# *Fire Control in Harpoon V*

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*Historicon 2021*

*Admiralty Trilogy Seminar*

# Outline

- **Major change to *Harpoon V* is Chapter Six – Fire Control**
  - **Some bits for SAM engagements in Chapter Eight – Surface Warfare**
  - **Rules focus on the amount of time to achieve a specific solution quality**
- **The Fire Control Problem**
  - **Kill Chain Concept**
  - **Tracking vs Targeting**
- **Quality of Sensor Data with Distance**
  - **Passive vs Active**
  - **Sensor Error**
- **Fire Control Process**
  - **Generations – Processing Capability**
  - **Data Links**
  - **Design for Effect Approach**
- **Conclusions**

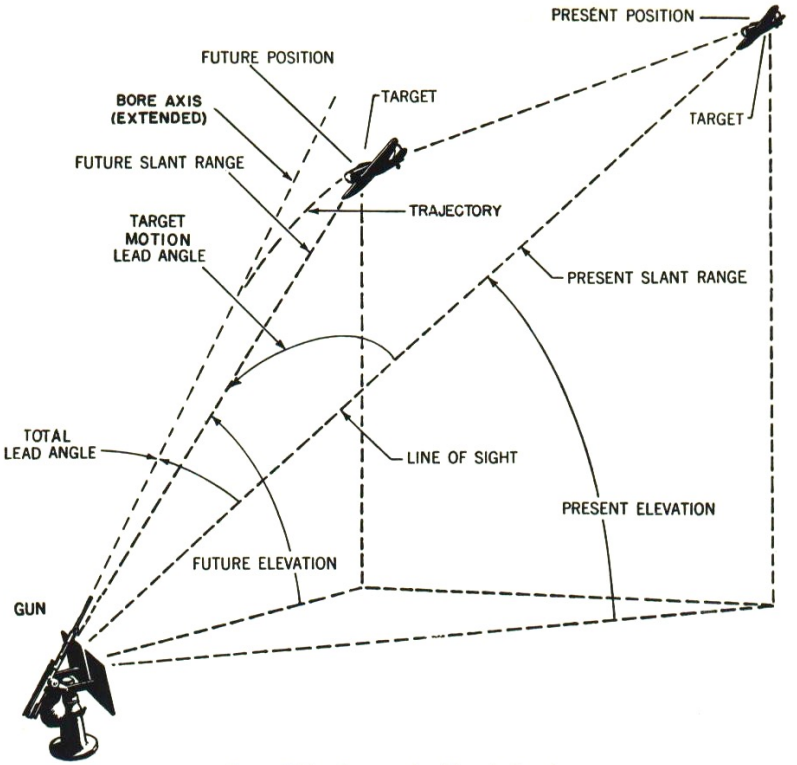


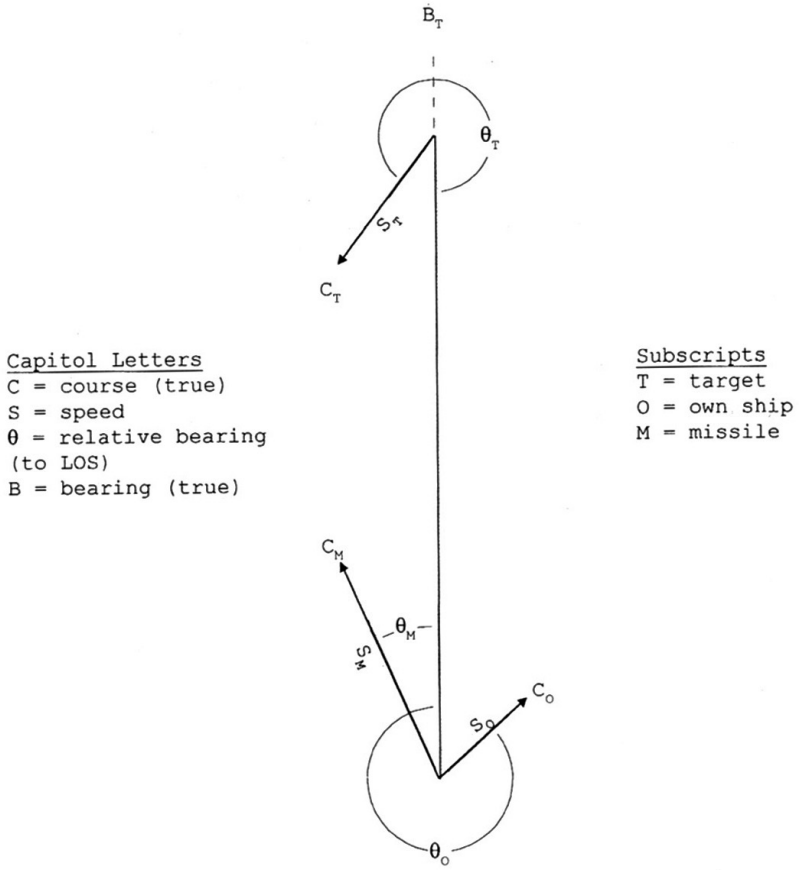

FIGURE 26A1.—Fire control problem; lead angle.

# Big Changes in Harpoon V

- **The fifth edition of Harpoon had a lot of changes:**
  - **Revised surface-to-air engagements and AA fire**
  - **Mine warfare, anti-ship ballistic missiles and BMD added**
  - **Revised sensor models to include the addition of radar ducting**
- **One the biggest changes was the introduction of fire control**
  - **A critical, if often overlooked, aspect of naval warfare**
  - **The Issue: Figuring out where the contact will be at some future time**
  - **Very complex set of calculations, especially in three dimensions**
  - **The number crunching takes time - greater the range, the more time it takes**
- **Why bother?**
  - **Instant targeting information is a gross misconception in many games**
  - **Great source of "friction" and "fog of war" – Clausewitz**
  - **System reaction time is largely driven by the fire control process**
  - **The quest for reach and/or speed drove significant research & development by both sides during the Cold War**

# The Fire Control Problem

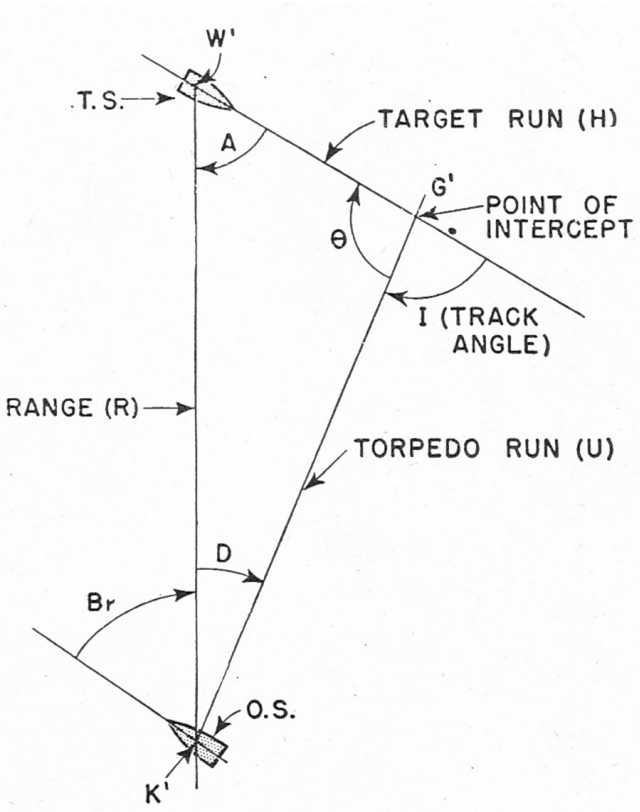
- **Wargamers have access to far too much information on the playing table**
  - **They know an engagement is coming**
  - **They can often see the other side's units and their movement**
  - **Believe detection means they can shoot**
- **What is fire control?**
  - **The planning, preparation, and delivery of fire on an adversary unit (ship)**
  - **Entire process of utilizing a ship's sensors and armaments to deliver maximum destruction in the shortest amount of time**
  - **In essence: predict the future and put ordnance in the same place, at the same time as the target**




**Missile Fire Control Problem**

# The Fire Control Problem

- **Fire control is a vector analysis problem**
  - Where is the target now?
  - Where is it going?
  - Where am I going?
  - Where does my fire need to go?
- **In the simplest sense, fire control is about figuring out a collision course for the weapon that is fired against the target**
  - Need to determine the target's range and bearing from own ship
  - Need to determine the target's course
  - Need to determine the target's speed
    - Speed across the line-of-sight – bearing rate
    - Speed in the line-of-sight – range rate
    - The rate at which speed components are changing




Torpedo Fire Control Problem

# Look Familiar?

**Torpedo Deflection Angle Table**

| Target Angle | Target Speed 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 10 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 |
| 20 | 2 | 3 | 5 | 7 | 9 | 10 | 12 | 14 |
| 30 | 3 | 5 | 8 | 10 | 13 | 15 | 18 | 2 |
| 40 | 3 | 6 | 10 | 13 | 16 | 19 | 23 | 26 |
| 50 | 4 | 8 | 12 | 15 | 19 | 23 | 27 | 31 |
| 60 | 4 | 9 | 13 | 17 | 22 | 26 | 30 | 35 |
| 70 | 5 | 9 | 14 | 19 | 24 | 28 | 33 | 38 |
| 80 | 5 | 10 | 15 | 20 | 25 | 30 | 34 | 39 |
| 90 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |

| Torpedo Speed 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | Deflection Angle |
|---|---|---|---|---|---|---|---|---|
| 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 5 | 7 | 9 | 10 | 12 | 14 | 15 | 17 | 20 |
| 8 | 10 | 13 | 15 | 18 | 20 | 23 | 25 | 30 |
| 10 | 13 | 16 | 19 | 23 | 26 | 29 | 32 | 40 |
| 12 | 15 | 19 | 23 | 27 | 31 | 35 | 38 | 50 |
| 13 | 17 | 22 | 26 | 30 | 35 | 39 | 43 | 60 |
| 14 | 19 | 24 | 28 | 33 | 38 | 42 | 47 | 70 |
| 15 | 20 | 25 | 30 | 34 | 39 | 44 | 49 | 80 |
| 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 90 |

*CaS* and *FG&DN* Torpedo Attack Aid

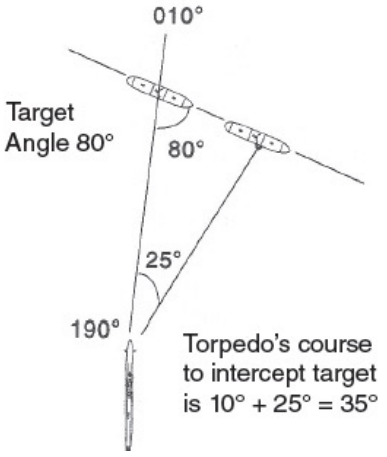
**Unguided Torpedo Firing Example**

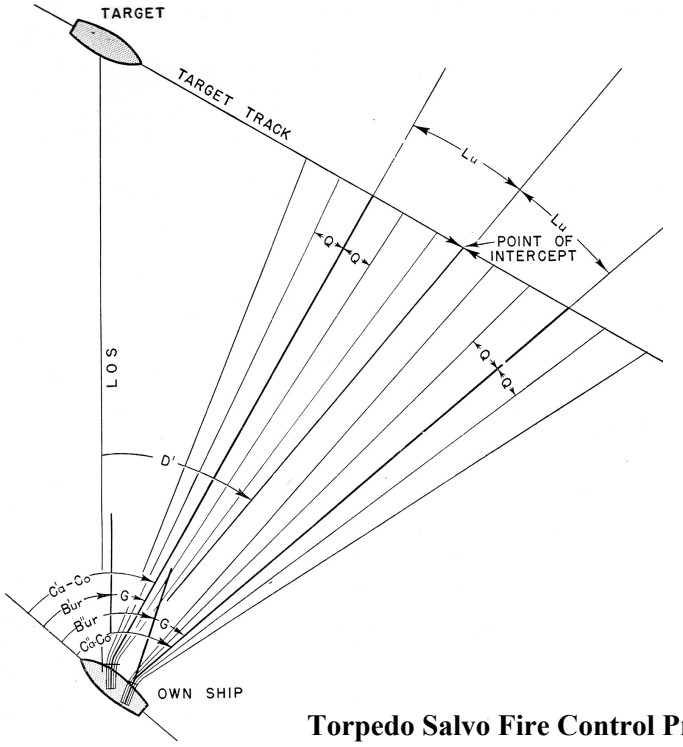
1. Target ship's track.
Course 110° T, speed 15 knots.

2. Line of bearing from the firing ship to the target is 010° T.

3. Apparent target speed is 15 knots, torpedo speed is 35 knots.

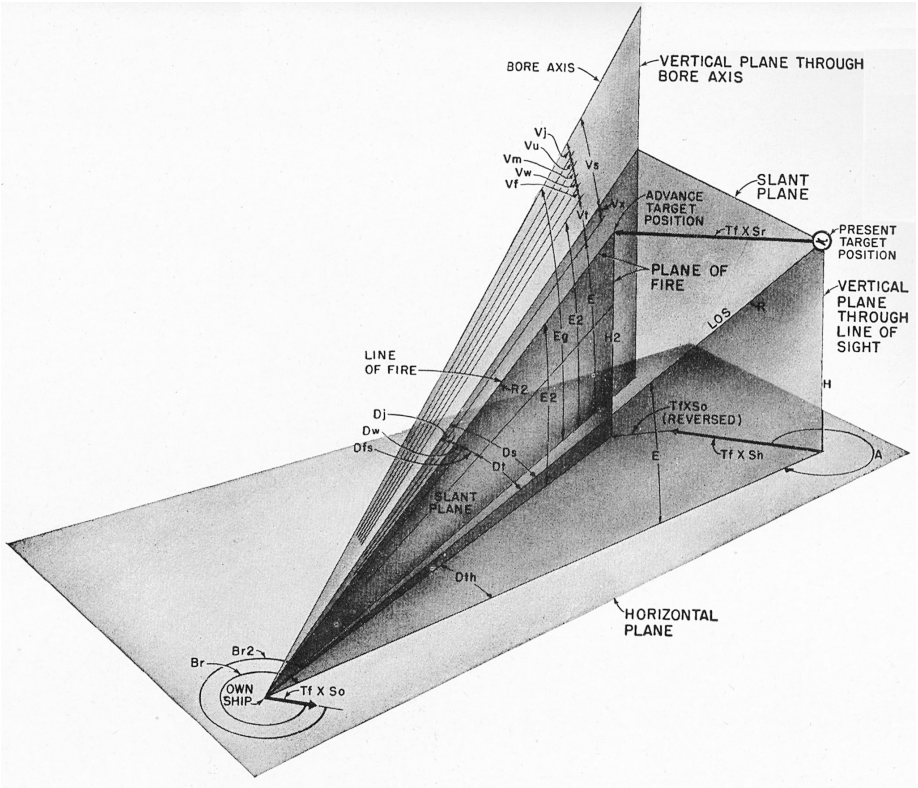
4. Deflection (lead) angle is 25°. Add this to target's bearing to get the intercept course for the torpedo – 35°.



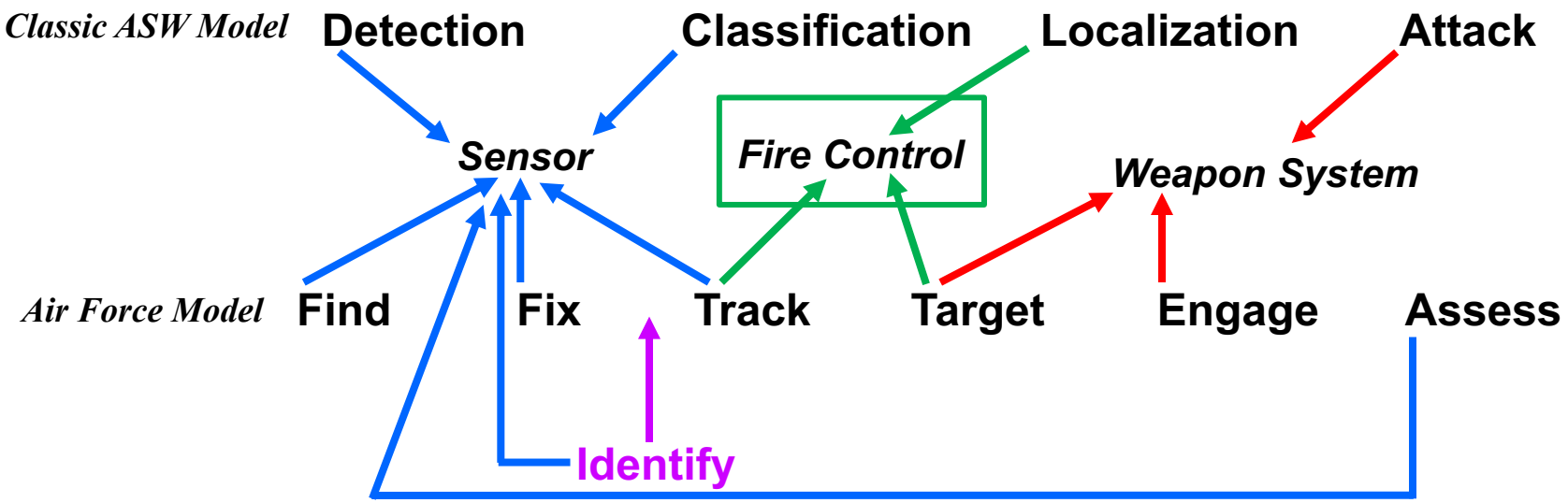

Torpedo Salvo Fire Control Problem

# The Fire Control Problem




- Use the target's movement vector to calculate a future position, at a specific time, and aim your weapon to collide with the target
  - Unguided weapons need to collide, guided weapons just need to get close enough for the homing system to acquire the target – a little easier
- 2D problems are tricky, 3D problems are just plain hard
  - This is why fire control computers were developed to do all the nasty math

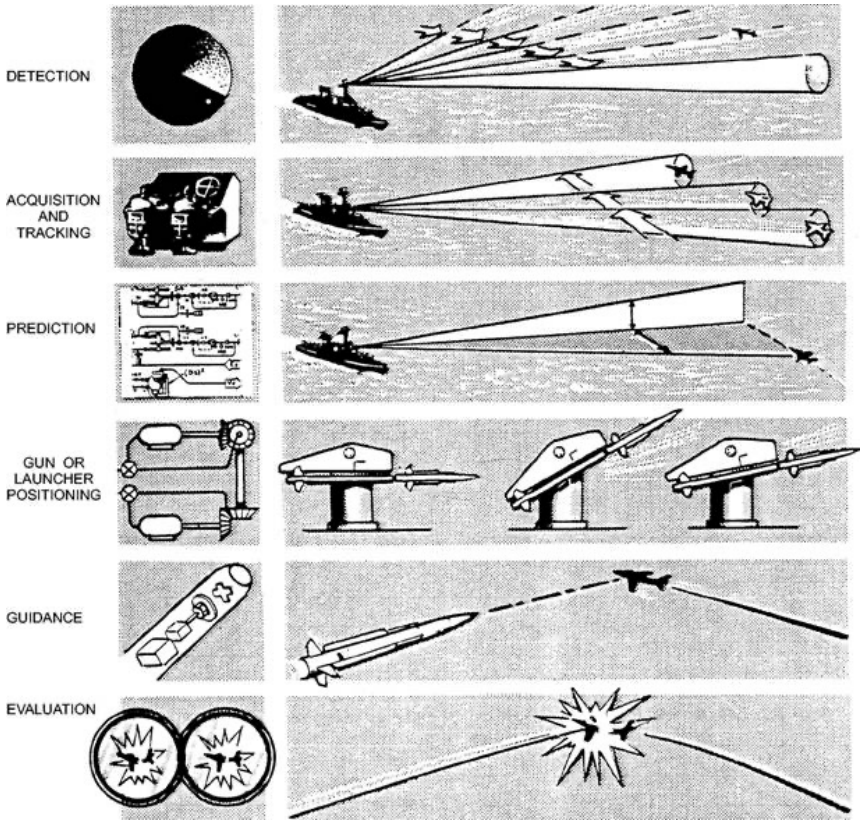
# Kill Chain Concept




- The "Kill Chain" is an abstract analytical model that breaks down the complex nature of combat into logical, manageable steps.
- Fire control systems link sensors via command, control, and display functions to weapon systems
  - In *Harpoon V*, these are referred to as "Combat Systems"

# Track vs Targeting Quality Data

- **In the Air Force model, "Target" has more to do with picking the right weapon to do the job**
- **In the ASW model, localization takes the form of two steps: tracking and targeting**
  - **Both involve following a target's movements**
  - **Tracking is maintaining sensor contact to "track" the target's motion**
  - **Targeting refines track data through computer systems or plots to accurately predict the target's future movement – develop a fire control solution**
  - **The best way to visualize this is to think in terms of Area of Uncertainty (AOU)**
    - **Targeting has a smaller AOU than tracking**

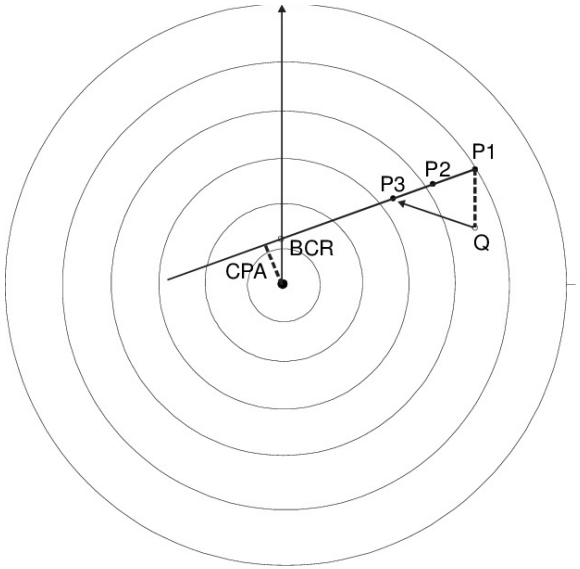



***Track quality = Poor solution***

***Targeting quality = Fair or Good solution***

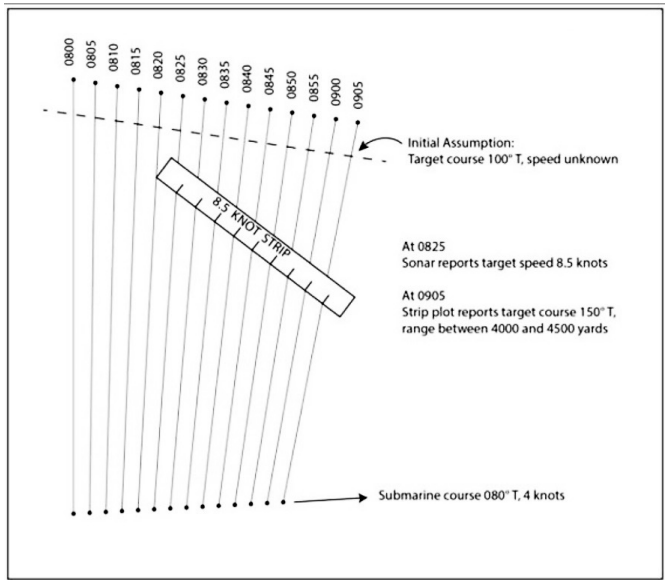
# Passive vs Active

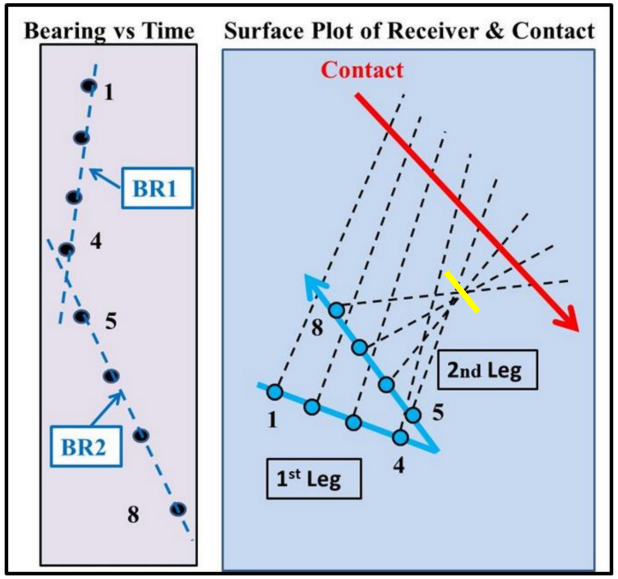
- The time to solve the fire control problem depends on how much information you have on the contact – e.g., bearing, range, speed
- Active sensors provide more information than passive ones
  - Active provide range and bearing
  - Passive provide bearing only
- Passive sensors may require own ship maneuvers to try and determine the contact's range – this takes a lot more time




Active Fire Control Problem

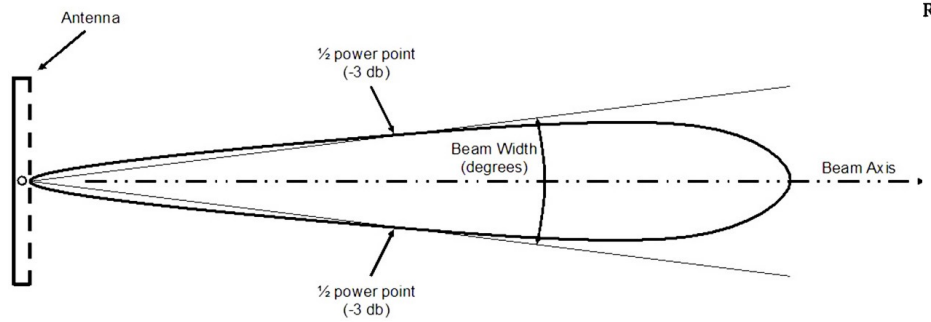
Passive Fire Control Problem



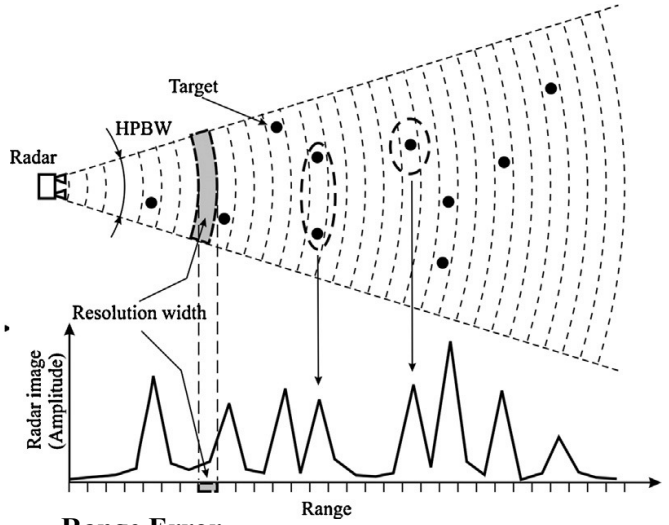



# Sensor Error

- All sensors have errors or accuracy limits due to their design
  - Search sensors tend to have larger errors then dedicated tracking sensors
- Crew proficiency and equipment health (maintenance status) can increase sensor error considerably
- Bearing and range error increases as the target's range increases, there is more space that the contact could be in
  - Propagation path can also distort what the sensor believes it is detecting
- The greater the sensor error, the more time is needed to develop a fire control solution




Bearing Error

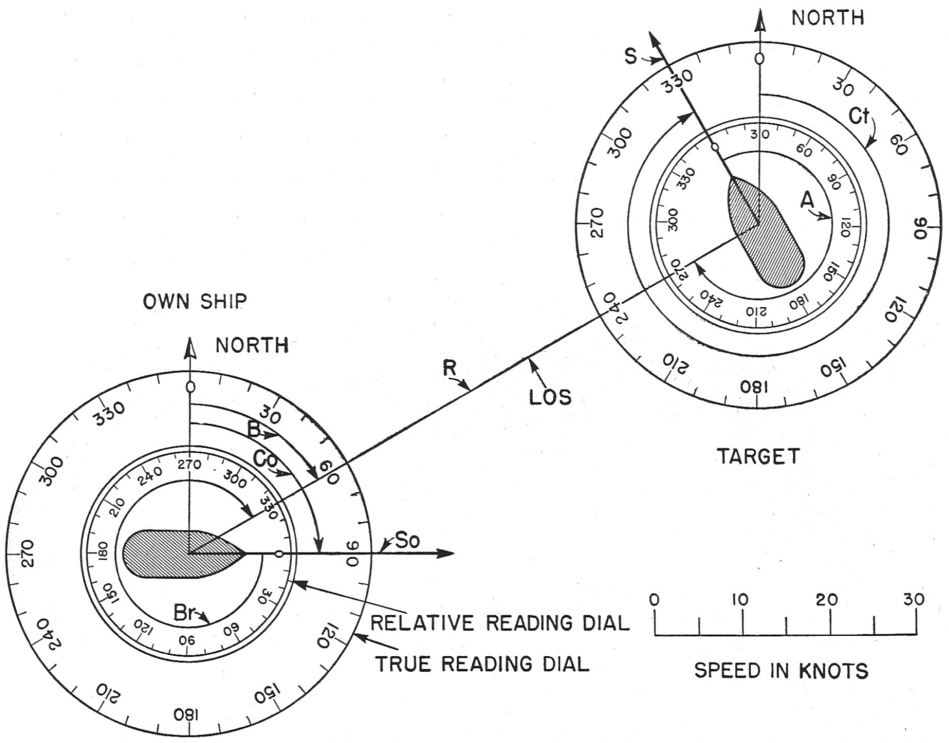


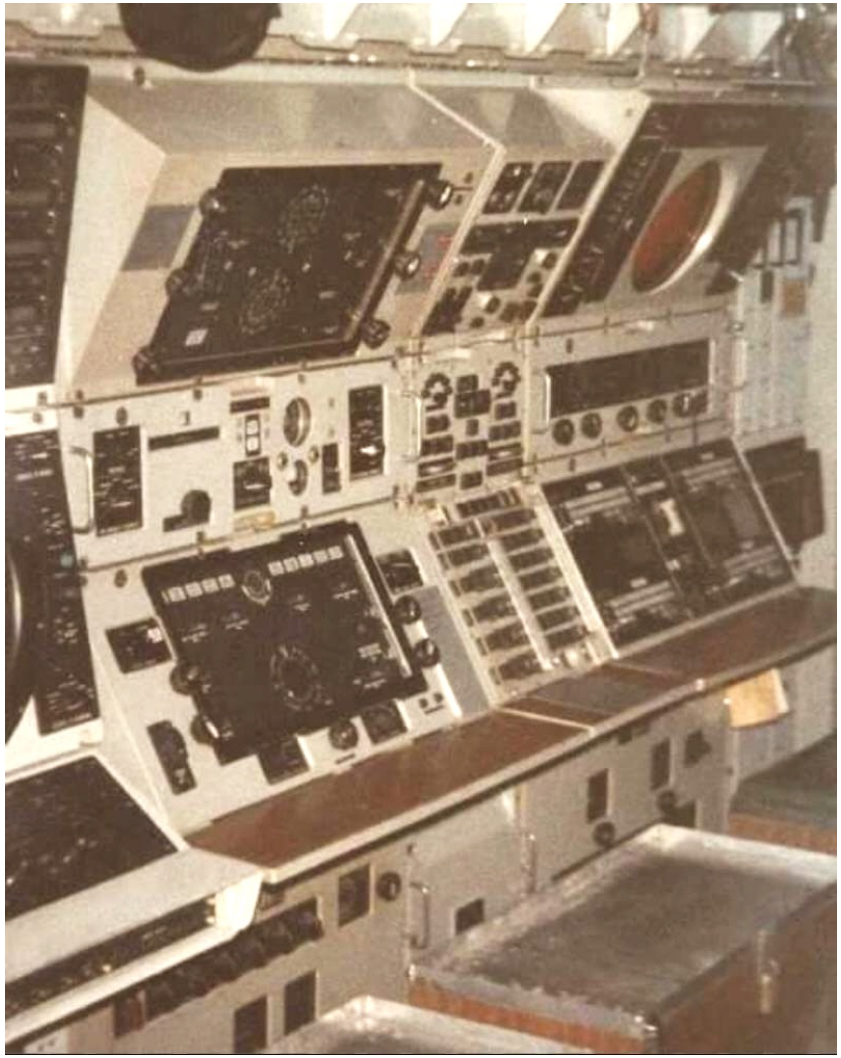

Range Error

# Combat System Generations

- ***Harpoon V*** **covers 1955 thru the present day, that's a lot of technological advances to fold into the various combat models**
  - **There are six technology levels or generations of combat systems**
    - **Gen 1 & 2 are manual analog computers and plotting tables**
    - **Gen 3 & 4 are semi-automatic but still require humans to make the final decisions**
    - **Gen 5 & 6 are largely automatic with either human control or fully automatic**
- **For AAW the system reaction time, which includes the time to develop the fire control solution, is reduced with more advanced systems (higher generation)**
  - **Kill assessment is also shorter for higher generations**
  - **Bottomline: Better combat system means more engagement opportunities**
- **For ASuW and ASW the higher generation systems require less time to achieve a "Good" quality fire control solution**
  - **Sensor limitations at longer ranges can limit the quality of the solution**
  - **Dedicated targeting complexes for over-the-horizon (OTH) targeting can significantly increase the range of high-quality fire control solutions**

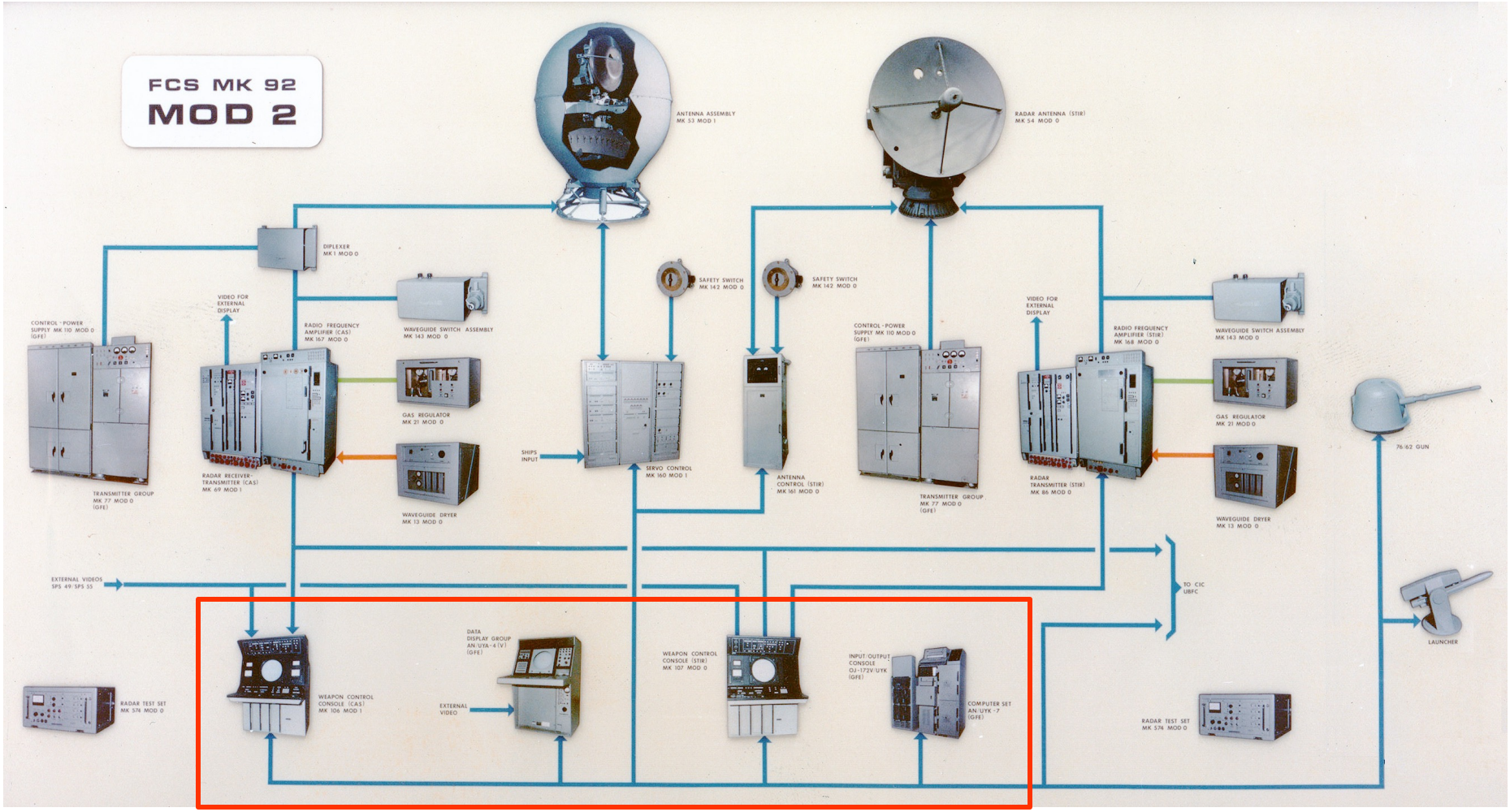
# Combat System Example



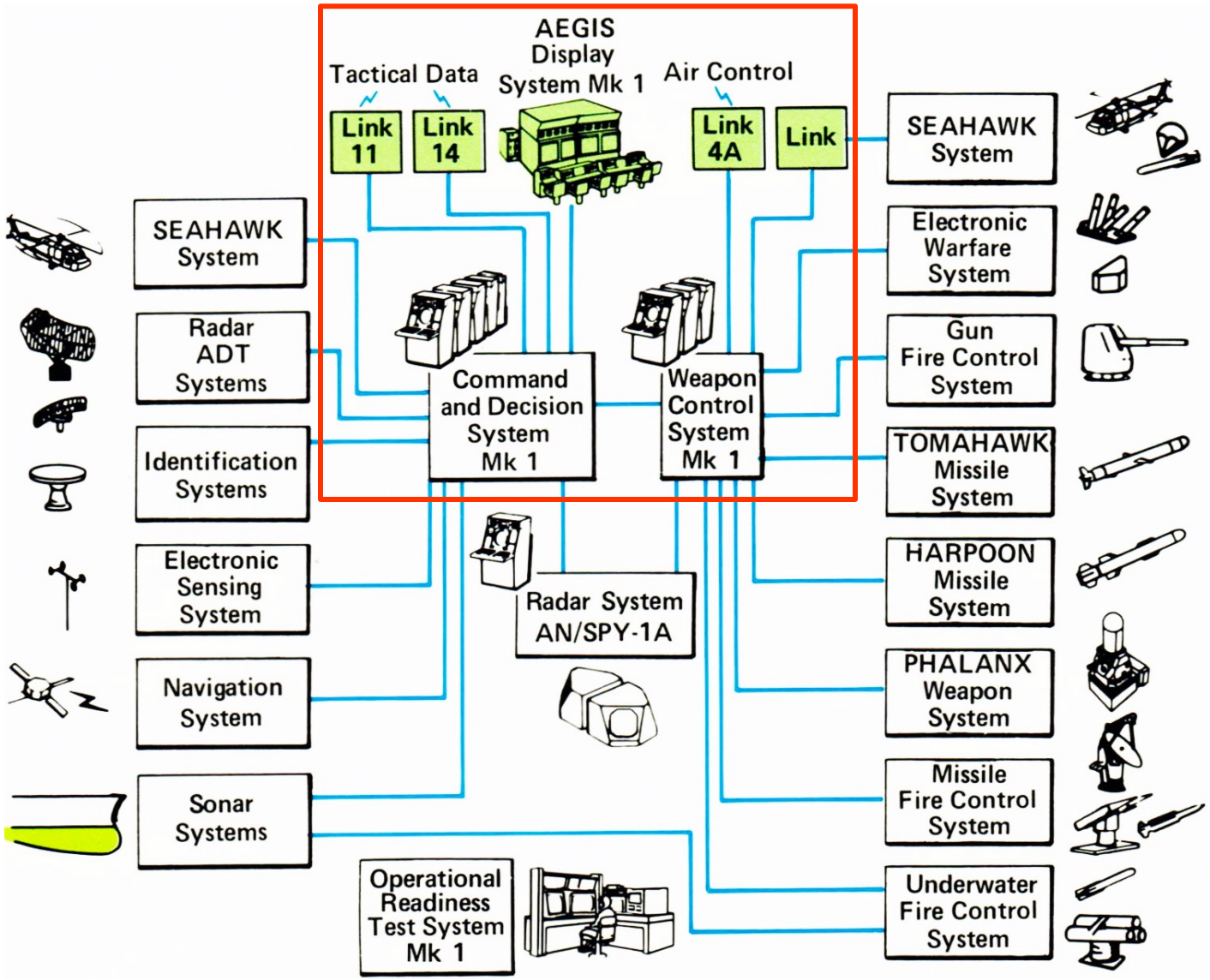
***Lafayette* SSBN Mk113 Mod 9 – Combat System: Gen 3 Semi-Automatic**

# Combat System Example




***O.H. Perry* FFG – Combat System: Gen 4 Semi-Automatic**

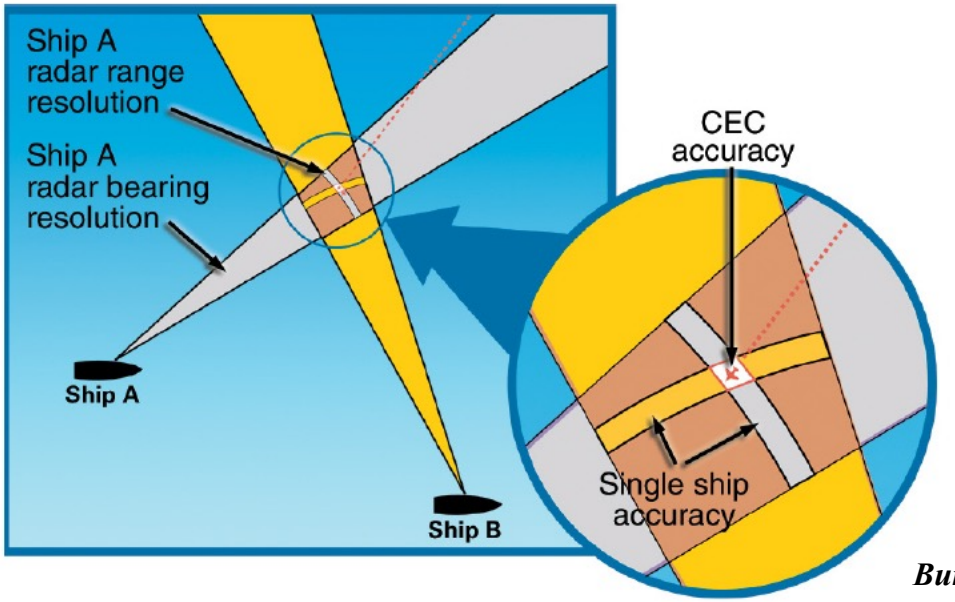
# Combat System Example




*Ticonderoga* CG – Combat System: Gen 5 Automatic

# Data Links

- **Data links transfer sensor or fire control information from another platform to the receiving ship's combat system**
  - **Time delays are just as important as the quality of the data**
    - **Good data, delivered slowly is just as ineffective as poor data, delivered quickly**
- **In some cases, a real time data link with high quality data allows a ship to engage without their sensors holding the contact**
  - **Cooperative Engagement Capability (CEC)**





*Burke II* DDG

# Design for Effect Approach

- **Historical wargames tend to fall into two major camps**
  - ***Design for Cause*: identify the major causal factors that impact an event and put them into the game design so that the event is likely to occur if the players' follow the same steps**
  - ***Design for Effect*: identify the "effect" or the outcome of an event and design the game mechanics such that the players' results is consistent with the historical data used as examples**
- ***Harpoon V* uses both techniques to replicate modern naval combat, however, if the process to be modeled is very complex, we tend to use the Design for Effect approach**
- **Since the primary outcome, or effect, of the fire control process is the *time* it takes to achieve an accurate fire control solution, quantifying the overall process in terms of time made a great deal of sense**
  - **Combat system generations and data links are means to reduce the time**
  - **Range, environment and enemy actions are means to increase the time**
  - **Besides, players really don't want to do all that boring math!**

# Conclusions

- ***Harpoon V*** **introduced the concept of the fire control process as this was largely missing from earlier versions and is critical to properly understanding modern naval combat as it has evolved**
  - **The time to generate a fire control solution is perhaps the most significant factor in the engagement process – assuming detection occurs**
  - **It helps put many of the R&D efforts and system developments during the Cold War into context**
    - **Soviet OTH targeting complexes**
    - **U.S. Aegis air defense system**
  - **To combat a serious misconception that just because you've detected a target doesn't mean you can shoot it and expect to get a hit**
    - **Wayne Hughes tactical maxim: Attack *effectively* first!**
- **Time to achieve an accurate firing solution was chosen as the "effect" to be modeled due to:**
  - **Complexity of the fire control process**
  - **Ability to incorporate the impact of technology, environment, and enemy actions**

# Questions

Former USS *John Young* (DD 973)

U.S. Navy photo