**DAHLGREN DIVISION**
**NAVAL SURFACE WARFARE CENTER**
Dahlgren, Virginia 22448-5100

(12)

**NSWCDD/MP-94/271**

# FALSE ALARM ANALYSIS (PRELIMINARY) HORIZON INFRARED SURVEILLANCE SENSOR



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**SHIP DEFENSE SYSTEMS DEPARTMENT**

**SEPTEMBER 1994**

# FOREWORD

The Horizon Infrared Surveillance Sensor (HISS) Phase 2 system was involved in testing at Wallop's Island, Virginia from November 1993 through April 1994. Currently, specific performance characteristics of the HISS are being analyzed. This report is the first in a series on the performance of the system. A final report will be generated later that will summarize the results presented to date and provide any required corrections or expansions of the analyses.

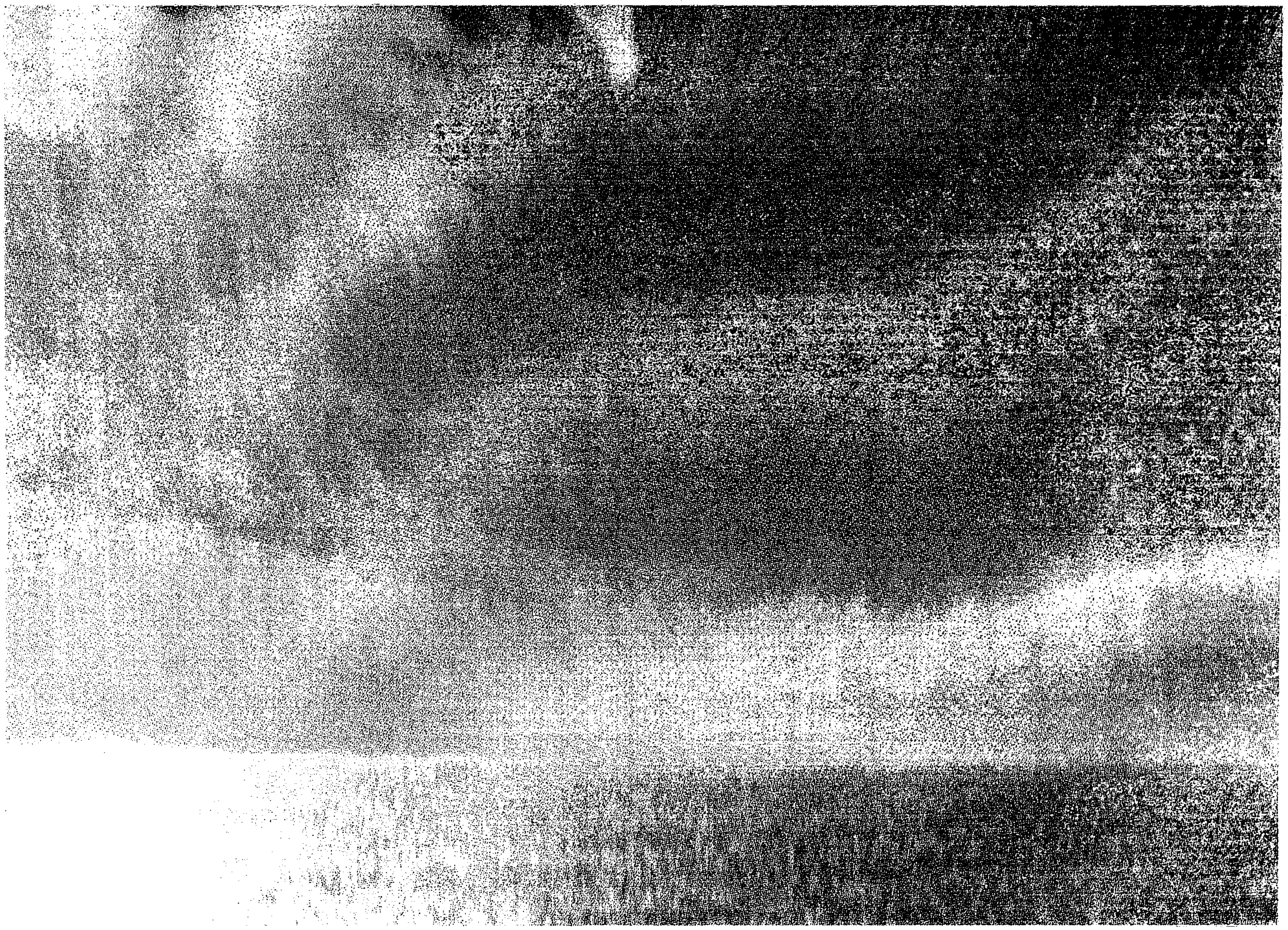
The source data for this report was collected by the HISS test team between January and April 1994. The author wishes to acknowledge the following test team members: Pat Dezeeuw (team leader), Everett Bryant, Connie Hoffman, Sheldon Zimmerman, Keith Merranko, and Robert Headley.

This report has been reviewed by Roger Carr, Head, Electro-Optical Systems Branch and Stuart Koch, Acting Head, Search and Track Division.



Approved by:

T. C. PENDERGRAFT, Head
Ship Defense Systems Department



Hello, my name is Dr. Kenneth Hepfer. Today I am going to present some preliminary results from our recent field tests of the Horizon Infrared Surveillance Sensor (HISS) Phase 2 system.

# FALSE ALARM ANALYSIS
# (Preliminary)
## Horizon Infrared Surveillance Sensor

**Analysis of Test Data Collected at NSWCDD, Wallop's Island Detachment**
**January - April 1994**

Ken Hepfer
Electro-Optical Systems Branch, F44
Naval Surface Warfare Center, Dahlgren Division

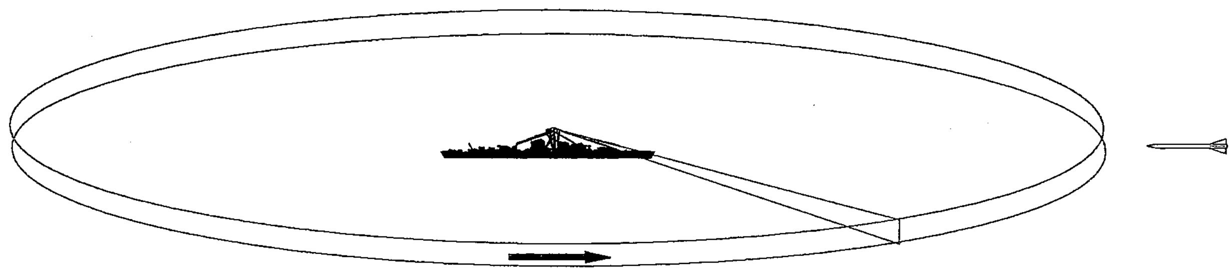
Traditional Infrared Search and Tracks (IRSTs) have operated as a stand-alone designation source and have attempted to achieve false declaration rates of less than one per hour.

In traditional IRSTs, the occurrence of a false alarm (which is reported out) is a sign of failure.

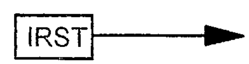
In a multisensor integration (MSI) context, where two or more sensors are operated cooperatively, the false alarm rate (FAR) for reporting to the MSI processor can be much higher (1/sec or more). By using cueing and multisensor track initiation and confirmation, the system range can be increased while keeping the system FAR low.

When an IRST is used as part of an MSI suite, the reporting of (some) false alarms is normal operation and is a means to achieve increased system performance.

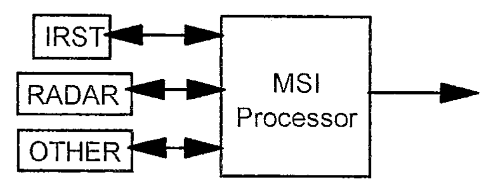
Although false alarms and clutter will be discussed, it should be understood that false alarms were NOT A PROBLEM during this test period.



- IRST:
  - Provides passive detection and declaration of inbound missiles
- Traditional IRST:
  - Several False Alarms = Failure




- MSI IRST:
  - Several False Alarms = Normal Operation




- False Alarms were not a problem during testing

First, a brief overview of the HISS program and a description of the Phase 2 system will be presented.

Then false alarm rate (FAR) will be defined and some discussion will be provided of FAR in the context of an MSI system.

Before going into the details of the false alarm analysis and results, an overview of the HISS signal processing will be provided. This will help to clarify the FAR that will follow.

In discussing the FAR results, a summary of the statistics for all the data analyzed will be presented.

Then it will be shown how the summary of statistics was derived, and a discussion on the different types of clutter will follow.

For each case considered, a panoramic image will be shown and an examination of those parts of the image that caused the most significant false alarms will be provided. For each clutter type, further steps will be discussed that could be taken to further reduce the FAR.

Clutter cases considered included sky with and without clouds, solar sea glint ranging from mild to moderate, land with structures, and a flock of birds.

Finally, a summary of the impact of the clutter observed during testing will be provided.

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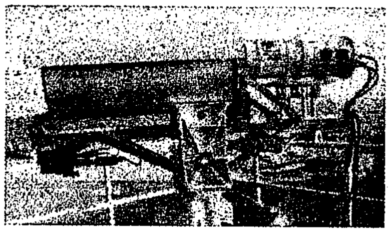
- HISS Introduction / System Description
- FAR Discussion / Definition
- Signal Processing Overview
- FAR Summary Statistics
- FAR Data
  - Panoramic Image
  - FAR Statistics
  - Examine Most Significant False Alarms
- Cases
  - Sky / Clouds
  - Solar Sea Glint
  - Land
  - Birds
- Summary / Implications

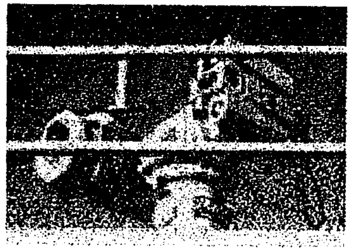
The HISS project involves integrating existing, commercially available equipment into a system that demonstrates basic horizon IRST capabilities.

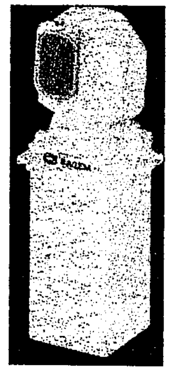
The project includes development at the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) of special target detection/discrimination algorithms that are then implemented in real-time hardware.

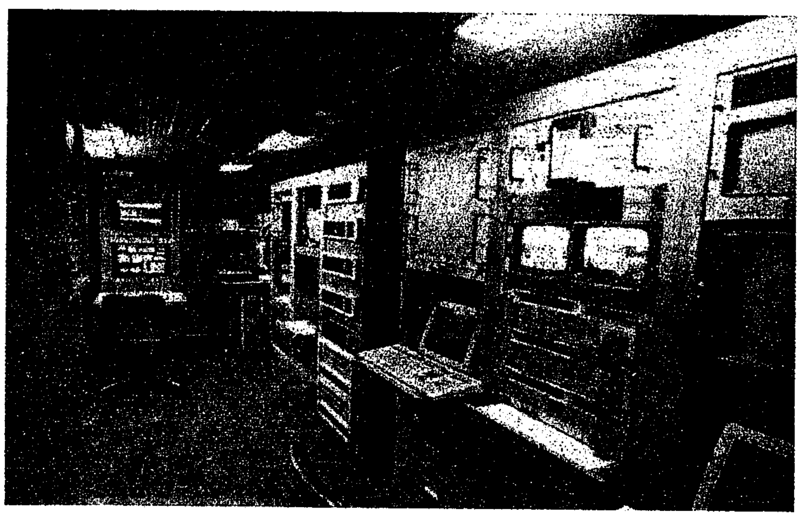
The HISS system was developed to support ongoing experiments in the area of MSI.

The gathered data is used to compare predicted performance against achieved performance and pass the data and lessons learned to follow-on efforts.









- Demonstrate basic horizon IRST hardware
- Develop / Implement real-time target detection processing
- Demonstrate IR contributions to an integrated sensor system
- Provide data and experience for follow-on efforts (IRST E&MD)
  - verification of detection range predictions
  - high resolution / high sensitivity scan images (land background, solar clutter, etc.)

The HISS system is designed to address the most stressing threat to the ship's combat system under a wide variety of conditions.

The HISS must provide single scan discrimination at a controllable FAR; must operate in any reasonable field test environment; and must provide its information to an external interface in real time. Typically, the detection report will leave the system less than 100 msec after the infrared (IR) radiation first impinges on the sensor.

- Detect supersonic (M2+), low flying targets at the horizon limit under most weather conditions
- Discriminate targets from near horizon clutter with a FAR consistent with MSI operation
- Operate in both land-based and shipboard test environments
- Provide target information in real-time to an external interface

The HISS project follows a phased approach to reduce risk and provide interim capability.

In Phase 1, data was recorded and non-real-time processing and analysis was performed to confirm that the basic approach was sound.

In Phase 2, a real-time subset of the final system was implemented to support real-time MSI field tests. This report provides the information on field performance achieved with this system.

In Phase 3, both sensor and processing aspects of the system are being upgraded to demonstrate a full performance horizon IRST.

The Phase 3 system is also designed to gather data to evaluate the merit of dual sub-band operation as an additional discrimination tool.

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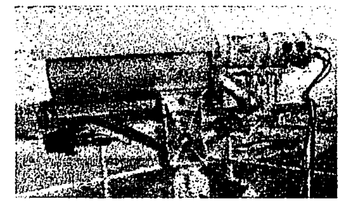
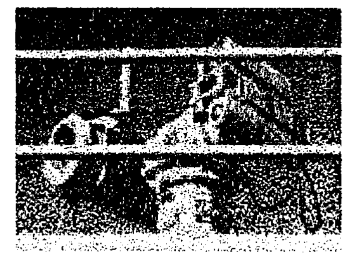
- Phase 1
  - prototype a sensor of requisite sensitivity and resolution
  - develop target detection algorithms (non-real time)



- **Phase 2**
  - **prototype sensor and mount to scan limited sector with required sensitivity, resolution and accuracy.**
  - **prototype real time signal processor which implements the algorithms developed under phase 1**
  - **develop interface to MSI processor**



- Phase 3
  - prototype mirror stabilized scanner configuration
  - upgrade signal processor capacity
  - evaluate dual sub-band discrimination

In comparing the HISS Phase 2 and Phase 3 system characteristics, one can see that the Phase 2 system is much more limited in terms of field of regard and processing complexity. Several design features such as the sensor and stabilization type were driven by expediency vice efficiency. In simple terms, the Phase 3 system is a functionally complete horizon IRST with characteristics generally similar to what one would expect in an Engineering and Manufacturing Development (E&MD) system. The Phase 2 system is a more limited IRST surrogate designed to be a stand-in to provide interim real-time IRST support to MSI field testing.

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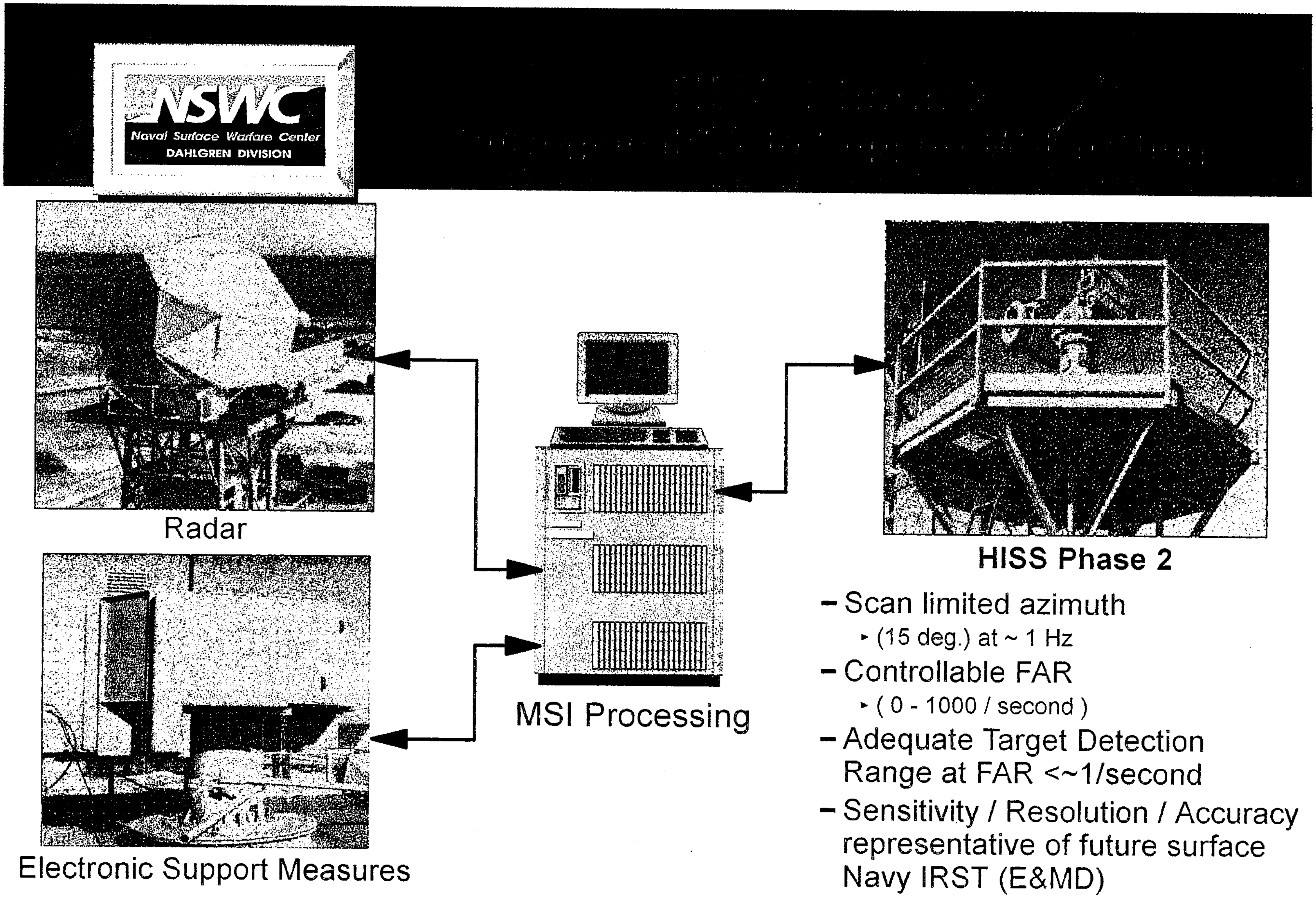
| | HISS Phase 2 | HISS Phase 3 |
|---|---|---|
| **Spectral Band(s)** | 3.8 - 4.2 μ meter [process and record] | 3.8 - 4.2 μ meter [process and record] 3.4 - 3.8 μ meter [record] |
| **IFOV (μradians)** | 80 x 80 | 100 x 184 |
| **Sampling (μradians)** | 80 x 80 | 67 x 87 |
| **Vertical FOV** | 1.17° | 1.85° |
| **Horizontal FOR** | 15° | 360° |
| **Scan Update Rate** | 1 Hz | 1 Hz |
| **NEI (W/cm2-ster)** | 2 x 10 E-14 | 1 x 10 E-14 |
| **Sensor Design Basis** | Imager | IRST Detective Assemblies |
| **Stabilization** | Mass | Mirror |
| **Above Deck Weight** | 2100 # | 858 # |
| **Processing** | Single scan detection | Single scan detection<br>Multiple scan detection<br>Track initiation |
| **Processing Coverage** | 1.17 x 15 degrees | 1.85 x 90 degrees |
| **MSI Interface** | One Way | Two Way |

Note: Processing coverage has been limited to 90 degrees in order to demonstrate capability while conserving funds.

This shows the basic functional requirements of the HISS Phase 2 as part of the MSI testing at Wallop's Island, Virginia.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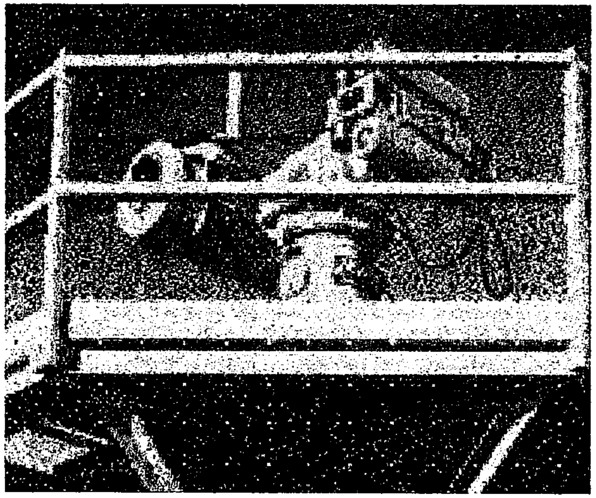
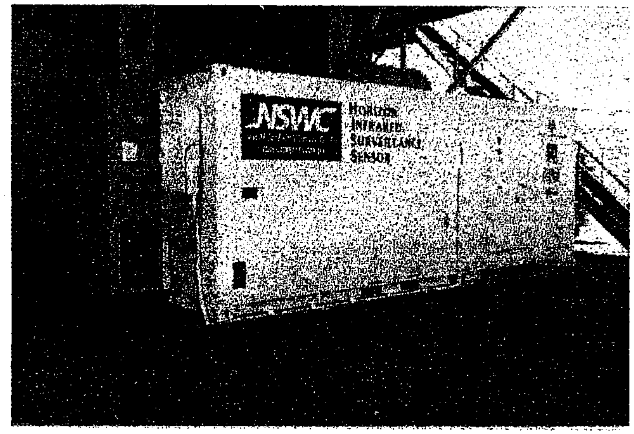
Radar
Electronic Support Measures
MSI Processing
HISS Phase 2
– Scan limited azimuth
‣ (15 deg.) at ~ 1 Hz
– Controllable FAR
‣ ( 0 - 1000 / second )
– Adequate Target Detection Range at FAR <~1/second
– Sensitivity / Resolution / Accuracy representative of future surface Navy IRST (E&MD)

This shows the components of the system as designed and integrated by NSWCDD.






- Sensor: Rockwell MIR band 256x256 Staring FPA TIS
- Mount: Kintec 3 Axis Pedestal
- Signal Processor (SP): Loral ASPRO based SIMD + co-processor
- Record (DVRS): RCI Trapix / Datastore
- Control (SCC): TAC-3 Workstation + card cage

Before presenting the analysis results, *false alarm* and *false alarm rate* will be defined. It is again stressed that in an MSI environment, a false alarm is not a problem or a failure. The purpose of the FAR analysis is to better understand the relationship between false alarm control and detection sensitivity and how to improve signal processing to suppress the most target-like false alarms.

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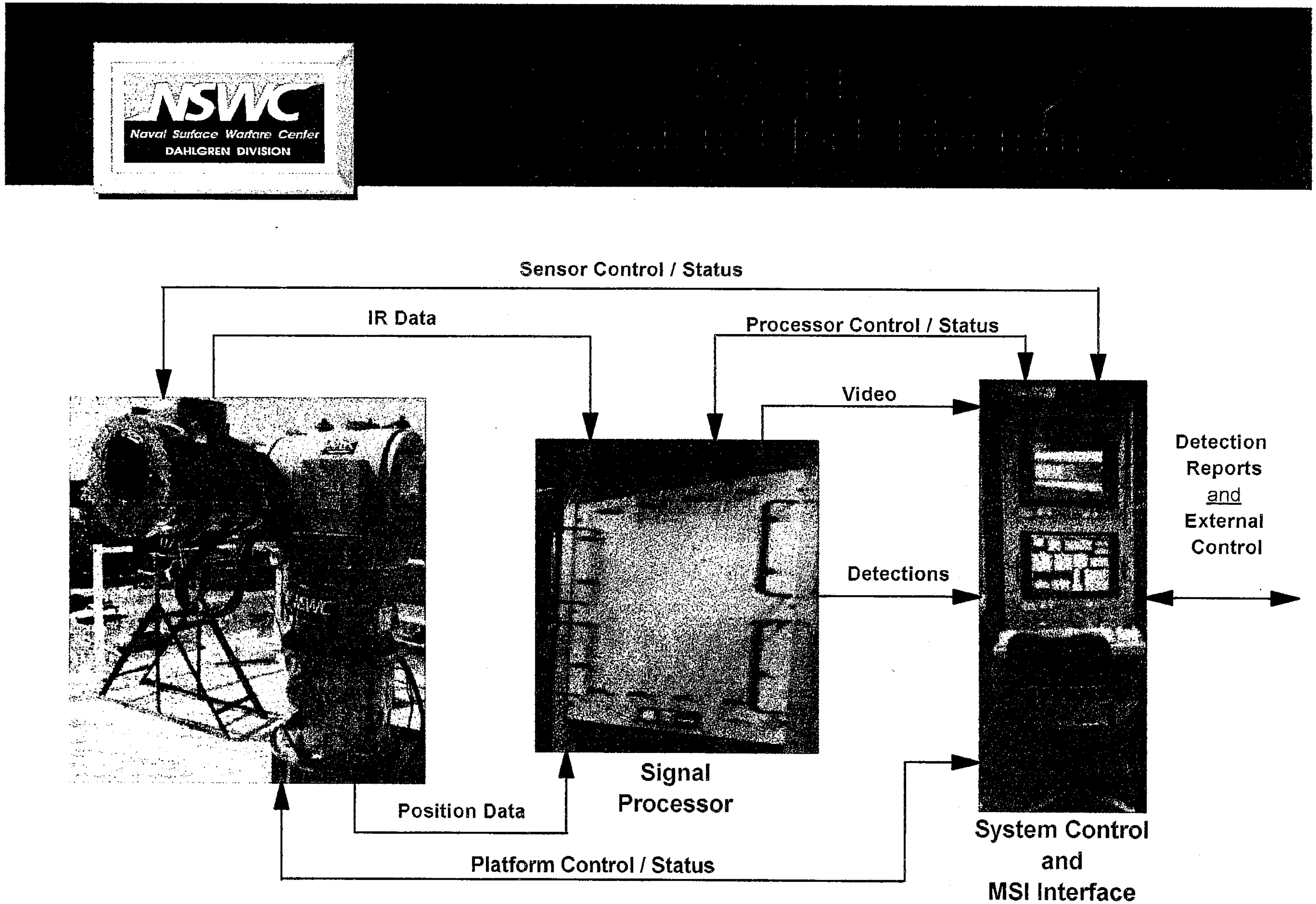
- False Alarm = threshold exceedance or "detection" not due to a target
- False Alarm Rate = Average number of False Alarms per Second
- False Alarm Rate is a function of:
  - Detection Threshold
  - System Noise
  - External Clutter
  - Signal Processing Parameters
- Want to understand how control of False Alarm Rate influences Detection of Target
- Want to understand how to improve signal processing
- False Alarms were not a problem during testing

This shows how the sensor and pedestal data are processed into detection reports that are sent to the system control center (CSS) for transmittal to the MSI interface. To understand how different types of clutter cause false alarms, it is necessary to understand how the IRST signal processing is performed.


Sensor Control / Status
IR Data
Processor Control / Status
Video
Detections
Detection Reports and External Control
Position Data
Signal Processor
Platform Control / Status
System Control and MSI Interface

The major steps in the signal processor are the spatial filter to suppress extended objects, the adaptive threshold to achieve an approximate constant FAR over the field of view (FOV), and the single scan discrimination function to rate each detection as to how *target like* it is. Comprehensive target metric (CTM) is the numerical value used to rate detections. Within the (SCC), there is a CTM threshold function to limit the detection reports sent out of the system. Within the SCC, the data extract function records all detection reports, which is the source for the FAR analysis. The following will illustrate typical data before and after the spatial filter and within and at the output of the adaptive threshold. Terms that go into the CTM function will also be defined.

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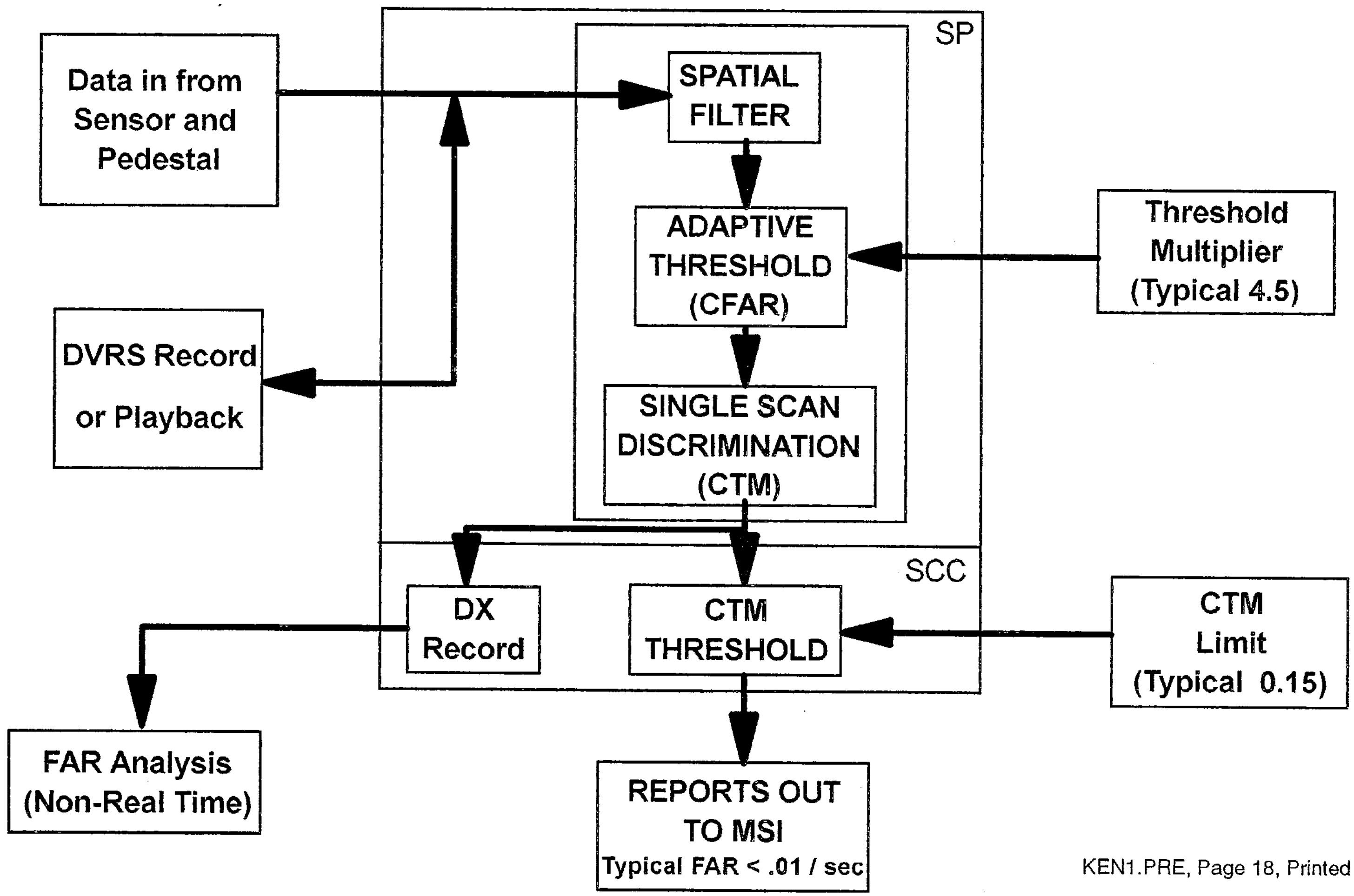


KEN1.PRE, Page 18, Printed 10/14/1994

This shows a typical frame of IR data with a target above the horizon, some solar glint below the horizon, and with some clouds visible just above the horizon and also at the top of the FOV. The plot along the left edge shows a vertical trace through the column containing the target.

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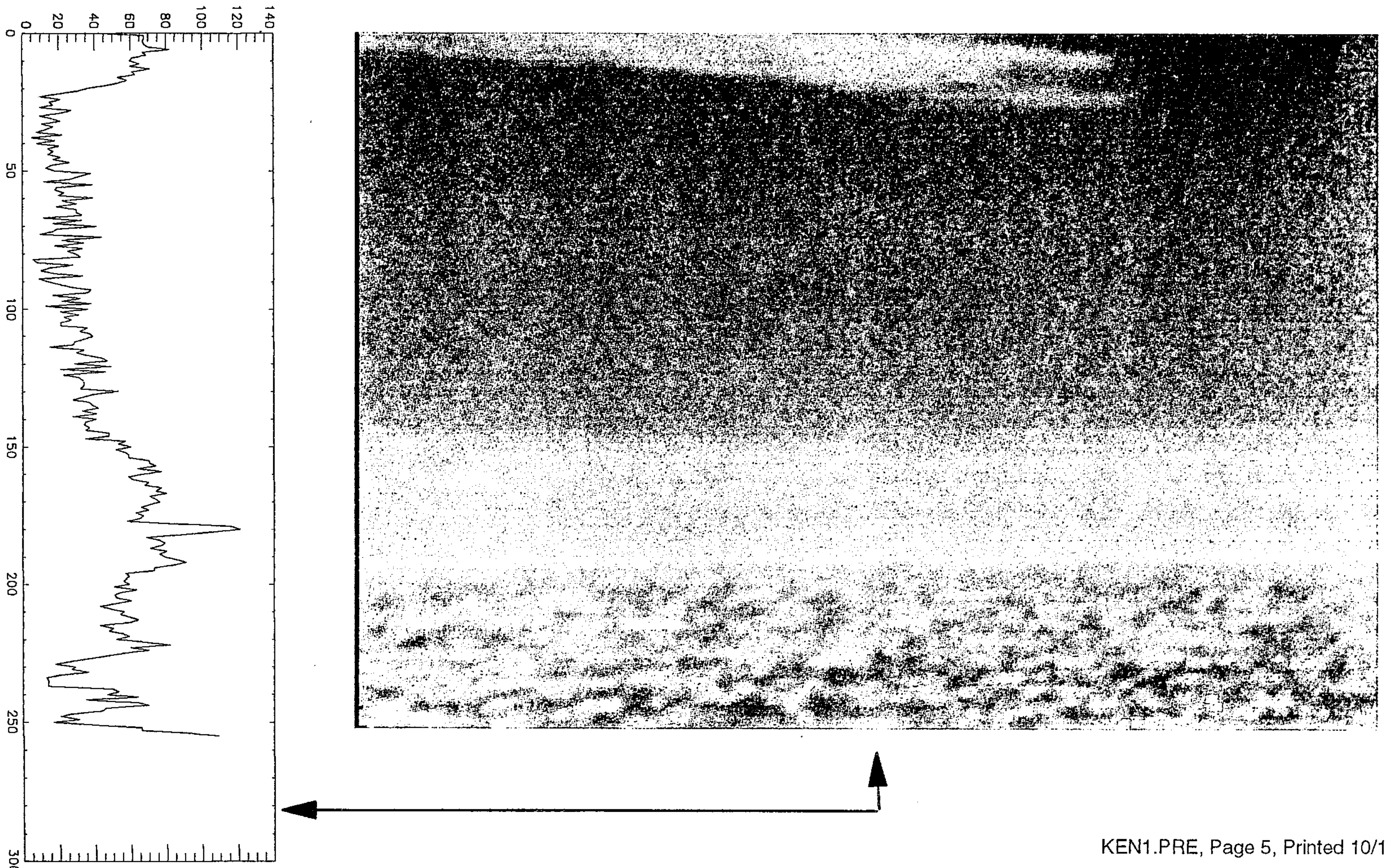


KEN1.PRE, Page 5, Printed 10/14/1994

After the zero mean, one-dimensional spatial filter is applied, the low frequency cloud structure is totally suppressed leaving only the target, the solar glint, and system noise. Note that the solar glint below the horizon has peak amplitudes equal to or greater than that of the target. If a simple fixed threshold was applied at this point, there would be many false alarms in the solar glint.

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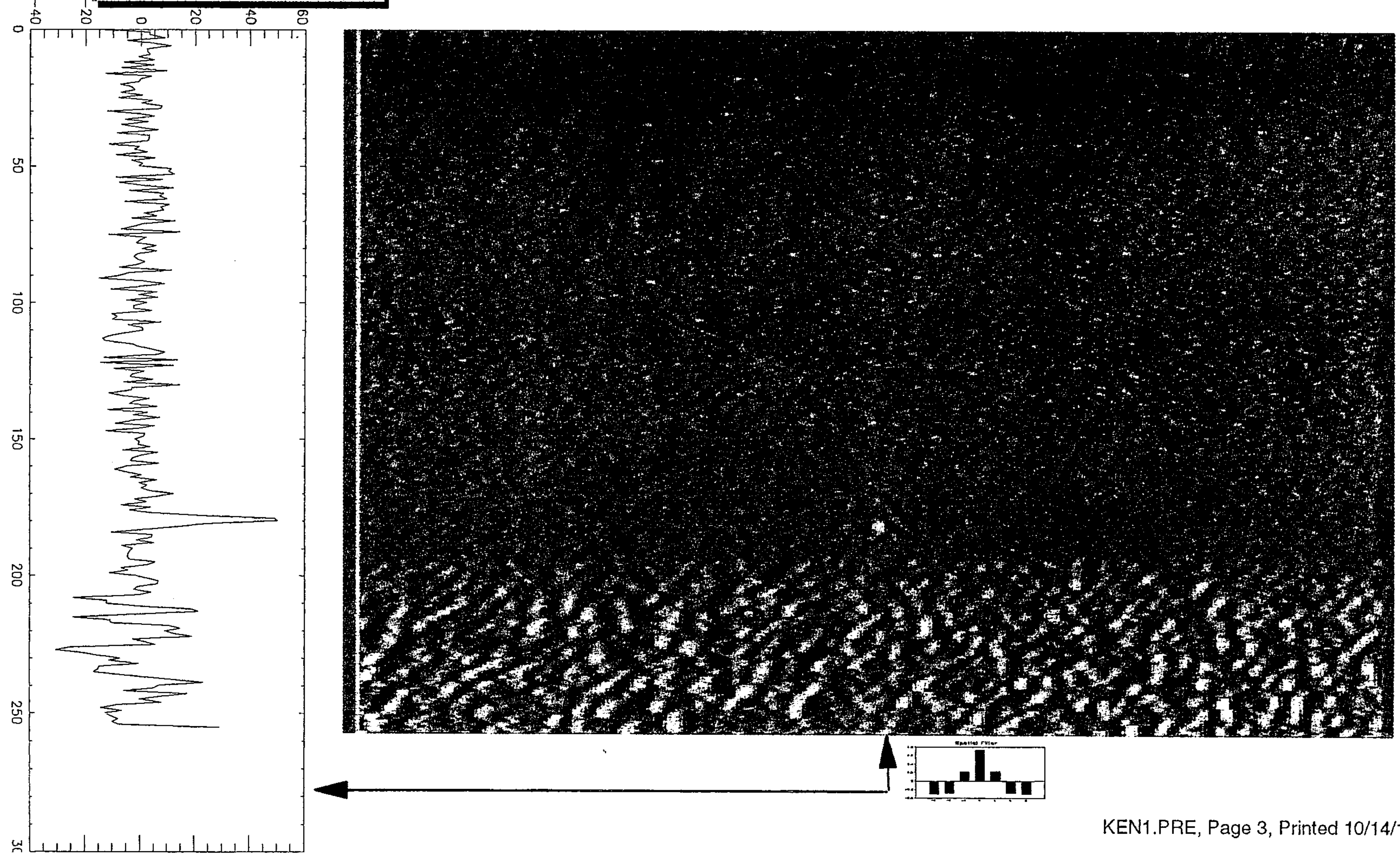


KEN1.PRE, Page 3, Printed 10/14/1994

Before thresholding the data, a local background or clutter estimate is performed by taking the root mean square (RMS) of the spatial filter output over a horizontal window with a central exclusion zone.

This clutter estimate is approximately constant above the horizon; but below the horizon, the solar glint raises the clutter estimate.

Notice how the target raises the background estimate on either side but not at the target location due to the exclusion zone in the background window.

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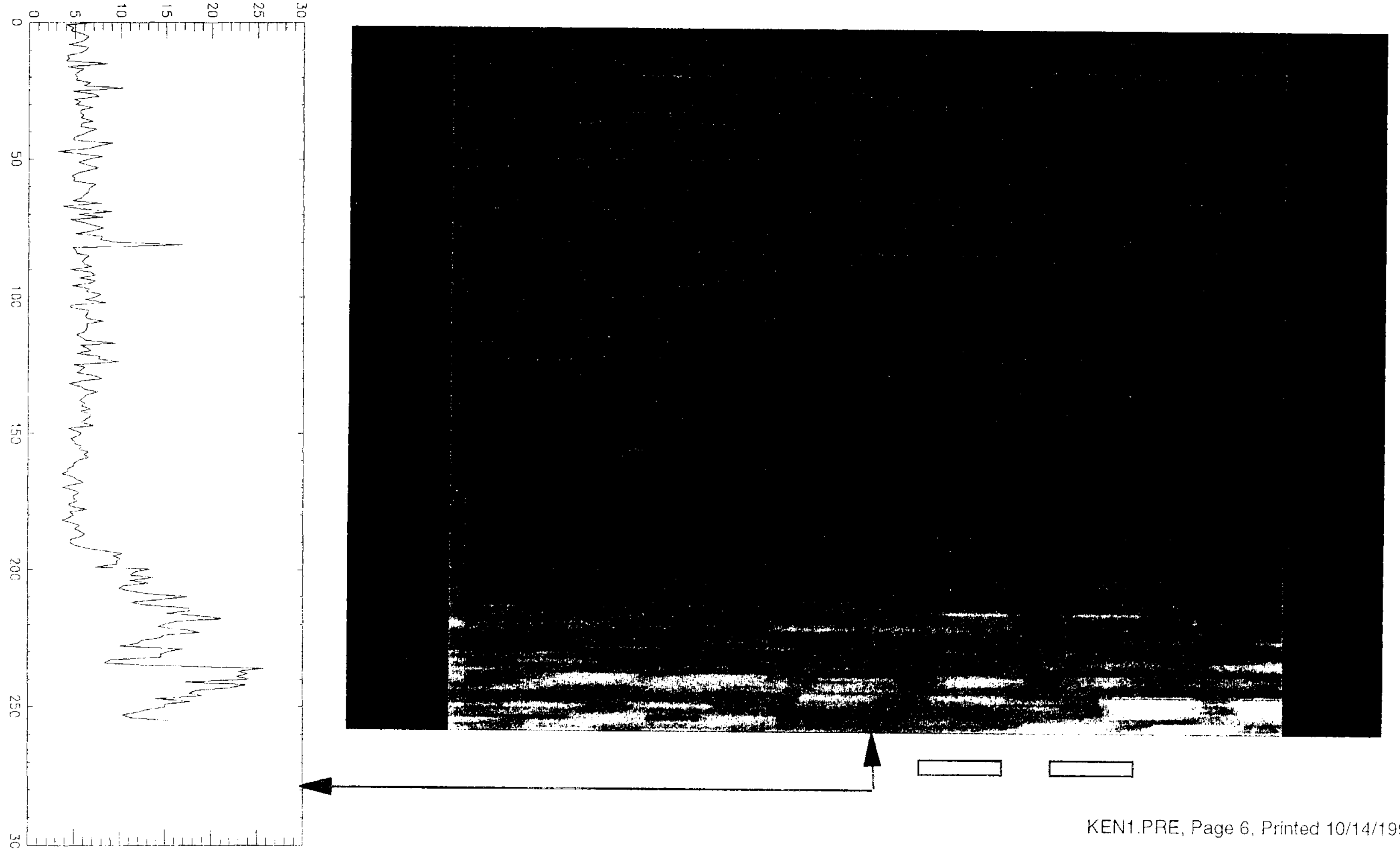


KEN1.PRE, Page 6, Printed 10/14/1994

The clutter estimate (and several other terms to be discussed) are multiplied by the threshold multiplier. Any spatial filter output values that exceed this threshold are considered to be detections. As can be seen from this illustration, the effect of the processing has been to achieve an approximate constant FAR over the FOV. At this point, all detections are evaluated and given a CTM score or value. The CTM value is the product of the following three terms.

The clutter estimate (and several other terms to be discussed) are multiplied by the threshold multiplier. Any spatial filter output values that exceed this threshold are considered to be detections. As can be seen from this illustration, the effect of the processing has been to achieve an approximate constant FAR over the FOV. At this point, all detections are evaluated and given a CTM score or value. The CTM value is the product of the following three terms.

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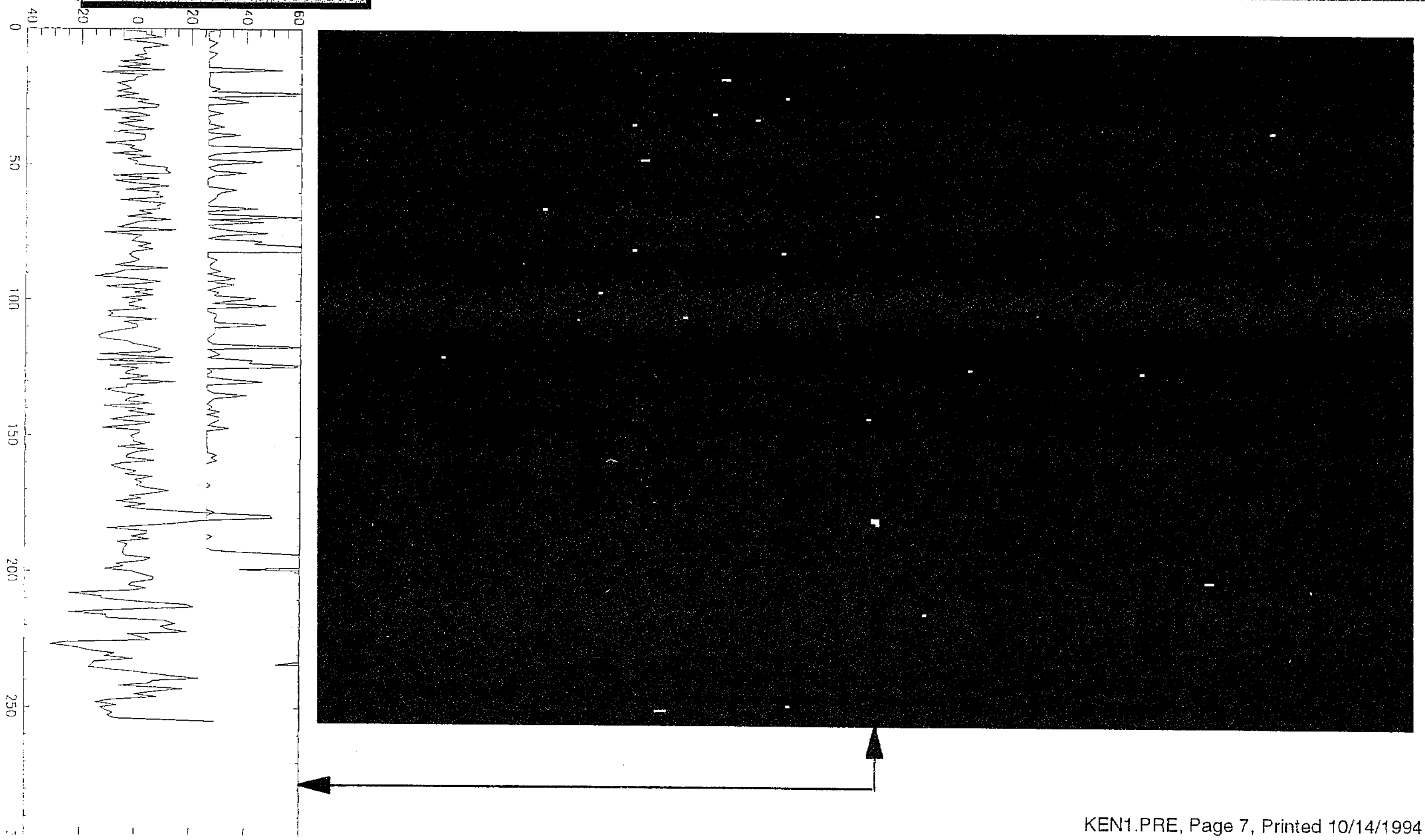
# Signal Processing Illustration
## Exceedances after adaptive threshold




KEN1.PRE, Page 7, Printed 10/14/1994

The signal-to-relative threshold multiplier (RTM) term is a modified signal-to-noise (SNR) or signal-to-clutter (SCR) term where the denominator is the larger of the noise, the clutter, or three times the clutter when the clutter greatly exceeds the noise. The 3 and .8 are typical values used for adjustable parameters. This same RTM term is the basis for the adaptive threshold.

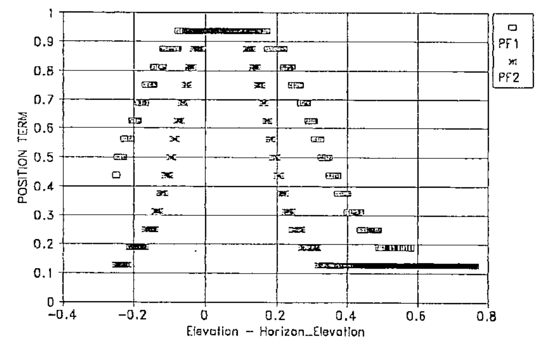
The position term is based on a look-up table (LUT) that rates objects as being more target-like if they are at or just above the horizon. When the horizon has not been detected, a wider function is used. When a high elevation target is expected, the upper part of the LUT can be set to one.

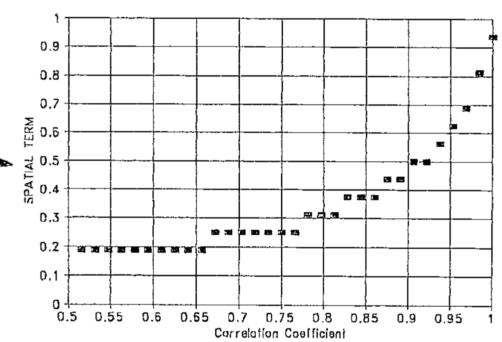
The spatial term is based on an LUT indexed by the correlation coefficient between the actual detection shape and the shape expected for an ideal target response.

# Single Scan Discrimination
## Comprehensive Target Metric (CTM)

CTM is product of three terms

- Signal to RTM Term
  - RTM is maximum of :
  - (Noise, Clutter, 3*(Clutter-0.8*Noise))
- Position Term
  - Look Up Table based on Elevation relative to the Horizon
  - Maximum for objects just above horizon
- Spatial Term
  - Look Up Table based on Correlation Coefficient of target response with ideal target response
  - Maximum for objects shaped like target (point source)

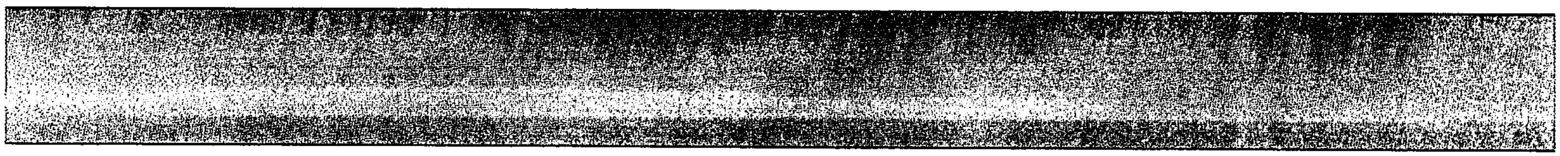


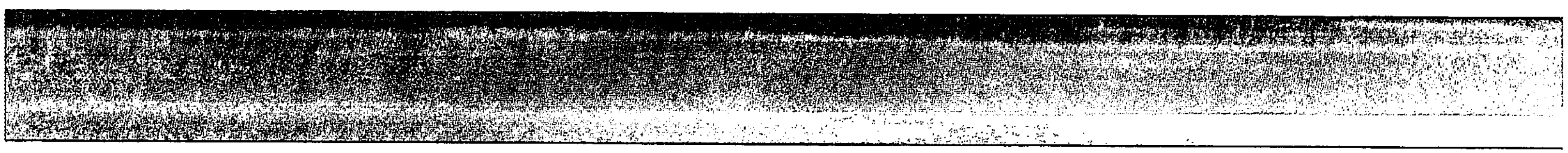
This provides representative scans from the solar glint and low cloud runs used in the false alarm analysis. These panoramic views were made by *pasting* together individual frames from the IR sensor to show approximately the region covered by the 15-deg wide scans. The HISS Phase 2 SCC had a similar situation awareness display with the 15-deg sector broken into three bands.

The terms *medium solar* and *low solar* have to do with the visual appearance of the scenes.

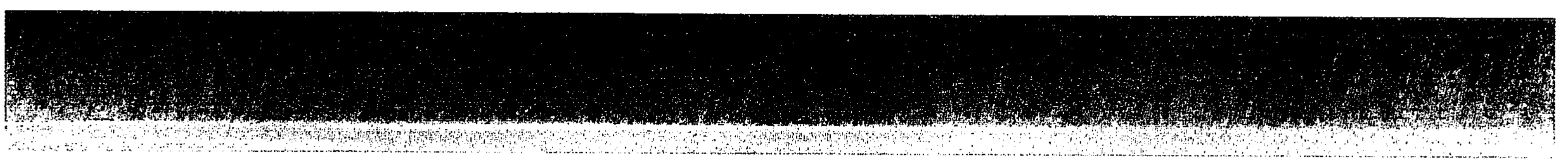
Medium Solar



Low Solar



Medium Solar



Medium Solar

This shows clouds at a slightly higher elevation angle, land to the north and south, and a flock of birds that were detected one day while doing high-elevation target runs.

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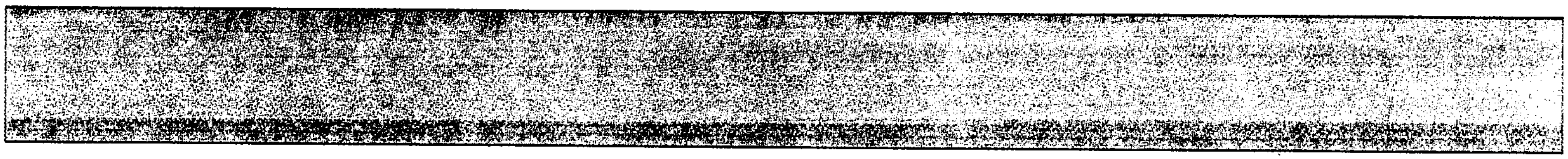
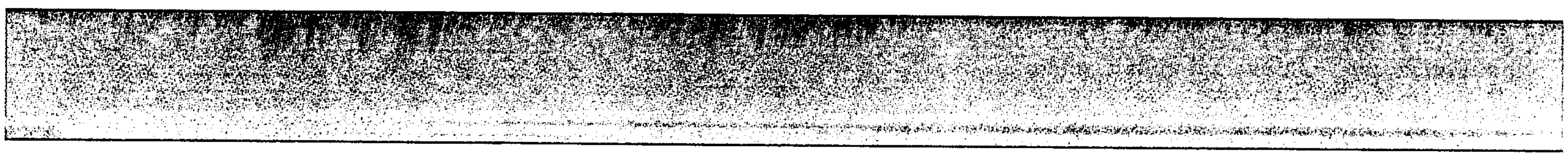
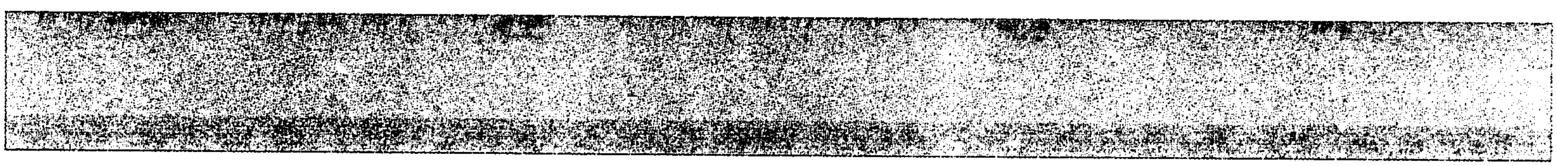
Elevation Center = 1.1 degree



Land to North



Land and Structures to South

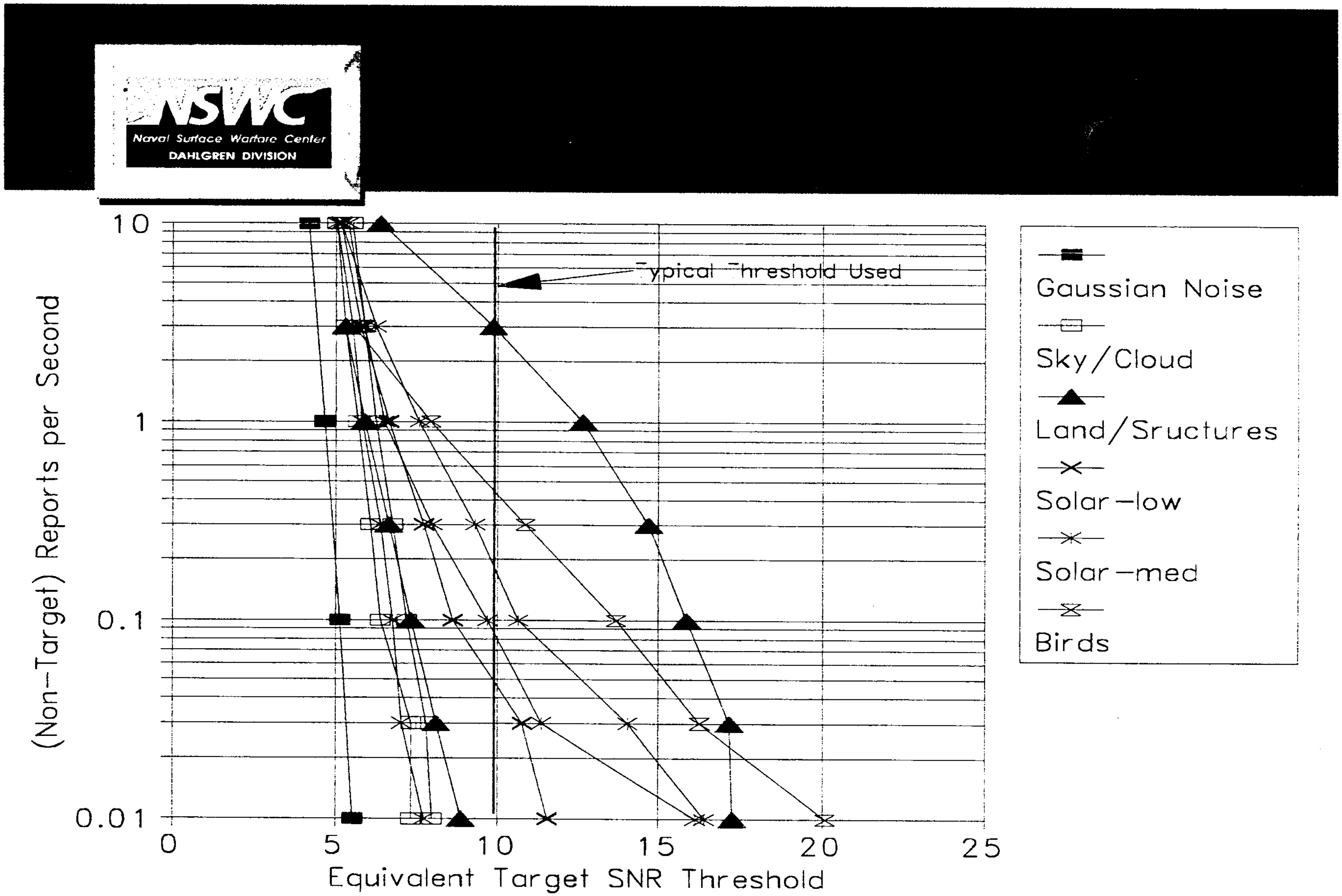


Birds

This summarizes the FAR statistics for all the runs analyzed to date. The observed FAR is plotted as a function of the equivalent target SNR (ETSNR) threshold. This term will be further defined shortly. For the time being, consider the ETSNR threshold to be a measure of target detection sensitivity.

For four of the nine cases considered, the FAR-vs.-threshold relationship was similar to that expected for Gaussian noise and these cases were essentially sensor noise limited. At the normal detection threshold used to filter reports being sent to MSI, the FAR for these cases was significantly less than 1/min.

For the other five cases, the FAR at the normal threshold ranged from several per minute to several per second. To keep the FAR below the normal reporting level of about 1/min or less (0.01), it was necessary to raise the detection threshold by a factor between 1.2 and 2.0. These cases that required some increase in the detection threshold will be examined in some detail, but first the definition of ETSNR will be provided.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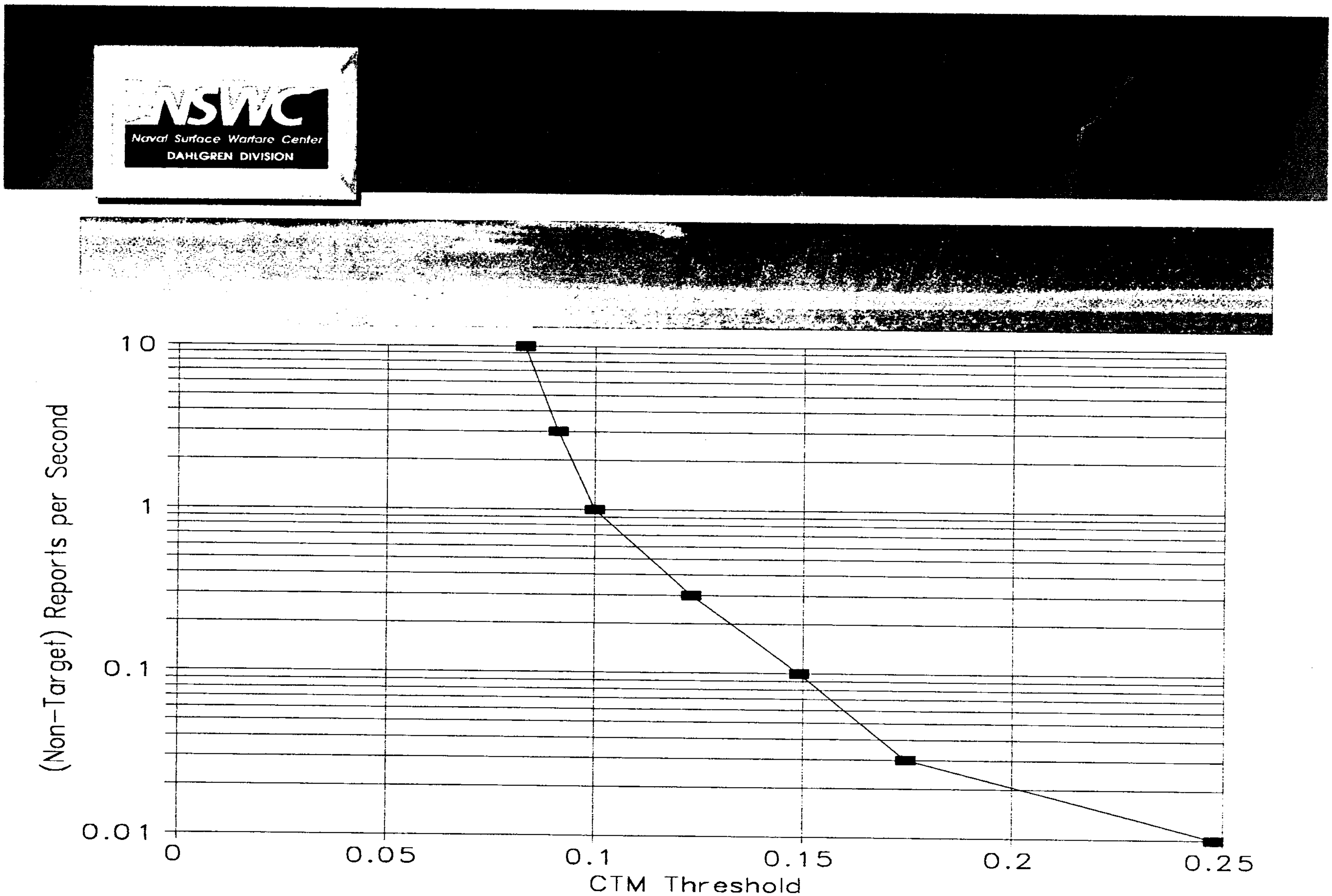
Typical Threshold Used
Gaussian Noise
Sky/Cloud
Land/Sructures
Solar-low
Solar-med
Birds
(Non-Target) Reports per Second
10
1
0.1
0.01
0
5
10
15
20
25
Equivalent Target SNR Threshold

The detection reports coming out of the signal processor are ranked according to CTM and a CTM threshold is used to control FAR to the MSI interface. For a given run such as this medium solar glint case, one can express FAR as a function of CTM threshold, but CTM threshold needs to be interpreted in terms of target detection sensitivity.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10
1
0.1
0.01
(Non-Target) Reports per Second
0
0.05
0.1
0.15
0.2
0.25
CTM Threshold

This plot shows CTM vs. SNR for one of the target runs involving a heater on a boat. Similar plots were obtained for other target runs involving various air targets. Based on the trend line of this data, the term ETSNR is defined to be CTM time 65.

In other others, a CTM threshold of 0.1 is approximately equivalent to an SNR threshold of 6.5. A CTM threshold of 0.15 is approximately equivalent to an SNR threshold of slightly less than 10, etc.

This relationship between CTM and target SNR is correct as long as the target is viewed against a non-cluttered background. This was almost always the case for this test series.

Due to an error in the real-time signal processor, the spatial CTM term was not effective during this test period.

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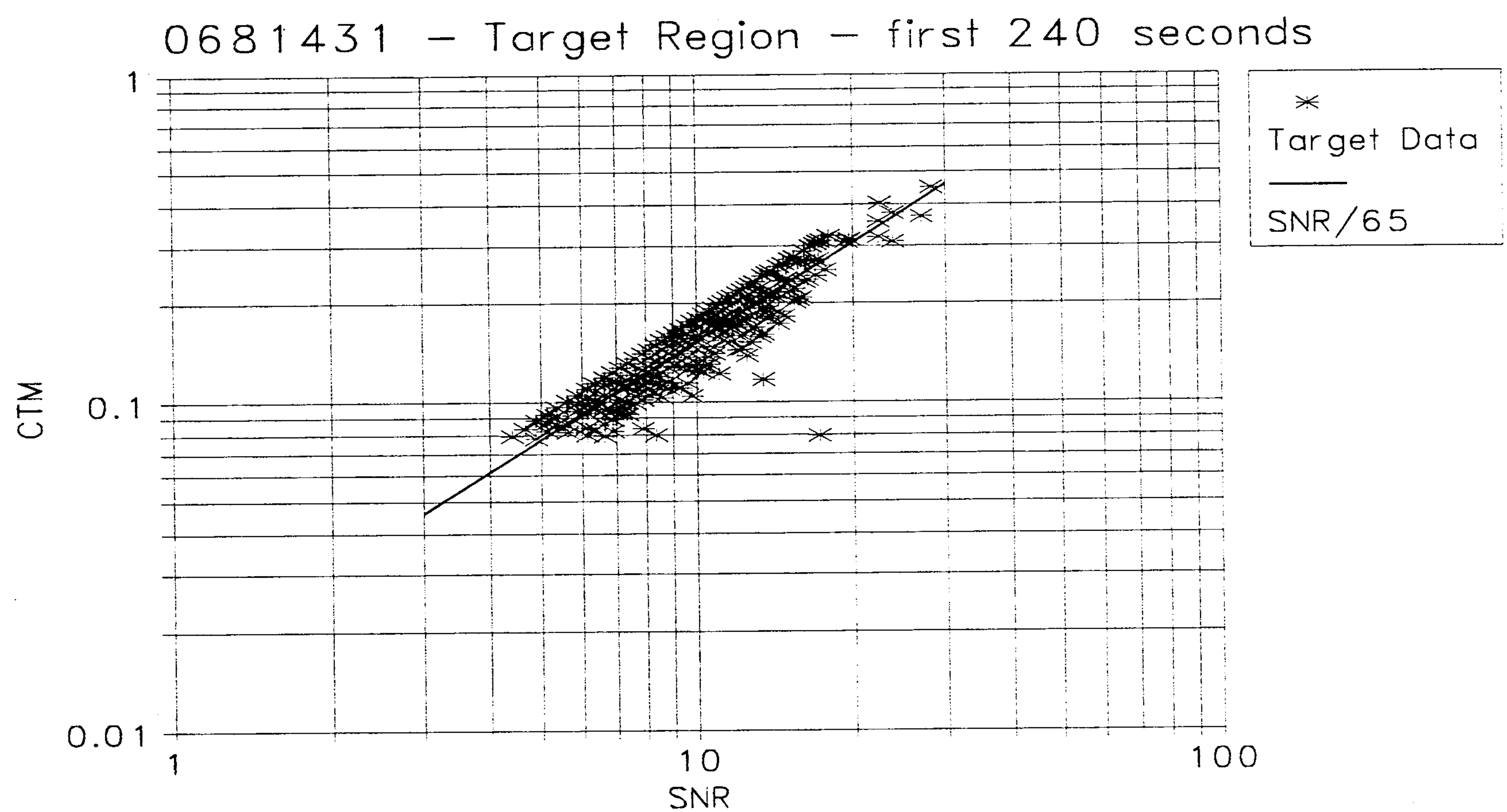
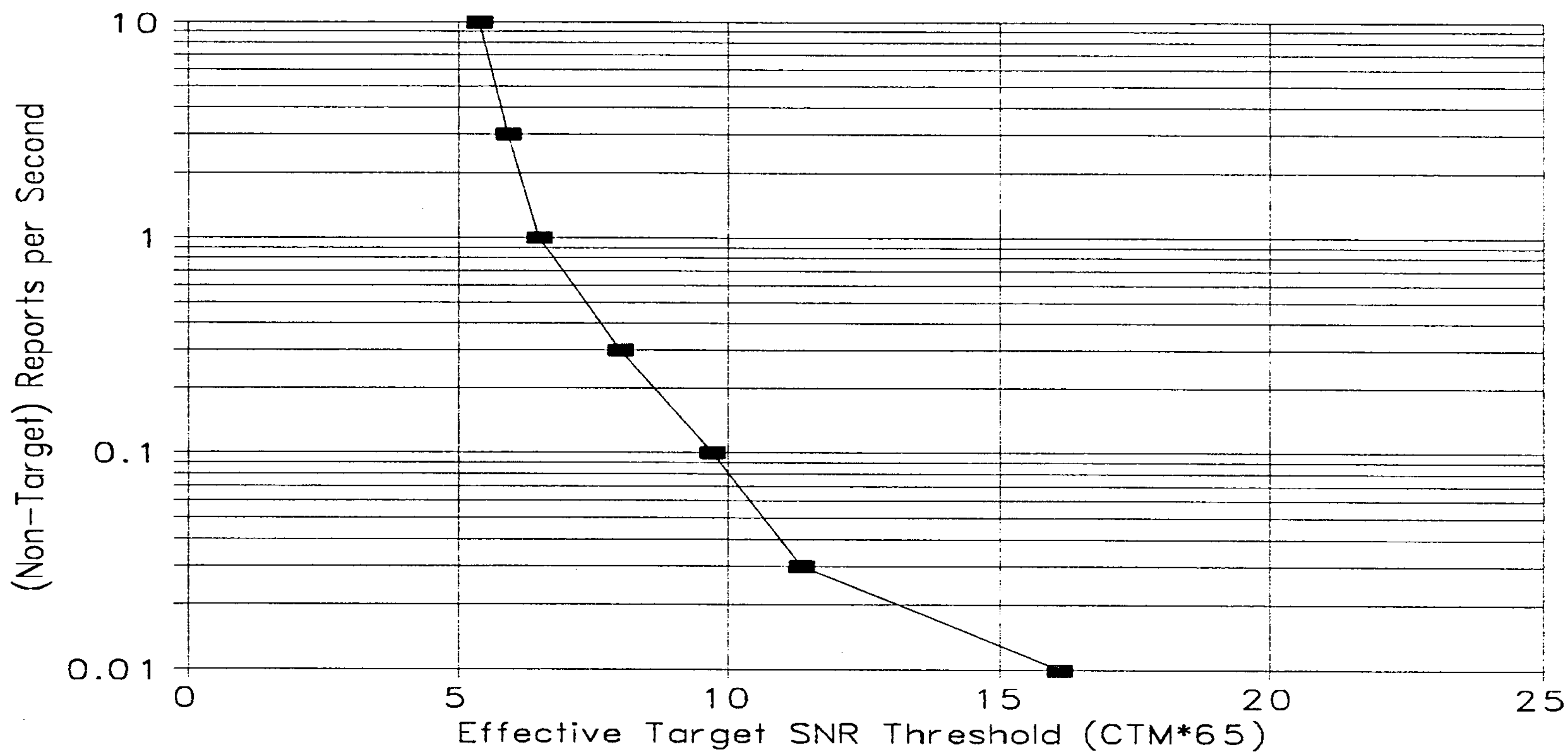


Based on this relationship, the previous FAR-vs.-CTM threshold plot can be converted to a FAR-vs.-ETSNR threshold plot. This was the conversion used in the summary FAR statistics plot shown previously.


(Non-Target) Reports per Second
10
1
0.1
0.01
0
5
10
15
20
25
Effective Target SNR Threshold (CTM*65)

Looking more closely at this solar glint case, this plot shows the azimuth, elevation location of all detections recorded over approximately 1 min of operation. At the normal CTM threshold of 0.15, false alarms would have been present at the two locations marked with the circles. Note that this plot shows an approximately constant FAR over the upper area, but below the horizon, the exceedance rate is noticeably higher to the right. The next slide will show an image of the scan with the vertical scale expanded to approximately match this plot.

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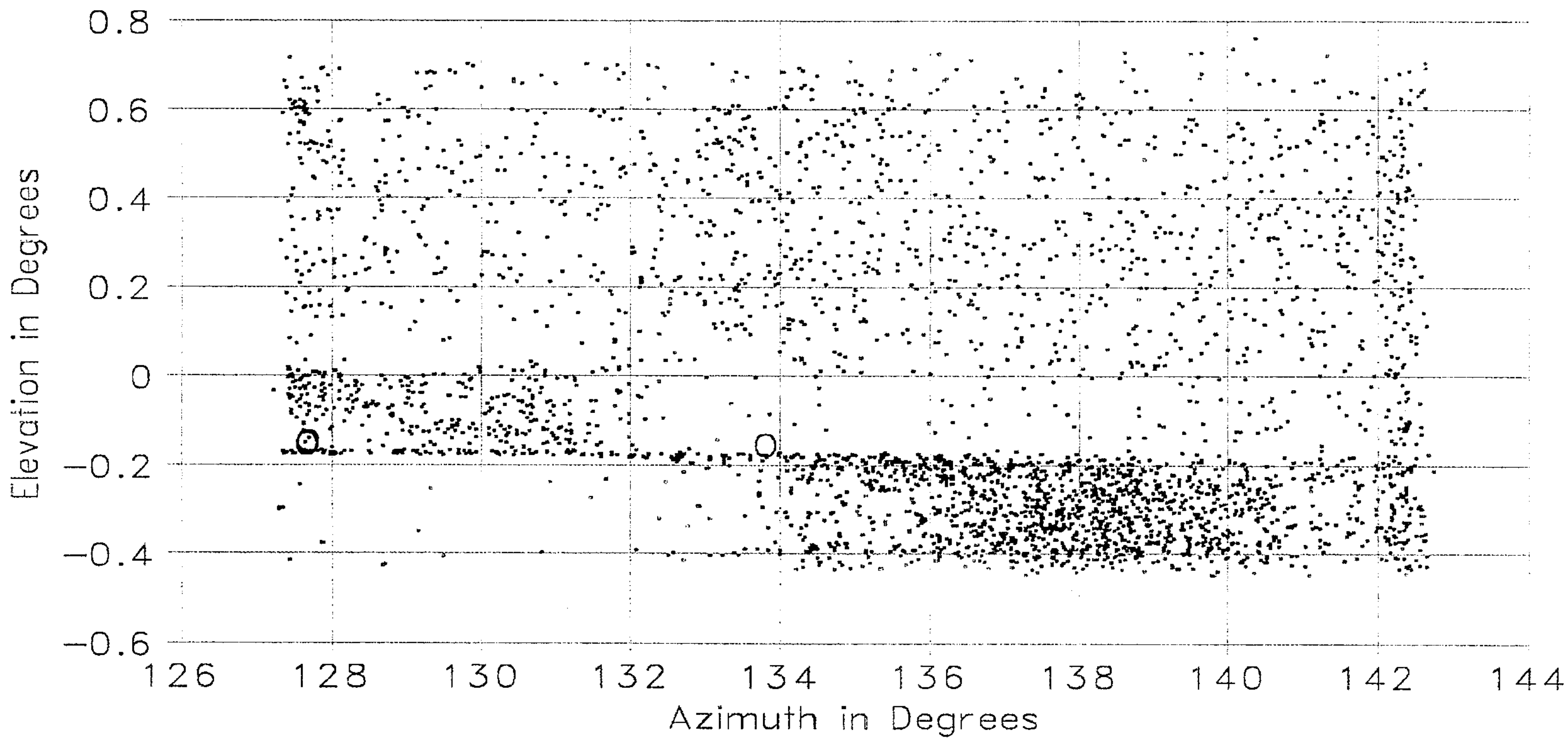
Day 91, RN01

All Exceedances, CTM > 0.15 Marked as O



At first, this comparison may seem strange as the region with the strongest clutter has the lowest FAR. Thinking back to the description of the adaptive threshold, this is not so surprising. In the region to the left, the clutter is dense and the background estimator does a good job of estimating the clutter and raising the threshold. To the right, the clutter is more scattered, and the threshold is not raised so effectively.

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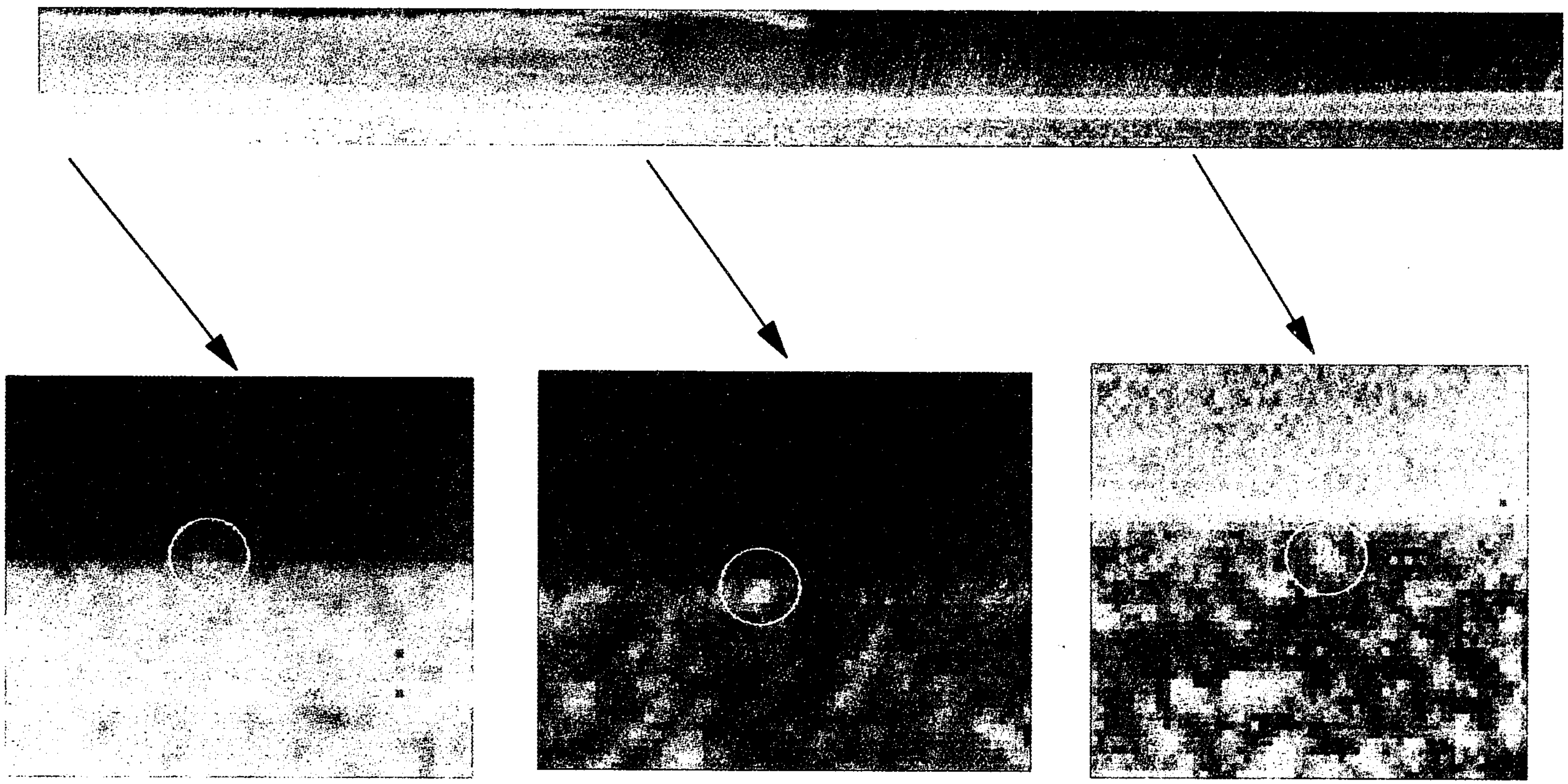
This examines in detail the three regions with the highest CTM exceedances. The exceedance on the left seems to have been due to a *rogue wave* that came up appreciably above the horizon for about 0.1 sec. This happened at the end of the scan and the wave was visible in the sensor FOV for about 10 frames. The other two high CTM events seem to have been *normal* glint points that just happened to be in an otherwise low clutter region and hence the adaptive threshold was less effective.



0.25 0.16 0.15

This summarizes the characteristics of solar sea glint and discusses some of the approaches that can be taken to further mitigate its impact.

For the HISS Phase 2 system, all of the changes could better suppress the below horizon clutter, but the *rogue wave* is hard to deal with as it is similar to a target.

For the HISS Phase 3 design, the track discrimination process will discriminate very well against clutter such as solar sea glint that is uncorrelated after 1 sec.

If even more discrimination is needed, two-color discrimination can be a powerful tool against clutter with a distinctive spectral shape. Although the HISS Phase 3 system is not intended to do two-color processing in real-time, it will collect simultaneous two-color data that can be used to evaluate two-color processing in non-real-time.

The effectiveness of some of these HISS Phase 2 and HISS Phase 3 techniques is being investigated in another study that will be reported at another time.

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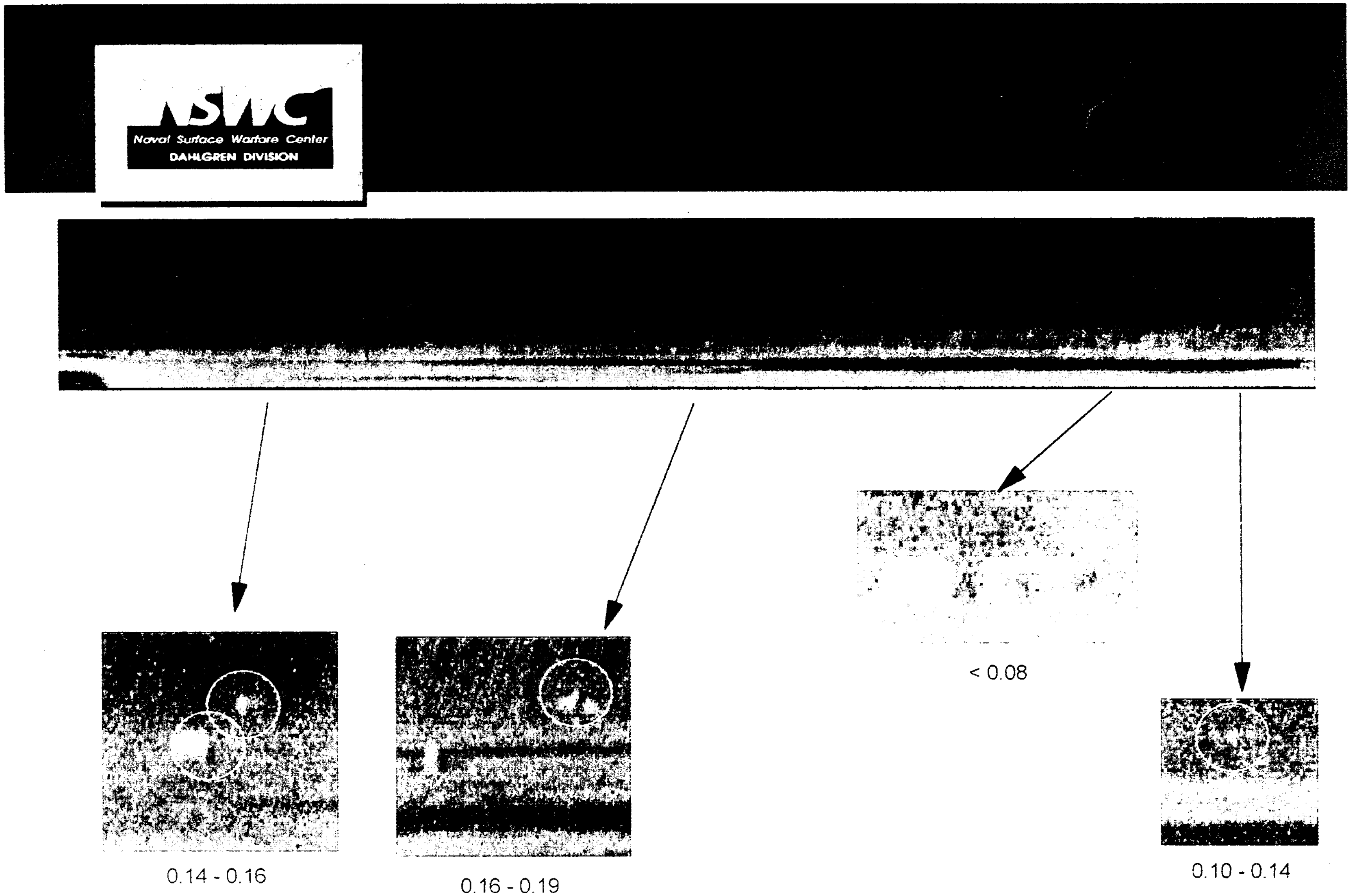
- Characteristics
  - High frequency (Small Bright Spots)
  - Transitory ( < 1 second)
  - Solar driven
- Further Mitigation
  - HISS-2: Increase background estimate window size
  - Change adaptive threshold parameters
  - Improve spatial part of CTM
  - Use 2D spatial filter below horizon
  - HISS-3: Track discrimination
  - Background classifier
  - Other: 2 color discrimination

This examines the land features that tended to produce the most target-like detections. The two structures to the left and middle had sharp edges or small protrusions that resulted in target-like detections. The larger structure to the right did not produce any high CTM detections but the little spot to its right did produce at least moderate CTM detections. The signature of the structures most certainly came from reflected sunlight, but the spot on the right may have been a small solar reflection or a thermal source of some type.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0.14 - 0.16
0.16 - 0.19
< 0.08
0.10 - 0.14

This summarizes the characteristics of land clutter and discusses some of the approaches that can be taken to further mitigate its impact. Because land clutter can be due to almost any man-made item and can have almost any number of target-like characteristics, the best approach is to use as many discriminants as possible (including $1/r^2$).

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- Characteristics
  - Sometimes high frequency (small or sharp edges)
  - Often persistent / stationary
  - Sometimes moving
  - Often solar driven
  - Sometimes thermal driven
- Further Mitigation
  - HISS-2:Improve spatial part of CTM
  - Use 2D spatial filter above horizon
  - HISS-3:Persistent track logic
  - Background classifier
  - Other: 2 color discrimination (solar)

This typical scan illustrates the common observation that detectable birds are normally extended, out-of-focus objects.

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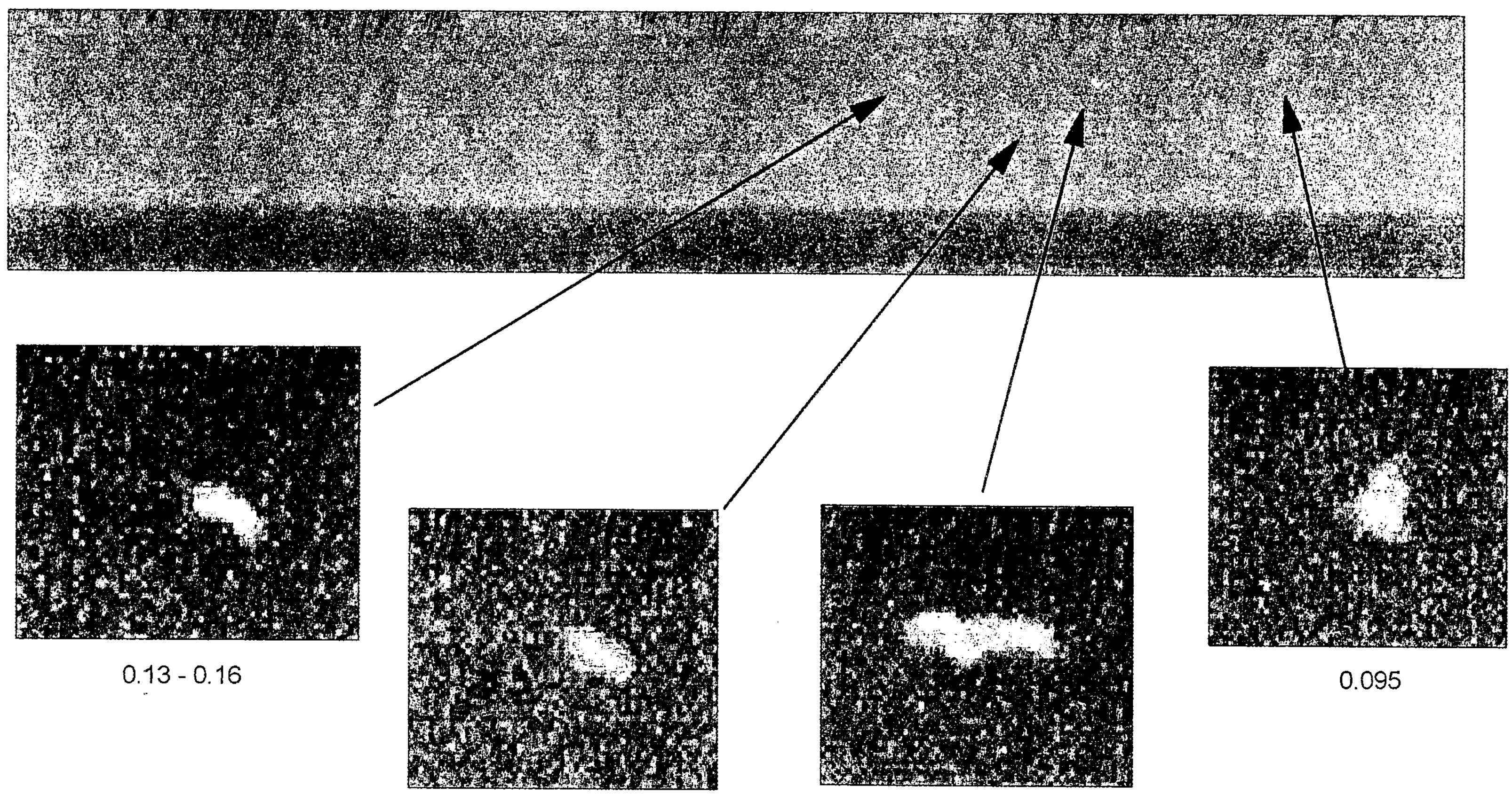

Size, position, motion, and spectral discrimination can all be used to further suppress birds as a source of false alarms. The detections for this particular run were recorded with the HISS set up for a high altitude target run. By using the normal *horizon* look-up table for the CTM position term, the FAR curve for this bird run is reduced to be only slightly worse than that for sensor noise-limited performance.

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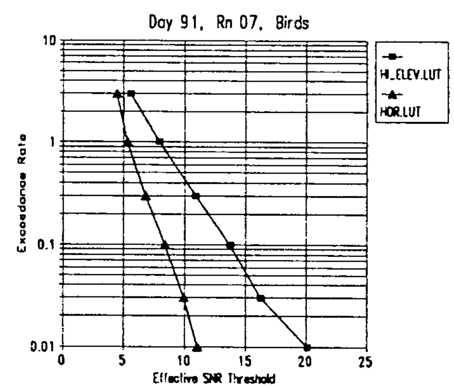
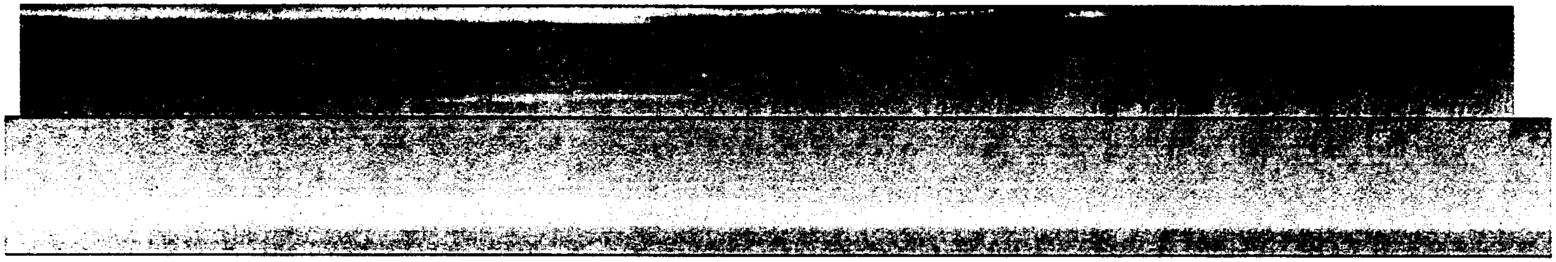
- Characteristics
  - Can be persistent for several scans or more
  - High frequency beyond several km
  - Low frequency (out of focus) at short range
  - Solar driven
- Further mitigation
  - HISS-2: Use position part of CTM
  - Improve spatial part of CTM
  - Use 2D spatial filter above horizon
  - HISS-3: Track discrimination
  - Track motion discrimination
  - Other: 2 color discrimination



For completeness, sky and low cloud clutter will be shown. Generally speaking, the spatial filter will almost always suppress this type clutter to well below the sensor noise level and further mitigation is not needed for a horizon IRST. For elevation angles above several degrees, this may not always be true, and other discriminates may be useful.



- Characteristics
  - Low frequency (especially below several degrees)
  - Low amplitude below several degrees
  - Very Low amplitude and very low frequency near horizon
  - Mostly solar driven
- Further Mitigation (not needed for horizon IRST)
  - HISS-2: Improve spatial part of CTM
  - 2D Spatial filter above horizon
  - HISS-3: Track logic
  - Background classifier
  - Other: 2 color discrimination (solar)

In summary, a representative set of clutter-limited data was analyzed. In some cases, the FAR was essentially sensor-noise-limited and no adjustment of the target detection sensitivity was needed. In other cases, there was a noticeable increase in FAR at the normal detection threshold and a threshold increase of 1.2 to 2.0 was needed to reduce FAR to the level of less than 0.01/sec. This level of increased threshold did not impair test objectives. Finally, to reiterate, false alarms were not a problem in testing.

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- Clutter limited data available
  - Not sensor artifact (bad pixel) limited
- Representative cases analyzed
  - Sky / Low Clouds, Solar Sea Glint, Land, Birds
- Sky/Cloud, some land, some solar
  - FAR is essentially sensor noise limited
  - FAR < 0.01/second at normal target SNR threshold of 10
- Birds, some land, some solar
  - FAR increases to 0.1 to 3/second at normal target SNR threshold of 10
  - FAR can be reduced to <.01/second with 1.2 to 2X increase in threshold
- Use of increased thresholds to control FAR did not impair test objectives (adequate detection range)
- False Alarms were not a problem in testing

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**13. ABSTRACT** *(Maximum 200 words)*

The Horizon Infrared Surveillance Sensor (HISS) Phase 2 system was involved in testing at Wallop's Island, Virginia from November 1993 through April 1994. Currently, specific performance characteristics of the HISS are being analyzed. This report is the first in a series on the performance of the system. A final report will be generated later that will summarize the results presented to date and provide any required corrections or expansions of the analyses.

**14. SUBJECT TERMS**
Infrared, Search and Track, Horizon Infrared Surveillance Sensor, HISS, False Alarm Rate, Multisensor Integration

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The Report Documentation Page (RDP) is used in announcing and cataloging reports. It is important that this information be consistent with the rest of the report, particularly the cover and its title page. Instructions for filling in each block of the form follow. It is important to ***stay within the lines*** to meet ***optical scanning requirements***.

**Block 1.** Agency Use Only *(Leave blank)*.

**Block 2.** Report Date. Full publication date including day, month, and year, if available (e.g. 1 Jan 88). Must cite at least the year.

**Block 3.** Type of Report and Dates Covered. State whether report is interim, final, etc. If applicable, enter inclusive report dates (e.g. 10 Jun 87 - 30 Jun 88).

**Block 4.** Title and Subtitle. A title is taken from the part of the report that provides the most meaningful and complete information. When a report is prepared in more than one volume, repeat the primary title, add volume number, and include subtitle for the specific volume. On classified documents enter the title classification in parentheses.

**Block 5.** Funding Numbers. To include contract and grant numbers; may include program element number(s), project number(s), task number(s), and work unit number(s). Use the following labels:

| | | | |
|---|---|---|---|
| C | - Contract | PR | - Project |
| G | - Grant | TA | - Task |
| PE | - Program Element | WU | - Work Unit Accession No. |

**BLOCK 6.** Author(s). Name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. If editor or compiler, this should follow the name(s).

**Block 7.** Performing Organization Name(s) and address(es). Self-explanatory.

**Block 8.** Performing Organization Report Number. Enter the unique alphanumeric report number(s) assigned by the organization performing the report.

**Block 9.** Sponsoring/Monitoring Agency Name(s) and Address(es). Self-explanatory.

**Block 10.** Sponsoring/Monitoring Agency Report Number. *(If Known)*

**Block 11.** Supplementary Notes. Enter information not included elsewhere such as: Prepared in cooperation with...; Trans. of...; To be published in.... When a report is revised, include a statement whether the new report supersedes or supplements the older report.

**Block 12a.** Distribution/Availability Statement. Denotes public availability or limitations. Cite any availability to the public. Enter additional limitations or special markings in all capitals (e.g. NOFORN, REL, ITAR).

| | |
|---|---|
| **DOD** | - See DoDD 5230.24, "Distribution Statements on Technical Documents." |
| **DOE** | - See authorities. |
| **NASA** | - See Handbook NHB 2200.2 |
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**Block 12b.** Distribution Code.

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| **DOE** | - Enter DOE distribution categories from the Standard Distribution for Unclassified Scientific and Technical Reports. |
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**Block 13.** Abstract. Include a brief ***(Maximum 200 words)*** factual summary of the most significant information contained in the report.

**Block 14.** Subject Terms. Keywords or phrases identifying major subjects in the report.

**Block 15.** Number of Pages. Enter the total number of pages.

**Block 16.** Price Code. Enter appropriate price code ***(NTIS only)***

**Block 17.-19.** Security Classifications. Self-explanatory. Enter U.S. Security Classification in accordance with U.S. Security Regulations (i.e., UNCLASSIFIED). If form contains classified information, stamp classification on the top and bottom of this page.

**Block 20.** Limitation of Abstract. This block must be completed to assign a limitation to the abstract. Enter either UL (unlimited or SAR (same as report). An entry in this block is necessary if the abstract is to be limited. If blank, the abstract is assumed to be unlimited.