Framework for analyzing Modular, Adaptable, and Flexible Surface Combatants

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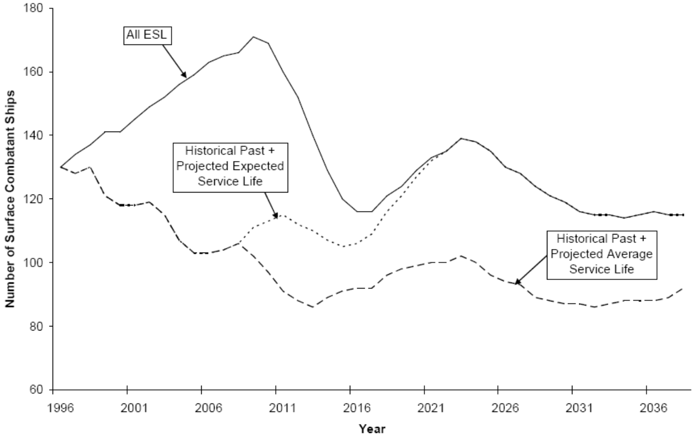
Observations

- Combat System Development vs. Ship Design and Construction

Attribute	Combat Systems	Ship Design & Construction
Timeline	Short	Long
Expertise required	Electronics, software	HM&E, Hardware
Configuration	Volatile	Stable
Effect on *Design* Ship Service Life	Little influence	Strong driver
Effect on *Actual* Ship Service Life	Strong driver – can't cost effectively update	Moderate driver – Ships decommissioned early

- Affordability will become increasingly important.

Modular, Adaptable , Flexible Ship Technologies enable ships to affordably remain Operationally Relevant over their Service Life.

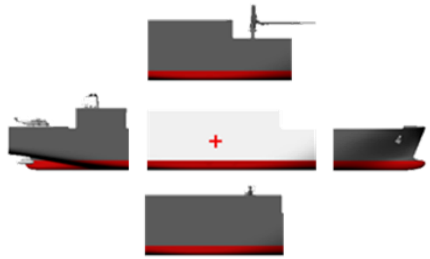


Koenig, Dr. Philip, Don Nalchajian, and John Hootman,"Ship Service Life and Naval Force Structure," ASNE ETS 2008, 23-25 Sept 2008

Modular, Adaptable, Flexible Ship Technologies

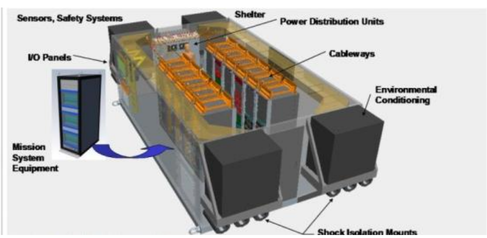
Container Stacks

Modular Hull Ship

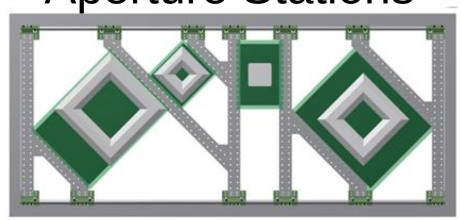


Off-Board Vehicles

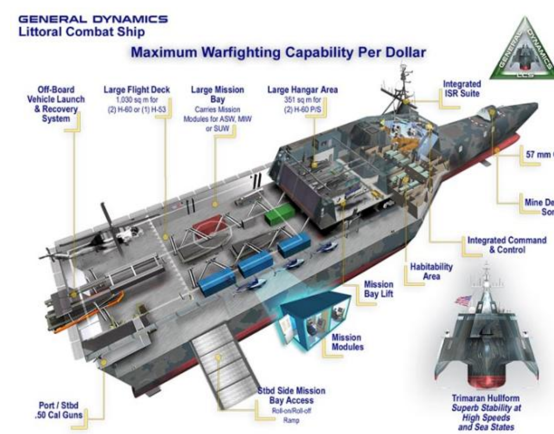
Electronic Modular Enclosures



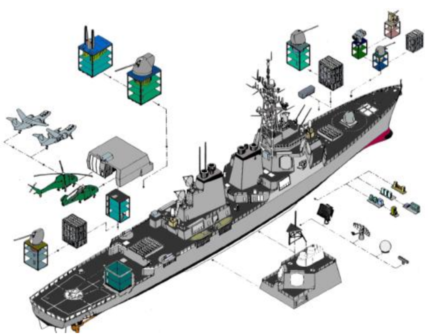
Aperture Stations



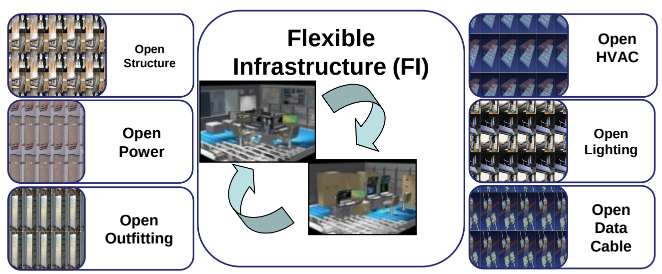
Mission Bay



Weapons Modules



Flexible Infrastructure



Impact on ship design and modernization

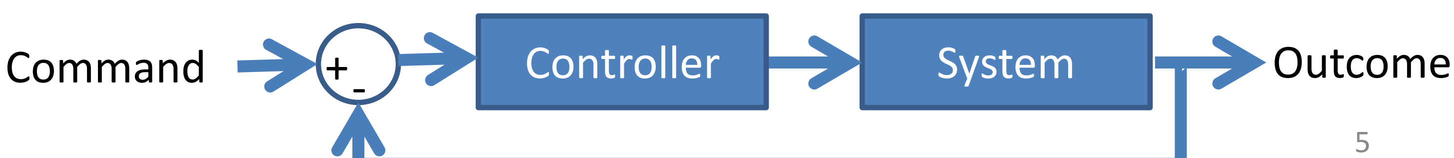
- Need a method to determine the best types and amount of modularity, adaptability, and flexibility.
- A modular, adaptable, and flexible ship is not sufficient; need to understand what the Navy’s infrastructure must do to ensure ships are affordable and militarily relevant over their service life.

Open-Loop vs Closed-Loop Systems

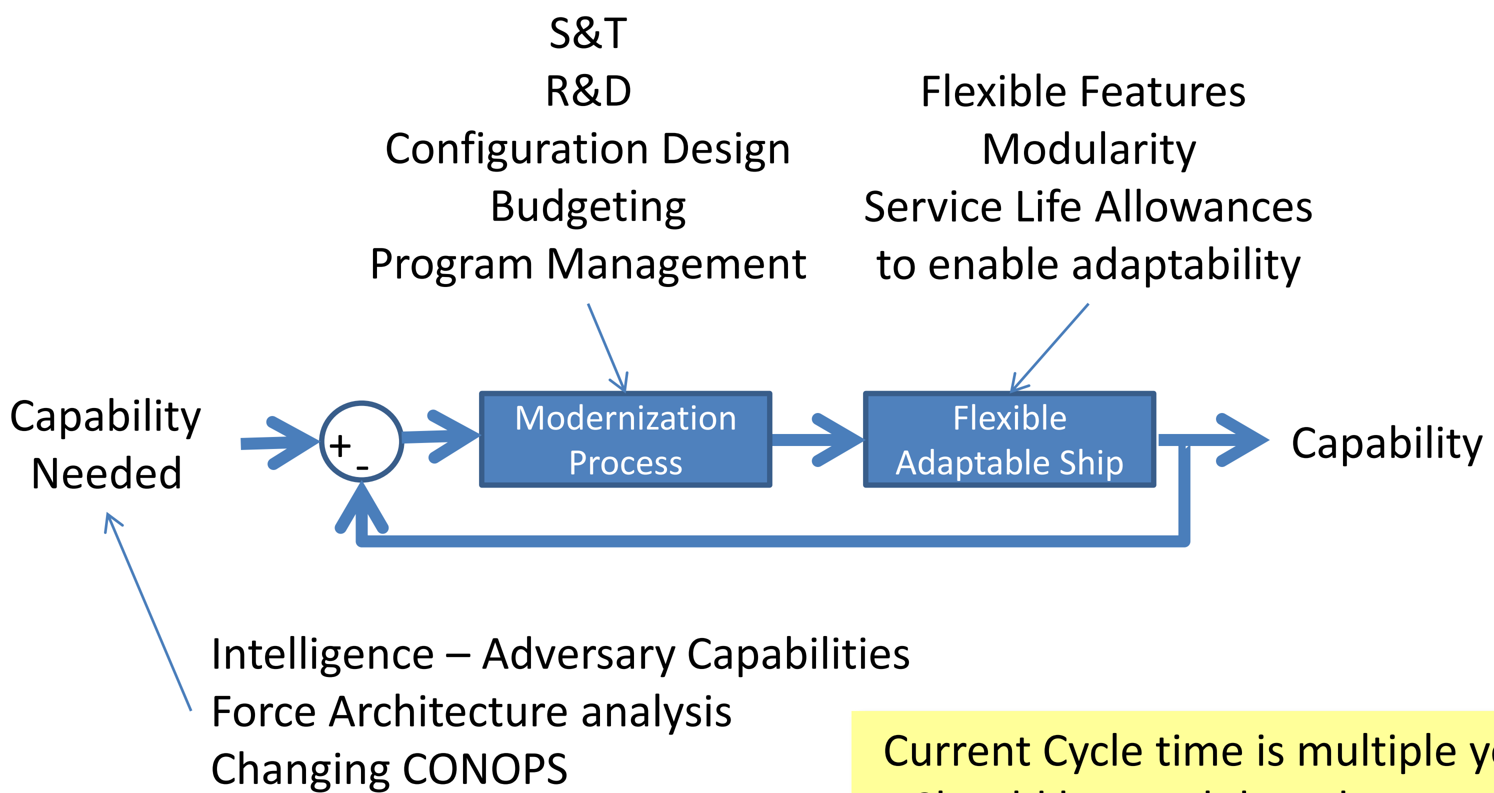
- Current Acquisition System acts like an open-loop system
  - Command = Requirements
  - Must get the requirements (aim point) nearly perfect for good outcome (but the target is moving fast and changing directions)
- Flexible-Adaptable Acquisition allows in-service course correction
  - "Control authority" becomes a more important attribute
  - System is corrected in-service to respond to changing needs.
    - Aim point is corrected by feedback to hit the target

Open Loop

Closed Loop



Need to rapidly evolve a ship over its service life to reflect evolving needs

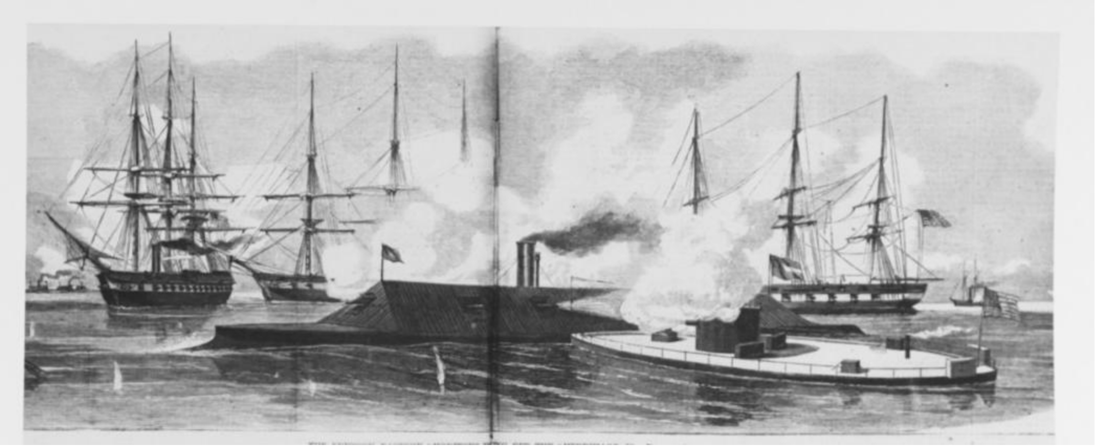


Current Cycle time is multiple years
Should be much less than a year

A Vision ....

As part of the normal course of business, be capable of successfully responding to a technological or CONOPS surprise within six months.

- July 11, 1861: Conversion of CSS Virginia ordered
- August 3, 1861: SECNAV issues RFP for ironclad vessels
- September 16, 1861: Ericsson's design from 1854 for France chosen as one of three designs
- October 4, 1861: Contract Award
- January 30, 1861: Monitor launched
- March 7, 1862: CSS Virginia is completed
- March 9, 1862: USS Monitor engages CSS Virginia



What do we need?

- Flexible Adaptable Ships
  - ***<u>How much of what type of modularity, adaptability & flexibility?</u>***
- Ability to rapidly assess own capability
- Ability to rapidly assess needed capability
- Ability to rapidly determine required change
  - In capability
  - To the ship configuration
  - To the CONOPS

  to achieve the needed capability
- Ability to rapidly acquire, install, and test the change to the ship configuration
  - And train the crew too!
- Continuous pipeline of technology moving from S&T into R&D
  - Technology must be transitionable to Acquisition ahead of the known needs
  - Acquisitions within the closed loop cycle integrate mature technology

Ability to rapidly respond to new threats Fleet-wide becomes a strategic capability.
We can't build and field a ship in 7 months like Ericsson did;
But we can modify a modular, adaptable & flexible ship in that time.

Real Options: A different view of design and modernization

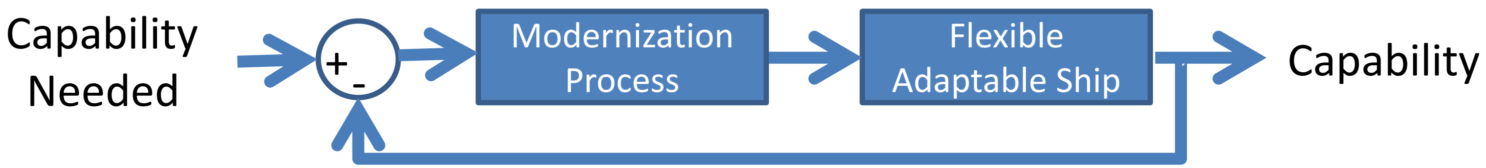
- Modularity, Flexibility, and Adaptability intrinsically create options having many (but not all) of the attributes of financial options.
- The value of these options is not currently calculated or documented in a formal way.
  - Net Present Value does not capture the value of being able to defer a decision until uncertainty has been reduced
- If option value were explicitly recognized, design and program decisions would benefit from additional insight, and certain types of design features would be more highly valued.

Based on presentations from Dr. Phil Koenig

Prerequisites for Real Options

- A financial model must exist
- Uncertainties must exist
- Uncertainties must affect decisions when leadership is actively managing the project and these uncertainties must affect the results of the financial model
- Management must have strategic flexibility or options to make mid-course corrections when actively managing the projects
- Management must be smart enough and credible enough to execute the options when it becomes optimal to do so

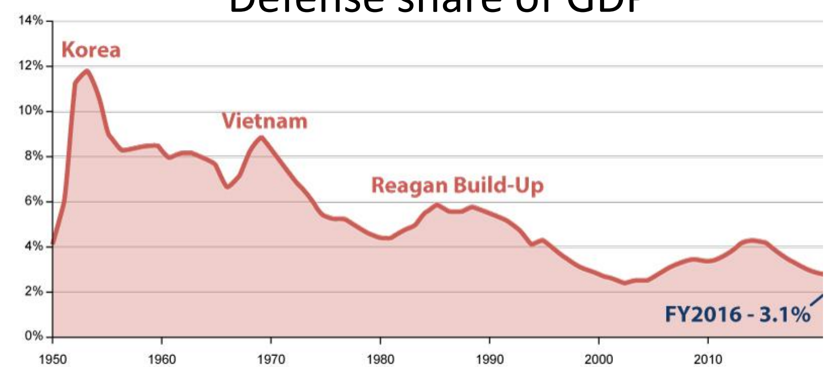
Based on Johnathan Mun, Real Options Analysis, John Wiley & Sons, Inc, 2006



Challenges

- Traditional Real Options Analysis monetizes the entire problem
  - Uncertainties impact future cash flows
  - Goal is typically to maximize profit, recognizing risk
- Warships don't exist to make money
  - Goal is to minimize magnitude of "capability gap" over service life
    - Especially during Major Combat Operations
  - Funding is constrained
    - Degree of constraint depends on perceptions of threat

Defense share of GDP



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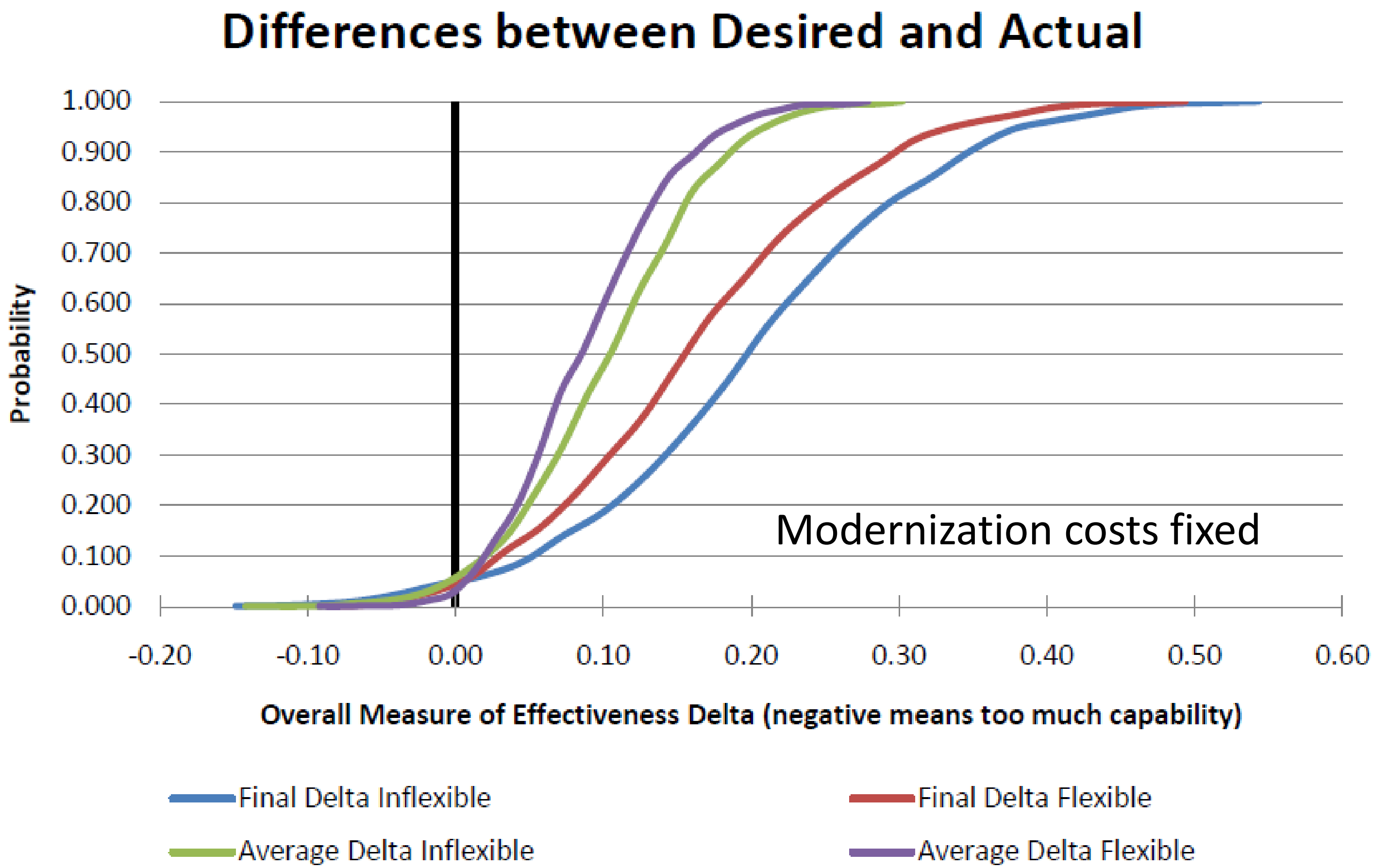
Modeling Capability / Capability Gaps

- Propose using Required Operational Capabilities (ROC) and Projected Operational Environment (POE) as the basis for Measures of Effectiveness (MOE)
- Measures of Performance (MOP) are based on own ships'
  - Weapons systems
  - Signatures
  - CONOPS
- MOEs are a function of MOPs and measures of potential adversary performance (which is a stochastic function of time)
- A mismatch between MOE achieved and MOE desired is a capability gap
  - May only occur for a finite period of time

Comparing Options



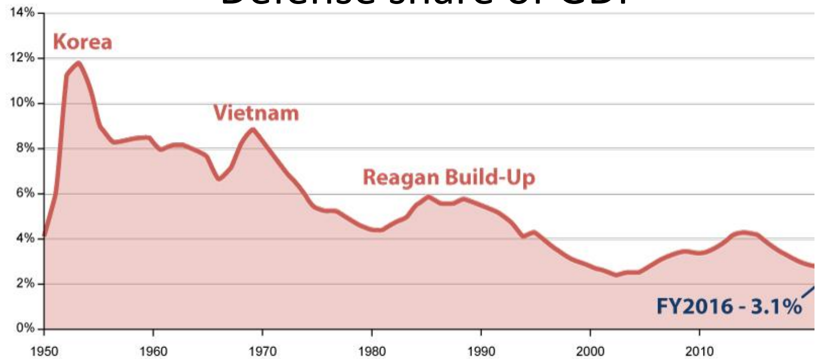
Page, Jonathan, " Flexibility in Early Stage Design of US Navy Ships: An Analysis of Options," SM and NE Thesis, MIT, Engineering Systems Division and the Department of Mechanical Engineering, June 2011

Severity of a Capability Gap

The impact of a capability gap depends on the state of international relations

- Major Combat Operations (MCO):
  - High Severity: Gaps lead to many lost lives; lost objectives
  - Availability of resources is the greatest
- Regional Conflicts, Preparing for MCO:
  - Medium Severity: Gaps hinder deterrence; may lead to some loss of life
  - Availability of resources is moderately constrained
- General Peace
  - Low Severity: Gaps hinder deterrence
  - Availability of resources is greatly constrained

Defense share of GDP



ROC / POE

- Established for each ship class
  - OPNAVINST 3501 series
- Required Operational Capabilities (ROC)
  - Defines primary and secondary warfare mission areas in a standardized way
  - Defines specific operational capabilities
  - Defines conditions of readiness
    - Defines desired level of achievement of each operational capability for each condition of readiness
- Projected Operational Environment (POE)
  - Provided Context for how the ship will operate within the battle force and threat environment
  - Does not identify specific threats

ROC Example: CG 47 Class

CG 47 Class														
AW	**AMW**	**ASW**	**CCC**	**FHP**	**FSO**	**INT**	**IO**	**LOG**	**MIW**	**MOB**	**MOS**	**NCO**	**STW**	**SUW**
P	P	P	P	S	P	S	P	S	S	P	P	S	P	P

AW:	Air Warfare	IO:	Information Operation
AMW:	Amphibious Warfare	LOG:	Logistic
ASW:	Anti-Submarine Warfare	MIW:	Mine Warfare
CCC:	Command Control and Communication	MOB:	Mobility
		MOS:	Mission Of State
FHP:	Force Health Protection	NCO:	Non-Combat Operation
FSO:	Fleet Ship Operation	NSW:	Naval Special Warfare
INT:	Intelligence Operation	STW:	Strike Warfare
		SUW:	Surface Warfare

CG 47 CLASS			I	III	IV	V
AIR WARFARE (AW)						
AW 1	**PROVIDE AIR DEFENSE INDEPENDENTLY OR IN COOPERATION WITH OTHER FORCES.**					
	AW 1.1	Provide area defense for a strike group (SG). NOTE: If equipped, provide regional tactical BMD during SG operations. III(L) - One of two launchers manned. Maximum use of automated engagement management systems. Requires manning of tactical action officer (TAO), combat systems coordinator, missile systems supervisor and air warfare (AW) coordinator. IV, V(L) - Plan and train.	F	F	L	L

OPNAVINST 3501.160C CH-2 , "Required Operational Capabilities and Projected Operational Environment for CG 47 (Ticonderoga) Class Guided Missile Cruisers", of 15 Aug 2014.

POE Example: CG 47 Class

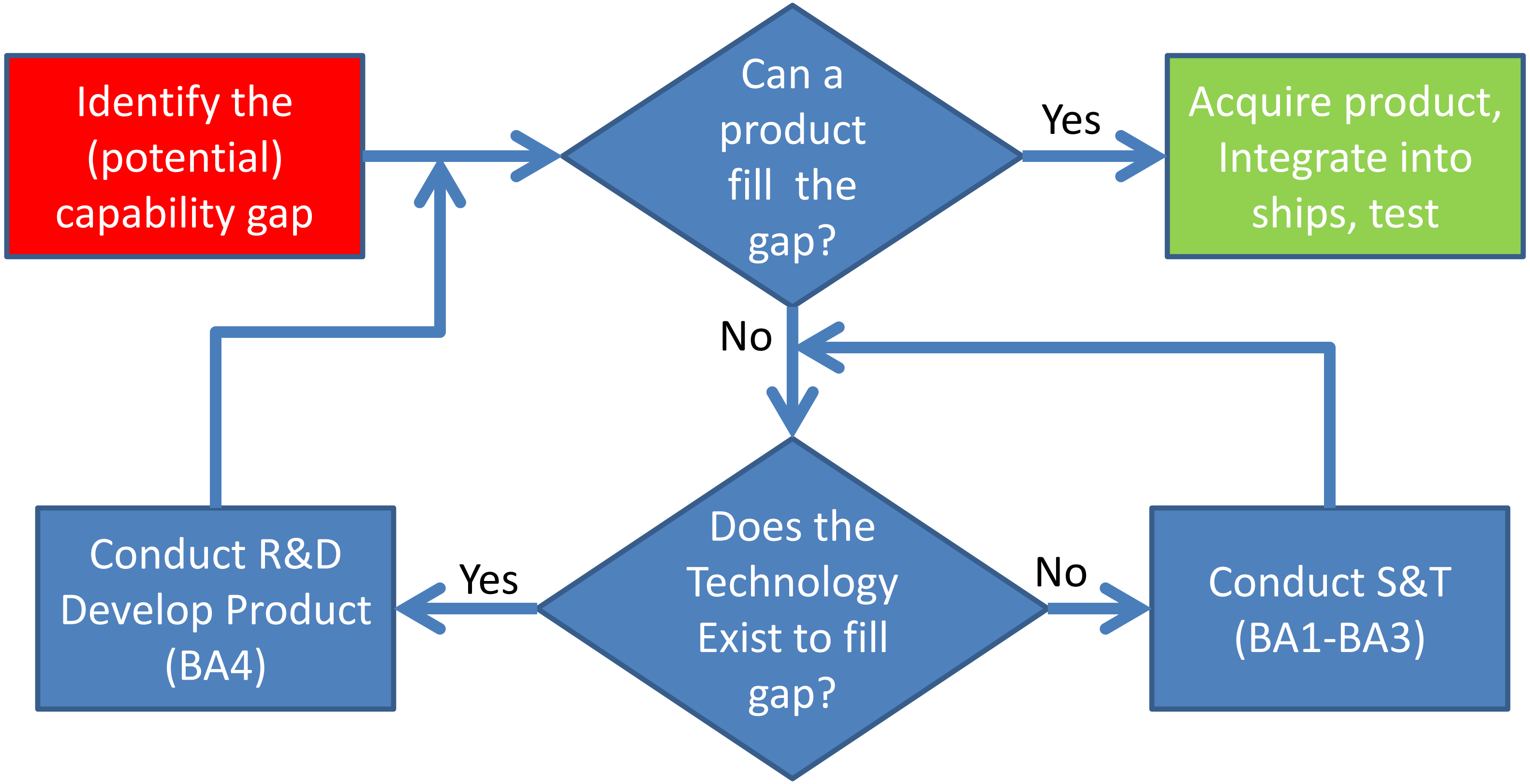
1. The CG 47 class guided missile cruiser's mission is to operate in up to and including a high density, multi-threat environment as an integral element of the task force (TF) or task group (TG). The mission includes strike warfare (STW) functions against inland targets beyond hostile shorelines and area air defense coordination. The CG 47 provides its own anti-air, anti-surface and anti-submarine self-defense, and must effectively provide local area protection and maritime ballistic missile defense (BMD), if so equipped, to the force, group, or other military shipping against air, surface and subsurface threats.

OPNAVINST 3501.160C CH-2 , "Required Operational Capabilities and Projected Operational Environment for CG 47 (Ticonderoga) Class Guided Missile Cruisers", of 15 Aug 2014.

Use of ROC / POE

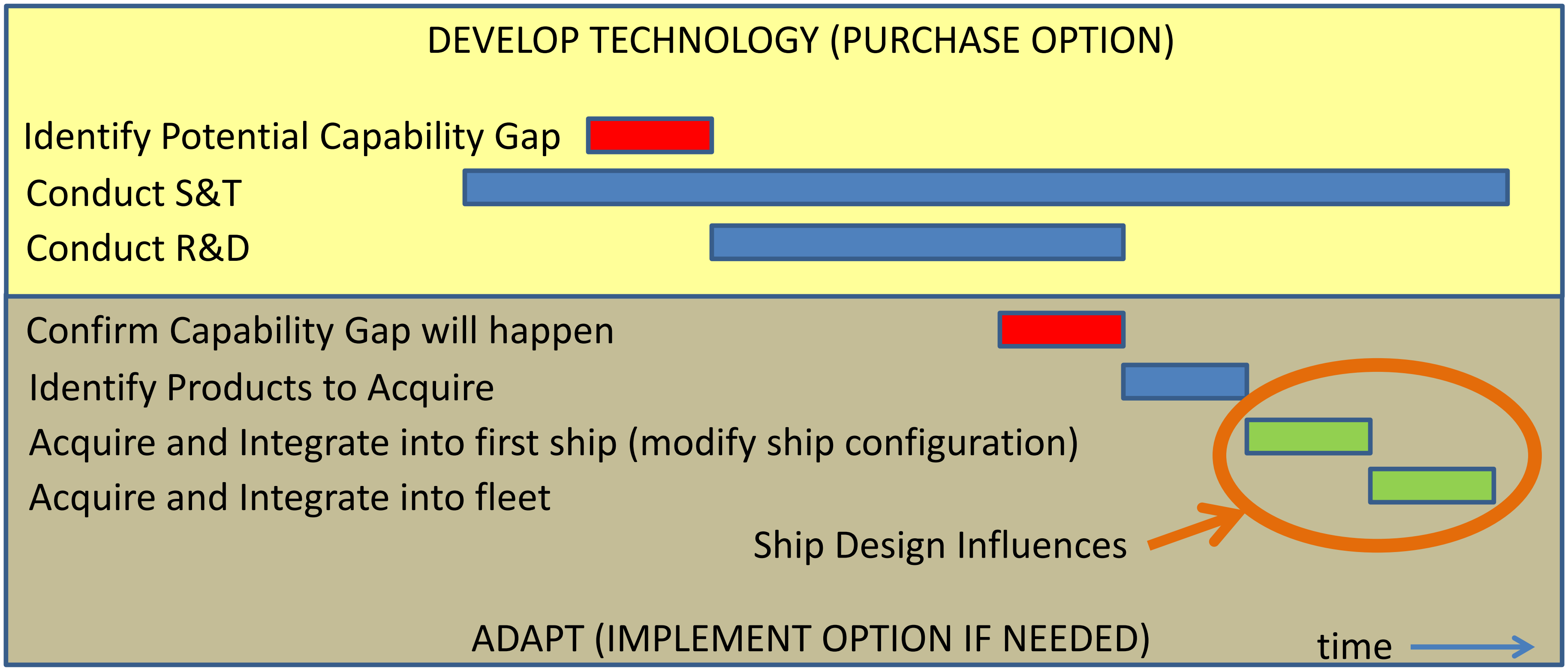
- The Enemy gets to vote
  - As a potential adversary improves, so must the capability of a warship improve to meet the same ROC / POE.
  - Or in other words, a ship's operational capability will decrease with time if not modernized.
  - Use Intelligence forecasts to project stochastically a potential adversary's capability in a given year.
- The degree to which assigned ROC / POEs are achieved at any given time is a metric of the success of the design and modernization process.

Technology and Product Development



The time to respond to a capability gap depends on prior S&T, prior R&D, resources available and ability of ship to integrate new technology

S&T and R&D as options



Minimize Duration of Actual Capability Gap while staying within resource constraints

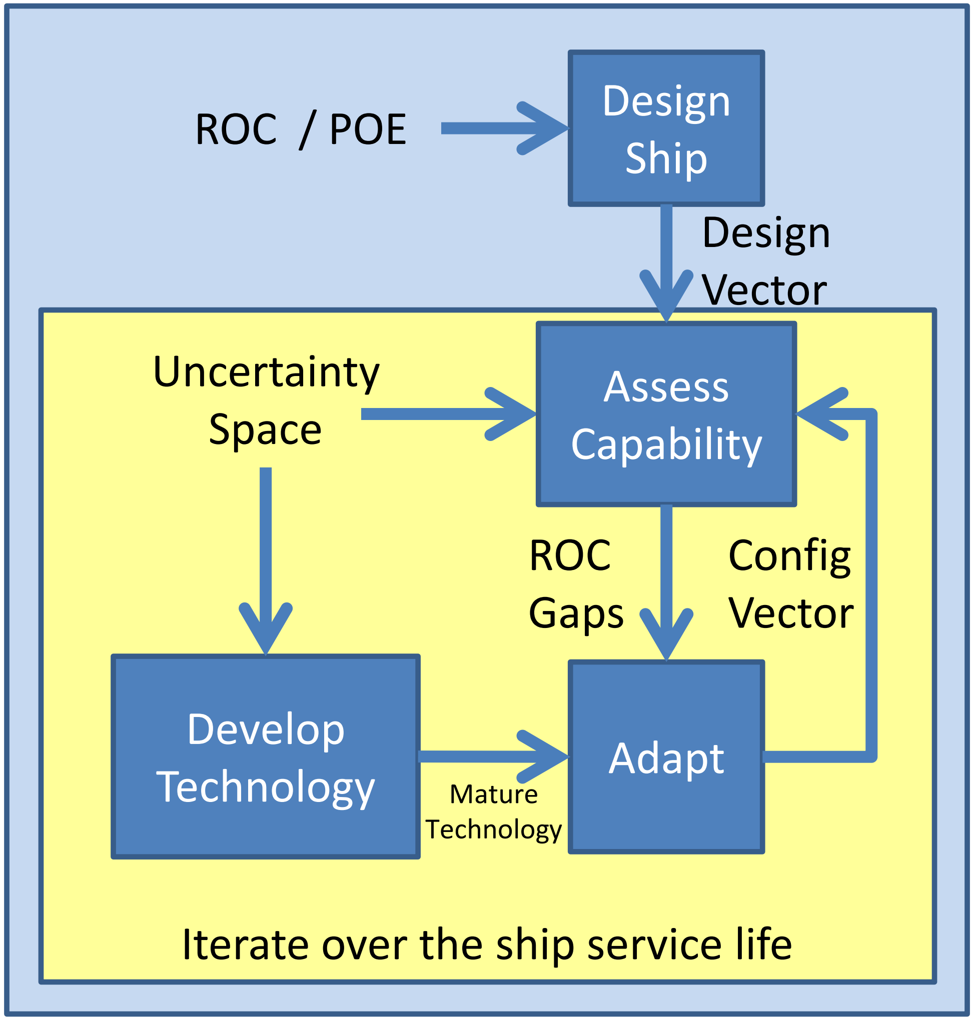
Uncertainty Space

- Stochastic properties that influence capabilities and capability gaps
- Markov chains likely a good way to model
- Examples
  - Adversary capabilities
  - State of international relations
    - Influence on available resources and severity of gaps
  - Progress of S&T and R&D
    - Influence on own ship capabilities and gap duration
  - Speed of Integration
    - Influence on gap duration

Modeling Flexible Ships

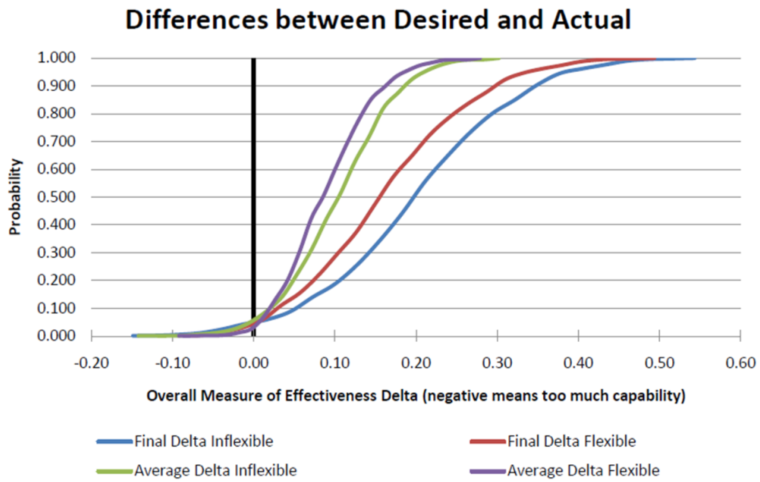
- Design Vector: Initial design of the ship + tactics + modernization process
- Configuration Vector: design of the ship + tactics as they evolve in time while in-service
- Uncertainty Space: adversary capabilities, technology breakthroughs, available budget, projections
- ROC Gaps: Primary Mission Area Required Operational Capabilities that are not meant or projected to meet.
- Mature Technology: Technology that can be applied to a ROC Gap to change the Configuration Vector

Track the cost of all the processes



Cost / Comparing Alternatives

- Cost is used to constrain the process, not as a direct measure.
  - Effective use of available resources to minimize the weighted capability gap is desired.
- Alternatives evaluated over many iterations of the Uncertainty Space
  - Monte Carlo Analysis
  - Develop statistics for capability gaps
- Alternatives are compared based on the same availability of resources.
  - Instead, alternatives compare statistics on the capability gaps.



Summary

- Cannot evaluate the value of modularity, flexibility, and adaptability by only examining the ship design.
- Must also consider
  - How gaps are identified.
  - How technology is developed.
  - How ship configurations are adapted to close the gap.
  - How resource constraints impact the response to a gap.
- Real Options provide a toolkit for addressing these issues.
  - Ongoing research efforts at NAVSEA, NPS, and elsewhere are exploring how to apply Real Options
- Compare alternatives by comparing statistics of capability gaps for same set of resource constraints.