NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

INTEGRATED PRIORITIZED CAPABILITIES LIST (IPCL) GAP ANALYSIS AND VISUALIZATION

by

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ABSTRACT

The Warfare Improvement Program (WIP) process is the formal framework for capturing, vetting, and prioritizing Fleet capability needs to improve readiness and optimize resources for Navy forces in the execution of Combatant Commander (CCDR) tasking. For each mission area, a WIP Fleet Collaborative Team (FCT) is constituted to participate in events that inform development of annual output products. A ranking tool is utilized throughout the WIP cycle to aid in objective prioritization of capability gaps and generation of an Integrated Prioritized Capabilities List (IPCL). In this research effort, we develop a methodology based on Multi-Criteria Decision Analysis (MCDA) methods to calculate and visualize a capability gap score at any given point in time to depict capability gap resolution progress based on substantiated real-time information in order to 1) support prioritization of capabilities based on hard data, 2) provide a clear and concise picture of progress being made, or not made, to close identified gaps and/or provide a capability, and 3) support the creation of a central repository for organizations to distribute pertinent information.

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I. IPCL GAP ANALYSIS AND VISUALIZATION

A. BACKGROUND

Commander, Naval Surface and Mine Warfighting Development Center (SMWDC) is tasked to provide oversight, alignment, synchronization and end-to-end assessment of Warfare Improvement Programs (WIP) for mission areas under the cognizance of the Surface Type Commander. The WIP process is the formal framework for capturing, vetting, and prioritizing Fleet capability needs to improve readiness and optimize resources for Navy forces in the execution of Combatant Commander (CCDR) tasking (Commander U.S. Pacific Fleet, 2013). For each mission area, SMWDC HQ is responsible to ensure a WIP Fleet Collaborative Team (FCT) is constituted to participate in events that inform development of annual output products. Each WIP conducts Executive Working Groups (EWG) in QI and Q2 and a Symposium in early Q3 of the current Fiscal Year Program Objective Memorandum (POM) cycle. A SMWDC HQ N8/9 endorsed ranking tool is utilized throughout the WIP cycle to aid in objective prioritization of capability gaps. Annual Capability Area Assessment (CAA), is a collaborative effort led by the EWG Chair with the support from the FCT working group leads and the Warfare Development Center. Intel briefs and FCT updates received during EWG one and two help inform creation of the CAA and ultimately provide the "homework" or supporting documentation, for prioritization of capability gaps. Each Capability Area Owner (CAO) briefs their CAA and IPCL to SMWDC N00. The CAA report serves as the basis for the development of the current WIP cycle IPCL through the efforts put forth in the WIP Symposium (Commander, Naval Surface and Mine Warfighting Development Center, 2018).

B. RESEARCH OBJECTIVE

This research effort's objective is to develop a methodology to calculate and visualize a capability gap score at any given point in time, to depict capability gap resolution progress based on substantiated real-time information. The application of this methodology would 1) support prioritization of capabilities based on hard data, 2) provide a clear and concise picture of progress being made, or not made, to close identified gaps and/or provide a capability, and 3) support the creation of a central repository for organizations to distribute pertinent information.

C. APPLICATION OF MULTI-CRITERIA DECISION ANALYSIS TO GAP ANALYIS

We propose using Multi-Criteria Decision Analysis (MCDA) to calculate a capability gap score for a given priority at a given point in time. MCDA is both an approach and a set of techniques, with the goal of providing an overall ordering of alternatives, from the most preferred to the least preferred. The alternatives may differ in the extent to which they meet several criteria, and no one alternative will be best meet all criteria. In addition, some conflict or trade-off is usually evident amongst the criteria. MCDA is a way of looking at complex problems that are influenced by many decision criteria, breaking the problem into more manageable pieces to allow data and judgements to be brought to bear on the pieces, and then reassembling the pieces to present a coherent overall picture to decision makers. This method serves as an aid to thinking and decision making, but not to making the decision (Department for Communities and Local Government, 2009).

In the case of gap analysis, the criteria represent the factors that affect a gap (e.g., doctrine, organization, materiel, funding, etc.) and the alternatives are the priorities as specified by the Prioritized Capability Lists. Weights are specified for each factor to reflect their relative importance, and are assigned by subject matter experts individually and collectively. Each priority is evaluated periodically (e.g., quarterly) with respect to each factor and a score is assigned according to an appropriate scale. A total score for each priority is then calculated and visualized using an appropriate MCDA method to produce a capability gap score.

In order to implement the proposed approach, the following tasks need to be completed:

1. Identifying a comprehensive list of factors that determine a capability gap using a suitable capability management framework. The factors are the measures of performance by which the capabilities will be judged. These may include such factors as: doctrine, organization, training, materiel, funding, etc. These factors can be grouped in a hierarchy of high-level factors and low-level sub-factors and so on.

2. Rating capabilities on each factor using an appropriate scale. For example, a scale from 1 to 5 could be used for the funding factor where 1 indicates considerable funding cuts and 5 indicates full funding availability for the priority at a given point in time. Similar scales would be developed for the other factors such as doctrine, organization, training, materiel, etc.
3. Assigning weights to the identified factors to reflect their importance. This could be based on methods that range from individual assessments to models that achieve consensus among groups of subject matter experts.
4. Calculating an overall priority gap score by combining the weights and ratings for each of the alternatives using a suitable MCDA model. These models include Weighted Sum Model (WSM), Weighted Product Model (WPM), and the Analytic Hierarchy Process (AHP) (Parlos, 2000).
5. Conducting a sensitivity analysis to reveal how different weights or preferences affect the capability gap score. Sensitivity analysis provides a means for examining the extent to which vagueness about weights and preferences or disagreements between evaluators makes any difference to the final overall results.
6. Visualizing the capability gap score across time to provide a clear and concise picture of progress being made, or not made, to close identified gaps on the identified factors.

1. Identifying Factors that Determine a Capability Gap

A capability is typically assessed and managed with regard to several dimensions or integrative elements. Therefore, it would be helpful to use a capability management framework that incorporates these dimensions as a basis for developing a capability gap score at a given point of time.

For example, The US military analyses its capabilities in the dimensions of "DOTMLPF", as defined in The Joint Capabilities Integration Development System, or JCIDS Process, being: Doctrine, Organization, Training, Materiel, Leadership, Personnel and facilities (DOTMLPF-P, n.d.). NATO uses a similar acronym, DOTMLPF-I, the "I" standing for "Interoperability": the ability to be interoperable with forces throughout the NATO alliance. The UK Ministry of Defense uses a similar framework, known by the acronym TEPID-OIL, that includes the following dimensions: Training, Equipment, Personnel, Information, Concepts and Doctrine, Organization, and Infrastructure. Although Interoperability is not mentioned specifically in the framework, The UK Ministry of Defense cites Interoperability as an overarching theme that must be considered when any Defense capability is being addressed. The Australian Defense Organization also analyses its capabilities in similar dimensions, known as Fundamental Inputs to Capability, and include: Command and Management, Organization, Major Systems, Personnel, Supplies, Support, Facilities, Collective Training, and Industry. The dimensions identified by these frameworks must be integrated and managed within a defined or constraining financial envelope in order to develop and sustain a capability: a deficiency in any one adversely impacts the whole.

In this effort we will use the Department of Defense DOTMLPF framework dimensions in addition to constraining financial envelop as the factors that determine a capability gap. Here is an example of how the dimensions of DOTMLPF would be used in determining the state of capability gap at a given point in time:

- Doctrine: Is there a doctrine describing the way we fight using the capability?
- Organization: Do we have the organization for using the capability to fight (e.g., divisions, air wings, Marine-Air Ground Task Forces (MAGTFs), etc.)
- Training: Do we have tactical training to use the capability? (e.g., basic training to advanced individual training, various types of unit training, joint exercises, etc.)
- Materiel: Do we have all the technology and "stuff" necessary to equip the forces so they can use the capability effectively?
- Leadership and education: Do we have leaders to lead the fight using the capability from squad leader to 4-star general/admiral?
- Personnel: Do we have qualified people to use the capability for peacetime, wartime, and various contingency operations?
- Facilities: Do we have the facilities (e.g., real property; installations and industrial facilities (e.g. government owned ammunition production facilities) to support the capability?

- Funding: Do we have adequate level of funding to sustain development for the current period?

2. Rating Capabilities on Identified factors

This step rates the preference of each capability against the identified factors. This can be accomplished using a relative or fixed preference scale. In a relative preference scale, the scale is anchored at its ends by the most and least preferred capability. For example, using a one to five scale, the most preferred alternative is assigned a preference rating of five, and the least preferred, a rating of one. Ratings are assigned to the remaining capabilities so that differences in the numbers represent differences in strength of preference. These are relative judgements comparing differences in consequences, and they are often easier for people to make than absolute judgements. The resulting ratings represent the relative strength of preference; a relative preference scale is particularly appropriate for comparing several capabilities at the same time.

If capabilities are evaluated against criteria serially, a fixed preference scale is more appropriate. In a fixed preference scale, the lowest value on a given criterion might be defined as the lowest preference that would be given to a capability. The highest value could be defined as the maximum feasible value that could be given to a capability ─ this would require imagining and defining a hypothetical capability as a top-scorer.

3. Assigning Weights to Identified Factors

Assigning weights to identified factors ensures that more important criteria have a greater impact on the final decision. These weights can be assigned by individual subject matter experts or collectively among a group of subject matter experts using a variety of weighting schemes. Common scales used are one to three, one to five, one to ten, one to one-hundred, and zero to five. Each scale has its own merits, but one to five seems to be the most common and is the one that we use for this effort. Other scale options include the one, four, nine scale or the one, three, nine scale, which forces people to decide if something is very important, somewhat important, or not important.

Weights can be assigned using the method of “swing weighting.” This method is based on comparisons of differences (swings) between capability preferences. In making weight assignments, evaluators consider the difference in ratings between the least and most preferred capability, and how much they care about the difference. If the difference in ratings among the capabilities on a given criterion is small, that criterion would receive a low weight.

Implementing the swing weighting method with a group of subject matter evaluators can be accomplished by using a “nominal-group technique.” First, the one criterion with the largest swing in preference is identified. With few criteria, this can usually be found quickly with agreement from evaluators. With many criteria, a binary pairwise comparison of all criteria for preference swings may be necessary. The one criterion with the largest swing in preference is assigned the highest weight (e.g., five). This criterion becomes the standard to which all other criteria are compared in a four-step process:

1. Another criterion is chosen and all evaluators are asked to write down, without discussion, a weight that reflects their judgement of its swing in preference comparted to the standard. For example, if the criterion is judged to represent two-fifth the swing in value of the standard, then it should be assigned a weight of two.
2. Evaluators reveal their judgement weights to the group and the results are recorded on a flip chart as frequency distribution.
3. Evaluators who gave extreme weights, high and low, are asked to explain their reasons to the group and a general group discussion follows.
4. Following the discussion, a subset of evaluators makes the final determination of the weight of the criterion under discussion. This subset usually consists of the decision maker, those representing the decision maker, or senior participants whose perspectives on the issues enable them to take a broad view.

The setting of weights raises the question of whose preferences count the most, and the choice may ultimately be political, and/or depend on the context. However, it should be noted that a broadly satisfactory criterion should reflect the informed preferences of people as a whole, to the extent that these preferences and the relative importance of the criteria can be expressed in numbers. Therefore, the process of determining weights is fundamental to the effectiveness of this approach. If there is not a consensus, then it might be best to take two or more sets of weights forward in parallel, for agreement on choice of alternatives can sometimes be agreed even without agreement on weights. Even if this does not lead easily to agreement, explicit awareness of the different weight sets and their consequences can facilitate the further search for acceptable compromise.

4. Calculating a Capability Gap Score Using an Appropriate Model

This step calculates an overall gap score for each capability from the ratings and the weights developed in the previous steps. There is a number of models to calculate an overall score. They include Weighted Sum Model (WSM), Weighted Product Model (WPM), and the Analytic Hierarchy Process (AHP). The weighted sum model is the best known (MCDA) method for evaluating a number of alternatives in terms of a number of decision criteria, and is the method we use for this effort.

Suppose that a given MCDA problem consists of *n* decision criteria with *m* available alternatives. Furthermore, let us assume that all the criteria are benefit criteria, that is, the higher the values are, the better it is. Next suppose that w_j denotes the relative weight of importance of the criterion C_j and a_{ij} is the score of alternative A_i when it is evaluated in terms of criterion C_j. Then, the total (i.e., when all the criteria are considered simultaneously) score of alternative A_i, denoted as $A_i^{WSM\text{-score}}$, is defined as follows:

$$A_i^{WSM\text{-score}} = \sum_{j=1}^{n} w_j \, a_{ij}$$

The best alternative then is the one that yields the highest total score value.

Consider a decision problem with three alternatives A_1, A_2, A_3 and three decision criteria C_1, C_2, C_3 as shown in Table 1. The weight of criteria is 1, 2, and 3 respectively. Each alternative is scored on each criterion as shown in the following table.

Table 1. Decision problem criteria and alternatives

		C_1	C_2	C_3
	Weights	1	2	3
Alternatives	A_1	3	2	1
	A_2	3	1	3
	A_3	3	2	2

The total score of Alternative A_1 ($A_1^{WSM\text{-}score}$) is calculated as follows:

$$A_1^{WSM\text{-}score} = 3 \times 1 + 2 \times 2 + 1 \times 3 = 10$$

Similarly, we get:

$$A_2^{WSM\text{-}score} = 14 \text{ and } A_3^{WSM\text{-}score} = 13$$

Thus, the best alternative is alternative A2 because it has the highest WSM score of 14. Furthermore, these numerical results imply the following ranking of these three alternatives: A2 > A3 > A1 (where the symbol ">" stands for "preferred over").

5. Conducting a Sensitivity Analysis

Sensitivity analysis examines the extent to which vagueness about the inputs or disagreements between people makes a difference in the final overall results. First, interest groups can be consulted to ensure that the model includes factors affecting capability gaps that are of concern to all the stakeholders and key players. Second, interest groups often possess differing views regarding relative importance of the factors, and of some ratings, though weights are often the subject of more disagreement than ratings. Using the model to examine how the capability gap scores might change under different rating or weighting systems can show, though their order may shift, that two or three capabilities always have the highest scores. If the differences between these best capabilities under different weighting systems are small, then accepting either option can be associated with little loss of overall benefit. This is usually not apparent in the ordinary thrust of debate between interest groups, given that they focus on their differences, as opposed to the many factors on which they agree. Third, sensitivity analyses can begin to reveal ways in which capabilities might be improved; in fact, there is a potentially useful role for sensitivity analysis in helping to resolve disagreements between interest groups.

6. Visualizing Capability Score Gaps across Time and Factors

Capability gap scores across time can be visualized using a variety of graphs and charts. Figure 1 is a radar chart that shows factor (dimension) scores by quarter for a given capability.

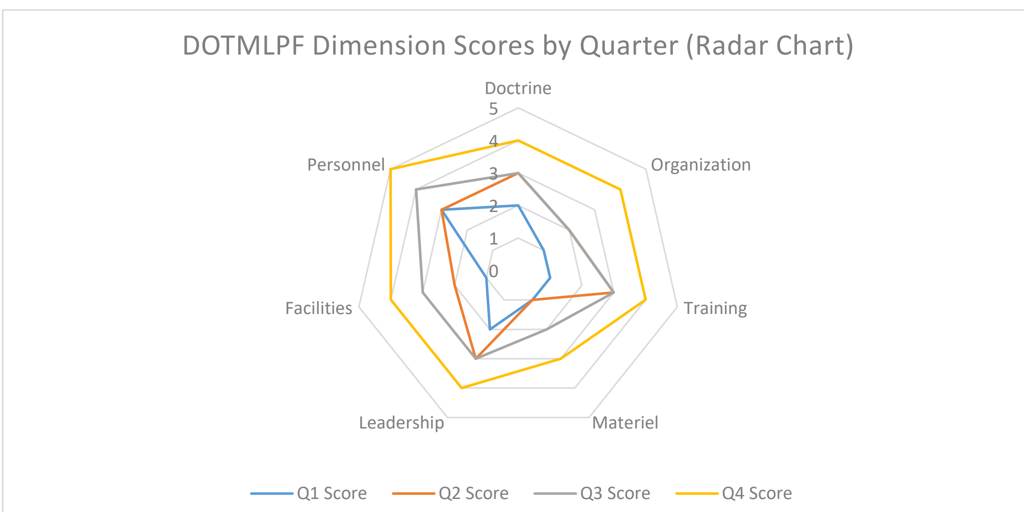

Figure 1. Dimension scores by quarter for a capability

Figure 2 is a line chart that depicts factor (dimension) scores by factor for a given capability.

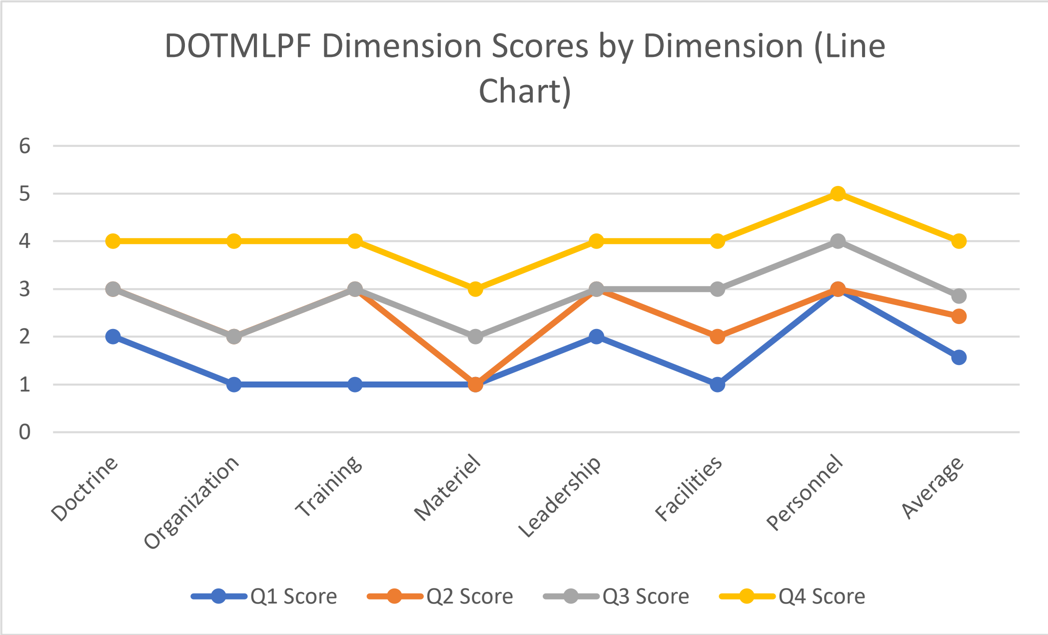

Figure 2. Dimension scores by dimension for a capability

Figure 3 depicts a proof-of-concept dashboard for displaying capability gap scores by capability, year, quarter, and factor. A dashboard is a type of graphical user interface which provides at-a-glance views of key performance indicators (KPIs) relevant to a particular objective. In this case the KPI is the capability gap score across time and dimensions. A dashboard is linked to a database that allows the display to be constantly updated thus providing a near real time progress report of capability gap progress.

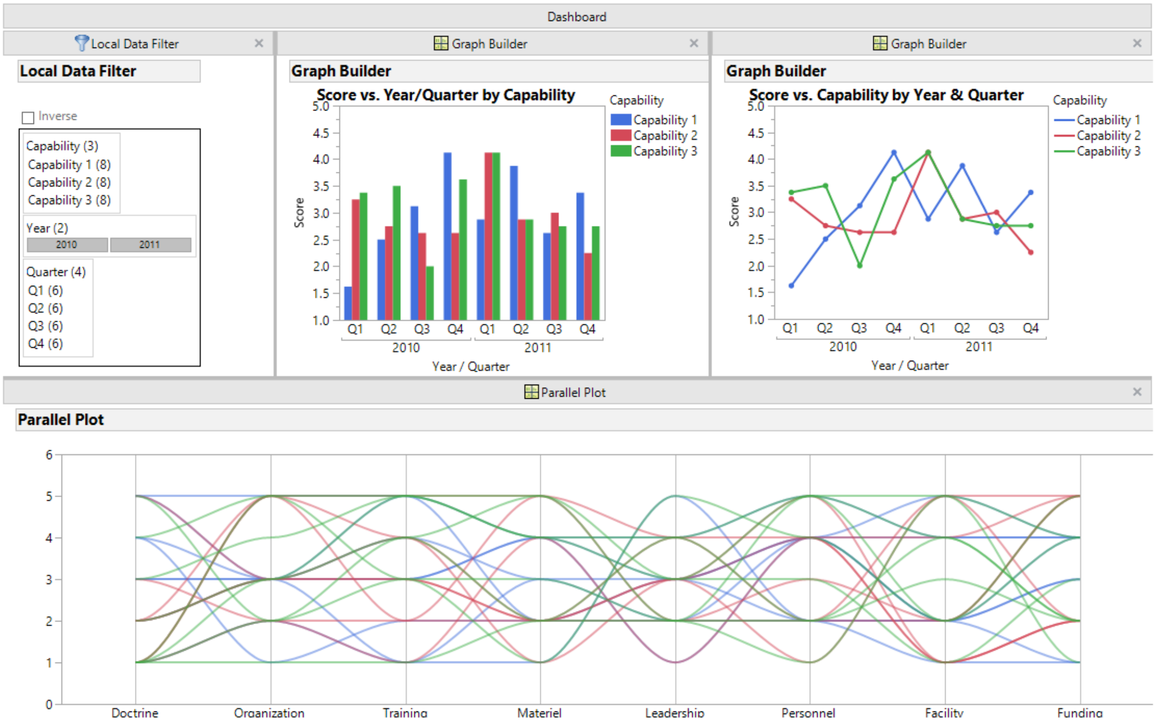

Figure 3. IPCL visualization dashboard

D. EXAMPLE CAPABILITY SCENARIO: THE LIGHTLY MANNED AUTONOMOUS COMBAT CAPABILITY (LMACC)

1. Mission Scenario of the Intended Capability

Our peer nations in Asia have enhanced their capabilities, which could create an anti-access, area denial (A2/AD) situation in the Indo-Pacific sea lanes of communications (SLOC). In particular, the Chinese Navy has the capability to threaten Taiwan, target US Fleet assets with precision long-range missiles, and use other means to take control of the “first Island Chain”—meaning shipping and defense in this area. In peacetime, an increasing force by the Chinese Navy and shore-based assets would create a *fait accompli*, meaning that when those forces are able to overwhelm US and allied forces, the US Fleet and Joint forces will be unable to push back, making it impossible to project dominance. In other words, it will be too late to act.

At the moment, the U.S. has too few combat ships to prevent this scenario. Specifically, the Arleigh Burke class DDG’s are very expensive, and their primary role is to defend a carrier battle group or an expeditionary battle group. Some are used in freedom of navigation operations (FONOPS), but they are constrained by the reality of distributed maritime operations with too few assets. Also, as the US and allies move from a phase 0 to phase 1 operational stance, these capital ships will move out of range of the sea- and land-based long-range precision surface to surface missiles.

Although autonomy may hold promise, achieving true autonomy will take time. Experimentation with Sea Hunter has shown promise, but a long way to being truly autonomous, apart from a battle group. What is missing is an armed autonomous platform, yet we are not ready to jump directly towards this capability. We need an intermediate step, and this is where the LMACC is a potentially useful platform. The platform would combine current capabilities for autonomy, such as navigation in avoiding collisions (COLGRES) and control of the internal shipboard functions, with a small but tactically and technically savvy crew. Given these capabilities, and armed with its own long-range missiles, we would then have a force forward already inside the first island chain. These 1000-ton vessels, with a crew of 15, would carry 10 long-range missiles. They would have long range engagement against shore-based missile batteries and sea-launched long-range missiles as their primary mission. Instead of piling numerous missions on one vessel, each LMACC would have its primary mission and one secondary (ASW, AAW, ASUW). This distributes capabilities and as these vessels spread out, and combined with the Sea Hunter, create a "Pack" which would greatly increase the adversary's targeting problem. These vessels would use littoral hiding, hiding within commercial fishing fleets, EW capabilities, and stealth technology, making targeting with certainty very difficult.

By having this force forward, we have then a deterrent force, which is able to face the Chinese *fait accompli.* The intended cost of these vessels is less than $100 million; the cost of a new DDG is around $4 billion. Simply put, for the price of one DDG, we can create a new and lethal class of vessel with first- and second-strike capability.

2. Application of Capability Gap Methodology to LMACC Problem

In the following sections, we apply the first four steps of the methodology developed in this effort to calculate a capability gap score for the current status of LMACC project.

a. Identifying the factors that determine the capability gap

The following is a general discussion of the elements (factors) required to achieve the LMACC capability and a brief description of their status:

- **Autonomy**: Already in use in Sea Hunter; primarily intended to ensure no collisions at sea.
- **Communications**: Satellite, but in satcom-denied situation, will use wideband HF to create a network between platforms.
- **Personnel**: Although the LMACC uses few people, it still requires a force of approximately 300 personnel. This is comparable to the personnel needed for a single DDG.
- **Shipyard availability**: Small yards are being identified to build the vessels.
- **Design**: NPS has a first version of LMACC drawings. Final drawings and testing in a wave tank will need to be accomplished to finalize the hull form.
- **Weapons**: The vessel is armed with weapons that already exist; however, the U.S. Navy does not have sufficient missiles to arm its current force plus the LMACC concept. 150 long range precision strike missiles will be needed. At $5 million apiece, this is a significant building and acquisition challenge.
- **Acquisition**: A technical report has been written, and use of non-traditional acquisition is being proposed. A briefing to the HASC is needed, also to the SECNAV, as the CNO doesn't buy ships, it only uses them.
- **Training**: The mission set for this vessel will expand. Because there are few personnel, and they would mostly be involved in sorting out targets, and making decisions beyond the capability of autonomy, it is necessary to create a separate training pipeline, similar to what naval aviation must do when it acquires a new aircraft.
- **Basing**: Could be forward deployed with maintenance on the West Coast.

We incorporate these elements into the DOTMLFP + Funding Framework by grouping these element under the appropriate DOTMLFP category. The resulting DOTMLPF hierarchy is shown in Figure 4.

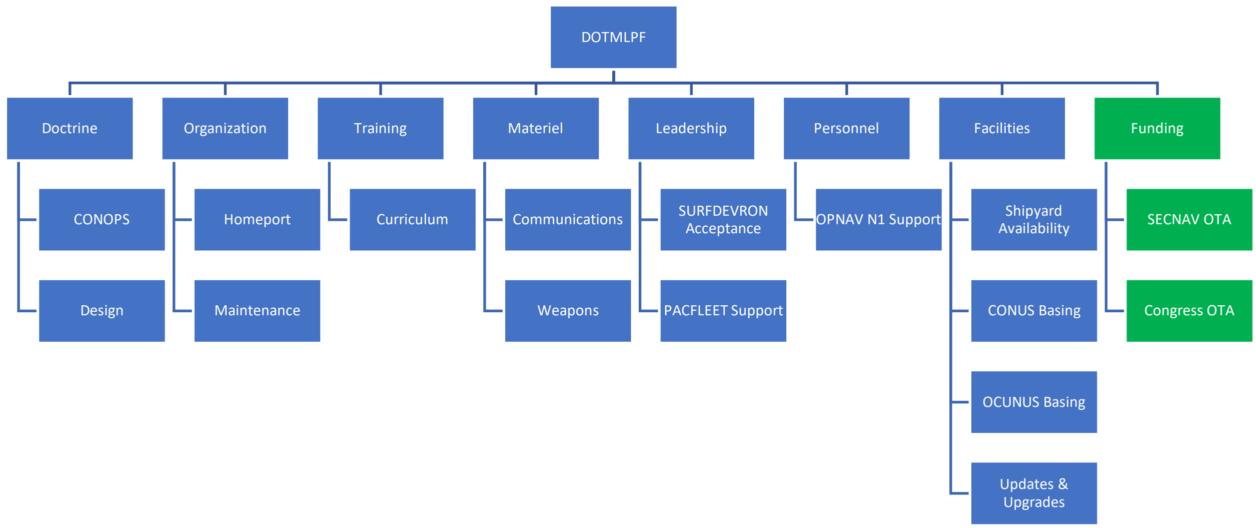

Figure 4. DOTMLPF-F hierarchy for LMACC

b. Rating current LMACC capability on the DOTMLPF factors

We use a fixed preference scale, from zero to ten, to rate the current LMACC capability on the DOTMLPF factors. The following is the resulting ratings and a justification for each one:

1. Doctrine: Consists of two sub-factors (elements):
    a. A concept of operations (CONOPS): A CONOPS development group has been formed for MUSV. That CONOPS will be similar to CONOPS for the LMACC. A first draft has been created. *Rating 7*.
    b. Design: The second element has been worked through with experts across a spectrum of designers. A working draft of the design has been promulgated in published articles and a technical report. A final version will be created with the shipyard selected for the prototype. *Rating 8*.
2. Organization: Consists of two sub-factors:

    a. Homeport: Discussions regarding the homeporting of the MUSVs are underway. Homeport also includes maintenance, upgrades, and further development. *Rating 6*.
    b. Maintenance. Homeport must be known in order to understand how and from where maintenance will be obtained. Location near the construction shipyard may be important. Here, maintenance is similar to the MUSV, except for additional weapons maintenance. *Rating 4*.
3. Training: Main element is curriculum development. The same as MUSV, with the added layer of fighting the ship with defensive and offensive weapons, and human-machine teaming. Surface Officer training will be initially sufficient, with an addition of working with autonomy and corresponding vessel doctrine. *Rating 4*.
4. Materiel: Consists of two sub-factors:
    a. Communications: Where there is a need to create a wideband, LPI/LPD HF network. *Rating 8*.
    b. Weapons: The core function of this vessel is operation within the first island chain as a deterrent, and then execute first-strike operations against long range precision surface to surface launch platforms ashore and at sea. No new weapons systems will need to be developed, but a mix of strike and self-defense weapons are needed. The current design includes these systems. *Rating 7*.
5. Leadership: Consists of two sub-factors:
    a. SURFDEVRON Acceptance: This includes acceptance of the vessel for experimentation and CONOPS development. *Rating 4*.
    b. PACFLT Support: PACFLT needs to accept the concept and be willing to support it. *Rating 2*.
6. Personnel: Main element is OPNAV N1 support. People are important, however, by reducing the Navy by one new DDG, nearly all personnel requirements can be met. Nothing has been introduced on this front, therefore, a new study is needed. *Rating 0*.
7. Facilities: Consists of four sub-factors:

a. Shipyard Availability: An initial study of shipyards has been completed with 30 candidates. No communications with shipyards will be conducted without funding. *Rating 2*.

b. CONUS Basing: This is also shared in a previous element, but here it is part of the overall concept in which one "pack" is forward for 60 days, is relieved on station by the next pack, and one is in CONUS being maintained. The concept is in place, but CONUS basing is not decided given needs for maintenance. *Rating 3*.

c. OCONUS Basing: This will facilitate the 3-pack concept and limit the distances required to make relief on station possible. Some analysis of OCONUS possibilities has been completed. *Rating 3*.

d. Updates and Upgrades. All LMACCs have the same primary mission plus one secondary. Each of these missions create subtle differences between platforms, and thus upgrades to autonomy and weapons systems will need to be accomplished. No work has been done in this area. *Rating 1*.

8. Funding: The operational staff (OPNAV) consisting of OPNAV N9, N96 and a program of record, PMS 406, are involved in future ship design. The current design is in conflict with the LMACC concept. Funding will be requested from two sources below. A briefing has been created for this purpose, and will be sent as the technical report is finalized.

   a. House Armed Services Committee. *Rating 4*

   b. SECNAV Assistant Secretary of the Navy Research and Development (ASN RDA). *Rating 4*.

c. Assigning weights to identified factors

This step assigns weights to identified factors and sub-factors, to ensure that more important factors have a greater impact on the final decision. These weights were assigned by a subject matter expert on a scale from zero to ten. Table 2 shows the ratings and weights assigned by the SME and Table 3 shows the normalized ratings and weights.

Table 2. Ratings and weights of DOTMLPF factors

Factor	Factor Weight	Sub-Factor	Sub-Factor Weight	Sub-Factor Rating
Doctrine	8			
		CONOPS	5	7
		Design	10	8
Organization	3			
		Homeport	8	6
		Maintenance	2	4
Training	2			
		Curriculum	10	4
Materiel	4			
		Communications	4	8
		Weapons	8	7
Leadership	4			
		SURFDEVRON Acceptance	3	4
		PACFLT Support	6	2
Personnel	3			
		OPNAV N1	10	0
Facilities	4			
		Shipyard Availability	8	2
		CONUS Basing	8	3
		OCONUS Basing	2	3
		Updates & Upgrades	2	1
Funding	5			
		SECNAV OTA	3	4
		Congress OTA	6	4

Table 3. Normalized ratings and weights of DOTMLPF factors

Factor	Factor Weight	Sub-Factor	Sub-Factor Weight	Sub-Factor Rating	Sub-Factor Score	Factor Rating	Factor Score
Doctrine	0.24					0.77	0.19
		CONOPS	0.33	0.70	0.23		
		Design	0.67	0.80	0.53		
Organization	0.09					0.56	0.05
		Homeport	0.80	0.60	0.48		
		Maintenance	0.20	0.40	0.08		
Training	0.06					0.40	0.02
		Curriculum	1.00	0.40	0.40		
Materiel	0.12					0.75	0.09
		Communications	0.53	0.80	0.43		
		Weapons	0.47	0.70	0.33		
Leadership	0.12					0.27	0.03
		SURFDEVRON Acceptance	0.33	0.40	0.13		
		PACFLT Support	0.67	0.20	0.13		
Personnel	0.09					0.00	0.00
		OPNAV N1	1.00	0.00	0.00		
Facilities	0.12					0.24	0.03
		Shipyard Availability	0.40	0.20	0.08		
		CONUS Basing	0.40	0.30	0.12		
		OCONUS Basing	0.10	0.30	0.03		
		Updates & Upgrades	0.10	0.10	0.01		
Funding	0.15					0.40	0.06
		SECNAV OTA	0.33	0.40	0.13		
		Congress OTA	0.67	0.40	0.27		

d. Calculating a capability gap score

This step calculates an overall capability gap score using the weighted sum method discussed in Section C.4. For the above scenario the resulting capability gap score is 0.47 which indicates that 47% of the capability gap is closed and 53% of the gap remains to be closed. Table 2 also shows the capability gap score for each element of the DOTMLPF framework. These gap scores are shown in the radar chart of Figure 5.

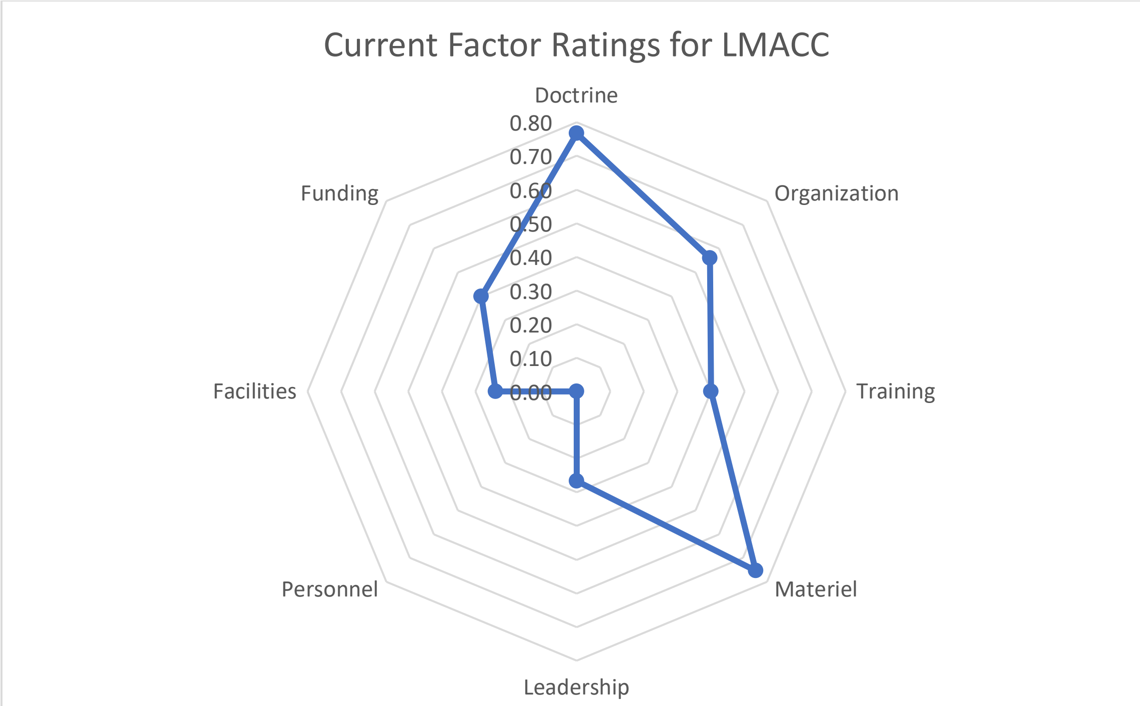

Figure 5. Current capability gap scores on LMACC factors

E. SUMMARY AND CONCLUSIONS

In this effort we developed a six-step methodology for calculating and visualizing capability gaps based on multi-criteria decision analysis methods and consists of the following steps: 1) Identifying factors that determine a capability gap, 2) Rating capabilities on identified factors, 3) Assigning weights to identified factors, 4) Calculating a capability gap score using an appropriate model, 5) Conducting a sensitivity analysis, and 6) Visualizing capability score gap across time and factors.

Application of this methodology to the IPCL problem would enable Navy leadership to have a clearer picture of what has been accomplished, what remains to be done, who has action, and the critical path to closing the gap and/or delivering the capability.

F. FUTURE WORK

For future effort, we recommend revisiting the capability management framework used in this effort (DOTMLPF) by adding new and/or removing existing factors. These factors can be grouped into a hierarchy of high-level factors and low-level sub-factors. We also propose investigating different approaches to weighting the factors that determine a capability gap as well as the methods for combining capability factor scores into an overall capability gap score. Most importantly, we recommend applying the proposed methodology to two or three real-life scenarios of desired capability and visualize the resulting gap scores across time and influencing factors. Finally, we recommend refining the proposed dashboard by incorporating additional charts and graphs to better visualize capability gaps.

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