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Infrared Sensors and Systems for Enhanced Vision/Autonomous Landing Applications

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ABSTRACT

Infrared Imaging Through Fog

There exists a large body of data spanning more than two decades, regarding the ability of infrared imagers to "see" through fog, i.e., in Category III weather conditions. Much of this data is anecdotal, highly specialized, and/or proprietary.

In order to determine the efficacy and cost effectiveness of these sensors under a variety of climatic/weather conditions, there is a need for systematic data spanning a significant range of slant-path scenarios. These data should include simultaneous video recordings at visible, midwave (3-5 micron), and longwave (8-12 micron) wavelengths, with airborne weather pods that include the capability of determining the fog droplet size distributions.

Existing data tend to show that infrared is more effective than would be expected from analysis and modeling. It is particularly more effective for inland (radiation) fog as compared to coastal (advection) fog, although both of these archetypes are oversimplifications. In addition, as would be expected from droplet size vs wavelength considerations, longwave outperforms midwave, in many cases by very substantial margins. Longwave also benefits from the higher level of available thermal energy at ambient temperatures.

Imager Technologies

The principal attraction of midwave sensors is that staring focal plane technology is available at attractive cost-performance levels. However, longwave technology such as that developed at FLIR Systems, Inc. (FSI), has achieved high performance in small, economical, reliable imagers utilizing serial-parallel scanning techniques.

In addition, FSI has developed dual-waveband systems particularly suited for enhanced vision flight testing. These systems include a substantial, embedded processing capability which can perform video-rate image enhancement and multisensor fusion. This is achieved with proprietary algorithms and includes such operations as real-time histograms, convolutions, and fast Fourier transforms.

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RELEVANT ACTIVITIES AT FSI

LOCKHEED (C-130) HTTB

OTHER AIR FORCE ACTIVITIES

RNLN - P3

SITUATION AWARENSS FLIR

SAFIRE (Q22)

- HIGH PERFORMANCE
- 3-AXIS INERTIAL STABILIZATION
- FULL DIGITAL FEATURES
- TURRET WILL ACCOMMODATE EVS SENSORS
  - FLEXIBILITY, COMPATABILITY

RELEVANT ACTIVITIES AT FSI (CONT)

COMPACT FLIR DEVELOPMENT - APPLY TO LONGWAVE EVS
STARING ARRAY DEVELOPMENT - APPLY TO MIDWAVE EVS

DUALBAND IMAGING RADIOMETER DEVELOPMENT
- APPLY TO DUAL-WAVELENGTH EVS

EMBEDDED PROCESSOR

SENSOR FUSION CONCEPTS

KEY: ECONOMICAL!

IR SENSOR TECHNOLOGIES

TECHNOLOGY	WAVEBAND	RESOLUTION (HxV)	SENSITIVITY (NETD)	IMAGER SIZE (IN)
COMPACT SCANNING	EITHER	500x375	0.5°C (3-5) 0.2°C (8-2)	5.7x5.7x10.9
STARING ARRAY (Pt Si)	3-5 MICRONS	320x244 640x488	0.08°C	5x5x9 6x6x10
STARING & UNCOOLED ARRAYS	8-12 MICRONS	FUTURE		

BASIC FSI TECHNOLOGY

DETECTOR MINI-ARRAYS WITH TDI: "BEST OF SERIAL AND PARALLEL S[illegible]"

PROPERTIES OF SERIAL-SCAN FLIRS:

CHALLENGES --

Low dwell time per resolution element

High speed azimuth scanner

ADVANTAGES --

Few detectors = high sensitivity and uniformity

optimized front-end electronics

high yield (economical)

efficient cold shield

Easy channel balance/low fixed-pattern noise

Freedom from vertical aliasing

BASIC FSI TECHNOLOGY, (continued)

Video output from simple electronics

- no complex E-Mux
- no complex DSC

AC coupling artifacts and low-frequency noise minimized

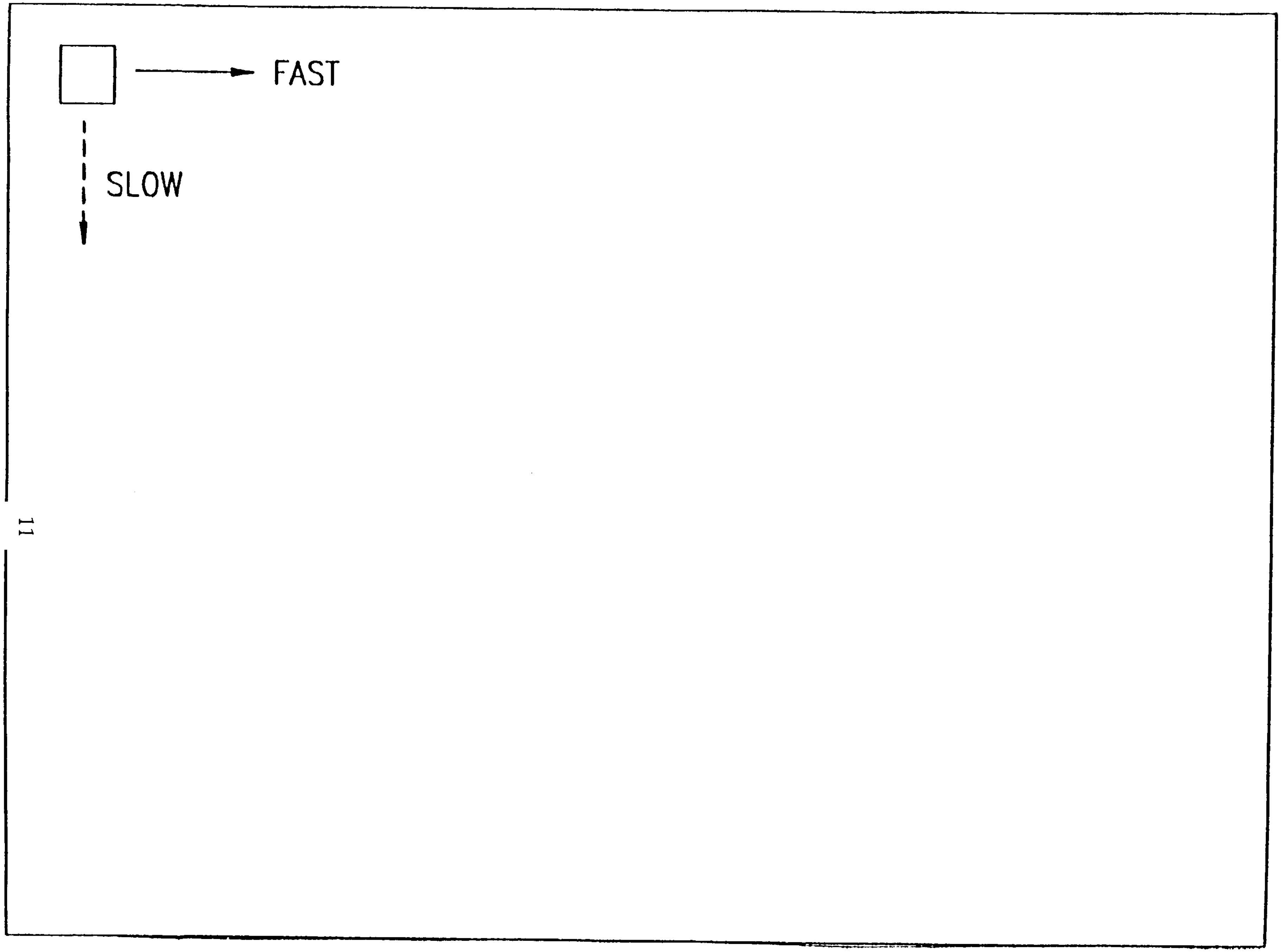
"Fast" optics (low f#'s)

TDI vs SPRITE:

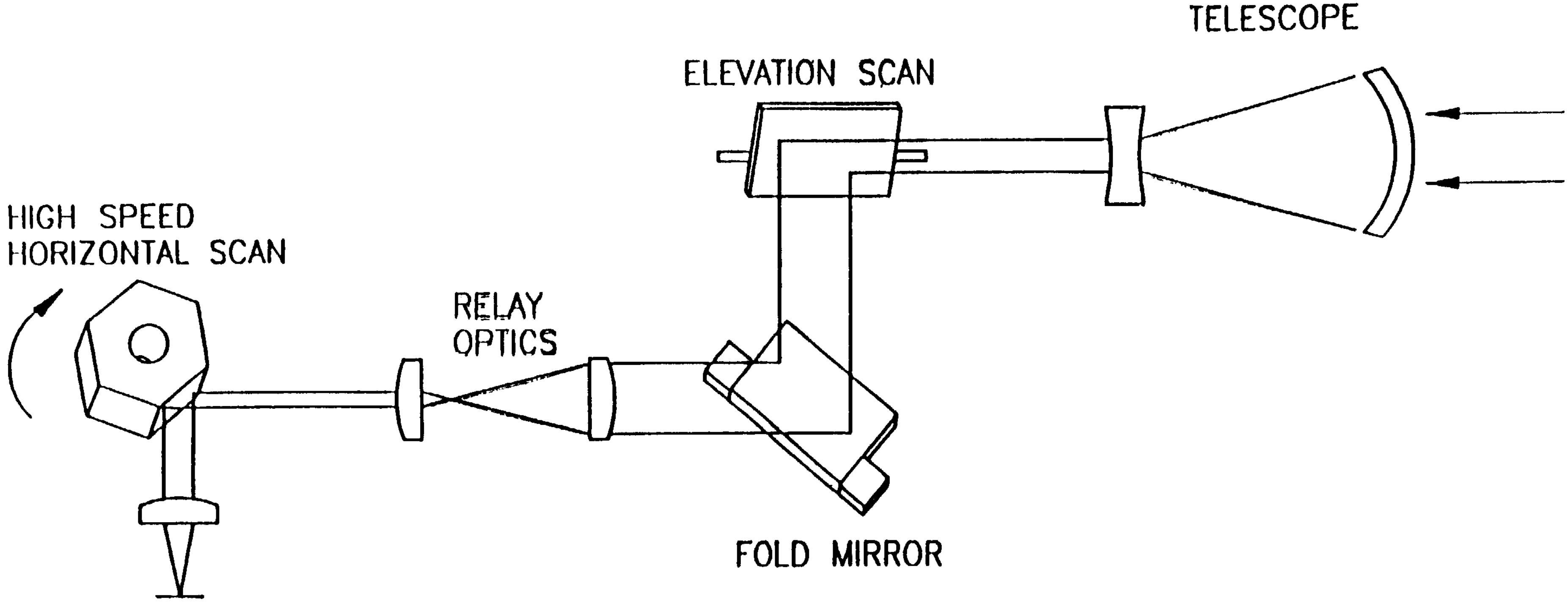
- freedom from charge carrier diffusion
- fast optics are permitted
- easier material fab (carrier lifetimes)
- less heat (resistance X bias current)

RELIABILITY
MAINTAINABILITY

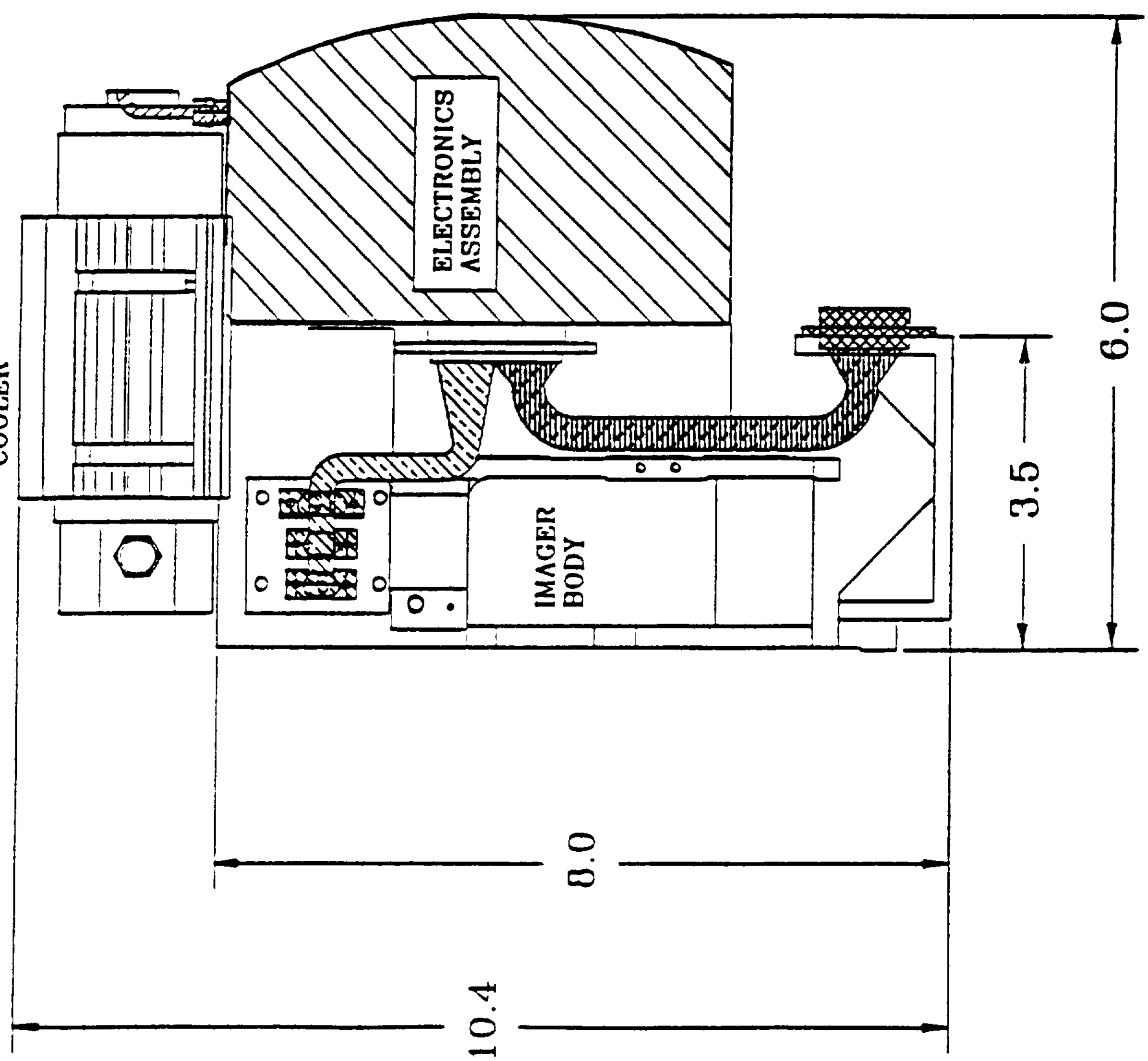
LIFE-CYCLE COST

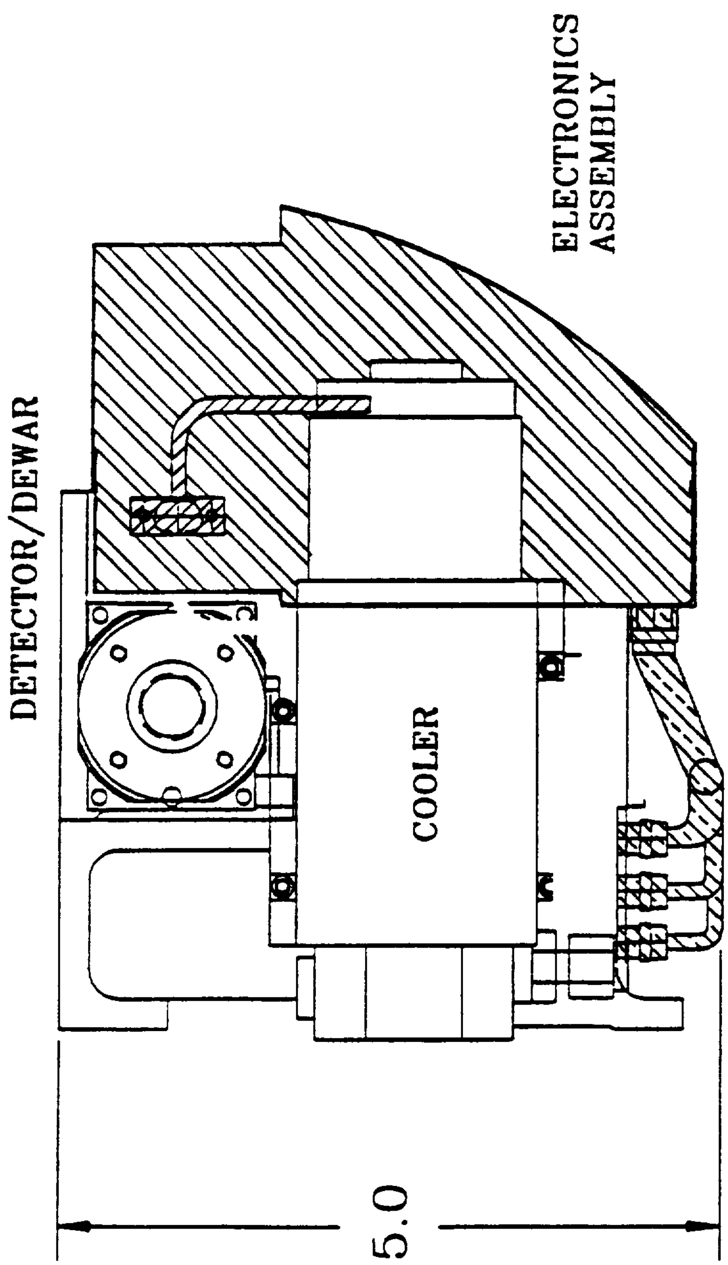


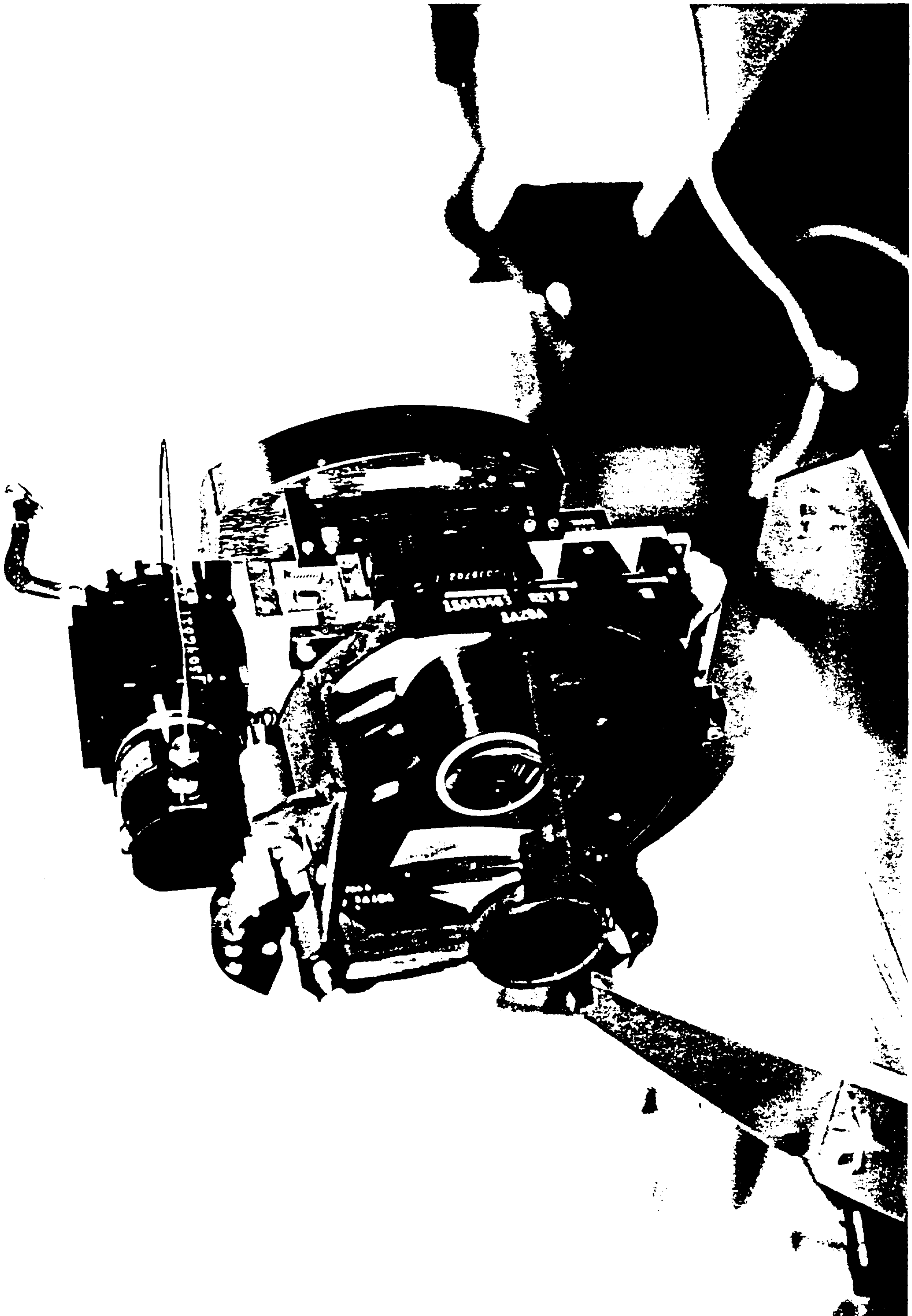
SERIAL SCAN



IMPLEMENTATION


ELECTRONICS ASSEMBLY
COOLER
IMAGER BODY
6.0
3.5
8.0
10.4


ELECTRONICS
ASSEMBLY
DETECTOR/DEWAR
COOLER
5.0



OPTIONAL AND GROWTH FEATURES

SIMPLE PAN-TILT

SNAP-LOOK INTO TURNS

DIGITAL ZOOM

COMMON PROCESSING WITH RADAR (SENSOR FUSION)

INTEGRATION WITH GPS

"CAN INFRARED PROVIDE SEE-TO-LAND AT 2400 FEET IN CAT IIIA

*** BASIS OF DECISIONS

- MEANINGFUL FLIGHT (APPROACH) AND FIELD DATA
- COMPLETE, OPEN VS ANECDOTAL, PROPRIETARY
- CHARACTERIZE PROPAGATION MEDIUM

SIMULATION

- EVS SENSOR AND HF ISSUES

RELATIVE ADVANTAGES OF WAVEBANDS

MIDWAVE (3 - 5 MICRONS)

STARING-ARRAY TECHNOLOGY MORE MATURE AT MIDWAVE COMPARED TO LONGWAVE

RUNWAY LIGHTS ARE "BEACONS" AT MIDWAVE

BETTER AT LONG RANGES IN HIGH HUMIDITY ATMOSPHERE

APPROPRIATE FOR TAXI AND TAKEOFF

- LANDING GEAR MOUNT
- FOG CHARACTERISTICS NEAR GROUND

RELATIVE ADVANTAGES OF WAVEBANDS (continued)

LONGWAVE (8 - 12 MICRONS)

BETTER PERFORMANCE IN LOW-THERMAL-CONTRAST AMBIENT CONDITIONS

BETTER PERFORMANCE IN MANY FOG SCENARIOS

- SEE 1-3 TIMES VISUAL RANGE
- ALWAYS AS GOOD AS MIDWAVE
- CAN BE 100'S OF TIMES BETTER THAN MIDWAVE

FLIR PERFORMANCE ISSUES (continued)

LONGWAVE (8-12 MICRONS) VS MIDWAVE (3-5 MICRONS) FLIRS

- LONGWAVE CAN HAVE HUGE ADVANTAGE FOR INLAND FOG
- SHORTWAVE CAN HAVE SOME ADVANTAGE IN HUMID ATMOSPHERES
- MAY BE COMPARABLE FOR COASTAL FOG
- STARING ARRAY FLIRS NOT AVAILABLE AT LONGWAVE

HIGHLY DESIRABLE: INTEGRATED DUAL-WAVEBAND FLIR AT LOW PRICE

PERFORMANCE SPECIFICATIONS
DUAL-WAVEBAND SYSTEM

	MIDWAVE	LONGWAVE
FIELD OF VIEW	30 x 20 DEG	30 x 20 DEG
RESOLUTION	1.5 MRAD	1.5 MRAD

SENSOR HEAD ENVELOPE — 10.5" H x 5" W x 6" L
SENSOR HEAD WEIGHT — LESS THAN 12 POUNDS
POWER REQUIREMENT — 28V AT 4A MAX

FIELD OF REGARD — FIXED, FORWARD (CONFORMAL WITH HUD)
AZIMUTH PAN/SNAP-LOOK OPTION
ELECTRONIC ZOOM OPTION

SPLIT-STIRLING COOLER
DUAL RS-170 OUTPUT

ENVIRONMENTALLY QUALIFIED TO MIL-STD-810D

ALTERNATIVE ("HYBRID") DUALBAND SYSTEM

SCANNING LONGWAVE / STARING MIDWAVE

COMMON VS CONTIGUOUS OPTICAL PATHS

DUAL OUTPUTS

RETAIN: COMPACTNESS, ECONOMY

- COMMON COOLER

SENSOR FUSION

IMAGE PROCESSOR SUMMARY

COMPONENTS
- SENSOR INTERFACE
- DISPLAY INTERFACE
- CENTRAL PROCESSOR INTERFACE

STRUCTURE
- VME BACKPLANE (32 ADDRESS/16 DATA)
- CUSTOM/PARALLEL 16-BIT VIDEO BUS
- DUAL EUROCARD STANDARD (6-U)
- Provides for easy addition of standard procesing alternatives

CENTRAL PROCESSOR PERIPHERALS
- SCSI I/O (TAPE, HARD AND FLOPPY DISK, OPTICAL STORAGE)
- RS-232 (OR 422 OR 485))
  - As a console for operator communication
  - Or in a protected host communication packet mode with error checking
- ETHERNET
- CENTRONICS

SENSOR FUSION

SENSOR INTERFACE

COMPONENTS
- SCAN CONVERTER
- INPUT PROCESSING ALU
- SENSOR IDENTITY MODULE
- FRAME MEMORY

SCAN CONVERTER

CONVERTS NON-STANDARD SENSOR SCANS INTO TELEVISION SYCHRONIZED RASTER FOR THE FRAME MEMORY

POSITION CONTROL	PAN/BORESITE
ZOOM	IMAGE REGISTRATION

OUTPUT INTO VME ADDRESSABLE BIT-MAP VIDEO MEMORY

VIDEO INPUT PROCESSOR

BRIGHNTESS CORRECTION	ALC
CONTRAST CORRECTION	AGC
REALTIME AVERAGING	NOISE REDUCTION
FAST FOURIER	(not supported in current products)

CAN PEAK DETECT/MASK SUBTRACT

SENSOR FUSION

SENSOR INTERFACE (CONTINUED)

- SENSOR IDENTITY MODULE
  - SENSOR SYNCHRONIZATION
  - SENSOR CONTROL
    - MANCHESTER OR RS-232 COMMUNICATIONS ARE COMMON
  - ANALOG INPUT option — 10 bit/w AGC
  - DIGITAL INPUT option — PARALLEL; SERIAL (TAXI - UP TO 10 BITS)

- FRAME MEMORY
  - CONFIGURES TO SCANNER RESOLUTION/SENSITIVITY
  - 256 X 512 X 8 UP TO 1024 X 1024 X 16
  - THREE PORTED MEMORY
    - VME READ/WRITE
    - SENSOR WRITE INPUT
    - TELEVISION RASTER SCANNED READ (CONTROLLED BY DISPLAY TIMING)

SENSOR FUSION

DISPLAY PROCESSOR

COMPONENTS

- 8 BIT CONFIGURABLE OVERLAY
- TMS 34020 GRAPHICS SUPPORT (TIGA)
- HISTOGRAM PROCESSOR (KEYPLANE ADDRESSABLE AREA)
- CONVOLUTION PROCESSOR (3 X 3)
- FULL DISPLAY LEVEL ADDRESSING (REMAPPING IN RAM LUT)
- OUTPUT SECTION
- WINDOWS SUPPORT
- INPUT SWITCHABLE BETWEEN 3 SENSORS

OVERLAY

- 1024 X 1024 X 8
  - (CAN BE CONFIGURED FOR LESS RESOLUTION)
- SHARED CPU/VME MEMORY ADDDRESING (for DMA)
- KEY-PLANE CONTROL OF WINDOW AREAS
- GRAPHICS PROCESSOR SUPPORT IS VME ADDRESSABLE

HISTOGRAM AND CONVOLVER ARE REAL TIME
HISTOGRAM MEMORY IS SHARED WITH CPU for DMA ACCESS

SENSOR FUSION

DISPLAY SUPPORT (CONTINUED)

VIDEO OUTPUTS
- RGB AND SYNC
- NTSC (0R PAL)
- S-VHS OUTPUT (Y/C)
- PARALLEL DIGITAL PROCESSING
- RS-170 (OR CCIR) BLACK AND WHITE OUTPUT
  (TO 10 BITS + SYNC)
- FULLY REMAPPABLE OUTPUT COLORS (TO 8 BITS EACH)
- PROVISION FOR CGA/VGA AND S-VGA
  (NOT IMPLEMENTED YET)

ON BOARD VIDEO MEMORY SUPPORT (not real time)
(QUADRANT DISPLAY (only one quadrant can be live at a time)

FULL 16 BIT TO 10 BIT BLACK AND WHITE OR 8 BIT COLOR REMAPPING ABILITY
(for histogram image correction, gamma correction, etc)

ACCEPTS EXTERNAL SYNCHRONIZATION