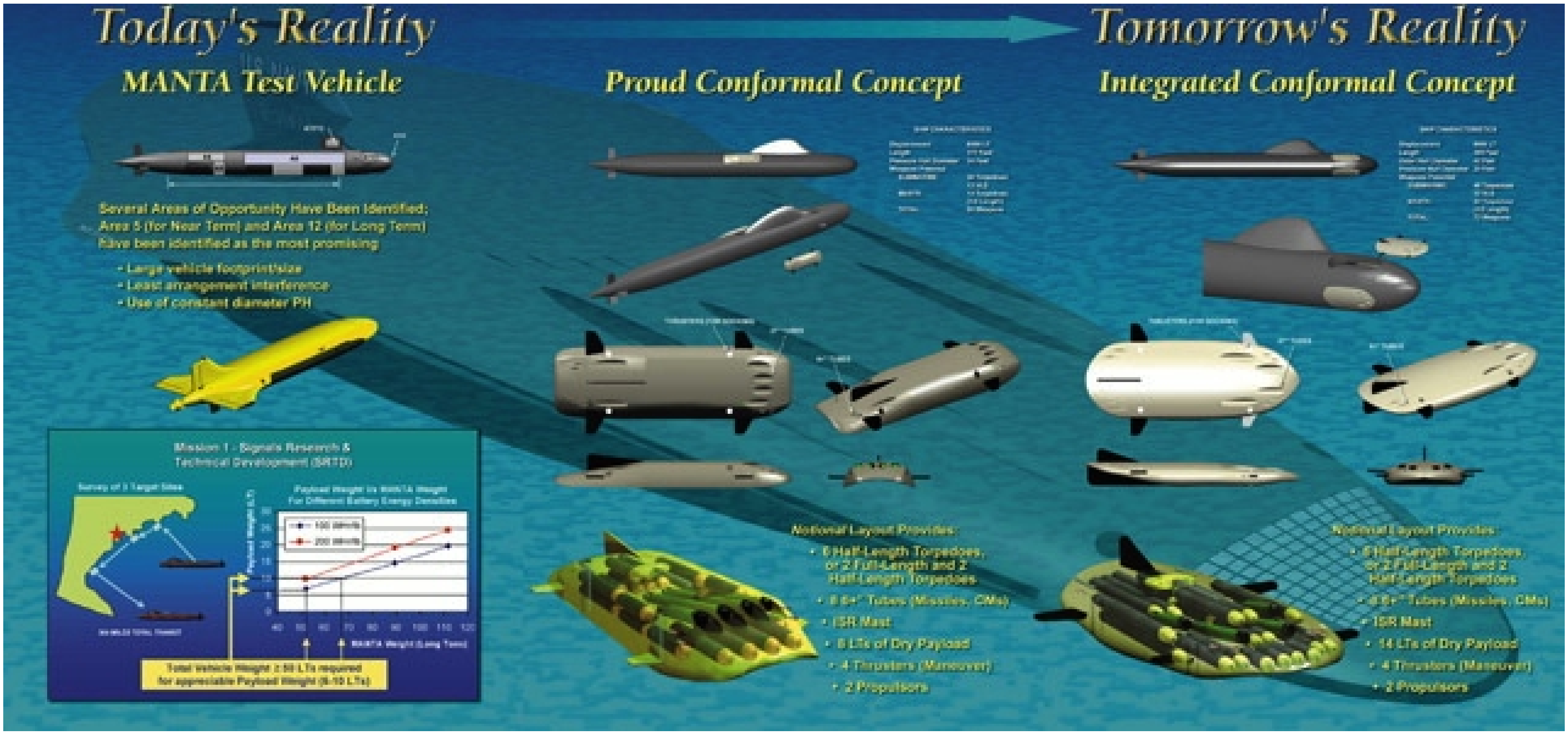


Team 2020 Submarine of the Future
RENEGADE 1
Distributed Presence…Transport of Undersea Adjuvants
UUV Docking
7' dia Payload Tubes with Top and Bottom Hatches
70'x38' dia Reconfigurable Payload Bay
18 Bunk SOF Berthing
Payload Workspace
Conformal Doors
External Torpedo Weapons Clips
Length: 335' LOA
Diameter: 42ft
Hydro. Disp.: 11,500 LT.
Speed: -0.4 kt
1

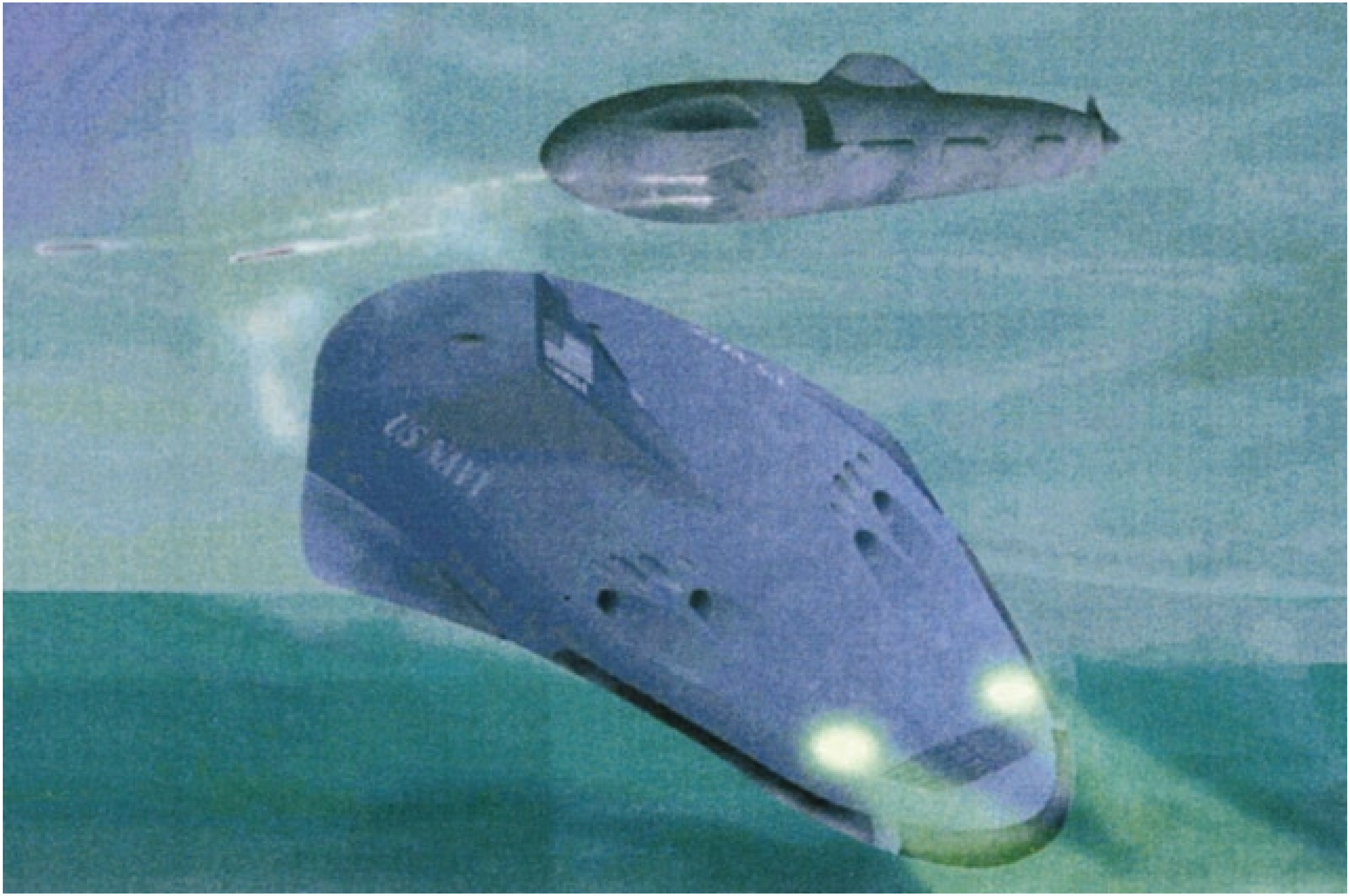


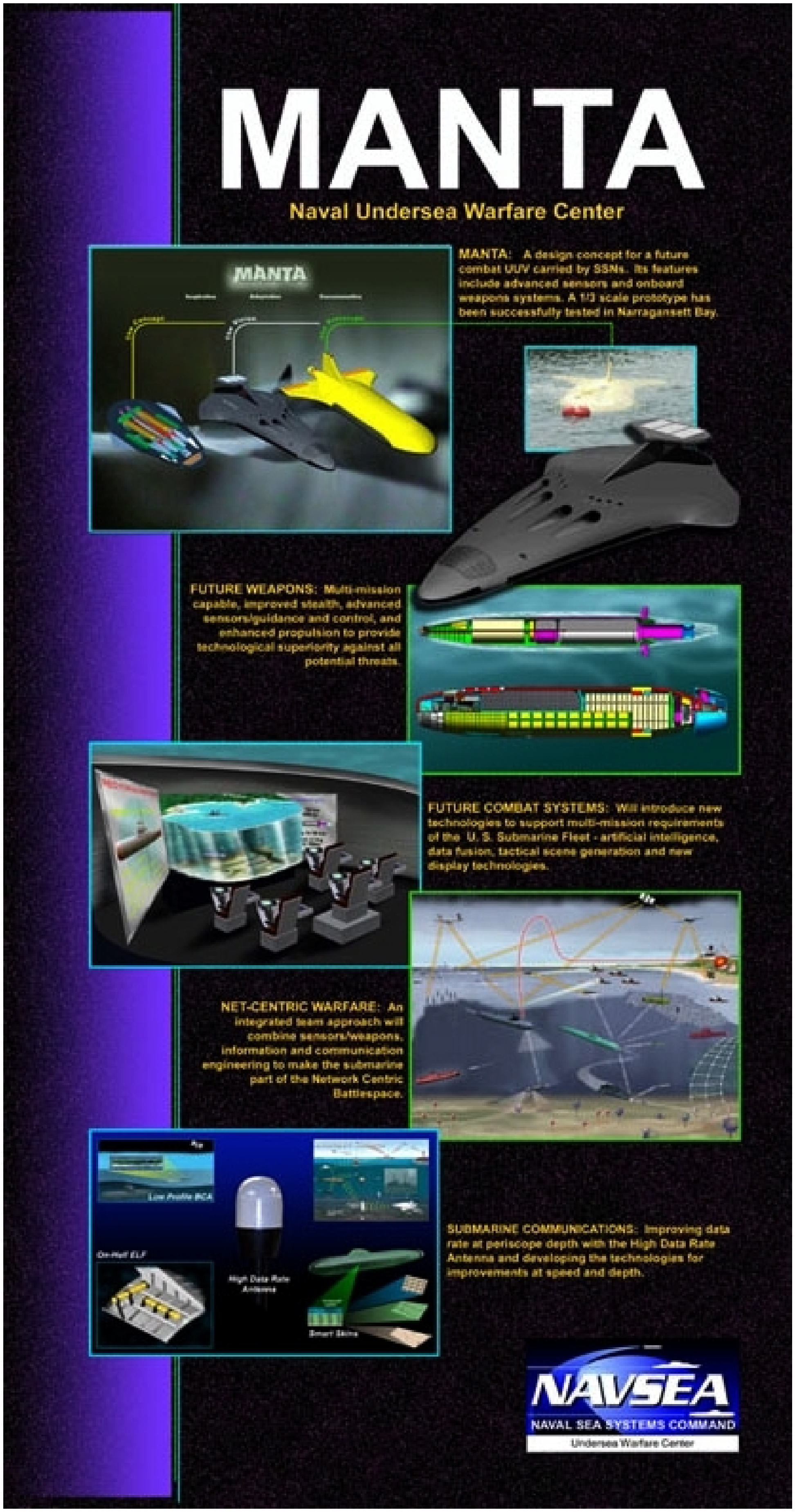
Team 2020 · Submarine of the Future ·
RENEGADE 2
All Electric…Unlimited Magazine…Servicing of Undersea Adjuvants
Electric Drive Aft End
UUV Docking
7' dia Payload Tubes with Top and Bottom Hatches
External Torpedo Weapons Clips
18 Bunk SOF Berthing
30'x38' dia Reconfigurable Payload Bay
High Energy Laser and Beam Director
Conformal Doors
Payload Workspace
Modular EM Gun in Payload Tube
Length: 295' LOA
Diameter: 42ft
Hydro. Disp.: 9,900 LT.
Speed: +0.5 kt





Today's Reality
MANTA Test Vehicle
Proud Conformal Concept
Tomorrow's Reality
Integrated Conformal Concept
Several Areas of Opportunity Have Been Identified;
Area 5 (for Near Term) and Area 12 (for Long Term)
have been identified as the most promising
• Large vehicle footprint/size
• Least arrangement interference
• Use of constant diameter PH
Mission 1 - Signals Research &
Technical Development (SRTD)
Payload Weight Vs MANTA Weight
For Different Battery Energy Densities
Total Vehicle Weight ≥ 50 LTs required
for appreciable Payload Weight (8-10 LTs)
Notional Layout Provides:
• 6 Half-Length Torpedoes,
or 2 Full-Length and 2
Half-Length Torpedoes
• 8 6+" Tubes (Missiles, CMs)
• ISR Mast
• 8 LTs of Dry Payload
• 4 Thrusters (Maneuver)
• 2 Propulsors
Notional Layout Provides:
• 6 Half-Length Torpedoes,
or 2 Full-Length and 2
Half-Length Torpedoes
• 4 6+" Tubes (Missiles, CMs)
• ISR Mast
• 14 LTs of Dry Payload
• 4 Thrusters (Maneuver)
• 2 Propulsors


US NAVY


MANTA
Naval Undersea Warfare Center
MANTA: A design concept for a future combat UUV carried by SSNs. Its features include advanced sensors and onboard weapons systems. A 1/3 scale prototype has been successfully tested in Narragansett Bay.
MANTA
FUTURE WEAPONS: Multi-mission capable, improved stealth, advanced sensors/guidance and control, and enhanced propulsion to provide technological superiority against all potential threats.
FUTURE COMBAT SYSTEMS: Will introduce new technologies to support multi-mission requirements of the U. S. Submarine Fleet - artificial intelligence, data fusion, tactical scene generation and new display technologies.
NET-CENTRIC WARFARE: An integrated team approach will combine sensors/weapons, information and communication engineering to make the submarine part of the Network Centric Battlespace.
Low Profile BCA
On-Hull ELF
High Data Rate Antenna
Smart Skins
SUBMARINE COMMUNICATIONS: Improving data rate at periscope depth with the High Data Rate Antenna and developing the technologies for improvements at speed and depth.
NAVSEA
NAVAL SEA SYSTEMS COMMAND
Undersea Warfare Center