



Operating and Support Cost Estimating Methods:  
**An approach to estimate the US Navy's future  
cost of Ballistic Missile Defense (BMD)**

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# Operating and Support Cost Estimating Methods: An approach to estimate the US Navy's future cost of Ballistic Missile Defense (BMD)



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# Outline

- Purpose
- Background
- Navy BMD Cost Element Structure (4 categories)
  - Aegis Ashore Cost Element Structure
- Methodology
- Other Considerations & Challenges
- Conclusion



# Purpose

## ***What's the Navy's cost of Ballistic Missile Defense?***

Question posed to NCCA by the Naval Air and Missile Defense Command (NAMDC)

- This brief will describe how the authors answered this question with respect to:
  - Working with NAMDC and the Office of the Chief of Naval Operations (OPNAV) to develop scope of effort
  - Addressing unique challenges
  - Developing a cost estimating approach
  - Use of data resources, methods, and conclusions
- This brief does not address policy, decisions made, or specific cost results



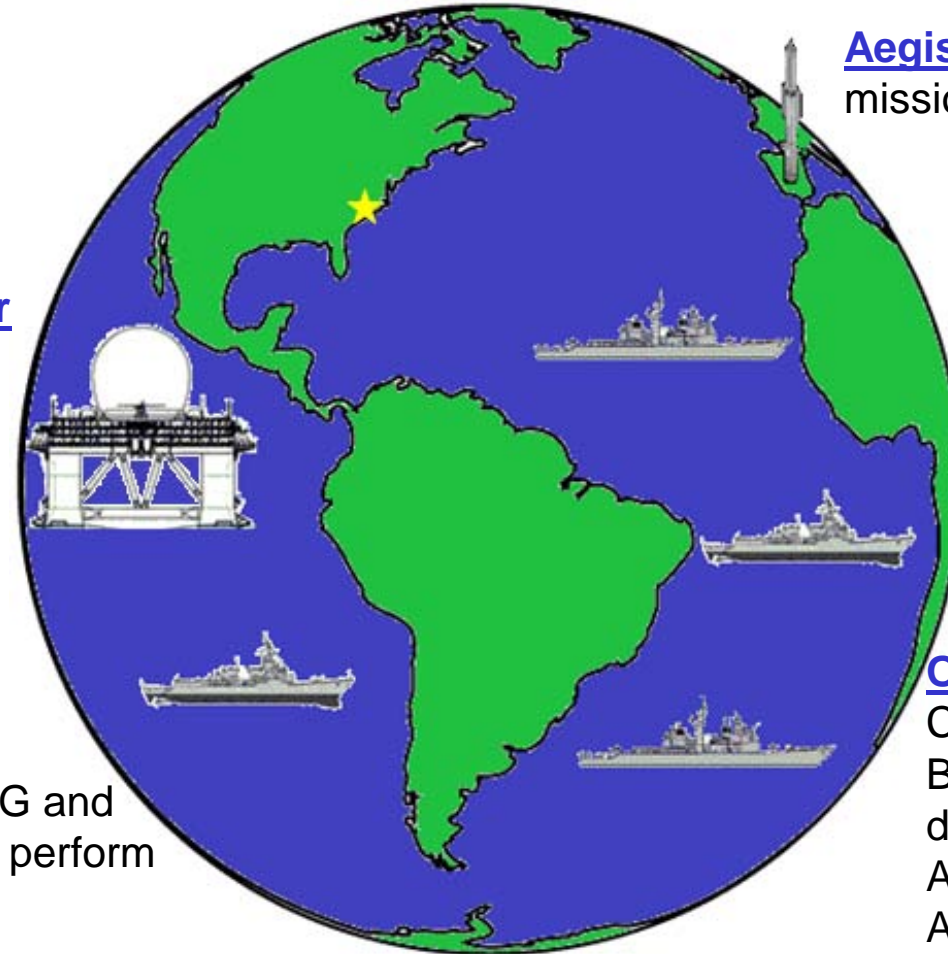
# Background: Some of the Questions

- What is the cost of BMD to the Navy?
- What types of cost should be considered (e.g. O&S only)?
- What is the life cycle of BMD; should we provide estimates for FY11, FY12, ... FY20?
- What are all of the Navy BMD components (e.g. at-sea, on-land, CONUS, OCONUS, etc.)?
- What are the future requirements per system?
  - # of Aegis Ashore personnel and type of personnel (occupation)
  - Square feet of Aegis Ashore facilities
  - Power needed to support Aegis Ashore
  - % of time a non-dedicated ship will perform BMD missions at-sea
- How many systems are required?
  - # of Aegis Ashore sites, # and type of missiles per site,
  - # of SBX
  - # of BMD-capable ships in a given year



# Navy BMD Cost Element Structure

The Navy's support for theater, regional, and homeland BMD were divided into **FOUR** categories that served as the Navy BMD Cost Element Structure (CES):



Aegis Ashore BMD mission performed on land

Sea-Based X-Band Radar (SBX) Floating platform that tracks long-range ballistic missiles

Aegis Afloat CG and DDG ships that perform BMD mission

Other BMD Efforts: Costs related to Navy BMD that could not be directly mapped to Aegis Ashore, SBX, or Aegis Afloat



# Aegis Ashore Cost Element Structure

- Navy O&S
  - Personnel: Mission, Security, Other and Base Operating Support
    - Other: Command Staff, Maintenance Support, EMS, Fire, and Management of Base Operating Support
    - Personnel costs include Pay, Training, and Travel
  - Aegis Ashore Missile Defense Facilities
    - These include Visitor Control, Dining Hall, a Dormitory, and Parking
  - Aegis Ashore Missile Defense System
    - Aegis Weapon System and Vertical Launch System (VLS)
      - Maintenance, Expendable Stores, Hardware Modernization, Software Support, and Engineering Support
    - SM-3 Missiles
      - Maintenance, Transportation, and Engineering Support
    - Mission Infrastructure
      - Includes Deckhouse, Central Power Plant, and Storage

**This Cost Element Structure (CES) was developed in a way to organize & quantify requirements and cost data that were available**



# Data and Approach: Overview

	Data Source	Methodology	Requirement Definition
<b>Aegis Ashore</b>	(1) VAMOSC (Infrastructure, Military Personnel, Civilian Personnel, Ships, Ship Systems and Missile Unverses) (2) Unified Facilities Criteria, DOD Facilities Pricing Guide (3) Foreign Exchange Rates (4) Manpower Cost Estimating Tool for Enhanced Online Reporting (METEOR)	(1) Engineering Build-up (Personnel) (2) Parametric (Facilities) (3) Factor (Location and System) (4) Exchange Rates	Low
<b>Aegis Afloat</b>	VAMOSC Ships Universe	(1) Average of actuals (2) Allocation of mission-related costs to BMD	Low/Medium
<b>SBX</b>	2011 President's Budget	(1) Thru-put from budget documents	High
<b>Other BMD Efforts</b>	NAMDC-provided Requirements and Budget Documents	(1) Thru-put from actuals (2) Engineering Build-up	Medium



# Methodology: Aegis Ashore

- Basis of Aegis Ashore O&S Cost Elements
  - Personnel
    - Includes pay, training, and travel for mission, security, command staff, system maintenance, EMS, Fire, and base operating and support personnel as required
      - Mix of personnel to fulfill requirements include military, government civilian, contractor, and host nation
    - Quantity, number of detachments, and deployment duration based on multiple courses of action
  - Facilities include:
    - Base infrastructure to support the mission including land, roads, parking, perimeter fence, etc.
    - All base support buildings such as a dormitory, cafeteria, water treatment facility, etc.
    - O&S costs of power plant and back-up generators
  - Aegis System: Comprised of Aegis Ashore combat system with vertical launch system (VLS) and standard missiles (SM-3)



# Methodology: Aegis Ashore Personnel

- Data
  - VAMOSC Military Personnel Universe and Civilian Personnel Universe
  - Quantity and grade requirement for personnel using the Military and Civilian Universe average pay by grade to estimate
- Approach
  - Pay
    - Military pay rates based on applicable Naval Enlisted Code (NEC) and/or Grade derived from VAMOSC data
    - Civilian pay rates determined by occupation type from VAMOSC data
    - US KTR rates adjusted to account for additional overhead & fee for overseas location
    - Host nation rates adjusted based on exchange rates
  - Training
    - Based on Aegis Sea-based VAMOSC data adjusted for number of mission personnel and deployment cycles (e.g. 6 month versus 1 year deployments)
    - Assumed ashore personnel will be analogous to sea-based training actuals
  - Travel
    - Travel based on VAMOSC Permanent Change of Station (PCS)/Temporary Additional Duty (TAD) data adjusted for airfare and per diem for deployment options



# Methodology: Aegis Ashore Personnel

- Cost analysis requirements received from subject matter experts
  - # of military personnel and pay grade
  - # of contractors and occupation
  - # of government civilian personnel and occupation
  - # of host nation personnel
- Example of pay by # of personnel and grade

Manning Category	# of Personnel	Rate	Total CY\$10
(1) Mission Personnel	# of Personnel1	Rate1	Personnel1 Cost
(2) Mission Personnel (Officer-in-Charge)	# of Personnel2	Rate2	Personnel2 Cost
(3) Command Staff	# of Personnel3	Rate2	Personnel3 Cost
(4) Maintenance Support for AAMDS	# of Personnel4	Rate4	Personnel4 Cost
(5) Security Personnel (US Ktr)	# of Personnel5	Rate5	Personnel5 Cost
(6) Security Personnel (Host Nation)	# of Personnel6	Rate6	Personnel6 Cost
(7) Base Operating Support (EMS, Fire, etc)	# of Personnel7	Rate7	Personnel7 Cost
(8) Base Operating Support (Other)	# of Personnel8	Rate8	Personnel8 Cost
<b>Annual Total Personnel &amp; Personnel Cost</b>	<b>Total</b>		<b>Total Peronnel Cost</b>
Total Training			Training Cost
Total Travel (PCS & TAD)			PCS & TAD Cost
<b>Annual Total Personnel &amp; Personnel Cost</b>	<b>Total</b>		<b>Total Peronnel, PCS &amp; TAD Cost</b>

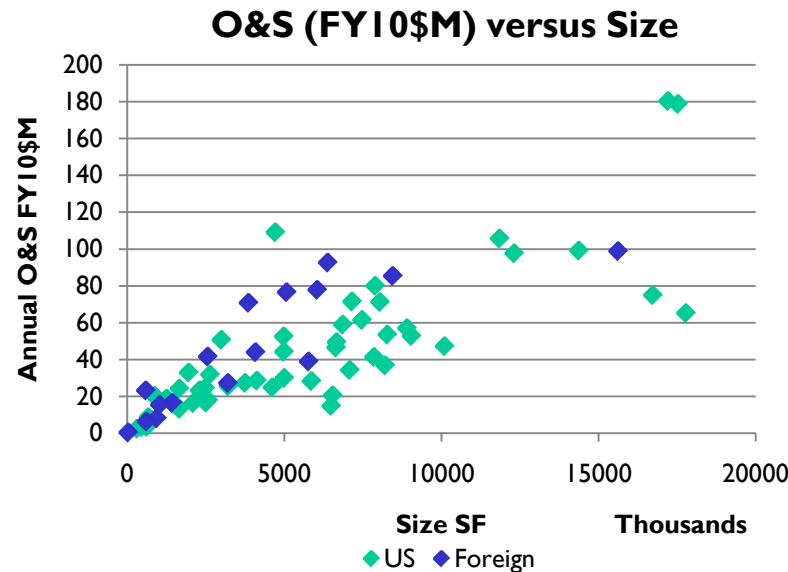


# Methodology: Aegis Ashore Facility

- Data collected from Navy VAMOSOC Infrastructure Database
  - Analyzed 49 US Naval bases and 16 Foreign Naval bases (e.g. Pensacola, Norfolk, Key West, Guam)
  - Data reflects only permanent facilities
- Developed O&S Cost Estimating Relationship (CER)
  - CER estimates cost as a function of building Square Feet (SF), parking Square Yards (SY), building replacement value, percent of permanent construction, and percent of SF utilization

$$\text{Annual O\&S} = v(\text{Building SF})^a + w(\text{Parking SY})^b + x(\text{Replacement Value})^c + y(\% \text{Permanent})^d + z(\% \text{SF Utilization})^e$$

- CER results consistent/cross-checked with DOD Facility Guide cost factors
- DOD location adjustment factors applied for site-specific locations
- Building SF was the biggest cost driver as seen below:



# Methodology: Aegis Ashore Facility

- CGs and DDGs generate power for ship systems while Aegis Ashore must generate its own power
  - Data
    - Federal Energy Regulatory Commission data for electric utilities included: nuclear, fossil steam, hydroelectric, and small scale gas turbine where small scale gas turbine is the most analogous
    - VAMOSC Ship O&S for General Electric LM2500 gas turbine engine which is utilized on both CG and DDG ships
  - Approach
    - Power Plant – utilized maximum power output for ships from VAMOSC and \$/kWh to determine annual power plant O&S
      - Annual Cost = kWh Requirement \* Annual \$/kWh
      - Example: \$1,250,000 = 2,500 kWh \* \$500/kWh
    - Back-up generators for system and facility – based on ship engine O&S and allocated based on utilization



# Methodology: Aegis Ashore System

- Deploying a sea-based Aegis weapon system on land
- Data Sources
  - VAMOSC Ships and Shipboard Systems
    - Aegis Weapon System
  - VAMOSC Shipboard Systems
    - Vertical Launch Systems (VLS)
  - VAMOSC Missiles
    - Standard Missiles (SM-3)
- Approach
  - Adjusted analogy accounted for number of VLS and SM-3 unit cost compared to historical data
  - Includes maintenance, expendable stores, hardware modifications, software and engineering support for the missiles, corrective action efforts only related to software support, transportation, and storage
  - SM-3 cost by analogy: 
$$SM - 3(O\&S\$) = SM - 2(O\&S\$) * \frac{SM - 3 \text{ Avg Unit Price}}{SM - 2 \text{ Avg Unit Price}}$$



# Methodology: Aegis Afloat

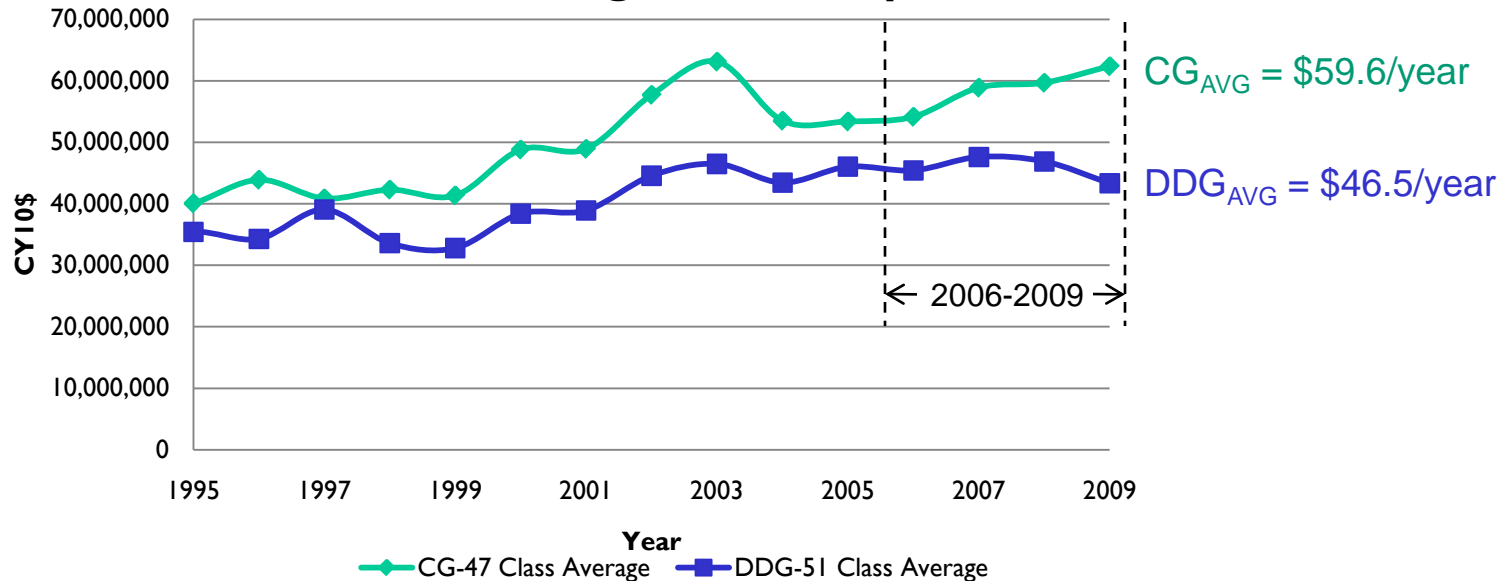
- BMD mission deployed using Ticonderoga class cruisers (CG) and Arleigh Burke class destroyers (DDG)
- Unique Requirements
  - Number of ships performing BMD mission?
  - Percent of time each ship performs BMD mission?
- Data Sources
  - VAMOSC Ships, Shipboard Systems, Missiles
- Approach
  - Analyzed O&S costs of ships with BMD capabilities
  - Analyzed effects of ship age in extrapolating future costs
  - Compared CG versus DDG costs
  - Estimated BMD related costs based on annual O&S cost per ship, number of ships, and percent time performing mission



# Methodology: Aegis Afloat

- Significant opportunity cost to Navy based on number of fully dedicated ships and number of ships partially performing BMD mission
- Currently 5 CGs perform BMD mission with 9 planned for 2018
- Currently 18 DDGs perform BMD mission with 28 planned for 2018
- O&S cost is directly related to percent performing BMD Mission

**CG-47 & DDG-51 Avg O&S Cost per Year**



# Methodology: Aegis Afloat

## FY11 example of opportunity cost of performing BMD Mission

Table 2. Aegis BMD Ships, Aegis Ashore Sites, and SM-3 Deliveries, FY2009-FY2018

	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
<b>Aegis cruisers modified to have:</b>										
3.6.1 version	2	4	3	3	3	3	3	1	1	0
4.0.1 version	0	0	2	2	2	2	0	0	0	0
5.0/5.1/5.2 version	0	0	0	0	0	3	6	9	9	9
Total	2	4	5	5	5	8	9	10	10	9
<b>Flight I/II Aegis destroyers procured in FY1985-FY1994 and later modified to have:</b>										
3.6.1 version	16	16	18	20	20	16	13	10	9	6
4.0.1 version	0	0	0	2	4	7	7	7	6	6
5.0/5.1/5.2 version	0	0	0	1	3	5	8	11	13	16
Total	16	16	18	23	27	28	28	28	28	28
<b>Flight IIA Aegis destroyers procured in FY1994-FY2005 and later modified to have:</b>										
versions TBD	0	0	0	TBD	TBD	TBD	TBD	TBD	TBD	TBD
<b>Flight IIA destroyers procured FY2010-FY2015 and built from the start with:</b>										
4.0.1 version	0	0	0	0	0	0	1	3	4	6
<b>TOTAL AEGIS BMD SHIPS</b>										
3.6.1 version	18	20	21	23	23	19	16	11	10	6
4.0.1 version	0	0	2	4	6	9	8	10	10	12
5.0/5.1/5.2 version	0	0	0	1	3	8	14	20	22	25
<b>ALL VERSIONS</b>	<b>18</b>	<b>20</b>	<b>23</b>	<b>28</b>	<b>32</b>	<b>36</b>	<b>38</b>	<b>41</b>	<b>42</b>	<b>43</b>
<b>Aegis Ashore Sites</b>	0	0	0	0	0	0	1	1	1	2
<b>Cumulative SM-3 missile deliveries</b>										
SM-3 Block IAs	n/a	80	106	112	112	112	112	112	112	112
SM-3 Block IBs	n/a	1	4	16	42	108	180	252	324	324
<b>TOTAL IAs/IBs</b>	<b>n/a</b>	<b>81</b>	<b>110</b>	<b>128</b>	<b>154</b>	<b>220</b>	<b>292</b>	<b>364</b>	<b>436</b>	<b>436</b>
SM-3 Block IIAs	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	n/a

Source: MDA briefing to CRS and CBO, March 18, 2010.



# Methodology: Aegis Afloat

Example of opportunity cost of performing BMD Mission (CY\$10M):

	<u>2011</u>	
<b>CG BMD Ships</b>	<b>5</b>	
# Dedicated	1.5	
# Non-Dedicated	3.5	
% BMD Mission of Non-Dedicated	5%	
<b>FY11 Example: CG Annual O&amp;S = \$59.6M</b>		
	<b>1.5 x \$59.6M + 3.5 x 5%(\$59.6M)</b>	<b>= \$100M</b>

	<u>2011</u>	
<b>DDG BMD Ships</b>	<b>18</b>	
# Dedicated	2.5	
# Non-Dedicated	15.5	
% BMD Mission of Non-Dedicated	5%	
<b>FY11 Example: DDG Annual O&amp;S = \$46.5M</b>		
	<b>2.5 x \$46.5M + 15.5 x 5%(\$46.5M)</b>	<b>= \$152M</b>

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**FY11 Example: CG Annual O&S + DDG Annual O&S = \$252M**

**Future opportunity cost has the potential to increase significantly**



# Methodology: SBX

- Current system is operational but actual O&S costs were not available at the time
- Utilized 2011 President's Budget for the MDA, budget was assumed to be based upon actuals
- Other assumptions related to the SBX cost to the Navy
  - MDA is currently funding O&S for SBX
  - The Navy will fund some or all O&S for SBX



# Methodology: Other BMD Efforts

- Costs that could not be directly mapped to Aegis Ashore, SBX or Aegis Afloat, including:
  - Additional O&S cost of trainers, billets needed at the Maritime Operations Centers, Aegis BMD baseline support costs, and program support provided by NAMDC
- Build-up of throughputs based on current or proposed funding associated with Navy BMD
- Verified that detailed requirements did not double count elements in top-level estimates



# Other Considerations & Challenges

- Awareness at all levels, across several organizations
  - 15+ briefings to stakeholders, many at the SES and Admiral level
- Constantly evolving definition/requirements
  - 12+ changes in requirements from June through September 2010
- Multiple and rapidly evolving options to consider
  - Required weekly coordination among (up to) 7 organizations
    - NCCA, Technomics, NAMDC, N86 (Aegis Ashore), NI25 (Manpower Acquisitions Branch), N4I (Installations Division), and Missile Defense Agency (MDA)
- Many varying and unique components
  - Examples: Personnel, facilities, systems, ships, and foreign locations
- Initial lack of existing methods/data
- Uncertainty/Cost ranges required: “Bounding the estimate!”
- Aggressive schedule to assist decision-makers

**Such challenges made this project much more than a routine application of cost estimating methods.**



# Conclusion

- **The aggressive schedule and continuously changing inputs required a flexible model**
  - Allowed for multiple courses of action of total personnel and personnel type mix (e.g. military, civilians, contractor, and host nation)
  - Capability to define “cost to the Navy” by selecting or deselecting elements at the CES to reflect the particular stakeholder’s definition
  - Capability to adjust the estimate to reflect the particular stakeholder’s certainty levels on the risk curve
- **Initial lack of existing methods/data necessitated top level estimating, the development of program level CERs, and utilization of estimates that have already been completed**
  - Estimated BMD related costs based on average annual O&S cost per ship, number of ships and percent time performing mission
  - Developed facilities CER as a function of building SF, parking SY, replacement value, number of personnel and construction type
  - Use of President’s Budget



# Conclusion (continued)

- **The varying degrees of data availability resulted in using many estimating techniques by cost element**
  - Parametric-based CERs and Engineering build-up
  - Average of actuals and thru-put from budget documents
- **Cost community can add value prior to Milestone B**
  - Can help in defining requirements
  - Can provide defensible ROM level cost estimates
- **Unique effort led to the discovery and use of many uncommon yet useful VAMOSOC data sources**
  - Military and Civilian Personnel Universes: Personnel pay by grade & occupation
  - Infrastructure Universe: CONUS and OCONUS Naval base O&S costs
  - Ships, Shipboard Systems, and Missiles Universes: Aegis System data include VLS, SM-2, and SM-3 O&S and average unit costs



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## **Questions?**

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# Tasking

- In April 2010, NAMDC requested NCCA to estimate Operating & Support (O&S) cost of BMD to the Navy
  - Scope included Aegis Ashore, Aegis Ballistic Missile Defense (BMD), and Sea-Based X-Band Radar (SBX)
- In late-April 2010, the Deputy CNO, Integration of Capabilities & Resources (N8) requested the Naval Center for Cost Analysis (NCCA) to provide an O&S cost estimate of Aegis Ashore
  - Includes Aegis Ashore Missile Defense System and Facility
- Aegis Ashore O&S cost results developed for N8 were used as part of the broader effort for NAMDC

