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"Collective C2 in Multinational Civil-Military Operations"

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Command and Control Rapid Prototyping Continuum (C2RPC)
The Framework for Achieving a New C2 Strategy

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Name of Author

Mr. Patrick Garcia
PMW 150
Space and Naval Warfare Systems Command
4301 Pacific Highway
San Diego, CA 92110-3127
(619) 307-9167

Patrick.garcia@navy.mil

Point of Contact
Mr. Ron Lambrecht

Deputy for Program Development
Space and Naval Warfare Systems Command Pacific
Command and Intelligence Division, Code 53210
53560 Hull Street
San Diego, CA 92152-5001
ronald.lambrecht@navy.mil

ABSTRACT

The U.S. Navy is undergoing a major Command and Control (C2) transformation to meet changes in its operational commitments and to ensure that necessary operational information (I2) is delivered to the "right person, at the right time, and in the right way." Almost a decade after the terrorist attacks on 9-11, Navy missions have expanded to include such unconventional warfare areas as counterterrorism, counterinsurgency, information operations, security cooperation, humanitarian relief, and *civil-military operations*. To meet these additional missions, the Navy increasingly needs to interoperate with other U.S. military services, U.S. governmental agencies, and a diverse list of international partners. In this new environment, Information and Intelligence (I2) have become core war-fighting enablers.

The Command and Control Rapid Prototyping Continuum (C2RPC) is a new initiative designed to produce enhanced operational concepts and capabilities and establishes a technology readiness venue for piloting new C2 capability increments at selected operational commands. C2RPC is a jointly-funded, cooperative effort spearheaded by the Office of Naval Research (ONR) and Program Executive Office for Command, Control, Communications, Computers, and Intelligence (PEO C4I), in cooperation with Commander, U.S. Pacific Fleet (COMPACFLT).

COMPACFLT proposed that ONR bring new technologies and ideas that advance the "Art of C2", to COMPACFLT for evaluation, validation, and refinement. COMPACFLT offered to provide access to the Command's resources and staff to validate the C2 technologies and to ensure that operational concepts were tested with realistic data, in an operational context. PEOC4I would ensure that the technology being developed would meet future operational requirements and assist with the transition of the new technology to a pre-selected C2 program of record (POR). The result is that C2RPC is the first, from the ground up, services architecture application designed to run on a shore based "cloud" infrastructure or from a new Consolidated Afloat Networks and Enterprise Services (CANES) infrastructure. This provides the opportunity for C2 and ISR to operate with an autonomous afloat capability when needed, with an ashore high performance computer and network infrastructure augmentation when available.

This paper is comprised of two related sections. The first section presents the new C2 strategy and describes the capability-related C2 prototype components being developed using an innovative experimentation methodology undertaken within the Navy Research and Development (R&D) environment, and at COMPACFLT, to rapidly mature new capabilities. The second section describes the Rapid Integration and Test Environment (RITE) employed to ensure that new technologies are successfully transitioned to future C2 programs of record (POR) in a near-continuous availability to meet the need for rapid technology change.

INTRODUCTION

The U.S. Navy is undergoing a major IT transformation to meet changes in its operational commitments and to ensure that necessary operational and intelligence information is delivered to the "right person, at the right time, and in the right way." Naval missions have expanded to include historically non-traditional mission areas such as counterterrorism, counterinsurgency, civil-military operations, information operations, security cooperation, and humanitarian relief.

The Program Management Warfare Office for Command and Control (PMW 150) is embarking on a new strategic initiative focused on dramatically changing the functional capabilities of the Navy's Maritime C2 systems, while fundamentally changing its software development and delivery processes (e.g. an "IT box"). PMW 150 is using C2RPC to deliver the strategic initiative. This new C2 strategy is codified in the Naval Warfare Publication 3-32 on "Maritime Operations at the Operational Level of War (OLW)", reference (a) and the Navy Planning, Naval Warfare Publication (NWP) 5-01, reference (b). An overview of the OLW is provided below as context for the initial C2RPC prototype development.

NAVY COMMAND AND CONTROL STRATEGY

The goal of C2 is to maintain alignment and provide status on the progress of the command plan. Current Navy C2 systems simply provide "Who and Where" information to battle commanders situational awareness. In order to meet changing mission areas and to be interoperable with other operational organizations, C2 systems need to fulfill OLW requirements and provide timely ***What, When, Why*** and ***How*** information, in addition to ***Who*** and ***Where***. Warfare requires more decentralized decision-making but an increased need to centralize situational awareness.

Mission management is the method for achieving and exercising C2 functions at the OLW and below, and can be defined as:

- Planning, executing [directing, monitoring] and assessing achievement of the intended purpose of a mission; and

- Managing multiple missions while continuing to prioritize available resources, targets, and objectives to mass activities in time, space, and purpose at the decisive times and places.

In concert with NWP 3-32, PMW 150's mission is to emphasize and build the means for naval OLW Commanders and subordinate Commanders to effectively deploy personnel and equipment through the use of a set of requisite tools that enable the Navy command structure to plan, execute, monitor, and assess its diverse mission requirements. The scope of this objective covers not only the primary elements of PMW 150's product line (C2 Planning & Decision Making, Situational Awareness, and Combat Support) but also includes the intersection with capabilities provided across PEO C4I including: Intelligence, Surveillance, and Reconnaissance (ISR), as well as select computing and Enterprise services of Joint C2 programs.

Command and Control Rapid Prototyping Continuum (C2RPC) Implementation

C2RPC couples emerging science and technology (S&T) developments, advanced prototypes, and experimentation processes to explore Maritime Operations Center (MOC) Operational Level of War (OLW) needs at COMPACFLT and Numbered Fleet Commands. C2RPC is serving as an incubator for technology and "proofs of concept" to produce capabilities that can be transitioned into future Command and Control (C2) PORs.

C2RPC addresses S&T developments in support of net-centric capabilities that enable the Fleet to be more adaptive to changing mission needs and more agile in response to changing adversary tactics and threats. C2RPC is establishing baseline technologies that demonstrate the feasibility of such dynamic C2. The core S&T challenge being addressed is how to implement a distributed enterprise based on: (i) a services oriented architecture, (ii) shared plans/tasks data model, and (iii) distributed data services to provide effective support to C2 operations? Such an enterprise must permit C2 planners and decision makers across OLW and lower echelons to conduct and maintain operations during disconnected, interrupted, and limited (DIL) communications conditions, and must support the Navy's Maritime C2 paradigm of centralized direction and de-centralized (across multiple echelons) execution.

Development of C2RPC follows the "build a little – test a little" philosophy using a series of incremental capability "drops." The process allows for:

- Closer alignment of S&T investment to POR requirements increasing the probability of successful transition;
- Rapid and continual technology insertion (e.g. continuous integration);
- Continuous prototype development and experimentation cycle;
- Development of individual smaller development components/increments therefore reducing overall C2 program risk.

Four Functional Pillars

PMW 150's C2 developmental roadmap is built around the four functional pillars of C2 Mission Management as shown in Figure 1. C2RPC's technical architecture has been designed to capture each pillar's functional components. The four pillars are Planning, Execution, and Assessment; Intelligence and Collection Management; Intelligence, Surveillance and Reconnaissance (ISR) Data Fusion; and Force, Unit, Network Capabilities and Readiness. There is an "invisible" pillar in C2RPC's approach. This "invisible" pillar is User Facing Services (UFS) and it is depicted in the center of Figure 1. This is where the majority of the C2RPC User interactions are performed.

It is important to note that PMW 150 is only responsible for providing the functionality associated with the Planning, Execution, and Assessment Pillar and the User Facing Services. Therefore PMW 150 must rely on external organizations for the services and data base repositories that are resident within their respective pillars. C2RPC has established links to the other pillars enabling operators' access to respective services and data at a central location, using a tailorable web-based interface. Vice Admiral Dorsett's (Deputy Chief of Naval Operations for Information Dominance (N2/N6)) *Vision for U.S. Navy Information Dominance*, reference (c), establishes a net-centric operational approach where *"ALL data and information needs to be universally discoverable, transparent and accessible"*. This approach is critical to ensuring that the Navy has the ability to share information seamlessly with other organizations, including international partners. C2RPC relies upon the full implementation of this net-centric approach for open access to the other pillars.

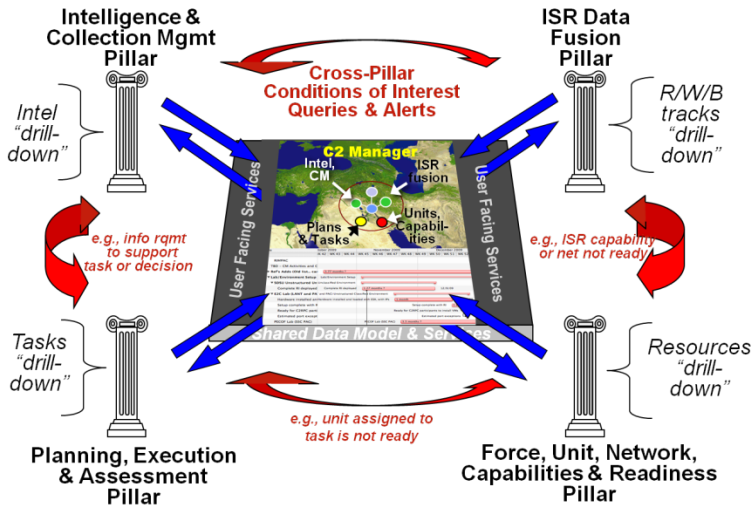

Figure 1. Functional Pillars of Mission Management

The Capabilities that are developed by C2RPC are in support of these four pillars plus the "invisible" UFS Pillar. The first COMPACFLT installation (Drop 1) in early 2010 was built around the short list of Planning, Execution, and Assessment Pillar and UFS Pillar capabilities shown in Figure 2 and Figure 3. In simplified terms, these Pillars represent any information about Plans/tasks, priority missions, decision points, and readiness. This C2 operational context provides the background for this paper and the incremental development methods used for rapid development and demonstration, and the additive nature of each of the developed components. To assist the reader, key C2-related acronyms are shown in Table 1 at the end of this paper.

The Capabilities & Readiness pillar provides related information on Blue Forces, their readiness, and conditions of interest related to the plans in progress or underway. The pillar leverages heuristic-based reasoning to determine the impact of aggregated capabilities. The Plan readiness information

is displayed using an Ozone Widget Framework (OWF) composed "Plans/Execution Dashboard." In the context of situation awareness (SA) and Intelligence, the configuration seeks to provide relationships between the Intelligence and Collection Management (CM) Pillar and the ISR Data Fusion Pillar. Those relationships result in the capability to perform heuristic reasoning on intelligence information.

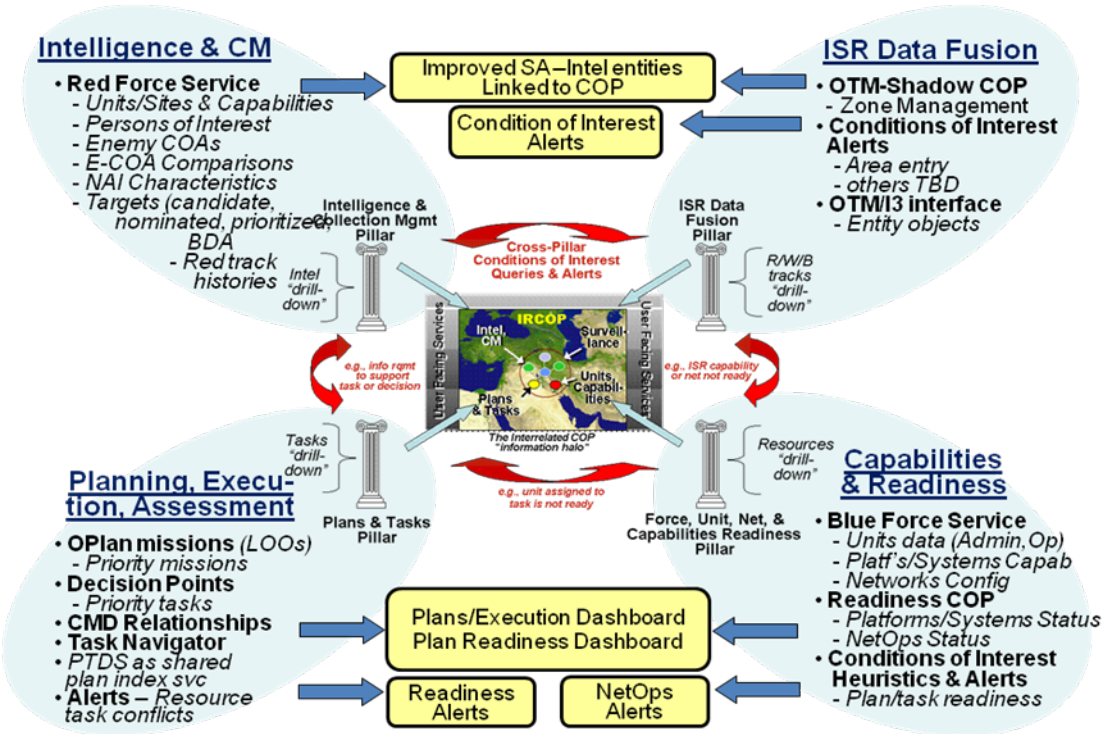

Figure 2. COMPACFLT Drop 1

C2RPC Incremental Functionality

PMW 150 has adopted a *component portfolio approach* to C2 system software acquisition. Incremental development is a key element of PMW 150's system software component strategy and requires close collaboration among developers, evaluators, and end users (Warfighters). Each component of capability provides a militarily useful and supportable operational capability. These components are iterated over time and delivered when mature. The system's architecture is designed to support these incremental deliveries and enables additional components to be added periodically to the core Navy C2 architecture.

Initial Operational Capability

The focus of the initial C2RPC prototype was to provide C2 planning functions to support high-priority missions and plans within the COMPACFLT area of responsibility (AOR). Figure 3 depicts this initial capabilities release set that is planned for transition to the Maritime Tactical Command and Control (MTC2) POR in December 2011.

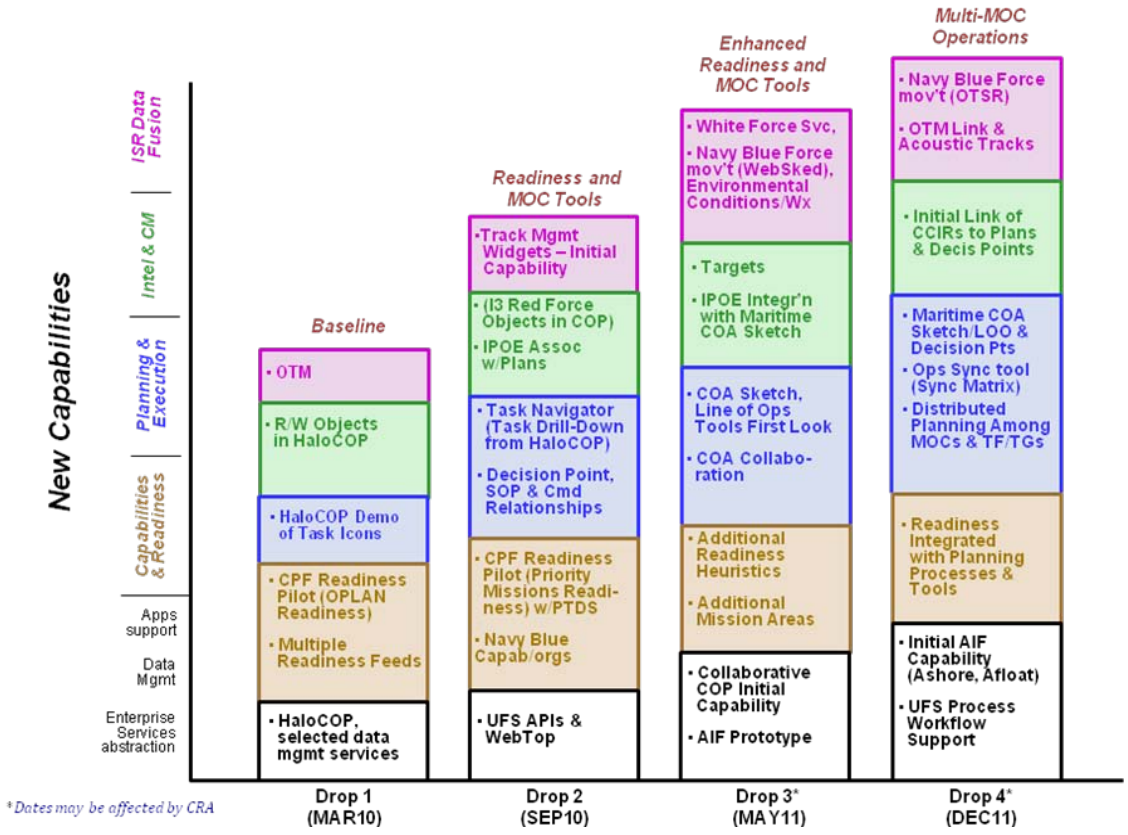

Figure 3. MTC2 Release One

The figure includes a core, or "central capability" consisting of Applications Support, Data Management and Enterprise Services abstraction, that components will be integrated to and will interact with. These core capabilities are shown in the bottom set of boxes in Figure 3. The additional capabilities align with the four functional pillars discussed previously and are shown in the color-coded boxes. This phased delivery is designed to add increased overall C2 functionality over time and to gather user-feedback to help drive future capability development. The components are additive and the proven, operator-validated capabilities from the collective set will, in total, represent the C2 capabilities as candidates for the MTC2 acquisition program. In all, there are four drops planned before the "capability cut-off", planned for December. At that time the aggregate release set of capabilities will undergo additional S&T funded development to achieve the maturity level required for a successful transition. Then during transition, the release configuration will receive further hardening and developmental testing (i.e. unit, regression, etc) under R&D funding before entering a formal Development Test and Operational Test (DT/OT) program. It is important to note that individual components, although based upon an initial set of requested capabilities from COMPACFLT, are dynamic. The final component functionality is a product of the baseline Warfighter capabilities and approved dynamic modifications resulting from the prototyping process and direct feedback from operational users. Therefore, the final capabilities list for transition may differ from Figure 3. The prototyping process will be described in a later section.

Prototyping Continuum

Under the C2RPC initiative, the development and maturing of new technology is ongoing and will continue using additional S&T funding after the capability cut-off for Release One. Figure 4 represents a listing of potential C2RPC capabilities proposed for future prototype development. In the

future drops, the objective is to support operational units expanding from the ashore MOCs to the afloat Navy (e.g. task force (TF) and task group (TG) level ships). The final set selected for MTC2 Release Two will be derived from the continually evolving set of mission oriented requirements and maturing prototypes.

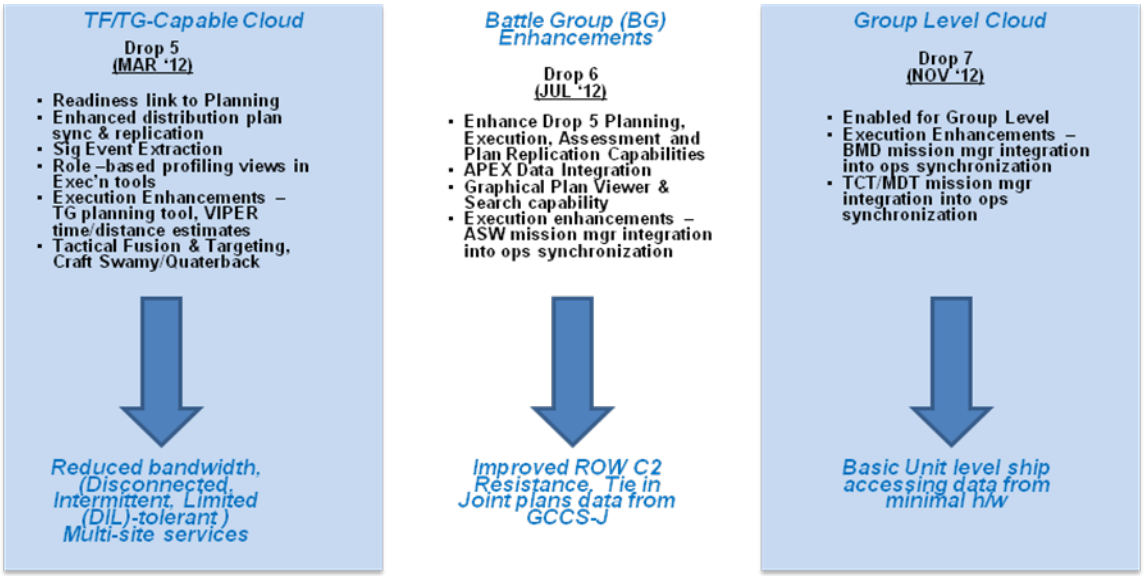

Figure 4. Proposed Navy Planning, Execution and Assessment Services

C2RPC PROTOTYPE DEVELOPMENT AND EXPERIMENTATION METHODOLOGY

The C2RPC methodology is described in this section. The C2RPC prototype development and experimentation methodology was designed to overcome the many challenges associated with the transition of S&T experimentation to acquisition programs. These shortfalls have been well documented and highlight a historically poor record of achievement within the Navy. A representative study is that conducted by the National Academy of Sciences on the Role of Experimentation in Building Future Naval Forces, reference (d). In this study, the committee focused on (1) doctrine and tactics, techniques, and procedures and (2) fielded capabilities, including acquisition programs. Observations were summarized as "transitions are very difficult, and processes for achieving them are seen as poor", "owing in part to budget pressures and to a lack of processes for new capabilities to compete with programs of record." The study further states that "mechanisms and processes for transitioning the results of experimentation directly to the fleet or to an acquisition program of record are inadequate and they curtail the effectiveness of experimentation in building future naval forces."

National Defense Authorization Act of 2010 Alignment

In 2010, Congress passed, and the President signed, the National Defense Authorization Act, becoming Public Law 111-84. This law defined a new acquisition process for IT systems. Conventional DoD acquisition processes were too long and cumbersome to fit the needs of IT systems that require near continuous change. This process for IT-intensive systems is to be based upon the recommendations provided in the March 2009 Report of the Defense Science Board (DSB) Task Force on Department of Defense Policies and Procedures for the Acquisition of Information Technology (hereafter referred to as DSB-IT), reference (e). This report echoes the findings of many other studies in listing the many issues surrounding the DoD acquisition life cycle and specifically identified the need for a new acquisition process. The Defense Science Board (DSB) came to the

conclusion that “there is a need for a unique acquisition process for information technology” (which includes Command and Control systems). “The process must accommodate the rapid evolution of information technologies; their increasingly critical position within DoD warfare systems, warfare support systems; and business systems; and the ever evolving and often urgent IT needs of the war fighters.” The proposed new acquisition process is shown in Figure 5.

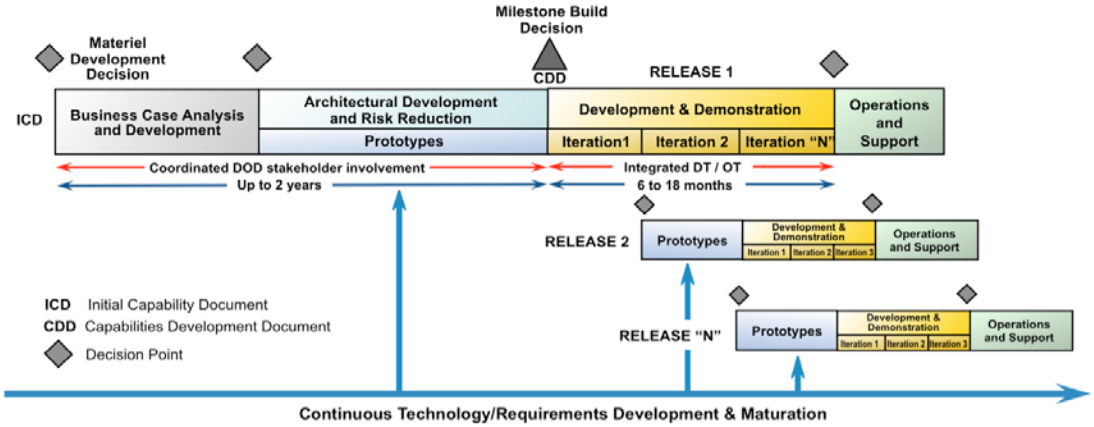

Figure 5. DSB-IT Recommended Acquisition Process for Information Technology

The new process is geared to delivering meaningful increments of capability in approximately 18 months or less, and leverages the advantages of modern IT practices. Multiple, rapidly executed releases of capability allow requirements to be prioritized based on need and technical readiness, allow early operational release of capability, and offer the ability to adapt and accommodate changes driven by field experience. The new process will include:

- Early and continual involvement of the user;
- Multiple, rapidly executed increments or releases of capability;
- Early, successive prototyping to support an evolutionary approach; and
- A modular, open-systems approach

The C2RPC methodology has all of the attributes and is described below.

C2RPC Implementation Roadmap

A notional C2RPC Implementation Roadmap with its various programmatic stages is shown in Figure 6. The graphic shows the relationships between the stages including the planned transition of new C2RPC technologies to the MTC2 POR after completing “Early” and “Late” Stage prototype development cycles. The Roadmap aligns with both traditional DoD Acquisition Life Cycle milestones required in DoD Instruction 5000.02, reference (f), and the processes recommended in the DSB-IT report.

C2RPC Capabilities Definition

In April, 2011 the Vice Chairman of the Joint Chiefs of Staff (JCS) announced at the 27th National Space Symposium that the DoD was scrapping the Joint Capabilities Integration and Development System (JCIDS) process because it was too slow and intends to rewrite the process to allow acquisitions to be made more quickly and at less cost. JCIDS is the formal DoD procedure that defines acquisition requirements and evaluation criteria for all defense programs and was not responsive to the needs of IT-intensive acquisition programs that require almost continuous technology upgrades.

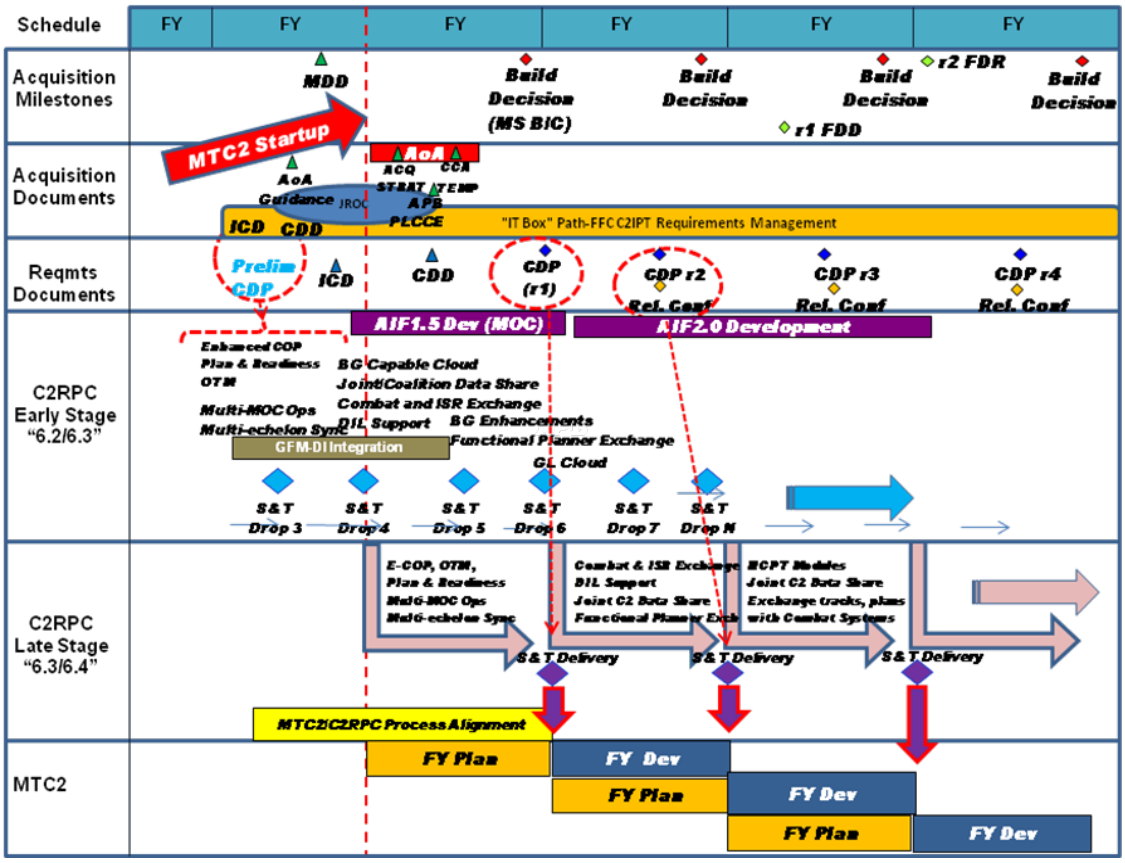

Figure 6. Notional C2RPC Implementation Roadmap

C2RPC was already employing a modified approach for the identification and assessment of C2 capability objectives which linked members of the S&T community, Maritime C2 Program Office, software developers and end-users together in real-time to establish prioritized C2 objectives. This C2 independent product team (C2IPT) consists of SMEs from ONR, working along with PMW 150 and COMPACFLT. The C2IPT meets in periodic workshops at COMPACFLT Headquarters to identify and prioritize operationally relevant C2 objectives. These 2-3 day forums are held every 3-6 months and normally coincide with Increment drops, so that the users have the opportunity to express their provide inputs to the software developers directly. The workshops are chaired by ONR but include representatives from all stakeholders.

The initial workshop was held June 24 to 26, 2008 where the first set of objectives was established, in response to COMPACFLT priorities. These included:

- C2 of Intelligence Operations
- C2 of Information Operations
- C2 of Network Operations
- C2 of Computer Network Protection
- Common Operational Picture (COP) Improvement

These agreed upon objectives were used to derive a set of “capability gaps” that were prioritized for the initial C2RPC C2 Increment. The capabilities have since evolved and new capabilities have been added as a result of experimentation results and early exposure to the operator who provided recommended modifications.

To support the requirements definition, the Roadmap, shown in Figure 6, lists several Requirements related documents that are important to establishment of an upfront Technology Development Strategy and are necessary to achieve acquisition Milestones and Build Decisions for a POR like MTC2. Even with the modified approach to establishing the initial capability objectives, the listed documents are needed to guide the acquisition activities and align them with POR requirements. These documents include:

- *Initial Capabilities Document (ICD).* As described in the JCIDS manual, reference (g), the ICD documents the *"need for a materiel approach, or an approach that is a combination of materiel and non-materiel, to satisfy specific capability gap(s)."* The ICD defines the gap in terms of functional area; relevant range of military operations; desired effects; time and Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities (DOTMLPF); and policy implications and constraints. The outcome of an ICD could result in one or more DOTMLPF Change Recommendations (DCRs) or Capability Development Documents (CDD).
- *Capabilities Development Document (CDD).* The Technology Development Strategy includes a description of how the materiel solution is sub-divided into Capability Increments, Releases, and Iterations (Drops). The CDD builds on the ICD and provides detailed operational performance parameters necessary to complete the proposed systems design. These requirements are prioritized and parsed into groupings to establish baselines for initial and subsequent releases. The objective of C2RPC is to develop and deploy the highest-priority mission capability first and reduce the technical risk to the POR. Therefore, capabilities defined in the CDD are prioritized and, where appropriate, grouped into a limited number of time-phased releases that correspond to mission priorities. An agile approach allows for the reprioritization of requirements for each iteration and release (and for the increment as a whole) based on subsets of functionality to prevent delay and facilitate rapid development and deployment.
- *Capabilities Development Plan (CDP) – Release 1 to Release (n).* The purpose of the Capability Development Plan (CDP) is to serve as the agreement between the Program Sponsor, the Program/Project Manager (PM), and the Acquisition Decision Authority (ADA) on the activities, cost, schedule, and performance boundaries of the work to be performed for the POR and the artifacts from C2RPC are used to substantiate the reduced risk. The CDP presents topics and issues, specific to the acquisition, that allow the PM to clearly define the "body of work" that must be accomplished during each planned software release. The process in Figure 6 indicates that CDPs occur on a 6-12 month cycle and coincide with Build Decisions and S&T increment drops. Note that CDR release (r) 1 coincides with the capability cut-off date and the initiation of transition to the MTC2 POR.

C2RPC Governance

The pace of technology change and the increasing levels of complexity in C2 systems necessitate a more agile governance model for the acquisition of IT-intensive systems. One of C2RPC's goals was to enhance the project agility and responsiveness to technology change and user requirements. C2RPC wanted to establish a process where the Combatant Command (Warfighter) had authority to reprioritize, add or delete non-key performance parameter requirements working along with the POR program sponsor and appropriate milestone decision authority. This new governance model allows the development programs to more rapidly evolve to support changing Fleet needs. C2RPC governance includes several different activities to ensure that Fleet inputs are addressed when making programmatic changes.

- *Periodic Workshops.* As stated previously, C2RPC conducts Periodic Workshops to develop and validate new C2 capability requirements and to gather operator feedback on recent capability installations. The Workshops are 2-3 day forums and are normally conducted

every 3-6 months coinciding with engineer drops. The workshops are chaired by ONR but include members of the C2 IPT. These workshops have been instrumental in establishing the operational objectives for the incremental development and related engineering drops. Feedback from each successive drop has been used by the development to further enhance the C2 capabilities being installed.

- *On-site Technical Representative*. Coinciding with C2RPC Drop 1, ONR assigned a C2RPC system engineer to work on-site at COMPACFLT. The C2RPC system engineer works with the operators, trains them on C2RPC, gathers additional user feedback and interests, and helps interpret the operators' new capability requests for C2RPC deliveries. This individual interacts with COMPACFLT's operational and technical personnel to document and report recommended component changes to the developer team. In some cases, software modifications have been done in near-real time and the operator was able to experience the rapid response to proposed system changes. This has helped to foster a strong working relationship between the developers and operators and has reinforced the operator's involvement in the development process. The operators are actively engaged in providing feedback and are committed to the success of the final set of C2 components. This feedback has resulted in multiple iterative improvements to upcoming drops, with minor updates occurring daily or weekly.

- *Software Change Requests.* In addition to the periodic workshop and on-site technical representation, C2RPC uses an online Software Bug Report and Change Request tool (the "JIRA" system) to submit change recommendations. A change request is a standard form for documenting what needs to be accomplished, but does not address how the change should be implemented. The JIRA "tickets" are used, in addition to the feedback received via the other methods, by the Engineering Review Board (ERB) to document longer range enhancements, re-prioritize, and to assign resources to the modifications or requested new capabilities.

- *Engineering Review Board.* The Engineering Review Board (ERB) is responsible for establishing the technical roadmap for C2RPC as well as setting the capability release cycle (Drops), prioritizing the capabilities and fixes, assigning technical resources within resources constraints handed down by Management for C2RPC. Additionally, it is responsible for ensuring the configuration control of the various software increment releases and ultimately determines the selection and timing of the components for migration from Early Stage – to-Late Stage – to –nominating technologies for Transition. Proposed changes to the C2RPC Drops gathered either through the workshops or the SCR process is reviewed by the ERB. This board is chaired by the C2RPC Chief Engineer (as designated by ONR and PMW 150) and includes representatives from each of the four functional Pillars (ISR, etc) described earlier. The ERB convenes weekly to review and adjudicate C2RPC technical and engineering topics. The ERB provides the C2RPC a level of project flexibility needed to meet the relatively short development cycle. It is necessary to have a Board with this responsibility and authority if the rapid prototyping and integration activities are to meet the 4-6-month release cycles envisioned as part of the IT-intensive systems acquisition process.

  The ERB is empowered to:

  - Establish capability requirements and prioritization
  - Approve proposed component changes submitted through SCR process
  - Modify prototype requirements to meet operator needs
  - Select the mature capabilities and propose them for transition

Continuous Prototype Development

C2RPC has separated prototype development into two distinct stages: Early Stage and Late Stage. These stages are related to overall technology maturity levels of the respective capability components and have separate S&T funding sources. The Early Stage, designated for Advanced Technology Development, is funded by 6.2 and 6.3 budgets, while the Late Stage, involving Demonstration and Validation experiments (along with approved prototype modifications and changes) conducted at COMPACFLT, is funded from 6.3 and 6.4 budgets. It is important to note that this separation of stages supports the continual progression of maturing capabilities that are available for graduation to the next level of development without unnecessary delay. For example, Early Stage capabilities that have reached an acceptable technology readiness level (TRL), as described in the Defense Acquisition Guide (DAG), reference (h), are moved to the Late Stage where they undergo relevant operational experimentation.

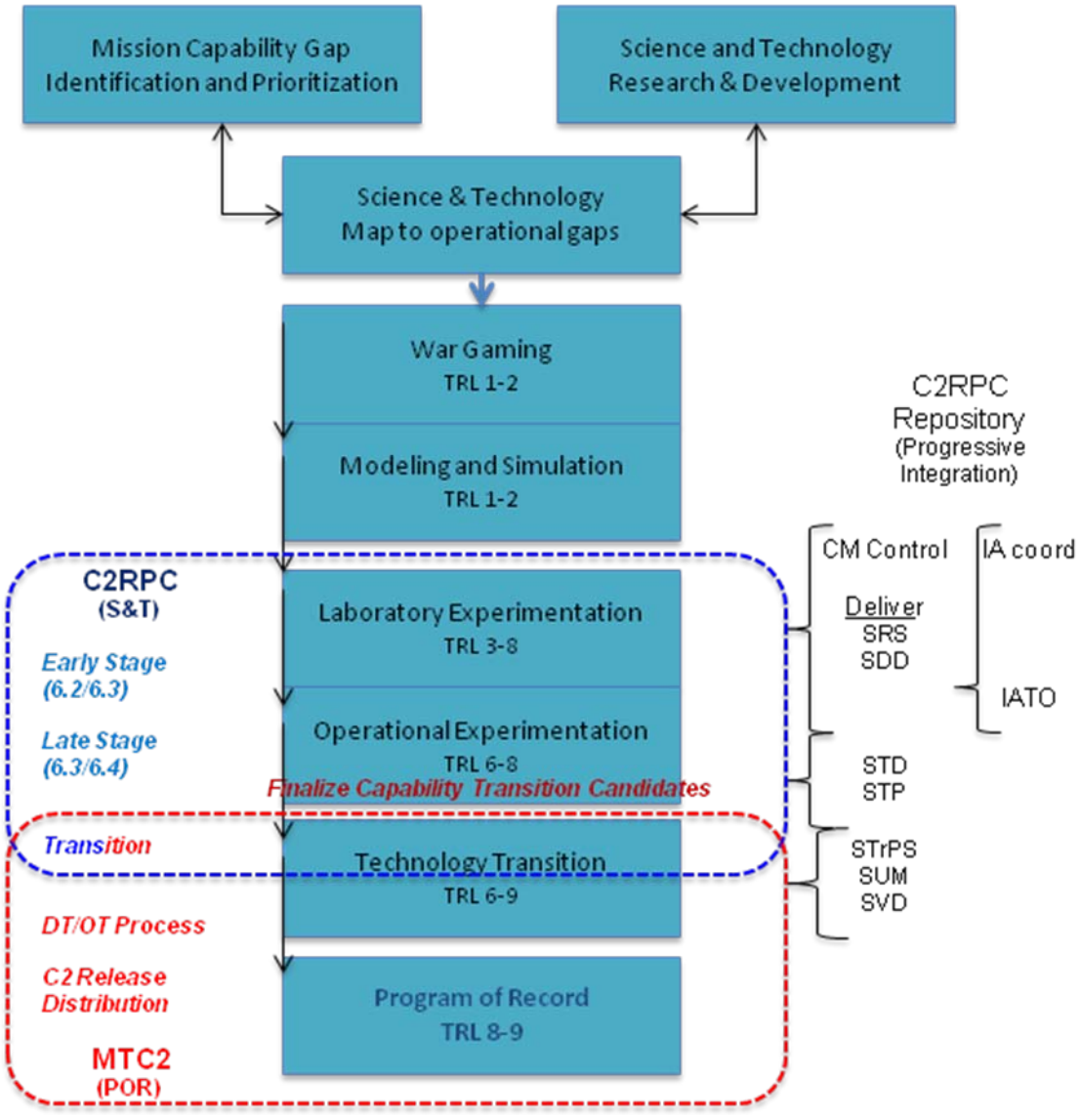

Figure 7. C2RPC and Technology Readiness Levels (TRLs)

Additionally, as Late Stage capabilities are evaluated at the requisite maturity level, they enter the transition phase, where they receive further capability enhancements and the software hardening necessary for final transition to the POR. Lastly, this separation of development stages allows the Early Stage to serve as the incubator of new technology with new prototype components being initiated as additional requirements are identified. The capability components need not adhere to pre-determined development cycles and independently move through the development process. This methodology allows the C2RPC to provide a "continuum" of new capability components that are being routinely evaluated for transition to the POR.

Figure 7 depicts the different TRLs and indicates the separation of C2RPC and POR responsibilities, including the overlapping transition of S&T to POR. The figure also introduces the "progressive" integration approach being employed by C2RPC to gradually introduce POR engineering processes to the various release components as they progress from Early-to-Late-to-Transition Stages. Early S&T stages (e.g. Applied Research and Advanced Technology Development) are often less structured and therefore the prototype, as part of the experimentation and maturing process, needs to incorporate POR best practices for such things as software configuration management and documentation. There is a desire to minimize the number of additional cost and schedule inhibitors and C2RPC employs knowledge management tools to streamline the accumulation of necessary project documentation.

Rapid Integration and Test Environment (RITE) for Continuous Integration

The iterative nature of incremental component software development and the migration to net-centric operations require a different set of software acquisition processes. PMW 150 has established the Rapid Integration and Test Environment (RITE) to facilitate needed C2 testing and integration process change. RITE is a modified life cycle model for Navy C2 software that places increased emphasis on early and frequent software testing, as well as necessary software engineering practices at the source code level. *RITE* provides an agile approach to software development, taking full advantage of technology advances and open source models to automate processes and shorten development cycles – thus increasing the maintainability of software baselines. RITE also clarifies software delivery requirements, adding engineering structure to final deliverables and reducing opportunity for misunderstanding between sponsors, end-users and developers.

From C2RPC, transition and integration of new, adapted, and adopted C2 system software capabilities and technologies will be synchronized into periodic C2 Releases (C2R), nominally on a four-to-six month cycle. This nominal release cycle time is subjected to business case analysis in determining the appropriate period. It will be constrained by the time it takes to certify a software baseline in all of its intended configurations and to train personnel to operate its new features. As the various incrementally developed capabilities achieve the requisite maturity level (TRL 6-7), they will individually be evaluated for integration into the POR.

The successful transition of increments developed under the C2RPC umbrella is critical to achieving rapid Navy C2 system enhancement. Therefore, close coordination between the Program Office and the individual prototype developers as the mature capabilities near transition is paramount. During the transition, the development program must begin adopting and implementing the software-development processes employed by the POR while it is effectively changing funding sources from S&T (6.3A, 6.3B) to POR acquisition (6.4-6.5). The RITE processes and infrastructure, as shown in Figure 8 will be used for the transition of C2RPC. Using the centralized repository, as the selected capability increments reach the requisite TRL for transition, they will enter the RITE testing and integration processes. These processes include completion of a pre-delivery qualification conducted by the vendor to ensure that the prototype is ready to be tested. Upon satisfactory completion of the acceptance checklist, the product will undergo daily source code analysis and other testing programs designed for the capability being hardened and evaluated.

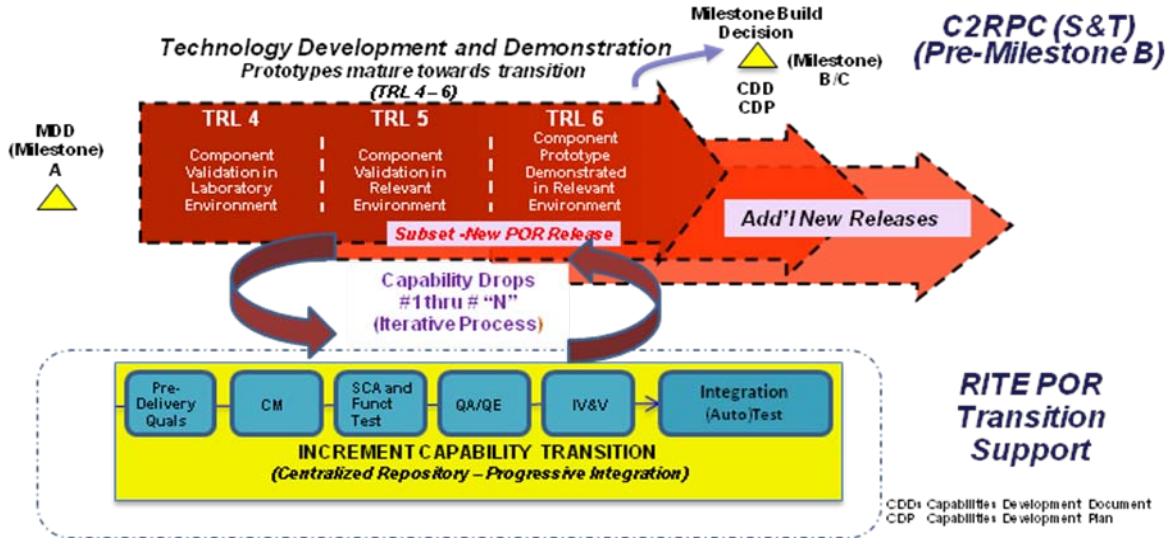

Figure 8. RITE Transition Processes for C2RPC Components

Hosted Centralized Repository

RITE hosts a software development and transition environment to facilitate continuous development and integration. The hosted environment is centered on an information repository (IR), where all stakeholders share information and have access to a common set of documentation and development tools. This hosted environment includes a segmented build environment for each developer to control its individual source code, but allows third party (public, with limited access) sharing of libraries and associated tools that are used across multiple developmental projects. The repository allows a broader stakeholder base to interact with the components as they progress through the various development and transition stages.

The services and support that are provided through the hosted environment include:

- Developer Version Control
- Communication / Tool Support
- Quality Control
- Automated Testing and Integration Environment

As shown in Figure 9, the Central Repository is actually a collection of three types of repositories. The cardinality of each repository type varies, but in the figure they are each represented as if they are single units. Each Repository can be accessed by the various stakeholders (developers, testers, and end-users) using the central configuration management system. The three Repositories include:

- *Application (Developer) Repositories.* The most numerous repository type is the developer repository. Each prototype development contractor has access to its own repository for developing source code. These modules can either be standalone applications, components of a parent application, or code libraries meant for use by other products. By combining these modules with shared code and external tools and for applying a build process to them, software configuration items (CI) can be produced for C2RPC use.

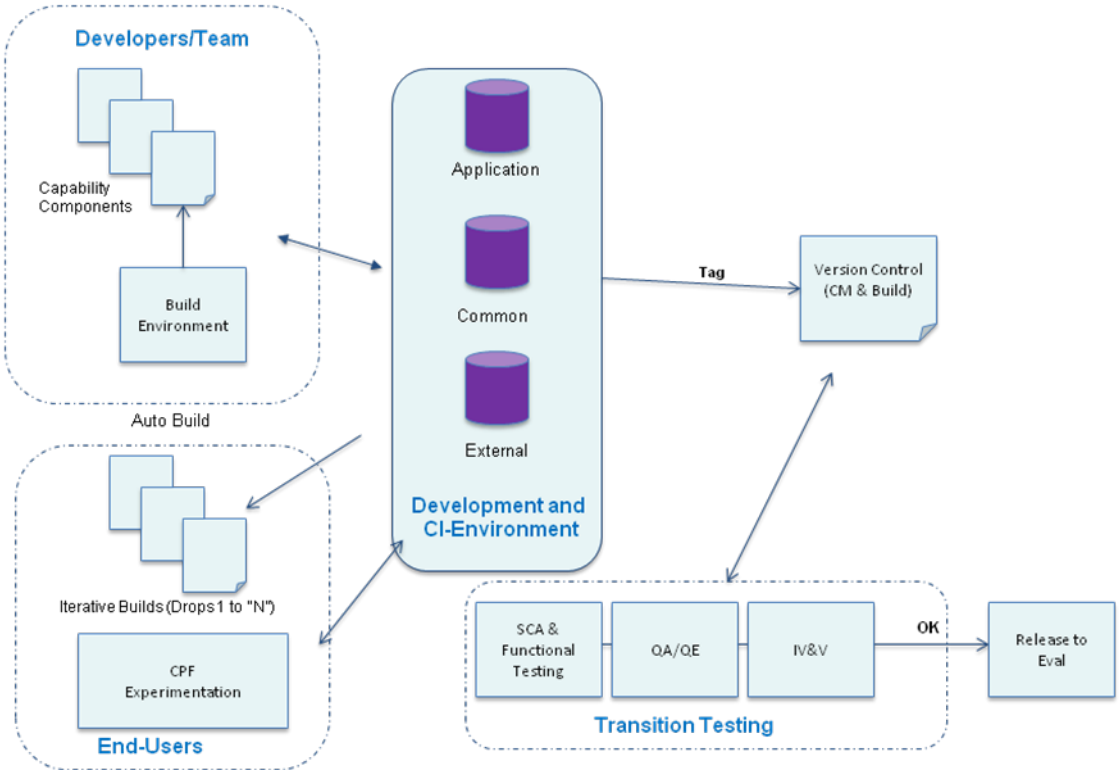

Figure 9. Repository Management, Prototype Development and Transition

- *External Repository.* The external repository is a public, read-only Subversion repository for use by all participating developers. Its purpose is to contain software CIs that meet the following criteria:

  - They are required for a developer to create a software product
  - They are publicly available and free to use (no proprietary tools are allowed)
  - They are not tied to a particular developer's project

  Items which would be found in this repository include:

  - Compilers and interpreters (JDK, gcc, Python, Perl, *et al*)
  - Build tools and frameworks (ant, Maven, ivy, *et al*)
  - Integrated Development Environments (IDEs) (Netbeans, Eclipse, *et al*)
  - External application programming interfaces (APIs) and libraries

  The external repository's primary role is to store all of the 3rd-party tools needed by developers to assemble and make ready their development environment. Because this repository is *read-only*, developers are not able to populate it themselves. In order to get the necessary tools, they must send a request to the Repository configuration management (CM) team, who works with the developers to place all needed tools into the repository. This is important as the CM team will be responsible for using the developer's build instructions to exactly replicate the software for testing and eventual release. Placing such tools in one location under version control thus serves several purposes:

  - It ensures that a project uses a well-defined set of 3rd-party tools;

- It also ensures that should the 3rd-party tools change, the documentation and repository will be updated to reflect the change;
- Placing these tools (which usually are much larger than the codebases they operate on) in one common location saves repository space and allows sharing;
- It encourages developers to make efforts to replicate a 'clean' build environment.

- *Common Component Repository.* The common component repository is a public, limited-access Subversion repository which contains libraries to be used across multiple developer projects. The typical example would be a repository containing common interfaces and base functionality to be used across a set of software products. The common repository, however, is populated by code written by the developers and not by external interfaces (thus differentiating it from the code in the external repository).

C2RPC Transition Process

A significant challenge facing the C2RPC effort is transitioning the technology prototype components to the MTC2 program of record. The transition involves the continued maturation, and hardening, of the final designated capability components within Release One while undergoing a change in program funding from S&T to POR. This "hand-off" is conducted in the proverbial "valley of death" for new development programs where the "initial funding" is often fully expended before funding needed for continuity of operation is received. There are numerous impediments to successful transitions including the lack of clear funding for "transition, the cultural differences between S&T and program acquisition communities which drive disparate goals and timelines, and the fact that Transition processes lack clear definition and visibility by either S&T or the Program Office. C2RPC has forged the partnership between ONR and PMW-150 to overcome these impediments, establishing shared expectations and addressing their respective budgets. It is critical during this transition phase that the S&T funded prototypes achieve the expected maturity level planned for by the MTC2 sponsor prior to entering the transition phase. Conversely, the Program Office needs to have established the necessary program plan, schedule, and funding needed to complete the software development, testing, integration and ultimate fielding. The program plan is generated based, in a large part, upon a specific set of assumptions and risks and the expected transition readiness of the C2RPC technology. If the C2RPC capabilities do not meet the minimum expected, the transition could fail leaving the MTC2 program in jeopardy.

C2RPC has a Technology Transition Plan (TTP) Level A with the MTC2 POR and a start date of 2013. The initial C2RPC drop was developed in approximately 18 months. Further "Drops" are planned at approximately four to six month intervals until FY 2012. The transition from the Late Stage development to the MTC2 POR for selected capability components is scheduled to begin in early 2012 and will be done in various steps. The transitional activities will be under the leadership of PMW 150 supported by SSC Pacific as part of its Navy C2 Software Support Activity (SSA) functions and will employ testing and integration processes established as part of the RITE initiative.

Configuration Management and Documentation

The documentation identified for completion as part of the C2RPC prototype transition will be developed collaboratively using a "Confluence" wiki. For the development of technical reports, Confluence combines online authoring capabilities and tools, Microsoft Office integration and the potential of using a plug-in catalog to help team members share information effectively. Additionally, although many individuals can contribute to the document development, the Program Office retains complete control over who can create, edit, and view and export documentation. During the Prototype development and transition stages, it is envisioned that different development teams, as well as end-users and testing teams will be asked to contribute to the respective document development. Using the Wiki will ensure that contributors are using the latest, up-to-date, version of each document for better document configuration control. The Wiki will also allow for periodic releases of the documents and seamless editing as the prototypes evolve as part of the transition

hardening development.

As the prototype continues to mature, required documentation is completed and filed on the Wiki for use by stakeholders in performance of their job requirements. The documents listed in Figure 7 are from MIL-STD 498 Standards, reference (i), whose purpose is to establish uniform requirements for software development and documentation. The standard and its Data Item Description (DIDs) are meant to be tailored for each type of software to which they are applied. Under the RITE process, SSC Pac works with the Program Office to tailor the specific standards that it wants to invoke for each specific contract. The POR will need to work closely with C2RPC in order to produce the following list of documents to make the technologies developed under C2RPC are transitioned successfully to the MTC2.

- *Software Requirements Specification (SRS).* Specifies the requirements for a Computer Software Configuration Item (CSCI) and the methods to be used to ensure that each requirement is met.
- *Software Design Description (SDD).* Describes the design of CSCI-wide design decisions, the CSCI architectural design, and the detailed design needed to implement the software.
- *Software Test Description (STD).* Describes test preparations, test cases, and test procedures to be used to perform qualification (transition) testing of a CSCI or software system or subsystem.
- *Software Test Plan (STP).* Describes plan for qualification testing of CSCI and software systems. Describes test environment to be used for testing, identifies tests to be performed, and provides schedule for test activities.
- *Software Transition Plan (STrP).* Identifies hardware, software, and other resources needed for life cycle support of deliverable software and describes developer's plans for transitioning deliverable items to the support agency (or the Acquirer).
- *Software Users Manual (SUM).* Explains how to install and use a CSCI, a group of related CSCI's, or a software system or subsystem.
- *Software Versions Description (SVD).* Identifies and describes a software version consisting of one or more CSCIs. It is used to release, track and control software versions, which in this case is the initial software release for transition to the POR.

ACRONYMS

Table 1 lists key C2 acronyms used in this paper.

Table 1. Key C2 Acronyms

Acronym	Definition
AOR	Area of Responsibility
C2	Command and Control
C2IPT	C2 Independent Project Team
C2RPC	C2 Rapid Prototyping Continuum
CANES	Consolidated Afloat Networks and Enterprise Services
CDD	Capabilities Development Document
CDP	Capabilities Development Plan
CI	Configuration Item
CM	Configuration Management
COMPACFLT	Commander, Pacific Fleet
COP	Common Operational Picture
CSCI	Computer Software Configuration Item

Acronym	Definition
DAG	Defense Acquisition Guide
DIDs	Data Item Descrition
DSB	Defense Science Board
DT	Development Test
ERB	Engineering Review Board
I2	Information & Intelligence
IATO	Interim Authority to Operate
ICD	Initial Capabilities Document
IDEs	Integrated Development Environments
JCIDS	Joint Capabilities Integration and Development System
JCS	Joint Chiefs of Staff
MOCs	Maritime Operations Center
MTC2	Maritime Tactical C2
NWP	Naval Warfare Publication
OLW	Operational Level of Warfare
ONR	Office of Naval Research
OT	Operational Test
OWF	Ozone Widget Framework
PEO C4I	Program Executive Office Command, Control, Communications, Computers and Intelligence
PMW 150	Program Management Warfare Office for C2
POR	Program of Record
R&D	Research and Development
RITE	Rapid Integration and Test Environment
S&T	Science and Technology
SA	Situational Awareness
SDD	Software Design Description
SMEs	Subject Matter Experts
SRS	Software Requirements Specification
SSA	Software Support Activity
SSC Pac	SPAWAR Systems Center Pacific
STD	Software Test Description
STP	Software Test Plan
STrPS	Software Transition Plan
SUM	Software Users Manual
SVD	Software Version Document
TF	Task Force
TG	Task Group
TRL	Technology Readiness Level
TTP	Technology Transition Plan

SUMMARY

C2PRC is an initiative jointly funded by ONR and PEO C4I to develop new C2 capability components for future maritime C2 PORs. The initiative is not only supporting the implementation of a new C2 strategy focused around the four functional pillars of the *Operational Level of War* but has also pioneered new prototype development and transition processes needed to rapidly develop, test and field new software technologies. Uniting the various stakeholders, C2RPC has streamlined the S&T phases of the acquisition process, coupling emerging technology requirements, development, testing and integration phases into a continuous agile software development model designed for IT-

intensive C2 systems. C2RPC is the first, from the ground up, services architecture application that has been designed to run on a shore based "cloud" infrastructure, currently hosted at SSC Pacific, or from a new CANES infrastructure. This provides the opportunity for C2 and ISR to operate with an autonomous afloat capability when needed, and ashore high performance computer and network infrastructure augmentation as available.

C2RPC prototypes have undergone an intensive development and demonstration process and selected components are expected to enter transition later this year. The proof will be in the ability to successfully integrate the new software into the C2 POR but the close coordination between ONR and the Program Office throughout the prototype development has reduced POR risk and should allow the POR to field the new C2 software earlier than would have been possible following a traditional acquisition cycle.

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