

Image Processing for Flight Crew Enhanced Situational Awareness

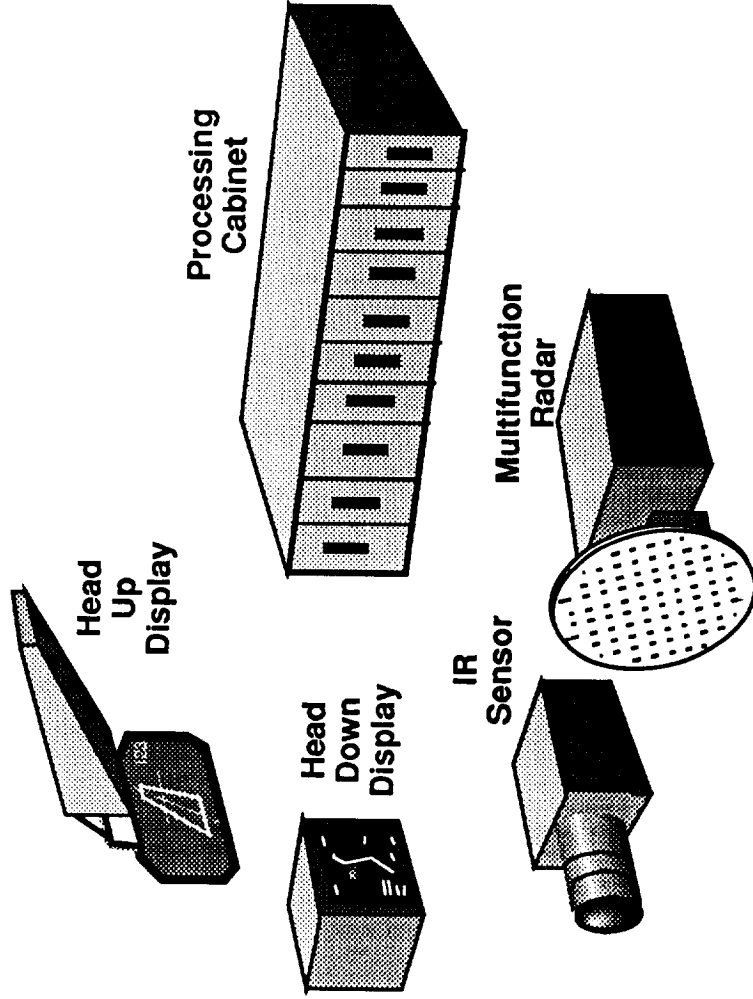
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ABSTRACT

This presentation describes the image processing work that is being performed for the Enhanced Situational Awareness System (ESAS) application. Specifically, the presented work supports the Enhanced Vision System (EVS) component of ESAS.

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Enhanced Situation Awareness System (ESAS)



ESAS Functions

- ⇒ SVS/EVS
- ⇒ Ground Taxi & Takeoff
- ⇒ Weather RADAR
- ⇒ Windshear/Microburst Detection
- ⇒ CAT Detection
- ⇒ CFIT Avoidance
- ⇒ Wake Vortex Detection
- ⇒ Dry Hail Detection

The processing of imagery and its display to the flight crew will enhance aircraft operation in three areas.

- ⇒ Airplane pitch and roll stabilization
- ⇒ Adverse weather landing guidance
- ⇒ Runway incursion/obstacle avoidance

Currently, the information in the processed imagery is conveyed to the flight crew through a display of raster imagery and/or extracted features on a Head Up Display (HUD).

Image Processing for the Enhanced Vision Function of ESAS

✈ **Information obtained from imaging sensors is displayed to the flight crew to enhance aircraft operation**

- ⇨ Airplane pitch and roll stabilization
- ⇨ Adverse weather landing guidance
- ⇨ Runway incursion/obstacle avoidance

✈ **Information presentation methods**

- ⇨ Enhanced sensor images for HUD raster presentation
- ⇨ Sensor derived information for symbolic/synthetic HUD stroke presentation

Sensor Image Enhancement is required to compensate for sensor artifacts, reduce image noise level, etc.

Image Metrics are computed to aid in decisions regarding the application of sensor fusion, assessment of image quality and image information content, etc.

Sensor Feature Extraction produces image features corresponding to runway and taxiway edges/boundaries, the location of runway lights, etc. The features that are produced are subsequently displayed in symbolic form on a HUD or are used in registration of images on the HUD.

Areas of Image Processing Research for ESAS

- ✈ **Sensor Image Enhancement**
- ✈ **Image Metrics**
- ✈ **Sensor Feature Extraction**

The end result of sensor image enhancement is improved imagery for HUD display. Also, the resulting imagery is used by the feature extraction and image metric algorithms.

Sensor Image Enhancement

- **Beam sharpening for MMW Radar data**
 - ⇒ Compensate for transfer function of wide beam antenna
- **Contrast enhancement and noise cleaning for MMW Radar data**
 - ⇒ Range adaptive contrast enhancement
 - ⇒ Noise filtering and edge preserving smoothing

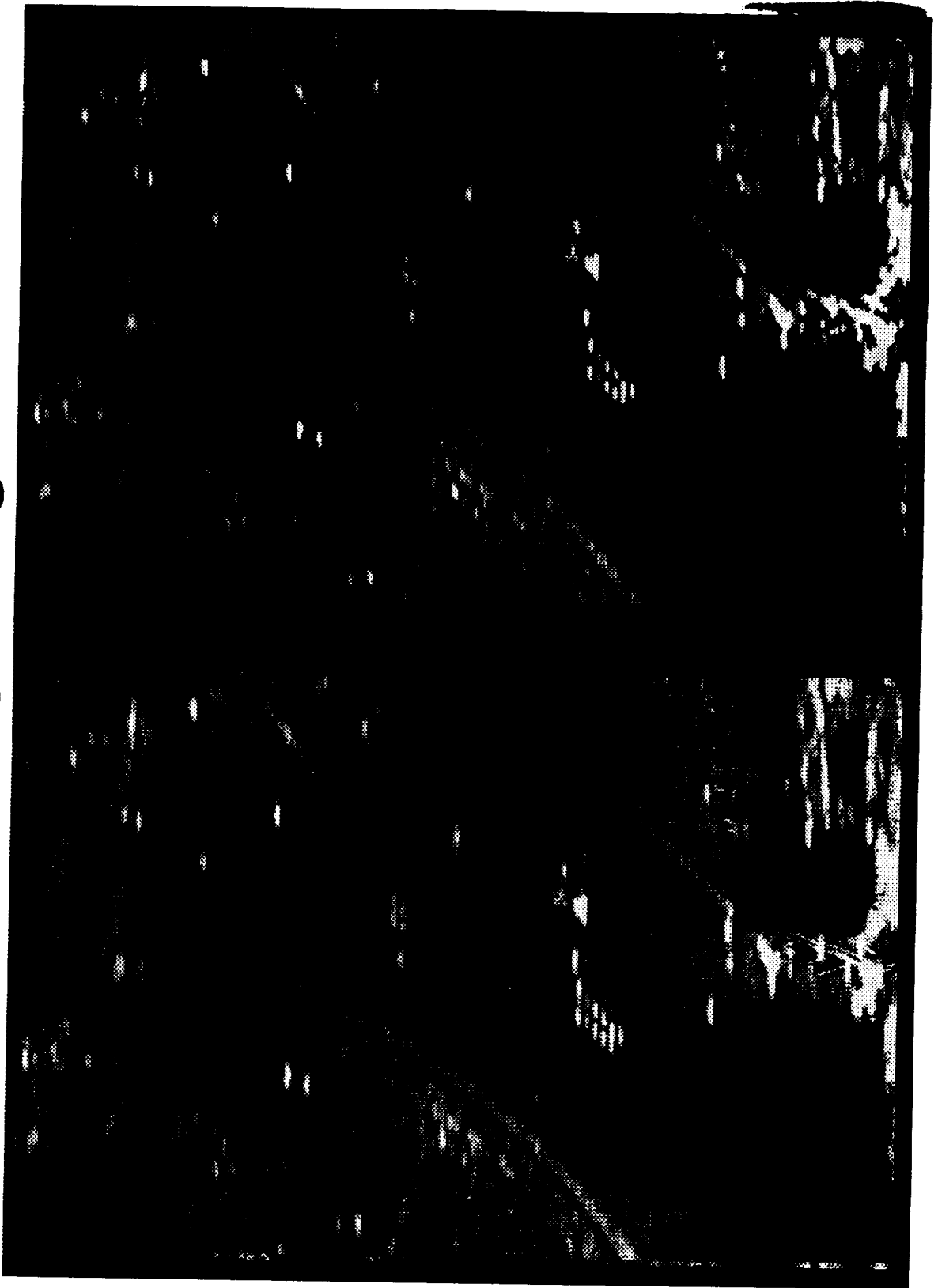
Right image: the raw imagery prior to beam sharpening

Left image: the beam sharpened image.

The Right image provides a factor of 2 improvement in image clarity/resolution which yields an improvement in the ability to distinguish adjacent objects in the radar image.

(The photo copying process doesn't do justice to the imagery.)

Beam Sharpening Results

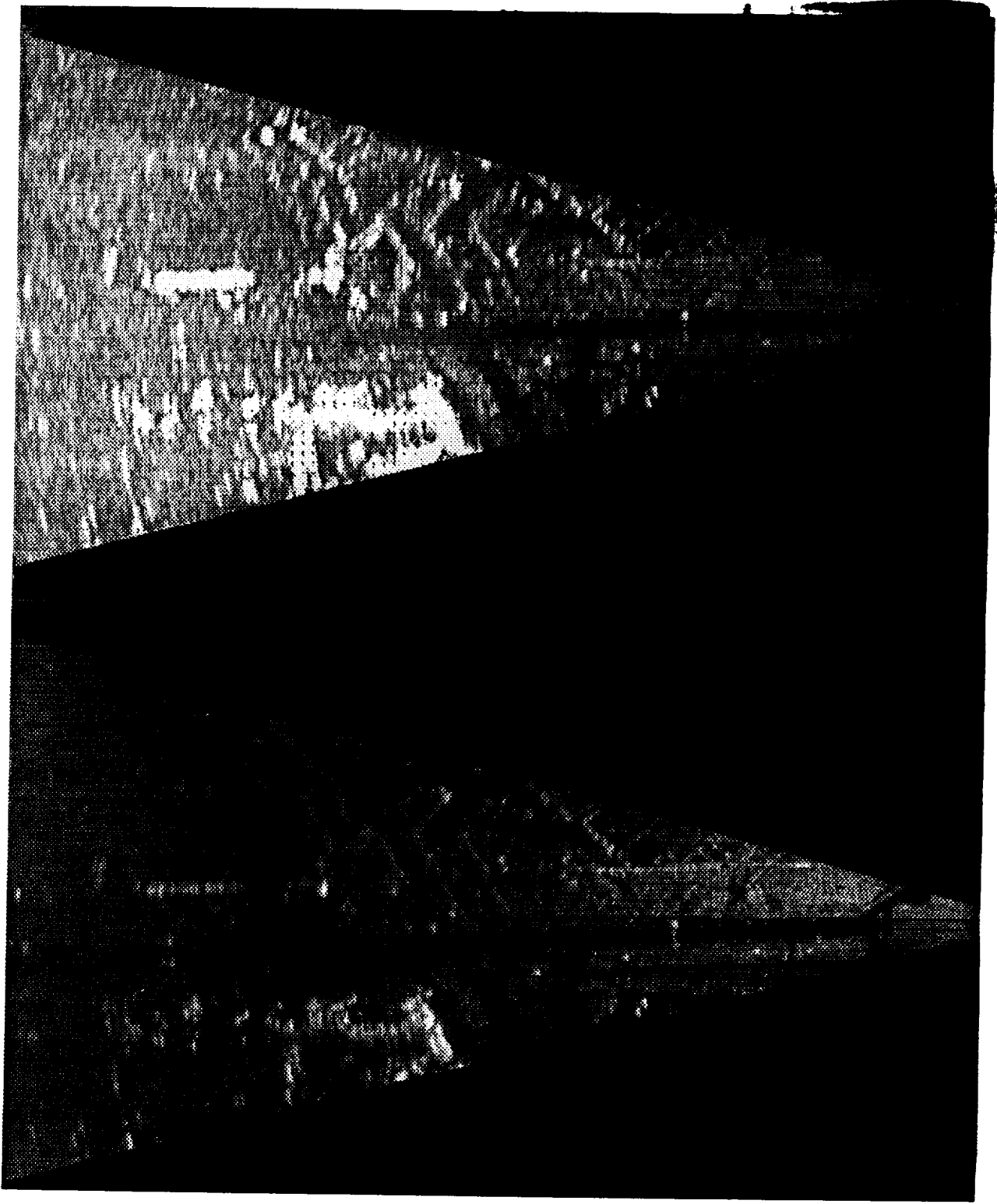


Left image: original radar image in B scan display (obtained from 35 GHz imaging radar; the site is Pt. Magu NAS).

Right image: range-adaptive, contrast enhanced image.

This contrast enhancement process provides range-adaptive gain control, which is determined from an empirically verified sensor model, to yield improved detail in the image at the far ranges.

Range Adaptive Contrast Enhancement



Multiple image metrics are being considered for use in characterizing/evaluating image quality/content. One application of these metrics is to control the application of a sensor fusion process.

Edge energy metric = local average of edge magnitude (the edge image is produced by a Sobel operator applied to the original image).

Contrast metric = convolution of two windows; one inside of the other.

$$\text{Metric} = \left[\frac{[(\text{Mean pixel value within large window}) - (\text{Mean pixel value within small window})]^2}{(\text{Standard deviation of pixel values within large window})} \right]$$

Sensor Image Evaluation

- **Sensor Image Metrics**
 - ⇒ Edge energy
 - ⇒ Spatial frequency content
 - ⇒ Local variance
 - ⇒ Contrast metrics
 - ⇒ Texture metrics (e.g., co-occurrence matrices)

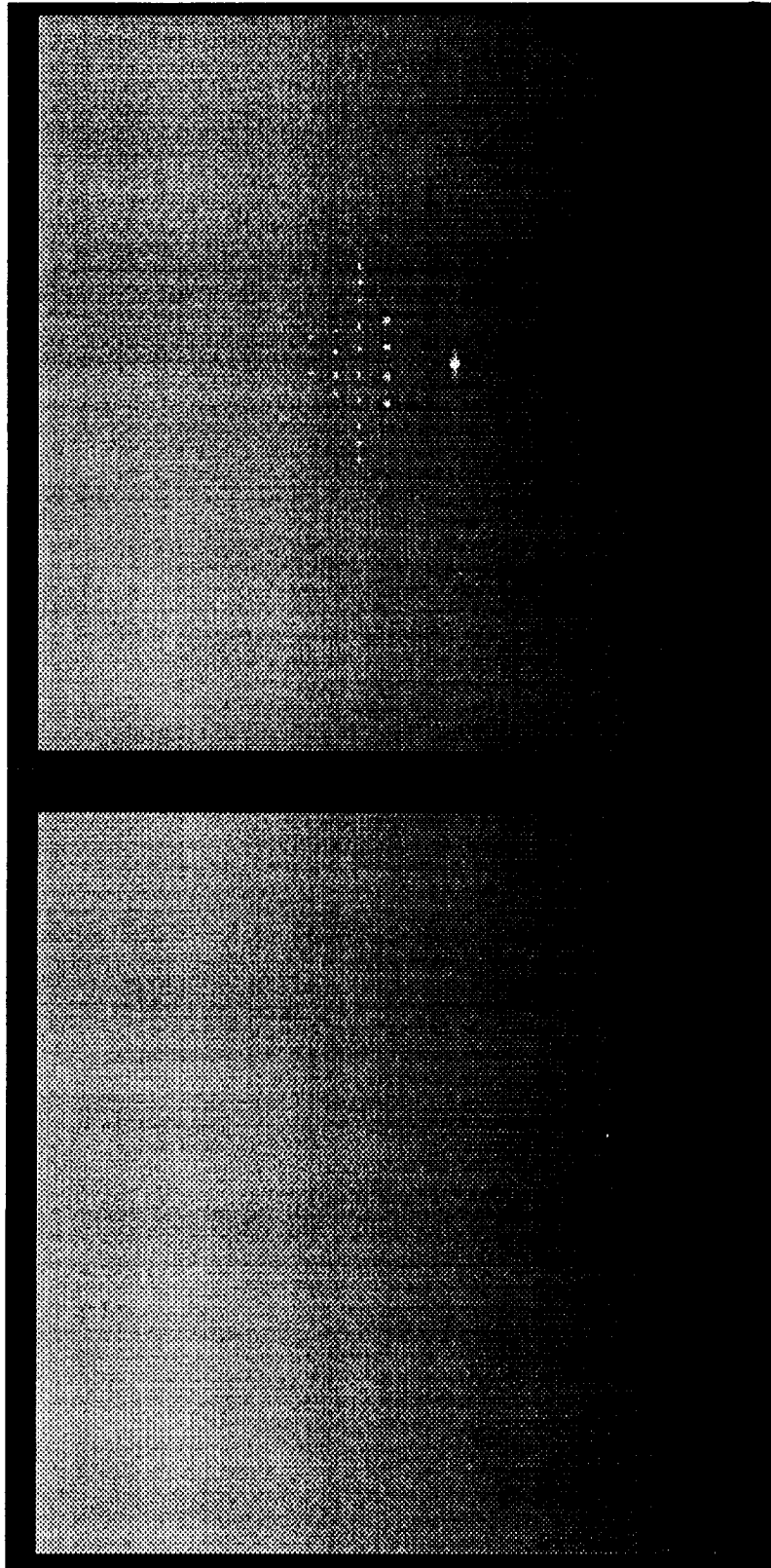
A collection of test images were synthesized for testing of the various forms of image metrics.

Set 1: .

Left image: a test image consisting of pure fog.

Right image: an image of landing lights in fog.

Image Metric Test Images



Additional synthesized test images.

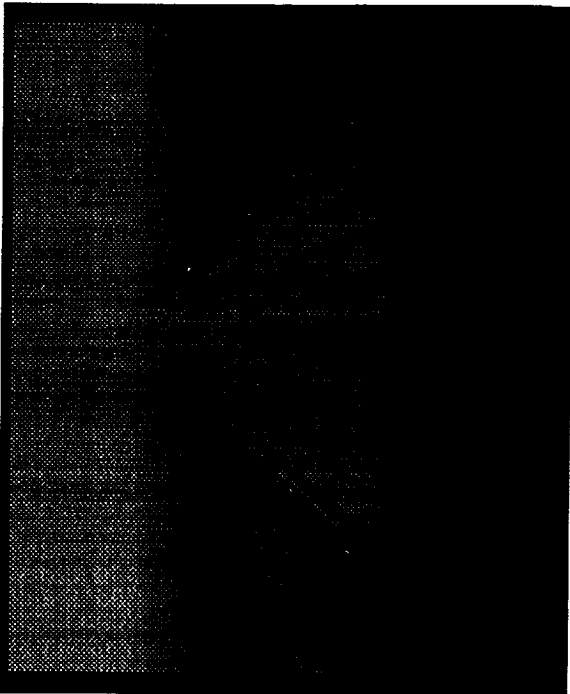
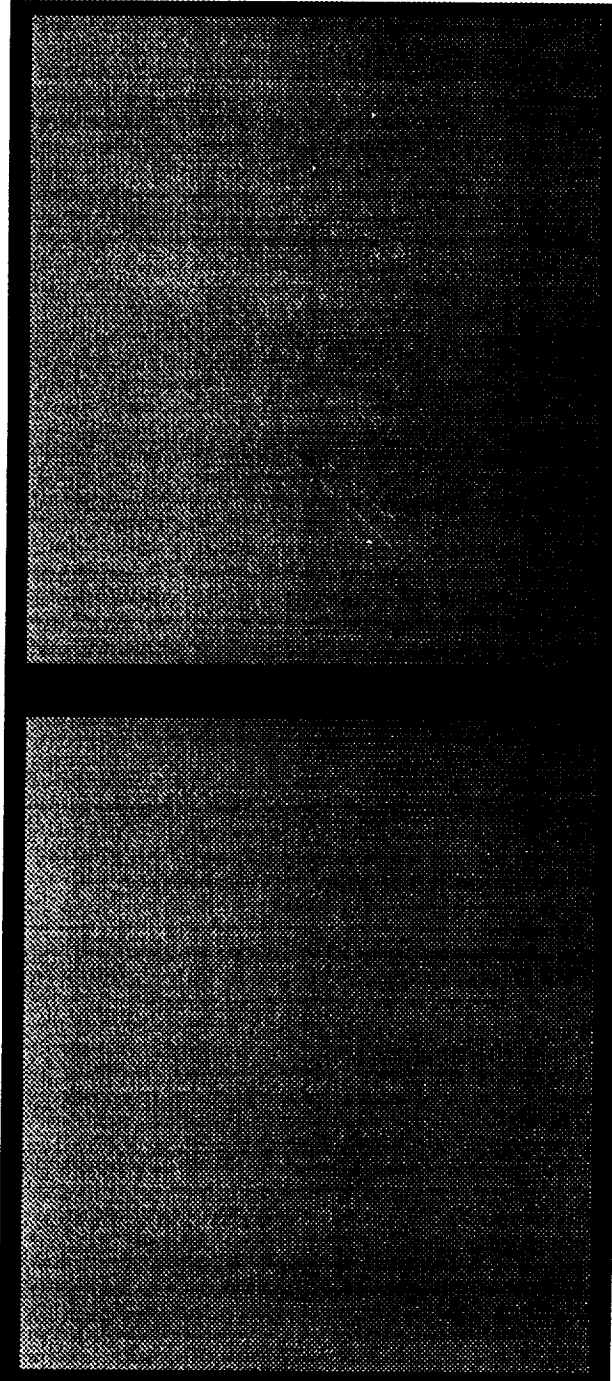
Set 2:

Top Left image: a test image consisting of pure fog.

Top Right image: an image with runway lights and markings showing through heavy fog.

Bottom image: an image of the same runway as above but with light fog.

Image Metric Test Images



Results of the edge energy metric as applied to the first set of test images.

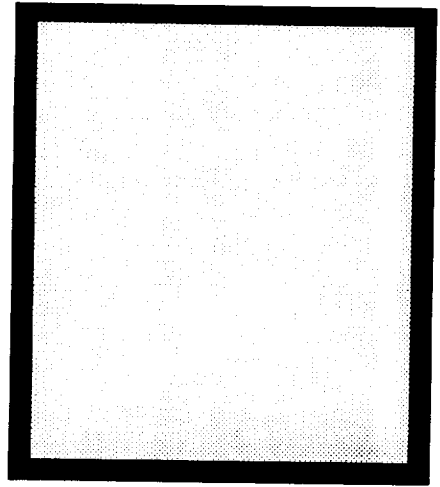
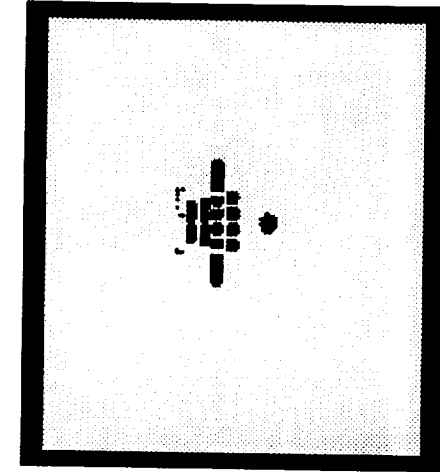
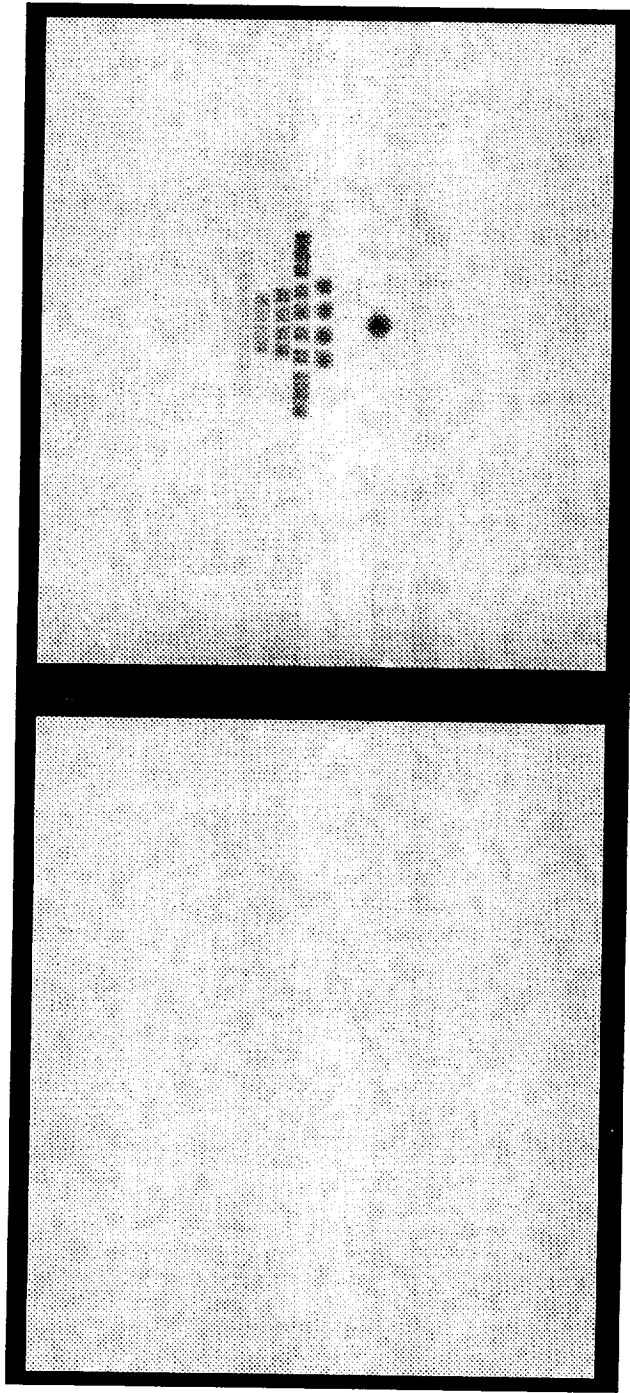
Top Left image: metric values of the pure fog image.

Top Right image: metric values for an image of landing lights in fog.

Bottom Left image: thresholded metric values for the top left image. (Note: the image is zero valued)

Bottom Right image: thresholded metric values for the top right image.

Edge Energy Image Metric Results



Edge metric applied to the second set of test images.

Top Left image: metric values of the pure fog image.

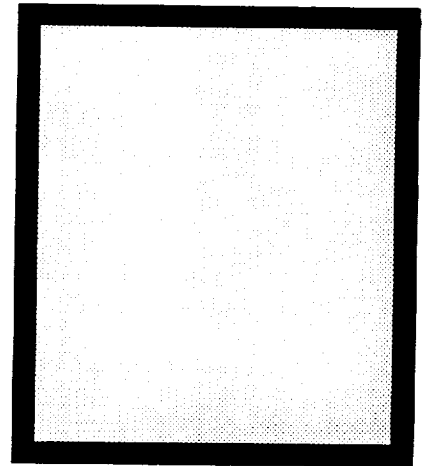
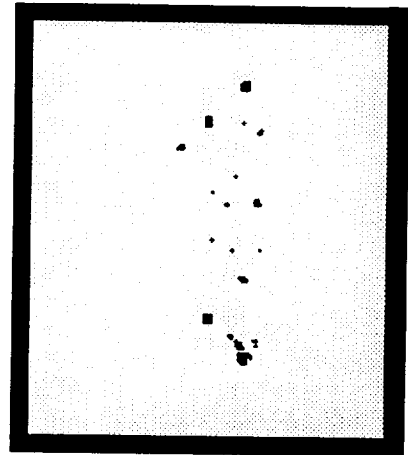
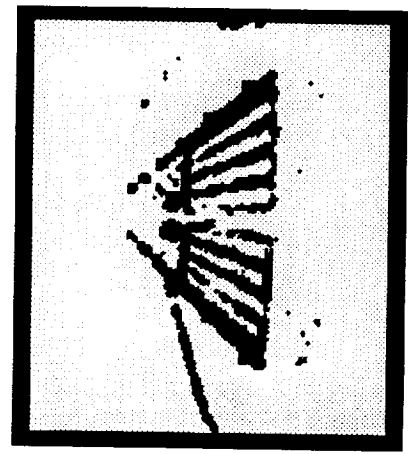
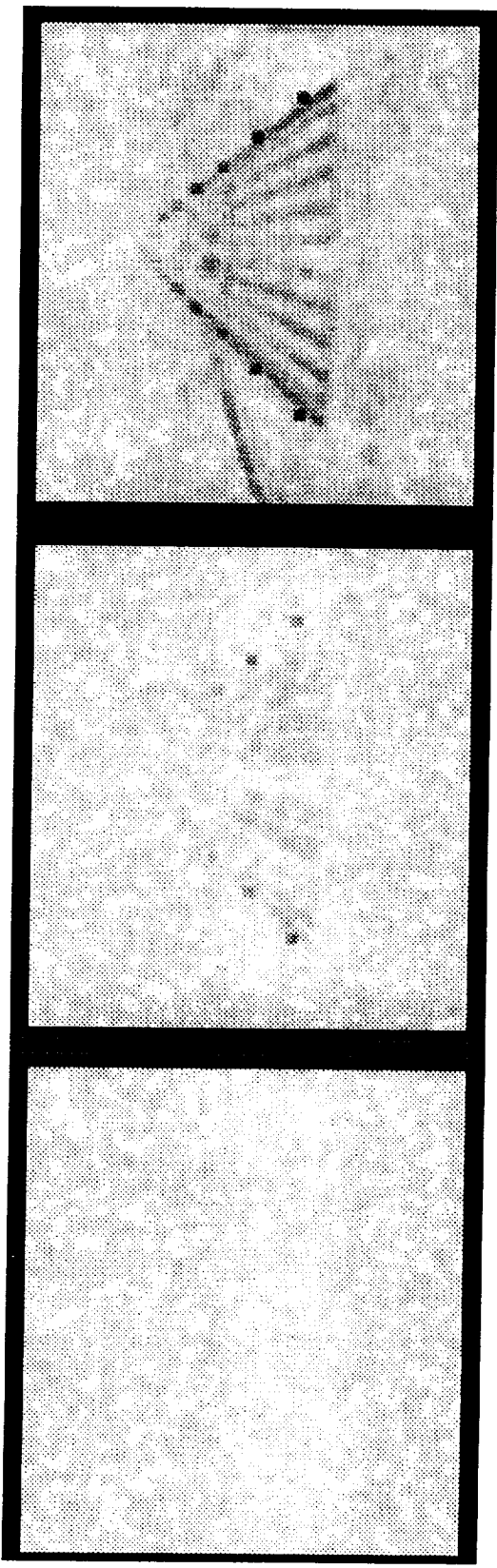
Top Middle image: metric values of an image with runway lights and markings showing through heavy fog.

Top Right image: metric values of an image of the same runway as above but with light fog.

Bottom images: thresholded versions of the Top row images.

(Note: the bottom left image is zero valued)

Edge Energy Image Metric Results



Contrast-based metric applied to the test images.

Top Left image: metric values for an image with runway lights and markings showing through heavy fog.

Top Right image: metric values for an image of the same runway as above but with light fog.

Bottom Left image: metric values for an image of pure fog.
(Note: this image is zero valued)

Bottom Right image: metric values for an image of landing lights in fog.

Contrast-Based Image Metric Results

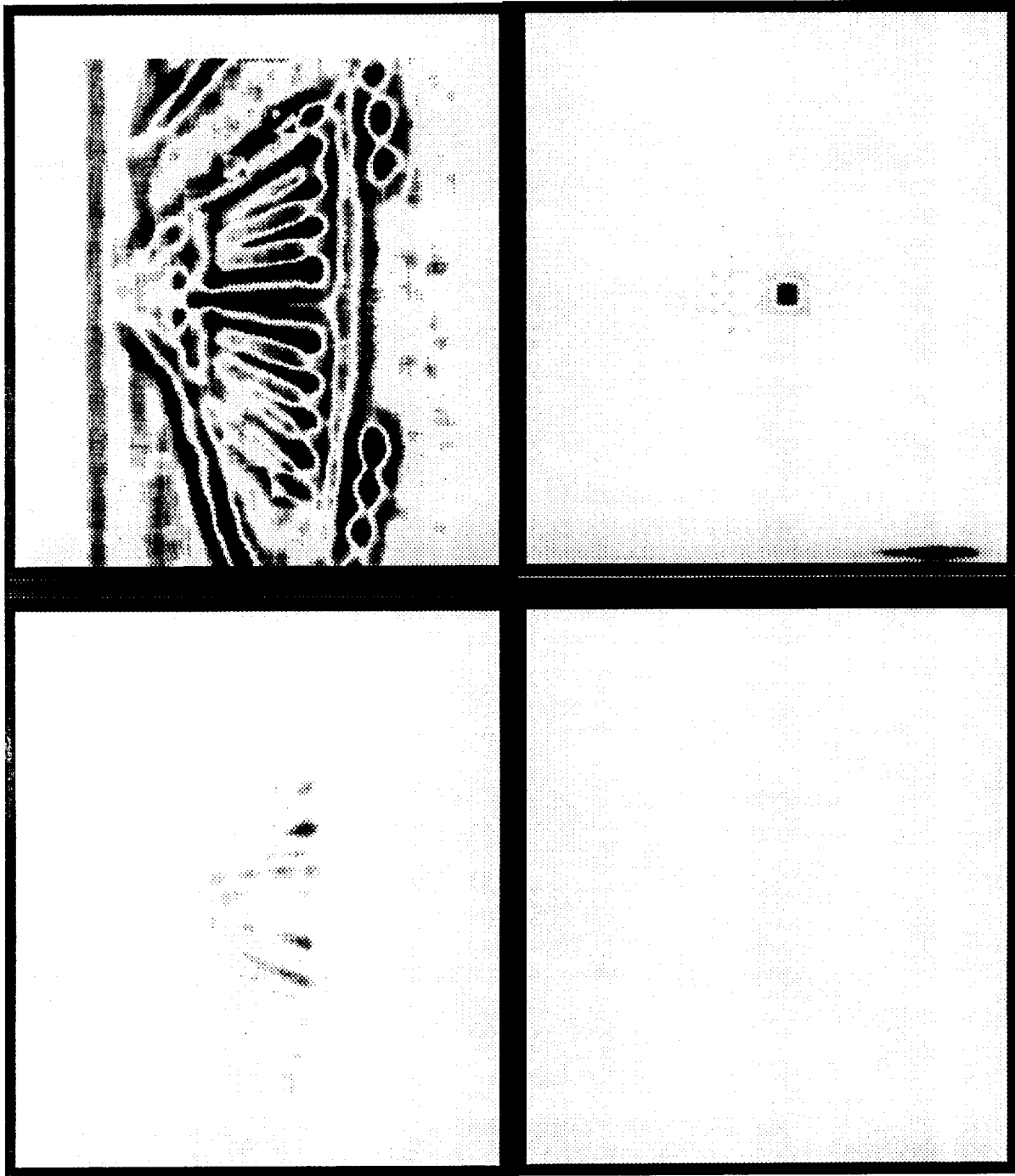


Image features are extracted for runways and taxiways for subsequent display on a HUD, etc.

Such features lead to improved situational awareness and can potentially lead to automatic performance of key functions:

- ✈ Runway/Taxiway Detection
- ✈ Runway Augmentation
- ✈ Runway Incursion/Obstacle Detection

Sensor Feature Extraction

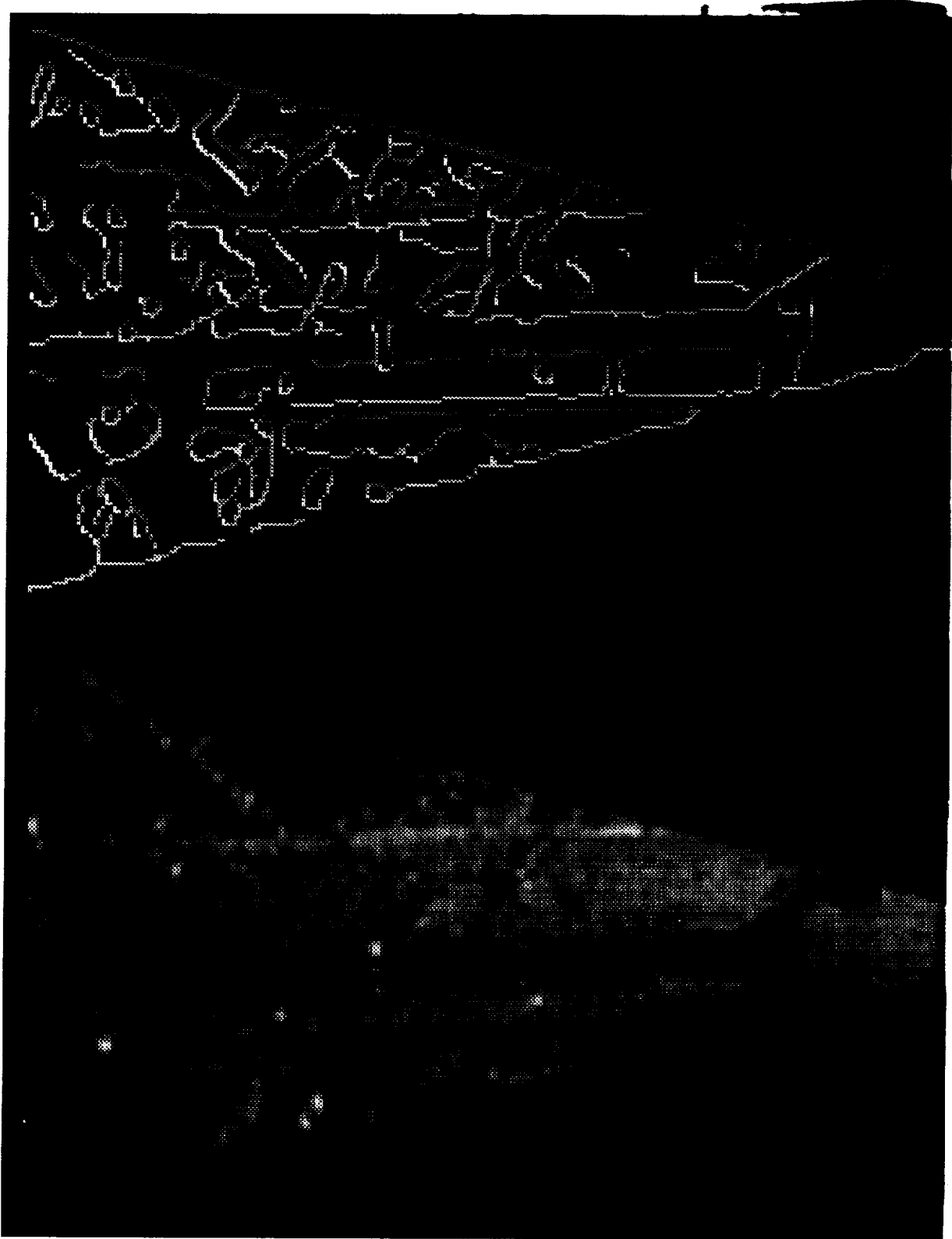
- ✈ **Runway/Taxiway Detection**
- ✈ **Runway Augmentation**
- ✈ **Runway Incursion/Obstacle Detection**

Left image: a subimage of the previous radar image of Pt. Magu NAS as produced by a 35 GHz radar.

Right image: edges extracted using a multi-threshold, edge linking algorithm.

Subsequent processing of the edge image will lead to runway boundaries being extracted and displayed on a cockpit HUD.

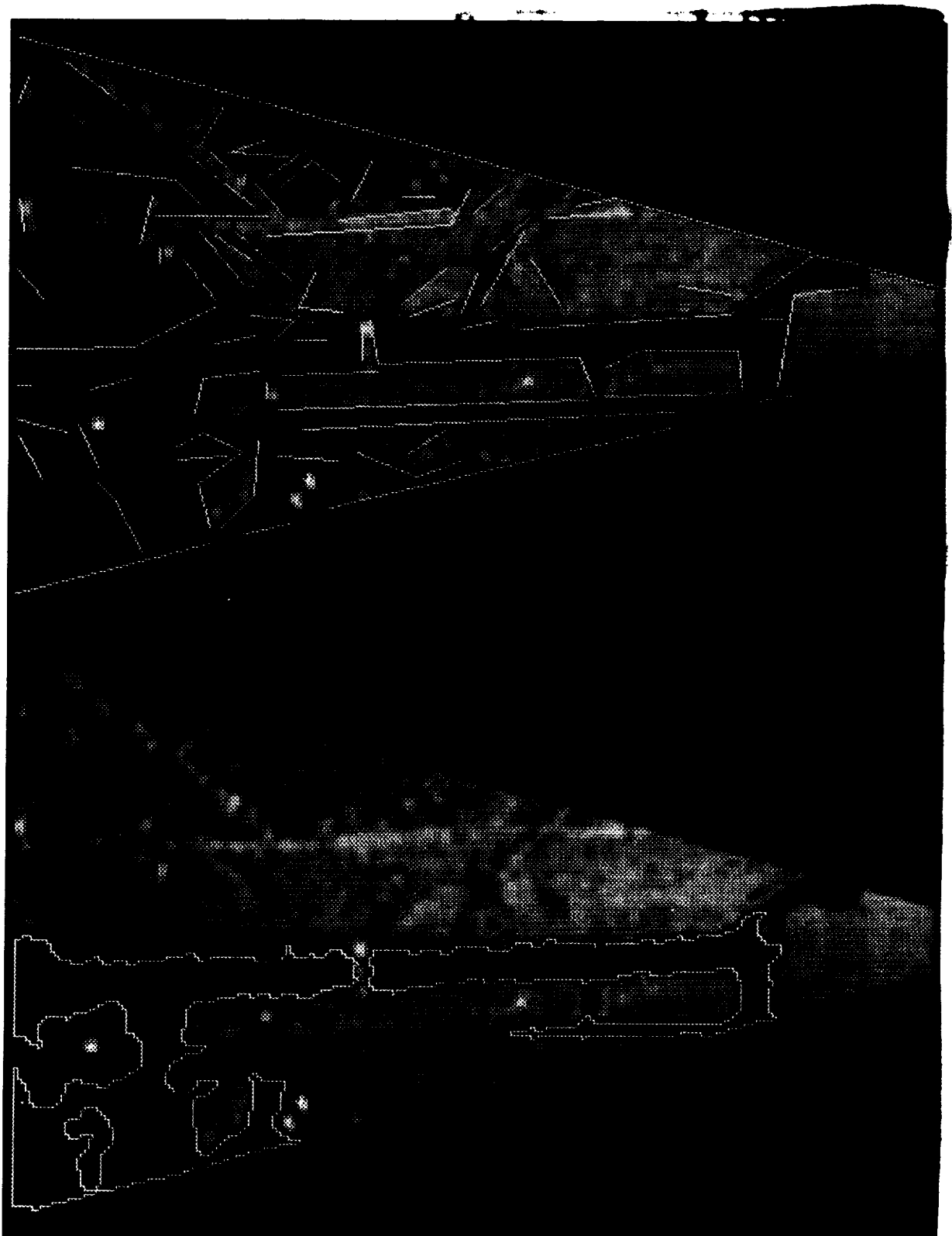
Runway/Taxiway Detection Results



Left image: a segmentation of the radar image as produced by a region growing algorithm. The white lines outline a nice definition of the runway and runway-like regions

Right image: the white lines represent line segments that have been fit to the edge contours shown on the previous viewgraph.

Runway/Taxiway Detection Results



Note that all of the processed imagery shown, constitute our initial explorations in these various areas of image processing. Much research remains to be done in these areas.

Conclusions

- ✈ **Image processing will provide important contributions to flight crew enhanced situational awareness.**
- ✈ **Ongoing efforts concentrate on techniques that deliver maximum performance and allow cost effective, real-time, implementation.**

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V. IMAGE PROCESSING: HUMAN VISION

