by Capt. Jim Stevens

The HOW and WHY of OPEN ARCHITECTURE

Sailors aboard a U.S. submarine.

Few things have brought more credit and admiration to the submarine force than our success in adapting the open architecture design philosophy and business model for our sonar and combat systems. It has attracted the attention of the rest of the Navy, the acquisition community at large, and Congress. This article is focused on the crux of the program, how and why open architecture works, and the hurdles we have faced, and are now facing, in this evolutionary program.

Introduction: The Processing Crisis

In the 1980s-90s, the front-line sonar system of the Submarine Force was the BQQ-5, its processing power in the Sperry/UNIVAC UYK-7 processor. The UYK-7 was the standard shipboard computer, designed in accordance with stringent military specifications for performance and ruggedness for use throughout the Navy. Configuration control was the primary goal, and we weapons officers and sonar men were proud of the racks of UYK-7's in our sonar equipment space. Yet, these UYK-7s rapidly approached obsolescence. Indeed they were obsolete by the time we got them in the fleet, and we realized it at the time as we were updating our home computers from Intel 80386 processors to 486 processors.

The software we ran on the BQQ-5 was proprietary to the contractor, with only minor corrective fixes possible until the next major sonar system update. This "closed architecture/closed business model" system, with software tied to the hardware, was the business model then, and still is today in many defense systems.

In Washington, D.C., those responsible for modernizing our submarine force faced a monumental task in keeping our BQQ-5 sonar system and its SSBN equivalent BQQ-6 system, modern and up to the threat, which was becoming quieter and quieter, and likewise, with the knowledge that whatever system was fielded it would also be obsolete by the time the fleet was able to use it. The system would be obsolete not only in performance, but in the repair and maintenance of the systems as well. Can you imagine today trying to get a replacement 386 processor? How about trying to run HALO 3 on it? The costs were tremendous, such that even the U.S. Submarine Force—the largest and best-funded in the world—could not afford it.

Pragmatism combined with vision yielded the submarine force launching of the Acoustic Rapid COTS Insertion program (ARCI). One could rightfully state that the C stands for "Capability," but COTS (commercial off-the-shelf technology) really is the key to its success.

Commercial Processors: Price vs. Performance

As anyone who has looked into replacing their home computer will attest, there is always a debate on which processor to base one's new computer. The first question is, "Should you go with the absolute latest processor and pay more, or buy last year's processor—which is good enough for today's software—at half the cost?" The question really is one of do you want "state-of-the-art" or "state-of-the -practice" technology? If we time our purchase correctly, we can purchase the processing power for the applications we need today, knowing that in two years, we are going to buy even newer processors for applications that software developers are currently developing. More importantly, in two years, these processors will become obsolete, and their cost and availability will sky rocket, thus perpetuating computer/software developers' business model.

Open Architecture: Software Independent of the Hardware

The old way of doing business was expensive. It guaranteed recurring revenue to manufacturers for the purchase of sonar and combat control systems. Any significant upgrade in capability resulted in a large sale for them since everything from the sensors, the beam forming hardware,

the computers, the detection and tracking software, and even the cabling were in need of replacement in order to use new system's capabilities. Previously on the order of $150 million per ship set we have achieved a near ten-fold reduction for current cost of about $15 million for today's shipsets.

In an open architecture/open business model system, the software is developed independently from the hardware (through the use of middleware), allowing us to choose the best software application from any company interested in doing business with us. Costs lie in changing lines of code. By continuously updating the small number of lines of code in the middleware, updates to large amounts of hardware-based code and application code are avoided.

Submarine Command Course students supervise Fire Control Technicians from USS *Columbia* (SSN-771) on the A/N BYG-1 TI-04 APB-04 Trainer at Naval Submarine Training Center, Pacific.

The Changing World: Pacing the Threat

Detecting increasingly quiet Soviet nuclear submarines in open ocean areas was the major issue facing the U.S. Navy during ARCI introduction in the 1990s. Subsequently, the Navy changed its emphasis to littoral operations characterized by high surface traffic, a proliferation of increasingly quiet third world diesel submarines (SSK's), and the prospect of mined waters. The U.S. SSN's unique ability to initiate and sustain covert operations in forward areas while detecting and engaging advanced threats is a critical enabler for these Navy littoral operations. A major challenge for Navy planners has been to build into the ARCI business model the flexibility to adapt and respond quickly with capabilities to respond to new needs. Typical of these new needs is the capability to detect a quiet SSK while sustaining operations in high surface traffic and conducting counter-mine warfare.

The Open Architecture Business Model: APBs and TIs

The ARCI business model is a two-year continual process of identifying and prioritizing fleet operational needs, or requirements, developing the software application to address those requirements, and assessing the processors available in the near future.

Fleet-driven Requirements Generation

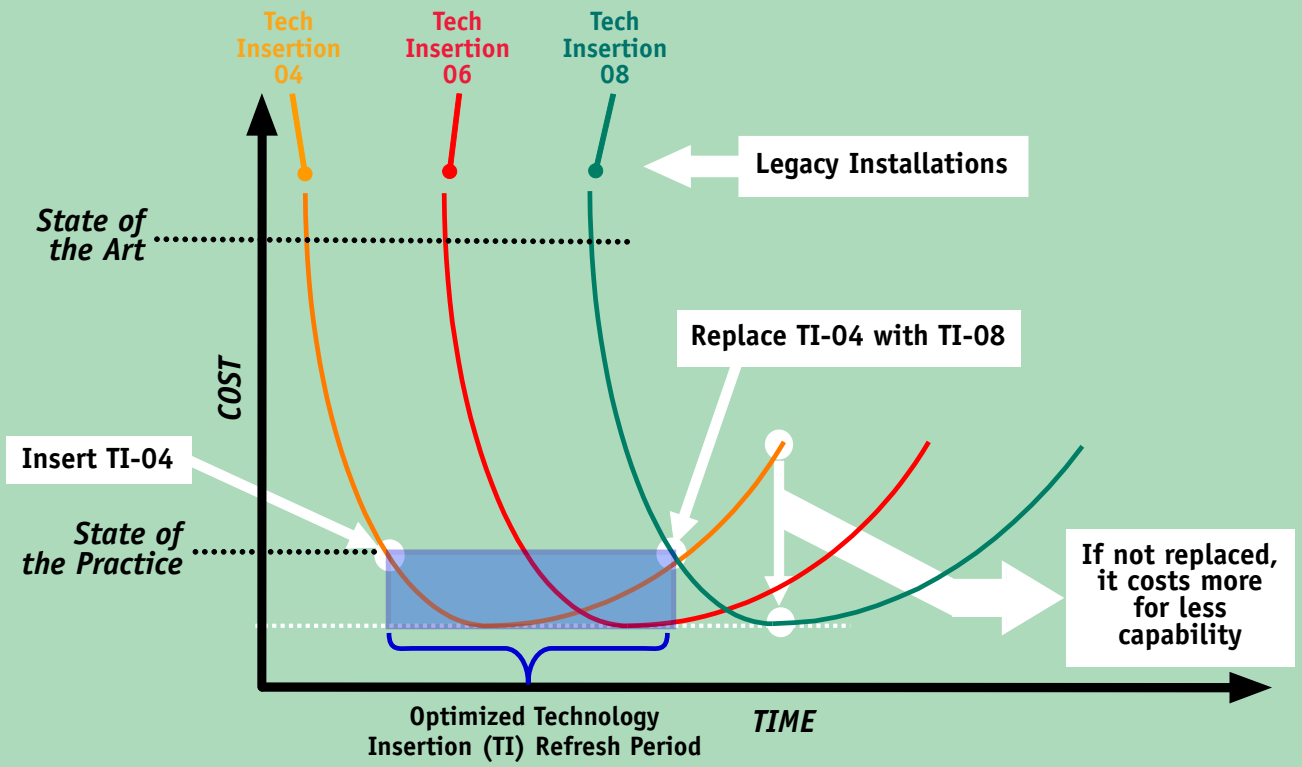
The Submarine Tactical Requirements Group (STRG) is charged with identifying and consolidating fleet tactical needs and prioritizing them for the software developers. It is led by the Submarine Development Group-TWELVE (DEVRON-12) Commodore, and its recommended requirements are endorsed by Commander Submarine Force, U.S. Pacific Fleet (SUBPAC) and Commander Submarine Force (SUBFOR) in an annual letter to the Director, Submarine Warfare (OPNAV N87). OPNAV N87, the resources and requirements sponsor, then provides those requirements to the acquisition community in a specific letter. The capability it demands needs to be analyzed using end-to-end methodology, rather than just going after the "issue du jour." The technical community then begins to develop it, and tell us how to attain the capability.

Developing New Capability

Armed with the STRG recommendations and the OPNAV N87 requirements letter, Naval Sea Systems Command (NAVSEA) engineers look at the requirements and solicit proposals from commercial, private contractor, university laboratories, and Navy laboratory software developers to develop solutions. They also look at the processors to be released in the near future that will become available on which to run the software. Two keys to this "open business model" process are peer-review of the algorithm and system level performance and rigorous testing using recorded real-world data culminating in integrated laboratory and sea testing with fleet operators. After each stage of development, software that is developed goes in front of a peer-review panel made up of experts from Navy laboratories, developing contractors, university laboratories and others, which assess whether it meets the requirements (using operational capability-based performance metrics approved by OPNAV N87), will be able to operate on the projected processors, and is reliable. If an application is not deemed by this peer review group to be "ready for prime time," it is sent back to the developer for additional work or for potential deferral to the next software build.

Introducing New Capability

Just as the Program Executive Officer Integrated Warfare Systems (PEO IWS) is responsible for developing the new capability, the sonar and tactical control program offices under the Program Executive Officer for Submarines, the Submarine Acoustics Program (PMS 401), and the Submarine Combat Systems Program (PMS 425), respectively, must make the new software ready for production



The ARCI business model maintains an optimized Technology Insertion (TI) refresh period to provide a cost-effective method to increase processing capabilility through the APB processes. Each new TI cycle (18–24 months) typically has double the capability due to Moore's Law.

and deliver it. Software builds are called advance processing builds (APBs) and hardware is delivered in technology insertions (TIs). Designing and producing TIs is also the responsibility of the program offices. Performance is delivered in the software, and operated on more capable hardware. TIs introduce new hardware as a hedge against obsolescence and to provide additional processing capability, and they incorporate new sensors. They are delivered every even year along with an APB based on the current capability. APBs containing capability improvements are now delivered every odd year. In response to fleet concerns about the burden of tactics, training, and procedural changes associated with the rapid rate of change, we have deliberately slowed down the process so that we are only doing capability-based APBs in the odd years. Even year APBs only support the new TI hardware, and should be transparent to the operators. The delivery model is each submarine will receive a TI with the preceding year's APB approximately every four years, and a new APB before each deployment. After a ship has received a new APB, there will be no more APB/TI upgrades until after the deployment.

Performance Feedback

During development, senior fleet operators participate in testing and provide input on the new software. Additionally, from the beginning, the hardware has embedded data recording capability. This provides the opportunity to see exactly how the system is operating. This recorded data is then used to test subsequent APBs. Another key use is to ensure the current APB builds are not missing any contacts of interest. Raw data from submarine operational missions are analyzed at both the Office of Naval Intelligence (ONI) and Johns Hopkins University's Applied Physics Laboratory (JHU/APL). Armed with hindsight and perfect cueing, and without the pressures of real time operations, acoustic analysts from the development community at large scrub the data, look for the root cause of any missed detection, and propose new processing and display techniques.

"So What?": The Proof is in the Pudding!

This process was developed to allow the U.S. Navy to introduce new capability, while faced with drastically declining budgets. Since it started, there have been nine APBs delivered and that goal has been met. Has performance been improved? Yes! The success of APB has been proven with a towed array Purpose Built Block (PBB). I believe that any submariner would look at the data and be convinced of the utility of our program—and want to get the newest APB for his sub!

Challenges: The Five Hurdles of the Evolutionary Process

The ARCI-APB Open Business/Architecture Model is an evolutionary process which has improved since its inception in 1997. We have five major challenges and have addressed the first three and are working on future challenges. The first hurdle was to separate the hardware and the software, through the use of transportable middleware. The second was to formalize the APB process, keeping it open to third party innovators, ensuring fleet requirements are met and providing a stable funding stream. The third was to avoid obsolescence in hardware with the TI process. With Moore's Law and the submarine deployment and availability cycle as guides, we established new hardware baselines every two years

with a goal of hardware replacement on each SSN every four years, i.e. the 2/4 TI Process. In ARCI's evolution, two more hurdles have been identified.

The fourth hurdle stems from the fact that the ARCI concept was built on the premise of "design once, use many times." The integration process was first designed for two very similar classes, the *Los Angeles*-class and modified *Los Angeles*-class. However, when the SSGN, *Seawolf*, and *Virginia*-class were rolled into APB/TI process, it caused a perturbation to the system, requiring much more engineering development time to match the integrations to the particular class. The solution is straight forward, but will require the integration process to mature. The addition of the combat control system to the ARCI/APB model also caused a perturbation, similarly requiring a fairly straight forward solution. Rather than just considering which hardware/software versions are out in the fleet, we will be establishing a "Fleet Capability Metric" as well, that looks at training, maintenance, and logistic support impact on operational regions and squadrons within a region. This N87/CSF assessment would then identify which hulls should be targeted for the next TI and APBs with the objective of improving fleet end-to-end capability. Merely slowing down the APB/TI process did not address current fleet concerns.

The fifth hurdle is the new and real APB capability must be linked to an Operational Capability Roadmap developed to deliver tactically relevant operational capability. Of all the issues, this requires the most discipline, but if addressed will bear the most fruit. This is where the STRG provides the most impact.

Can you have too much capability?

There is no question that more capability is better, but in 2004–05 it became apparent that the "dB per dollar" curve was approaching its asymptote for current sensors, the TB-16/23/29 and current spheres. At the same time, the increased success in detecting contacts, the broad availability of processing displays, and the great flexibility you now have in the system became a double-edged sword in operating the system. The BQQ-10 can turn any sonarman into a "Jonesy," but only if he's looking at the right display and can interpret the quiet diesel amongst the noisy merchants. So, emphasis and investment turned to building tools to help the operator get his "eyes on the target" across the expanding number of sensors, the improved processing, and the interfering surface contacts. The initial payoff arrives with APB-06, which has the initial introduction of Single Faceplate (SFP) Search, and consolidates all of the processing for a towed array sensor onto a single display surface, cueing from bell ringers, and prioritization algorithms such as the harmonic set tracker which allows drill down to the full resolution ARCI displays for final classification.

The immediate future APB deliveries

For quiet SSK search, the "eyes on target"/Single Faceplate approach from APB-06 is being extended to all sonars beginning with APB-07. Also in APB-07, we are integrating AIS, radar/PATRIOT, periscope, HF active, and sphere PBB contacts onto a command display with capabilities modeled after modern commercial charting/navigation systems, designed for situational awareness and collision avoidance in high surface traffic. In addition, we are eliminating some redundant display surfaces and providing tools for fire control technicians to see previously unavailable sonar solution data such as speed, range rate, and sphere D/E.

Our goals for APB-09 emphasize improving the tools for detecting the quiet SSK (change detectors, prioritization, removal of surface clutter, and reduction in contact multiplication), incorporating WAA ranging as part of maintaining tactical control of the SSK while managing dense surface traffic, developing off-board cueing integration, and incorporating the HF Nav/RLGN systems for improved MCM.

DEVRON-12 is scrubbing the BQQ-10 Operating Guidelines in an effort to provide more focused direction on how to employ the system in various scenarios and against differing contacts. And, for the first time in the history of the APB process, DEVRON-12 recently delivered the new version of the sonar employment manual to the ship before they sailed with their new sonar/combat system (USS *Asheville* (SSN-758) with APB-06).

Every electronic system can lend itself to the open architecture model, but the particular timing of the TIs needs to be carefully selected. We have already applied it to the BYG-1 Combat Control System, and there are seam issues that have arisen with each new APB that needed to be solved with some overarching integration at the overall systems level. We are bringing Integrated Submarine Imaging System (ISIS) and the BLQ-10 system into the model. However, one size does not fit all, other systems may not be optimized with a 2/4 model. For example, TIs of torpedoes and missile systems may be better tied to their maintenance due dates.

Conclusion

ARCI has been a success story at the Department of Defense level for delivering real capability to the war fighters in record time. It is not without its critics, especially those wedded to the classic defense procurement model. However, we could not afford to have done otherwise, either fiscally or operationally. Congress has recognized this: Senate Armed Service Committee Report 110-77 notes that "the Navy's success in building a future force of 313 ships, and with that, the Navy's ability to meet its long-range war fighting requirements, is directly linked to its success in implementing open architecture."

You at the waterfront have an input into the ARCI development process, and your voice is heard. Feed your inputs to your squadron, who will relay it to CSDS-12 or your TYCOM N7 and the Submarine Tactical Requirements Group. We are keenly interested in your input!

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