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Undersea Warfare Systems Engineering

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1st Principle:
A WARFARE AREA'S CHARACTERISTICS ARE REFLECTED IN THE DESIGN AND ENGINEERING OF THEIR SYSTEMS

- **A key characteristic of Undersea Warfare is that the water medium is predominant**
- **Although the Wave Equation describes the motion, the boundary condition assumptions do not properly result in linearity**
  - **And the air-water and bottom-water boundaries are always present**
- **Sound in sea water has significant – first order - propagation velocity effects from the natural environment**
  - **And the environment is time and location variable**

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Governing Environmental Characteristics of acoustics which influence Undersea Warfare Greatly

- **Sound Velocity is SLOW – nominally 4800ft/sec (2880 mi/hr) – which adds stress to those warriors engaged**
- **Oceans are always full of various noises which complicates – particularly - the detection and classification functions**
- **Snell's Law governs propagation above ~320Hz so acoustic system performance is environmentally driven**
- **Attenuation is proportional to frequency such that systems engineers are always searching for techniques for system performance optimization**

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Looking deeper at some Environmental Characteristics

- **Sound Velocity is proportional to salinity, temperature, and pressure**
- **The ocean environment is variable vertically AND horizontally**
- **Ambient noise is time varying and both locally and distance generated – a cacophony!**
- **Surface scattering is generally a gaussian distribution which helps – if you know the sea state variation locally**
- **Bottom scattering is variable by location, frequency, and angular interaction**

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2nd Principle:
Undersea Warfare Systems have complex and significant platform driven performance issues

- **Water flow affects acoustic sensors noise levels, so it is a speed dependent factor which must be carefully engineered to fit tactical doctrines**
  - **Slowing down to listen is an unnatural act for some "Destroyer Drivers"**
  - **Search patterns, system performance estimates, and platform speed are complex tradeoffs**
- **Mechanical isolation of sensors from platform vibrations can be particularly difficult**
- **Modeling the Air-Water interface is a system engineering challenge**

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3rd Principle:
Undersea Warfare Systems success is proportional to simplicity of operation

- **The requirements matrix for undersea warfare systems processing will match the complexity of the environment**
  - **That complexity cannot be passed to the operators without reducing their performance**
- **System Engineering of system controls, display surfaces, and display sequences must: First - be simple to understand; Second - have the minimum detail and accuracy needed; and Third – be compliant with warfare doctrines**
- **Sensor, Weapon, Command Information, and Combat Systems interfaces are a system engineering responsibility**

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4th Principle
Undersea Warfare is a TEAM effort

- **Undersea Warfare doctrines, especially Anti Submarine Warfare, have evolved as requiring multiple platforms**
- **Performance Requirements should place "your" system in an operational context with other platforms and systems**
- **System Engineering tradeoffs should not be made in isolation**
  - **they need to include the other platforms and their systems to achieve success**
  - **Multi-platform system interfaces are part of good system engineering**

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5th Principle: Competent Undersea Warfare Systems Engineers are very rare - and priceless

- **The level of complexity is at least a full order of magnitude higher than any other Warfare Area**
- **Incredible leadership exhibiting patience, determination, and diplomacy are required because the tradeoffs are very performance critical and interrelated**
  - **Teaching and explaining often frustrates engineers**
  - **Engineers sometimes lack a good sense of humor**