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# IMAGE VELOCITY SENSOR SUBSYSTEM REVIEW

(PRESENTATION CHARTS)

20 SEPTEMBER 1968

BYE 68432-68

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# SCOPE OF PRESENTATION

- RELATED EXPERIENCE
- THEORY OF OPERATION
- ENGINEERING PROTOTYPE
- EQUIPMENT REQUIREMENTS
- DEVELOPMENT PROBLEMS AND CORRECTIVE ACTIONS

INTRODUCTION. . . . . MAJOR GENERAL JAMES STEWART

MAJOR GENERAL JAMES STEWART OPENED THE COMMITTEE MEETING WITH A MOL OVERVIEW PRESENTATION WHICH INCLUDED PRIME CONTRACTOR HARDWARE PHOTOGRAPHS AND SLIDES OF THE COMMITTEE'S CHARTER OUTLINE

PROGRAM DEVELOPMENT PLAN . . . . . DR. M. S. MALKIN

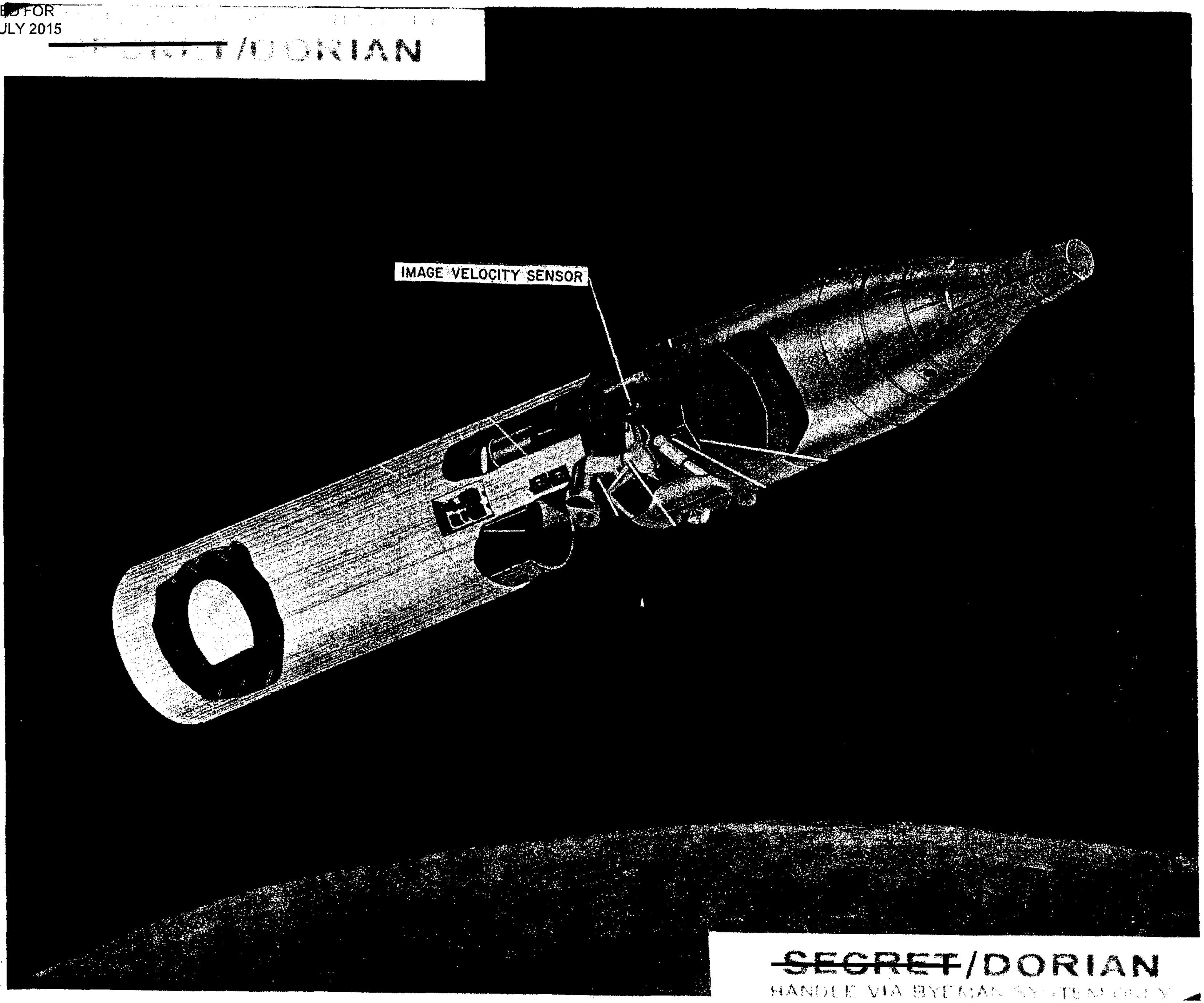
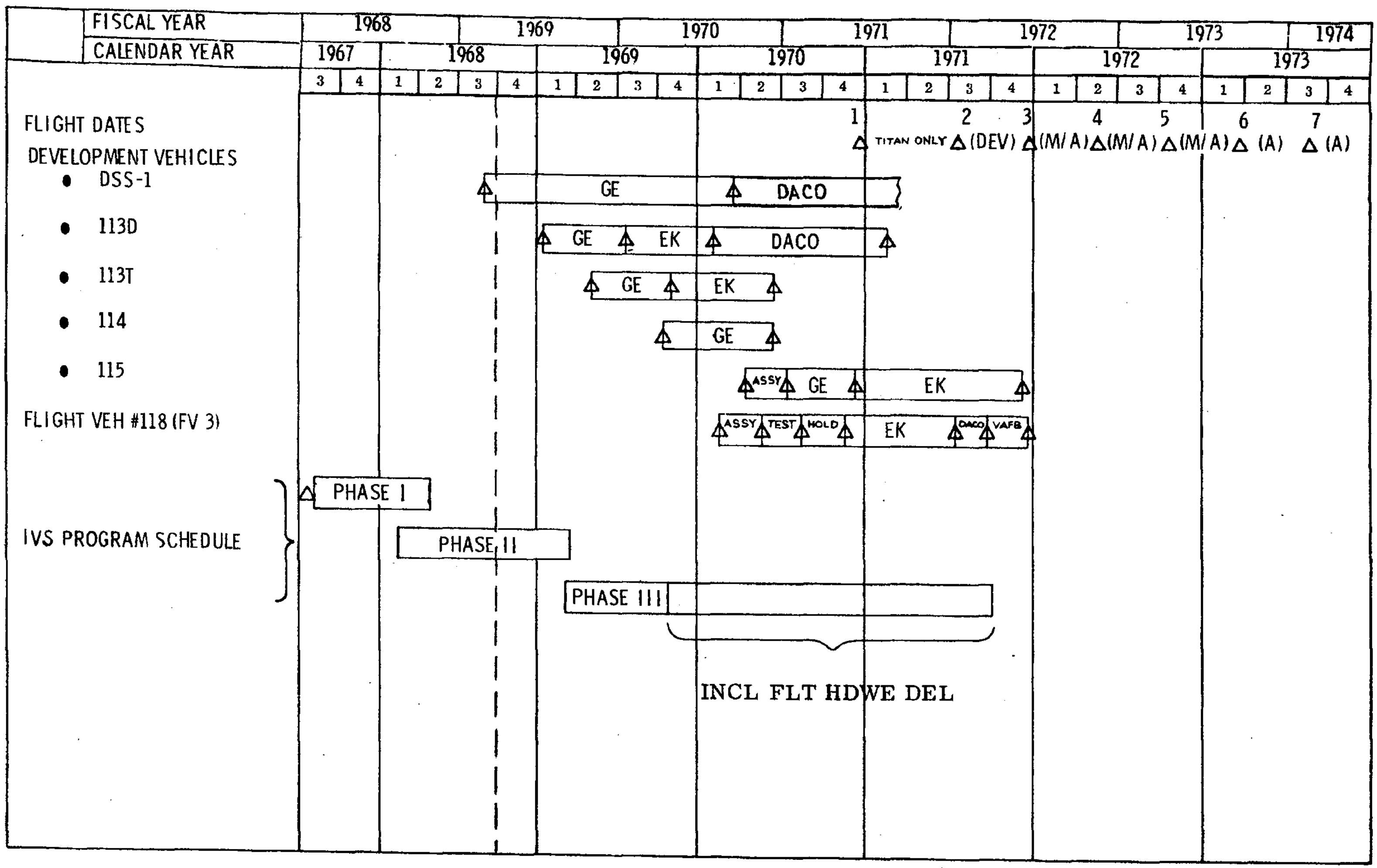


IMAGE VELOCITY SENSOR

# IMAGE VELOCITY SENSOR

- REDUCE LINE OF SIGHT RATE ERROR FROM SLEW RATE TO TRACKING RATE
- SUPPLIES ERROR SIGNAL TO NULL TRACKING ERROR
- MANDATORY FOR UNMANNED OPERATION
- ESSENTIAL FOR PLANNED USE OF MAN

# MOL MISSION PAYLOAD SCHEDULE






~~SECRET~~/DORIAN
HANDLE VIA BYEMAN SYSTEM ONLY

# IMAGE VELOCITY SENSOR DEVELOPMENT PROGRAM

PHASE I

- DEVELOP IVS BREADBOARD UNITS (CONTINUE ON TWO AF CONTRACTS)
- DEVELOP OPEN LOOP IVS TESTER
- EVALUATE THREE VENDOR'S BREADBOARDS

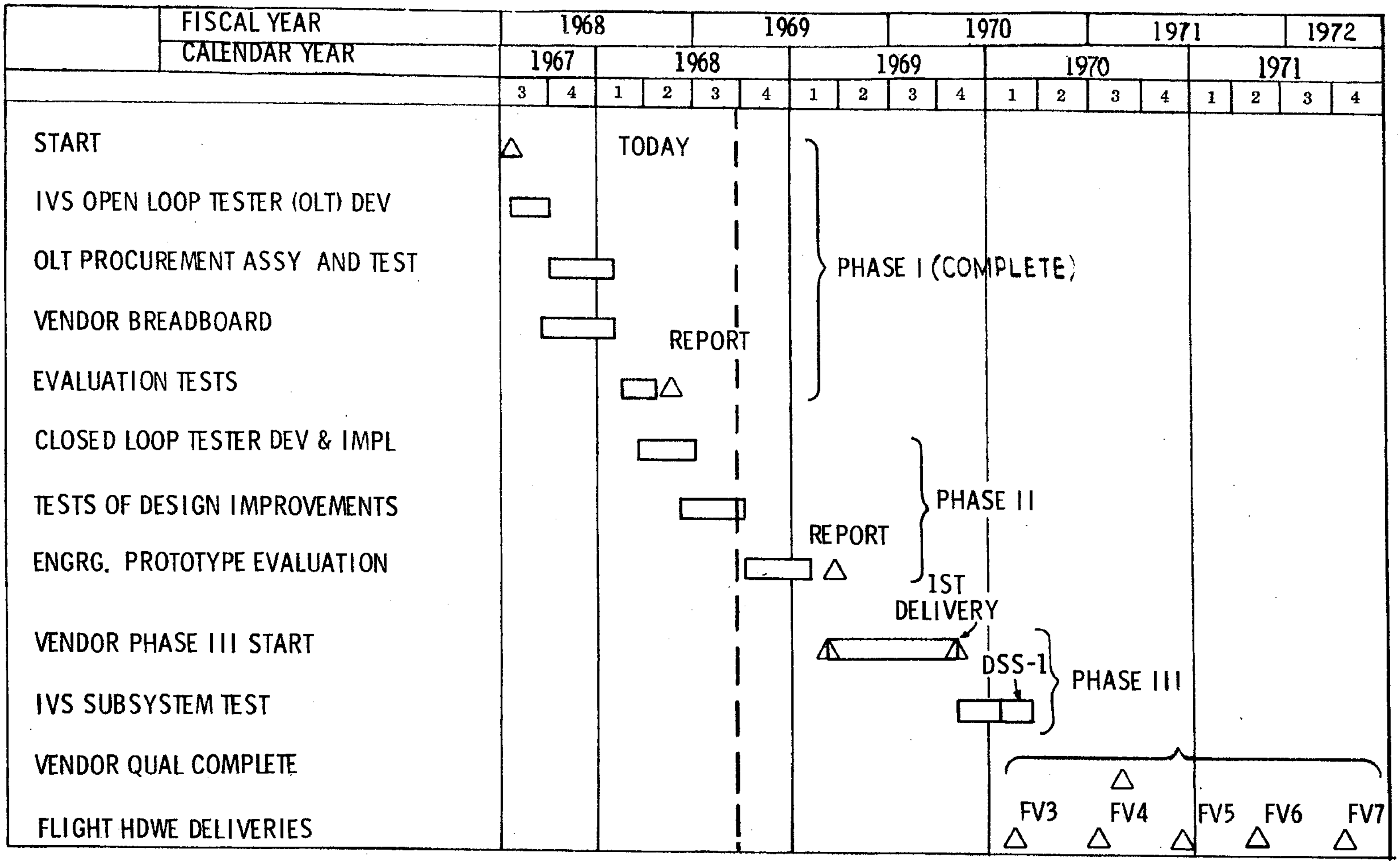
PHASE II

- INCORPORATE DESIGN SOLUTIONS
- CONDUCT CLOSED LOOP TESTS
- DEVELOP PROTOTYPE ENGINEERING MODELS

PHASE III

- IVS COMPONENT QUALIFICATION
- PRODUCE FLIGHT HARDWARE

# IMAGE VELOCITY SENSOR SCHEDULE



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## IVS VENDOR STATUS SUMMARY

| | ITEK | GOODYEAR | HYCON |
|---|---|---|---|
| DYNAMIC NULL | ○ | □▽ | □▽ |
| SIGNAL LOSS DURING TRACK | ○ | ○□ | ○▽ |
| ILLUMINATION SENSITIVITY & CONTRAST | ○ | □▽ | ○ |
| CROSS COUPLING | □▽ | ○ | ○ |
| LINEARITY | □▽ | ○ | ○ |
| SCENE SENSITIVE BIAS | ▽ | ○ | ○ |
| SCALLOPING | ○ | ○ | ○□ |

LEGEND:

○ ON TARGET □ MARGINAL ▽ PROBLEM ○▽ PREVIOUS STATUS

# SUMMARY

- IVS REQUIREMENTS ARE NECESSARY AND SUFFICIENT
- TEST PROGRAM
  - IVS TESTER IS A VALID SIMULATION
  - TEST PROGRAM PROVIDES ADEQUATE COMPARISON
- TWO VENDORS ARE ABLE TO MEET THE TECHNICAL AND SCHEDULE REQUIREMENTS OF PROGRAM

SYSTEMS CONSIDERATIONS . . . . . G. S. HALL

# MOL SYSTEM CONSIDERATIONS

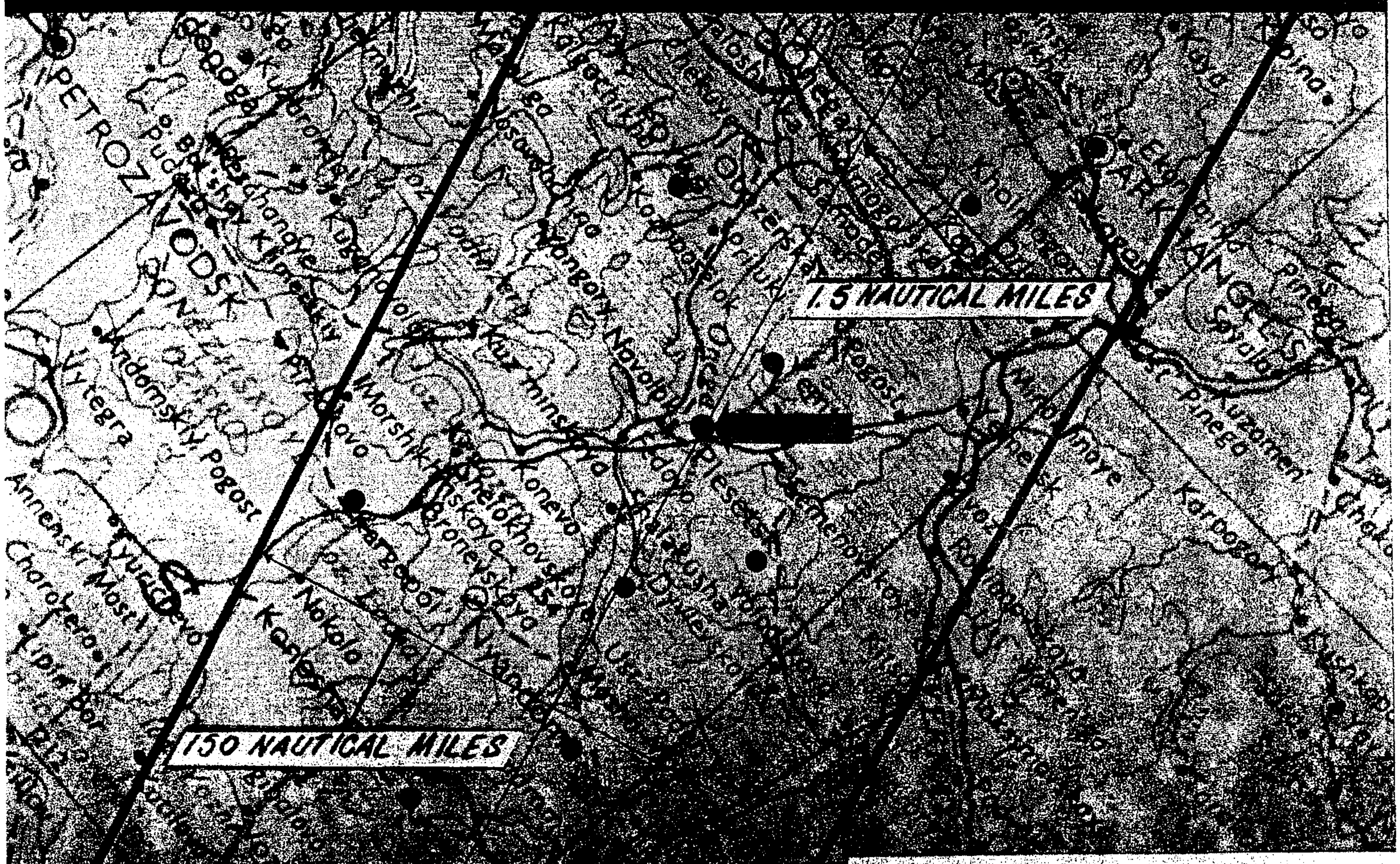
- MISSION REQUIREMENTS
- SYSTEM IMPLEMENTATION
- IMAGE VELOCITY SENSING REQUIREMENTS
- ADDITIONAL TECHNICAL CONSIDERATIONS

# MISSION REQUIREMENTS

MISSION REQUIREMENT

- [redacted] GROUND RESOLUTION
  - 2:1 CONTRAST AT APERTURE
  - 890 FT LAMBERTS AVERAGE MINIMUM SCENE LUMINANCE AT APERTURE
  - NADIR TARGET
  - 80 N MI ALTITUDE
  - AVERAGE TOTAL SMEAR RATE - [redacted]
  - [redacted] FOCUS ERROR

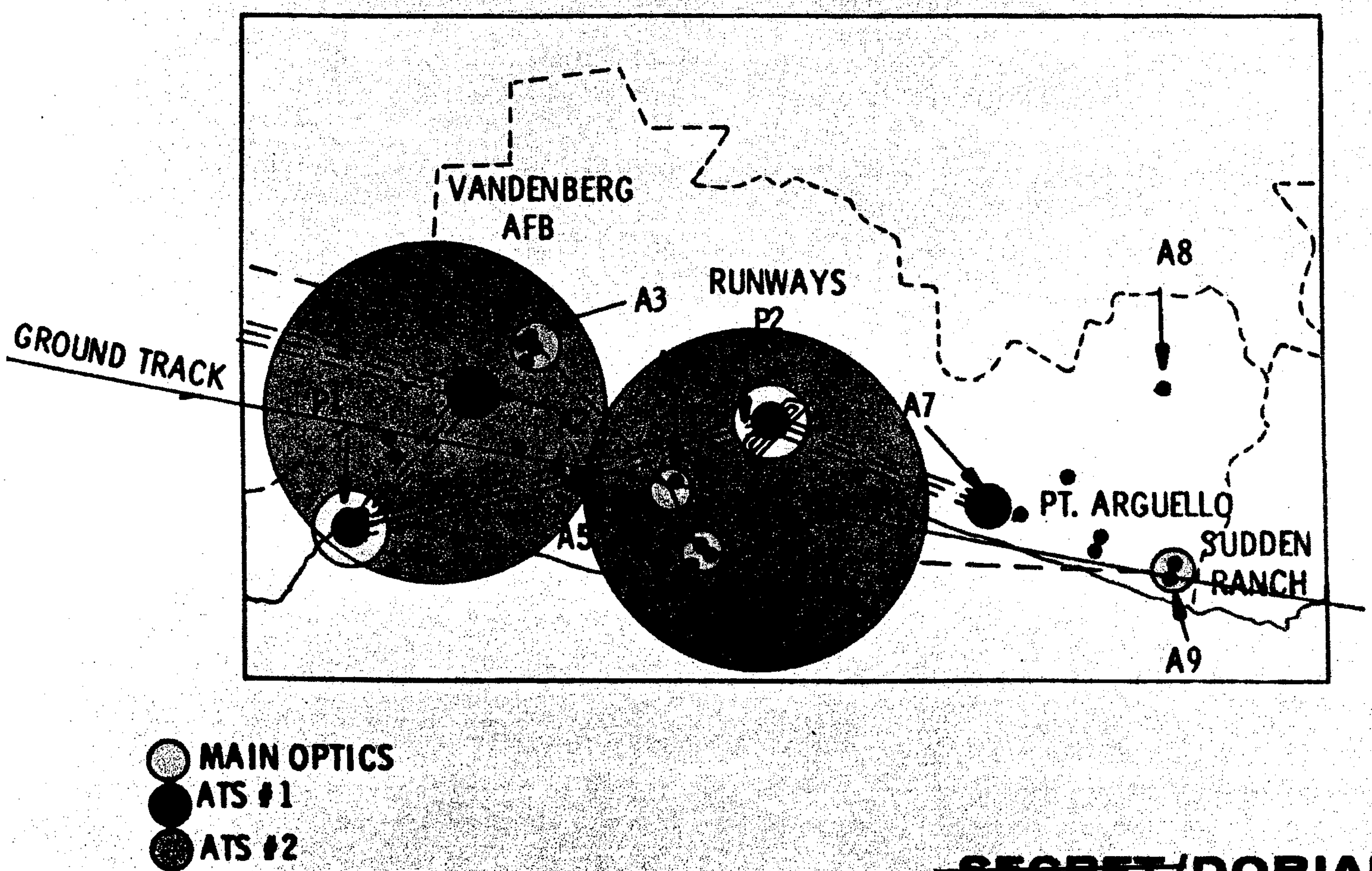
# SECTION OF TYPICAL PASS




[redacted]

## VANDENBERG AIMING POINT

## PROGRAMMED



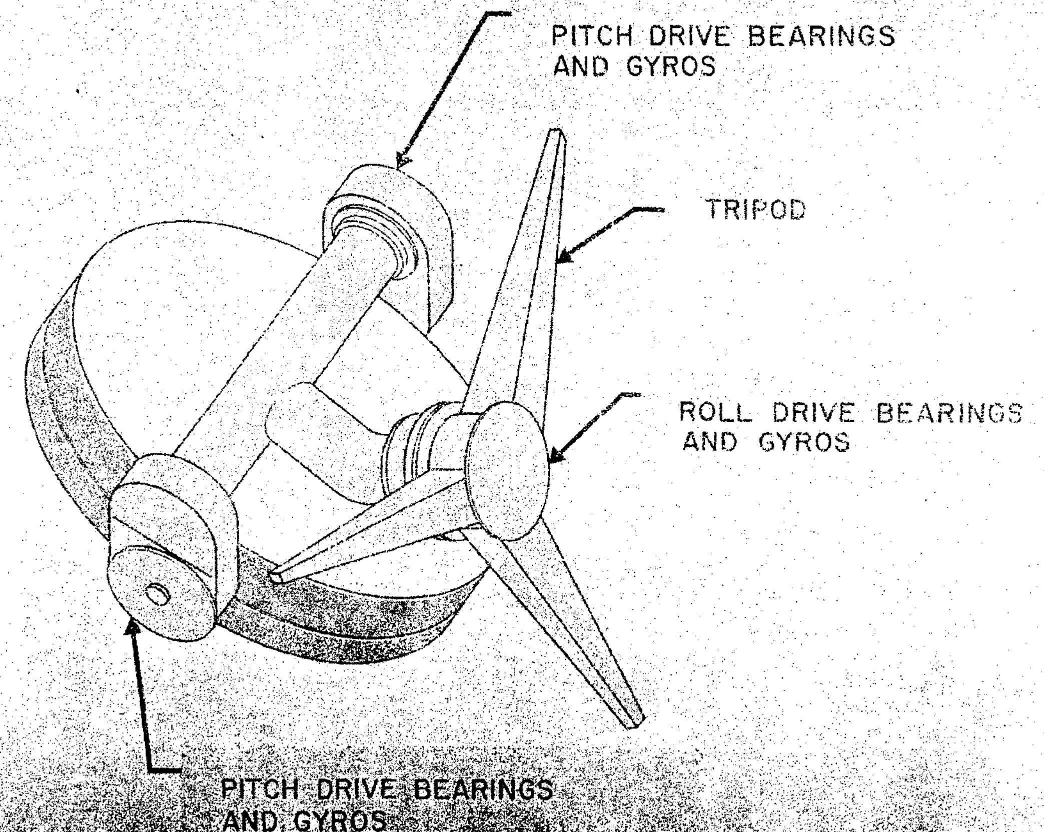
## SYSTEM CONCEPT

- THIS IS ACHIEVED IN THE DORIAN SYSTEM WITH A FRAME CAMERA, USING A SERVO-DRIVEN MIRROR TO TRACK THE TARGET AND STABILIZE THE IMAGE ON THE FILM DURING EXPOSURE

- THE CAMERA HAS A FOCAL PLANE SHUTTER WHICH TRAVELS ACROSS THE FILM IN 0.2 SEC

- EXPOSURE TIME 1/200 SEC NOMINAL

# TRACKING MIRROR GIMBAL ASSEMBLY



NRO APPROVED FOR
RELEASE 1 JULY 2015

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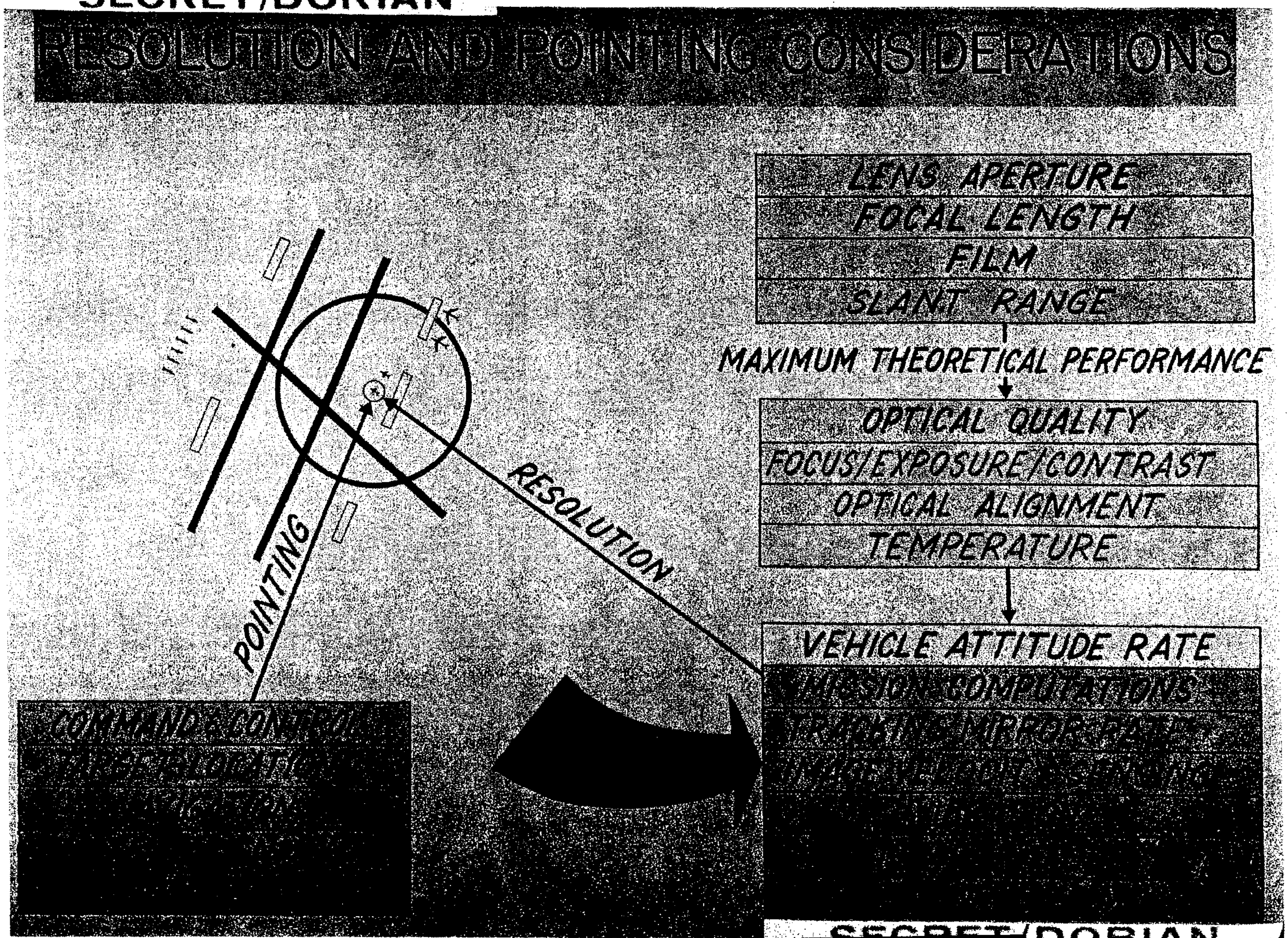


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## SMEAR APPORTIONMENT (0. 95p)

| | SMEAR RATE | LINEAR IMAGE MOTION IN 1/200 SEC | |
|---|---|---|---|
| | | GROUND (80 N MI NADIR) | ON FILM |
| TOTAL ALLOCATION | [redacted] | | |
| SYSTEM VIBRATION | | | |
| TRACKING MIRROR CONTROL (NOISE) | | | |
| IMAGE VELOCITY SENSOR (CREW) | | | |

NOTE: [redacted] AT THE MAIN OPTICS IMAGE PLANE
- [redacted] RADIANS
- [redacted] ON THE GROUND (NADIR, 80 N MI)

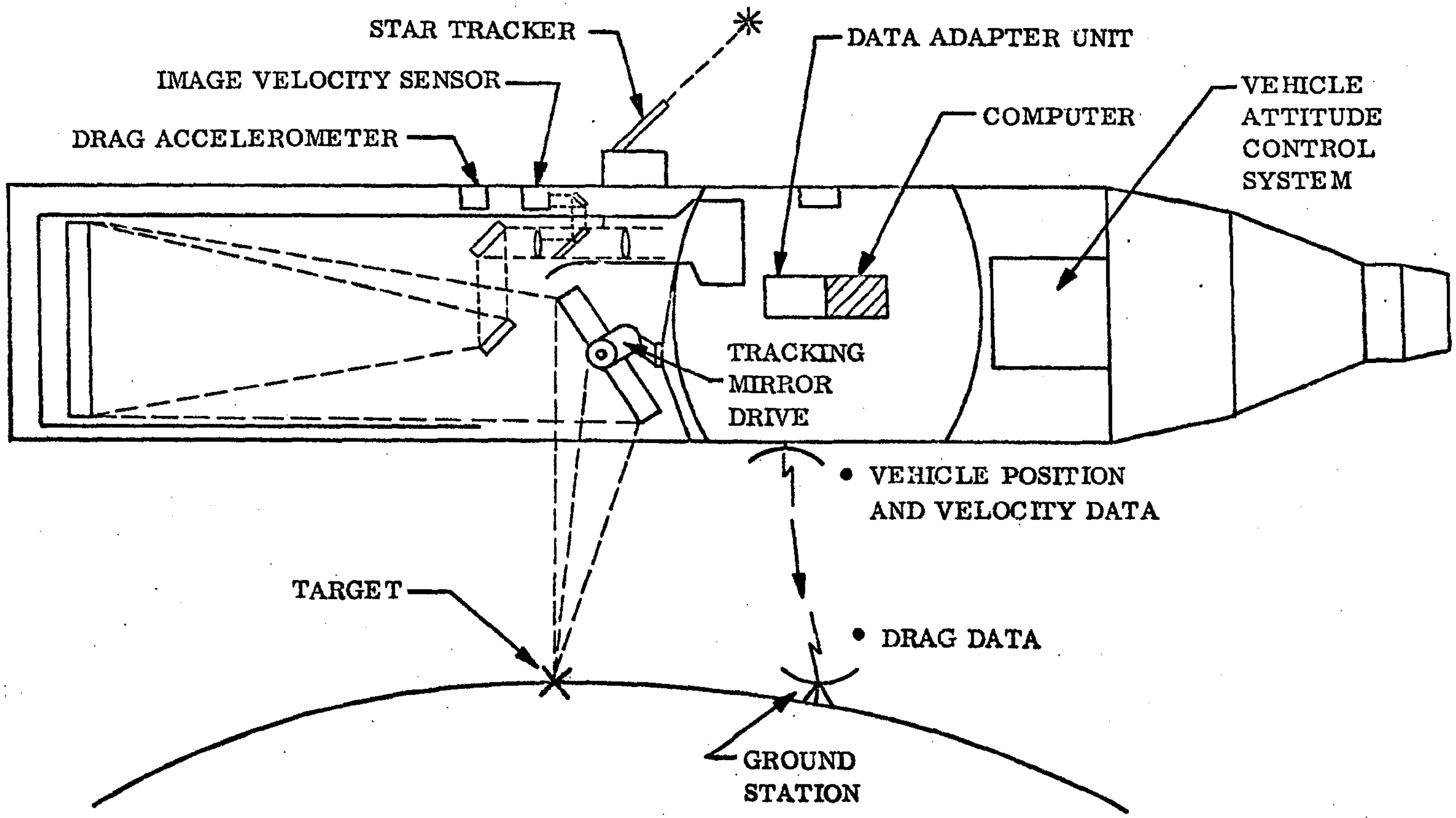
SENSITIVITY TO SMEAR

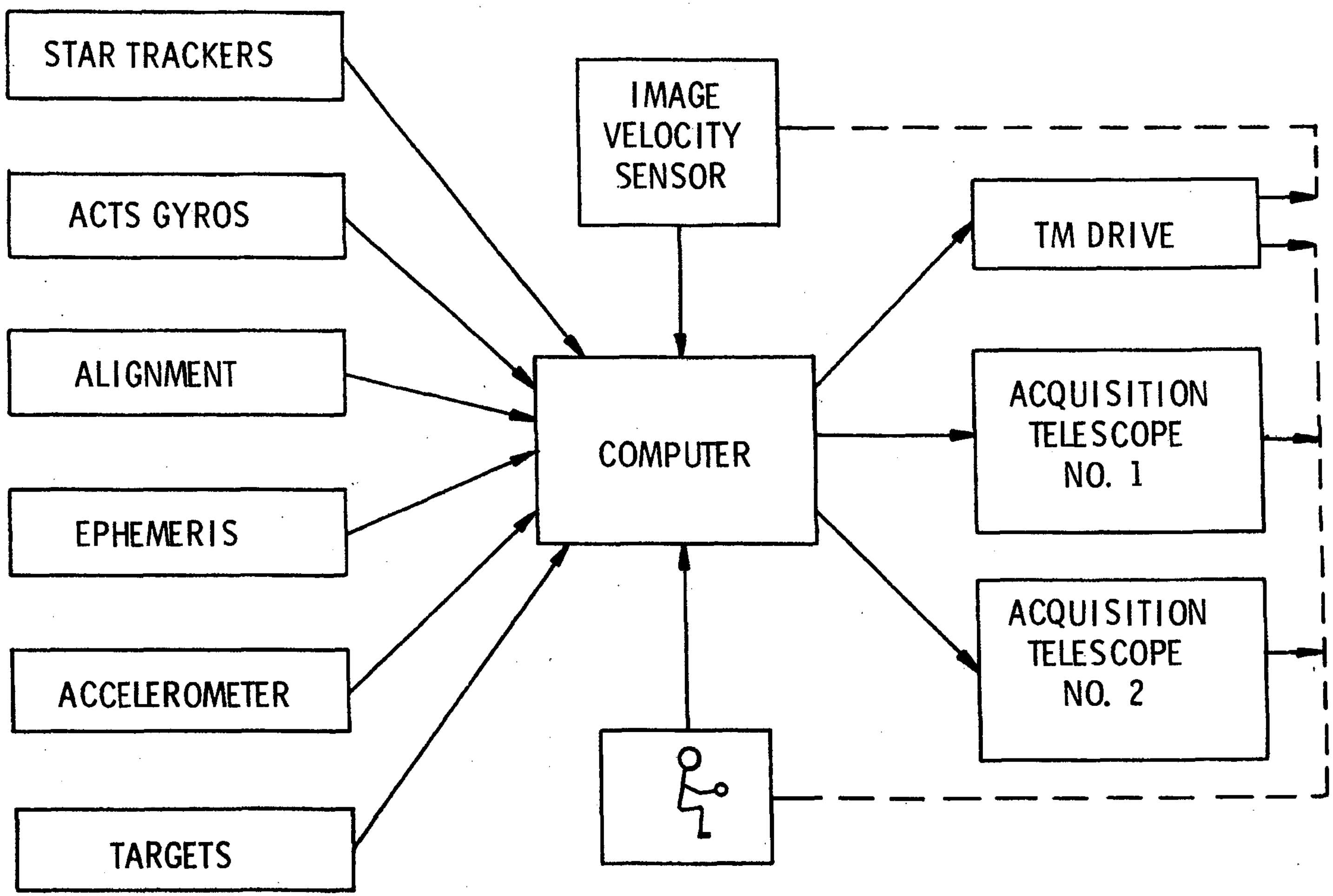
[redacted]

TOTAL SMEAR ( $\mu$ RAD/SEC)

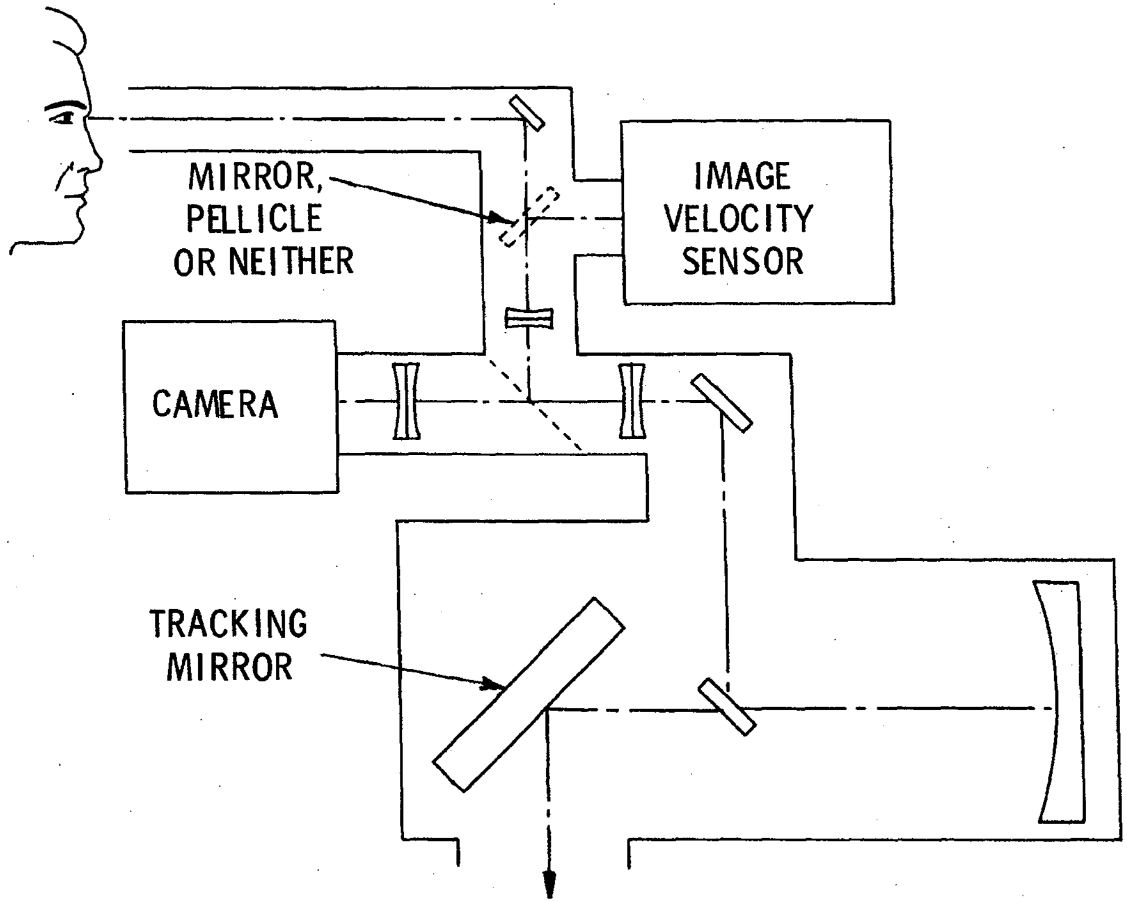
SYSTEM IMPLEMENTATION

## POINTING AND TRACKING OPERATION




STAR TRACKERS
ACTS GYROS
ALIGNMENT
EPHEMERIS
ACCELEROMETER
TARGETS
IMAGE VELOCITY SENSOR
COMPUTER
TM DRIVE
ACQUISITION TELESCOPE NO. 1
ACQUISITION TELESCOPE NO. 2

# OPTICAL FLOW DIAGRAM

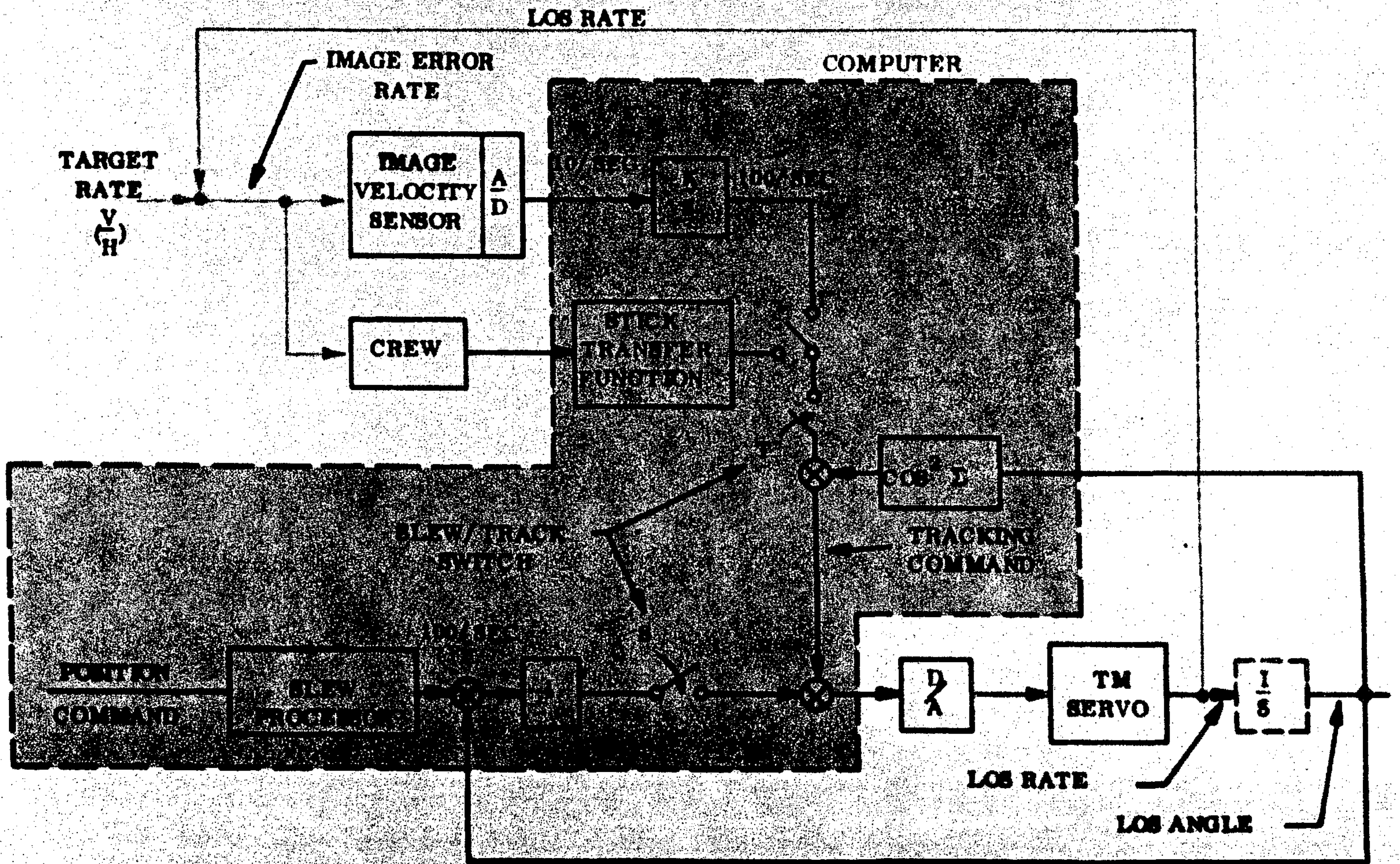


# IMAGE VELOCITY SENSOR DYNAMIC REQUIREMENTS

- TRACKING LOOP CONSIDERATIONS
  - SOFTWARE COMPLEXITY
  - SETTLING TIME RESPONSE
  - STABILITY CONSTRAINTS
  - LOOP REJECTION OF IVS NOISE

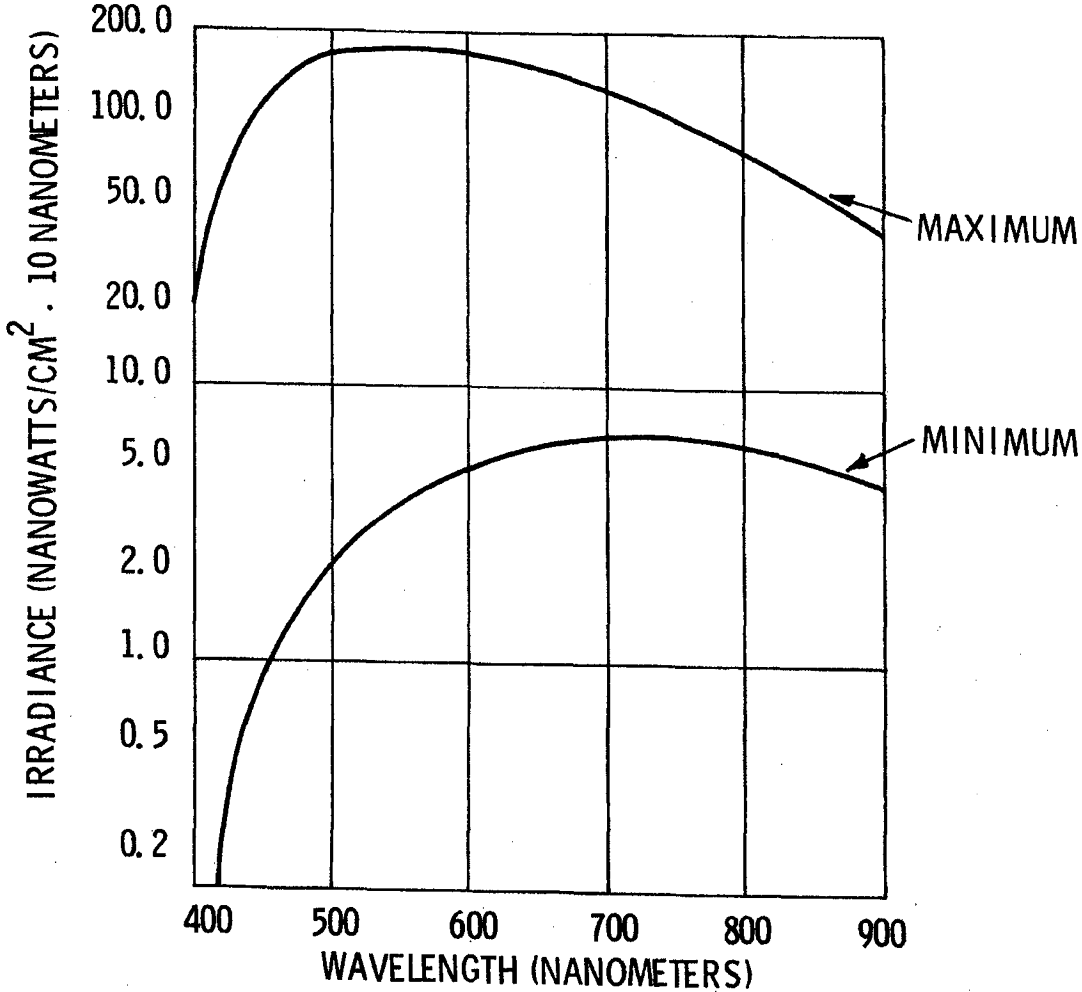
- SENSOR PERFORMANCE CHARACTERISTICS
  - NOISE AND BIAS (INCREASED SMEAR)
  - GAIN (INCREASED SMEAR AND SETTLING TIME)
  - FREQUENCY RESPONSE (LOSS IN STABILITY)

# TRACKING MIRROR CONTROL SYSTEM



# IMAGE VELOCITY SENSING REQUIREMENTS

AVERAGE SPECTRAL IRRADIANCE IN IMAGE PLANE



## IMAGE VELOCITY SENSING REQUIREMENTS

- INDICATE VELOCITY OF THE CENTER OF THE IMAGE ON THE FILM
- UTILIZE A PORTION OF THE SCENE IMAGERY DIVERTED FROM THE MAIN OPTICAL SYSTEM
- OPERATE DOWN TO 5 DEG SUN ELEVATION ANGLE WITH ALL THE DIVERTED LIGHT
- OPERATE DOWN TO 15 DEG SUN ELEVATION ANGLE WHEN SHARING DIVERTED LIGHT

IMAGE VELOCITY SENSING REQUIREMENTS (CONT)

- ACCURATE TO $\pm$ [redacted] VECTOR SUM OF TWO AXIS OUTPUT (0.95p)

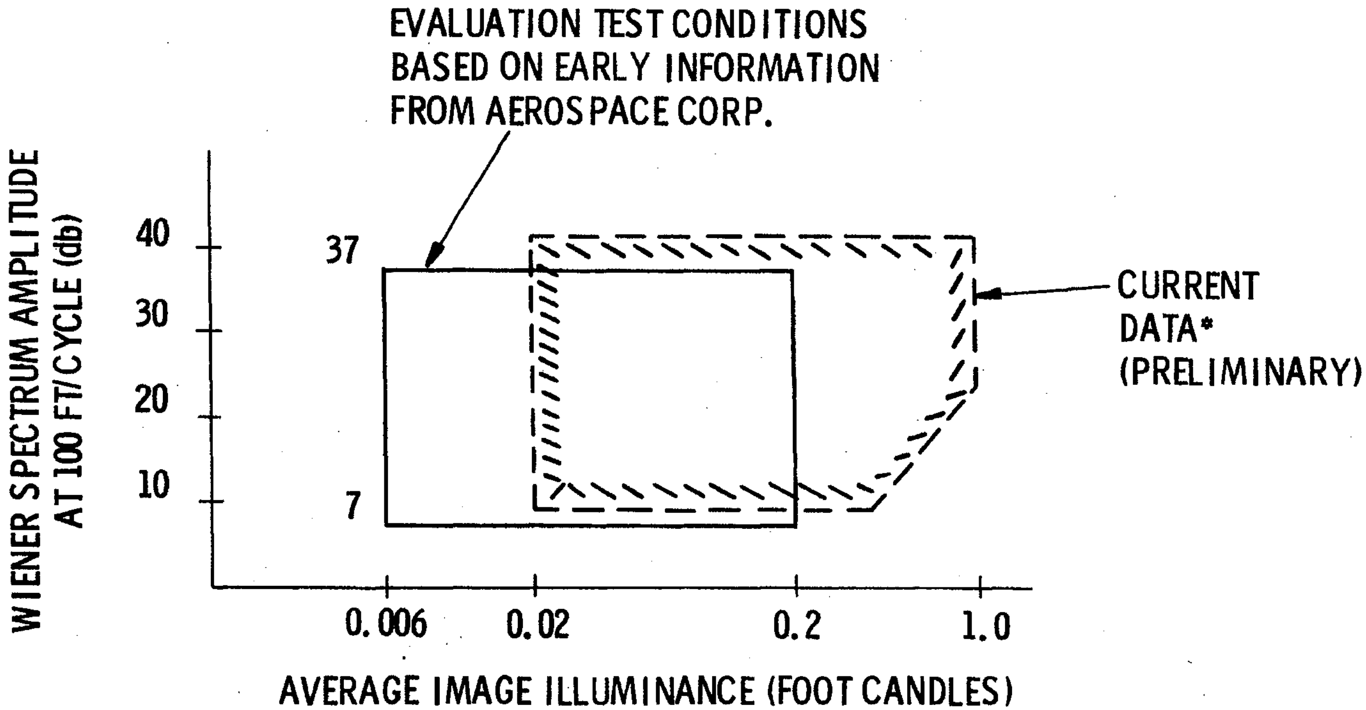
- USING IVS, THE TRACKING MIRROR CONTROL SYSTEM MUST SLEW THE LINE OF SIGHT TO A NEW TARGET, TRACK, AND BE READY TO PHOTOGRAPH [redacted] TOTAL SMEAR RATE) IN $\left(\frac{\Delta\theta}{6} + 4\right)$ SECONDS

NOTE: WITHOUT IVS, THE CONTROL MUST SLEW, SETTLE AND TRACK TO WITHIN 540 $\mu$RAD/SEC IN $\left(\frac{\Delta\theta}{6} + 3\right)$ SECONDS

# IMAGE VELOCITY SENSING REQUIREMENTS (CONT)

- OPERATING RANGE
  - $+30^0$ TO $-40^0$ STERO
  - $+37.3^0$ TO $-37.3^0$ OBLIQUITY
- SCENE BRIGHTNESS/MODULATION CONDITIONS FOR REQUIRED OPERATION ARE DEFINED IN TERMS OF WIENER SPECTRUM GAIN AND AVERAGE LIGHT LEVEL

# IMAGE PLANE MODULATION VS AVERAGE ILLUMINANCE




*BASED ON LATEST INTERFACE AGREEMENTS, UP DATED AEROSPACE CORP. INFORMATION, AND RE-EVALUATION OF VIGNETTING EFFECTS

# ELECTRICAL OUTPUT REQUIREMENTS

- DYNAMIC RANGE: 0 TO $\pm$ 0.3 IN/SEC (0 TO $\pm$ 600 $\mu$ RAD/SEC)
- NOISE AND BIAS: NULL REGION: TOTAL NOISE PLUS BIAS AT THE TRACKING MIRROR NOT TO EXCEED [redacted]
- SIGNAL LINEARITY:
  - LARGE SIGNAL: $\pm$ 25 PERCENT (MONOTONIC)
  - NULL REGION: $\pm$ 10 PERCENT (MONOTONIC)
- TYPE OF OUTPUT SIGNAL: DIGITAL - GE FURNISHED A/D CONVERTER

# ADDITIONAL TECHNICAL CONSIDERATIONS

# ADDITIONAL TECHNICAL CONSIDERATIONS

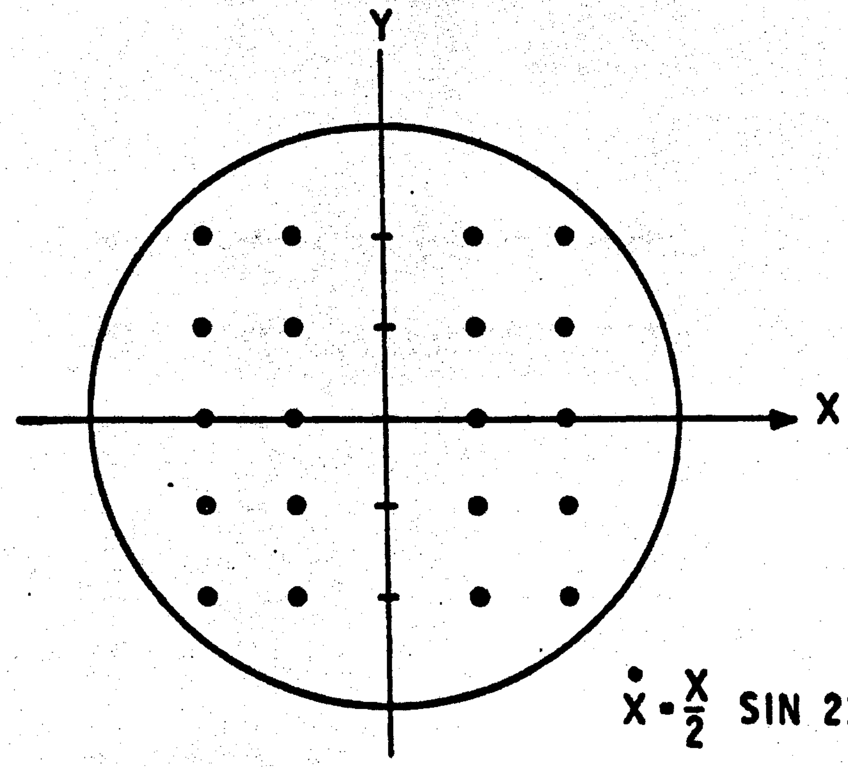
- SCENE DYNAMICS
  - "DYNAMIC NULL"
- CLOUDS
- OPEN LOOP TRACKING CAPABILITY

# SCENE DYNAMICS

- CHANGING SLANT RANGE AND ASPECT ANGLES CAUSE POINTS IN THE IMAGE TO MOVE WITH RESPECT TO THE CENTER OF THE IMAGE

- THIS PHENOMENON PRESENTS A PROBLEM TO THE IVS IN INDICATING VELOCITY AT THE CENTER OF THE IMAGE

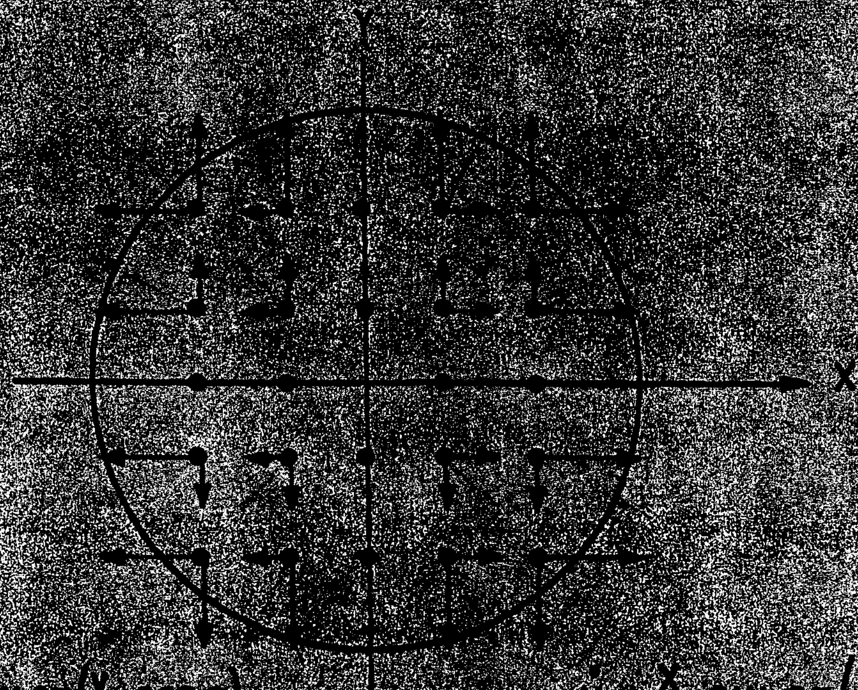
## SCENE DYNAMICS




$$\dot{X} = \frac{X}{2} \; SIN \; 2\Sigma \left( \frac{v}{h} \; COS\Omega \right)$$

IN-TRACK EXPANSION DUE TO CHANGE IN ASPECT ANGLE

## RADIAL EXPANSION DUE TO CHANGE IN SLANT RANGE

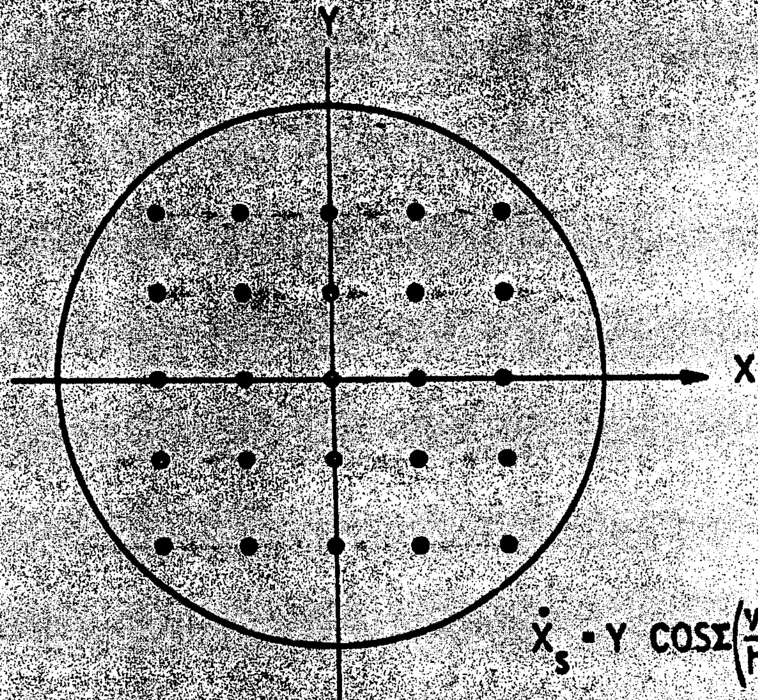



$$\dot{R} = \frac{R}{2} \, \text{SIN} \, 2\Sigma \left( \frac{V}{h} \, \text{COS} \, \Omega \right)$$

$$\dot{X}_c = \frac{X}{2} \, \text{SIN} \, 2\Sigma \left( \frac{V}{h} \, \text{COS} \, \Omega \right)$$

$$\dot{Y}_c = \frac{Y}{2} \, \text{SIN} \, 2\Sigma \left( \frac{V}{h} \, \text{COS} \, \Omega \right)$$

## SHEAR DUE TO CHANGING ASPECT OF OBLIQUE TARGET




$$\dot{X}_s = Y \cos\Sigma\left(\frac{v}{h} \sin\Omega\right)$$

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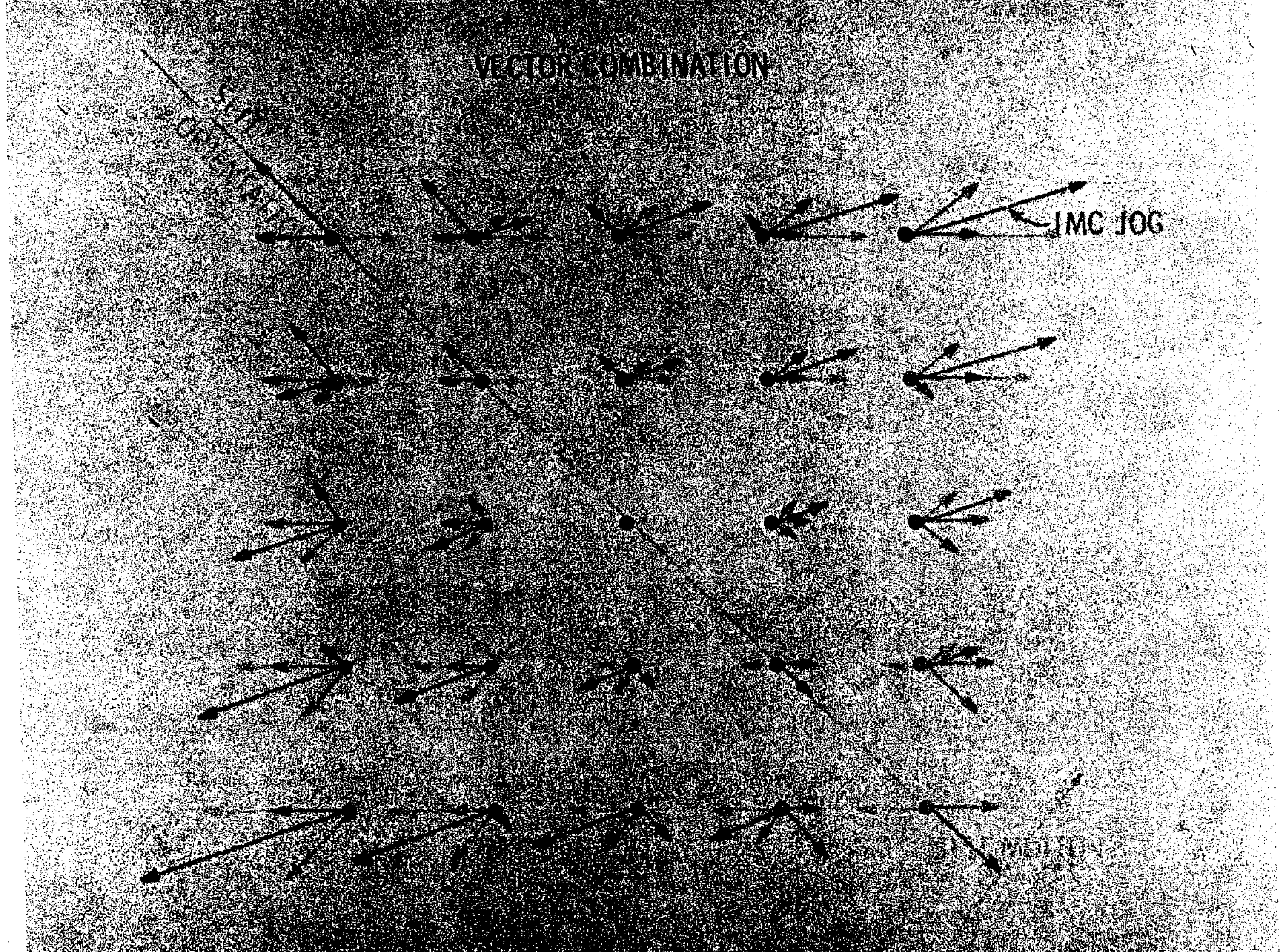

VECTOR COMBINATION
IMC JOG

## SCENE DYNAMICS

- IN WORST CASE, EACH COMPONENT CAN BE 80 μRAD/SEC OR MORE, AT EDGE OF 2.8 IN. IMAGE
- WORST COMBINATION IS 120 μRAD/SEC
- CROSS-FORMAT IMC WILL NOT REDUCE ANY ERRORS INTRODUCED BY IVS

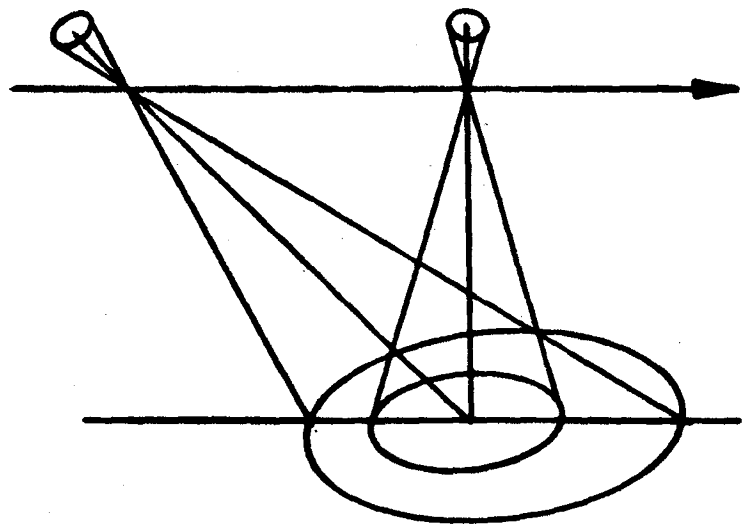
"DYNAMIC NULL"

- THE CHANGE IN SLANT RANGE AND ASPECT CAUSES THE SCENE CONTENT OF THE IVS IMAGE TO VARY, IN ADDITION TO PRODUCING SCENE DYNAMICS

- THE THREE IVS DESIGNS CURRENTLY RESPOND TO THIS IN INDIVIDUALLY CHARACTERISTIC WAYS

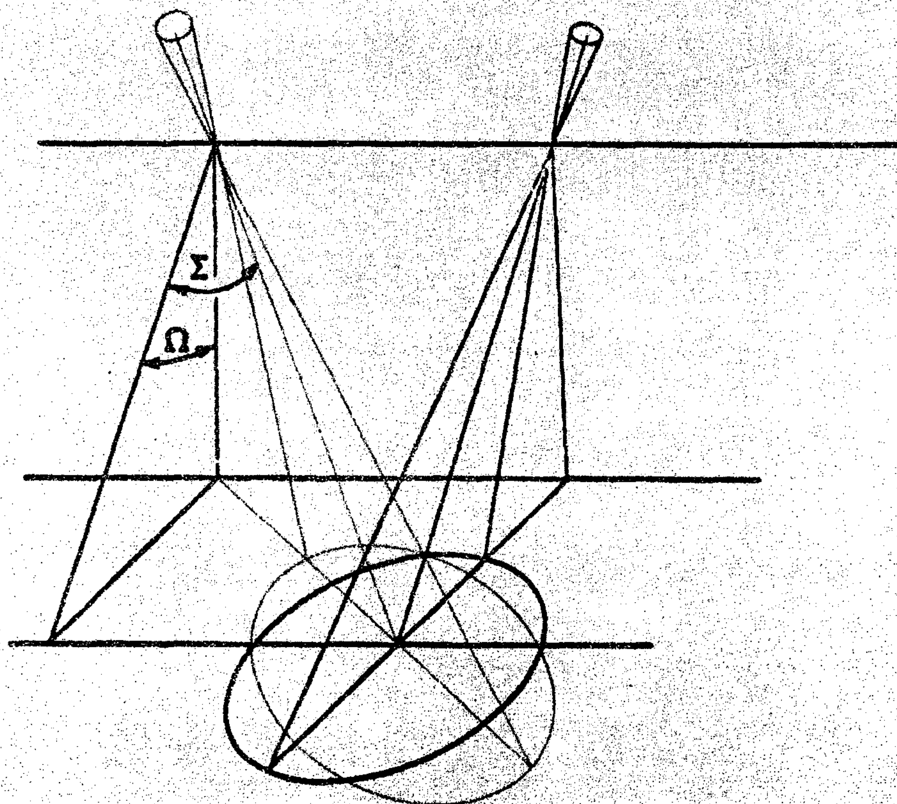
- ERRORS ARISING FROM THESE SOURCES HAVE BEEN TERMED "DYNAMIC NULL" ERRORS

## CHANGE IN IMAGE VELOCITY SENSOR FOOTPRINT
## (ZERO OBLIQUITY)



- POINTS ENTER AND LEAVE THE IMAGE AS STEREO ANGLE CHANGES

## CHANGE IN IMAGE VELOCITY SENSOR FOOTPRINT (OBLIQUE TARGET)




- SCENE CONTENT CHANGES AS ASPECT ANGLE CHANGES

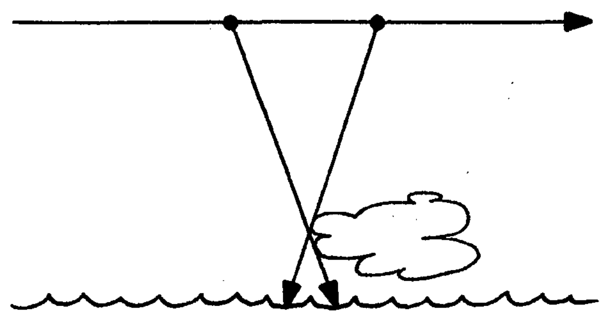
## $\frac{V}{H}$ SENSING VS NULL TRACKING

- SCENE DYNAMICS ARE ALSO PRESENT IN A $\frac{V}{H}$ SENSING SYSTEM BUT THEY ARE SMALL COMPARED TO $\frac{V}{H}$

- HOWEVER, IN A NULL TRACKING SYSTEM, SCENE DYNAMIC MOTIONS WITHIN THE IMAGE ARE LARGE COMPARED TO TRACKING ERROR; THEY ARE SLOW ENOUGH FOR THE SENSOR TO RESPOND TO THEM

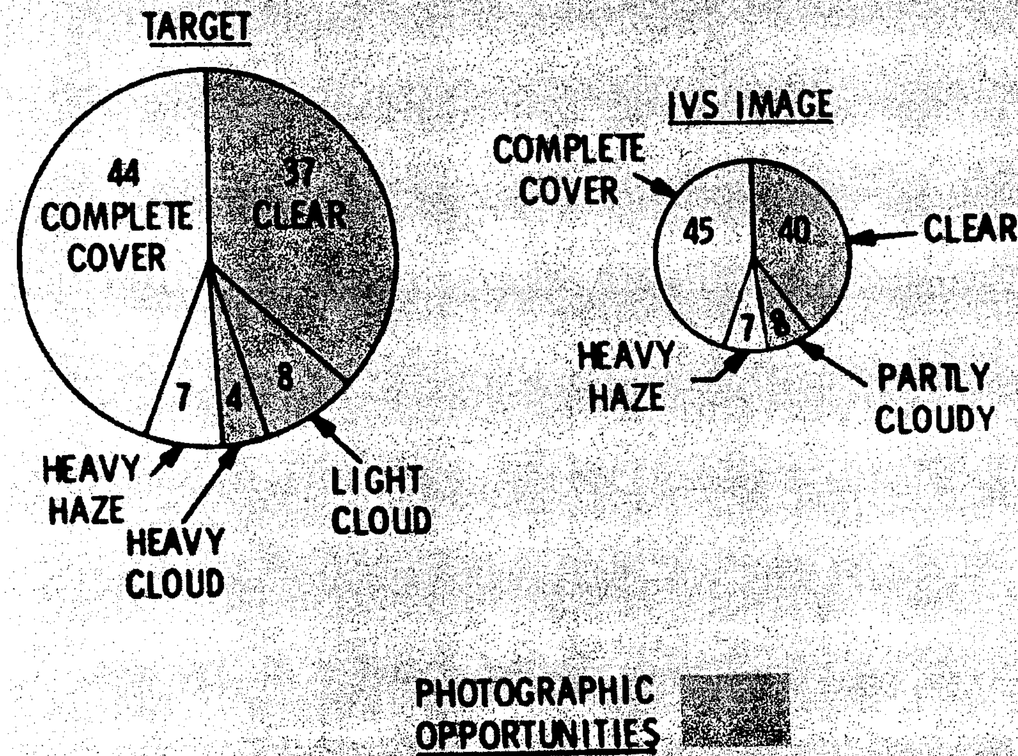
- THIS EFFECT IS FOUND ONLY WHEN TRACKING A TARGET USING ORBITAL GEOMETRY

CLOUDS



- APPARENT VELOCITY
  - 100 μ RAD/SEC PER 1000 FT CLOUD ALTITUDE
  - 3 μ RAD/SEC PER MI/HR WIND
- MULTIPLE RATES IN SCENE
  - AVERAGING EFFECTS UNCERTAIN
- OBSCURES TERRAIN
- CENTER OF POWER SHIFT

# CLOUD PROBABILITY




- CLOUDS ARE ENCOUNTERED BY THE IVS IN 17% OF THE CASES WHERE PHOTOGRAPHS ARE POSSIBLE
- IVS OPERATION IS UNCERTAIN WHEN CLOUDS ARE PRESENT

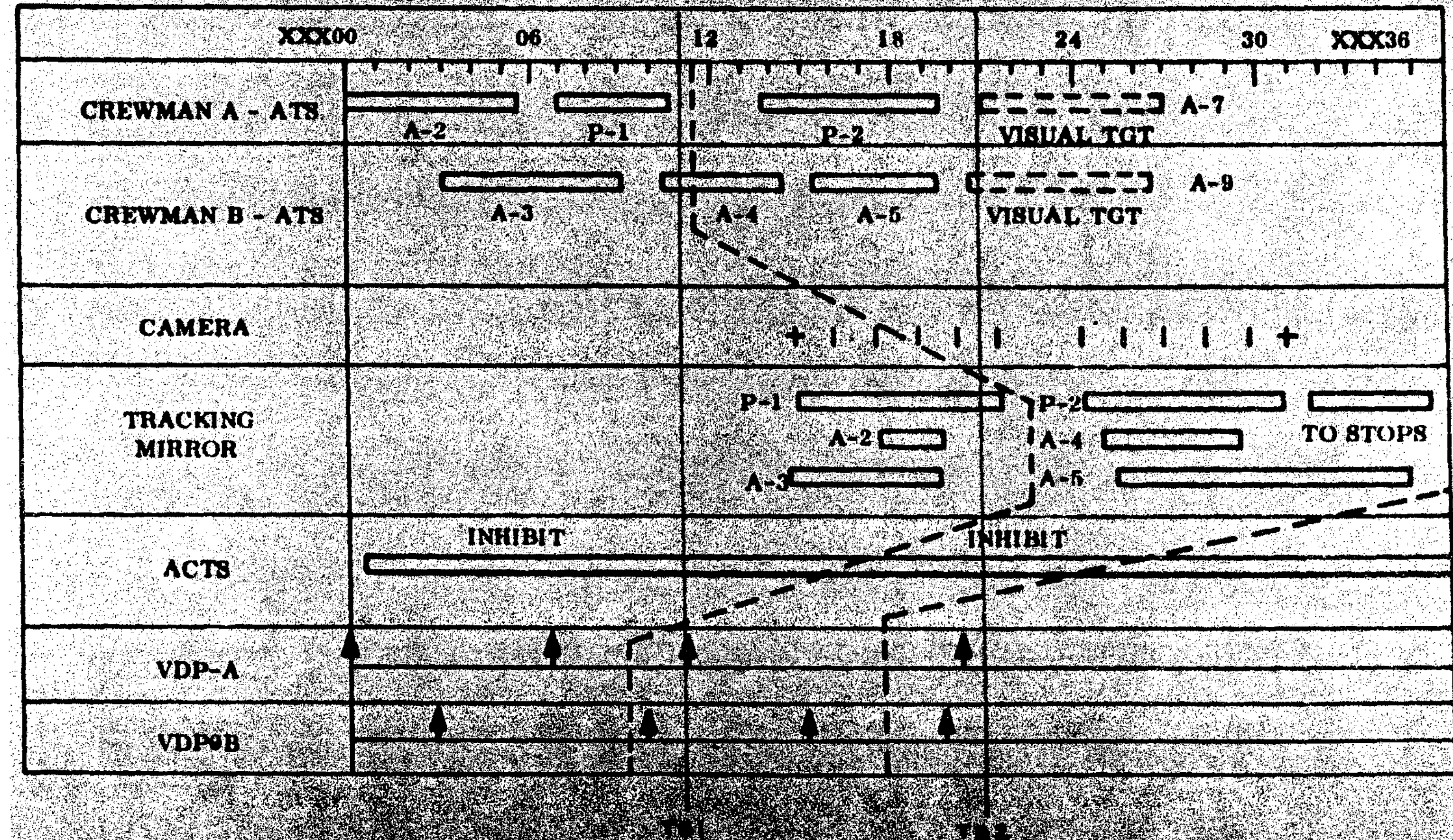
# OPEN LOOP OPERATION

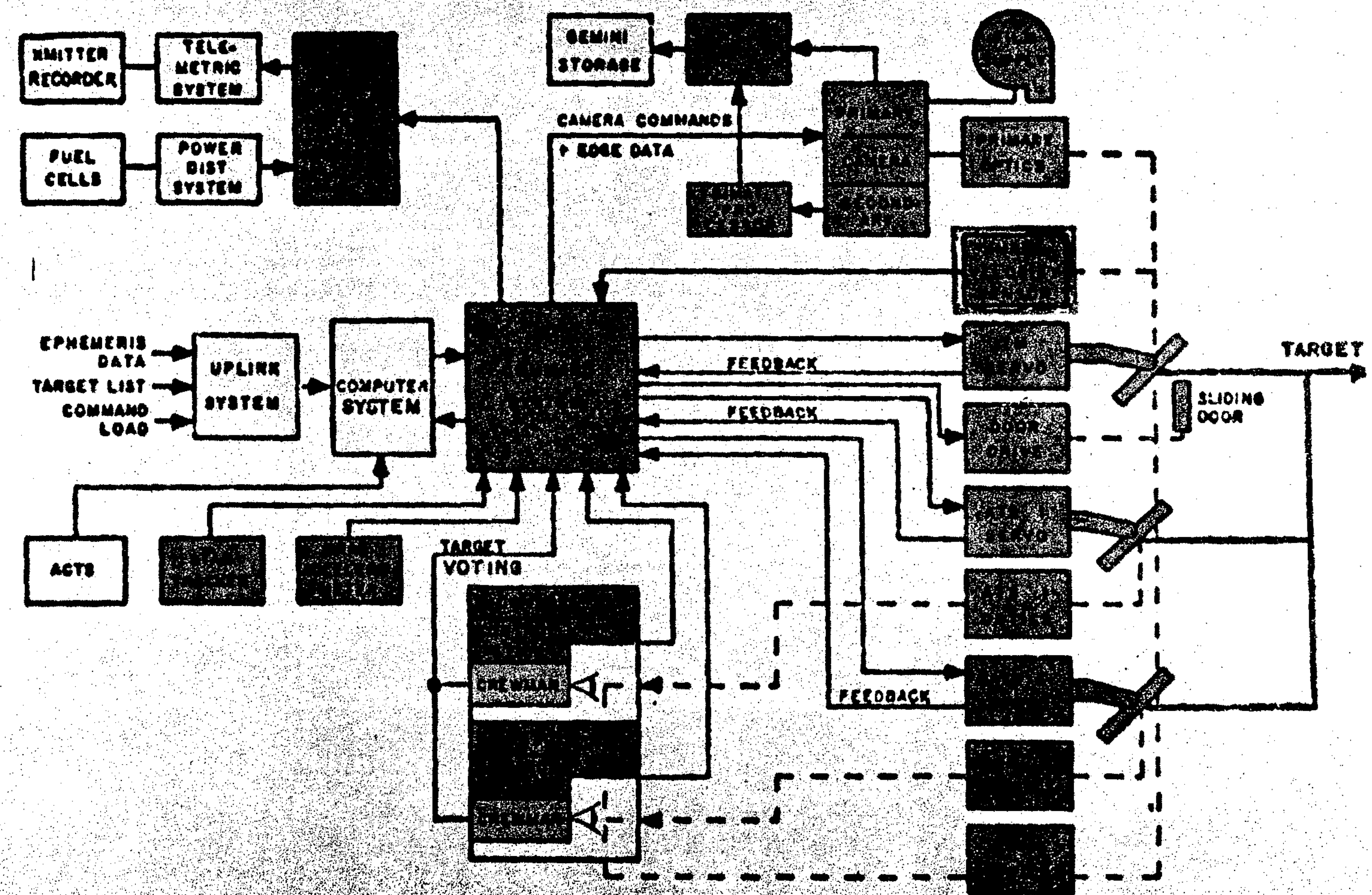
- A CAPABILITY TO OPERATE OPEN LOOP APPEARS NECESSARY

# OPEN LOOP OPERATION

- CURRENT DESIGN ≈ 270 μ RAD/SEC
- POTENTIAL IMPROVEMENTS REDUCE ERROR TO ≈ 100 μ RAD/SEC

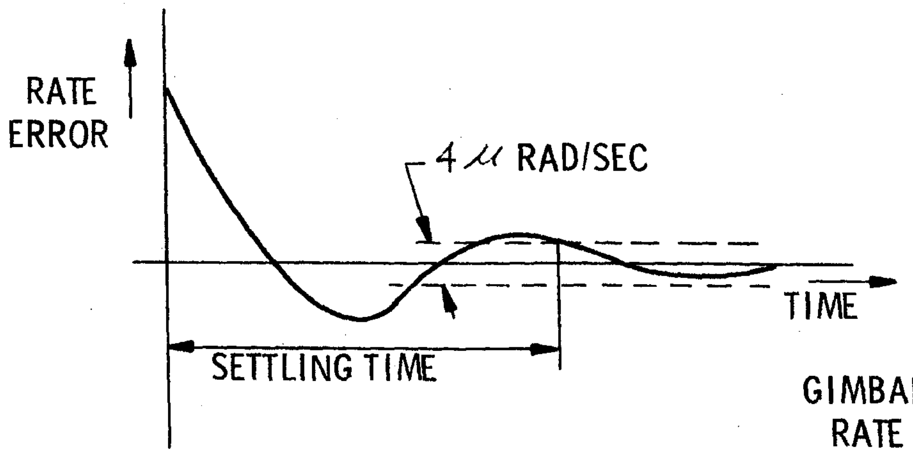
# FINELINE TARGET PASS - VANDENBERG AFB



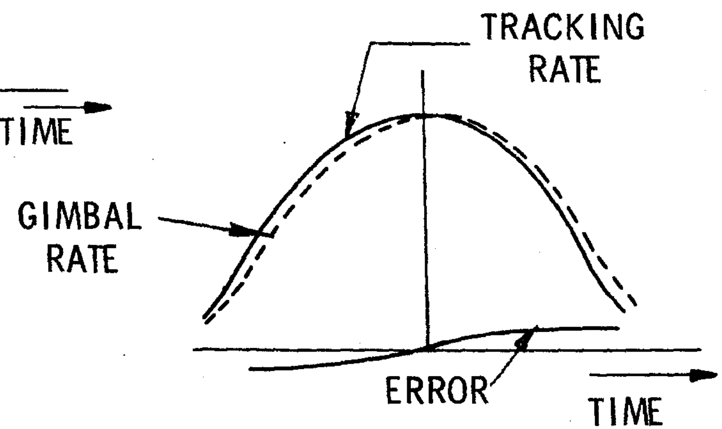

XMITTER RECORDER
TELE-METRIC SYSTEM
FUEL CELLS
POWER DIST SYSTEM
GEMINI STORAGE
CAMERA COMMANDS
+ EDGE DATA
EPHEMERIS DATA
TARGET LIST
COMMAND LOAD
UPLINK SYSTEM
COMPUTER SYSTEM
FEEDBACK
FEEDBACK
FEEDBACK
TARGET
SLIDING DOOR
ACTS
TARGET VOTING

# IMAGE VELOCITY SENSOR TRACKING LOOP DESIGN CONSIDERATIONS

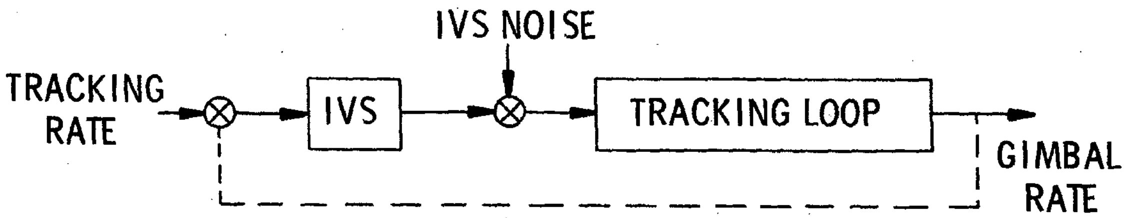
- SETTLING TIME



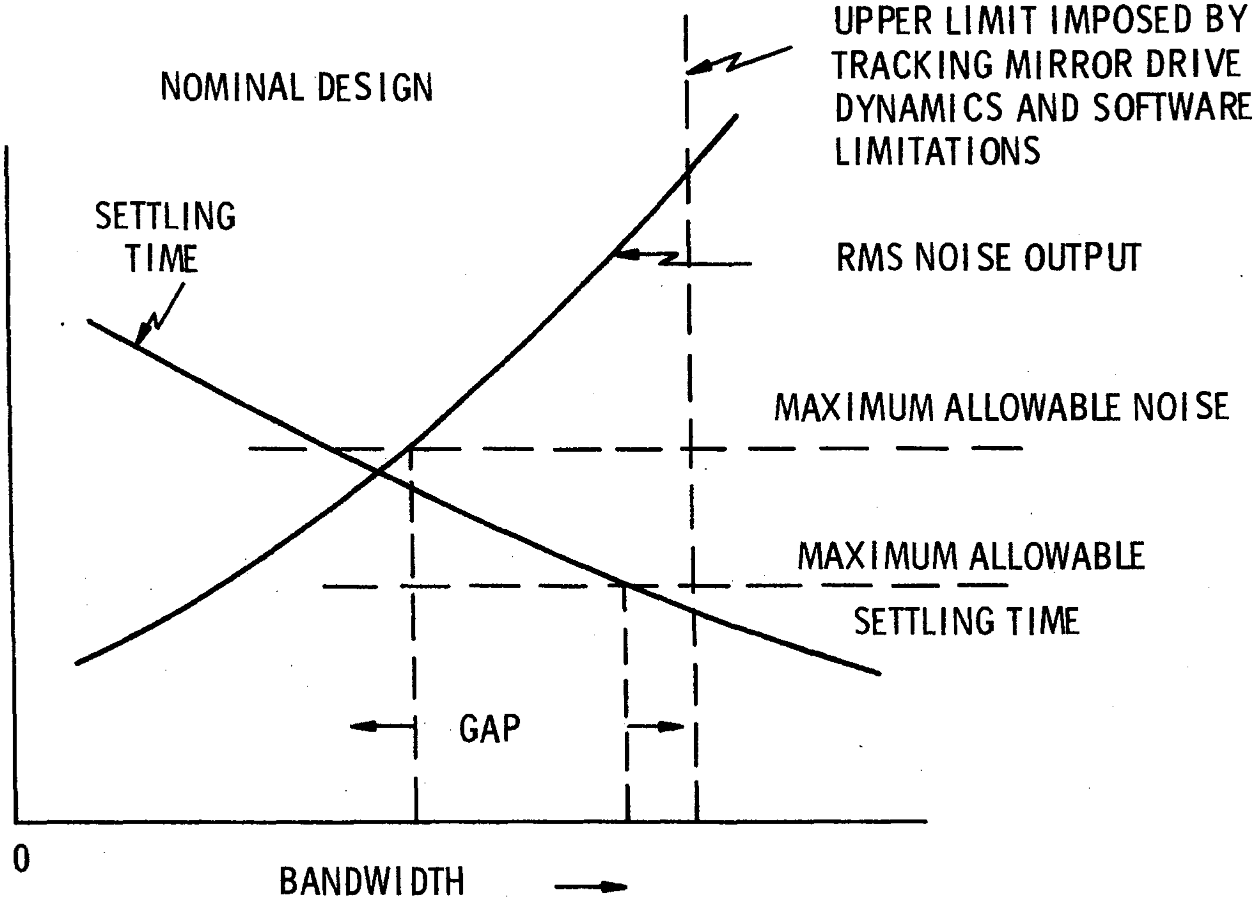

- SERVO TRACKING ERROR




- NOISE TRANSMISSION



PICTORIAL REPRESENTATION OF DESIGN PROBLEM

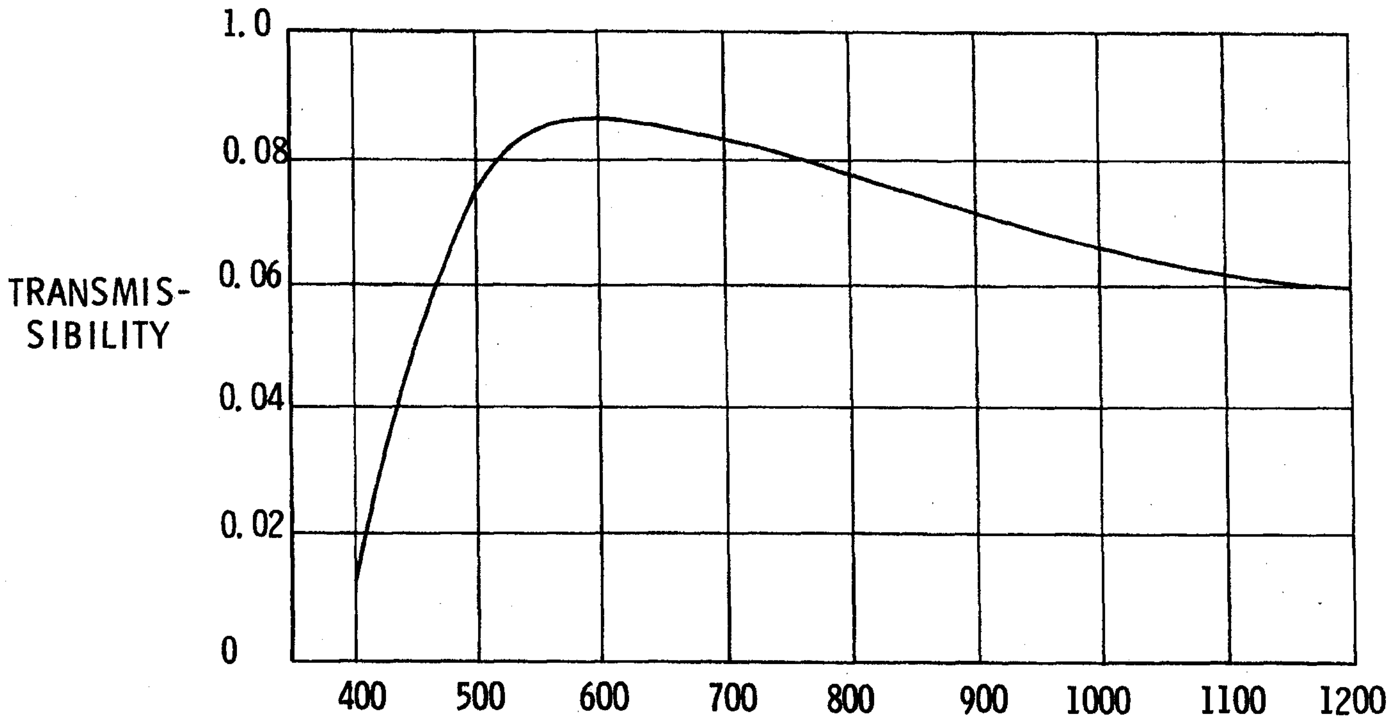



BRIDGING THE GAP:
- DESIGN OPTIMIZATION
- COMPROMISE

## CHANGES TO IMAGE PLANE MODULATION AND AVERAGE ILLUMINANCE

| | NEW DATA (REV 6) | OLD DATA (REV 5 REQUIREMENT AND TEST) |
|---|---|---|
| 1. OPTICAL TRANSMISSION | 7.5 PERCENT | 2 TO 5 PERCENT |
| 2. VIGNETTING | 0.32 TO 0.64 | NOT KNOWN |
| 3. WIENER GAIN | APPROXIMATELY SAME | |
| 4. WIENER SLOPE | 1.5 ASSUMED BY AEROSPACE<br>1.1 TO 1.7 USED AS REQUIRED | 1.1 TO 1.7 |
| 5. AVERAGE LIGHT LEVEL | 150 TO 4000 FOOT LAMBERTS | 150 TO 1200 FOOT LAMBERTS |

TRANSMISSIBILITY TO IVS IMAGE WITH MIRROR IN PLACE



## OPEN LOOP OPERATION

| | DRIVE | COMMAND | TGT & VEH ALTITUDE | VIBRATION | TOTAL |
|---|---|---|---|---|---|
| • BASELINE | 253 | 72 | 63 | 26 | 271 |
| • SINGLE POINT DRIVE CALIBRATION | 52 | 72 | | | 112 |
| • TEMPERATURE STABILIZATION<br>• MULTI-POINT CALIBRATION<br>• IMPROVED ATTITUDE (SOFTWARE) | 35 | 66 | | | 101 |
| • TEMPERATURE STABILIZATION<br>• MULTI-POINT CALIBRATION<br>• IMPROVED ATTITUDE (SOFTWARE & HARDWARE)<br>• IMPROVED GYRO ALIGNMENT | 35 | 53.5 | 63 | 26 | 93.4 |

## OPEN LOOP OPERATION

| | DRIVE | COMMAND | TGT & VEH ALTITUDE | VIBRATION | TOTAL |
|---|---|---|---|---|---|
| • BASELINE | 253 | 72 | 63 | 26 | 271 |
| • SINGLE POINT DRIVE CALIBRATION | 52 | 72 | 63 | | 112 |
| • TEMPERATURE STABILIZATION<br>• MULTI-POINT CALIBRATION<br>• IMPROVED ATTITUDE (SOFTWARE) | 35 | 66 | 25 | | 83 |
| • TEMPERATURE STABILIZATION<br>• MULTI-POINT CALIBRATION<br>• IMPROVED ATTITUDE (SOFTWARE & HARDWARE)<br>• IMPROVED GYRO ALIGNMENT | 35 | 53.5 | 25 | 26 | 73.4 |

IMAGE VELOCITY SENSOR TEST AND EVALUATION PROGRAM . . . . . . S. HOBBS

# APPROACH TO IMAGE VELOCITY SENSOR DEVELOPMENT

- STUDIES
- COMPONENT DESIGN
- TEST AND EVALUATION

# IMAGE VELOCITY SENSOR TEST PHILOSOPHY

- IDENTIFY MAJOR INPUT CONDITIONS AFFECTING IVS PERFORMANCE
- DESIGN, FABRICATE AND CHECKOUT TESTER TO PROVIDE CLOSEST PRACTICAL SIMULATION
- IDENTIFY AND DETERMINE EFFECTS OF LIMITATIONS OF TESTER COMPARED TO REAL WORLD CONDITIONS
- SUBJECT ALL IVS UNITS TO IDENTICAL TEST SERIES TO PERMIT EVALUATION AGAINST COMPONENT SPECIFICATION

# IMAGE VELOCITY SENSOR TEST PLAN

| TEST | OBJECTIVES |
| --- | --- |
| PHASE 1 | |
| • BENCH TESTS | - FUNCTIONAL CHECKOUT OF UNITS<br>- PERSONNEL FAMILIARIZATION<br>- SUPPLEMENT OPEN LOOP TESTS |
| • OPEN LOOP TESTS | - EVALUATE CAPABILITY OF EACH UNIT TO MEET SPECIFIED PERFORMANCE REQUIREMENTS UNDER SIMULATED REAL WORLD INPUT CONDITIONS |
| PHASE 2 | |
| • CLOSED LOOP TESTS | - COMBINE TRACKING MIRROR LOOP WITH IVS |

# IMAGE VELOCITY SENSOR OPEN LOOP TEST OBJECTIVE

EVALUATE CRITICAL IVS PERFORMANCE CHARACTERISTICS:

- NULL ACCURACY
- LINEARITY OF RESPONSE
- VELOCITY SENSING AT CENTER OF FORMAT
- OPERATION AT MINIMUM AVERAGE ILLUMINATION
- OPERATION AT MINIMUM CONTRAST (WIENER SPECTRUM MODULATION VS AVERAGE ILLUMINATION)
- VELOCITY THRESHOLD AND DYNAMIC RANGE
- SCENE CONTENT DEPENDENCE
- CROSS COUPLING
- FOCUS CRITICALITY

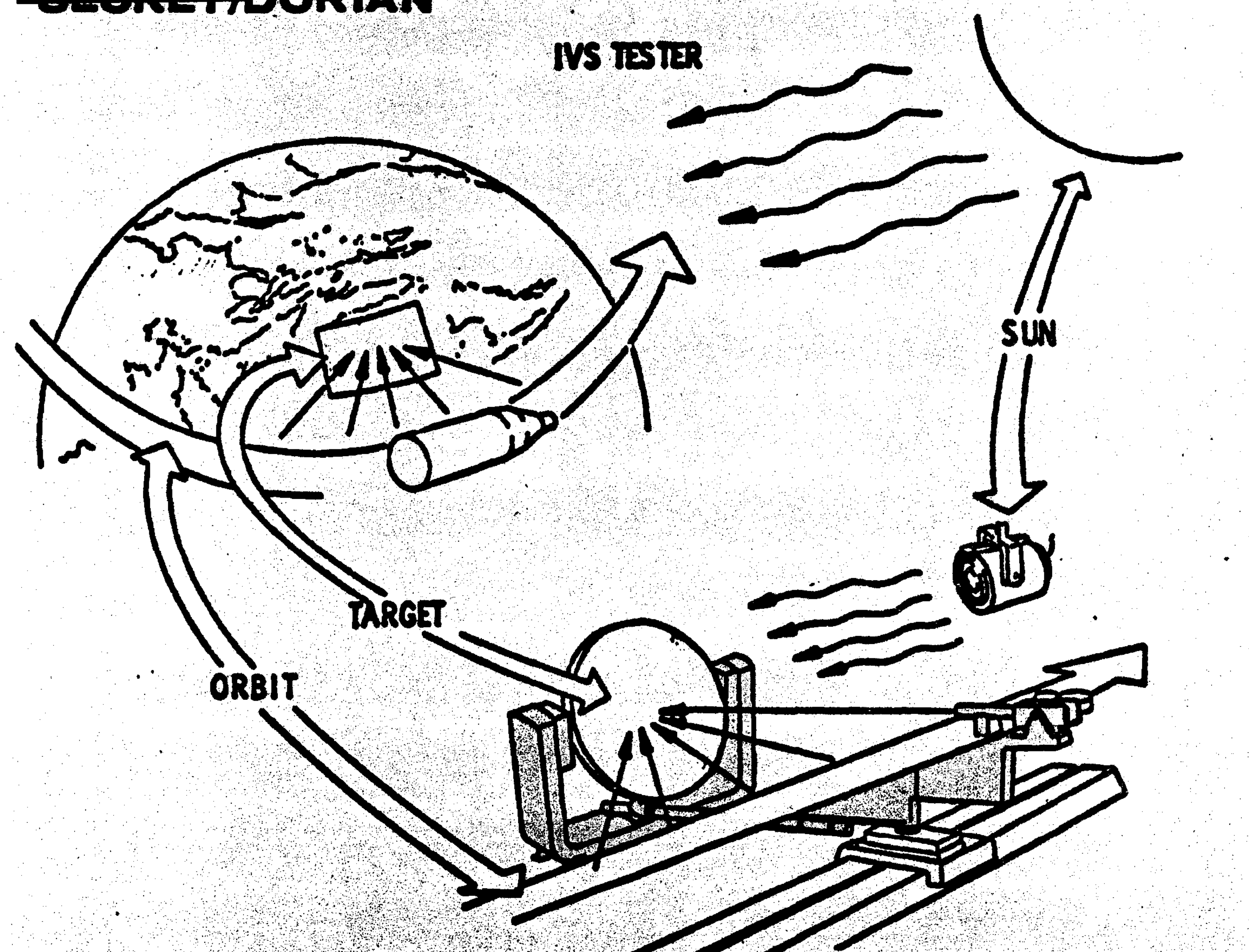
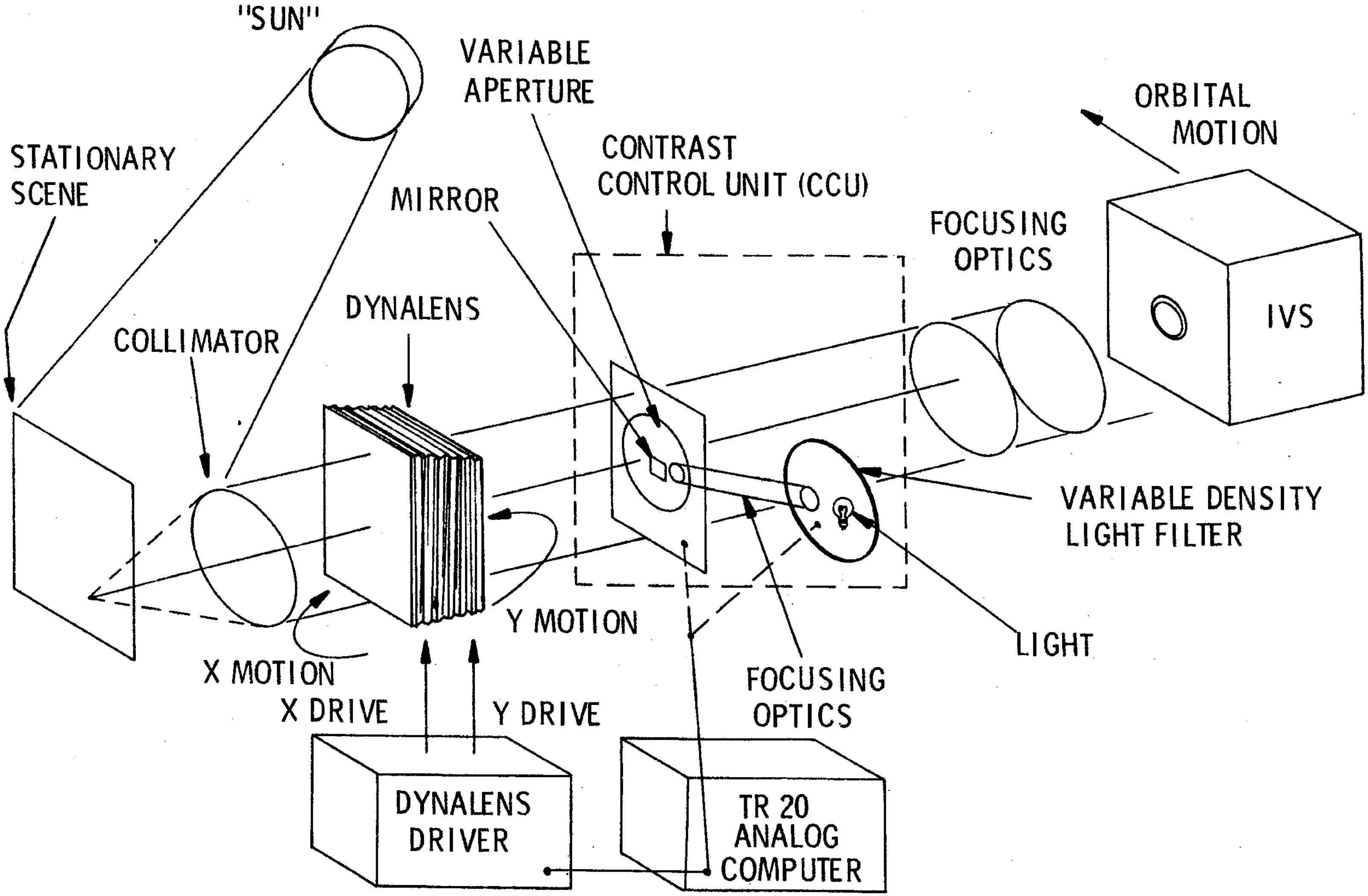
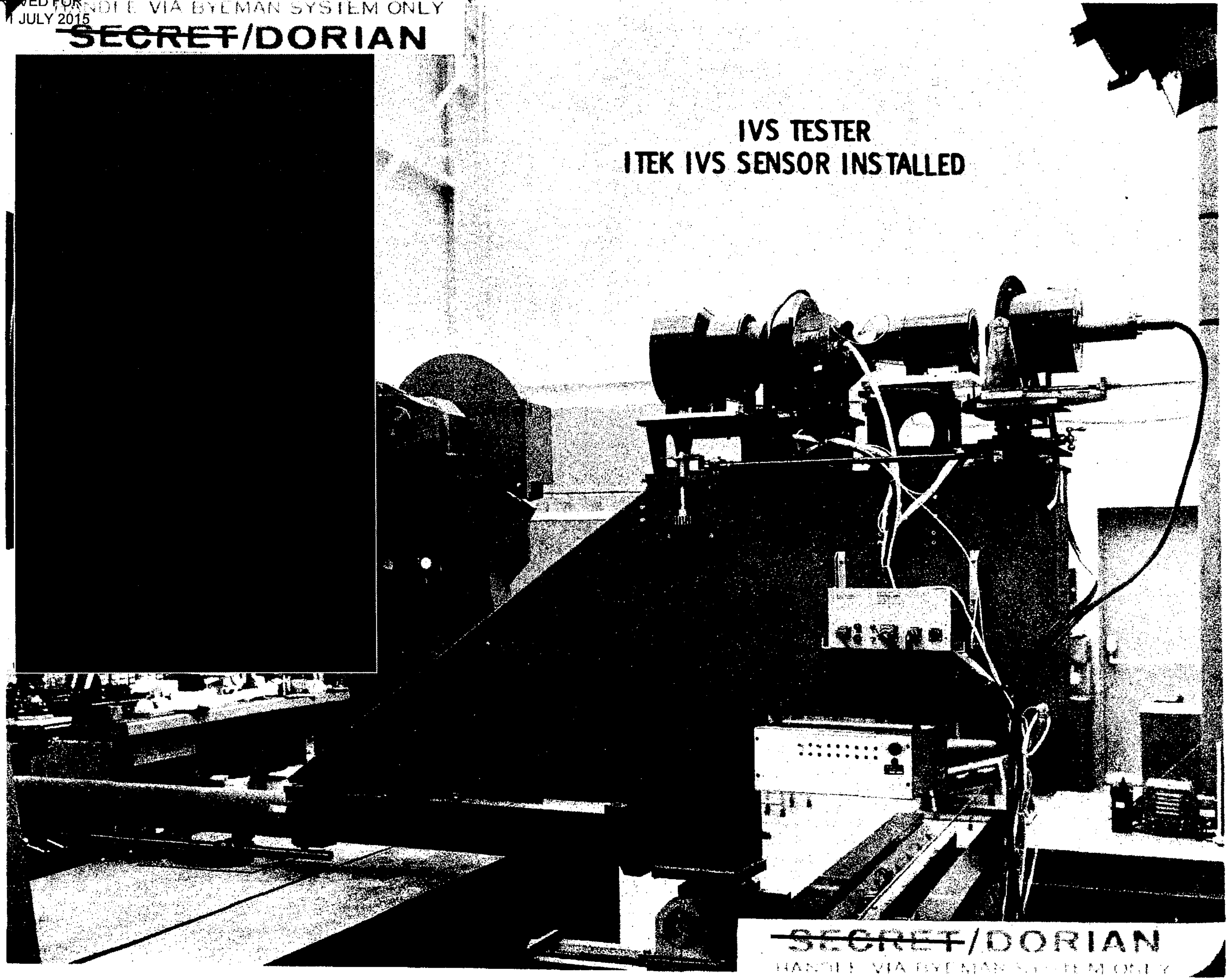

IVS TESTER
SUN
TARGET
ORBIT

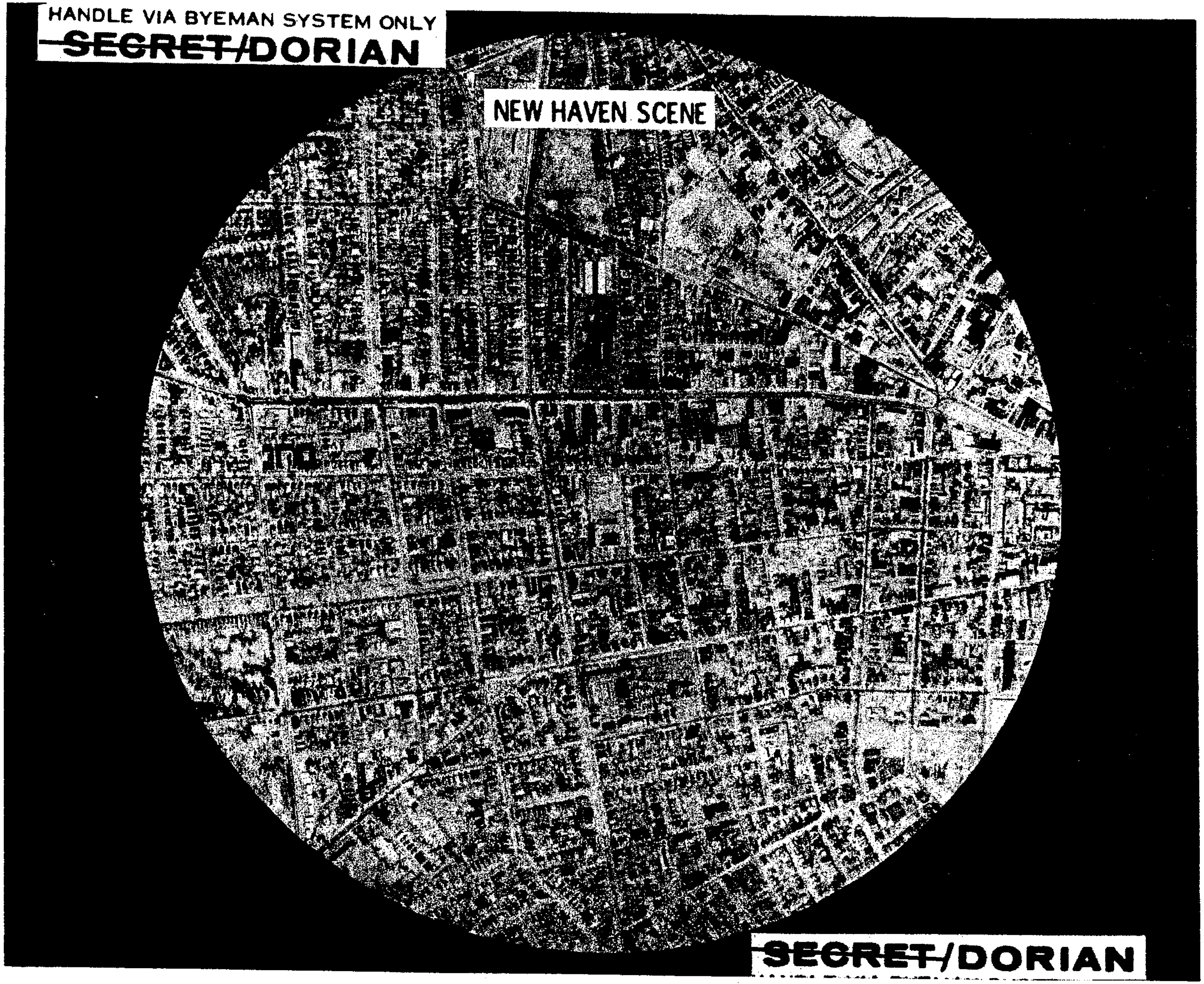
IMAGE VELOCITY SENSOR OPEN LOOP TESTER SCHEMATIC






[redacted]

HANDLE VIA BYEMAN SYSTEM ONLY
~~SECRET~~/DORIAN




~~SECRET~~/DORIAN


LANCASTER SCENE

OPEN LOOP TESTER

| PARAMETER | REQUIREMENT | DEGREE OF SIMULATION |
|---|---|---|
| SCENES | REPRESENTATIVE OF REAL WORLD | GOOD CONTRAST AND GEOMETRICAL SCALING<br>3D AND COLOR NOT INCLUDED IN PHASE I PROGRAM |
| OPTICS | SIMULATE CAMERA OPTICS INPUT TO IVS | GOOD SIMULATION OF F/NO. AND TELECENTRIC PROPERTIES<br>ADEQUATE RESOLUTION GEOMETRIC DISTORTIONS INTRODUCED BY LARGE FOV |
| TRACKING MIRROR DRIVE AND ORBITAL MOTIONS | SIMULATE IMAGE DYNAMICS CAUSED BY ORBIT AND TRACK | STRAIGHT TRACK EFFECTS NEGLIGIBLE<br>VIBRATION MINIMIZED |
| LIGHTING AND CONTRAST | SIMULATE SUN AND HAZE LIGHT | GOOD SIMULATION OF LEVELS AND MODULATION<br>SPECTRAL PROPERTIES NEED REFINING TO INCORPORATE NEW INFORMATION |

UNIT CONVERSION

| LOS RATE | IMAGE PLANE RATE | GROUND RATE |
| --- | --- | --- |

[redacted]

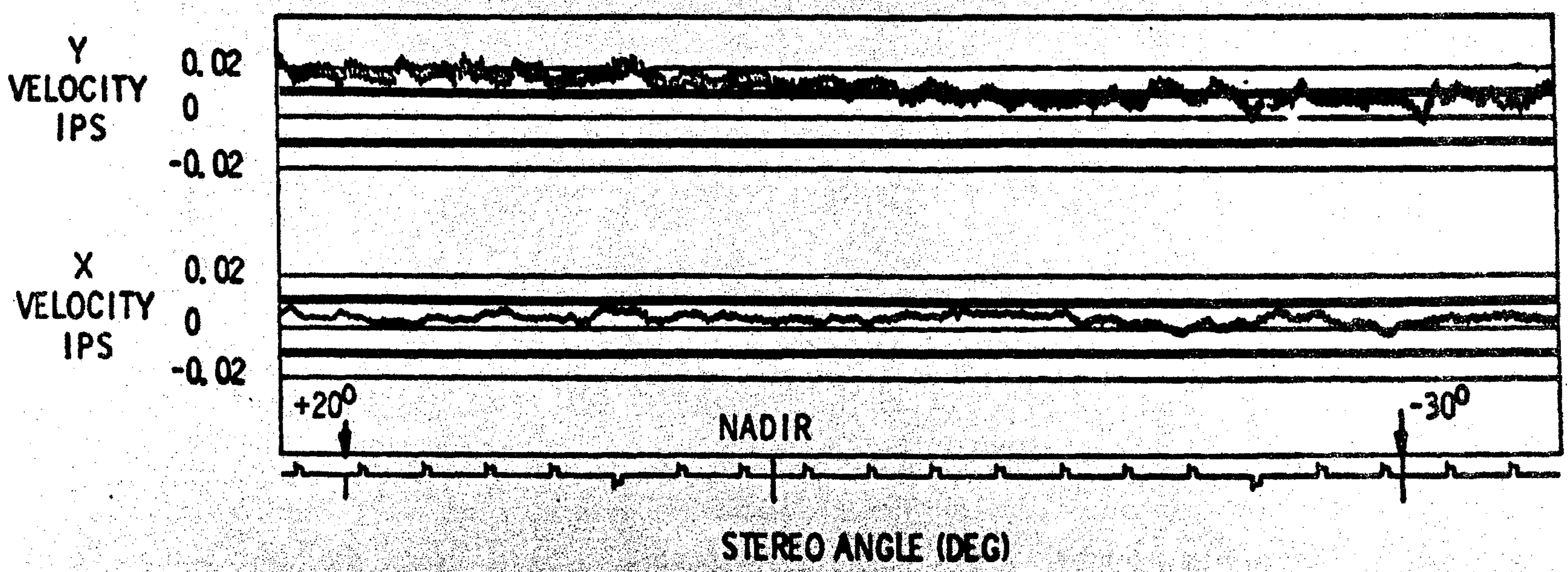
NOTE: NADIR TRACK ANGLE 80 N MI ALTITUDE

# IMAGE VELOCITY SENSOR - ITEK

## SCENE SENSITIVE BIAS

PROBLEM

- SCENE SENSITIVE BIAS - VARIATION IN IVS OUTPUT SIGNAL WITH SCENE CHARACTERISTICS AND ILLUMINATION LEVEL

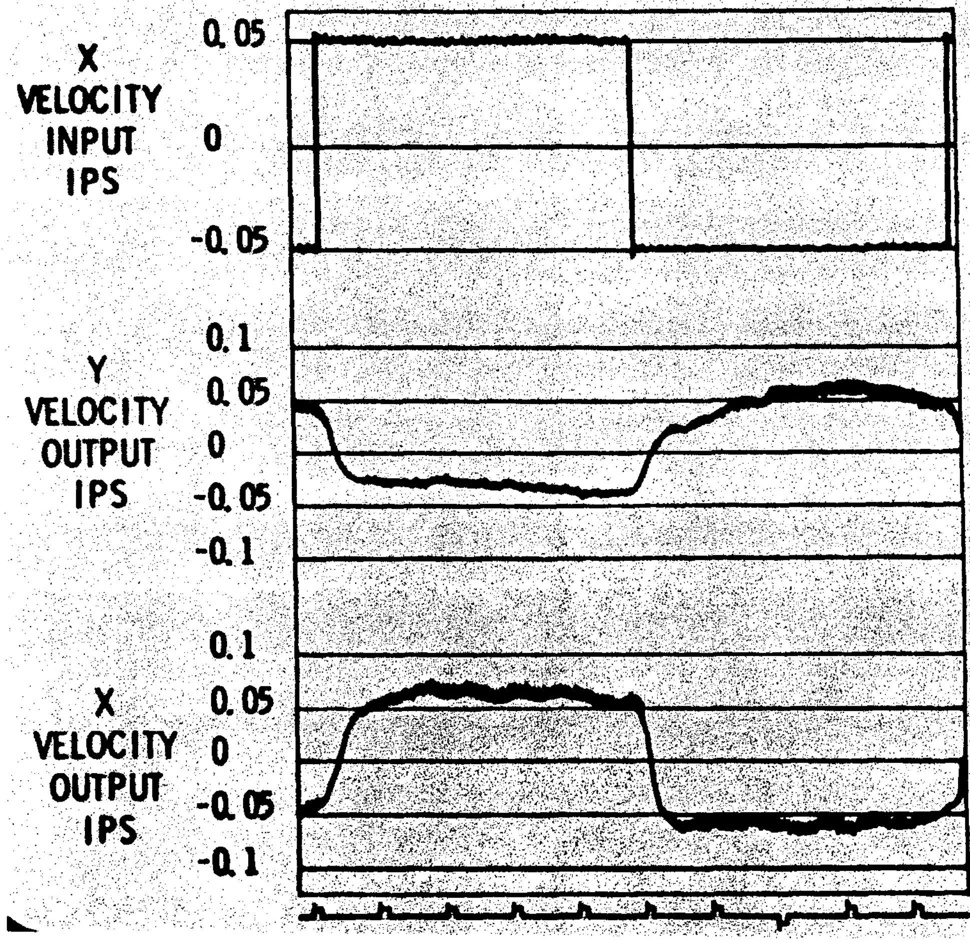



NOTE: INPUT VELOCITY = 0

## ITEK, AXES CROSS-COUPLING, LD SCENE - STATIC TEST AT NADIR, "C" SETTING (Y INPUT VELOCITY = ZERO)

**PROBLEM**

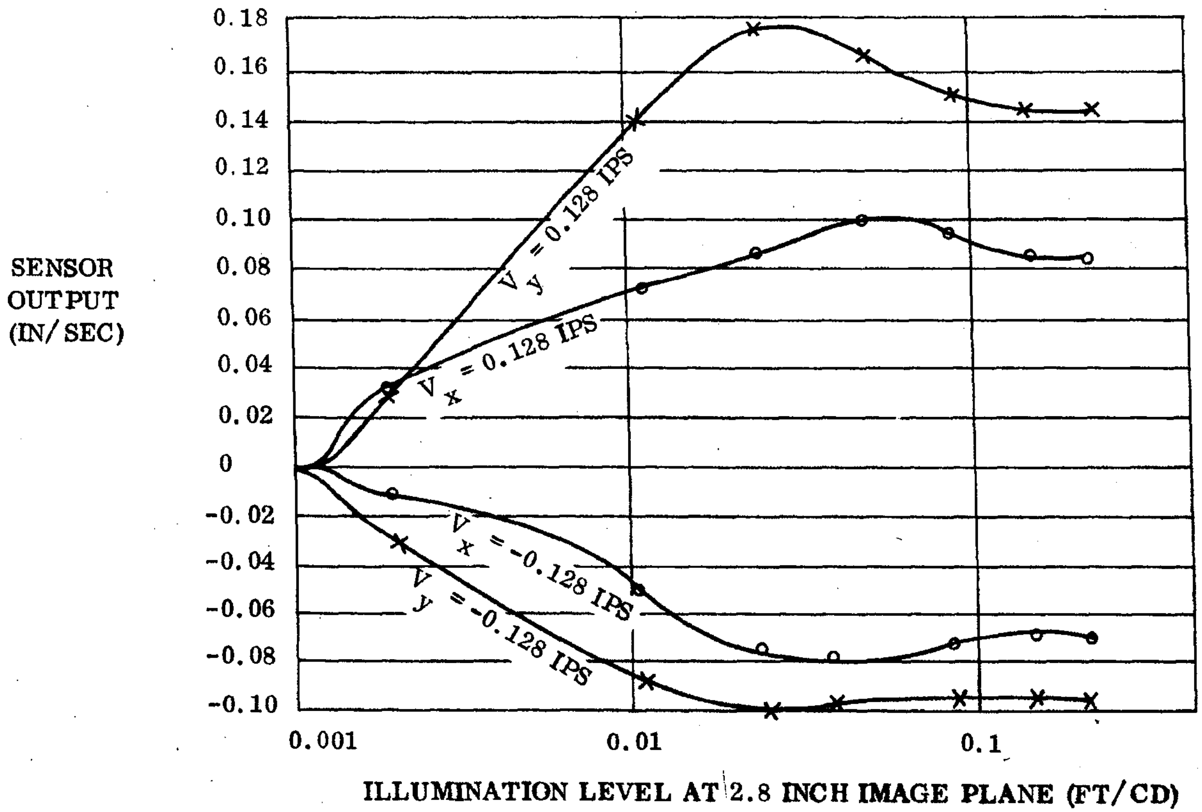
- CROSS-COUPLING - IMAGE MOTION IN ONE AXIS BEING SENSED IN THE ORTHOGONAL AXIS



# IMAGE VELOCITY SENSOR - ITEK

PROBLEM

- LINEARITY - VARIATION IN SENSOR GAIN WITH CHANGE IN ILLUMINATION

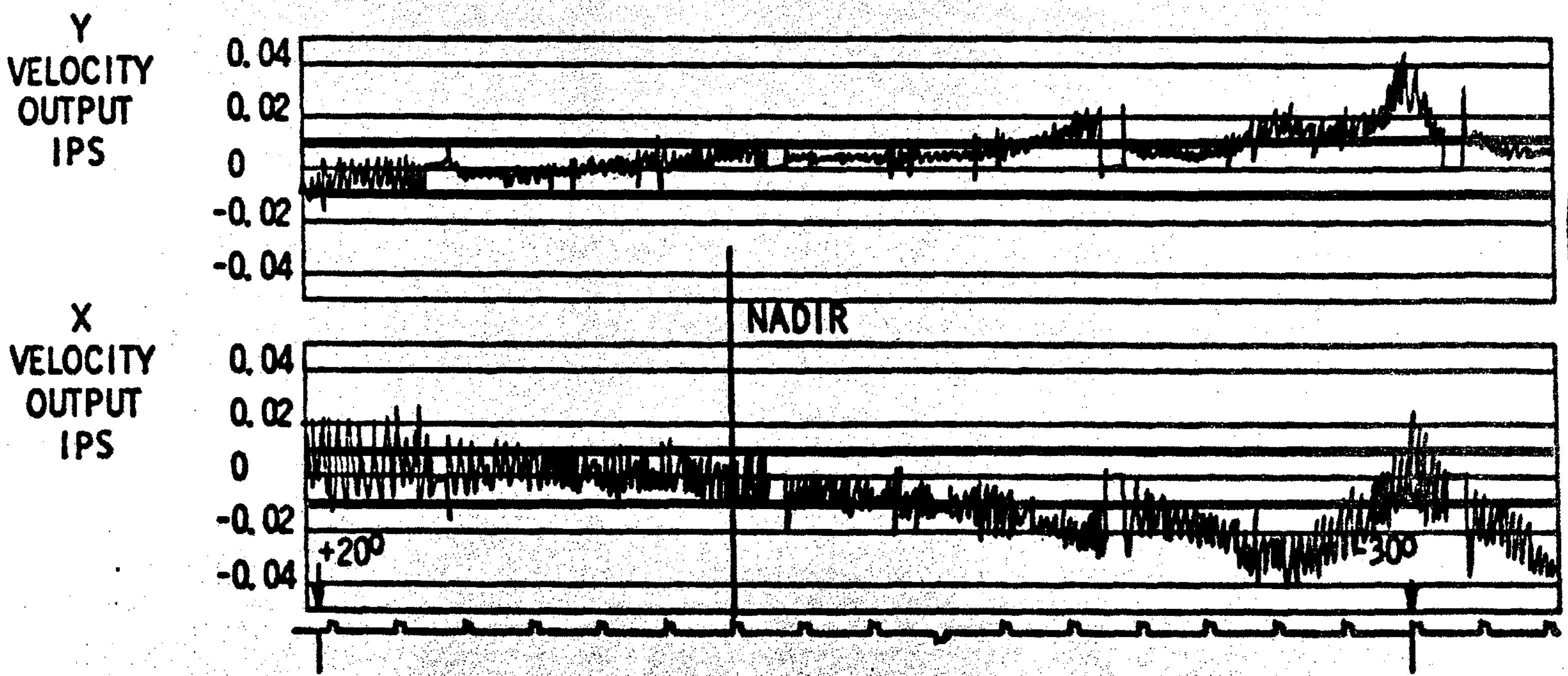


[redacted]

# DYNAMIC NULL ERROR

PROBLEM

- DYNAMIC NULL - IVS OUTPUT SIGNAL WHICH VARIES WITH ASPECT ANGLE

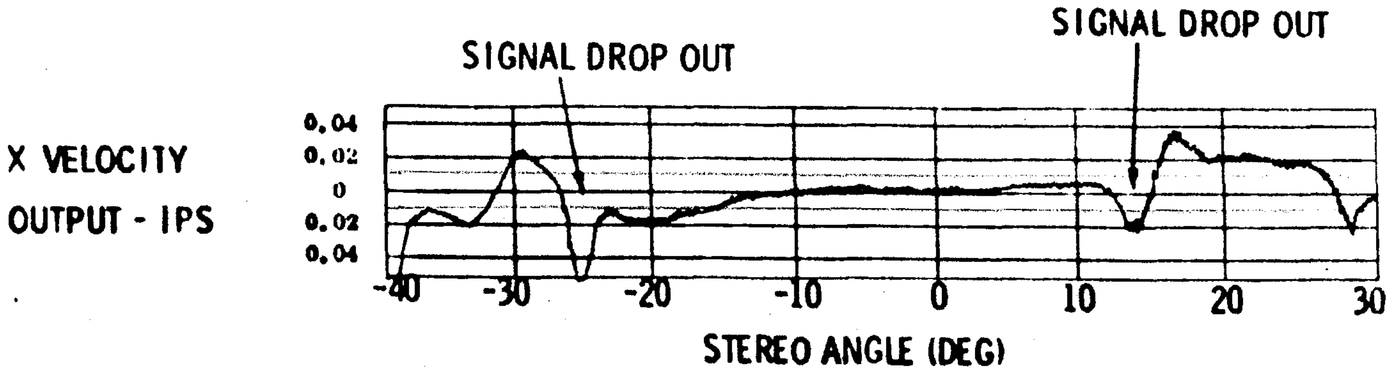



NOTE: INPUT VELOCITY = 0

## IMAGE VELOCITY SENSOR - HYCON
## DYNAMIC NULL AND SIGNAL DROP OUT ERRORS

PROBLEMS

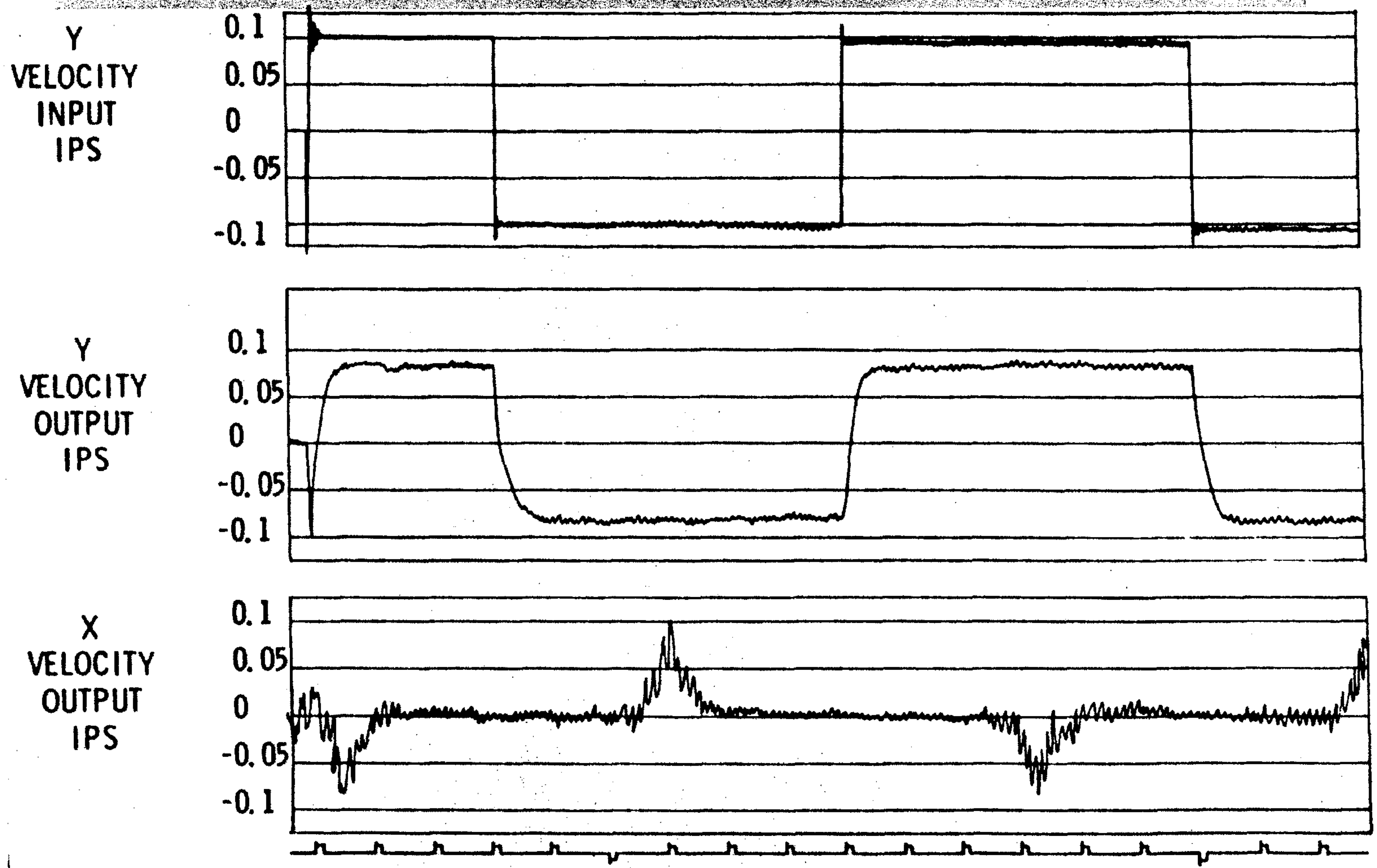
- DYNAMIC NULL - IVS OUTPUT SIGNAL WHICH VARIES WITH ASPECT ANGLE
- SIGNAL DROP-OUT - PERIODS WHERE SENSORS DO NOT CORRECTLY MEASURE IMAGE MOTION DUE TO INTERNAL SIGNAL LEVELS




NOTE: INPUT VELOCITY = 0

HYCON RESPONSE AT SIGNAL DROPOUT

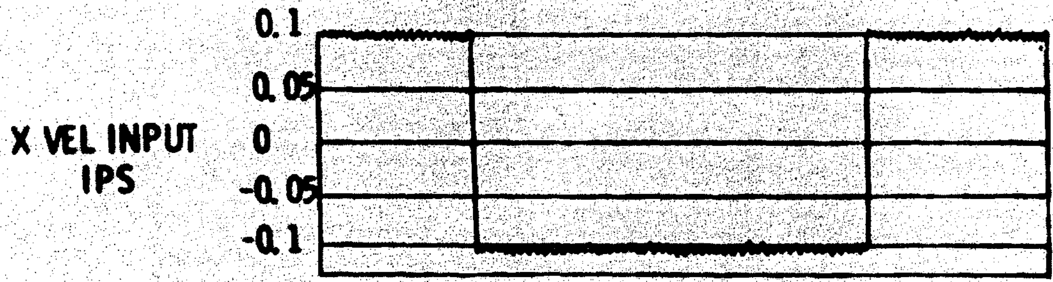
(STATIC TEST CONDUCTED AT ±20 DEGREES IN STEREO ABOUT THE SIGNAL DROPOUT POINT)

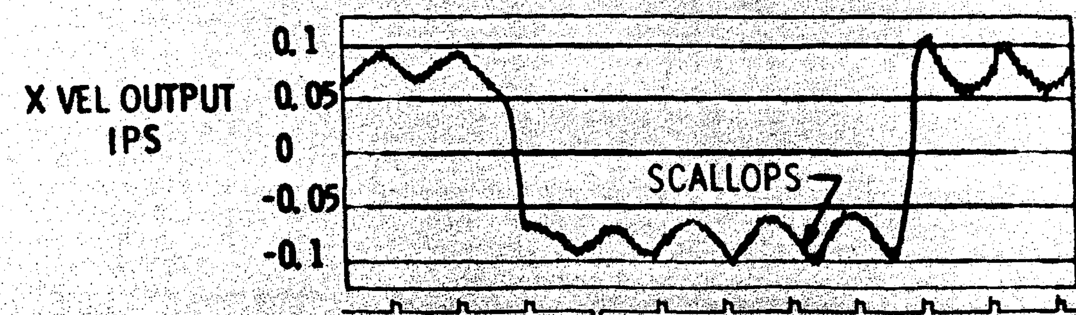


## HYCON SCALLOPING STATIC TEST AT NADIR

**PROBLEM**

- SCALLOPING
  - PERIODIC VARIATIONS IN OUTPUT SIGNAL AS A FUNCTION OF IMAGE VELOCITY




(0.045 FT CANDLES AVG (0.037 F-C FROM CCU)

## PHASE 1 - DEVELOPMENT MODEL PERFORMANCE - ILLUMINATION LEVEL VS SCENE CONTENT

WIENER SPECTRUM CONTENT
(FOOT LAMBERT$^2$
PER CPF AT 0.01 CPF)

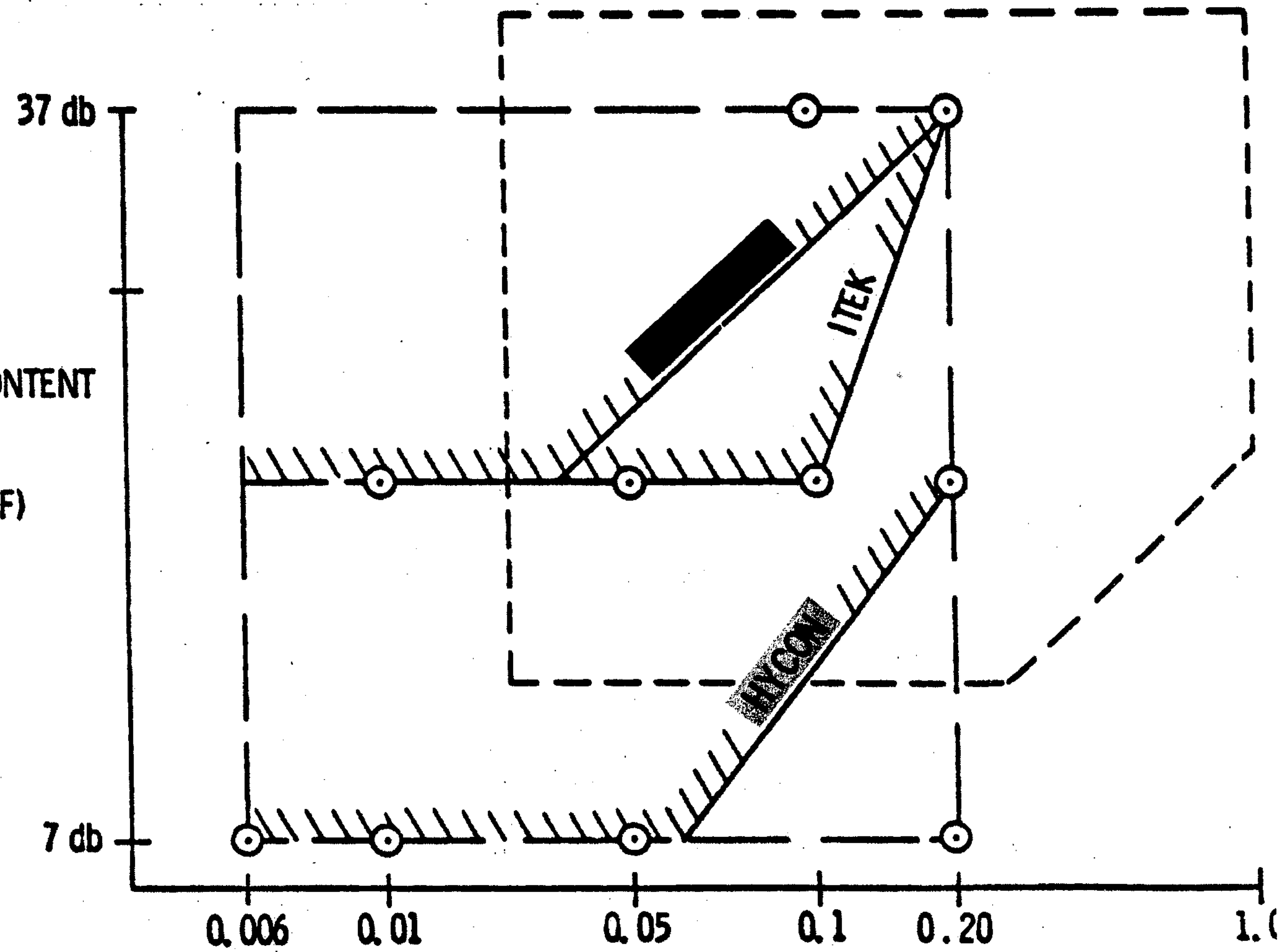



IMAGE PLANE AVERAGE LIGHT LEVEL (FT CD)

— — — PHASE I RQTS
- - - - ANTICIPATED REVISION
\\\\\\\\ OPERATING CAPABILITY
⊙ TEST POINT

## IVS CRITICAL PROBLEM SUMMARY FROM BB EVALUATION TESTS

| PROBLEM | IMPACT | ITEK | GOODYEAR | HYCON |
|---|---|---|---|---|
| DYNAMIC NULL | IMAGE SMEAR | MEETS ○ | EXCESSIVE INDICATED VELOCITY ERRORS ▽ | EXCESSIVE INDICATED VELOCITY ERRORS ▽ |
| SIGNAL LOSS DURING TRACK | IVS DEAD PERIODS | MEETS ○ | RECYCLE □ | SIGNAL DROPOUT ▽ |
| ILLUMINATION SENSITIVITY AND CONTRAST | LIMITS NUMBER | FAILED ▽ | FAILED ▽ | MEETS ○ |
| CROSS COUPLING | TRACK LOOP INSTABILITY INCREASED SETTLING TIME | SEVERE FOR SOME SCENES ▽ | MEETS ○ | MEETS ○ |
| LINEARITY | SLOWER LOOP RESPONSE IMAGE SMEAR | NONLINEAR WITH LIGHT CHANGES ▽ | MEETS ○ | MEETS ○ |
| SCENE SENSITIVE BIAS | IMAGE SMEAR | BIAS EXCEEDS WHOLE ERROR ALLOTMENT ▽ | MEETS ○ | MEETS ○ |
| SCALLOPING | INCREASE SETTLING TIME | MEETS ○ | MEETS ○ | MODULATED VELOCITY INDICATION □ |

MAY 1968 STATUS

# VENDOR CONTRACT HISTORY

| | |
|---|---|
| • ITEK - USAF CONTRACT | DECEMBER 65 |
| • GOODYEAR - USAF CONTRACT | JULY 66 |
| • USAF TRANSFERRED THE IVS FROM GFE TO GE RESPONSIBILITY | SEPTEMBER 67 |
| • ITEK - GOODYEAR - HYCON ON CONTRACT TO GE | OCTOBER 67 |
| • BREADBOARD DELIVERIES - ITEK AND GOODYEAR | 29 FEBRUARY 68 |
| - HYCON | 11 MARCH 68 |
| • ENGINEERING PROTOTYPE DELIVERIES - GOODYEAR AND HYCON | 1 OCTOBER 68 |
| • BREADBOARD DELIVERY - ITEK | 15 NOVEMBER 68 |

# SUBCONTRACTOR PRESENTATIONS

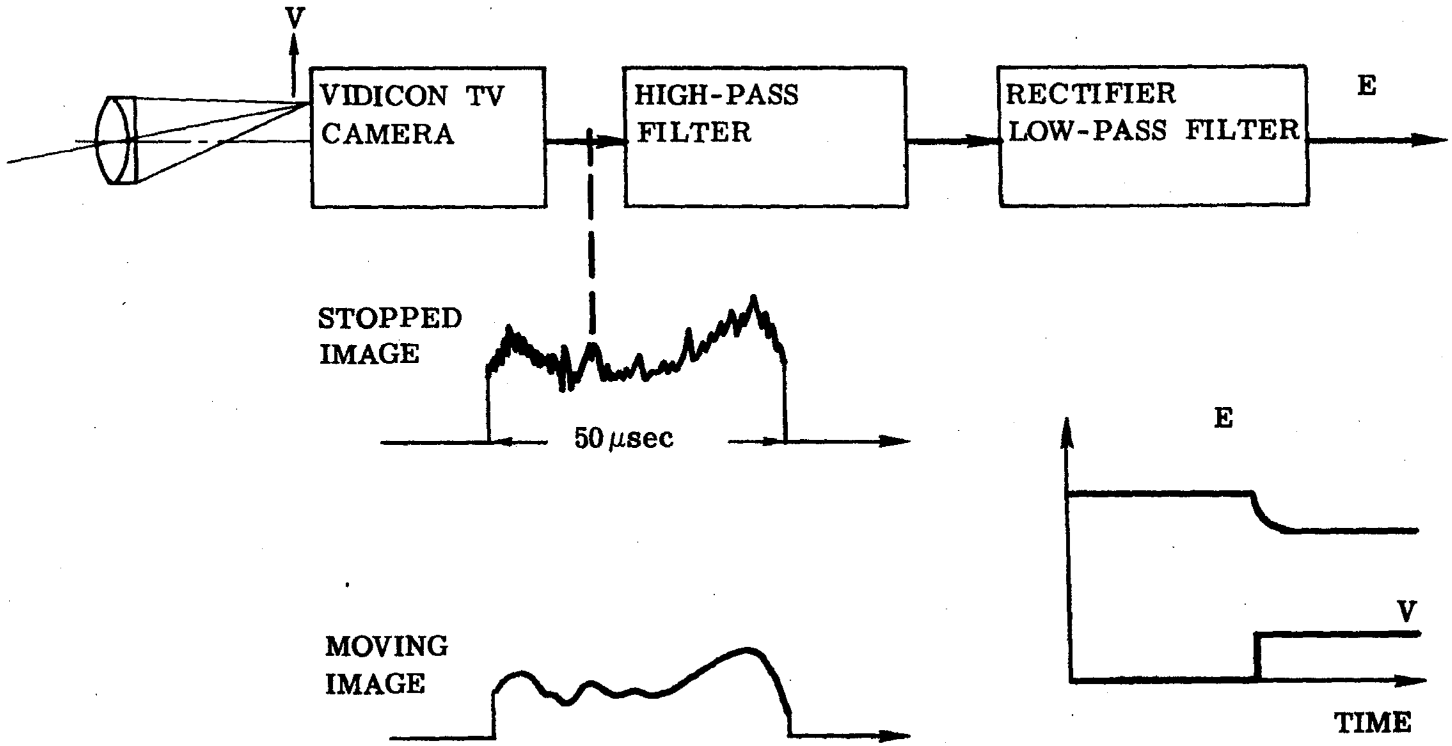
- ITEK
- GOODYEAR
- HYCON

# ITEK IMAGE VELOCITY SENSOR PROGRAM

# RELATED EXPERIENCE

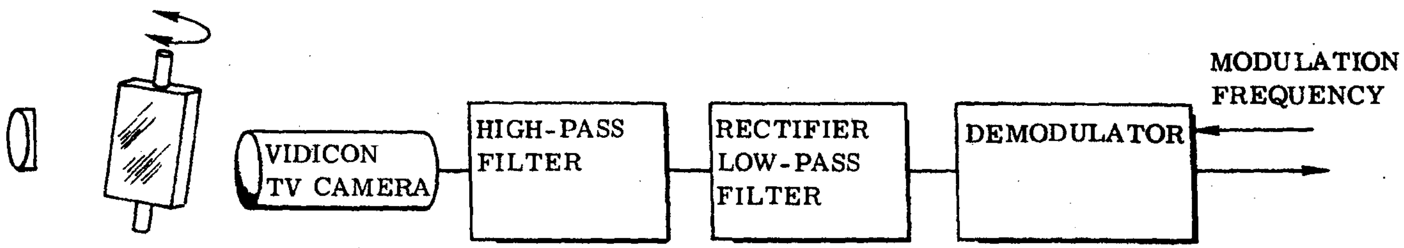
- V/h SENSOR
- INTENSIFIERS FOR NIGHT VISION
- IMAGE VELOCITY SENSORS, RETICLE TYPE
- ELECTRONIC IMAGE MOTION STABILIZATION (EIMS)

# RUDIMENTARY SENSOR

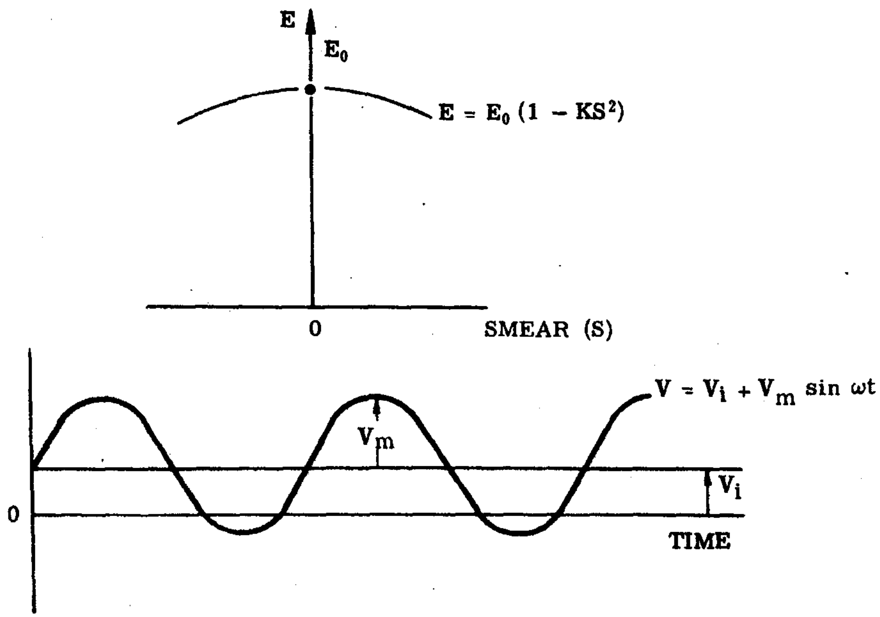


# SENSOR WITH MODULATION

CYLIC IMAGE MOTION ADDED WITH MODULATOR



# VARIATION OF RECTIFIED HIGH FREQUENCY VIDEO SIGNAL WITH SMEAR




$$S \simeq \left[V_i t_i + \frac{2V_m}{\omega} \sin \omega\left(t - \frac{t_i}{2}\right) \sin\left(\frac{\omega t_i}{2}\right)\right]$$

# RECTIFIED VIDEO VOLTAGE

$$E = E_0\left[1 - k\,V_i^2 t_i^2 - \frac{2kV_m^2}{\omega^2}\sin^2\left(\frac{\omega t_i}{2}\right)\right]$$ $E_{DC}$ AVERAGE VALUE

$$+ E_0\left[-\frac{4kV_m}{\omega}\,t_i\,\sin\left(\frac{\omega t_i}{2}\right)\right] V_i \sin\omega\left(t - \frac{t_i}{2}\right)$$ $E_f$ FUNDAMENTAL

$$+ E_0\left(+\frac{2kV_m^2}{\omega^2}\sin^2\frac{\omega t_i}{2}\right)\cos 2\,\omega\left(t - \frac{t_i}{2}\right)$$ $E_{2f}$ SECOND HARMONIC

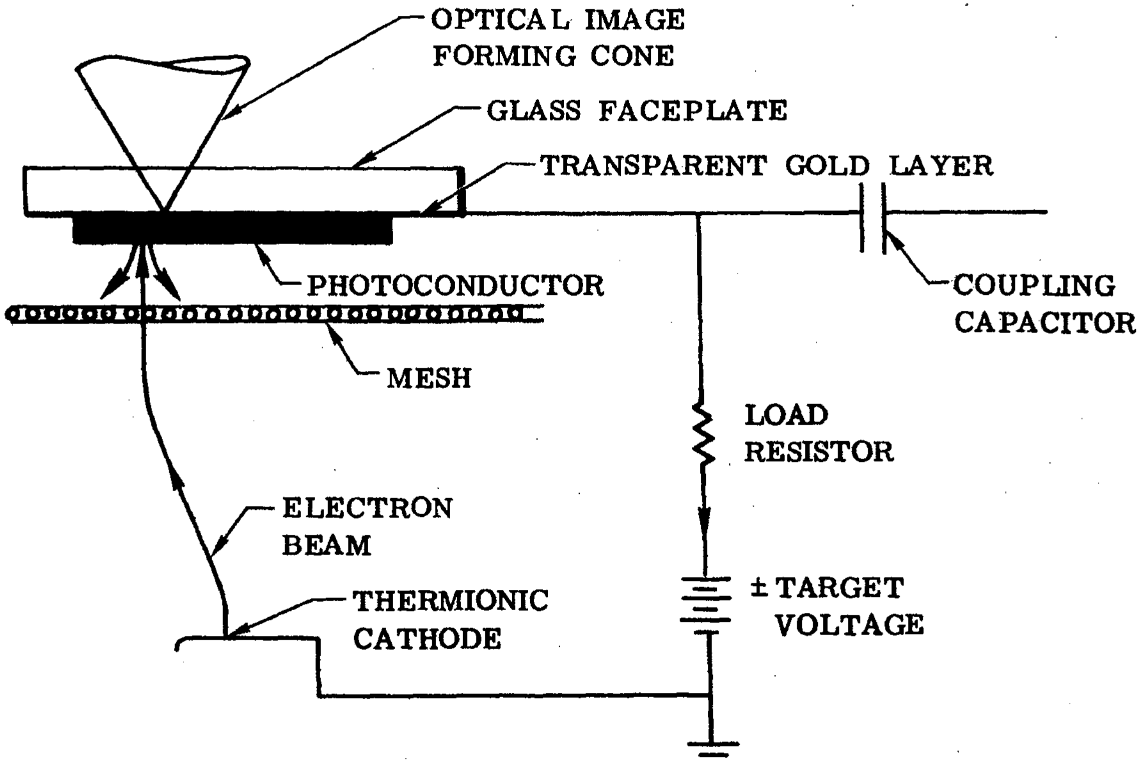
NORMALIZATION SIGNALS (AGC)

(1) $$\frac{E_f}{E_{2f}} = \frac{4V_i}{V_m}\,\frac{\left(\frac{\omega t_i}{2}\right)}{\sin\frac{\omega t_i}{2}}$$

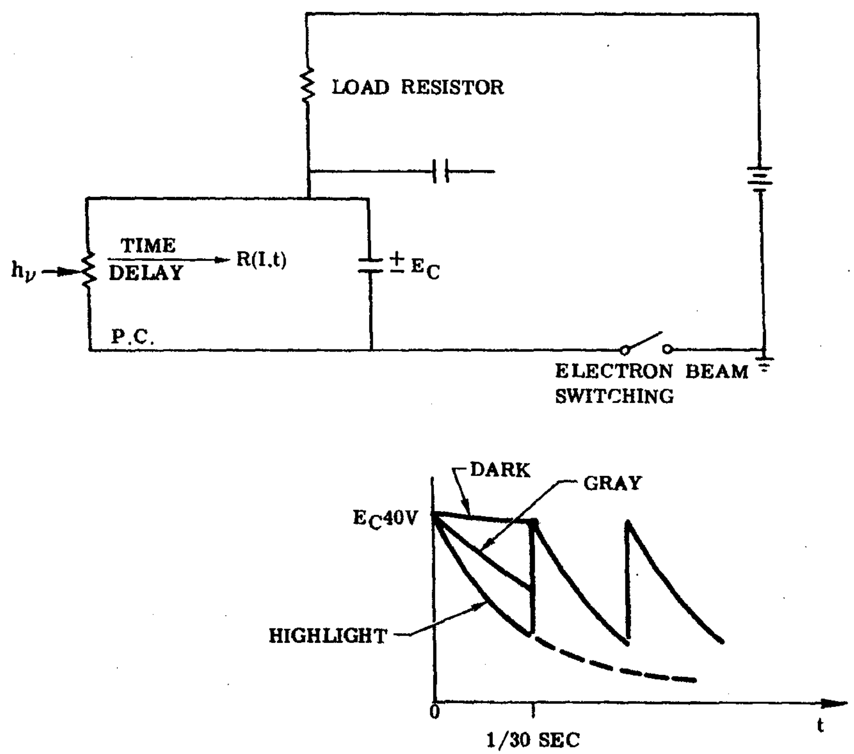
$$\phi_{lag} = \frac{\omega t_i}{2}$$

(2) $$\frac{E_f}{E_0} \simeq \frac{4kV_m t_i}{\omega}\sin\left(\frac{\omega t_i}{2}\right) V_i$$

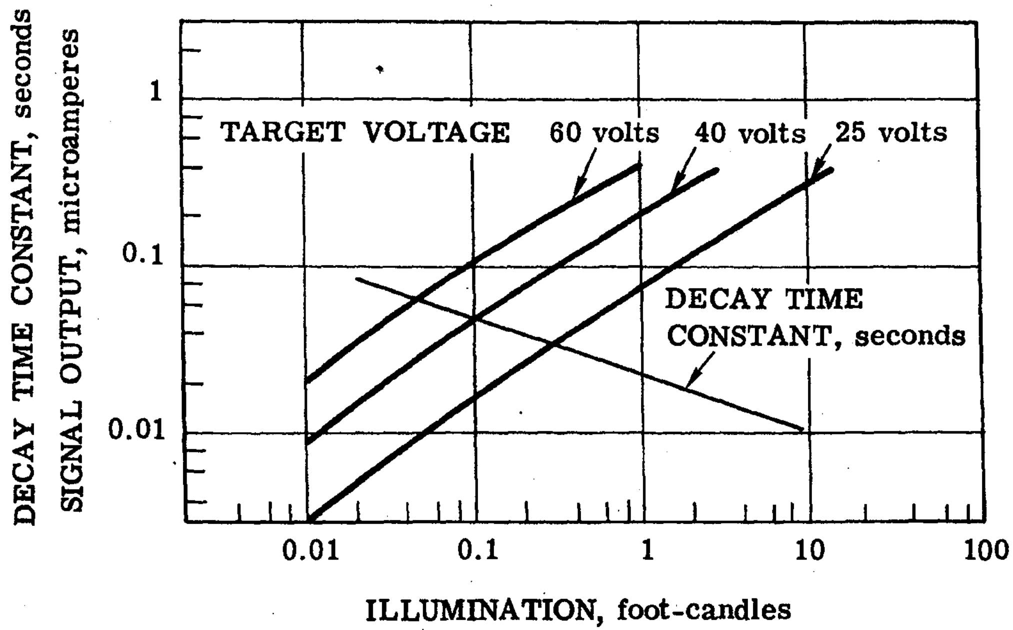
# VIDICON PRINCIPLE



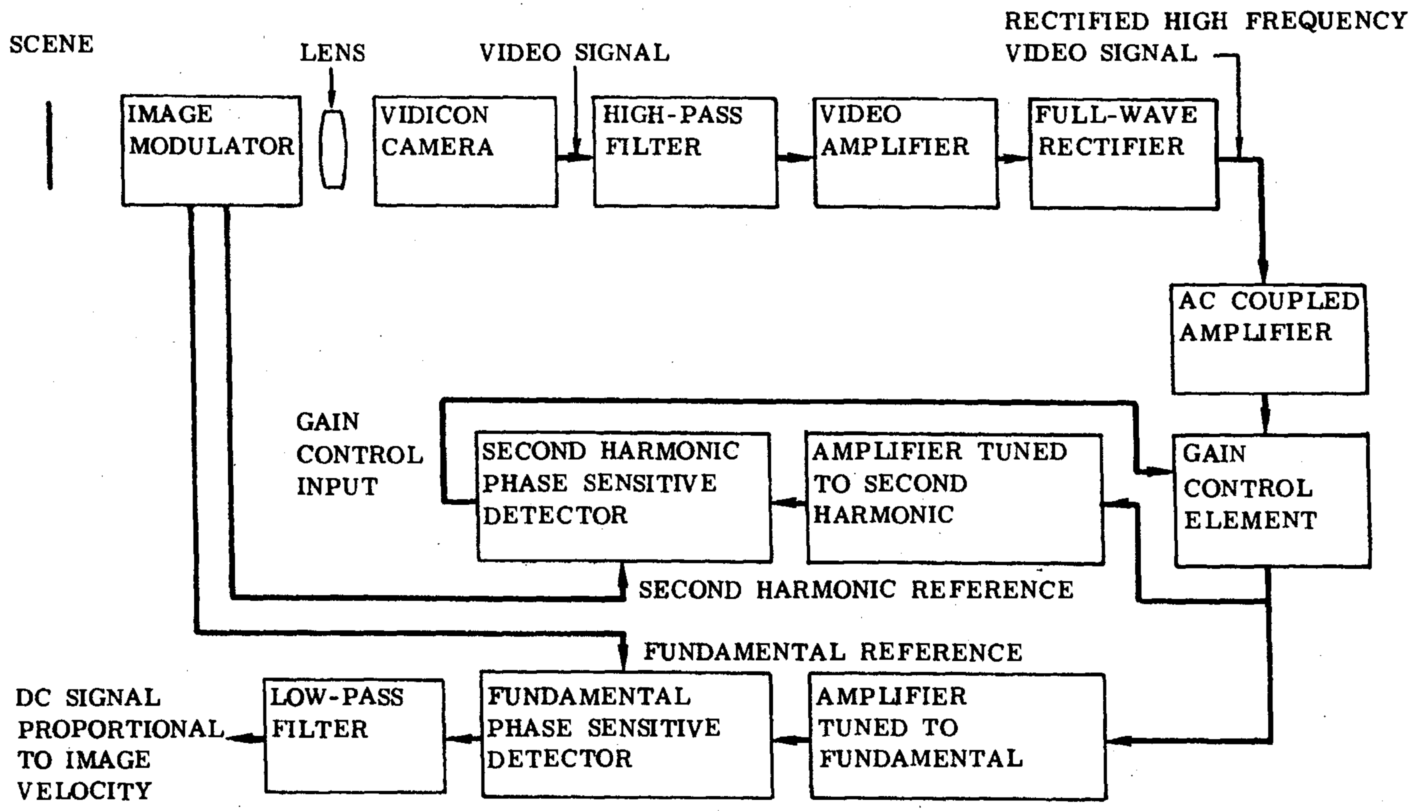
# EQUIVALENT CIRCUIT OF VIDICON



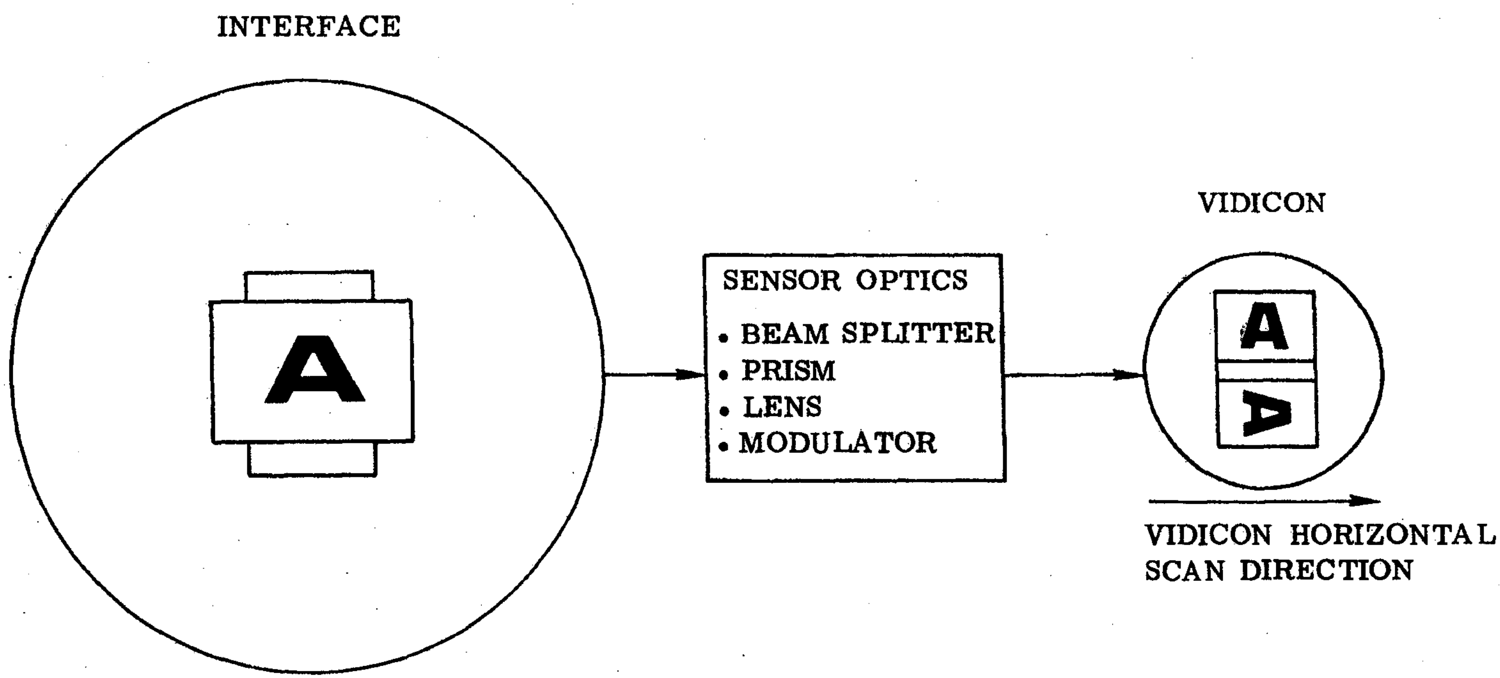
# VIDICON CHARACTERISTICS



# SINGLE-AXIS SENSOR



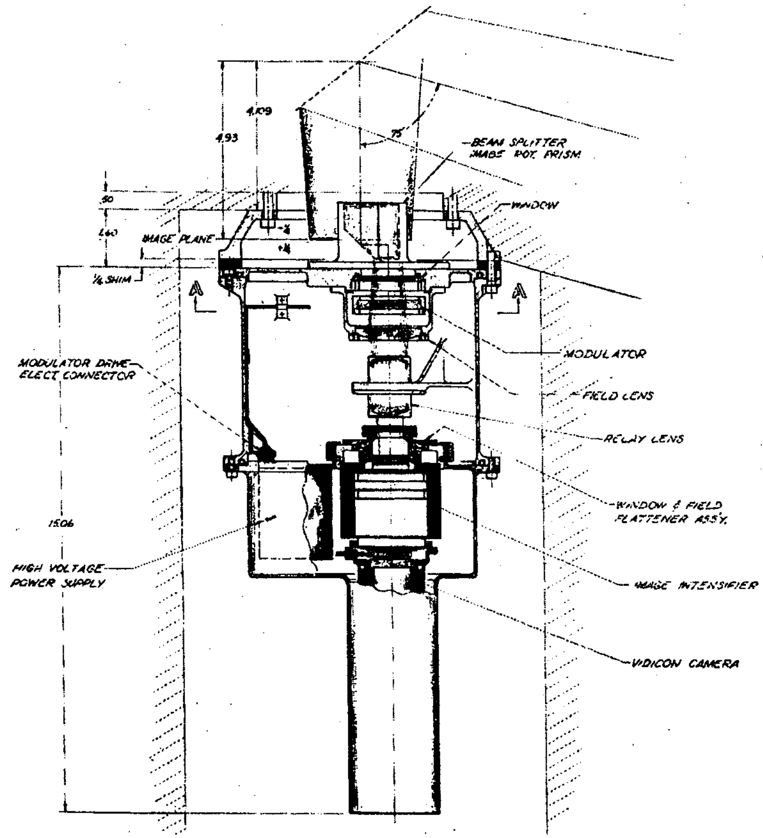
# TWO-AXIS SENSOR APPROACH



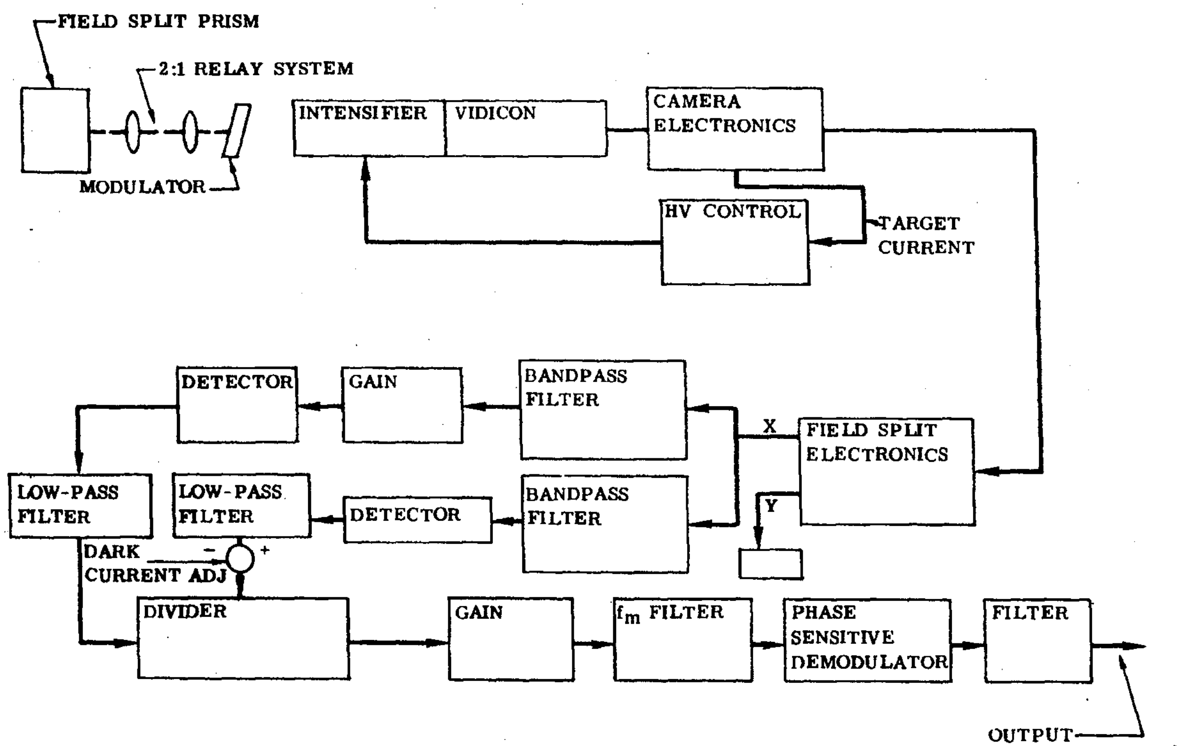
## MAJOR DESIGN CHANGES

| ENGINEERING TEST MODEL DECEMBER 1967 | ENGINEERING PROTOTYPE EVALUATION MODEL NOVEMBER 1968 | REASON |
|---|---|---|
| VIDICON | IMAGE INTENSIFIER—VIDICON | IMPROVED LINEARITY |
| LINE SPLIT | FIELD SPLIT | IMPROVED NULL ACCURACY |
| COMMERCIAL LENS | ITEK—DESIGNED LENS | BETTER IMAGE QUALITY |
| OFFSET PATCH | CENTRAL PATCHES | ELIMINATES NEED FOR ROLL SERVO |

# SENSOR HEAD LAYOUT



# TWO-AXIS SENSOR BLOCK DIAGRAM



# SPECIFICATION REQUIREMENTS PERFORMANCE

| | | | NOW | ESTIMATED AT CDR |
|---|---|---|---|---|
| (G) | DYNAMIC RANGE | 0 TO 0.3 ips | MEET | MEET |
| [Y] | GAIN FACTOR | 16.67 volts/ips | DON'T MEET | MEET |
| (G) | LINEARITY<br>LARGE SIGNAL REGION<br>SMALL SIGNAL REGION | <br>0.75 TO 1.25<br>0.9 TO 1.1 | MEET | MEET |
| (G) | SATURATION | 5 volts/0.3 ips | MEET | MEET |
| [Y] | NOISE AND BIAS (NULL REGION) | 0.010 ips (2Σ) | DON'T MEET | MEET |
| ▽R | FREQUENCY RESPONSE | FIRST ORDER LAG OVER OUTPUT RANGE 0.001 TO 0.25 ips; BREAK FREQUENCY ≥ 1 hz | AMPLITUDE MEETS SPEC; PHASE LAG MEETS SPEC TO 1 hz, EXCEEDS SPEC BY 25 AT 3 hz; ANOMALOUS RESPONSE NEAR fm/2 | SAME |
| (G) | RECOVER TIME AFTER SATURATION | SATURATION ≥ 2 sec<br>TIME ≤ 0.5 sec<br>SATURATION ≥ 2 sec<br>TIME ≤ 0.1 sec | MEET | MEET |
| (G) | SUBTHRESHOLD IRRADIANCE SIGNAL | FLAT INPUT OF $4 \times 10^{-8}$ wt/cm$^2$ per 10 nm (Δλ) OVER RANGE 400 TO 900 nm | CAN MEET | MEET |
| ▽R | RELIABILITY | MTBF ≥ 10,000 hours | DON'T MEET | 7,500 hours |
| (G) | WARMUP TIME | 2 minutes | MEET | MEET |

# SPECIFICATION REQUIREMENTS INTERFACE

| | | | NOW | ESTIMATED AT CDR |
|---|---|---|---|---|
| | INPUT POWER | | | |
| [Y] | AVERAGE | <26 watts | PERFORMANCE | MEET |
| | PEAK | <50 watts | BREADBOARD | |
| | WEIGHT | | | |
| [Y] | HEAD | ≤14 pounds | PERFORMANCE | 10.7 pounds |
| | TOTAL | ≤23 pounds | BREADBOARD | 22.7 pounds |
| | SPACE ENVELOPE | | | |
| [Y] | HEAD | PER DRAWING 711-03013 | PERFORMANCE | MEET |
| | ELECTRONICS BOX | 6 · 9 · 7 inches | BREADBOARD | |
| | CG OF HEAD | | | |
| (G) | DISTANCE FROM CENTERLINE NORMAL TO MOUNTING PLANE | WITHIN 0.25 inches | MEET | MEET |
| | DISTANCE FROM INPUT IMAGE PLANE | ≤7.25 inches | | |
| [Y] | THERMAL DISSIPATION OF HEAD | MINIMUM POSSIBLE — DESIGN GOAL ≤ 3 watts | PERFORMANCE BREADBOARD | <6 watts |
| | GENERATED DISTURBANCES | ≤3.0 in.-oz (ANY AXIS) | MEET | MEET |
| (G) | VIBRATION (DURING EXPOSURE) | ≤0.01 pound AXIAL FORCE (ANY AXIS) | | |
| | VIBRATION (DURING SLEW) | 2· ABOVE | | |
| | RESONANCE | ≥55 hz | | |
| | ACOUSTIC NOISE | PER 3.2.12 of DR1100B | | |

# PROBLEM AREAS

- LINEARITY
- NULL ACCURACY
- GAIN FACTOR
- CROSS-COUPLING
- FREQUENCY RESPONSE
- CLOUD COVER

LINEARITY

# LINEARITY

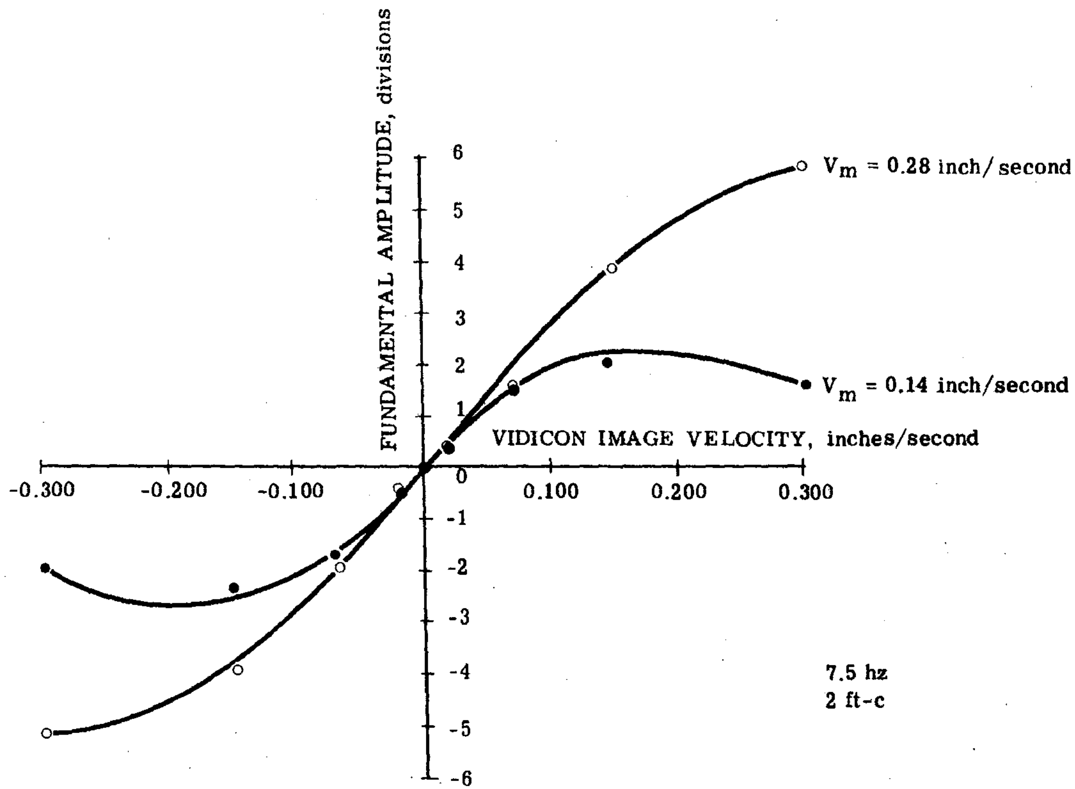
IMPACT

- NONLINEARITY COMPLICATES SERVO STABILIZATION

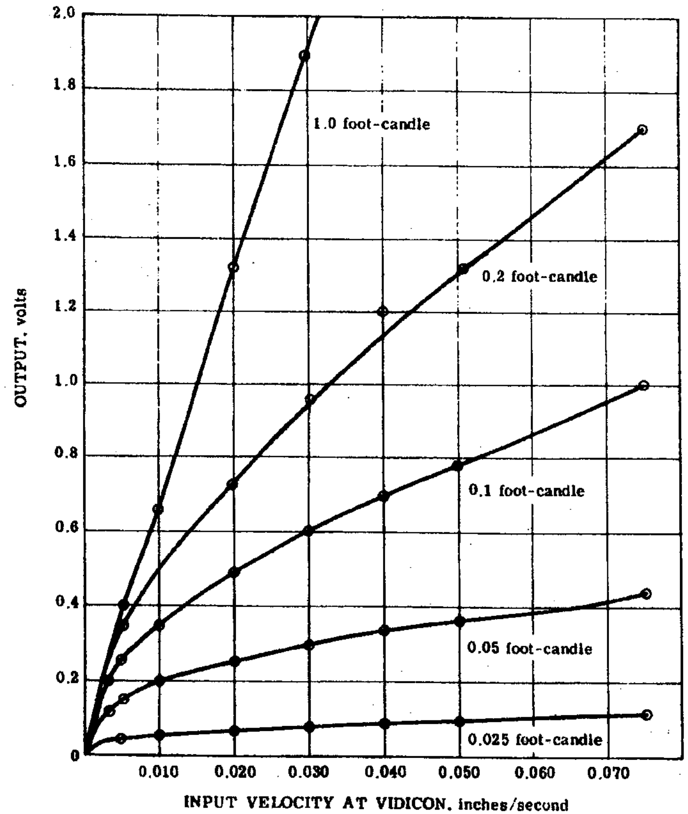
SOLUTION

- IMAGE INTENSIFIER
- ADEQUATE MODULATION VELOCITY

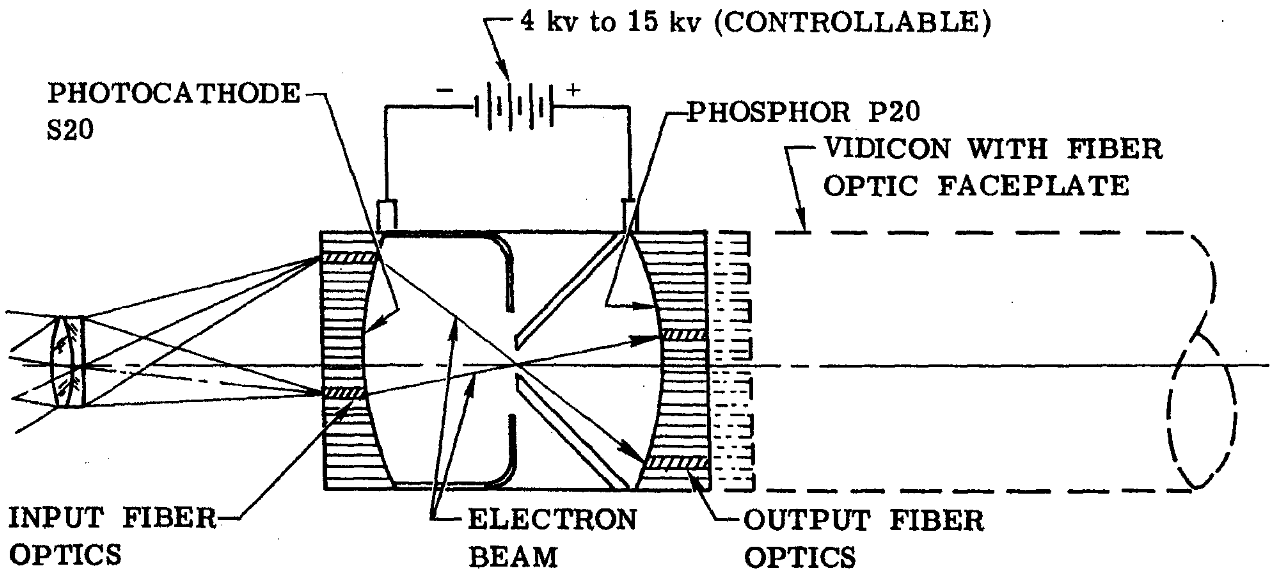
# DYNAMIC RANGE AS A FUNCTION OF MODULATION AMPLITUDE



# LINEARITY AS A FUNCTION OF VIDICON ILLUMINATION



# IMAGE INTENSIFIER



# NULL ACCURACY

# NULL ACCURACY

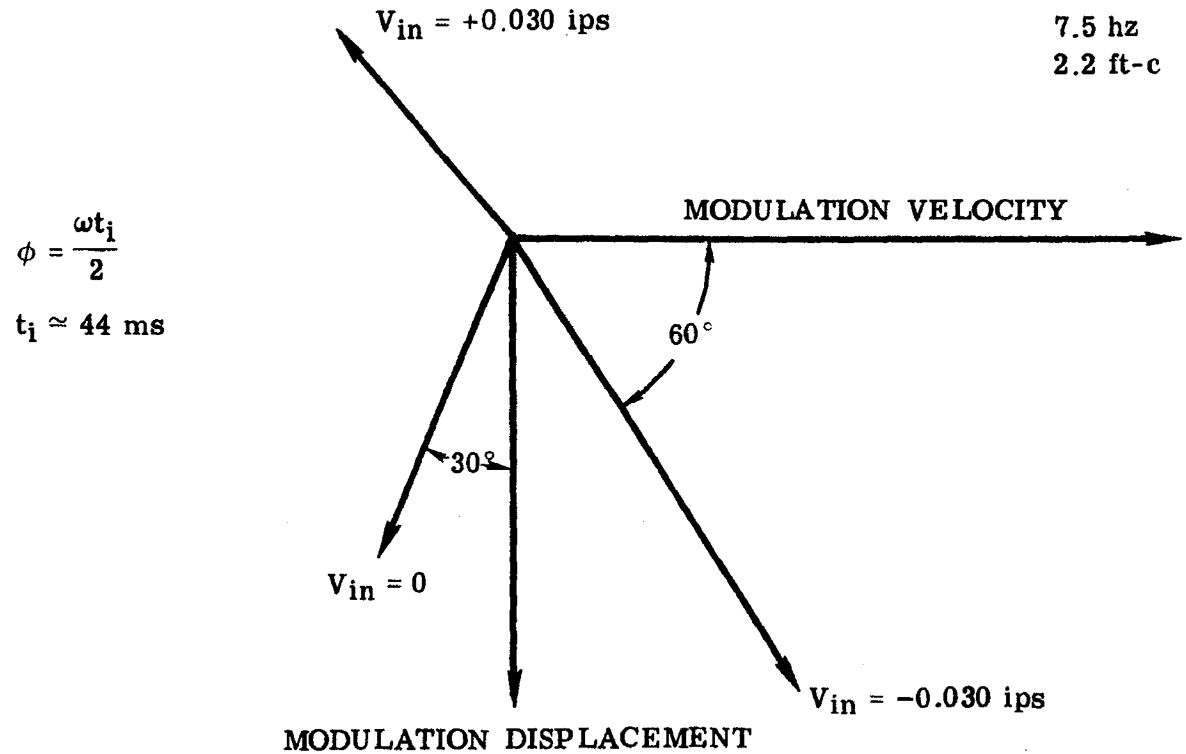
IMPACT

- OUTPUT SIGNAL WITH NO VELOCITY PRESENT RESULTS IN IMPERFECT TRACKING

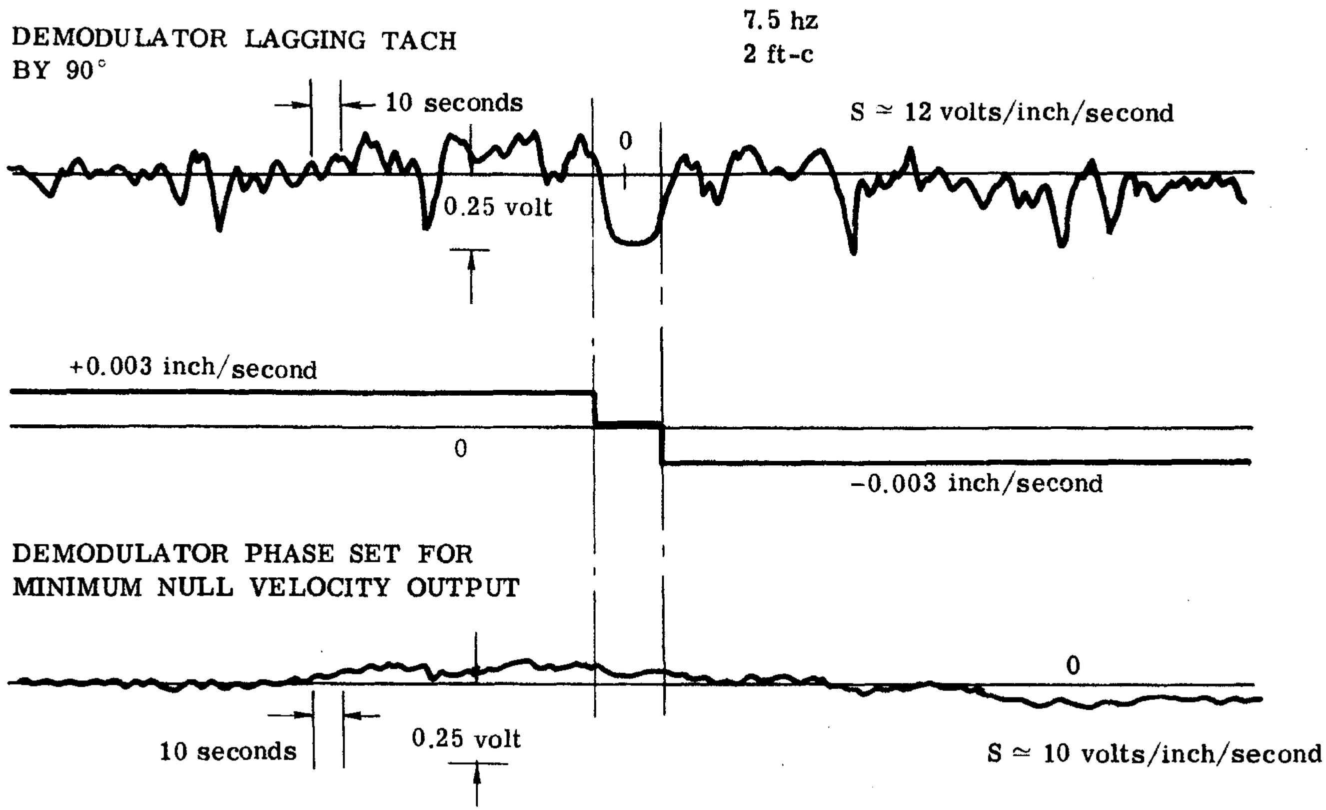
SOLUTION

- PROPER PHASE OF DEMODULATOR ELIMINATES NULL SIGNAL BUT NOT SENSITIVITY

# NULL AND VELOCITY PHASE RELATIONSHIPS



# DEMODULATED OUTPUT



GAIN FACTOR

# GAIN FACTOR

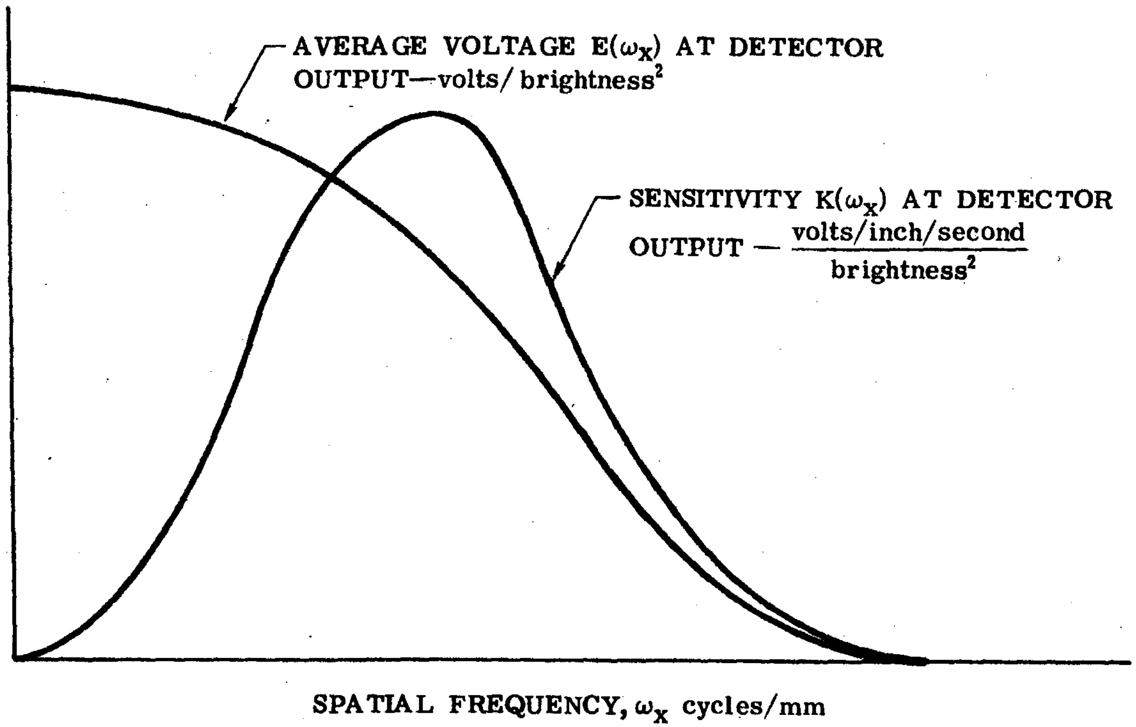
IMPACT

- GAIN FACTOR MUST BE CONSTANT FOR SERVO STABILITY

POTENTIAL SOLUTION

- VIDEO AGC

# AGC PRINCIPLE




SHAPING FILTER WILL MAKE $E(\omega_x)$ PROPORTIONAL TO $K(\omega_x)$

# AGC

AVERAGE RECTIFIED VIDEO


FUNDAMENTAL FOR CONSTANT SCENE VELOCITY

AVERAGE VALUE AND FUNDAMENTAL SIGNAL VARY WITH SCENE IN THE SAME MANNER

# CROSS-COUPLING

# CROSS-COUPLING

IMPACT

- A SCENE WITH PREDOMINANT DIAGONAL LINES PRODUCES X OUTPUT FOR Y VELOCITY WHICH AFFECTS SERVO RESPONSE AND/OR STABILITY

SOLUTION

- OPTIMIZE FIELD OF VIEW

# FREQUENCY RESPONSE

# FREQUENCY RESPONSE

IMPACT

- EXCESSIVE PHASE LAG AFFECTS SERVO RESPONSE
- IMAGE VIBRATION NEAR fm/2 COULD PRODUCE FALSE OUTPUT

SOLUTION

- INCREASE TV CAMERA FRAME RATE AND MODULATION FREQUENCY

CLOUD COVER

# CLOUD COVER

2:1 RELAY

- SENSOR FORMAT — 635 × 870 ft
- FORMAT PROBABLY COMPLETELY OBSCURED OR COMPLETELY FREE

LARGER FIELD OF VIEW

- VIDEO SIGNAL MAY BE USED TO SENSE CLOUD PRESENCE

# SUMMARY

- VIDICON ILLUMINATION > 1 ft-c FOR LINEAR RESPONSE
  INTENSIFIED VIDICON WITH ILLUMINATION CONTROL
- PEAK MODULATION VELOCITY > MAXIMUM IMAGE VELOCITY AT VIDICON
- DEMODULATOR PHASE SET FOR MINIMUM BIAS VARIATIONS
- VIDEO BANDWIDTH SET FOR OPTIMUM SENSITIVITY/BIAS RATIO
- AGC USING SHAPED RECTIFIED VIDEO AND/OR SECOND HARMONIC

# ADVANTAGES OF ITEK SENSOR

- EXTREMELY LOW ILLUMINATION AND CONTRAST OPERATION
- NO DYNAMIC NULL PROBLEM
- SENSES VELOCITY AT CENTER OF FORMAT
- UTILIZES REDUCTION OF VIDEO POWER EVERYWHERE IN SENSOR FORMAT
- SPACE-QUALIFIED VIDICON CAMERA
- MIL-SPEC IMAGE INTENSIFIER

# GOODYEAR IMAGE VELOCITY SENSOR PROGRAM

# GOODYEAR PRESENTATION TOPICS

- RELATED EXPERIENCE
- THEORY OF OPERATION
- COMPLIANCE FORECAST VS REQUIREMENTS
- IDENTIFIED PROBLEMS AND SOLUTIONS
- GROWTH
- SUMMARY

# RELATED EXPERIENCE

# RELATED CONTRACTS (CORRELATION)

## MISSILE GUIDANCE

- △ ATRAN RESEARCH & DEVELOPMENT
- △ MODEL M ATRAN DEVELOPMENT
- △ AN/DPQ-4 DEVELOPMENT
- ● TRITON GUIDANCE RESEARCH & DEVELOPMENT
- △ AN/DPQ-4 PRODUCTION
- ● REGULUS II GUIDANCE DEVELOPMENT
- △ PINPOINT GUIDANCE RESEARCH & DEVELOPMENT
- △ MIDCOURSE GUIDANCE STUDY
- △ ICBM GUIDANCE RESEARCH & DEVELOPMENT
- △ TERMINAL GUIDANCE STUDY
- △ GLOBAL RANGE MISSILE GUIDANCE STUDY
- △ TERMINAL POSITION LOCATION SYSTEM STUDY
- △ HITTING MISSILE GUIDANCE STUDY
- △ OPTAG GUIDANCE DEVELOPMENT

## CAMERA CONTROLS

- △ V/H SENSOR DEVELOPMENT
- △ V/H NIGHT SENSOR DEVELOPMENT
- △ AUTOMATIC EXPOSURE CONTROL DEVELOPMENT
- △ FREM SENSOR DEVELOPMENT

FUNDED BY
- △ AIR FORCE
- □ ARMY
- ● NAVY

## AIRCRAFT NAVIGATION

- △ ATRAN BOMBING EQUIPMENT DEVELOPMENT
- △ CHECKPOINT SYSTEM DEVELOPMENT
- △ PARADROP NAVIGATION DEVELOPMENT
- △ REPEATABLE FLIGHT LINE DEVELOPMENT

## WEAPON POINTING

- □ TANK GUN CONTROL DEVELOPMENT
- □ HELICOPTER OPTICAL TRACKER DEVELOPMENT

## IMAGE PROCESSING

- △ CORRELATION DATA CONVERSION
- △ CORRELATION FOR TARGET RECOGNITION
- □ MINE DETECTION TECHNIQUES
- □ AUTOMATIC CHANGE DETECTOR
- ● REFERENCE DATA EVALUATION
- △ LONG TERM CHANGE DETECTOR
- △ MULTIPLE IMAGE INTRODUCTION

## IVS PROGRAMS

- FEASIBILITY PROGRAM - AF 04(695)-914
  4 OCT 1965

- DEFINITION PROGRAM - AF 18(600)-2967
  1 JULY 1966

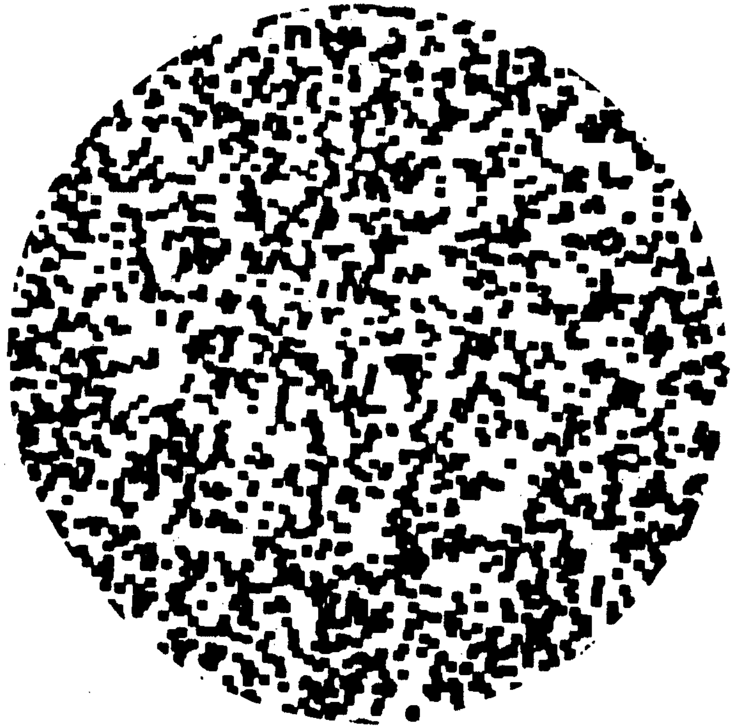
- EVALUATION PHASE OF DEFINITION PROGRAM - AF 18(600)-2967 MOD NO. 2
  2 MAY 1967

- PROTOTYPE EVALUATION PROGRAM - GE PO 029B25006
  8 SEPT 1967

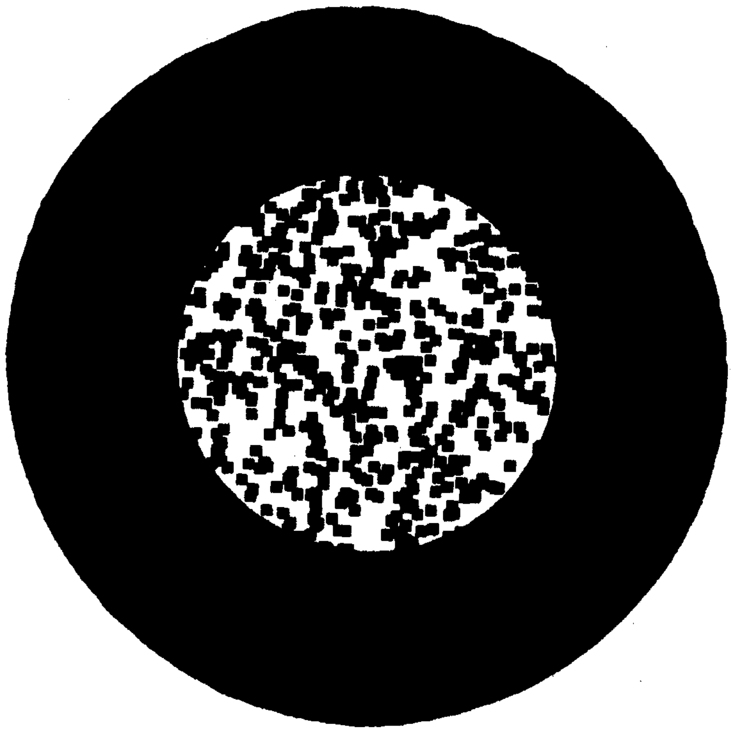
# THEORY OF OPERATION

# THEORY OF OPERATION

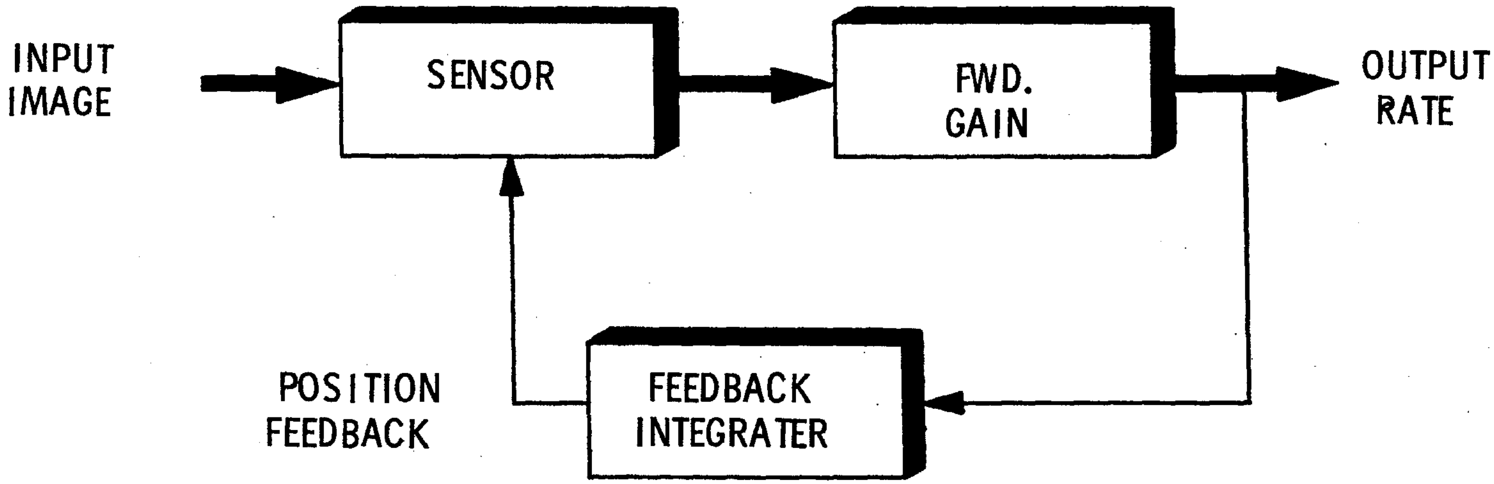
- AREA CORRELATION PRINCIPLE
- IVS CONCEPT
- CORRELATRON OPERATION
- GENERATION OF ERROR SIGNAL
- CORRELATRON FEATURES



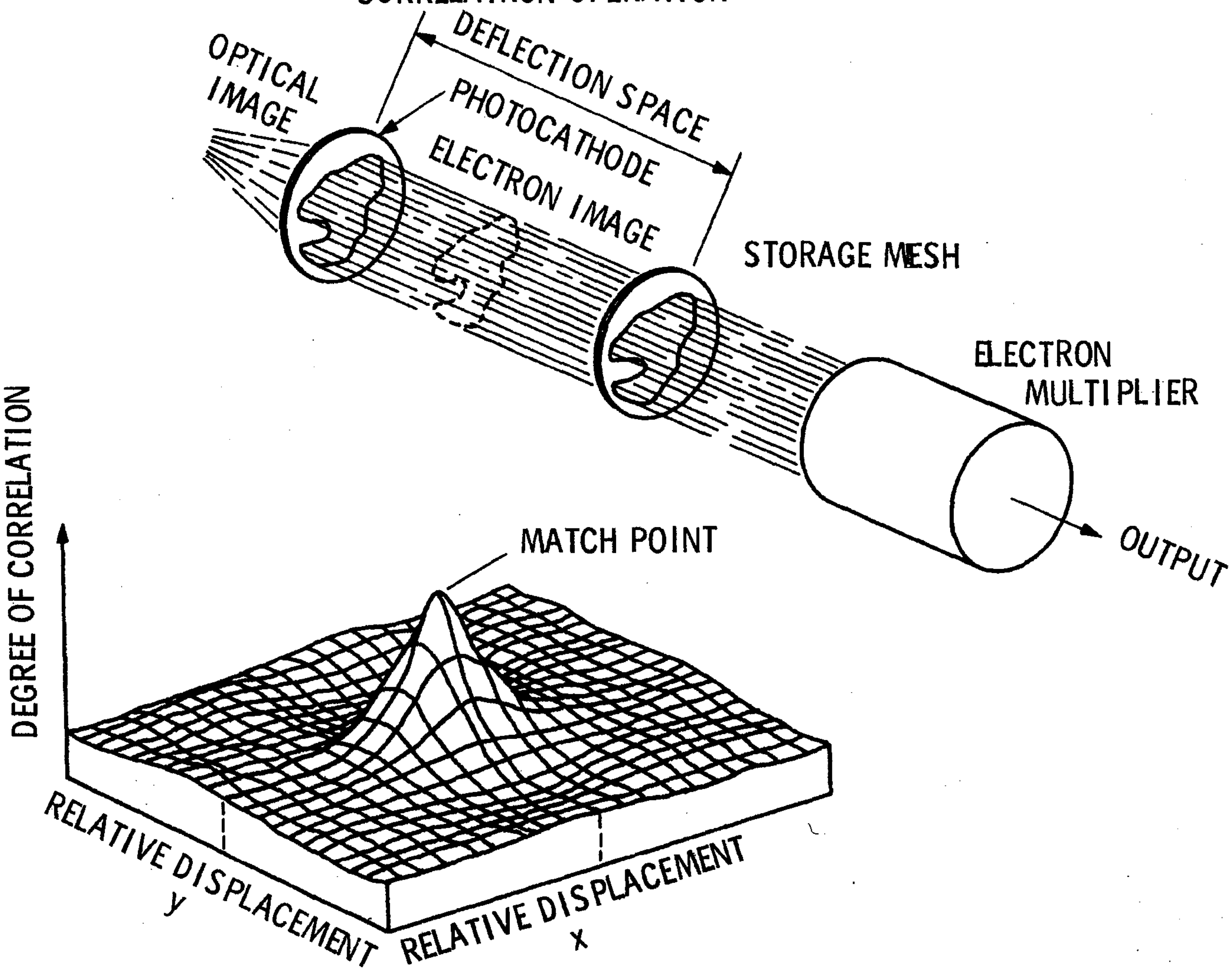
STORED



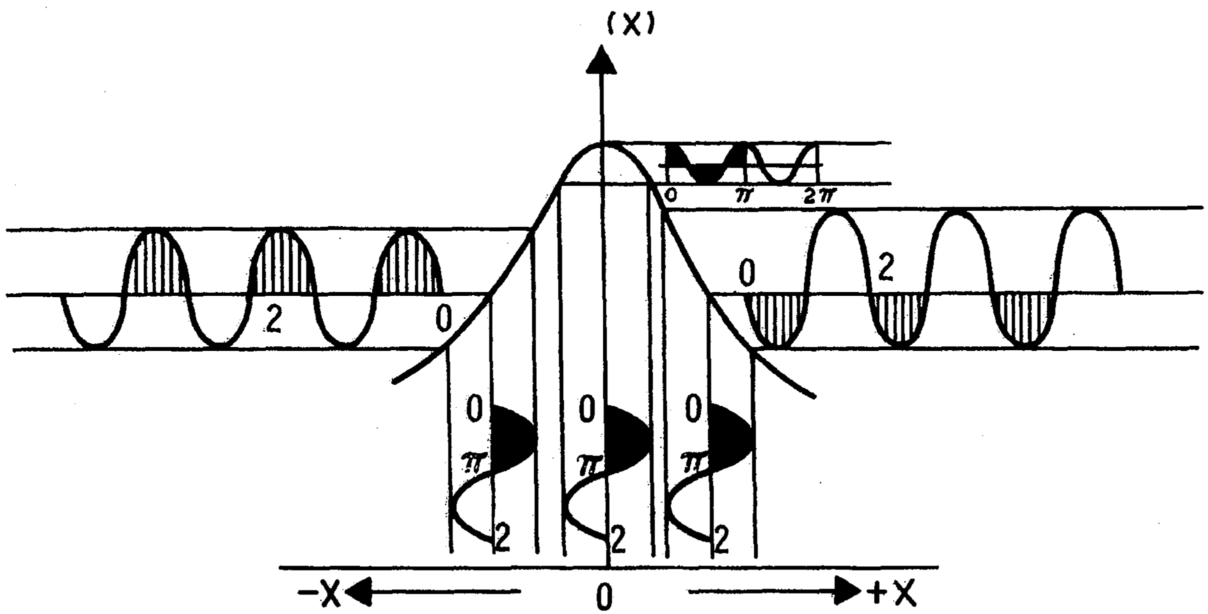
IVS CONCEPT


INPUT
IMAGE
SENSOR
FWD.
GAIN
OUTPUT
RATE
POSITION
FEEDBACK
FEEDBACK
INTEGRATER

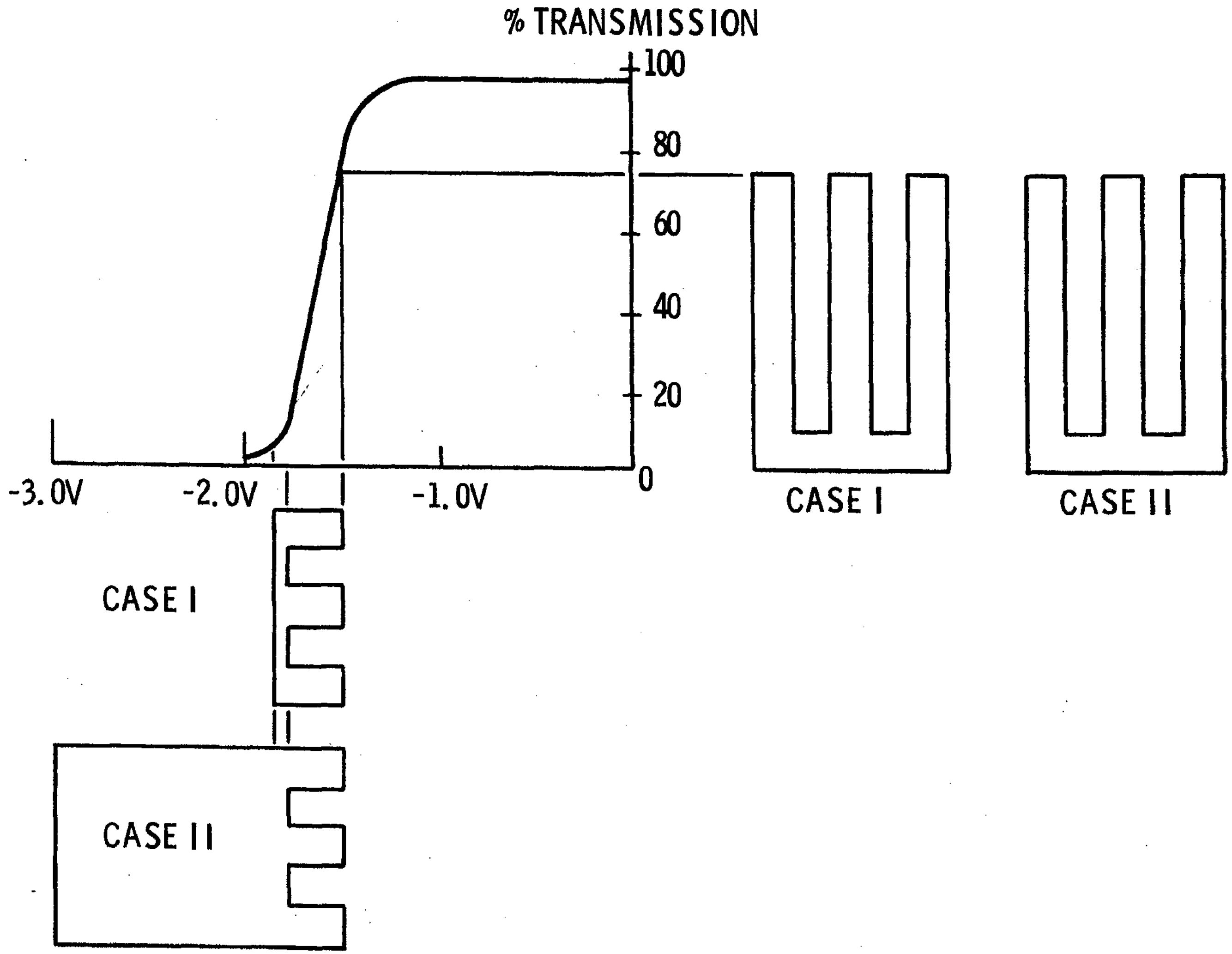
CORRELATRON OPERATION



GENERATION OF ERROR SIGNAL



CONTRAST ENHANCEMENT



COMPLIANCE FORECAST VS REQUIREMENTS

# EQUIPMENT PERFORMANCE REQUIREMENTS

| ITEM | REQUIREMENT | STATUS PRESENT | STATUS CDR |
|---|---|---|---|
| ○ DYNAMIC RANGE | 0-0.3 IPS | 0-0.5 IPS | 0-0.5 IPS |
| □ GAIN FACTOR | 16.67 V/IPS | 16.67 V/IPS (LOW LIGHT LEVEL ) | 16.67 V/IPS |
| ○ LINEARITY | | | |
| LARGE SIGNAL REGION | SLOPE LIMITS (0.75-1.25) | 0.9-1.1 | 0.9-1.1 |
| NULL REGION | SLOPE LIMITS (0.9-1.1) | 0.9-1.1 | 0.9-1.1 |
| ○ SATURATION | 5V/0.3 IPS | 5V/0.3 IPS | 5V/0.3 IPS |
| □ NOISE & BIAS (NULL REGION) | 0.01 IPS ($2\sigma$) | 0.01 IPS ($2\sigma$) | 0.01 IPS ($2\sigma$) |
| ○ FREQUENCY RESPONSE | 1ST ORDER LAG OVER OUTPUT RANGE 0.001-0.25 IPS BREAK ≥ 1 HZ | 1ST ORDER LAG AT 3.5HZ | SATISFY SYSTEM REQUIREMENTS |
| □ RECOVERY TIME AFTER SATURATION | IN SATURATION OVER 2 SEC, RECOVERY ≤ 0.5 SEC | 0.25 SEC (MAX) | 0.25 SEC (MAX) |
| | IN SATURATION 2 SEC OR LESS, RECOVERY ≤ 0.1 SEC | 0.1 SEC (MAX) UNLESS RECYCLE OCCURS | 0.1 SEC (MAX) |
| ○ SUB-THRESHOLD IRRADIANCE SIGNAL | FLAT INPUT OF $4 \times 10^{-9}$ WT/CM$^2$ PER 10 NANOMETER ($\Delta\lambda$) OVER RANGE 400-900 NANOMETERS | MEETS REQUIREMENTS | MEETS REQUIREMENTS |
| ○ RELIABILITY | MTBF ≥ 10,000 HRS | 15,500 HRS | 15,500 HRS |
| ○ WARMUP TIME | ≤ 2 MIN | 10 SEC | 10 SEC |

# EQUIPMENT INTERFACE REQUIREMENTS

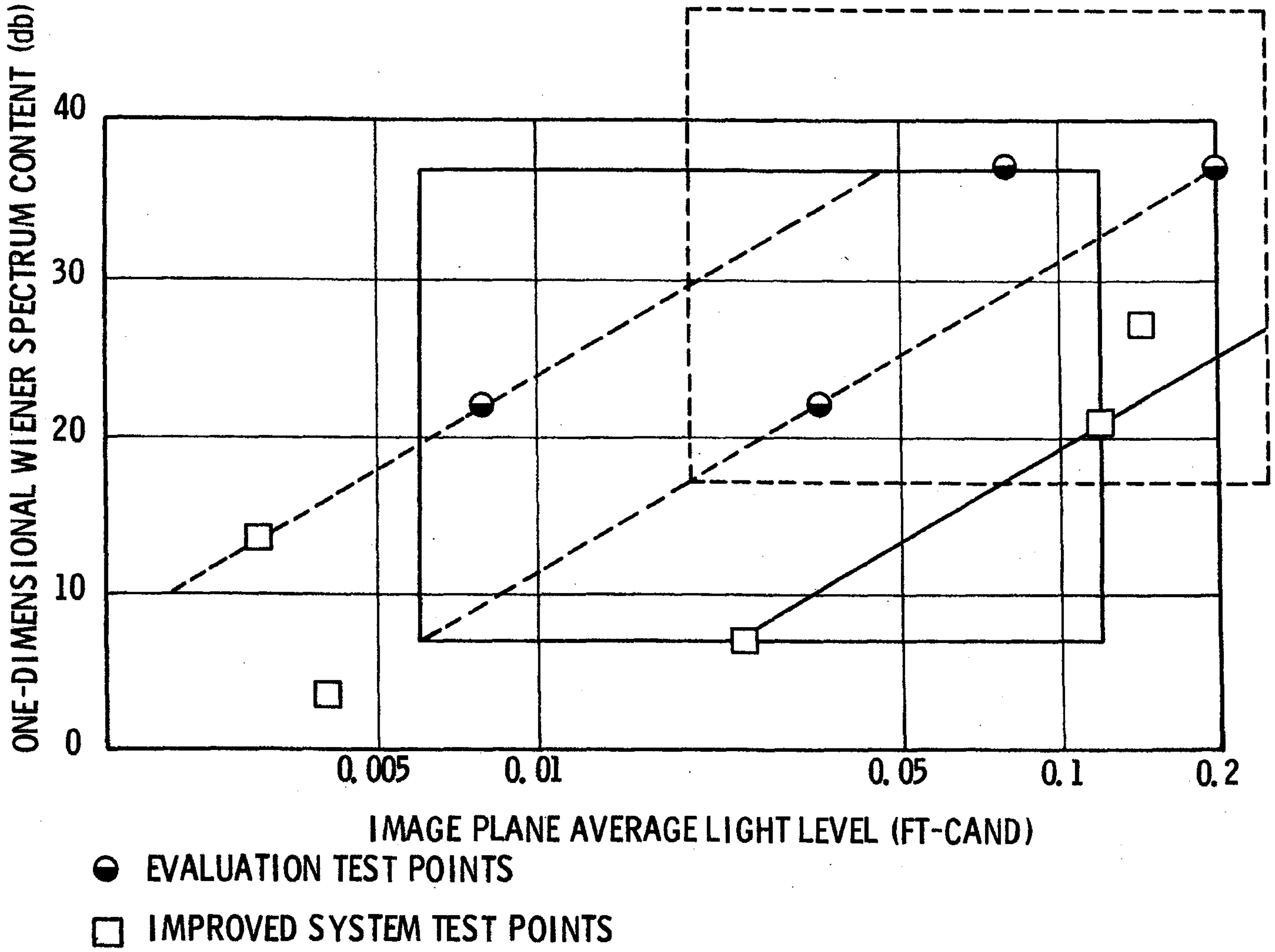
| ITEM | REQUIREMENT | STATUS PRESENT | STATUS CDR |
|---|---|---|---|
| ○ INPUT POWER | | | |
| AVERAGE | < 26 WATTS | 25.6 WATTS | 21 WATTS |
| PEAK | < 50 WATTS | 29.5 WATTS | 29.5 WATTS |
| ○ WEIGHT | | | |
| SENSOR | ≤ 14 LB | 14.8 LB | 11.5 LB |
| SYSTEM | ≤ 23 LB | 21.5 LB | 19.5 LB |
| ○ SPACE ENVELOPE | | | |
| SENSOR | PER DWG 711-03013 | 8.9 DIA X 18.75 | 7 DIA X 16 |
| ELECTRONICS ASSY | 6X9X6 IN. | 6X9X6 IN. | 6X9X6 IN. |
| ○ CG OF SENSOR | | | |
| DISTANCE FROM MTG PLANE ℄ | WITHIN 0.25 IN. | WITHIN 0.1 IN. | WITHIN 0.1 IN. |
| DISTANCE FROM IMAGE PLANE | ≤ 7.25 IN. | 7.23 IN. | 4.9 IN. |
| □ THERMAL DISSIPATION | | | |
| HEAD | DESIGN GOAL < 3 WATTS | 8.9 WATTS | 3 WATTS |
| ○ GENERATED DISTURBANCES | | | |
| VIBRATION (DURING EXPOSURE) | ≤ 3.0 IN.-OZ. (ANY AXIS) ≤ 0.01 LB AXIAL FORCE (ANY AXIS) | NONE | NONE |
| (DURING SLEW) | 2 X ABOVE | NONE | NONE |
| RESONANCE | > 55 HZ | NONE | NONE |
| ACOUSTIC NOISE | PER 3.2.13 OF DR 1100B | NONE | NONE |

# IDENTIFIED PROBLEMS AND SOLUTIONS

# IDENTIFIED PROBLEMS AND SOLUTIONS

| PROBLEMS ENCOUNTERED IN BREADBOARD TESTING | SOLUTIONS | |
|---|---|---|
| • LOW ILLUMINATION | - IMPROVED CORRELATRON | |
| • LOW CONTRAST | INCREASED SENSITIVITY | • 4:1 |
| | - CIRCUITRY REFINEMENTS | |
| | S/N IMPROVEMENT | • 2:1 |
| | - EXTENDED ILLUMINATION | • 3:1 |
| | TOTAL IMPROVEMENT | • 24:1 |
| • DYNAMIC NULL | - RESULT OF SIMULATION FOV | |
| | - NON-EXISTENT IN REAL CASE | |

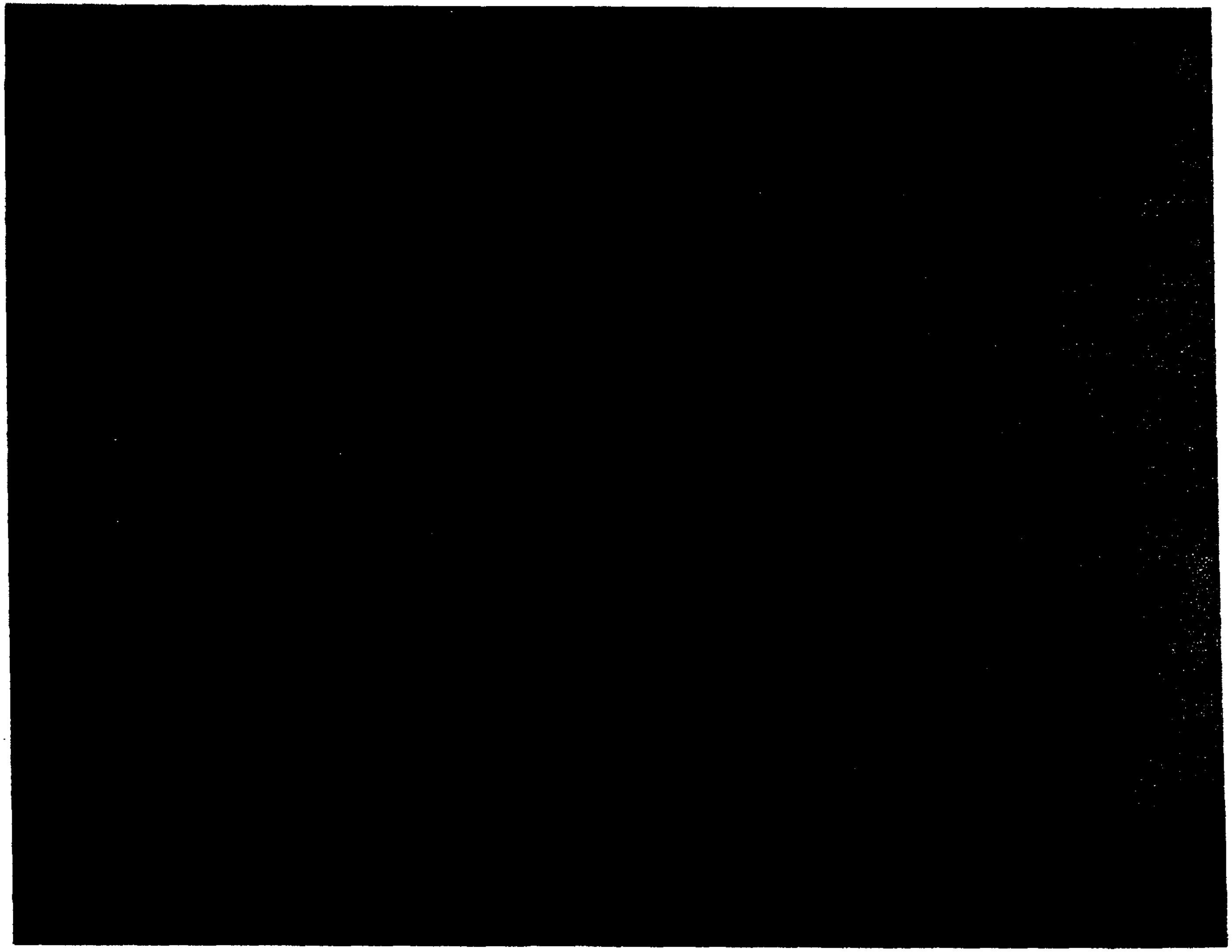
GOODYEAR PERFORMANCE VS SCENE CONTENT



## HIGH CONTRAST, MID-RANGE ILLUMINATION IMAGERY

[redacted]

MINIMUM MODULATION AND ILLUMINATION IMAGERY




~~SECRET~~/DORIAN
HANDLE VIA BYEMAN SYSTEM ONLY

MINIMUM CONTRAST, MAXIMUM ILLUMINATION IMAGERY

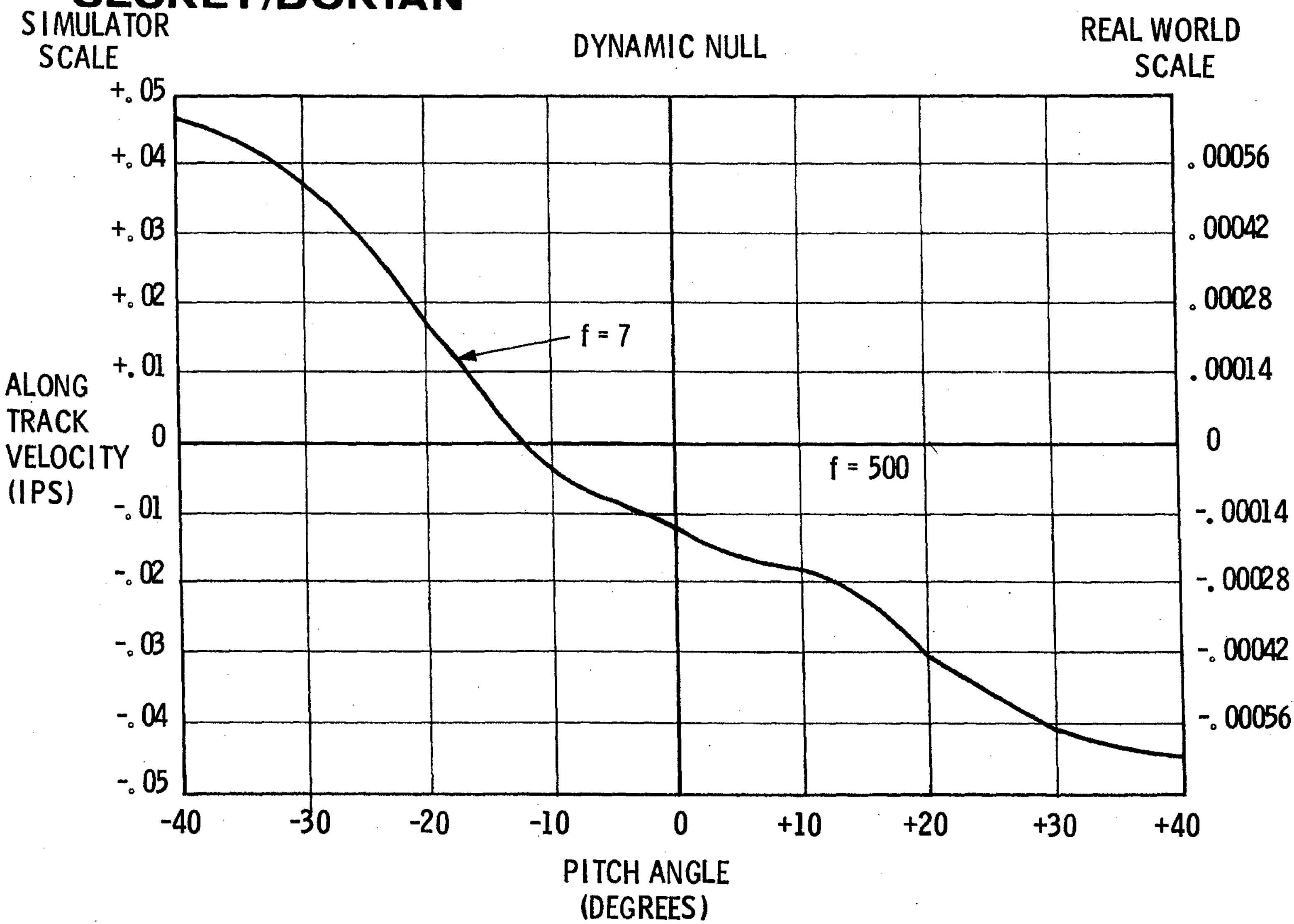
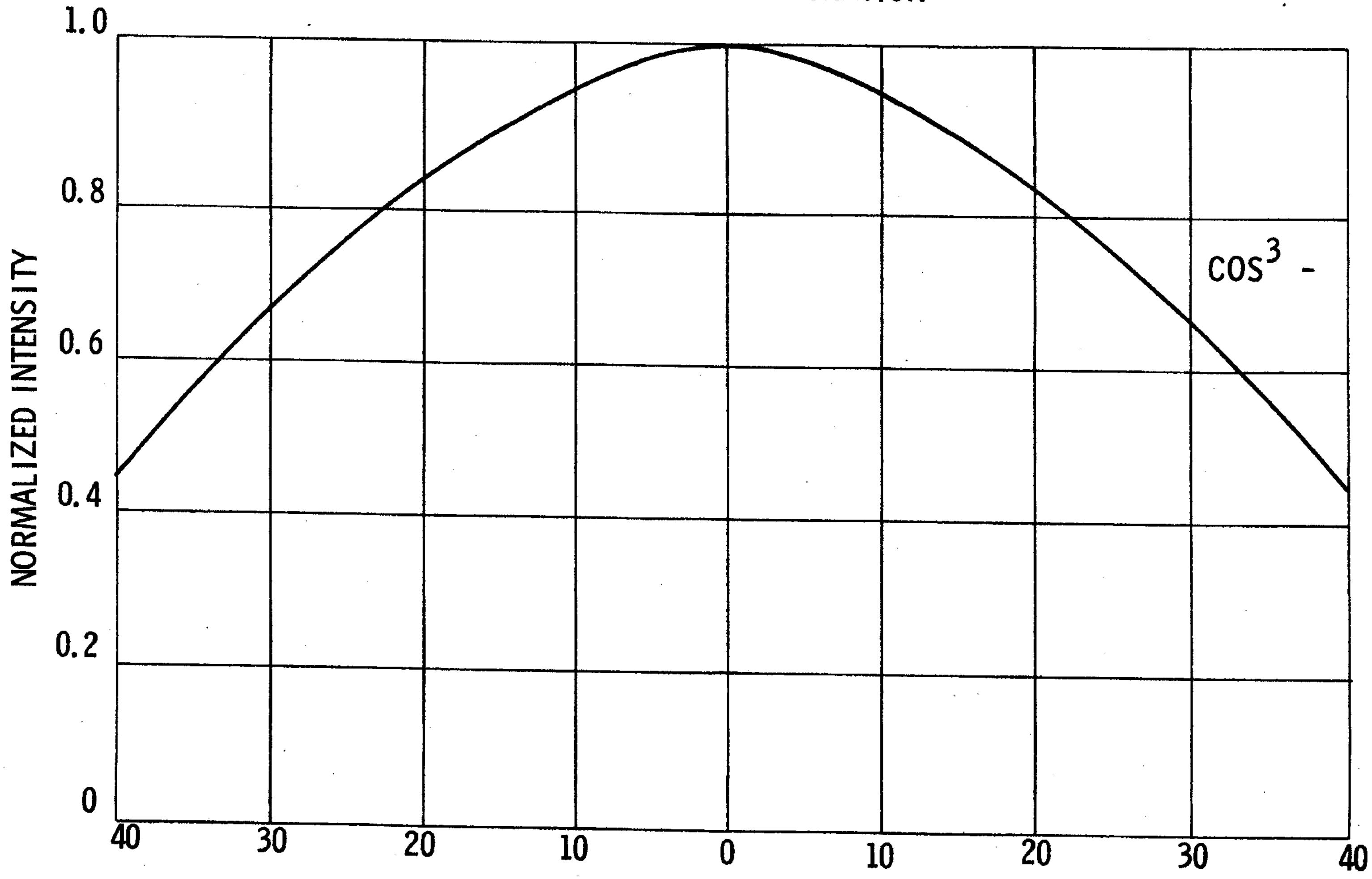
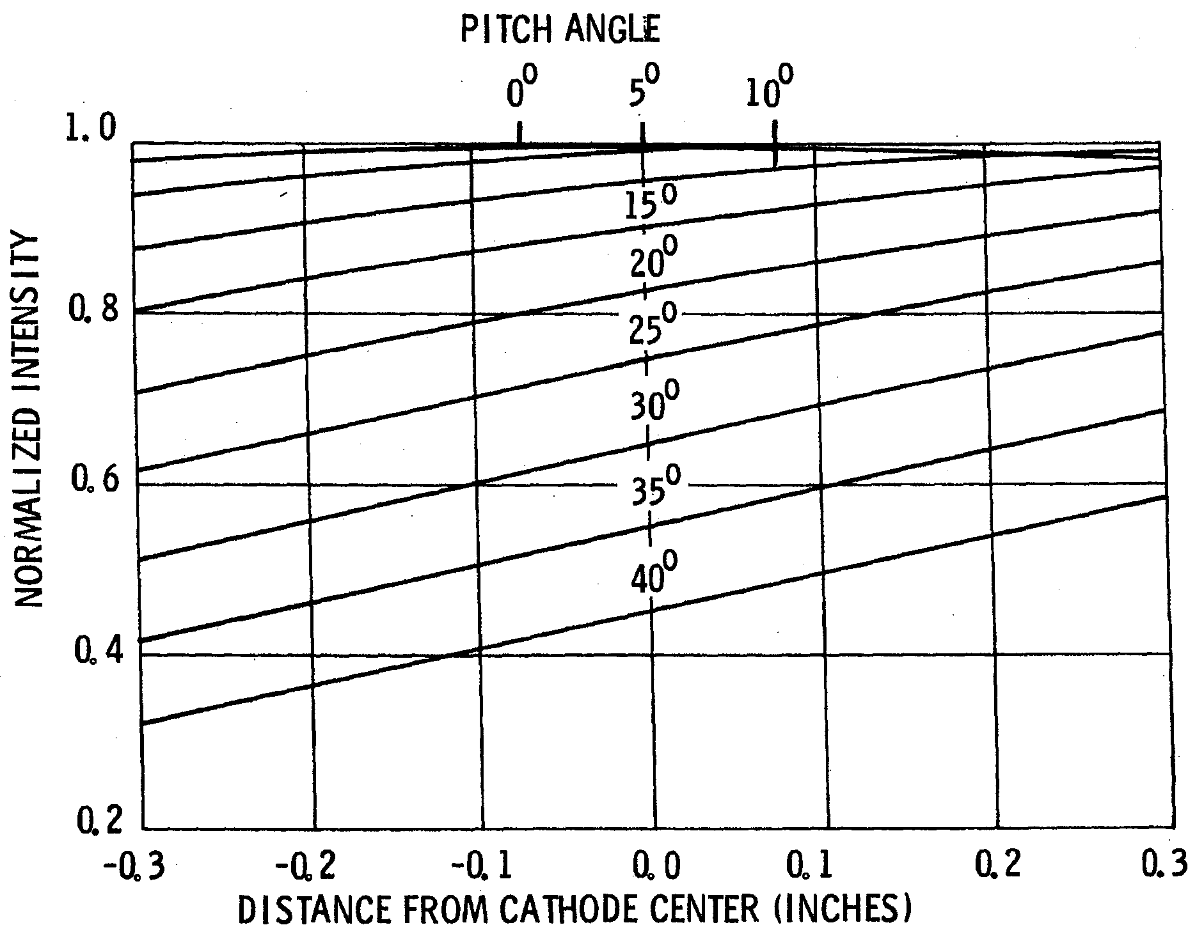

SIMULATOR SCALE
DYNAMIC NULL
REAL WORLD SCALE
+.05
+.04
+.03
+.02
+.01
0
-.01
-.02
-.03
-.04
-.05
.00056
.00042
.00028
.00014
0
-.00014
-.00028
-.00042
-.00056
ALONG TRACK VELOCITY (IPS)
f = 7
f = 500
-40
-30
-20
-10
0
+10
+20
+30
+40
PITCH ANGLE (DEGREES)

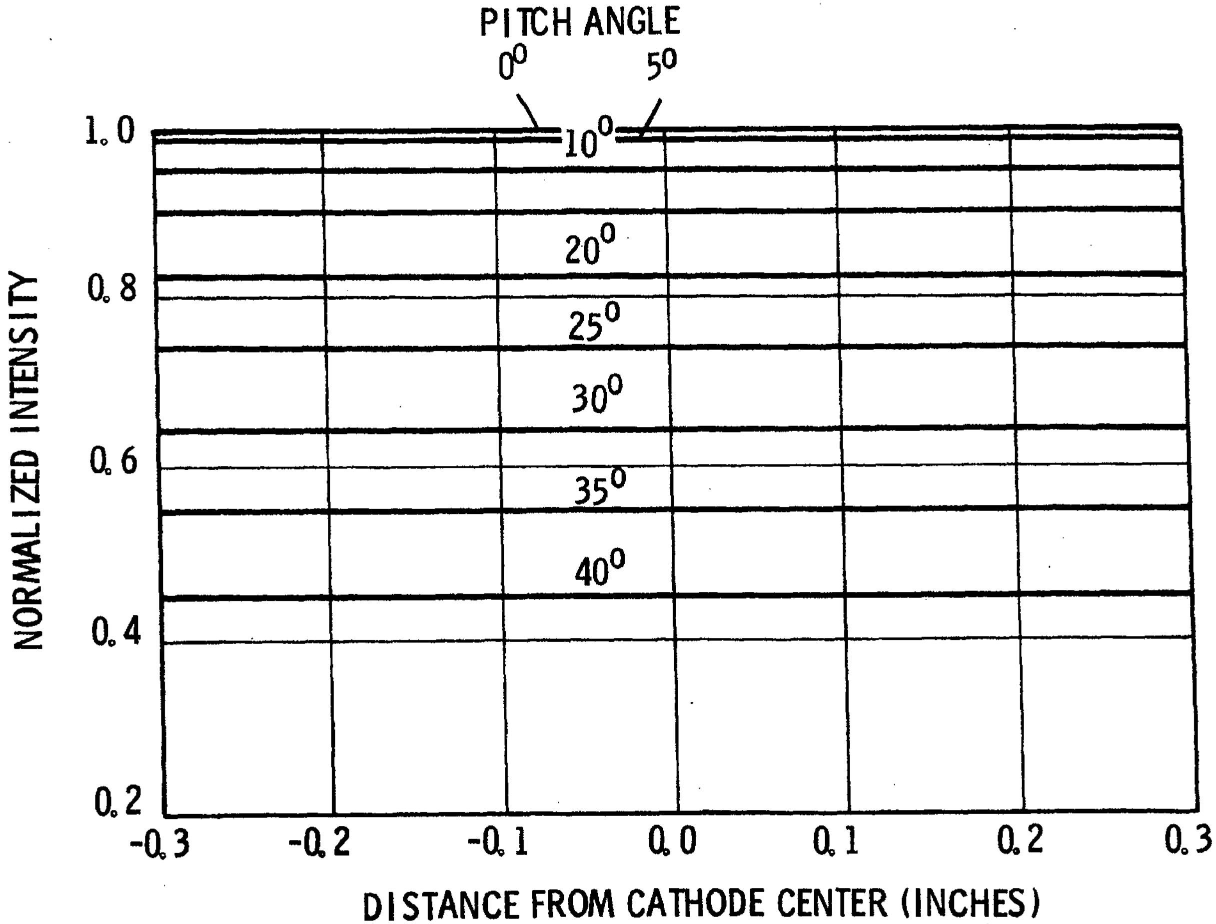
IMAGE PLANE ILLUMINATION



INTENSITY VARIATION OF THE SIMULATED CASE
HAVING A FOCAL LENGTH OF 7"



INTENSITY VARIATION OF THE REAL CASE
HAVING A FOCAL LENGTH [redacted]



# TRADE-OFFS TO DATE

| IMPROVEMENT | PENALTY |
|---|---|
| • INCREASED TUBE SENSITIVITY | - NEGLIGIBLE |
| • IMPROVED CIRCUIT SIGNAL-TO-NOISE | - NEGLIGIBLE |
| • CONTRAST ENHANCEMENT | - NORMAL OUTGROWTH OF ABOVE ITEMS |

## GOODYEAR SYSTEM FEATURES

- PERFORMANCE - FULL COMPLIANCE
  - FAST RESPONSE
  - INSENSITIVITY TO DEFOCUS
  - LOW VELOCITY THRESHOLD
  - NULL SEEKING
  - LOW ILLUMINATION
  - LOW CONTRAST
  - NO GENERATED DISTURBANCES
- RELIABILITY - 15,500 HOURS MTBF
  - NO MOVING PARTS
  - NO HOT CATHODES
  - MAXIMUM USE OF INTEGRATED CIRCUITS
- USEFUL LIFE - GREATER THAN 4000 HOURS
  - ALL SOLID-STATE SWITCHING
  - HERMETICALLY SEALED ASSEMBLIES
  - MAXIMUM USE OF INTEGRATED CIRCUITS

# GROWTH

# GROWTH POTENTIAL

- IMAGE QUALITY ASSESSMENT
- POINTING
- PERFORMANCE IN THE PRESENCE OF CLOUDS

## REQUIRED TASKS - CLOUDS

- ESTABLISH CLOUD CHARACTERISTICS
- EVALUATE PRESENT SYSTEM PERFORMANCE (13 TO 88 PERCENT)
- DETERMINE TRADE-OFFS TO PROVIDE SYSTEM PERFORMANCE
  - RESTRICTED FOV
  - RECYCLE TIME
  - SELECTED NUTATION DIAMETER
  - EXPOSURE SELECTION
  - "READ" BIAS SELECTION
  - SIZE, WEIGHT, POWER & RELIABILITY
- DEVELOP SYSTEM MODIFICATION
- PERFORM SYSTEM EVALUATION TESTS
- INCORPORATE DESIGN INTO IVS

## SUMMARY

- GOODYEAR IVS SATISFIES ALL CRITICAL PERFORMANCE REQUIREMENTS
  - LOW LIGHT LEVEL
  - LOW CONTRAST
  - VELOCITY THRESHOLD
  - NULL ACCURACY
  - DYNAMIC RANGE
  - LINEARITY
  - NO GENERATED DISTURBANCES
- GOODYEAR IVS CAN SATISFY ALL SECONDARY OBJECTIVES
  - SENSOR AND SYSTEM WEIGHT
  - SENSOR SYSTEM POWER
  - SAFETY
  - RELIABILITY
  - DYNAMIC RESPONSE
- GOODYEAR IVS HAS GROWTH POTENTIAL
  - IMAGE QUALITY ASSESSMENT
  - PERFORMANCE IN THE PRESENCE OF CLOUDS

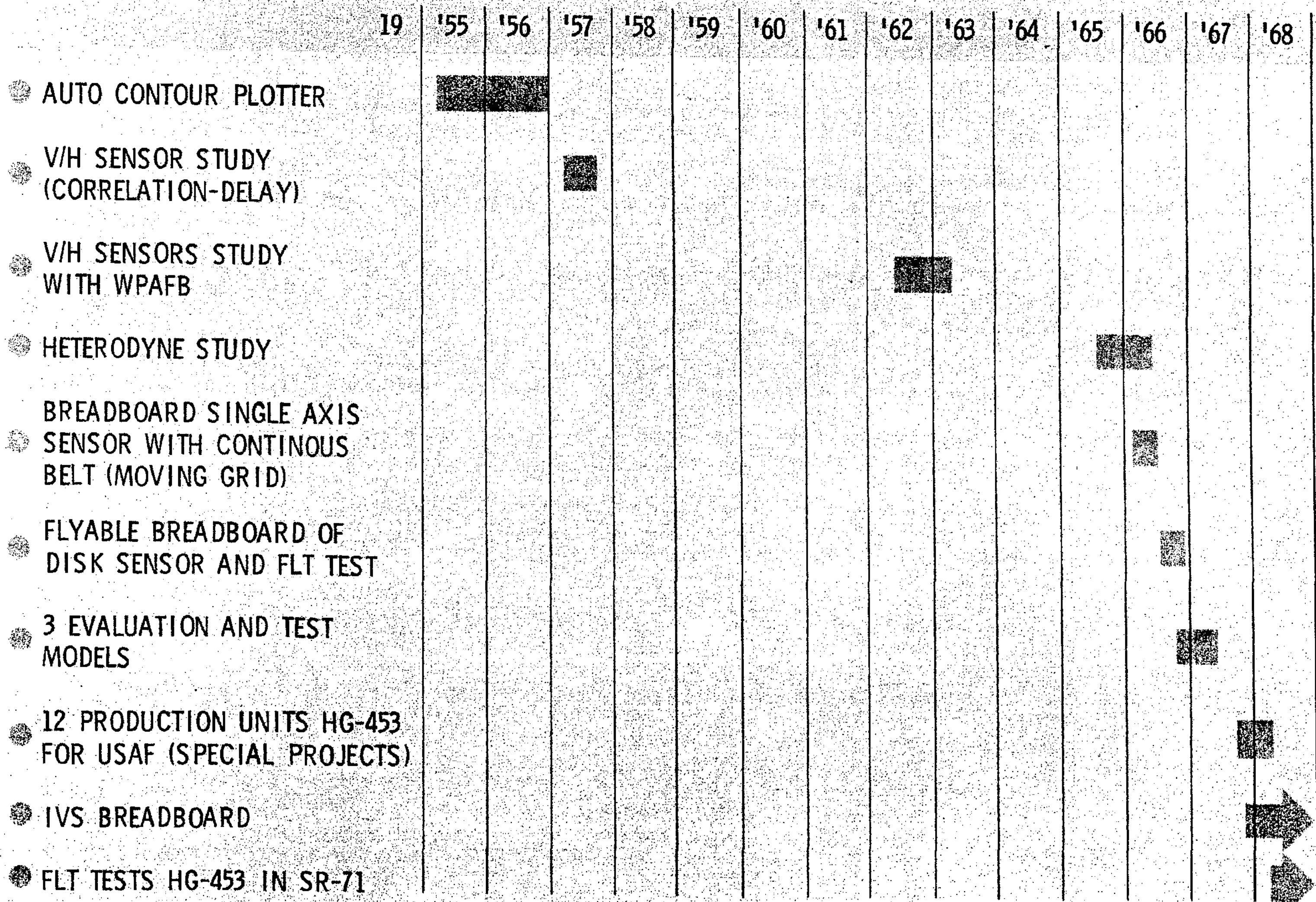
# HYCON IMAGE VELOCITY SENSOR PROGRAM

# SCOPE OF PRESENTATION

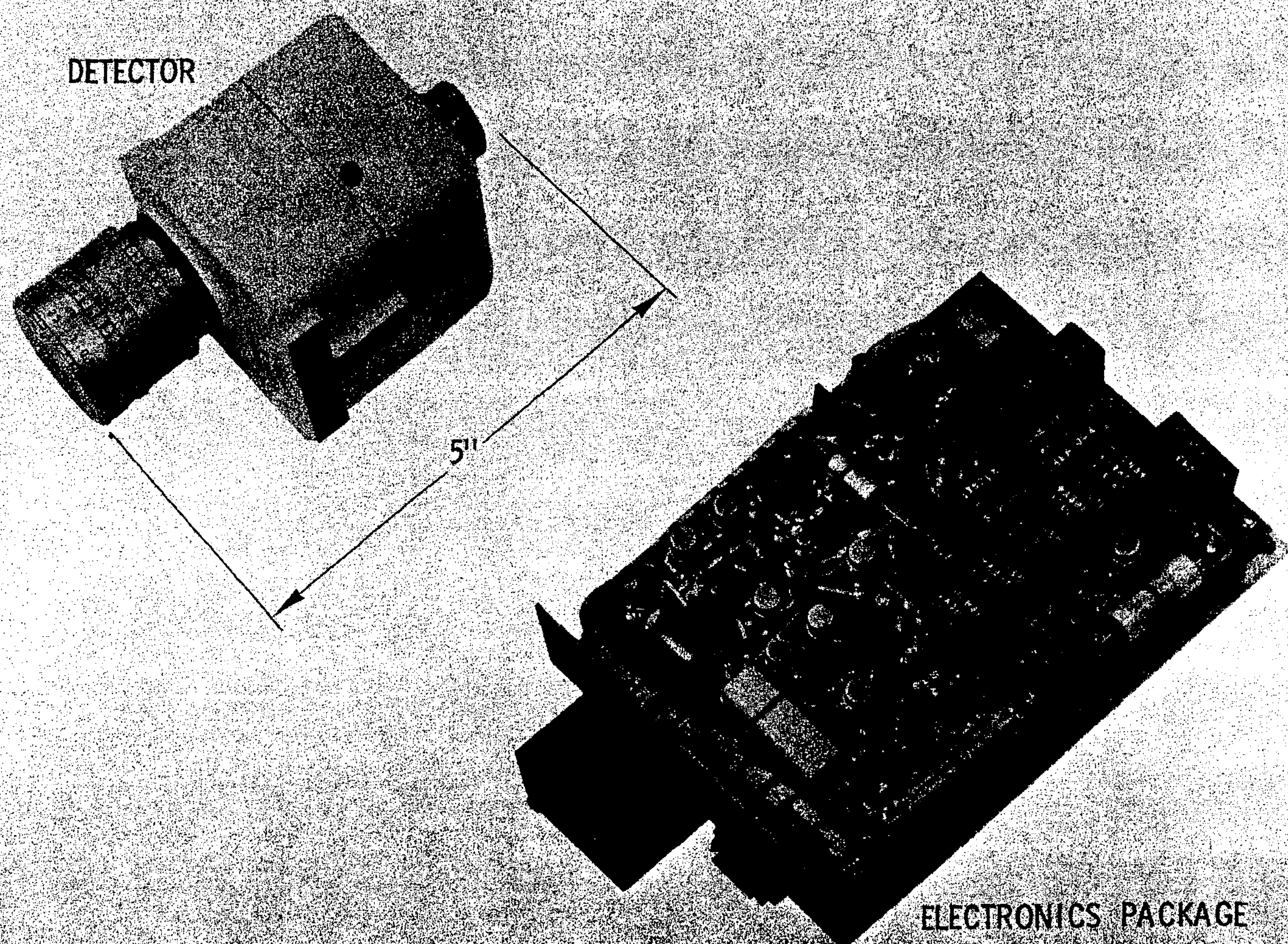
- RELATED EXPERIENCE
- THEORY OF OPERATION
- ENGINEERING PROTOTYPE
- EQUIPMENT REQUIREMENTS
- DEVELOPMENT PROBLEMS AND CORRECTIVE ACTIONS

# RELATED EXPERIENCE

# DEVELOPMENT MILESTONES



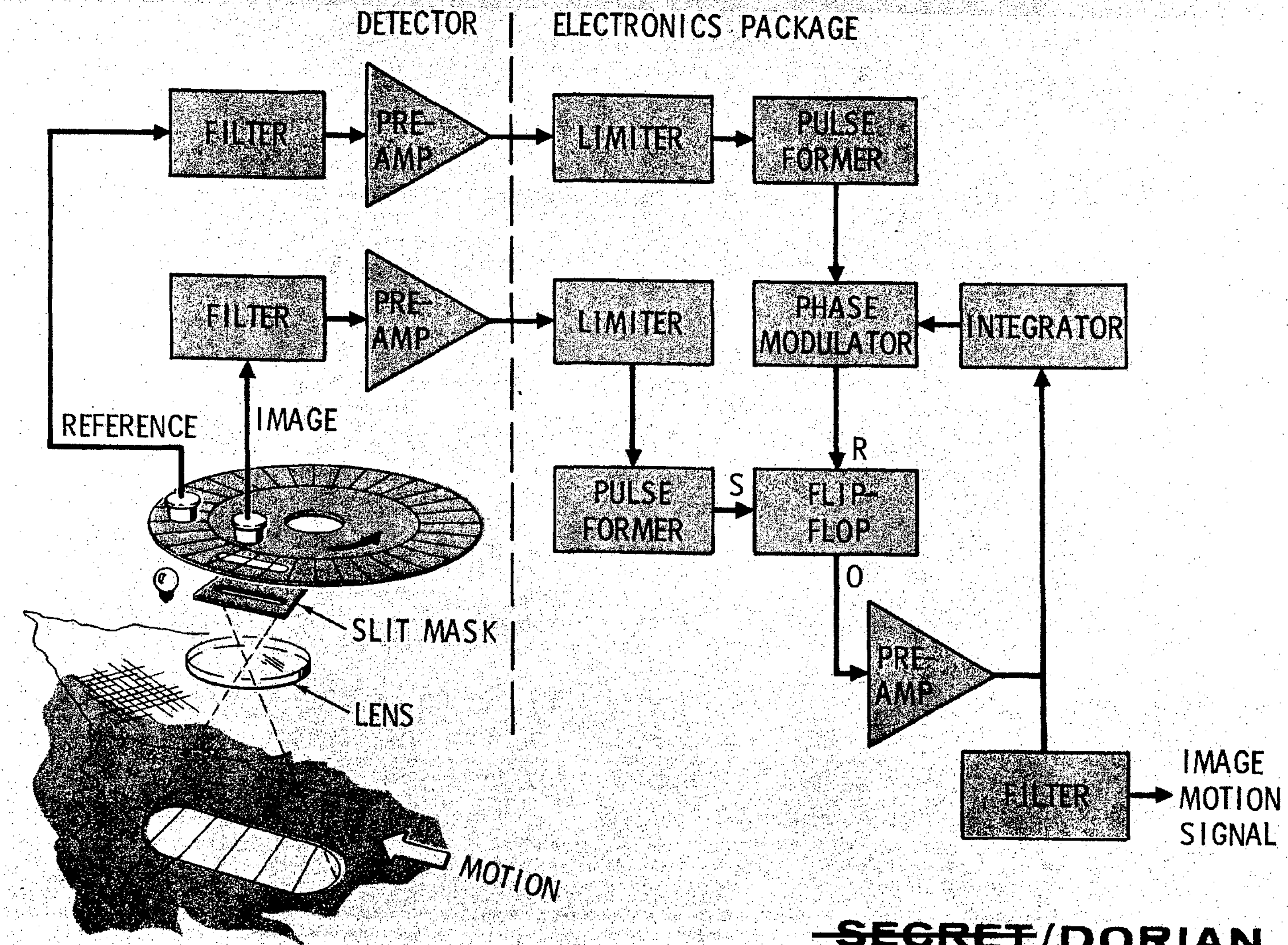
# SINGLE-AXIS IVS, HG-453A



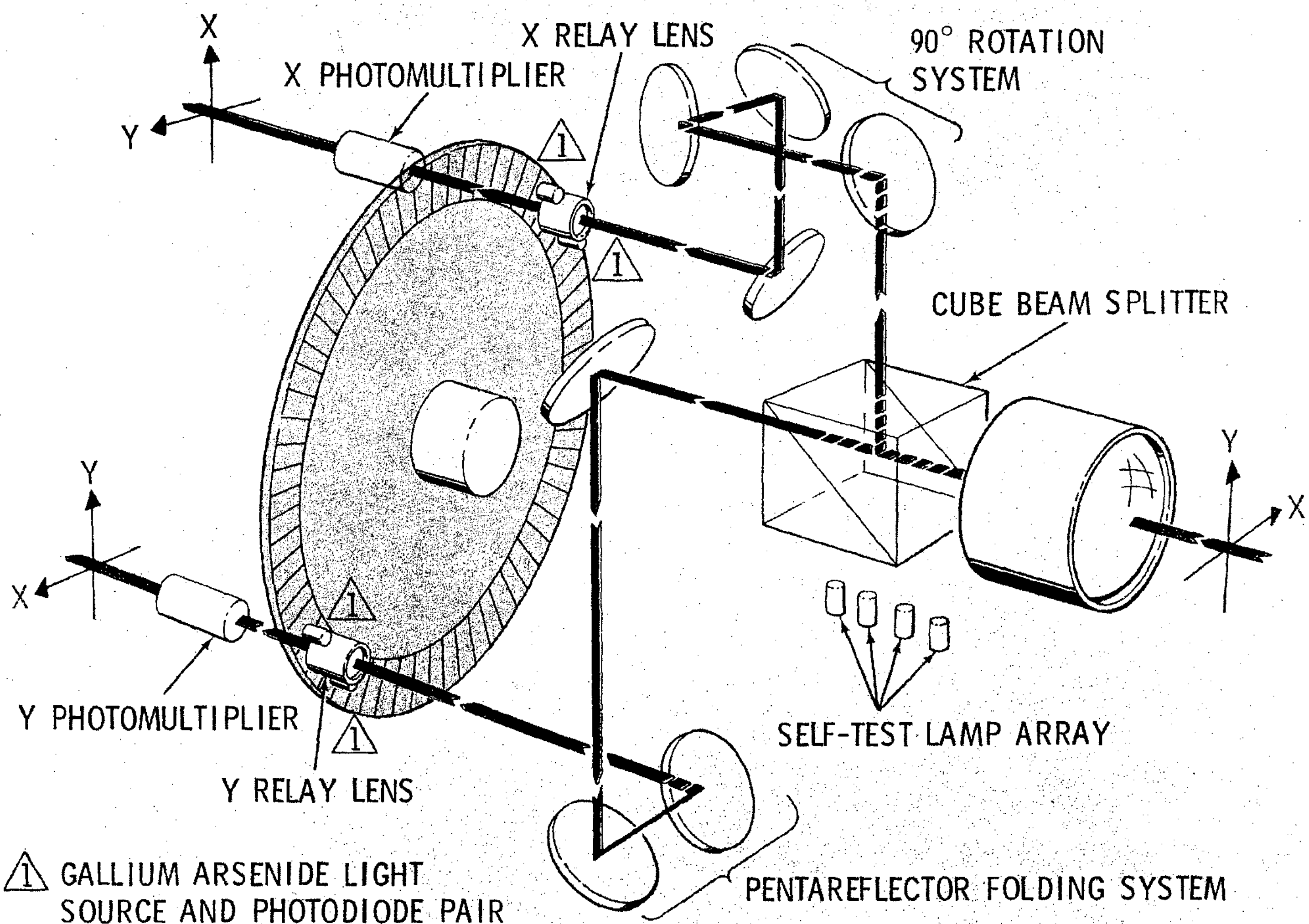
# THEORY OF OPERATION

DORIAN

# 453A SENSOR BLOCK DIAGRAM

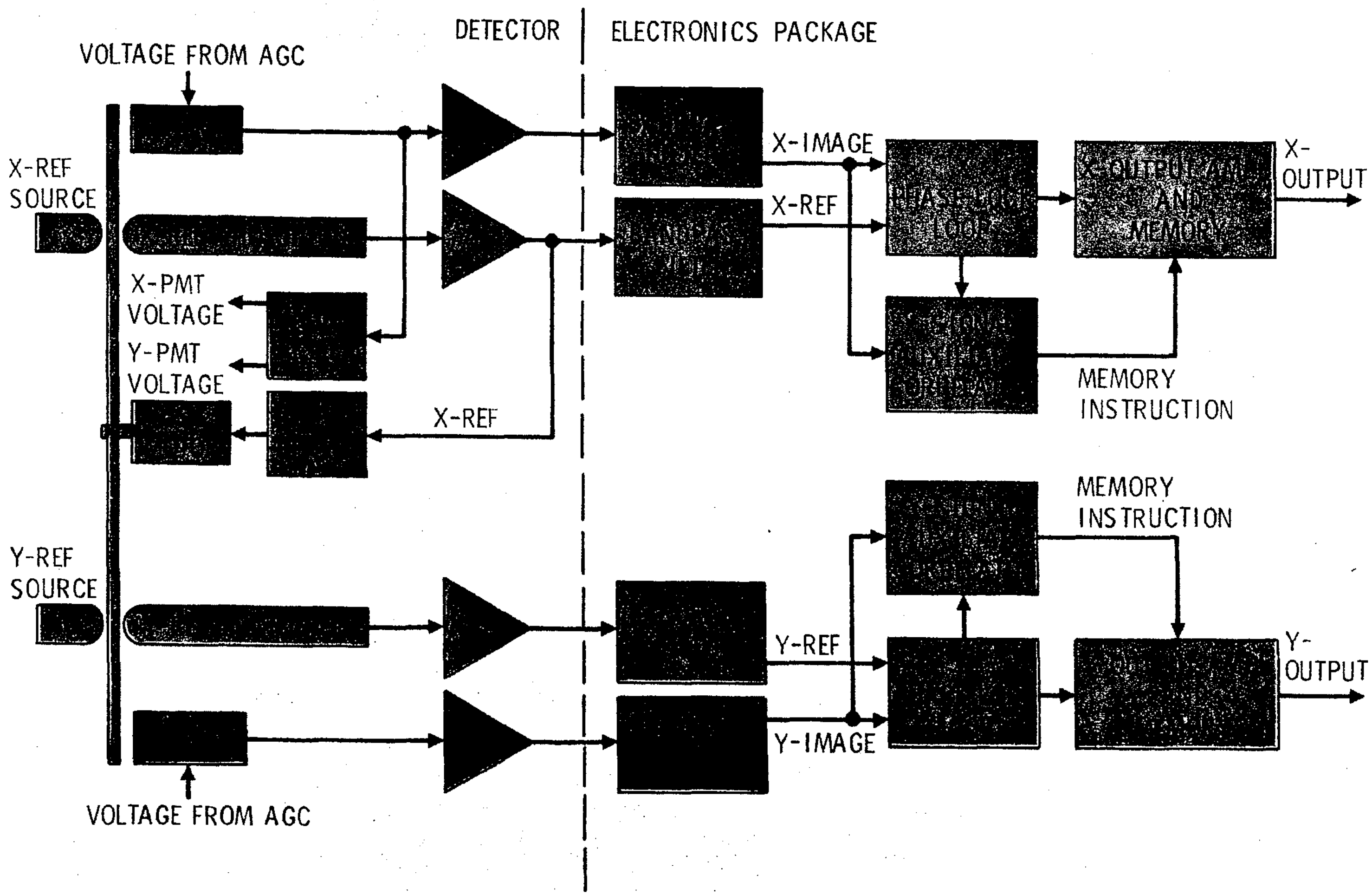


# IVS OPTICAL SCHEMATIC

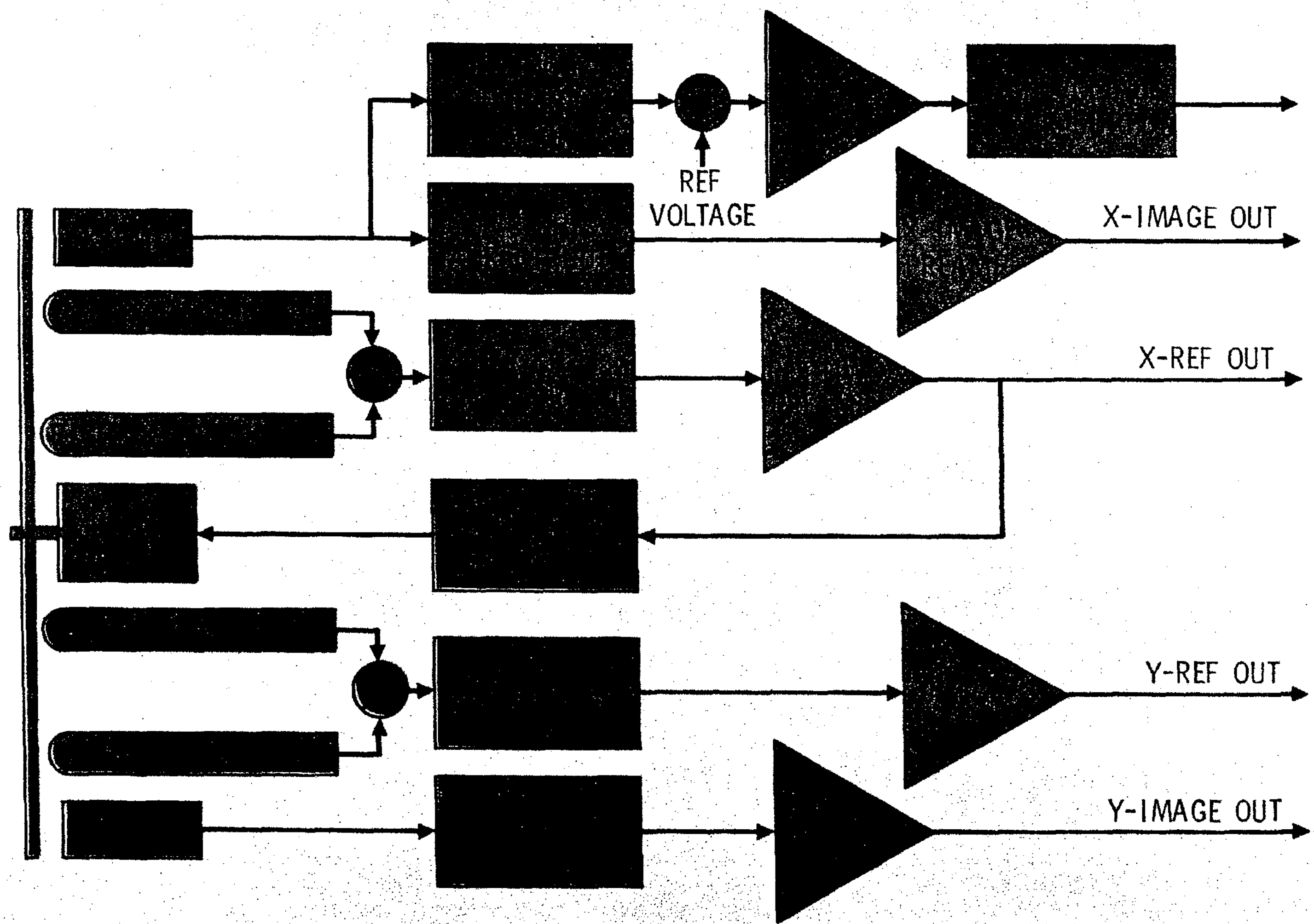



1 GALLIUM ARSENIDE LIGHT SOURCE AND PHOTODIODE PAIR

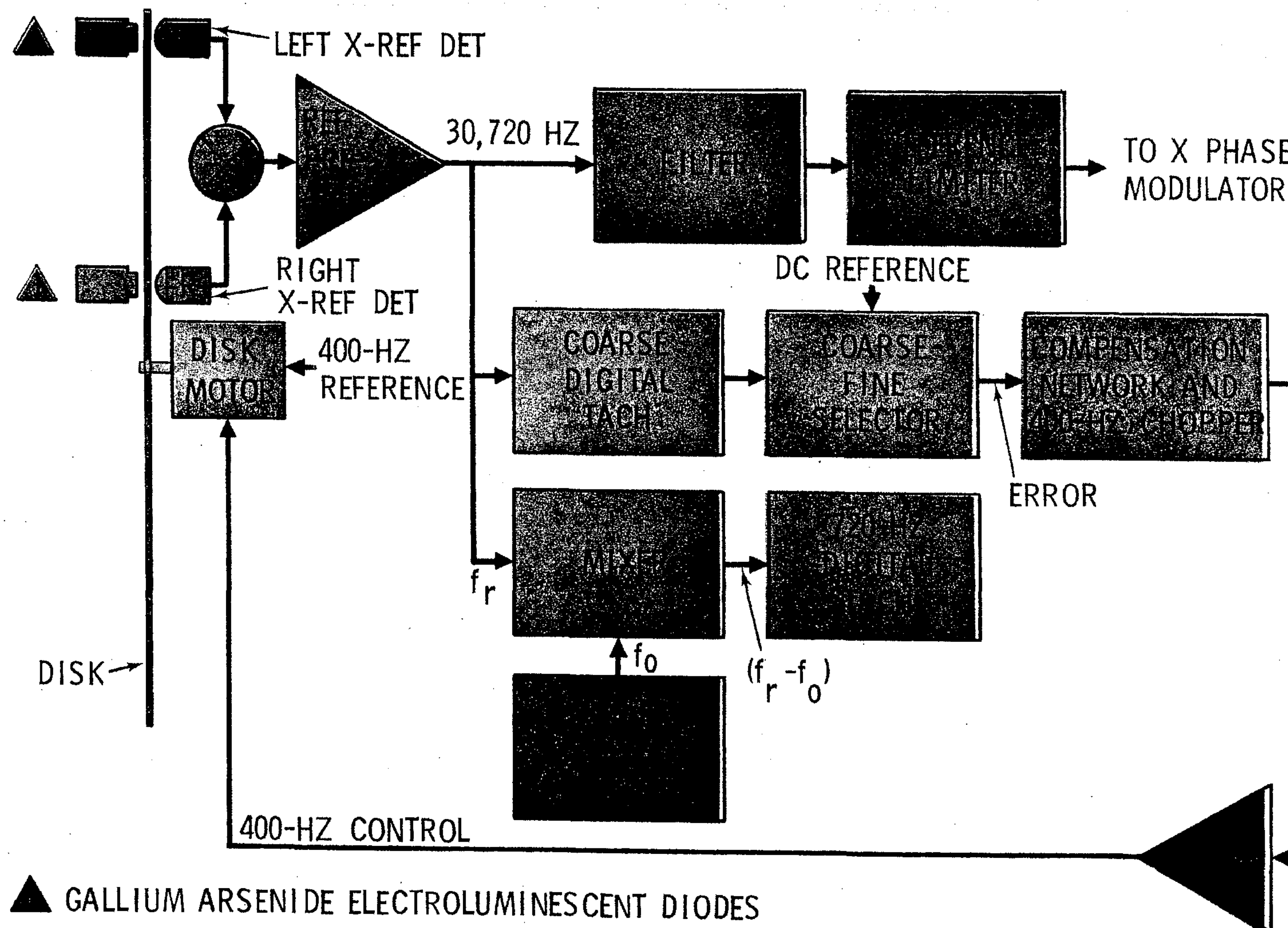
# IVS BASIC BLOCK DIAGRAM



# DETECTOR ELECTRONICS

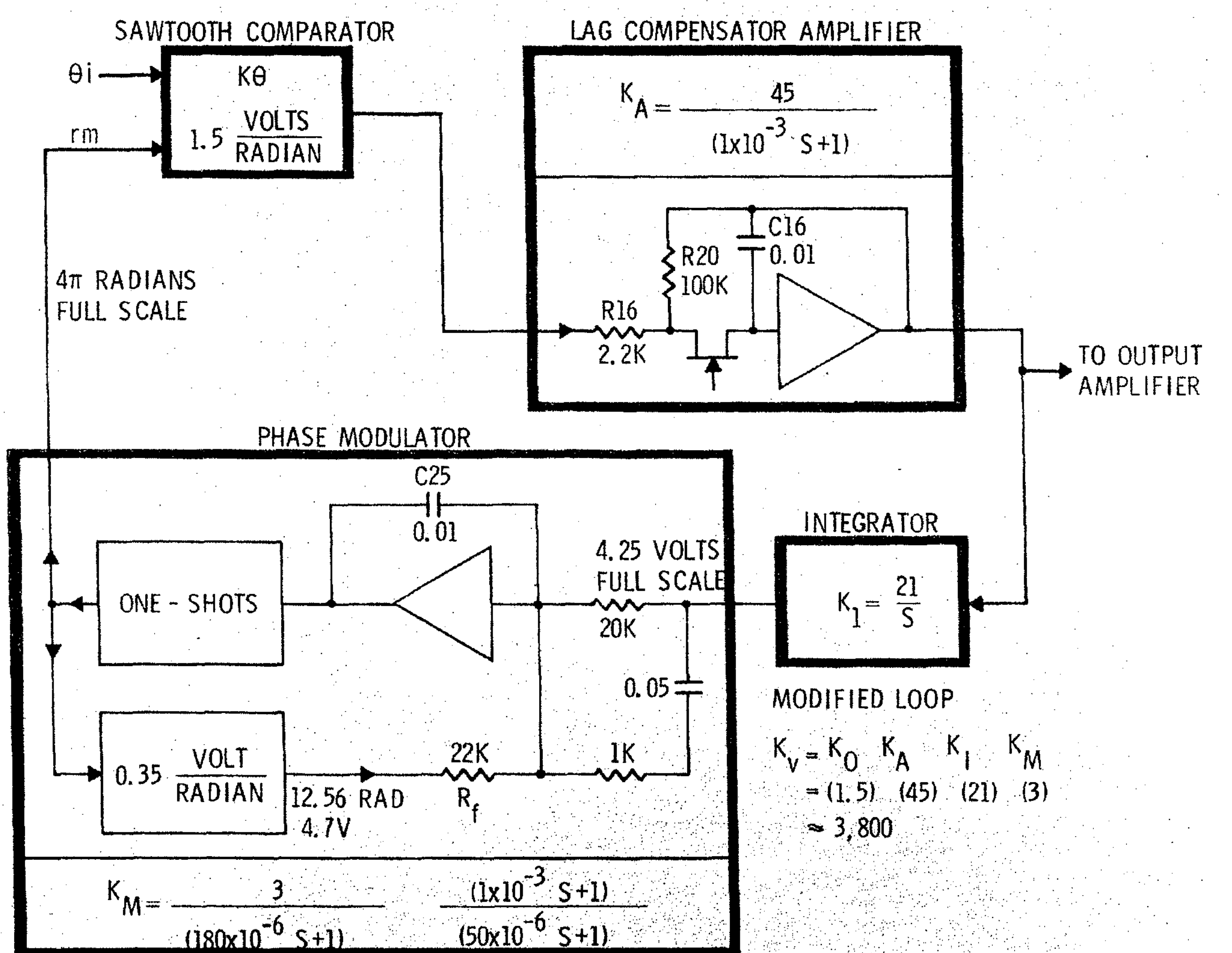


# DISK SERVO BLOCK DIAGRAM




▲ GALLIUM ARSENIDE ELECTROLUMINESCENT DIODES

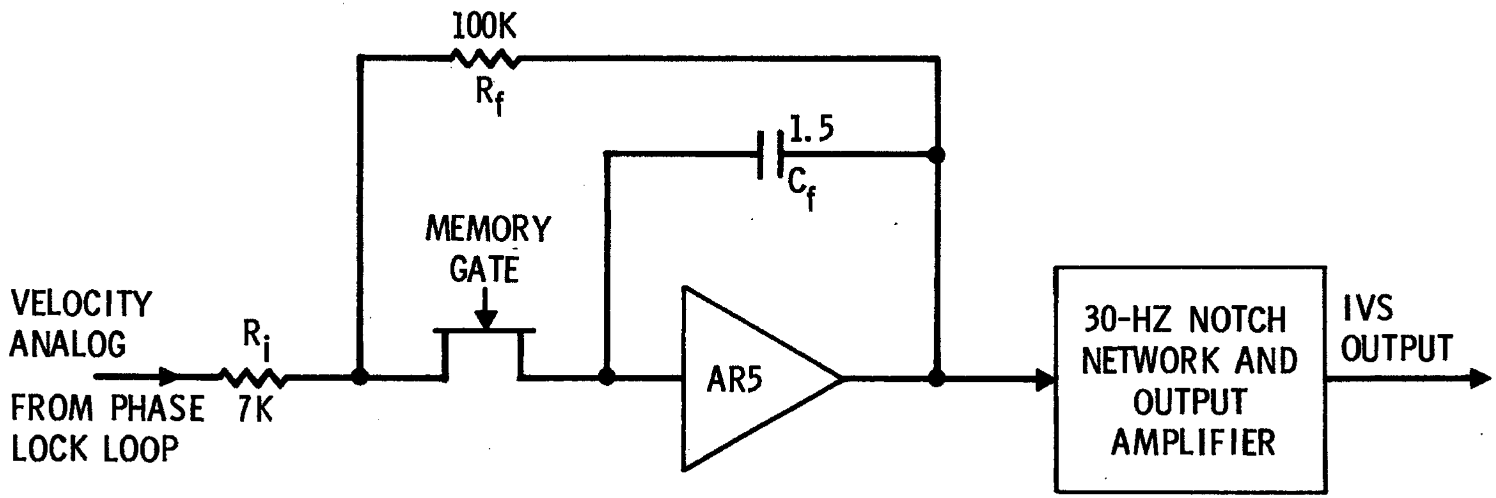
# PHASE-LOCK LOOP




MODIFIED LOOP

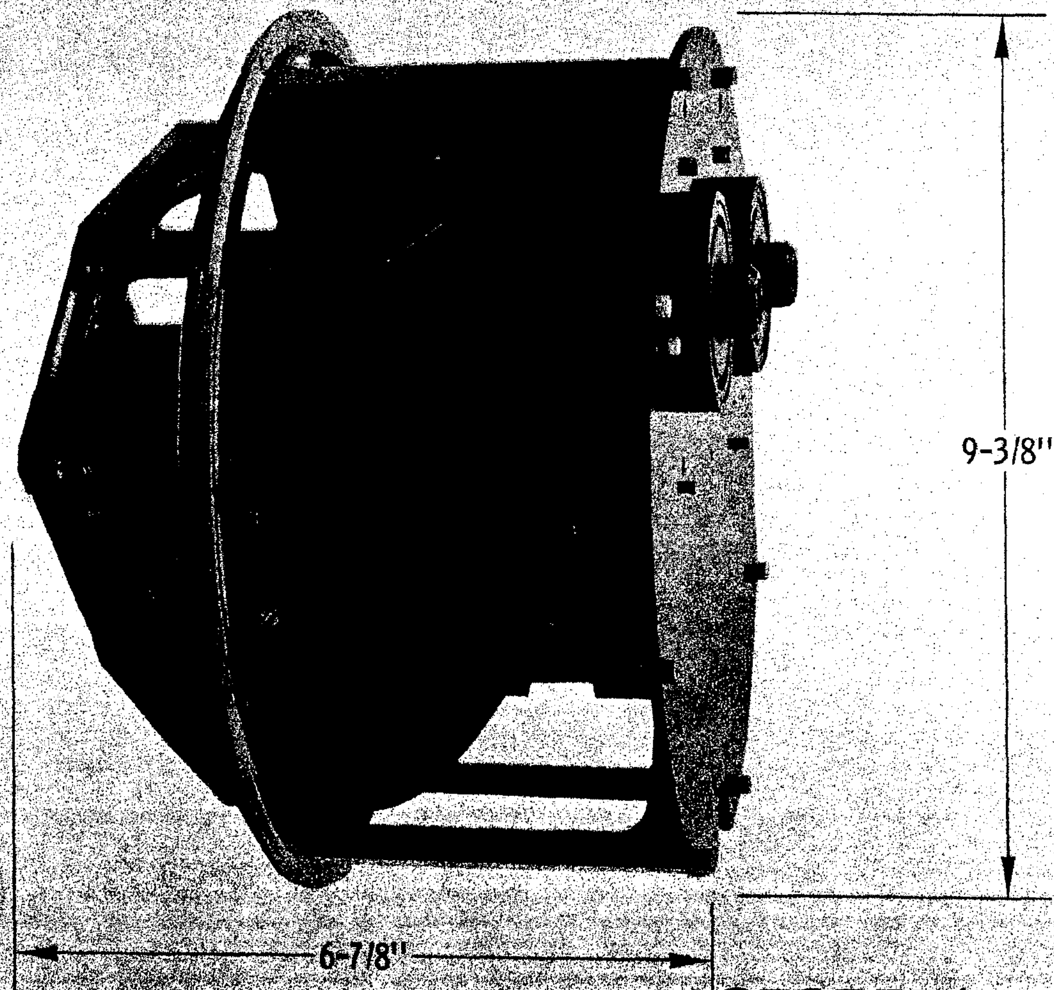
$$K_V = K_O \; K_A \; K_I \; K_M$$
$$= (1.5) \; (45) \; (21) \; (3)$$
$$\approx 3,800$$

# MEMORY AND OUTPUT

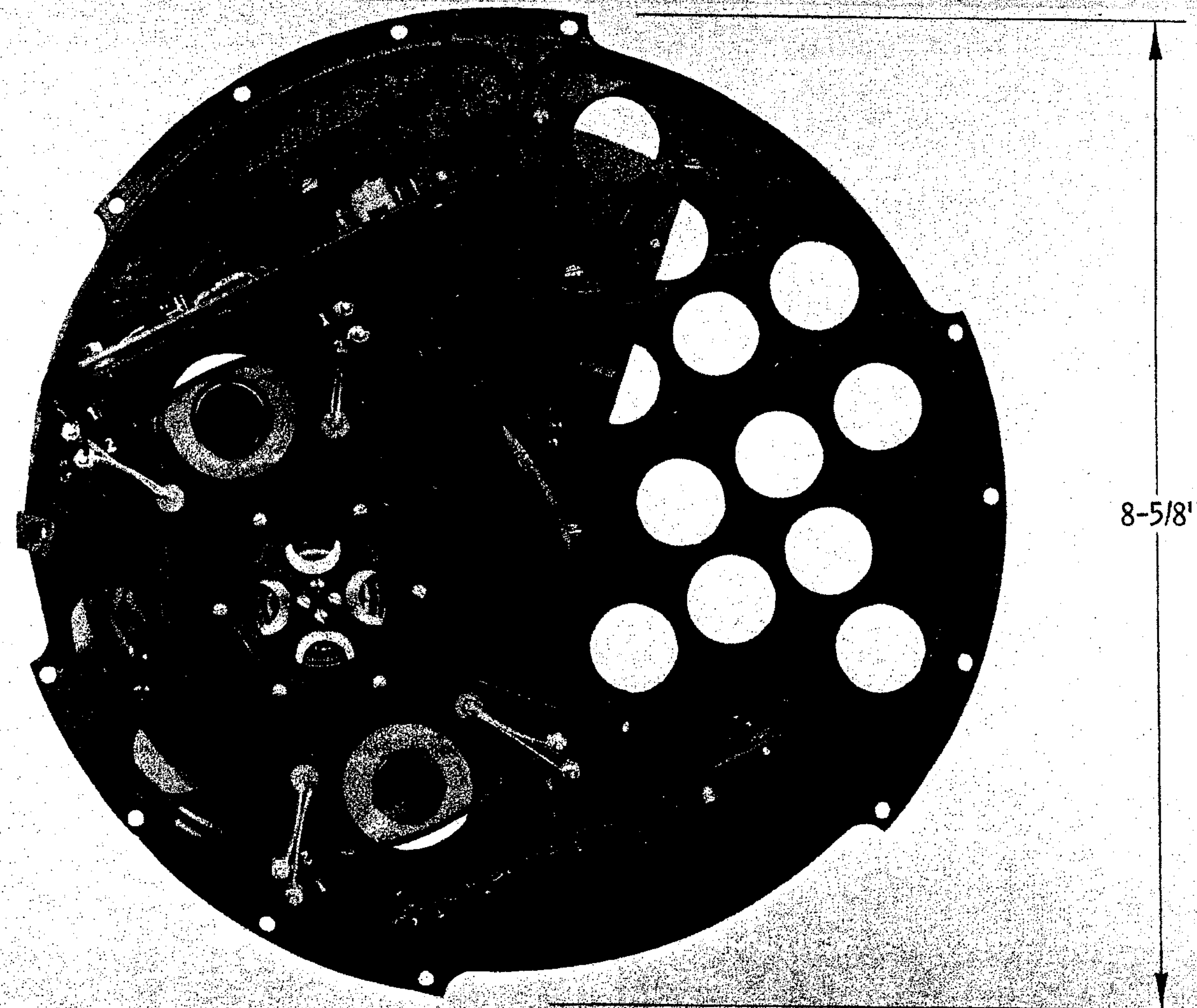


# ENGINEERING PROTOTYPE

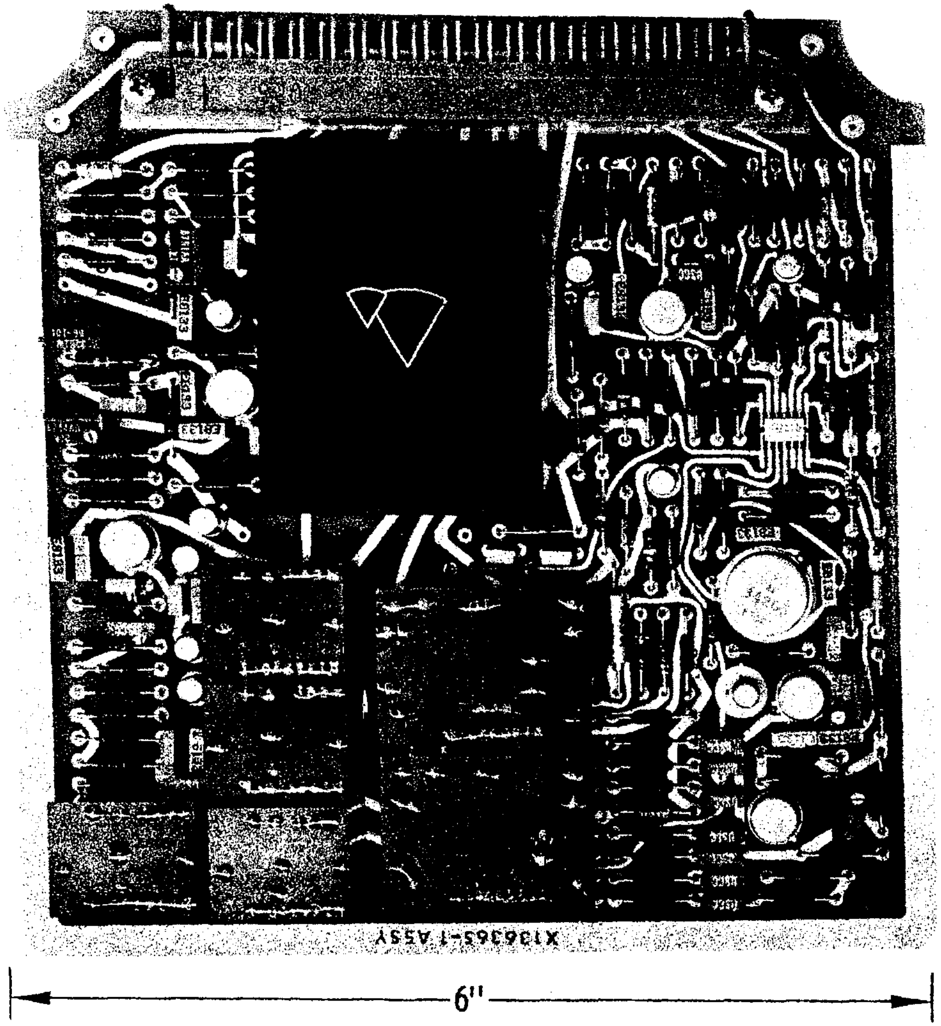
# OPTICAL SUBASSEMBLY.



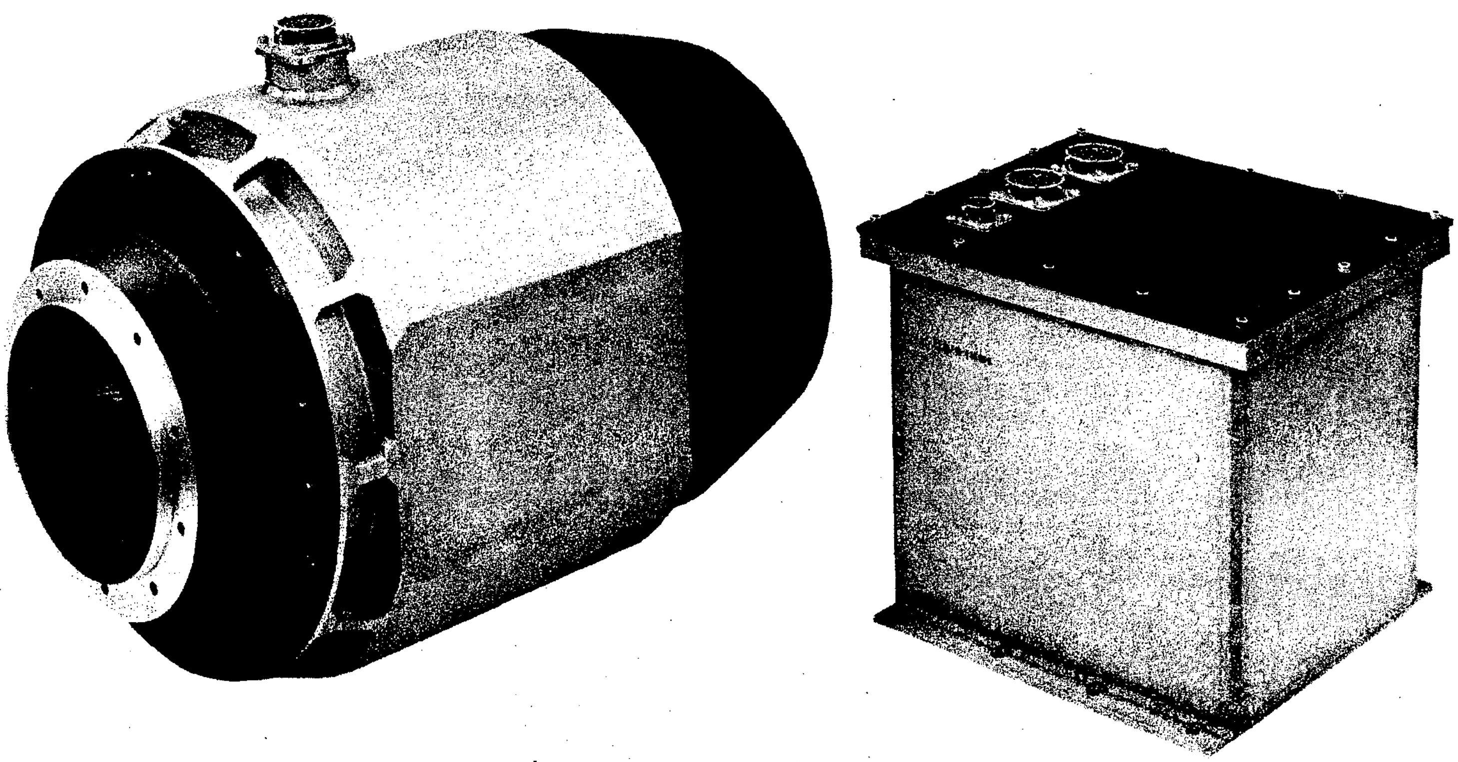
# CHOPPER SUBASSEMBLY



# INPUT/OUTPUT PC BOARD



# HYCON IVS ASSEMBLY



# EQUIPMENT REQUIREMENTS

# EQUIPMENT PERFORMANCE REQUIREMENTS

| | REQUIREMENT | PERFORMANCE NOW | PERFORMANCE CDR (EST) |
|---|---|---|---|
| DYNAMIC RANGE | 0 - 0.3 IPS | 0 - 1.0 IPS | SAME |
| GAIN FACTOR | 16.67 V/IPS | 16.67 V/IPS | SAME |
| LINEARITY | | | |
| LARGE SIGNAL | SLOPE LIMITS | SLOPE LIMITS | SAME |
| | 1.0 ± 0.25 | 1.00 ± <0.10 | SAME |
| NULL | SLOPE LIMITS | SLOPE LIMITS | SAME |
| | 1.00 ± 0.10 | 1.00 ± <0.05 | SAME |
| SATURATION | 5V/0.3 IPS | MEETS REQUIREMENTS EASILY | SAME |

# EQUIPMENT PERFORMANCE REQUIREMENTS (CONT)

| | REQUIREMENT | PERFORMANCE NOW | PERFORMANCE CDR (EST) |
|---|---|---|---|
| NOISE AND BIAS (NULL REGION) | 0.010 IPS (2 $\sigma$) | ≤0.010 IPS (2 $\sigma$) | SAME |
| FREQUENCY RESPONSE | 1ST ORDER LAG OVER OUTPUT RANGE .001 - 0.25 IPS. BREAK FREQ ≥1 HZ | MEETS REQUIREMENTS | SAME |
| RECOVERY TIME AFTER SATURATION | IN SATURATION OVER 2 SEC., RECOVERY ≤ 0.5 SEC.; IN SATURATION 2 SEC. OR LESS, RECOVERY ≤ 0.1 SEC. | <0.050 SEC. | SAME |

# EQUIPMENT PERFORMANCE REQUIREMENTS (CONT)

| | REQUIREMENT | PERFORMANCE NOW | PERFORMANCE CDR (EST) |
|---|---|---|---|
| SUB-THRESHOLD IRRADIANCE SIGNAL | FLAT INPUT OF 4 X $10^{-9}$ WATTS/$CM^2$ PER 10 NANOMETERS ($\Delta r$) OVER RANGE 400 - 900 NANOMETERS | MEETS REQUIREMENTS | SAME |
| RELIABILITY | MTBF $\geq$10,000 HOURS | 21,500 HRS (CAL) | WILL MEET |
| WARM-UP TIME | $\leq$ 2 MINUTES | <40 SECONDS | SAME |

# EQUIPMENT INTERFACE REQUIREMENTS

| | REQUIREMENT | PERFORMANCE NOW | PERFORMANCE CDR (EST) |
|---|---|---|---|
| **INPUT POWER** | | | |
| AVERAGE | < 26 WATTS | 27 WATTS | 25 WATTS |
| PEAK | < 50 WATTS | ≤ 30 WATTS | ≤ 30 WATTS |
| **WEIGHT** | | | |
| HEAD | ≤ 14 POUNDS | 21.8 POUNDS | 7.3 POUNDS |
| TOTAL | ≤ 23 POUNDS | 33 POUNDS | 17.2 POUNDS |
| **SPACE ENVELOPE** | | | |
| HEAD | PER DWG 711-03013 | MEETS | WILL MEET |
| E.P. | 6 X 9 X 6 INCHES | MEETS | WILL MEET |

# EQUIPMENT INTERFACE REQUIREMENTS (CONT)

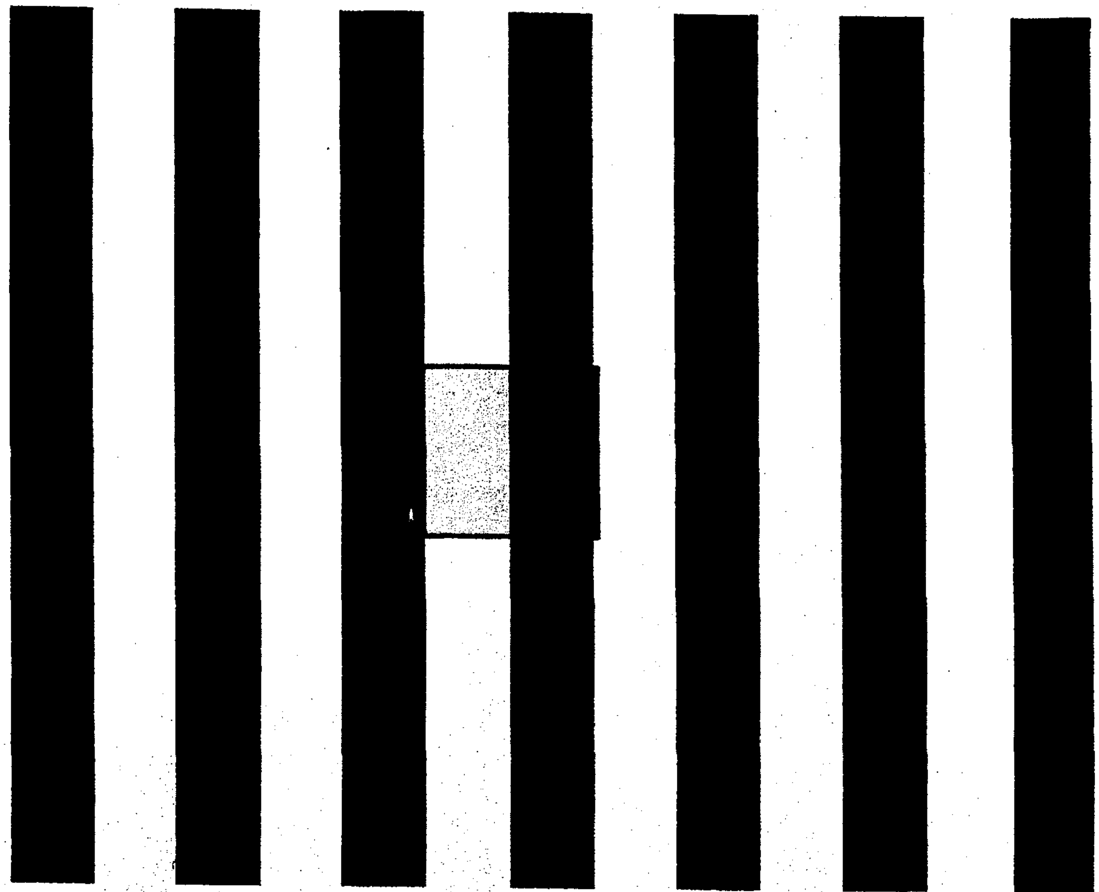
| | REQUIREMENT | PERFORMANCE NOW | PERFORMANCE CDR (EST) |
|---|---|---|---|
| ● CG OF HEAD | | | |
| DISTANCE FROM CENTERLINE NORMAL TO MOUNTING PLANE | WITHIN 0.25" | X = 0.17", Y = 0.49" | WILL MEET |
| DISTANCE FROM INPUT IMAGE PLANE | ≤7.25" | 4.53" | 4.43" |
| ■ THERMAL DISSIPATION | | | |
| HEAD | MINIMUM POSSIBLE DESIGN GOAL ≤3 WATTS | <5 WATTS | <4 WATTS |

# EQUIPMENT INTERFACE REQUIREMENTS (CONT)

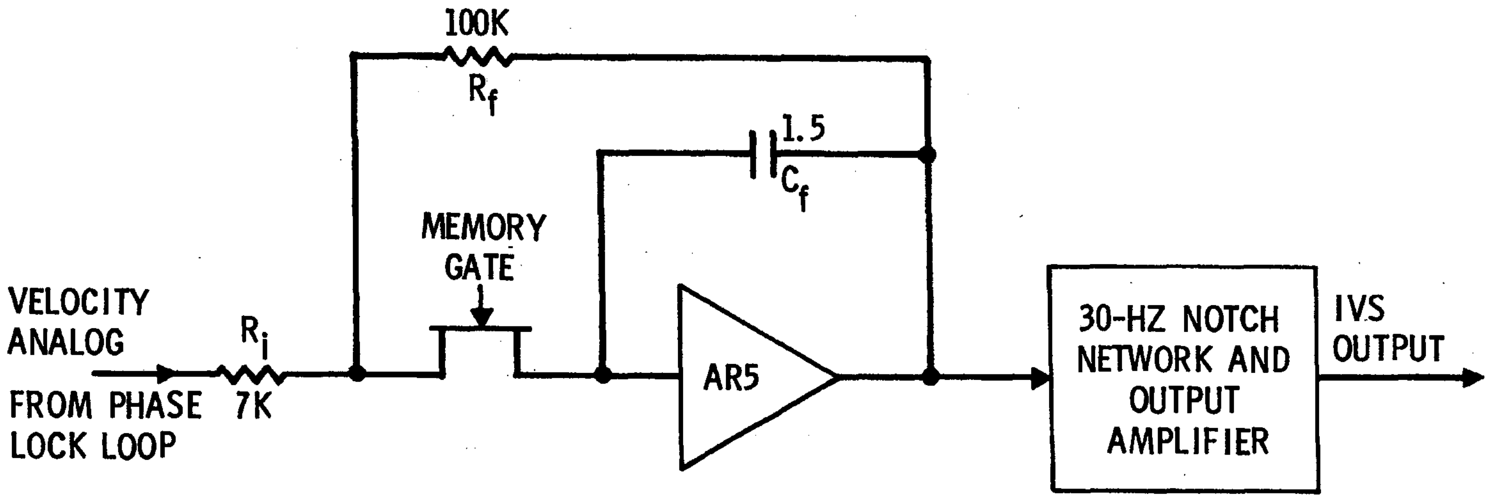
| | REQUIREMENT | PERFORMANCE NOW | PERFORMANCE CDR (EST) |
|---|---|---|---|
| ● GENERATED DISTURBANCE | | | |
| VIBRATION (DURING EXPOSURE) | ≤ 3.0 IN-OZ (ANY AXIS) | MEETS | WILL MEET |
| | ≤ 0.01-LB AXIAL FORCE (ANY AXIS) | MEETS | WILL MEET |
| VIBRATION (DURING SLEW) | 2 X ABOVE | MEETS | WILL MEET |
| RESONANCE | > 55 HZ | MEETS | WILL MEET |
| ACOUSTIC NOISE | PER 3.2.13 OF DR-1100B | MEETS | WILL MEET |

# DEVELOPMENT PROBLEMS AND CORRECTIVE ACTIONS

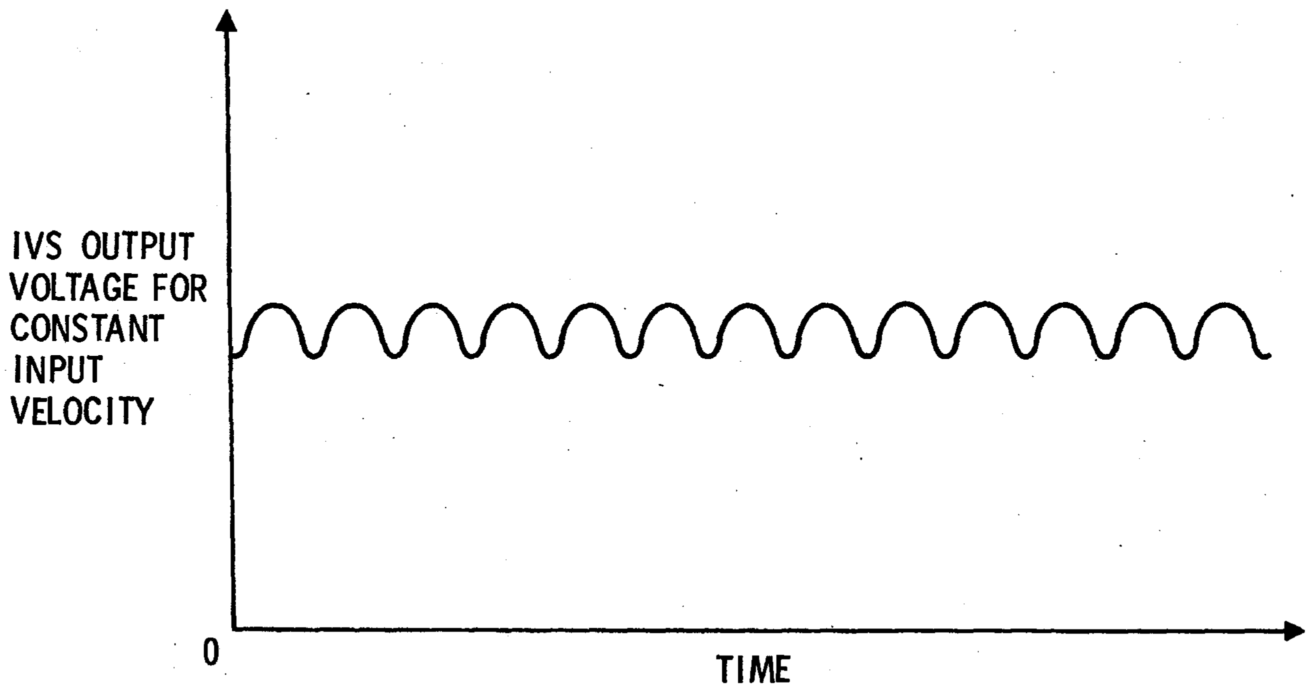
# DROPOUTS



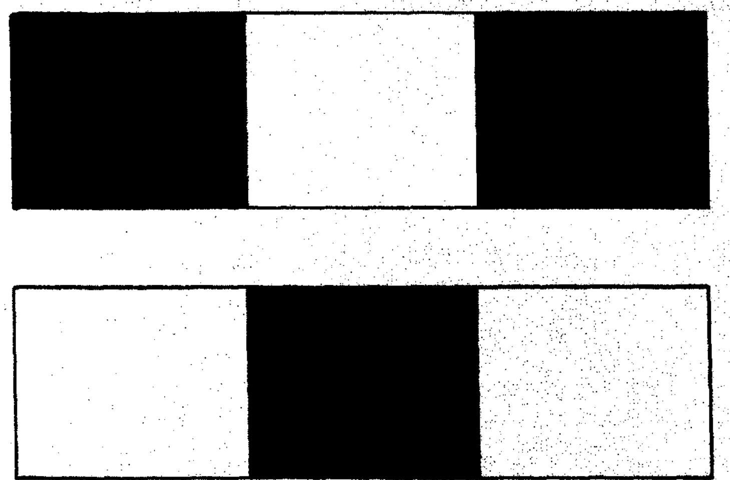
# MEMORY AND OUTPUT



# SCALLOPING

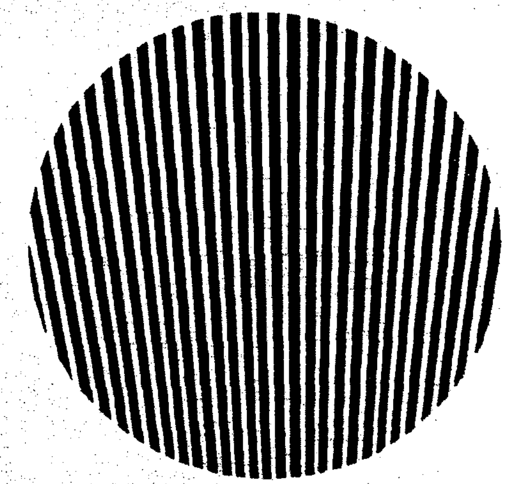


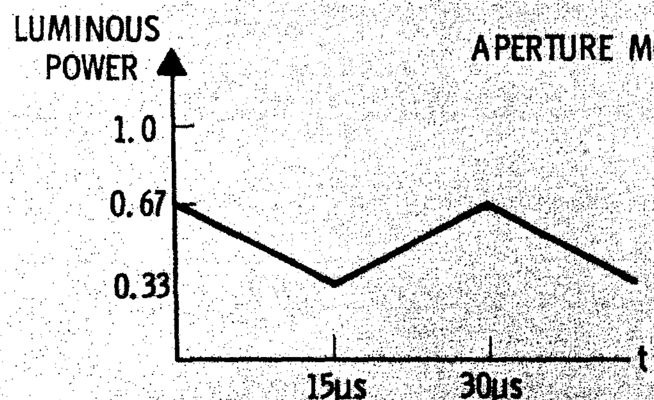
# GAUSSIAN APERTURE



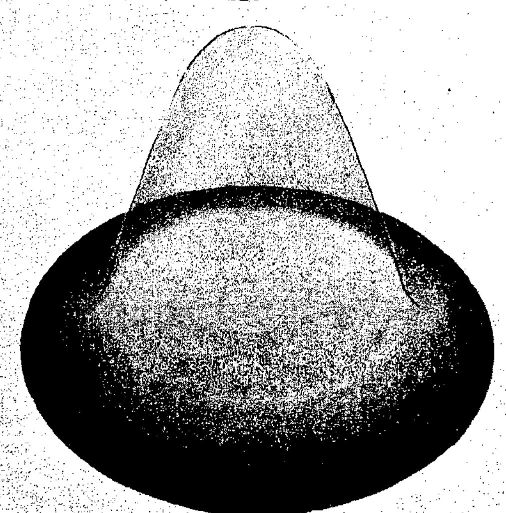
$T_1 = 0.33$

$T_2 = 0.67$

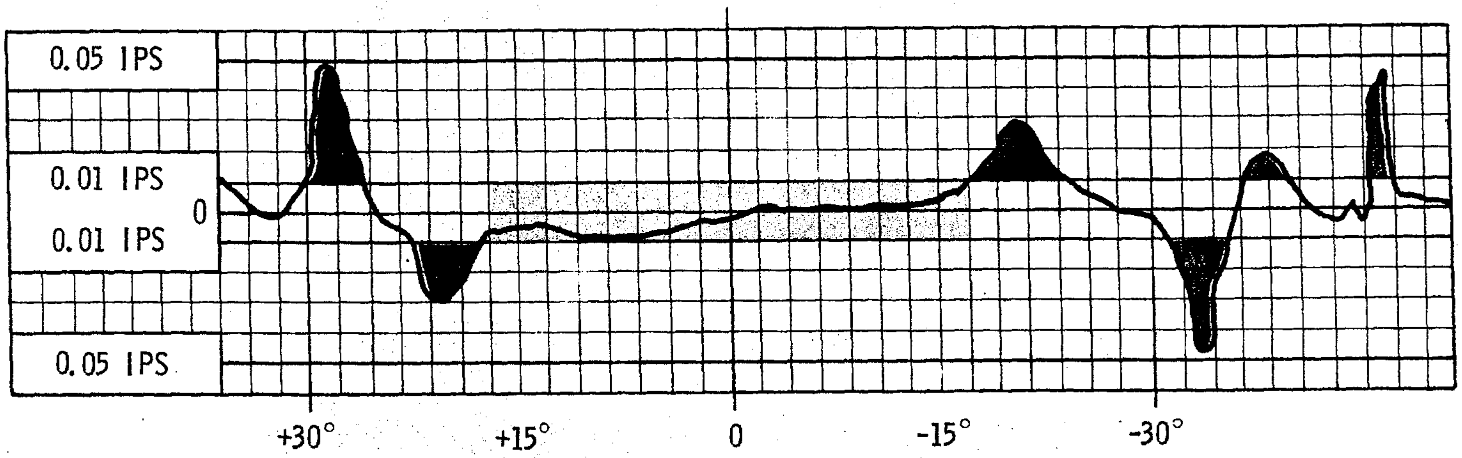


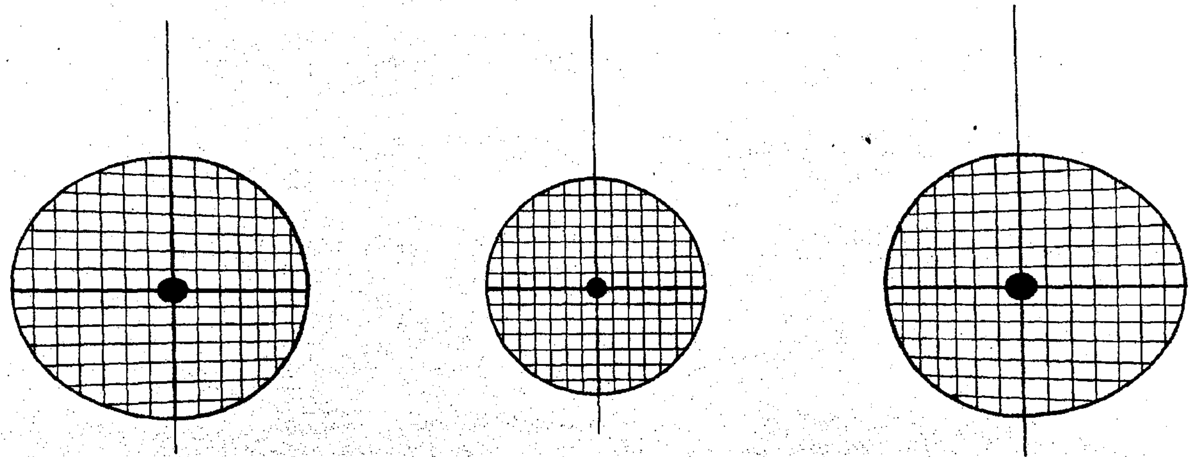



APERTURE MODULATION



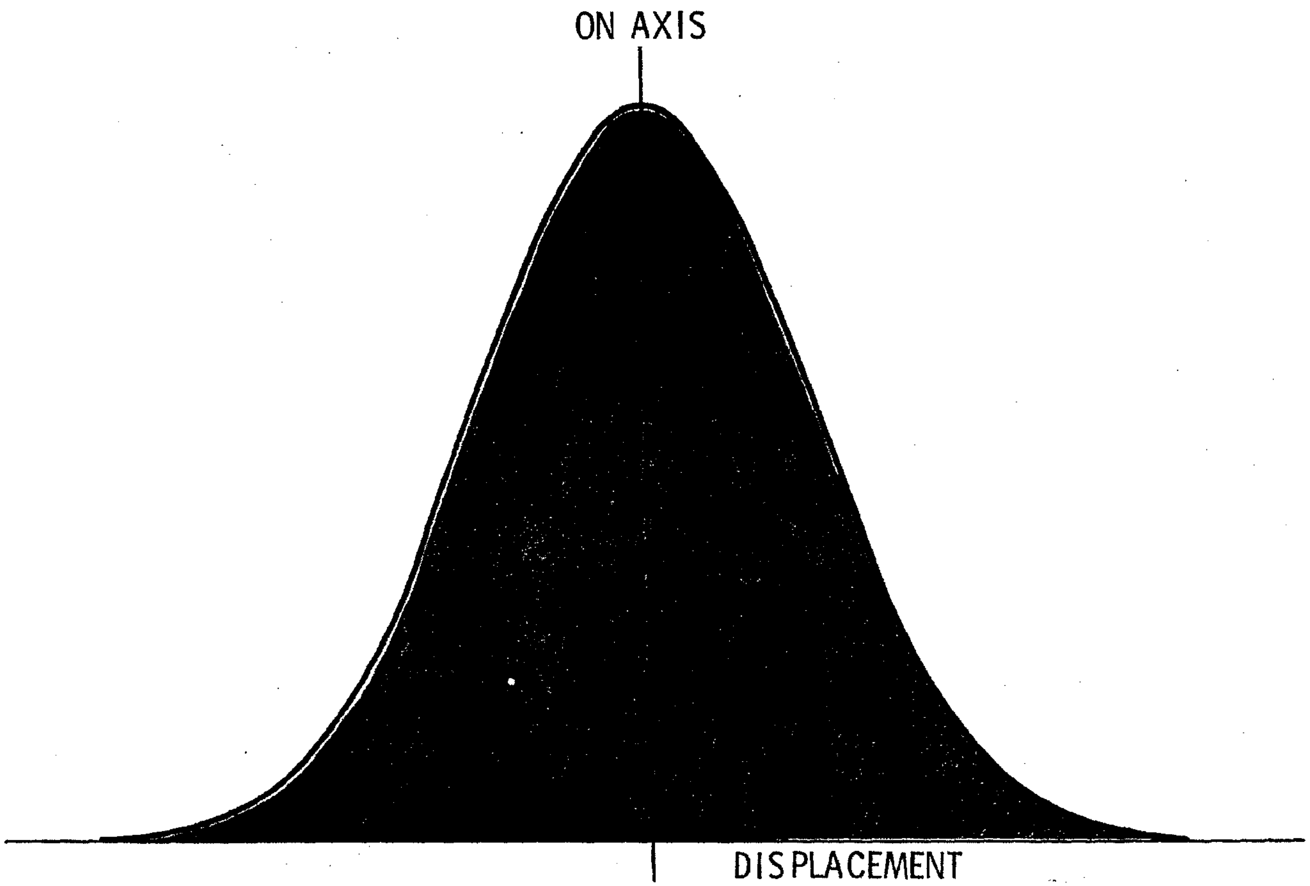
# DYNAMIC NULL



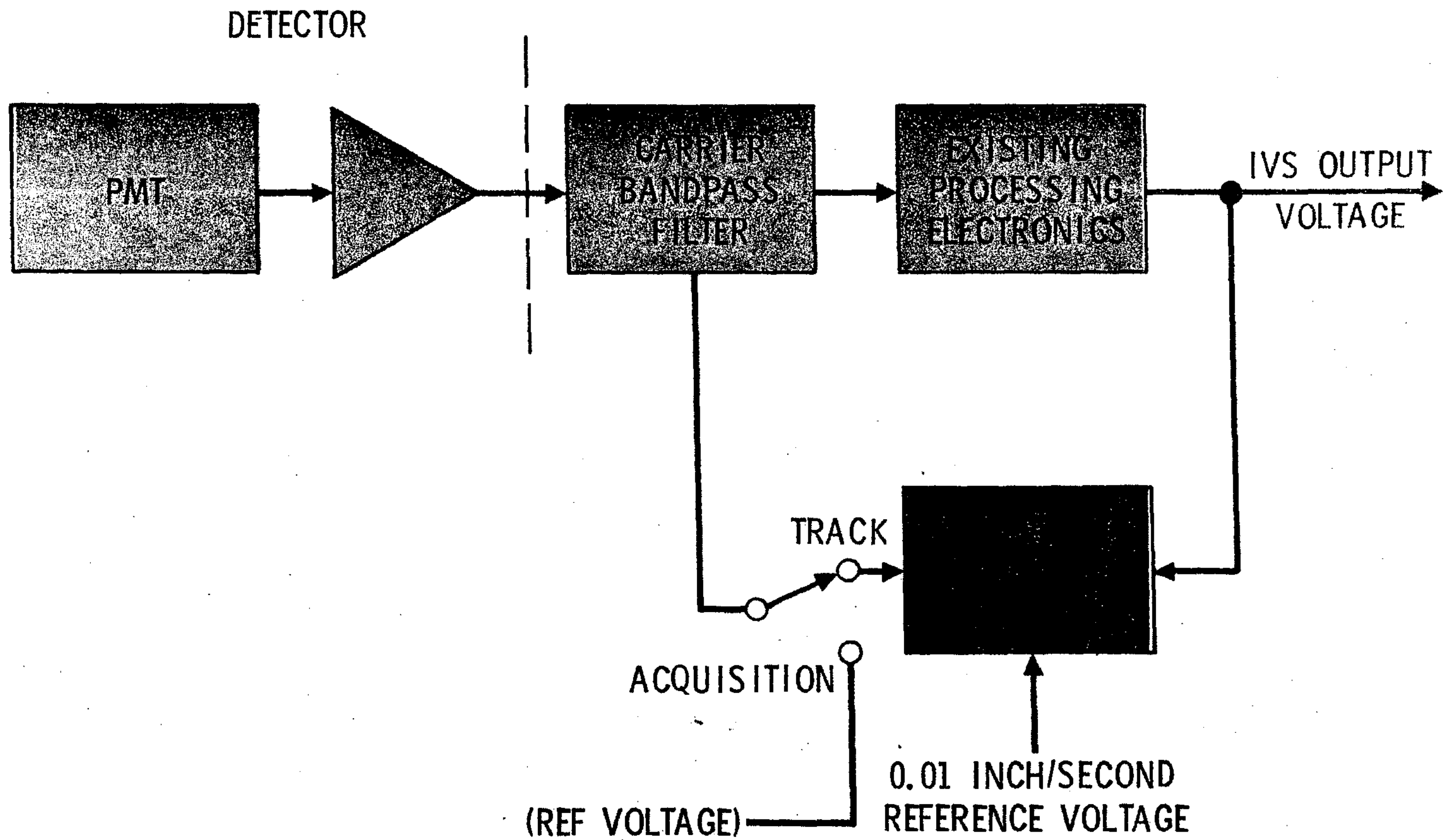
# POSSIBLE SOLUTIONS

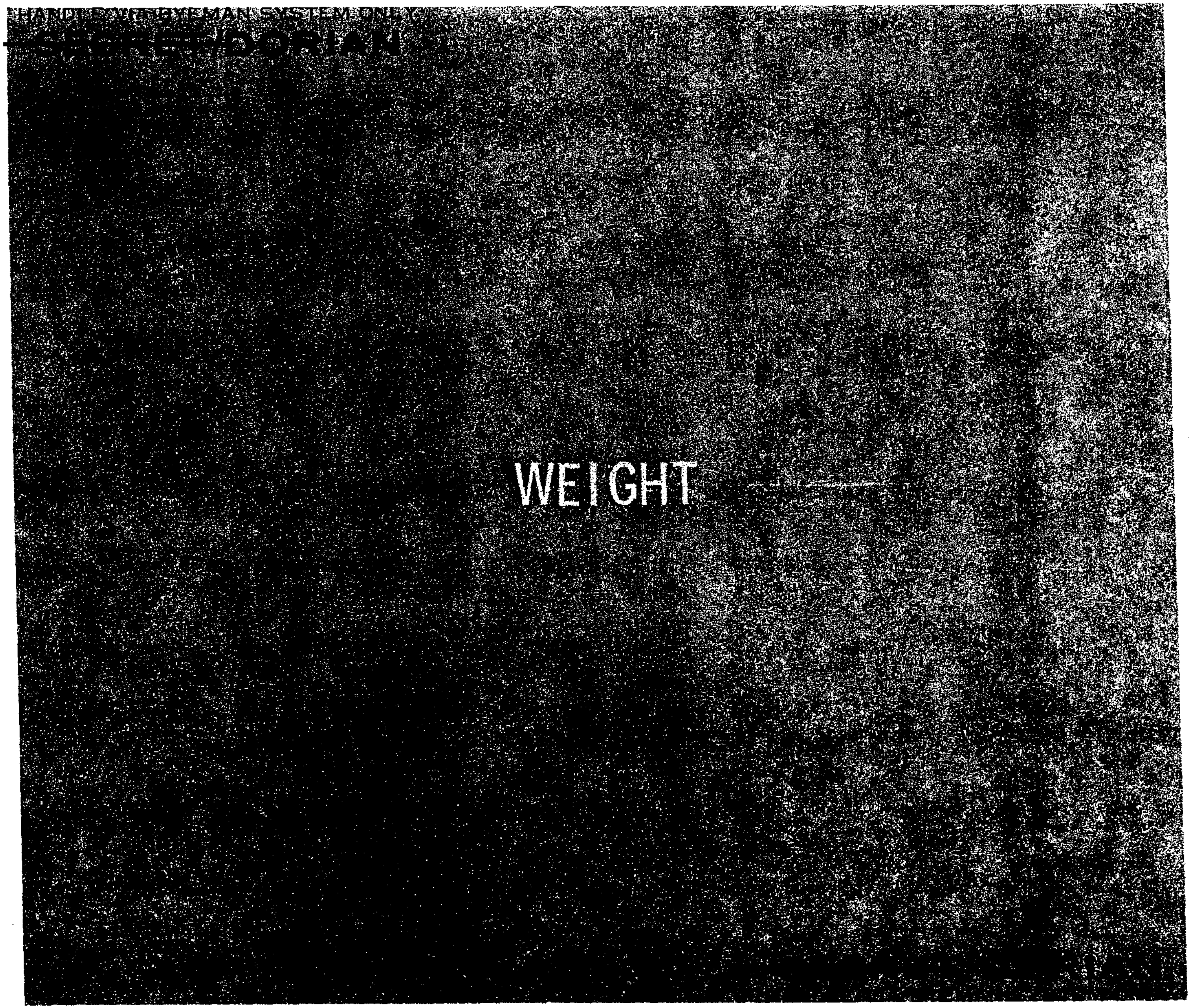
# GAUSSIAN APERTURE



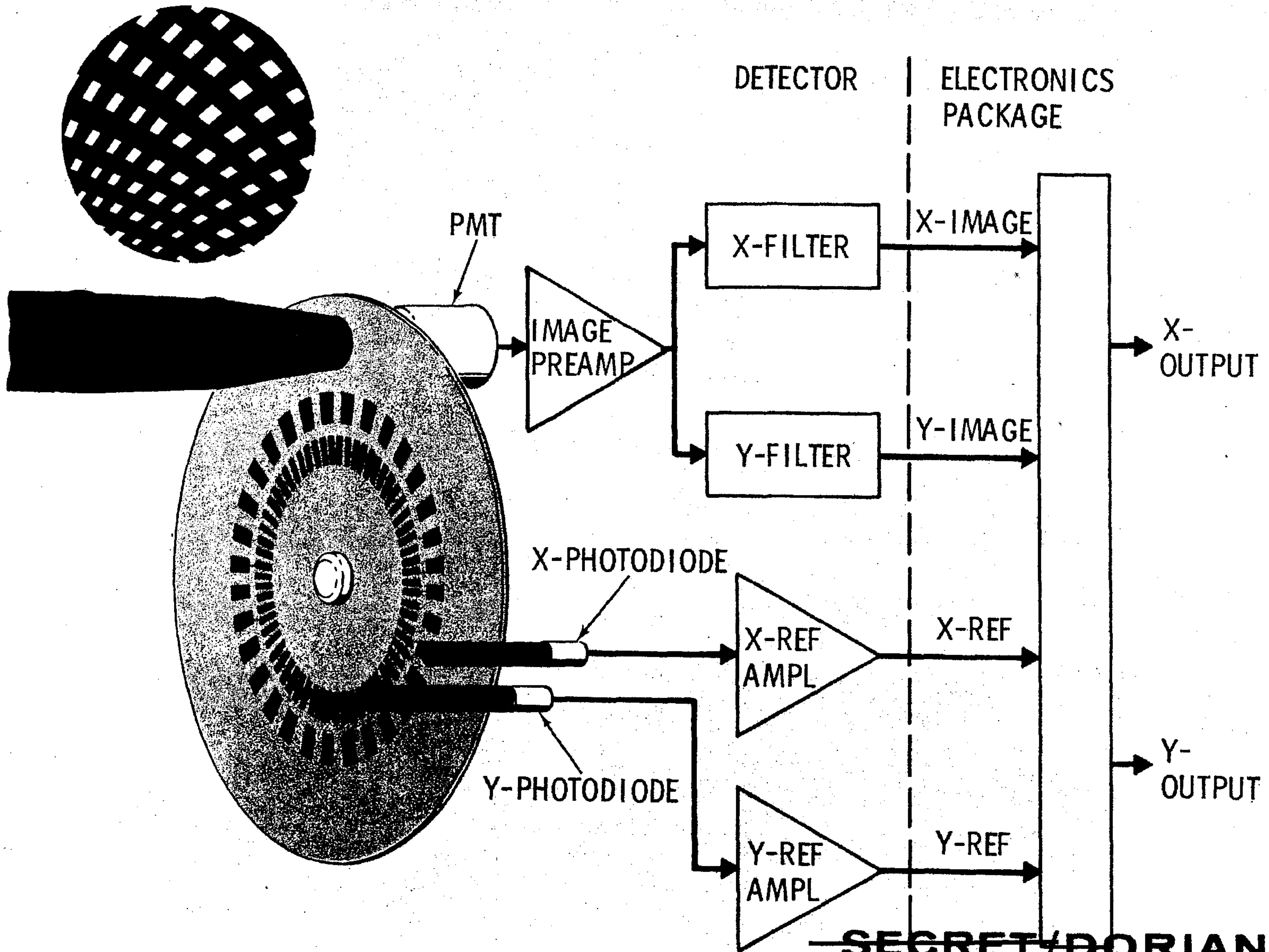

ATTENUATION OF PERIPHERAL ELEMENTS

# ADAPTIVE BANDWIDTH CONTROL

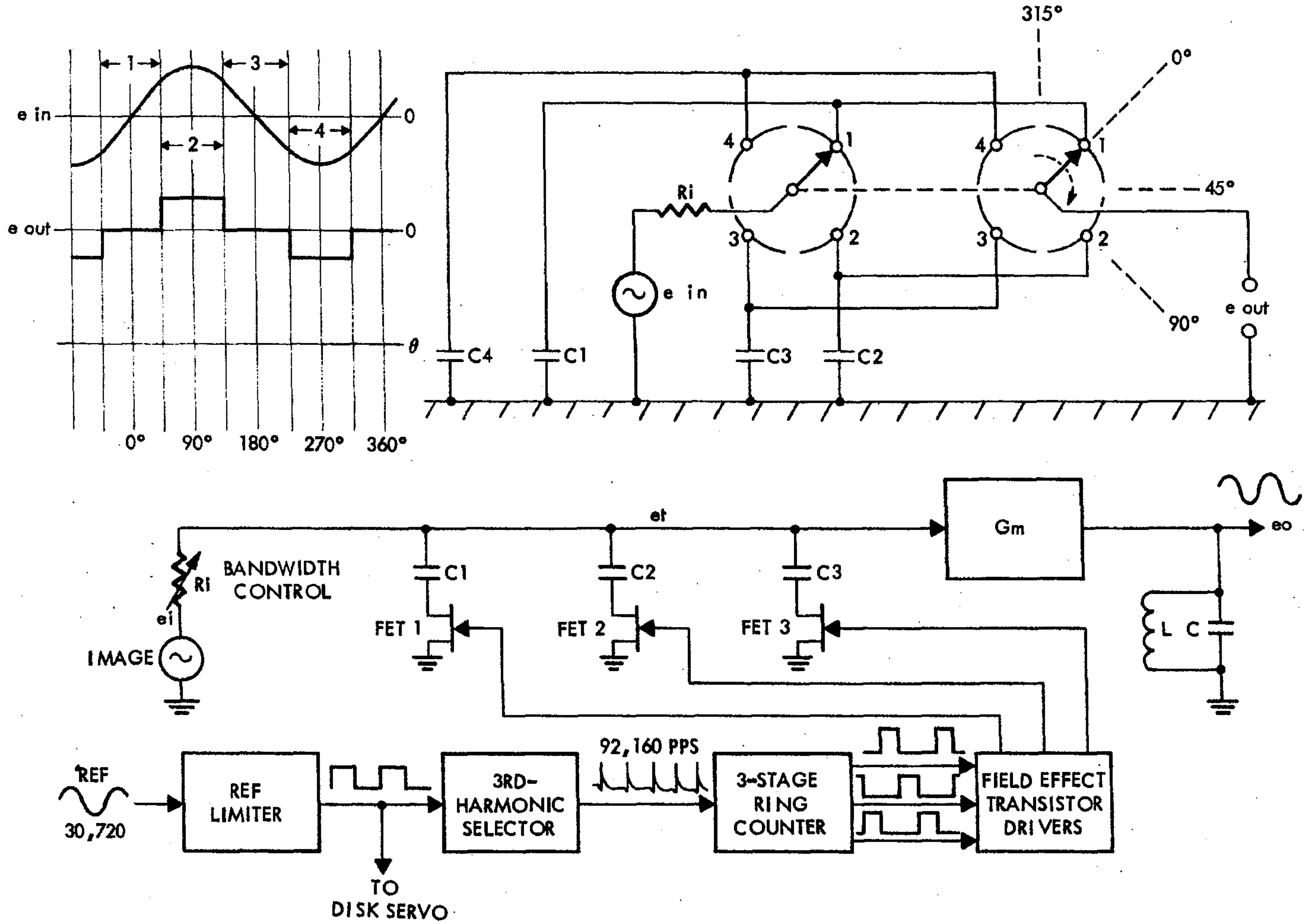



WEIGHT

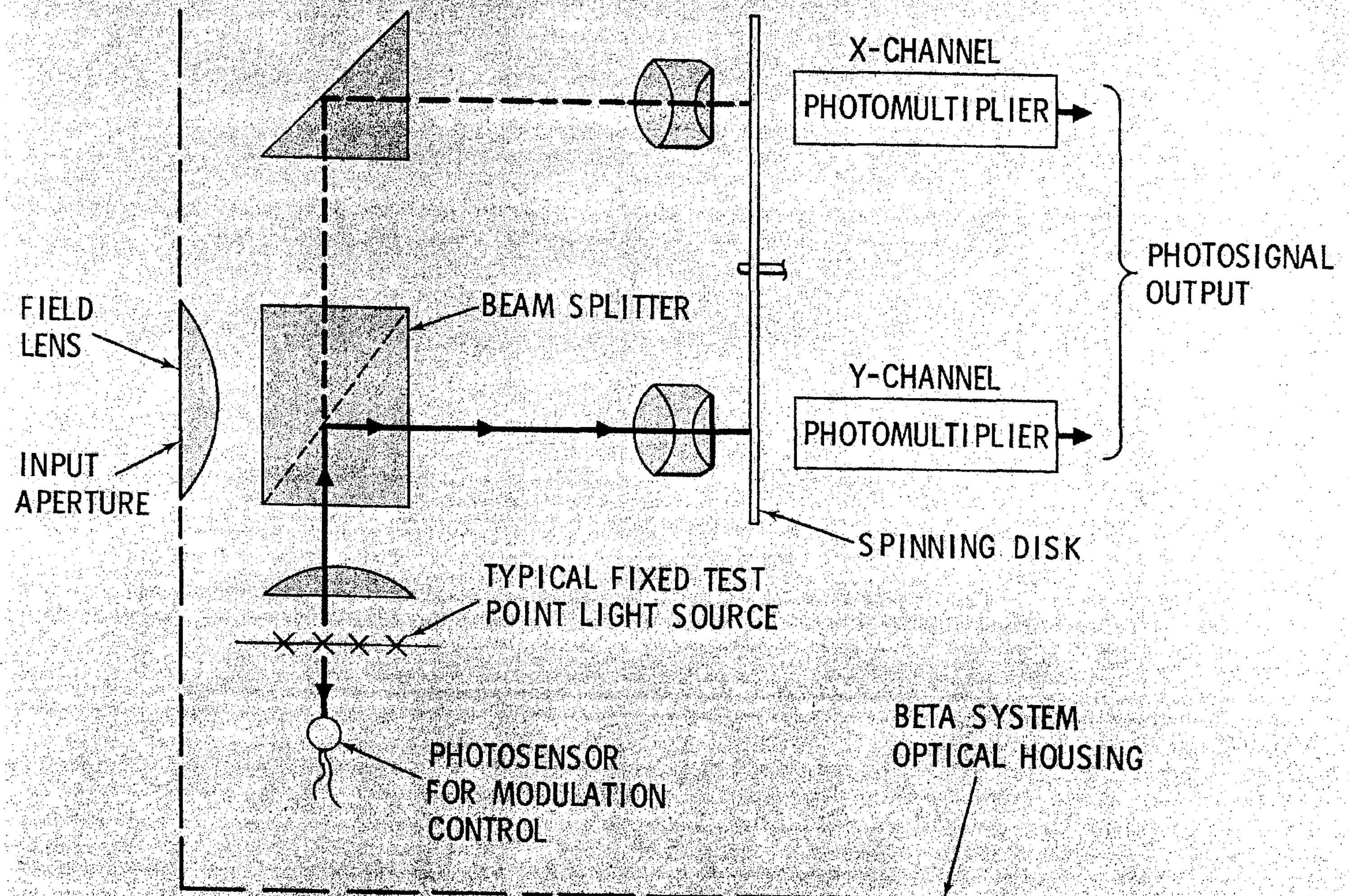
# HERRINGBONE X-Y SENSOR



# THE COMMUTATING FILTER



# SELF TEST

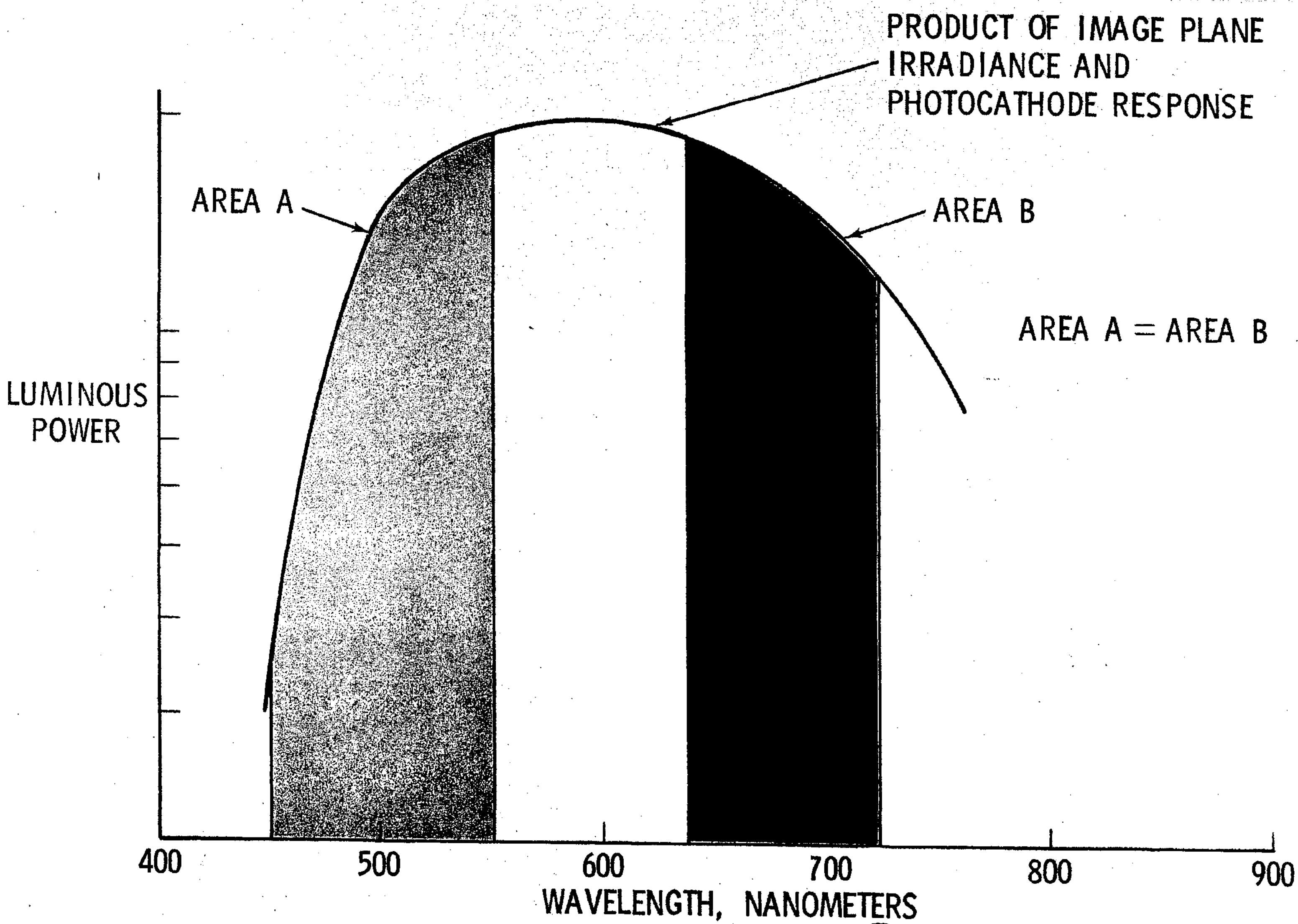

X-CHANNEL
PHOTOMULTIPLIER
PHOTOSIGNAL OUTPUT
FIELD LENS
BEAM SPLITTER
Y-CHANNEL
PHOTOMULTIPLIER
INPUT APERTURE
SPINNING DISK
TYPICAL FIXED TEST POINT LIGHT SOURCE
BETA SYSTEM OPTICAL HOUSING
PHOTOSENSOR FOR MODULATION CONTROL

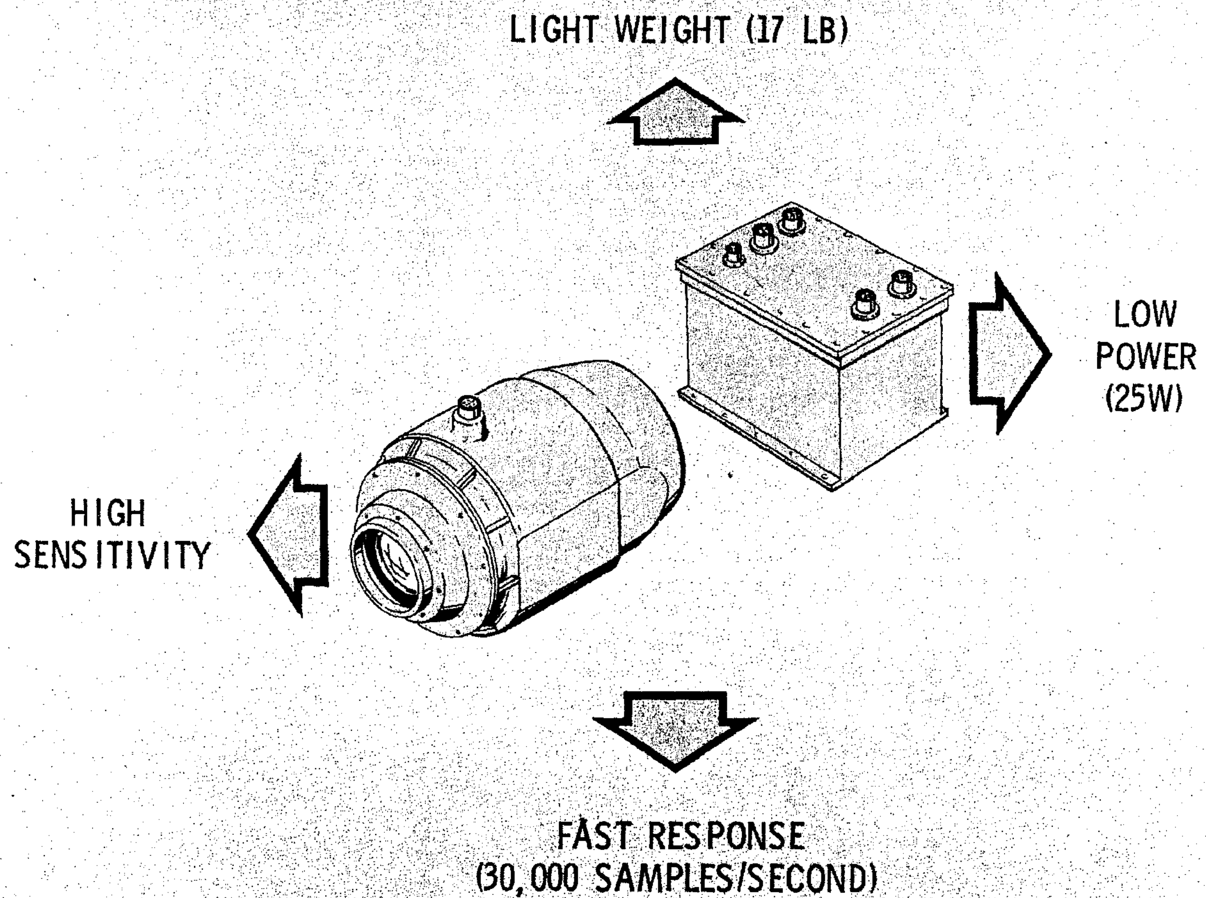
# CLOUD DISCRIMINATION

# CLOUD CANCELLATION-RED AND BLUE FILTERING

- ALTERNATE RED AND BLUE DISK SECTORS.
- EQUAL RESPONSE OF DETECTOR TO RED AND BLUE CLOUD SIGNAL YIELDS NO RESPONSE.
- TERRAIN REFLECTIVITY IS DIFFERENT FROM CLOUD REFLECTIVITY.
- A DIFFERENTIAL RESPONSE BETWEEN RED AND BLUE FILTERING YIELDS A USEFUL SIGNAL AT HIGH SUN ANGLES.

# DISK COLOR STRIPING




LIGHT WEIGHT (17 LB)
LOW POWER (25W)
HIGH SENSITIVITY
FAST RESPONSE (30,000 SAMPLES/SECOND)

GE EVALUATION AND SUMMARY . . . . . S. HOBBS

ITEK IVS STATUS

| PROBLEM | CAUSE | VENDOR SUGGESTED FIX | STATUS |
|---|---|---|---|
| SCENE SENSITIVE BIAS<br><br>INDICATED VELOCITY UNDER STATIC NULL CONDITION | NON LINEARITIES IN SENSOR FRONT END | • MINIMIZE NON LINEARITIES BY FIELD SPLITTING | △ OBSERVED FIX AT ITEK SHOWS THAT FIELD SPLITTING IMPROVED NULL ACCURACY FOR LIMITED SCENES TESTED |
| | | • OFFSET PHASE SENSITIVE DETECTOR TO MINIMIZE STATIONARY BIAS VECTOR | • NEW POINT JUST MADE BY ITEK - GE HAS NOT EVALUATED PROBABILITY OF SUCCESS |
| NON LINEAR RESPONSE GAIN OF SENSOR STRONGLY DEPENDENT ON AVERAGE LIGHT | INHERENT NON-LINEAR RESPONSE OF VIDICON WITH CHANGING ILLUMINATION | • ADD IMAGE INTENSIFIER IN AGC CONFIGURATION TO MAINTAIN CONSTANT HIGH LEVEL OF ILLUMINATION AT VIDICON | ☐ FIX TECHNICALLY FEASIBLE BUT NOT DEMONSTRATED |
| | | • IMPROVE SECOND HARMONIC AGC LOOP | • IMPROVED SECOND HARMONIC AGC LOOP NOT DEMONSTRATED |

## ITEK IVS STATUS (CONT)

| PROBLEM | CAUSE | VENDOR SUGGESTED FIX | STATUS |
|---|---|---|---|
| CROSS COUPLING<br><br>X AND Y AXES NOT INDEPENDENT OF ONE ANOTHER | • USE OFOFF AXIS PATCH FOR CROSS TRACK INFO<br>• DIAGONAL ELEMENTS IN FOV | • ADD BEAM SPLITTER; TAKE BOTH PATCHES FROM CENTER | ☐ DEGREE OF EFFECT-IVENESS UNKNOWN |

GOODYEAR IVS STATUS

| PROBLEM | CAUSE | VENDOR SUGGESTED FIX | STATUS |
|---|---|---|---|
| SENSITIVITY<br><br>ILLUMINATION THRESHOLD TOO HIGH | INHERENT IN CORRELATRON SENSOR | IMPROVED CORRELATRON<br>• HIGHER TRANSMISSIBILITY MESH<br>• LOWER CAPACITANCE STORAGE GRID<br>• MORE SENSITIVE PHOTOCATHODE | ○ CORRELATRON IMPROVEMENTS HAVE DEMONSTRATED A 4:1 INCREASE IN SENSITIVITY<br><br>RECENT TESTS AT GE SHOW ADEQUATE SENSITIVITY FOR IMPROVED CORRELATRON |
| CONTRAST<br><br>INOPERATIVE ON LOW-CONTRAST SCENES, AND HIGH CONTRAST SCENES WITH HAZE | RESULT OF LIMITED LATITUDE OF OPERATION FOR STORAGE GRID OF CORRELATRON | OPTIMIZE TRADE-OFF BETWEEN SENSITIVITY AND OPERATIONAL LATITUDE | ☐ GOODYEAR STILL EXPERIMENTING WITH CORRELATRON AND ITS OPTIMAL OPERATIONAL MODE<br><br>NO DEMONSTRATED SOLUTION TO DATE |

## GOODYEAR IVS STATUS (CONT)

| PROBLEM | CAUSE | VENDOR SUGGESTED FIX | STATUS |
|---|---|---|---|
| DYNAMIC NULL ERRORS | IVS TRACKING CENTER OF POWER | EFFECT NOT PRESENT IN REAL WORLD OPERATION | ☐ GOODYEAR ANALYSIS SHOWS ERROR TO BE COMBINATIONS OF GE TESTER WIDE FOV AND GOODYEAR MODE OF OPERATION. GE HAS PARTIALLY VERIFIED RESULTS BY TESTS |
| RE-CYCLING | REQUIREMENT TO UP-DATE STORED IMAGE | RE-CYCLE TIME CUT FROM 0.48 SEC TO 0.28 SEC MAX | ○ IVS WILL EXTRAPOLATE LAST VALID DATA THROUGH RE-CYCLE PERIODS |

# HYCON IVS STATUS

| PROBLEM | CAUSE | VENDOR SUGGESTED FIX | STATUS |
|---|---|---|---|
| DYNAMIC NULL ERROR<br><br>ERRONEOUS INDICATED VELOCITIES IN EXCESS OF 0.10 IPS AT ORBITAL NULL | • IVS TRACKING CENTER OF PWR<br><br>• SCENE ELEMENTS LEAVING AND ENTERING FOV | SHADED OPTICAL APERTURE | ☐ GAUSSIAN SHADED APERTURE DETERMINED BY HYCON TO BE OPTIMAL<br><br>GE COMPUTER RUN OF MATH MODEL WITH NON-GAUSSIAN SHADED APERTURE AND 40 POINT SCENE SHOW SOME IMPROVEMENT IN DYNAMIC NULL ACCURACY |
| SIGNAL DROP-OUT AVERAGE - 3 PER RUN DURATION 0.5 SEC | • VECTORIAL SUM OF SCENE ELEMENTS INSTANTANEOUSLY GOES THROUGH ZERO | EXTRAPOLATE LAST VALID DATA THROUGH DROP-OUT PERIODS | ○ FIX IMPLEMENTED IN BB; TESTING INDICATES THAT FIX IS ADEQUATE |
| SCALLOPING SEVERE MODULATION ON TRUE, MEASURED SCENE VELOCITIES | • STATIONARY PHASE VECTOR GENERATED BY CHOPPER MODULATION OF OPTICAL APERTURE | • SIZING OPTICAL APERTURE TO SUBTEND INTEGRAL NO. OF CHOPPER SPOKE PAIRS<br><br>• APERTURE SHADING | ○ FIX DEMONSTRATED ON BB UNIT - APPEARS ADEQUATE |

IVS CRITICAL PROBLEM SUMMARY FROM BB EVALUATION TESTS

| PROBLEM | ITEK | GOODYEAR | HYCON |
|---|---|---|---|
| DYNAMIC NULL | MEETS ○ ○ | EXCESSIVE INDICATED VELOCITY ERRORS ▽ □ | EXCESSIVE INDICATED VELOCITY ERRORS ▽ □ |
| SIGNAL LOSS DURING TRACK | MEETS ○ ○ | RECYCLE □ ○ | SIGNAL DROPOUT ▽ ○ |
| ILLUMINATION SENSITIVITY AND CONTRAST | MEETS ▽ ○ | FAILED ▽ □ IMPROVED | MEETS ○ ○ |
| CROSS COUPLING | SEVERE FOR SOME SCENES ▽ □ | MEETS ○ ○ | MEETS ○ ○ |
| LINEARITY | NONLINEAR WITH LIGHT CHANGES ▽ □ | MEETS ○ ○ | MEETS ○ ○ |
| SCENE SENSITIVE BIAS | BIAS EXCEEDS WHOLE ERROR ALLOTMENT ▽ ▽ | MEETS ○ ○ | MEETS ○ ○ |
| SCALLOPING | MEETS ○ ○ | MEETS ○ ○ | MODULATED VELOCITY INDICATION □ ○ |

PRESENT STATUS

# PLANNED EVALUATION ACTIVITY - PHASE II

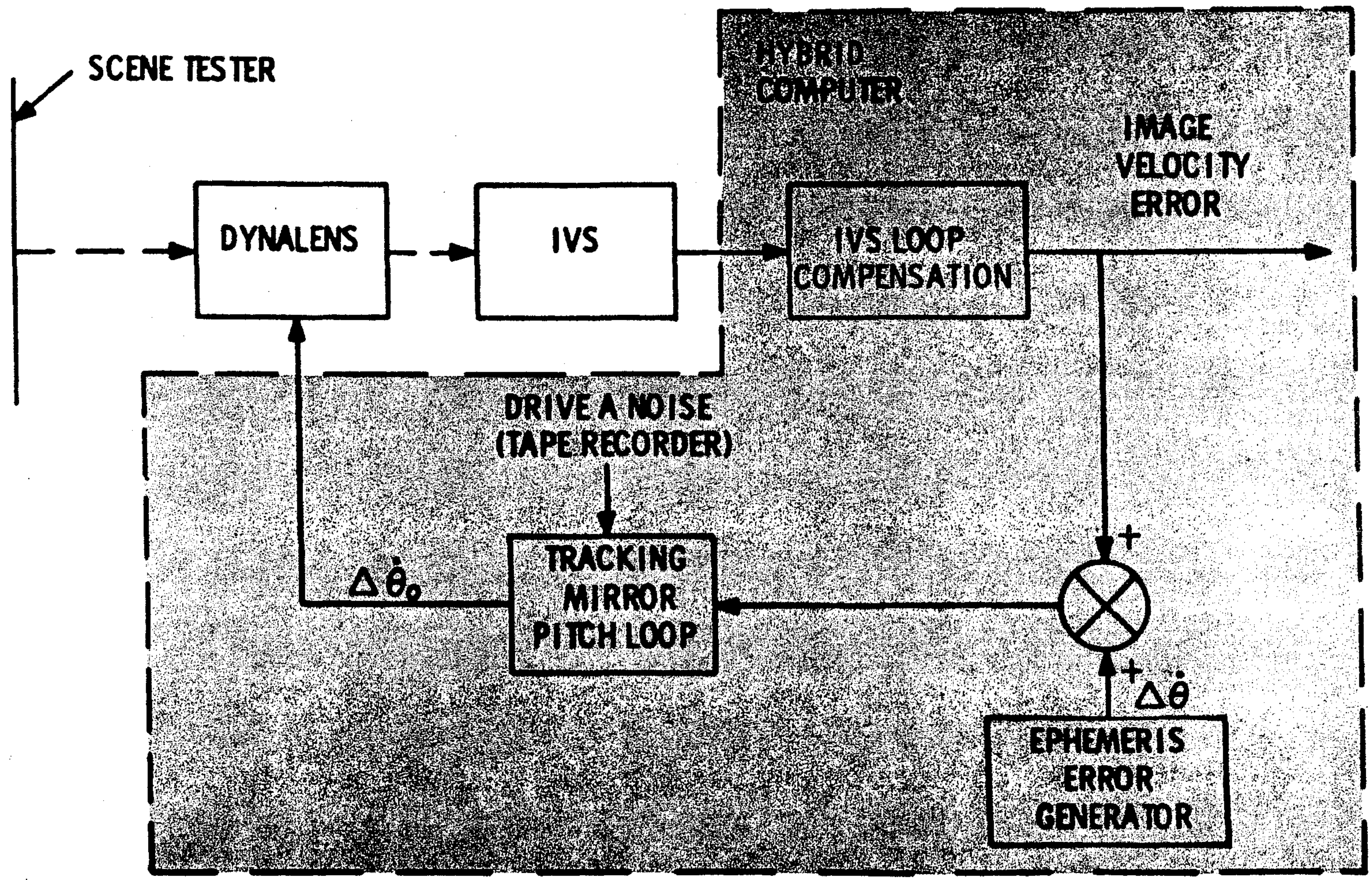
STUDIES

- MATH MODELS AND ANALYSIS
- DSS-1 TEST CONCEPTS
- FLIGHT TESTS

TESTING

- SCENE MATERIAL - 3D, COLOR
- CLOSED LOOP
- PROTOTYPE SENSORS
- CLOUD SIMULATION

# CLOSED LOOP CONCEPT
(PITCH AXIS ONLY)



# CLOSED LOOP TESTING STATUS

ACCOMPLISHMENTS TO DATE

- SIMULATION OF TRACKING MIRROR DRIVE BY HYBRID COMPUTER
- CLOSED LOOP BASELINE IN PITCH AXIS FOR HYCON AND GOODYEAR IVS UNITS

RESULTS TO DATE

- HYCON AND GOODYEAR UNITS STABLE IN PITCH
- NULL OFFSET IN SENSOR TRANSFERRED TO TM DRIVE

REQUIREMENTS RELATIONSHIP

SPDR / CEI SPECIFICATION / COMPONENT SPECIFICATION

## System Performance and Design Requirement (SPDR)

3.0.1.1.1 Photographic Requirements

[redacted] Resolution Photography (On Axis)
with:
2:1 contrast
890 ft lamberts (avg scene light at aperture)
At Nadir - 80 n mi orbit
Focus Error - [redacted]
[redacted] smear rate (1 sigma)

3.1.1.6.23
Smear Rate Limits and Tracking Mirror Target Acquisition Time

Slew and settle time = $\frac{\Delta\theta}{6}$ + N

| | LOS Accuracy | N |
|---|---|---|
| Without IVS | 540 | 3 |
| With IVS | [redacted] | 4 |

*RSS of vibration, servo and IVS - no cross format IMC, target not obscured by clouds.

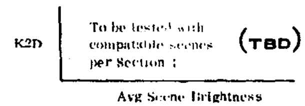
3.3.3.1.2
Total Navigation Control System (NCS) Contribution to Smear

- Smear limit for IVS - [redacted] (.95P)
- NCS limit exclusive of IVS contribution [redacted] (.95P) Vector Sum

## Contract End Item Specification (CEI)

3.1.1.2.8.3.5.3 C IVS Light Level Performance

- IVS shall operate to specification over Weiner Spectrum Range defined by




3.1.1.2.8.5 Tracking Rate (With IVS) in Automatic Operation MA&A

- Image Velocity Sensor Image characteristics (e.g. alignment, centering, focus, transmittance, etc)
  *Note - will be removed from CEI via IFS

3.1.1.2.8.3.2.4 Tracking Mirror Rate Accuracy With Vernier Correction Provided by IVS

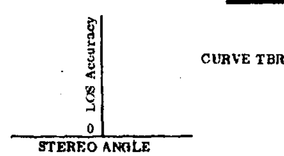
(Same as on Page 4)

3.1.1.2.8.3.3 Time Between Targets

| Mode | IVS Vernier Correction | LOS Rate Accuracy (.95p) | N |
|---|---|---|---|
| Manned Automatic | No | 540 μ rad/ sec | 3 |
| | Yes | [redacted] | 4 |
| Automatic | No | 540 μ rad/ sec | 3 |
| | Yes | [redacted] | 4 |

*3.1.1.2.8.3.2.4 Tracking Mirror Rate Accuracy With Vernier Correction Provided by IVS

Provide means for automatic sensing and correction of LOS rate error from ±540 μ rad/ sec to [redacted] (0.95P) stereo and obliquity vector sum in accordance with Figure A. A vibration error of [redacted] (0.95P) is included in the [redacted] (IVS error plus tracking mirror drive error RSS to [redacted]




Maximum IVS contribution [redacted] when IVS plus tracking mirror drive RSS to [redacted]

TBD percent of area of IVS image within TBD feet of target altitude.

Performance shall be satisfied with either IVS in the control loop (A mode) and with IVS in the control loop (MA mode)

## IVS - Specification EC701 (Rev-4)

3.2.1.2.4.2 Characteristics of Component Images

d. Average irradiance in component image - specified in terms of nanowatts/cm$^2$/ 10 nanometers by maximum and minimum curve
f. Image contrast and spatial frequency distribution GE to provide set of standard scenes
   Expected range of Wiener spectrum gain and roll off characteristic are TBD.

3.1.1.1.1 Image Velocity Output Signals

c. Noise and bias
   See Sheet 3

## System Performance and Design Requirement (SPDR)

3.1.1.6.26
Image Velocity Compensation

- Sense and control velocity, automatically at the center of format - (compliant w/3.1.1.6.23)
- Utilize portion of scene imagery diverted from main optical system

3.3.3.2.1.5
Image Velocity Sensing

- Image Velocity Sensing shall be provided by the NCS
- Operate, compliant with 3.1.1.6.23, at center of format
  - $5^{\circ}$ sun angle minimum
  - 5% of image forming light (with adequate modulation)
- Two IVS systems for automatic

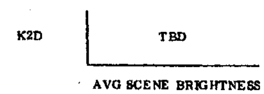
## Contract End Item Specification (CEI)

3.1.1 Functional Characteristics
(c) Provide capability to automatically null the LOS rate error utilizing an IVS - Manned Automatic

3.1.1.2.8.3.5 Image Velocity Sensor
3.1.1.2.8.3.5.1 General
Sense and measure residual image velocity within central 2.8 inch of the 9.4 inch COA image.

3.1.1.1 Mission Requirements
Operate, in automatic mode, with a minimum sun angle of $5^{\circ}$ in an orbital pass between $80^{\circ}$N and $80^{\circ}$S latitude.
3.1.1.2.8.3.5.3 C IVS Light Level Performance

- IVS shall operate to spec over Wiener spectrum range defined by




3.1.1.2.8.3.5.2 Image Velocity Sensors provided single (nonredundant) IVS for MA mode. Two (redundant) IVS systems for A mode

## IVS - Specification EC701 (Rev-6)

3.3.1 Functional Characteristics
Sense translational image velocity of center of format, resolve into two vector components

3.1.1.1.1 Image Velocity Output Signals
16.67 V/IPS - Absolute value with polarity sense signal

a) Dynamic range - 0 to 0.3 IPS (0 to 600 μrad/sec)
b) Linearity - Large signal ±25%
   - Null region ±10%
c) Noise and bias - null region total of noise plus bias at tracking mirror less than 0.01 IPS 2 sigma
   Large signal - noise plus bias at tracking mirror requirement 0.01 IPS at 0.02 IPS (increases linearily to 0.03 IPS at 0.3 IPS)
d) Saturation - shall not saturate for indicated image velocities less than 0.3 IPS, polarity correct up to 0.5 IPS, recovery from saturation within 0.1 sec if saturation less than 2 seconds, 0.5 second if saturation in excess of 2 seconds.
e) Frequency response - 1st order lag with break frequency greater than 1 Hz

3.2.1.2.4.2 Characteristics of Component Images

a) Image format - [redacted]
b) Image dynamic effects - image rotation, blooming, shearing will result from tracking scenes from +30 degrees to -40 degrees in stereo and obliquity angles between ±40 degrees.
c) Location of image plane - 4.93 inches from intersection of component axis and secondary pellicle or mirror. Plane will shift total of 0.041 inches over altitude range of 70 to 230 miles. MTF for these defocused conditions shown by curves.
g) Uniformity of image irradiance - for uniformly reflecting target variation from center shall not exceed ±5%.
h) Polarization - at 550 nanometers degree of linear polarization will be approximately 0.80

$$P = \frac{H\,max - H\,min}{H\,max + H\,min}$$

where
P = Degree of polarization
H = Irradiance measured through linear polarizer at orientations which produce max/min irradiance

3.2.1.2.2.1 A/D Converter - GE will provide A/D converter to be incorporated into component electronics box by vendor.

3.2.1.2.3.4 Alignment

a. Rotation - X, Y electrical axes aligned to mounting base within 0.5 degrees.
b. Centering - intersection of X, Y electrical axes located to center of mounting base to ±0.005 inch.
c. Tilt - optical axes of X, Y shall be normal to mating face within 6 minutes of arc.

| System Performance and Design Requirement (SPDR) | Contract End Item Specification (CEI) | IVS Specification EC701 (Rev-6) |
|---|---|---|
| <u>3.3.13.2.3.1</u><br><u>Visual Optics</u><br>Target viewing shall be provided with the IVS in or out of operation. | <u>3.1.1.2.8.3.5.3 D</u><br><u>IVS Performance with Sliding Pellicle (MA)</u><br>• IVS shall operate to specification over a range of sun angles from 15 degrees to 90 degrees with the sliding pellicle reflecting scene imagery to the IVS | 3.2.1.2.4.2d Characterics of Components Input Images<br>d. Average irradiance in component image specified by min/ max curve |
| • The GE-AVE (Mission Module Subsystem) shall provide a cloud detection capability utilizing IVS outputs | 3.1.1.2.8.3.5.4 Image Velocity Sensor (IVS) Anomalies<br>• Signals available from IVS in performance of primary function shall be processed<br>• Objective of processing - to detect conditions of probable invalid IVS image rate measurement<br>• Either<br>- Inhibit photography<br>- Inhibit IVS loop<br>- Warn astronaut | 3.1.1.1.2 Lock on Signal - Provide signal for each axis indicating sensing input condition within 0.3 IPS<br>3.1.1.1.3 Operational Readiness Signal - Provide signal indicating ability to perform requirements of this specification when provided with appropriate stimuli<br>3.1.1.1.5 Subthreshold Irradiance Signal - The components shall indicate that average irradiance in primary image is insufficient for performance within requirements of this specification<br>3.2.1.2.2.3 Monitor and Alarm S/S - Two signals required as absolute value of rate signal<br>a. 4V = 0.3 IPS<br>b. 4V = 0.03 IPS<br>output impedance 10K or less. |
| | 3.1.1.2.8.3.5.3 A Self Test Capability<br>• Remove IVS from control loop<br>• Exercise self test option<br>• Indicate results to astro and AVE computer | No requirement at present |
| | 3.1.1.2.8.3.5.3 B Operability<br>• IVS shall operate over full range of TM gimbal angles given in 3.1.1.2.8.3.1.3 *3.1.1.2.8.3.1.1 | 3.2.1.2.4.2 Characteristics of Component Image<br>See 3.2.1.2.4.2b Sheet 7 |

PROGRAM ASSESSMENT. . . . . MAJOR GENERAL JOSEPH BLEYMAIER

MAJOR GENERAL JOSEPH BLEYMAIER CLOSED THE FORMAL MEETING OF 20 SEPTEMBER 1968 WITH A VERBAL SUMMARY OF THE IMAGE VELOCITY SENSOR SUBSYSTEM