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Passive MMW Camera for  
Low Visibility Landings.

M. Shoucri,  
TRW Applications Technology Div.

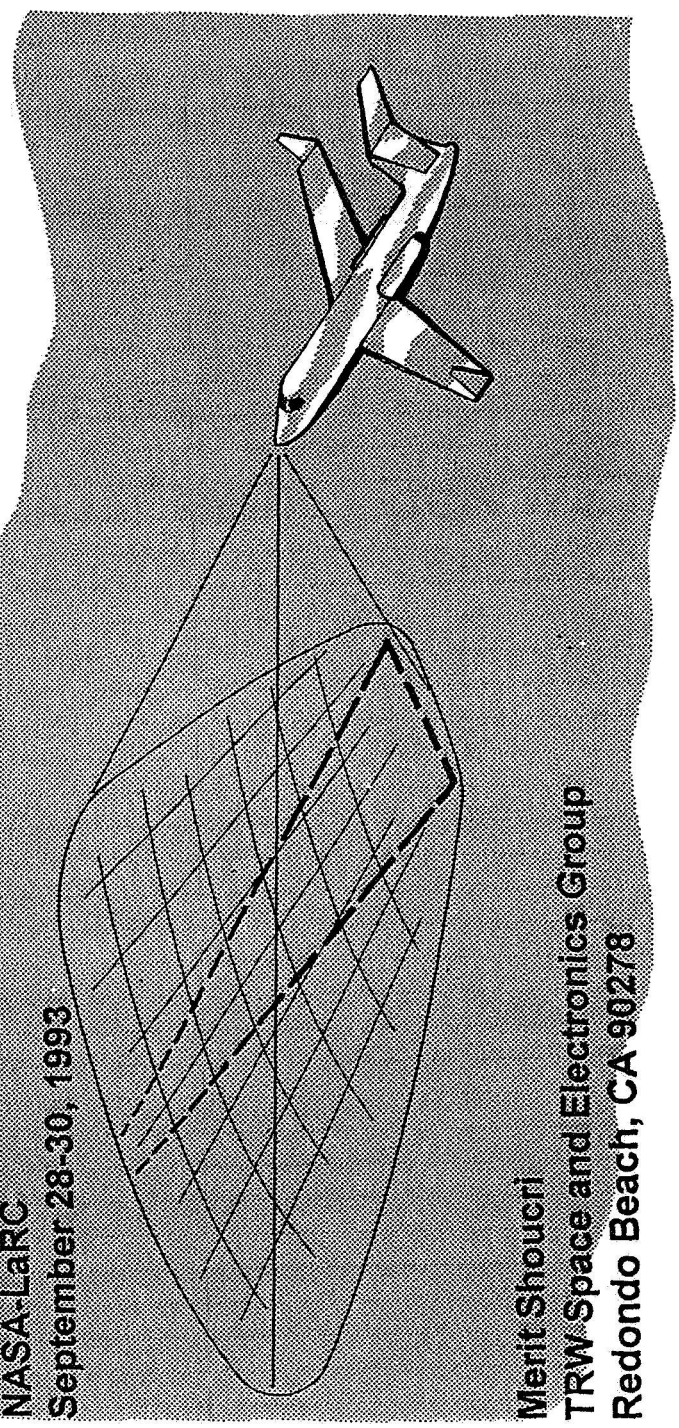
No abstract

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# A Passive Millimeter Wave Imaging Sensor for Aircraft Landing in Poor Visibility Conditions

Fifth (and Final) Combined Manufacturers' and Technologists' Airborne Windshear Review Meeting  
NASA-LaRC  
September 28-30, 1993



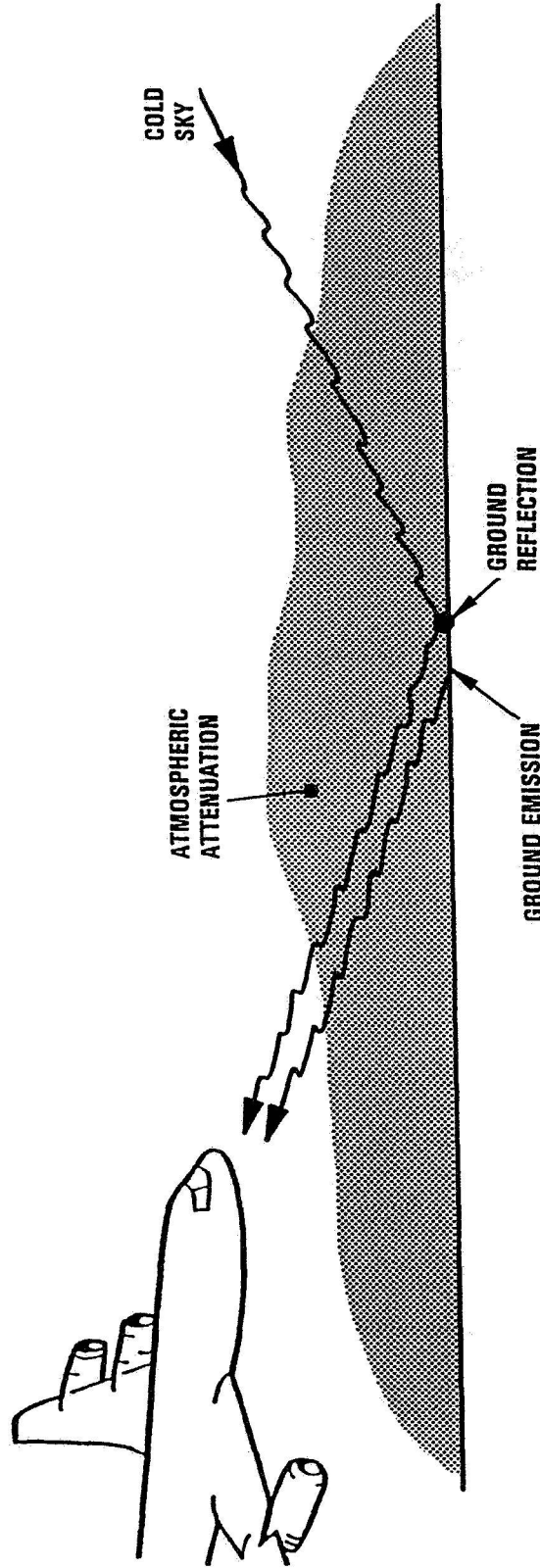
Merit Shoucri  
TRW Space and Electronics Group  
Redondo Beach, CA 90278

# **A Camera that sees through fog**

- **System Engineering**
- **Sensor Hardware**
- **Synthetic Vision System**



## Camera Images Are Obtained from Naturally Occurring Millimeter Waves



Scene contrast is provided by difference in material reflectivities, temperature and sky illumination of the scene



## Passive MMW Sensing

$$T_{obs}(\theta; p) \sim T_a(\theta) + \{e(\theta; p) T_{scn}\} + [1 - e(\theta; p)] T_{sky}(\theta) / L_a(\theta)$$

OBSERVED MMW TEMPERATURE AT GIVEN ANGLE  $\theta$  AND POLARIZATION  $p$

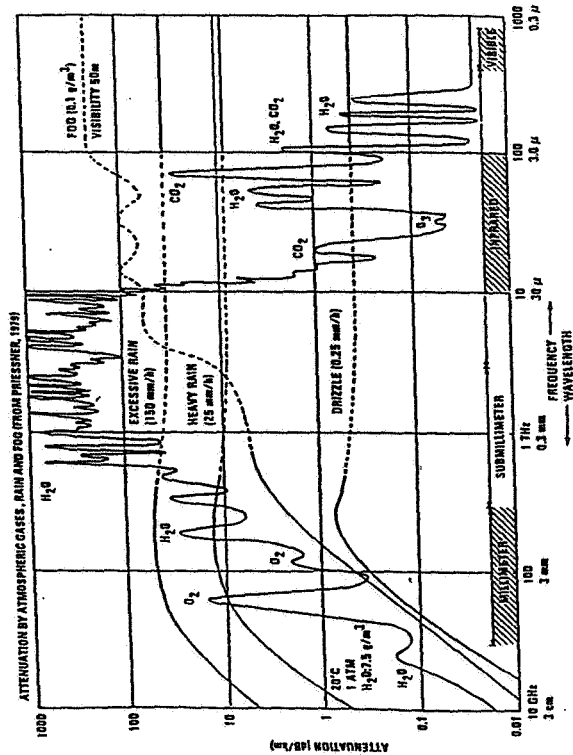
ATMOSPHERIC EMISSION EQUIVALENT RADIOMETRIC TEMPERATURE BETWEEN SCENE AND SENSOR

SCENE EMITTED RADIOMETRIC TEMPERATURE

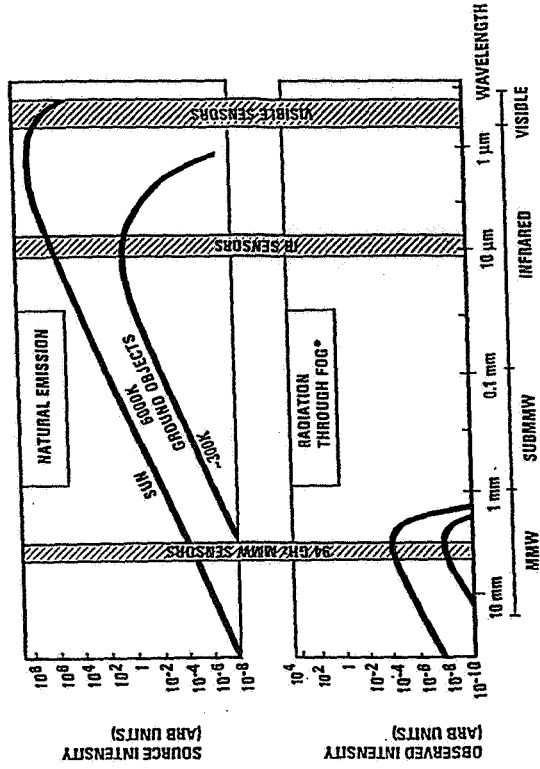
REFLECTED SKY (OR BACKGROUND) RADIOMETRIC TEMPERATURE

ATMOSPHERIC ATTENUATION BETWEEN SCENE AND SENSOR

## Attenuation by Atmospheric Gases, Rain and Fog (from Preissner, 1979)

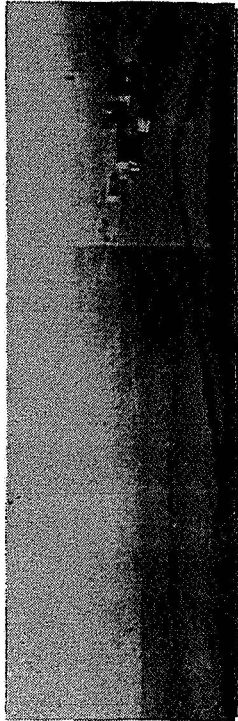


## Millimeter Waves Give the Strongest Observed Radiometric Signals

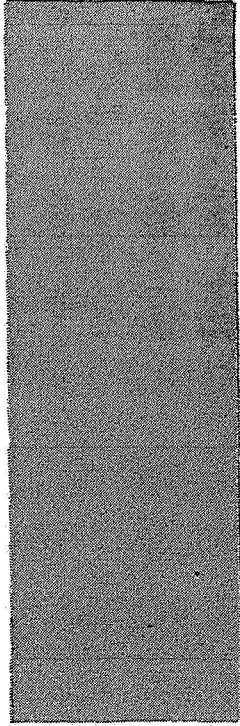


# Fog Penetration Using 94 GHz MMW Propagation Window **TRW**

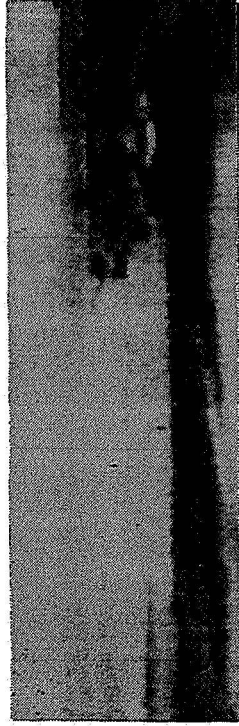
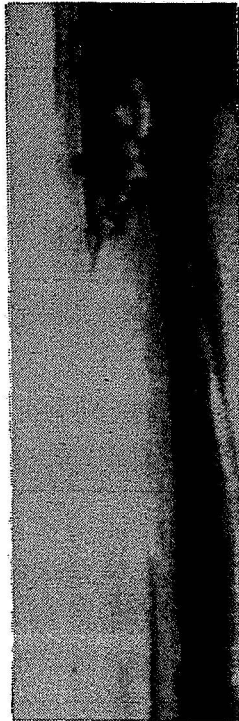
**CLEAR**



**FOG, 120 M VISIBILITY**



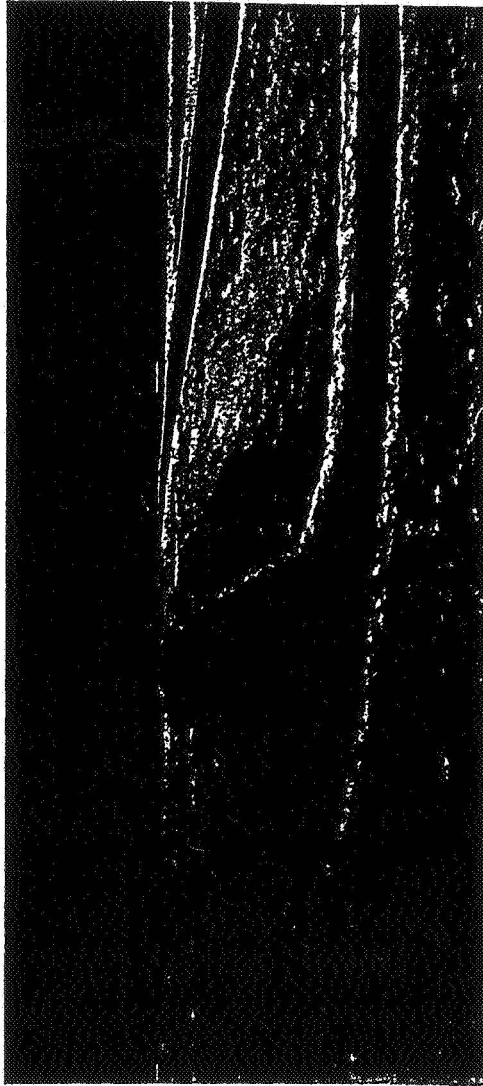
**VISUAL LIGHT PHOTOGRAPHY**



**94 GHz RADIOMETRIC IMAGERS**

**SHAFTER, AIRPORT, CALIFORNIA**

# Passive MMW Radiometry Gives Day/Night Navigation and Landing Capabilities



Visible Light Photograph



Day

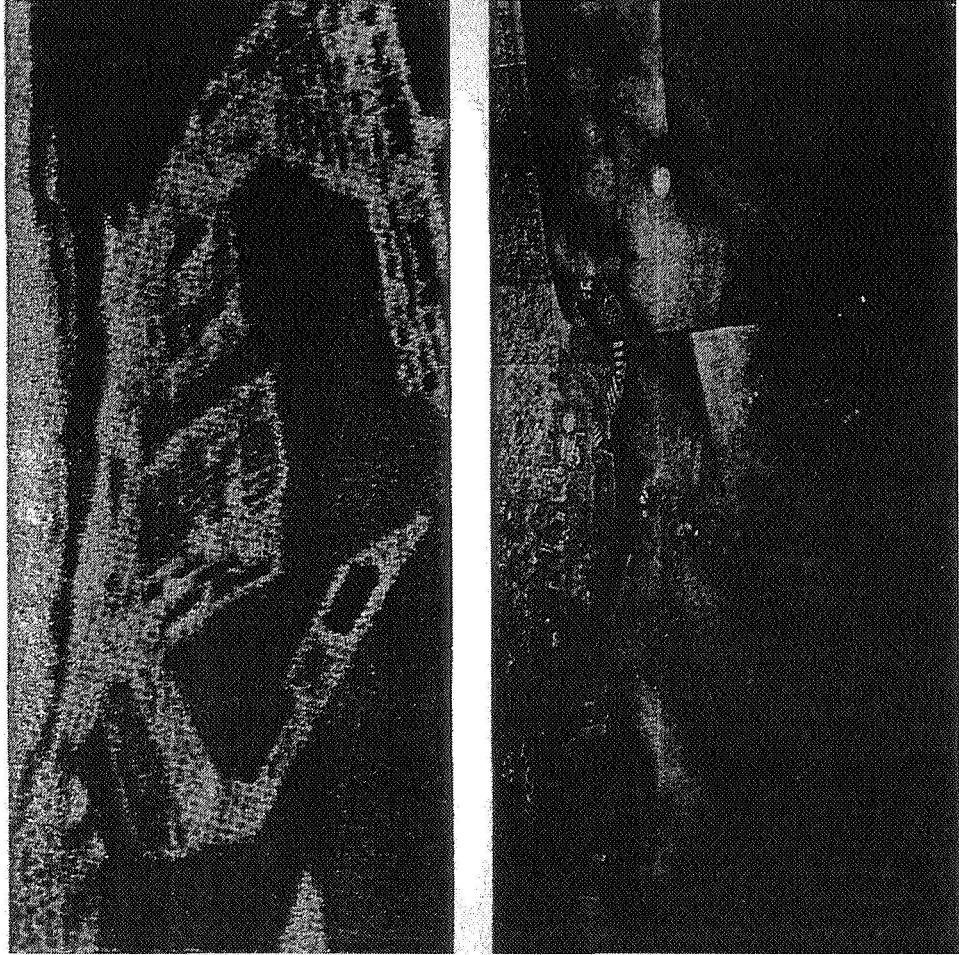


Night

94 GHZ RADIOMETRIC IMAGE AT TRUCKEE-TAHOE AIRPORT



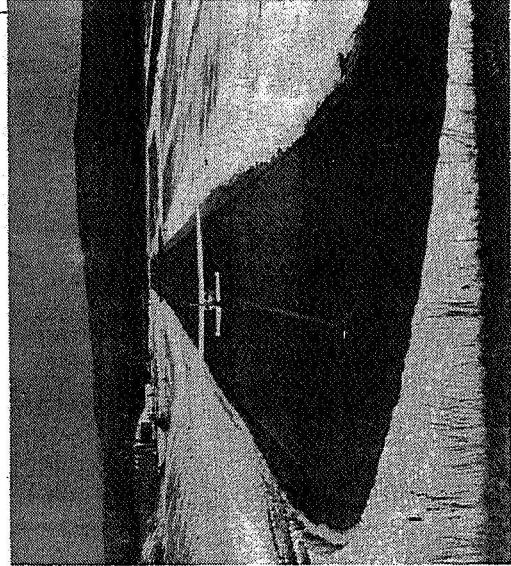
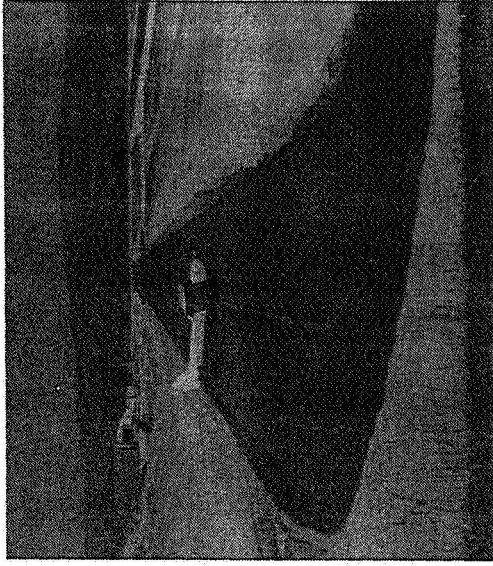
94 GHz Image of Long Beach Harbor





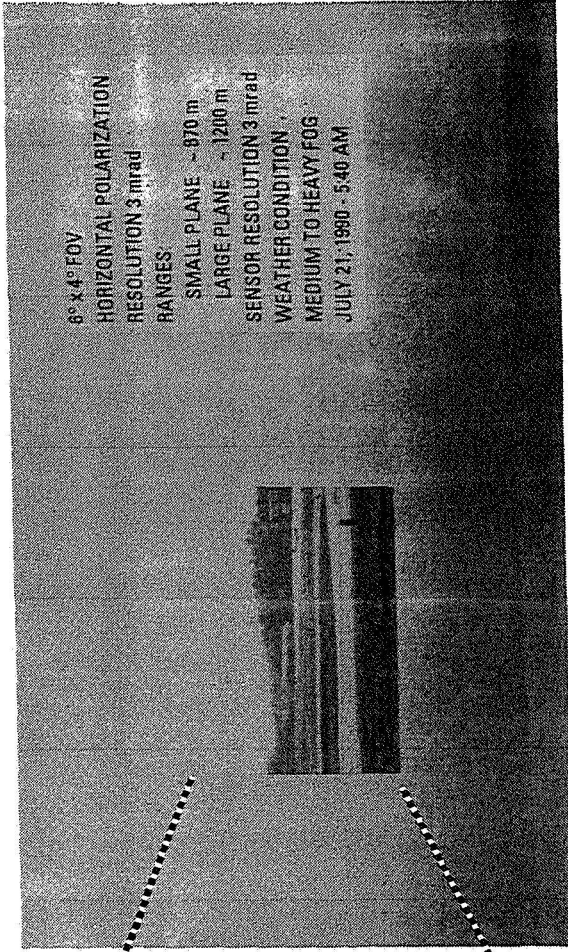
**TRW**

**Aircraft Is Clearly Visible on Taxiway**

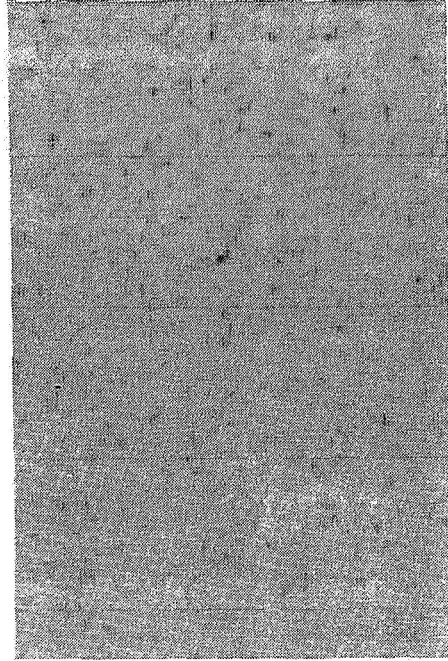


**15° x 15° field of view with 6 mR resolution. Aircraft is 390 feet from camera**

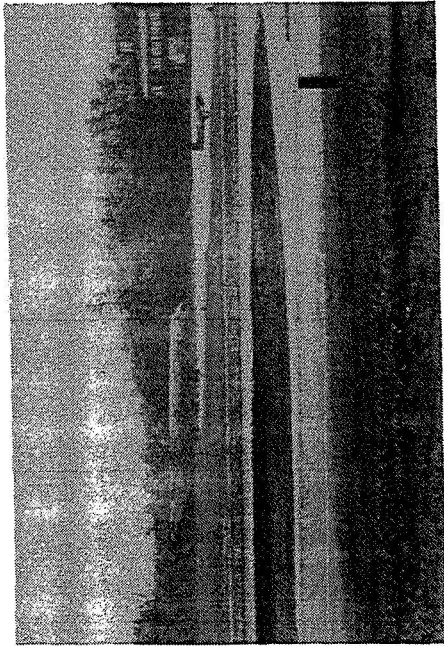
# Ground Tracking of Aircraft in Airfield Brunswick, Maine NAS



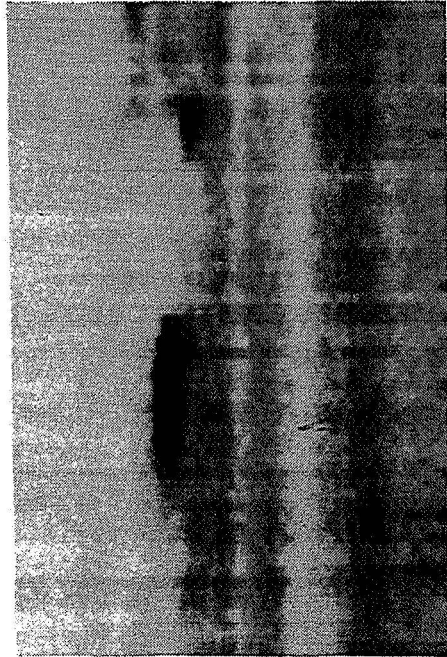
VISIBLE LIGHT IN FOG



IR RADIOMETRIC IMAGE IN FOG



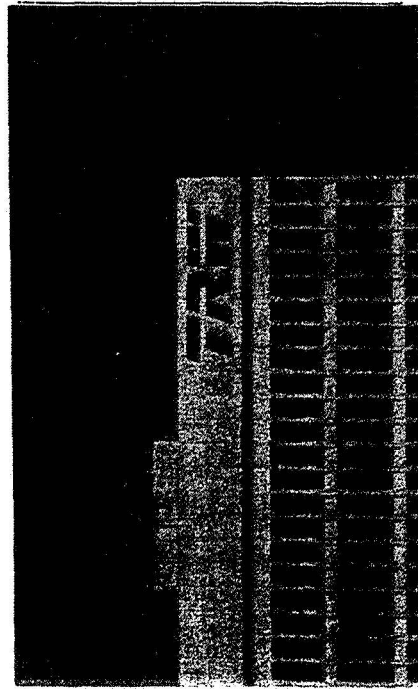
VISIBLE LIGHT MAGNIFIED IN CLEAR WEATHER



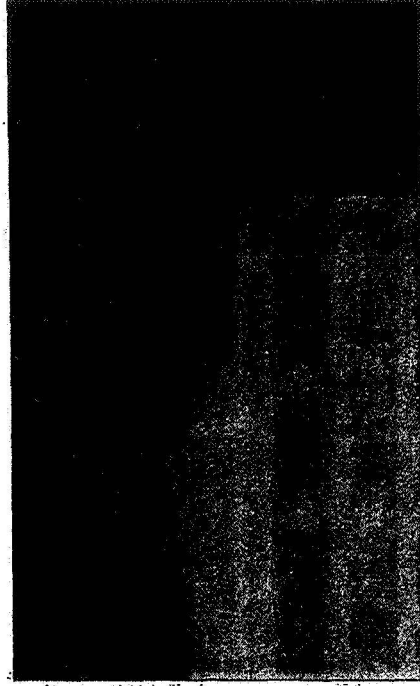
94 GHz RADIOMETRIC IMAGE IN FOG

**TRW**

**Passive Millimeter Wave Radiometric Image  
(Building E2 at a Range of 180 Meters)**



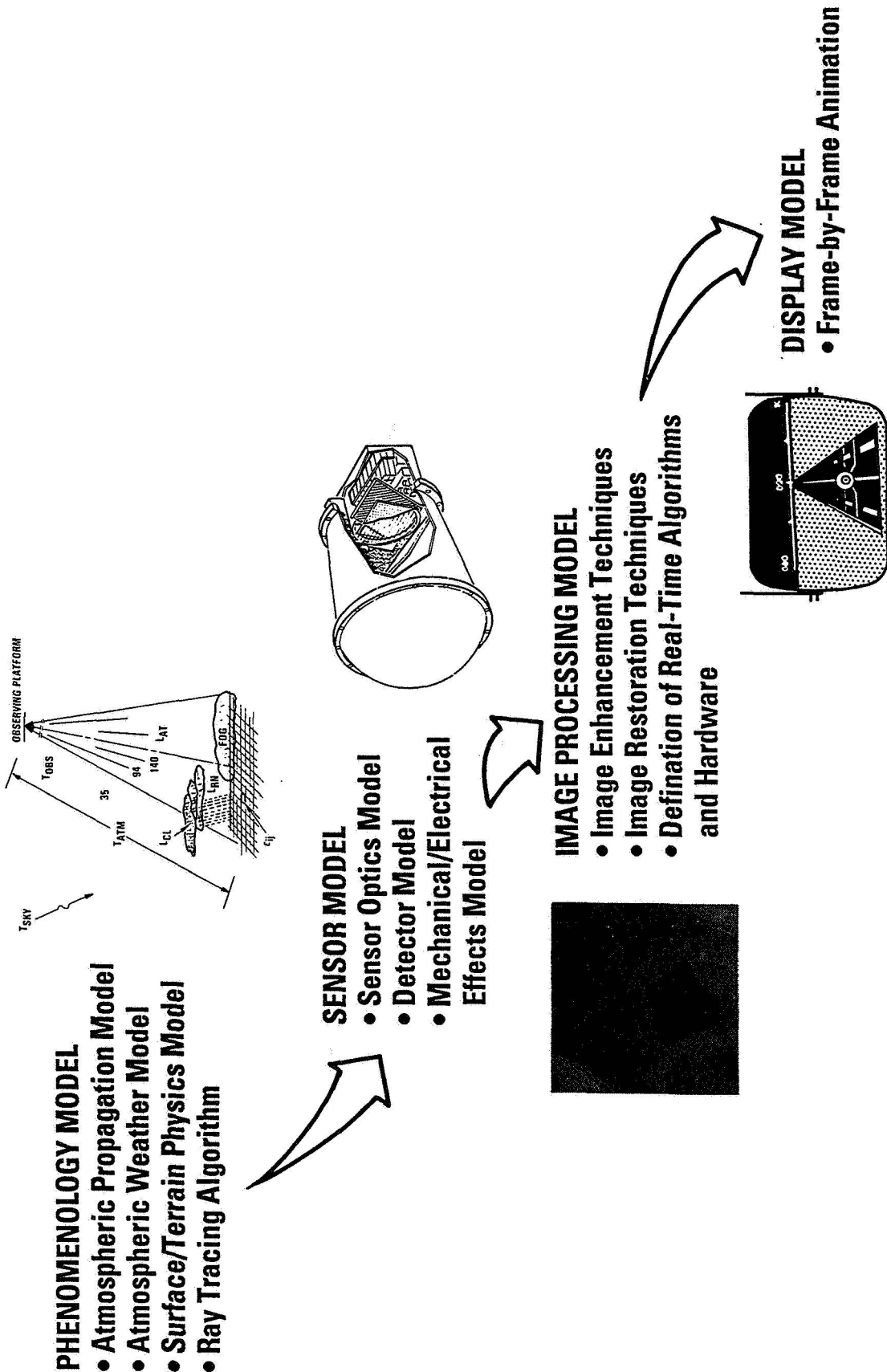
VISIBLE LIGHT PHOTOGRAPH



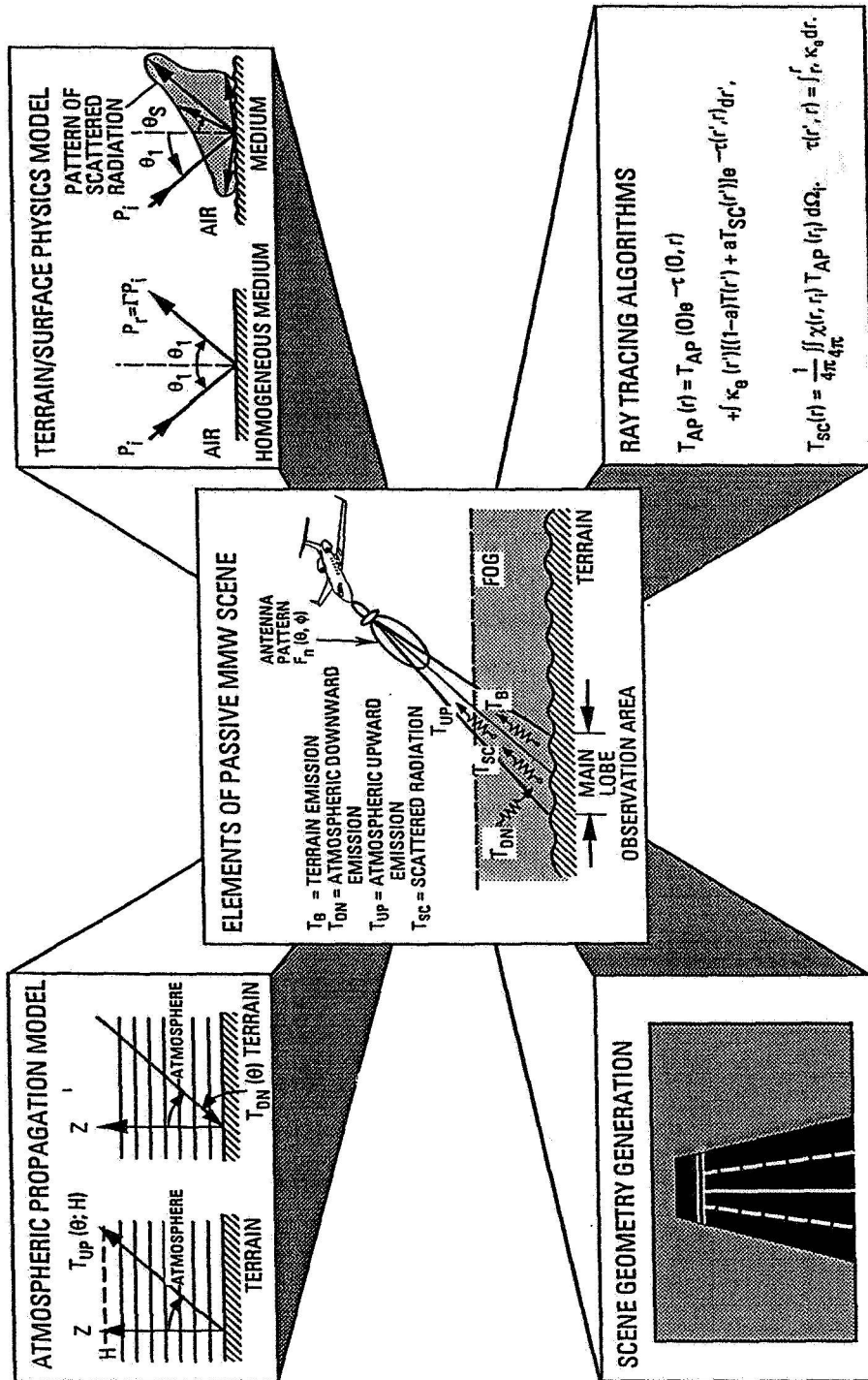
94 GHz RADIOMETRIC IMAGE

# End-to-End Passive MMW Scene Simulation

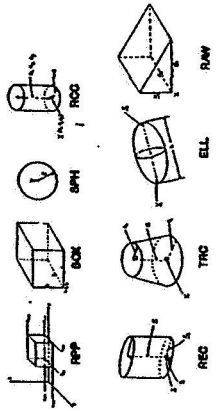
## A State-of-the-Art Capability to Predict Radiometric Scenes for a Wide Variety of Weather/Ground Conditions and Platform Operating Modes



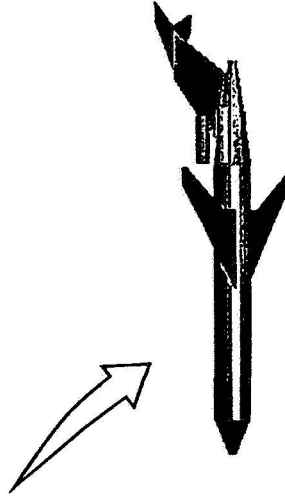
# The Phenomenology Model Includes All Aspects of the Passive MMW Scene



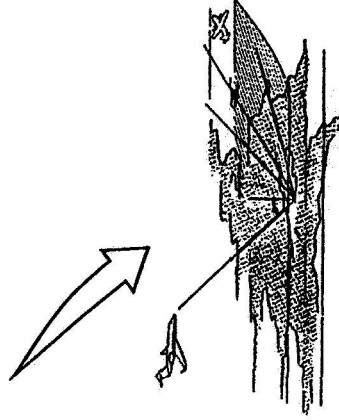
# Scene Geometries Are Constructed Using the Combinatorial Geometry Technique



• Eight basic geometric shapes constitute the building blocks for 3-D complex-shaped objects



• The building blocks are combined via union, intersection and exclusion operations to form 3-D scene objects



• The combinatorial geometry package determines ray intercepts with scene objects, providing the specific surfaces and propagation distance for the scene

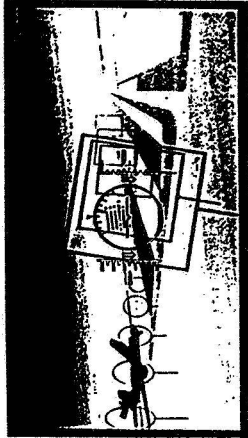
# **Synthetic Vision Research Underway at LaRC**

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## **NASA/TRW ASSIST PROGRAM**

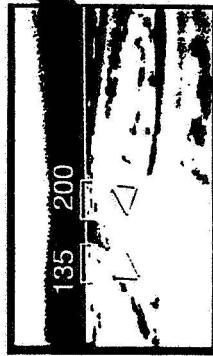
**GOAL:** Provide Flight Sensor/Display Technology to Enable Safe & Efficient Aircraft Operations Under Restricted-Visibility Conditions

Pictorial Display Augmented With Sensor-based Info.



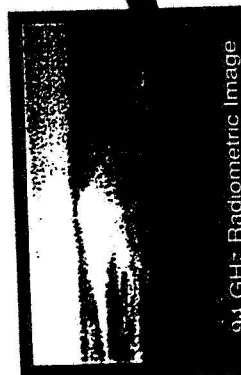
**Flight**

Sensor Image Augmented With Graphic Symbolology

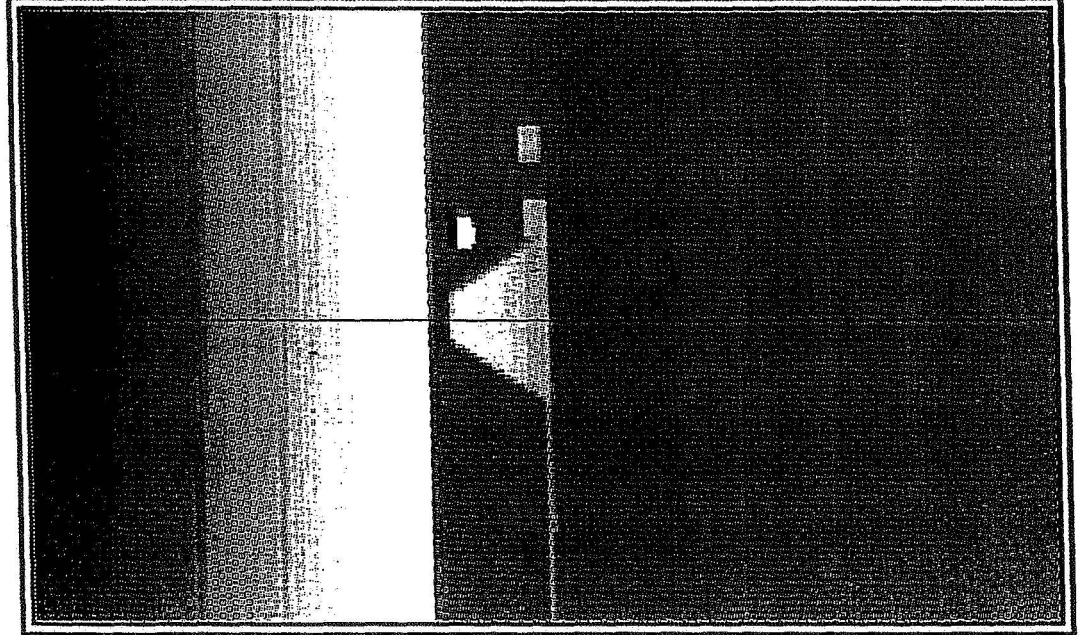
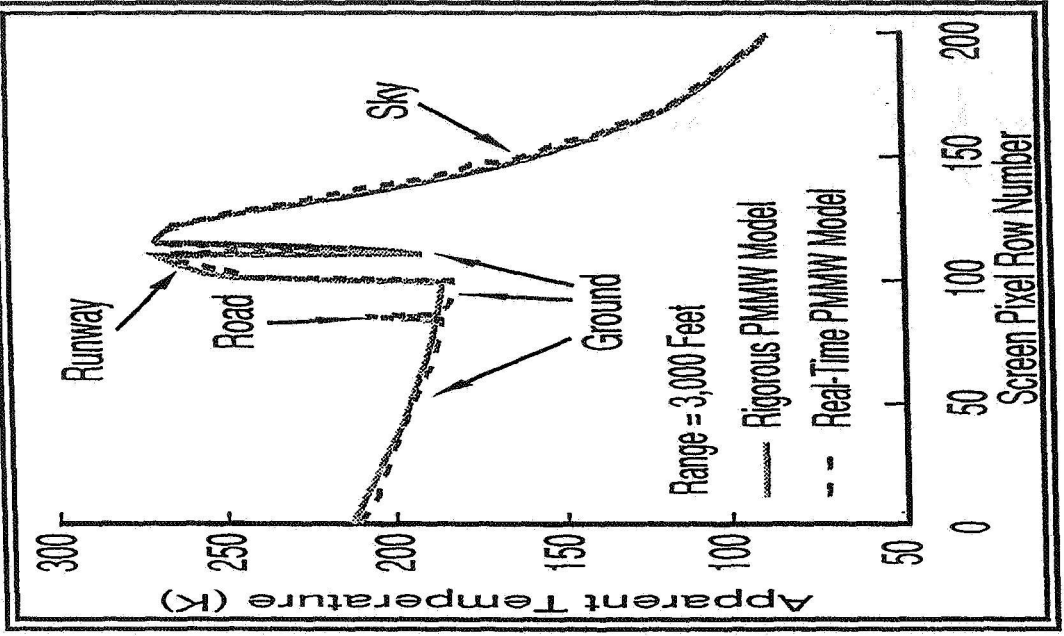


**Simulation**

Passive Millimeter Wave (PMMW) Sensor Imagery



**Modeling**

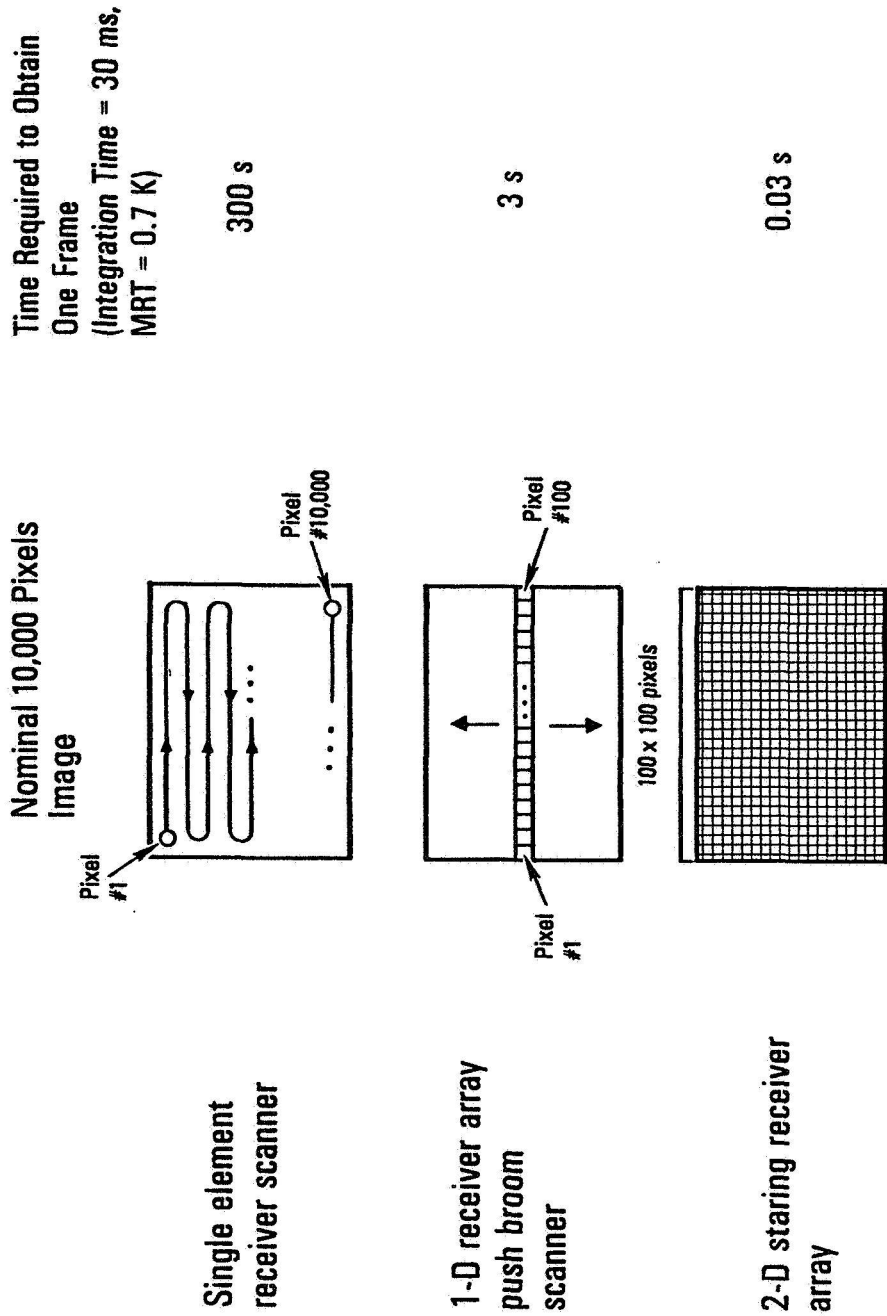


Validation of Real-Time PMMW Model Using Intensity Profile Test



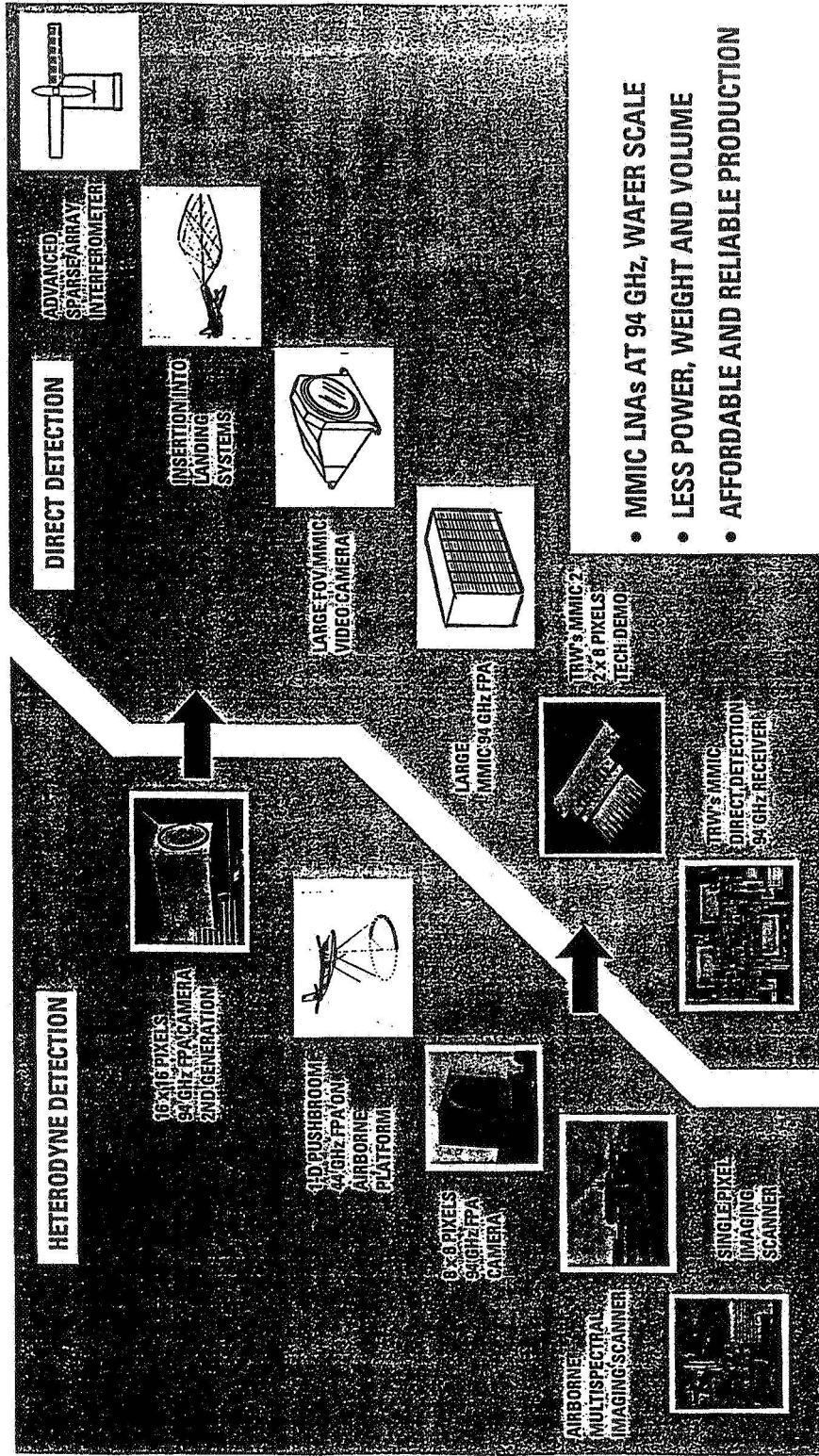


# The Development of MMW Staring 2-D Focal Plane Receiver Arrays is a Major Innovation that Permits Video Imaging at High Frame Rates





# TRW has Over 10 Years Experience in Developing PMMW Systems



- MMIC LNAs AT 94 GHz, WAFER SCALE
- LESS POWER, WEIGHT AND VOLUME
- AFFORDABLE AND RELIABLE PRODUCTION

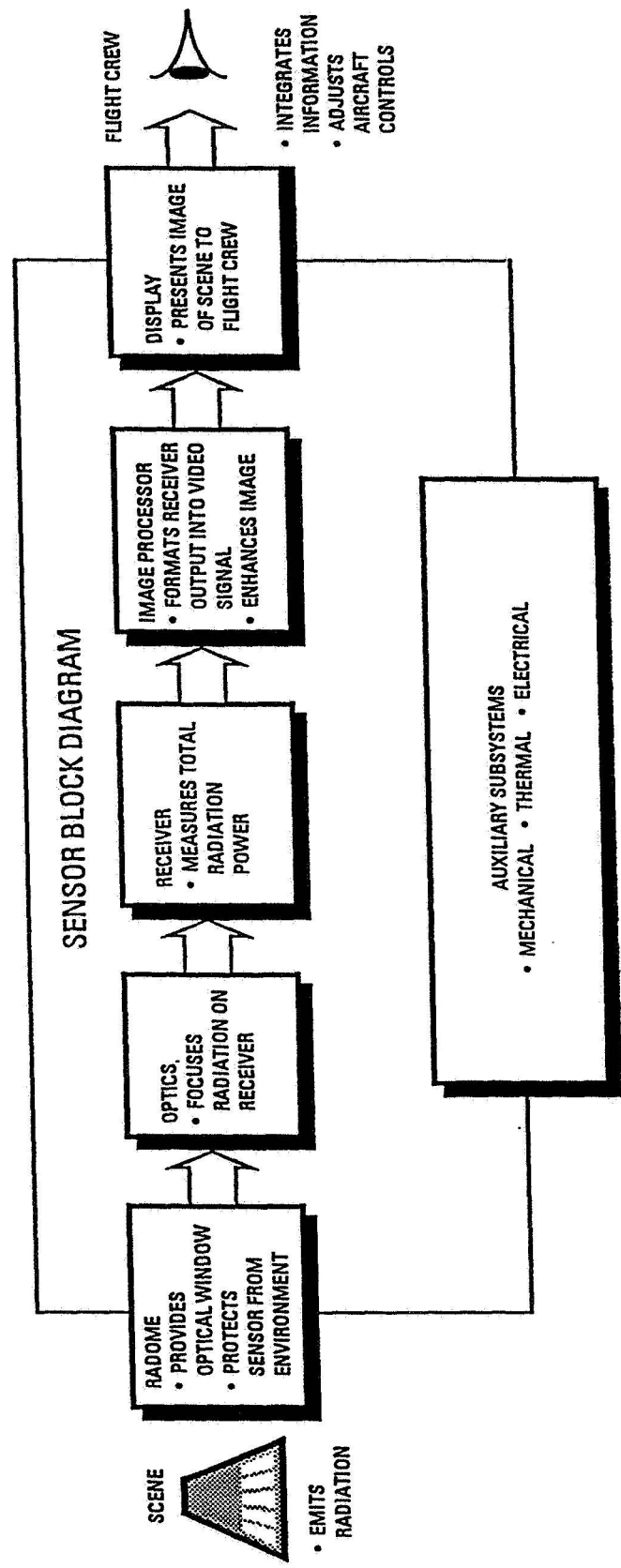
UTILITY HAS BEEN VALIDATED BY PRECURSOR WORK



RTM 92.0129.03



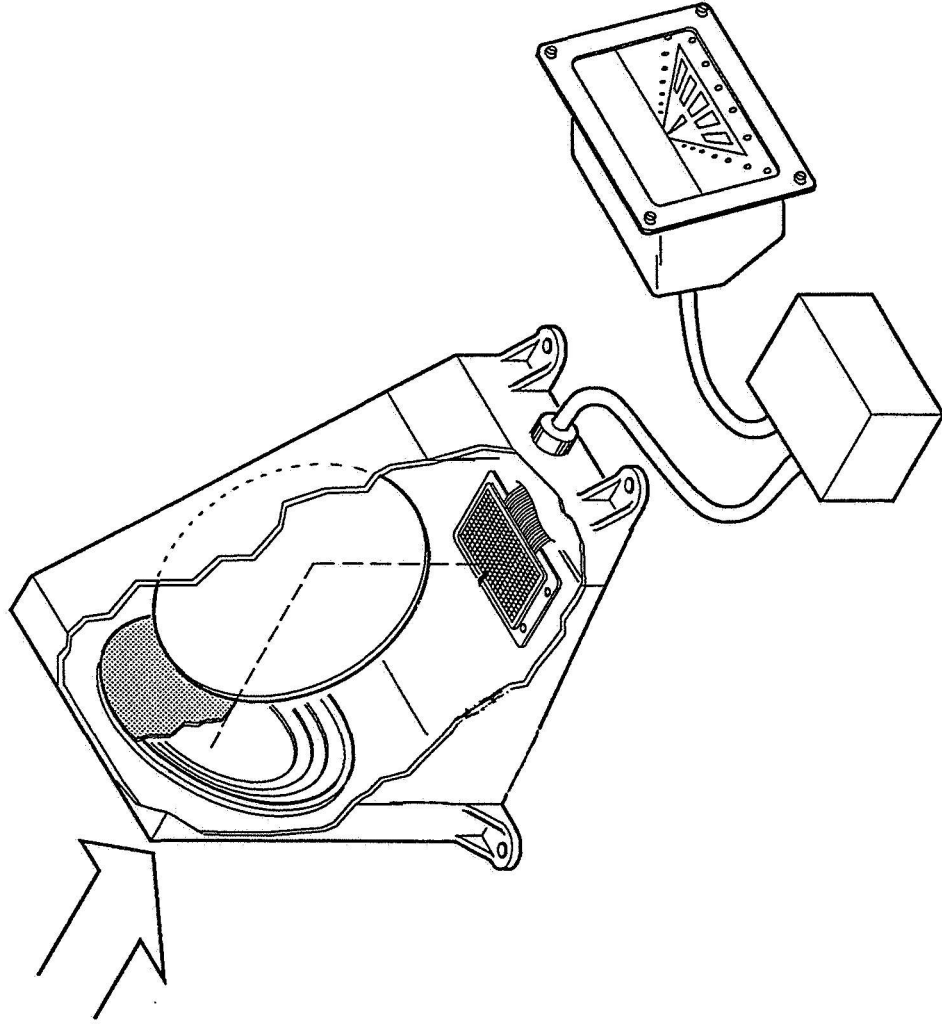
# Elements of Passive MMW Video Camera





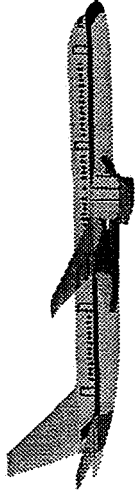
## Product Description

Passive millimeter wave MMIC camera with real time imagery and ruggedized for field and flight tests





# PMMW Camera is an Attractive Vision Sensor for Future Enhanced/Synthetic Vision Systems



A typical system will comprise: PMMW camera; Differential GPS; Head-up/down displays

- Displays high contrast real time images with direct detection W-band MMIC
- Displays true visual-like images directly amenable to fusion
- Not vulnerable to RFI
- Does not radiate in airport environment
- No issues of minimum range, image latency or high processing overhead
- Operates with "W-band runway lights", similar to night aircraft operations
- Can be manufactured economically within four years