# Shipboard IRST Support



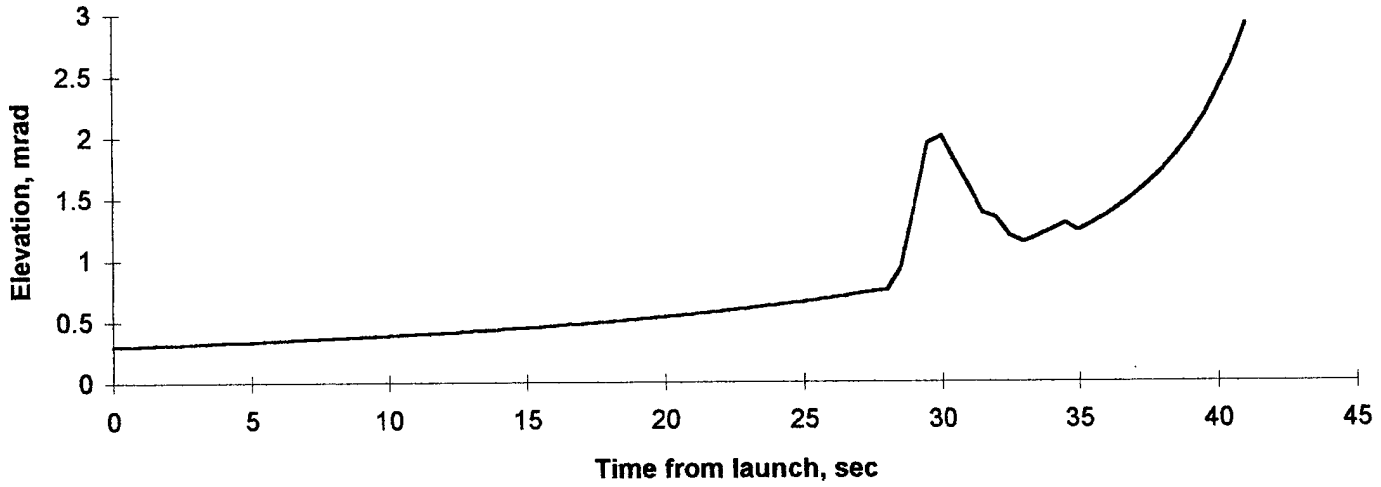
## Final Briefing to
## Office of Naval Research
## October 1994

Environmental Research Institute of Michigan

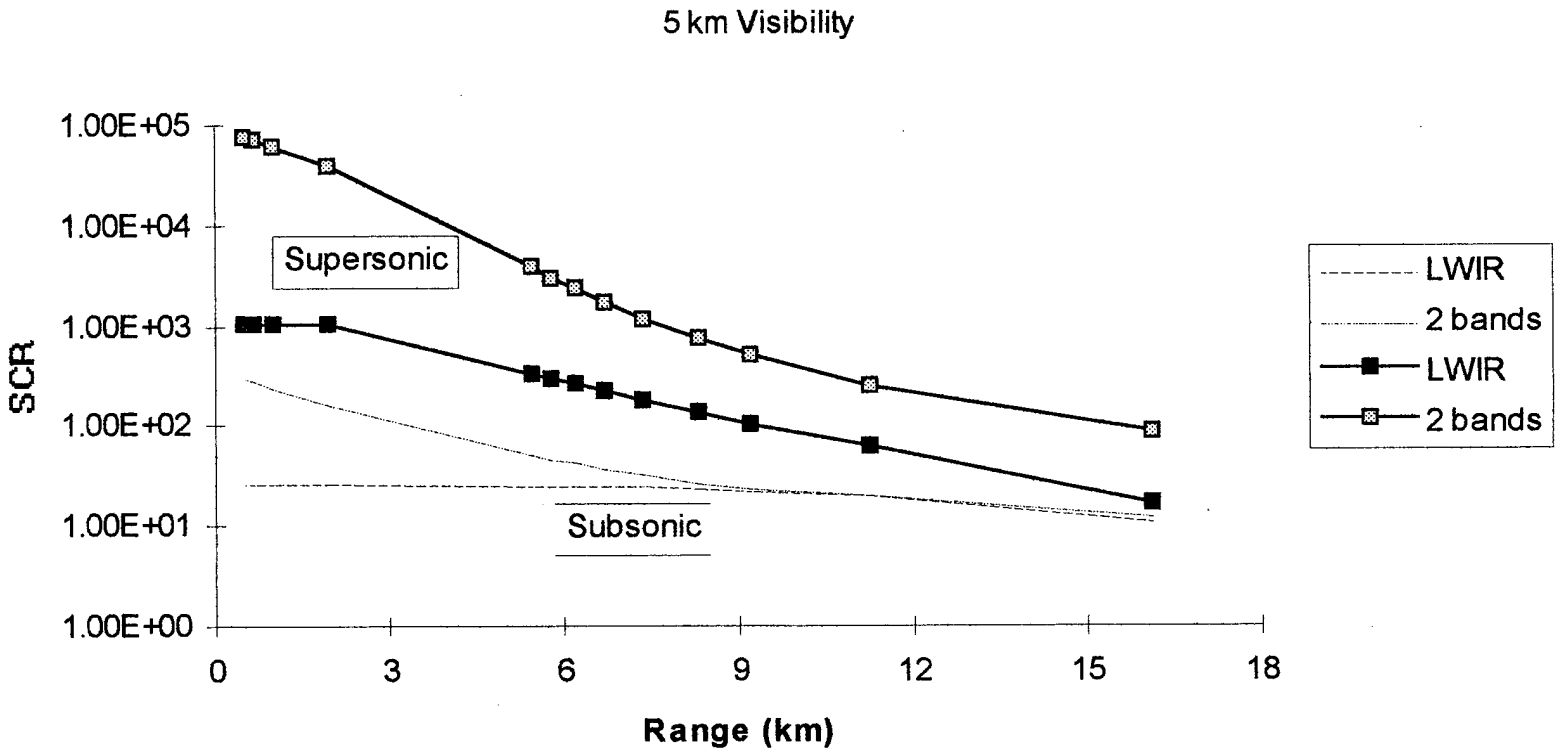
# Project Tasks

- Target vehicle signature
  - dynamic variation due to maneuvers (including effects of guidance and control)
  - vehicle reflectance properties
- Environmental effects
  - atmospheric refraction (including turbulent effects)
  - emission and reflection from opaque backgrounds
- Sensor Trade Studies
- Advanced Discriminants
  - selection of spectral band or bands
  - spectral diversity.

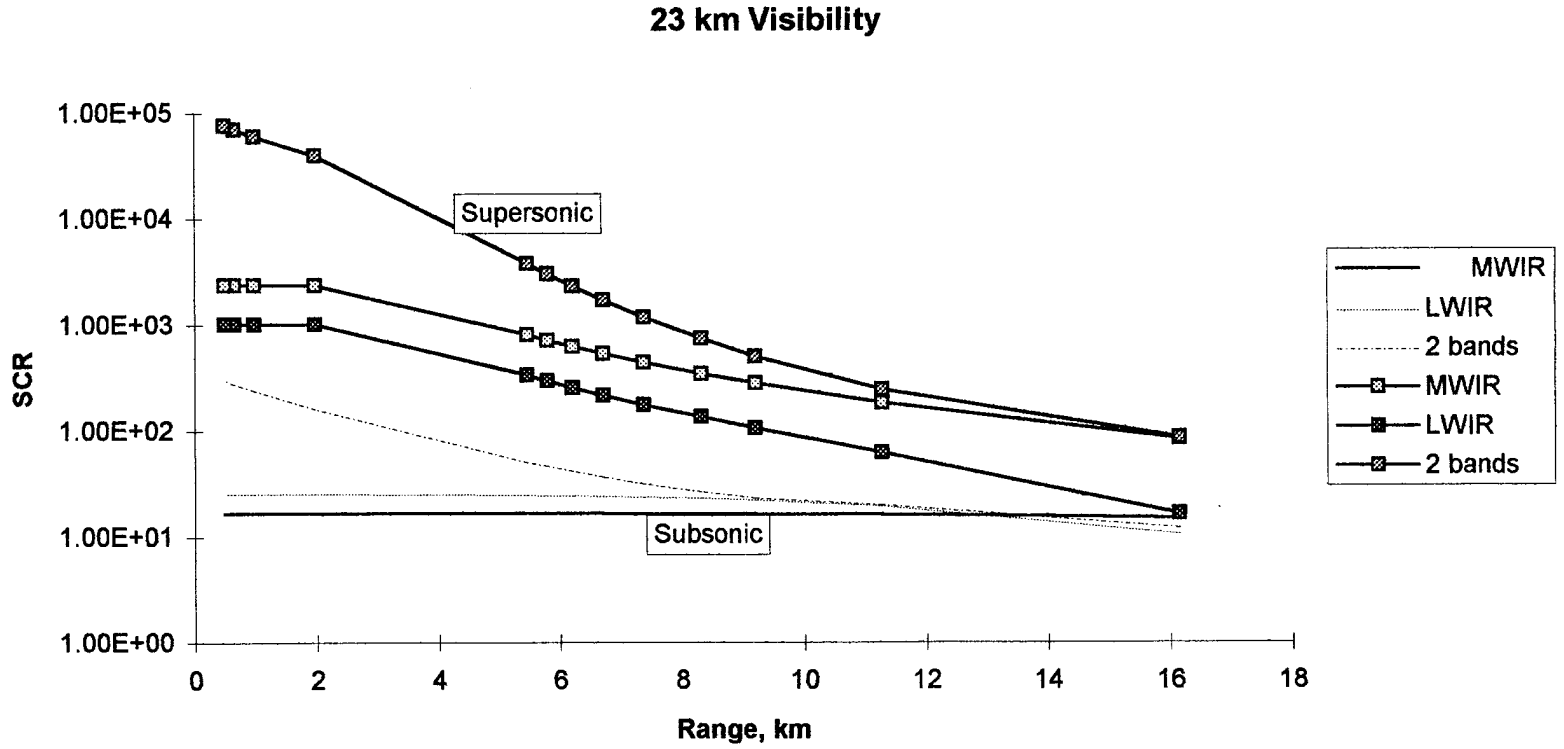
# Elevation Variation during CM Approach



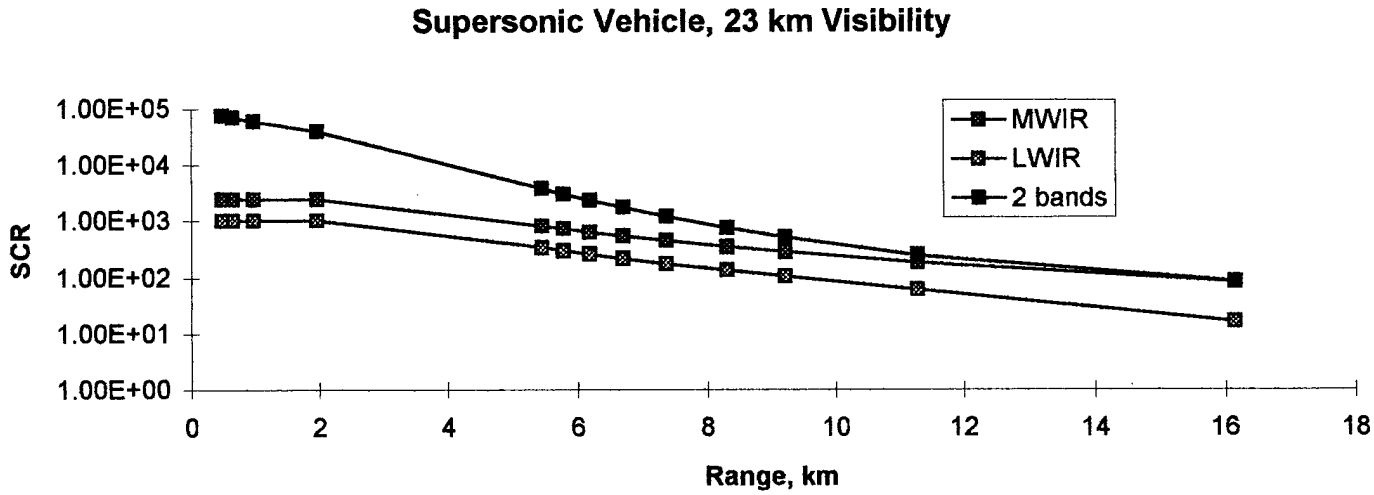
# Multispectral Gain for Two Target Classes



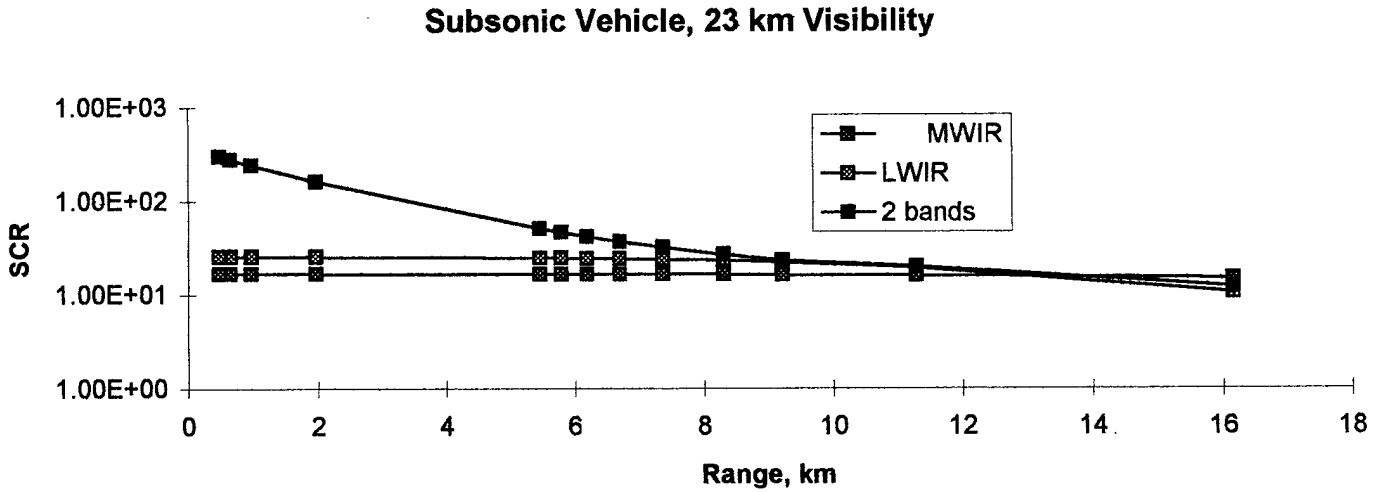
# Multispectral Gain, Good Visibility



# Multispectral Gain, Good Visibility



# Multispectral Gain, Good Visibility (Cool Vehicle)



# Coating Effects on Target Signature

- Detection ranges are sensor noise limited not clutter limited
- BRDF of various aircraft coatings are not all diffuse
- Specularity decreases target contrast and therefore SCR since target signal is primarily reflected background and not thermal emission from the target itself

# Glossy Coating

- The reduction in SCR is apparent
- Multispectral processing does have some small benefit when the target has a glossy coating

# Target Insertion in Backgrounds

- Target-environment interaction
  - reflectance of the environment from target surfaces
  - heat transfer from the environment
  - occultation of the background by the target
- Point targets
  - will appear as an Airy spot filling more than one detector
  - technique for efficiently inserting point targets
    - » **compute the FFT of a single pixel**
    - » **phase shift the transform to give it the correct sub-pixel shift**
    - » **multiply by the MTF of the IRST optics and detector**
    - » **inverse transform and add the radiance to the image**

# Extended Target Insertion

- Edges must be blended properly with the background
- Compute target signature for chips which include a portion of clutter surrounding the target
- Spatial sample interval should be no more than half of that of the final image

# Transmission and Path Radiance

- Transmittance can be as small as 6-10% even with high visibilities.
- For long ranges, SCR dominated by the sensor noise.
- Short range SCR is dominated by background clutter.
- Path radiance adds a bias to the signals detected by an IRST.
  - At long ranges it can fill a significant portion of the detector dynamic range
  - Random photon arrival times of this energy can increase the level of noise added to the signal by the sensor

# Turbulence and Scintillation

- Turbulence will also cause the scintillation of extended sources, such as the background clutter.
- Variance will be less than that of a point source due to spatial averaging over the extended background.
- Refractive index structure parameter is a weak function of wavelength.

# Vertical Refractive Index Gradients

- Temperature increases with altitude
  - Air density decreases with height
  - Light rays are bent toward the Earth
  - This can cause the image of an object to appear:
    - » **above its true position (looming)**
    - » **to have an angular size larger (towering)**
    - » **smaller (stooping) than the true angular extent**
- Temperature decreases with altitude
  - Air density increases with height and light rays are bent away from the earth.
    - » **Causes the image to appear below its true location (sinking).**
    - » **Unstable atmosphere causes turbulence that produces fluctuations in image location as well as scintillation**

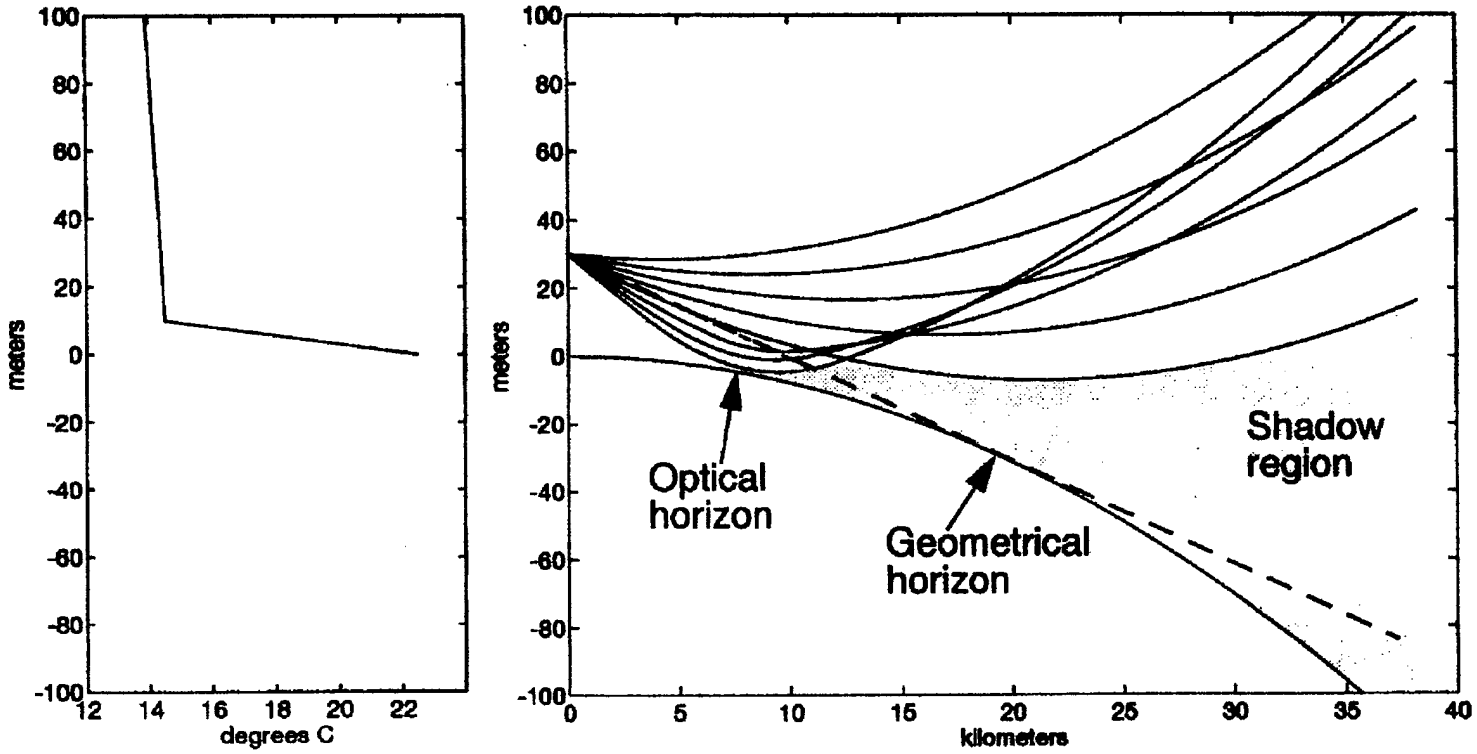
# ONR Sensor at Diamond Shoals

- Shows a distinct horizon with an elevation that changes by as much as three pixels
  - Could be attributed to "giant waves" [Takken, et al., 1993]
  - Similar to undulations seen in the visible images taken from a video tape
- Features were observed to propagate with the wind at speeds that are improbably high for low frequency "giant" waves
- Possible that these features are due to an air mass having azimuthal changes in the temperature profile propagated across the field of view by winds

# Shadow Zones

- The optical horizon occurs where the rays are tangent and intersect the Earth's surface.
- Horizon is closer under these conditions
- There is a region below the optical horizon yet above the geometrical horizon in which targets cannot be seen.
- Analogous to shadow regions in sonar

# Shadow Zone


meters
degrees C
Optical horizon
Geometrical horizon
Shadow region
kilometers

# Temperature Data Availability

- Standard meteorological practice is to measure air temperature at least two meters above the surface to avoid surface effects.
- Temperature measurements are usually made at a single height
- Profiles of the fifty meters closest to the ground are not generally available
- Majority of temperature data collected world wide is of little use in determining what profiles should be used in any particular situation or location

# Sensor Trade Studies

- Multispectral and temporal processing of imagery from the AADEOS sensor
- AADEOS sensor is capable of preserving at least two nines (0.99) of correlation in the data collected.

# Statistical Characterization

- Estimate of clutter and correlation levels from four locations in images
- Fifty contiguous sky pixels used to characterize sensor noise levels
- Estimates made of correlation lengths of four types of backgrounds after removing linear trend

# Conclusions

- Some targets exhibit anomalous relative motion
  - effect pronounced during turns
  - non-linear motion may impact target detection performance
- Multispectral processing results in modest gain for standard targets in an open ocean scenario.
  - More gain is realized against targets with advanced (reflective) coatings.
  - Greater payoff for multispectral is expected for an cruise missile viewed against a land background.
  - The use of multispectral processing for combat identification was not addressed.

ERIM

# Conclusions (2)

- A simple ocean clutter model agrees well with measured data acquired under different environmental conditions
- Atmospheric refractive effects can cause significant variations in the infrared scene
- SIRST performance may be radically reduced under certain atmospheric conditions
  - Refractive shadow zones may exist under some conditions
  - Additional data on temperature lapse rate are needed to determine the frequency of occurrence of this phenomenon.