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PROGRESS TOWARD DEVELOPMENT AND DEMONSTRATION OF OPTICAL COMMUNICATIONS FOR NASA'S FUTURE MISSIONS

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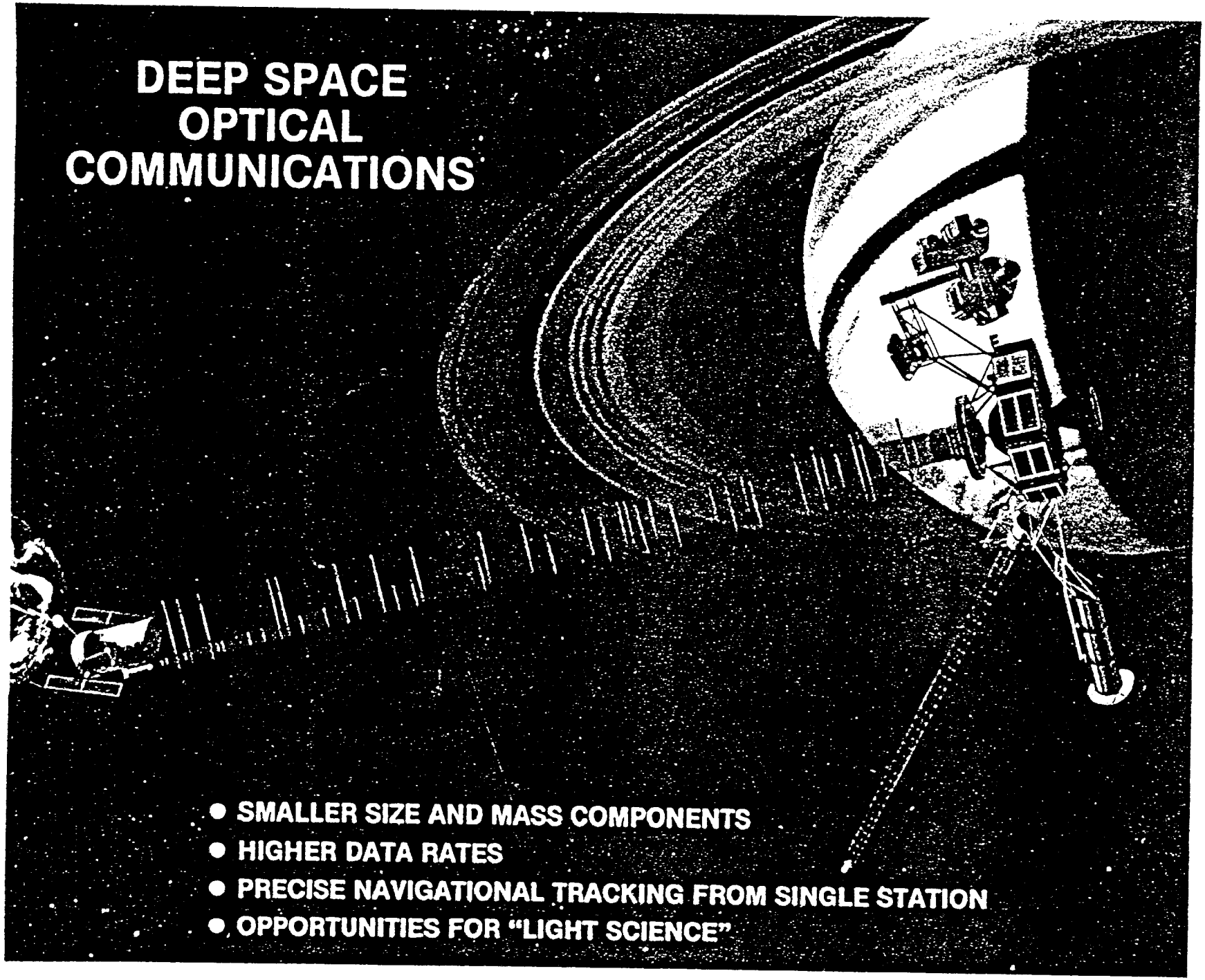
DEEP SPACE
OPTICAL
COMMUNICATIONS
● SMALLER SIZE AND MASS COMPONENTS
● HIGHER DATA RATES
● PRECISE NAVIGATIONAL TRACKING FROM SINGLE STATION
● OPPORTUNITIES FOR "LIGHT SCIENCE"

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NASA's FUTURE COMMUNICATIONS NEEDS

- **MORE COMMUNICATIONS CAPACITY**

  CURRENT MISSIONS CARRYING ANTENNAS OVER LAUNCH TO IMPROVE PERFORMANCE

  GALILEO REQUIREMENTS PROVE NEED FOR UNFURLABLE ANTENNA

  FUTURE MISSIONS WILL DO MORE IN-DEPTH INVESTIGATIONS (INCLUDES MULTI-SPECTRAL IMAGES)

- **LESS IMPACT ON HOST SPACECRAFT**

  FOCUSING ON MICRO-SPACECRAFT MISSIONS

  LOWER MASS, SIZE AND POWER

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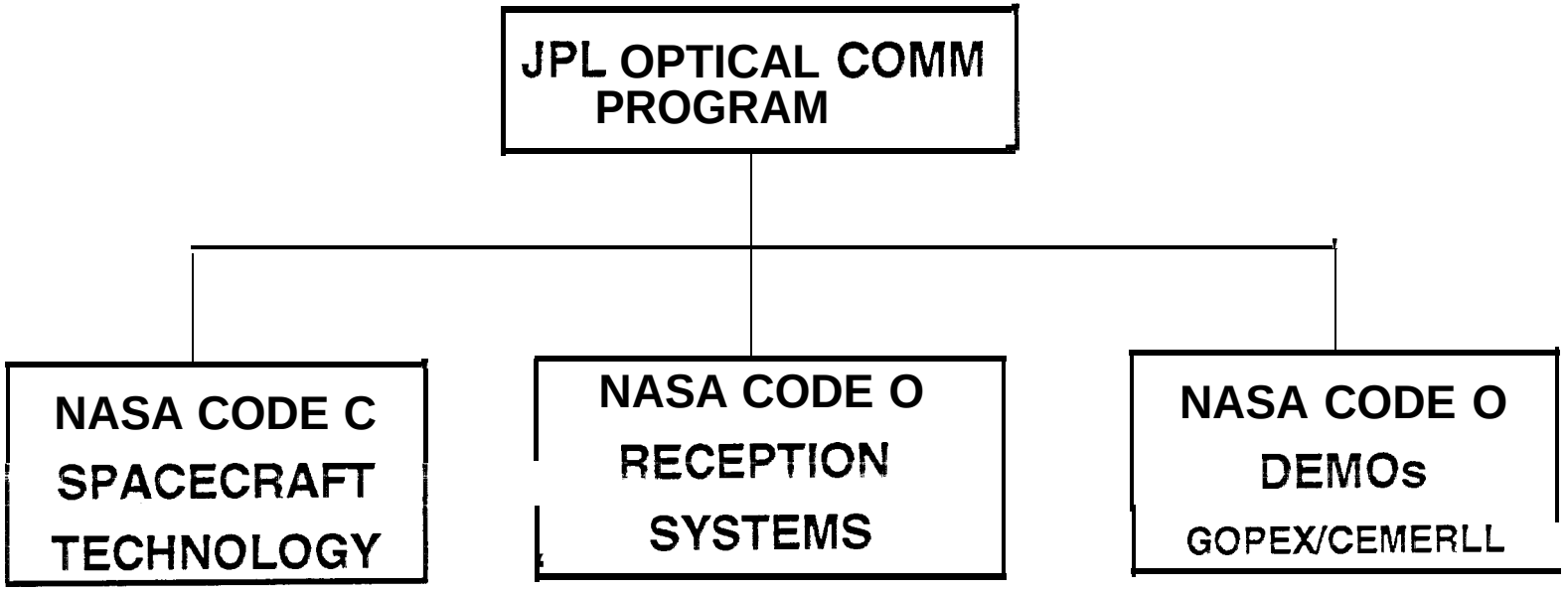
OPTICAL COMMUNICATIONS PROGRAM STRUCTURE



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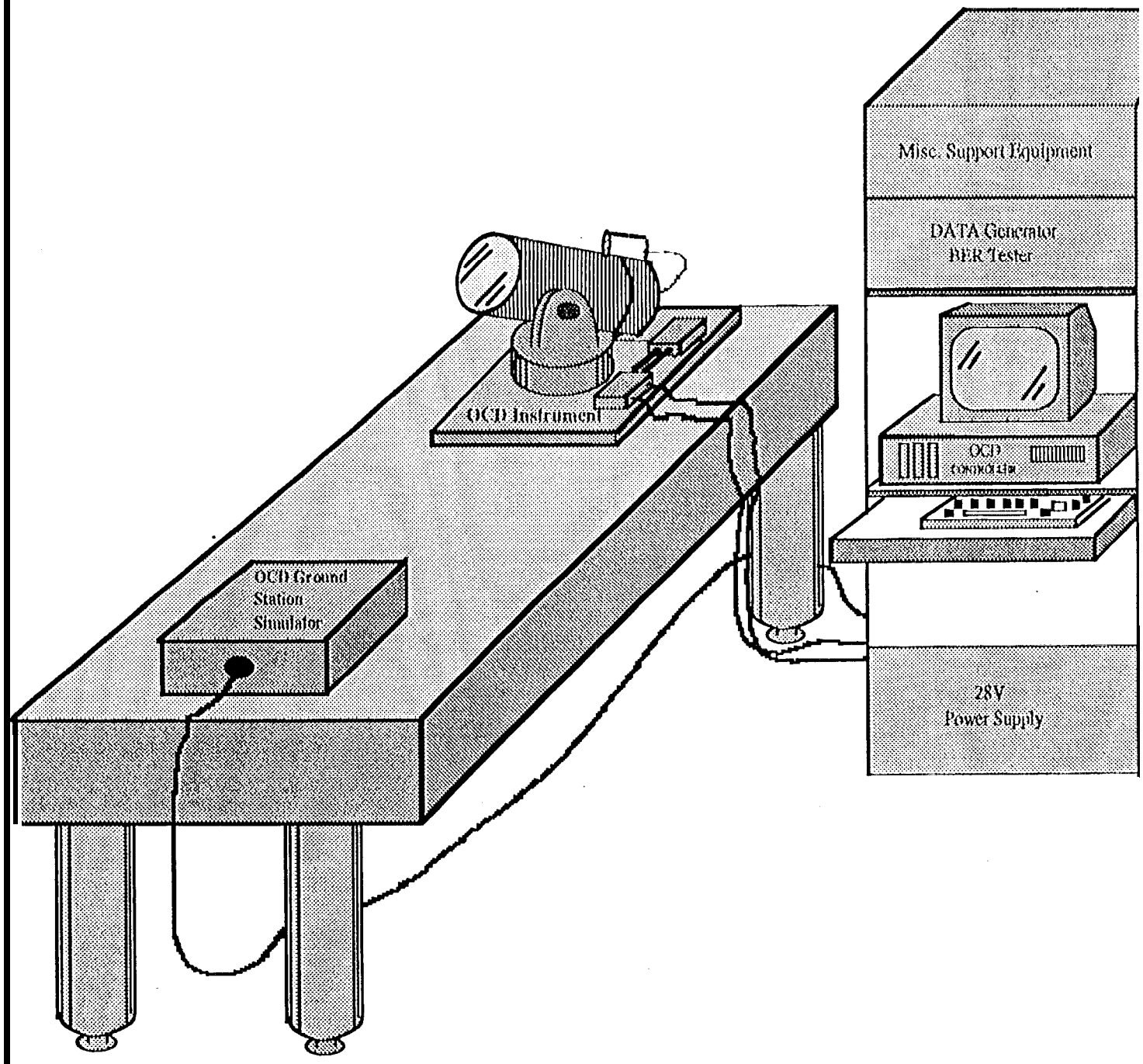
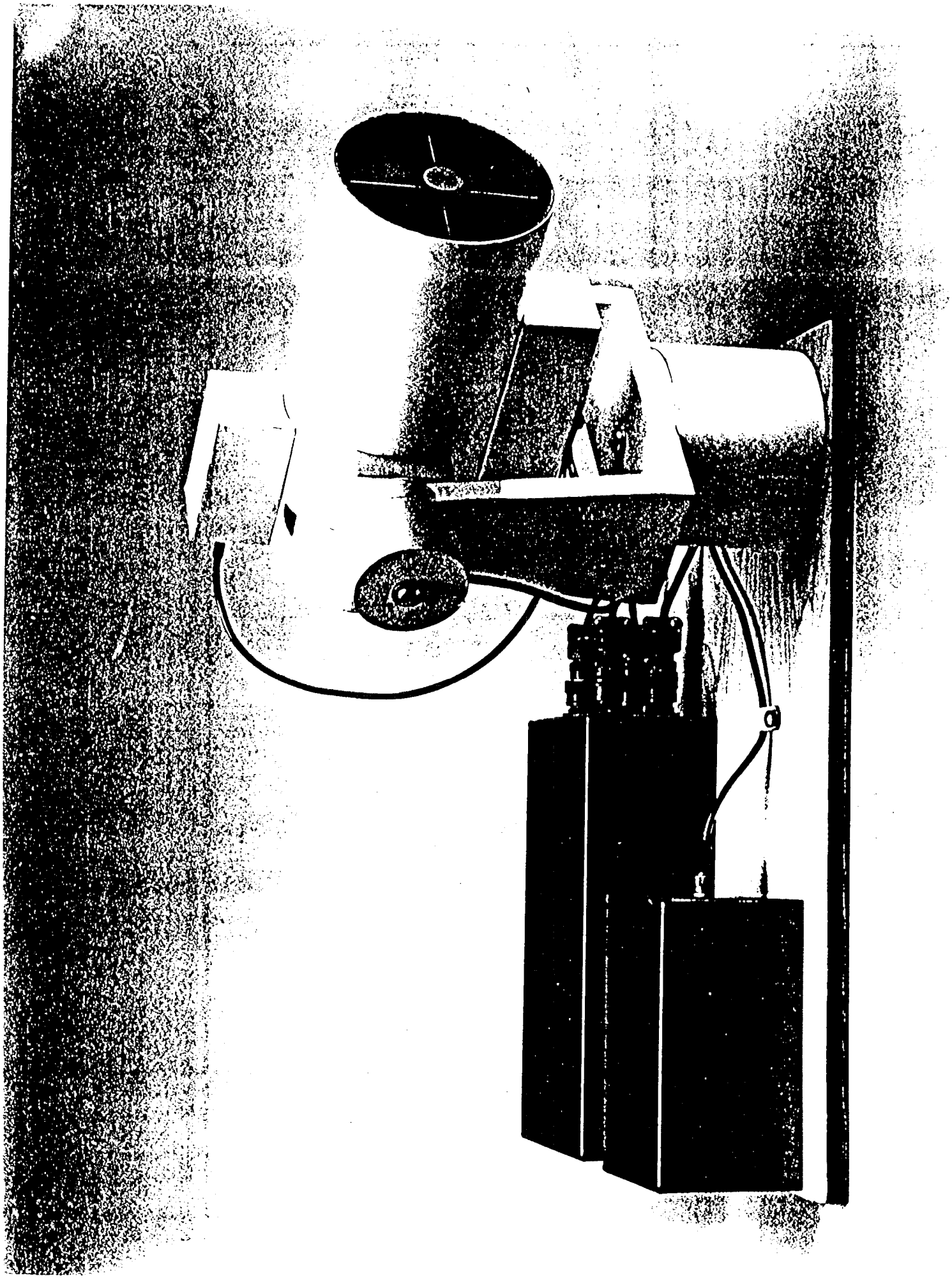
SPACECRAFT TECHNOLOGY

OPTICAL COMMUNICATIONS DEMONSTRATOR





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OCD Instrument Characteristics

Breadboard model of future flight terminal

Minimimum complexity to keep mass and power down

- 1 steering mirror
- 1 detector for ACK/TRK/point ahead

Fiber coupled laser for versatility and thermal control

Supports >100 Mbps LEO to Ground (325 Mbps goal)

Engineering model for deep space microspacecraft optical comm terminal (e.g 4 kbps from Pluto)

- Remove gimbal
- Change laser

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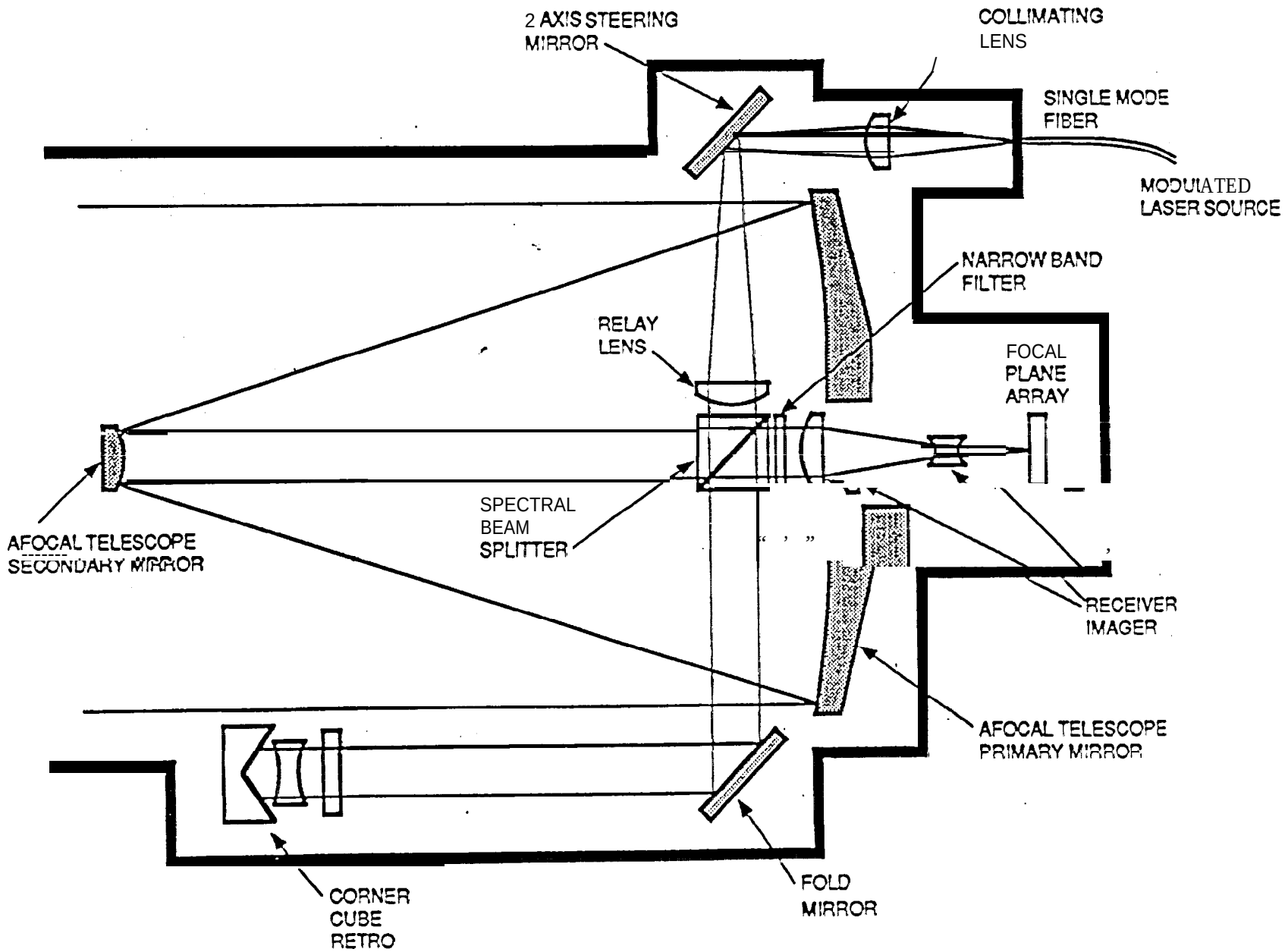
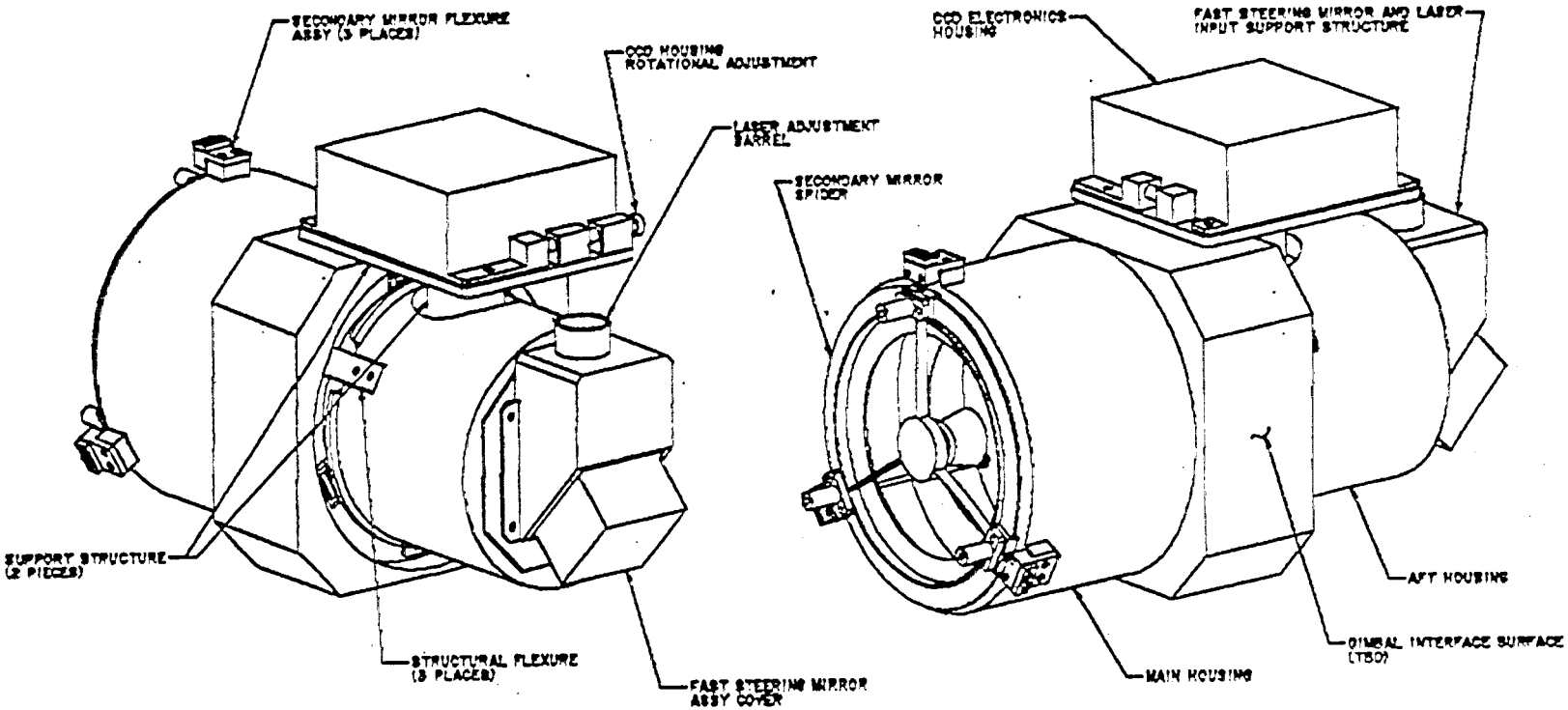
OPTICAL COMMUNICATION SYSTEM
OPTICS LAYOUT





OCD EXTERNAL SOMETR C VIEWS

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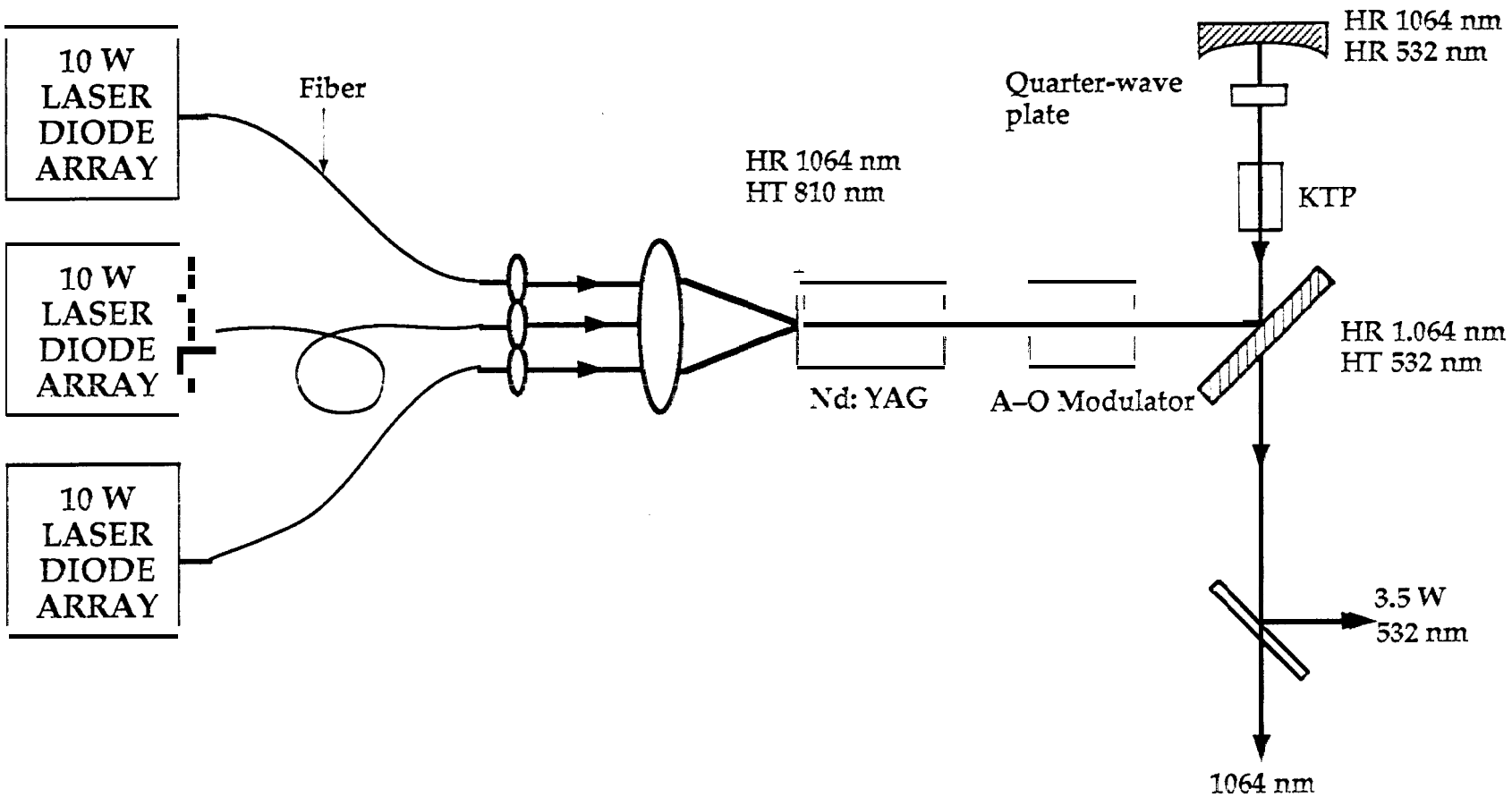
2-Watt Laser Design



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RECEPTION SYSTEMS AND TECHNOLOGY

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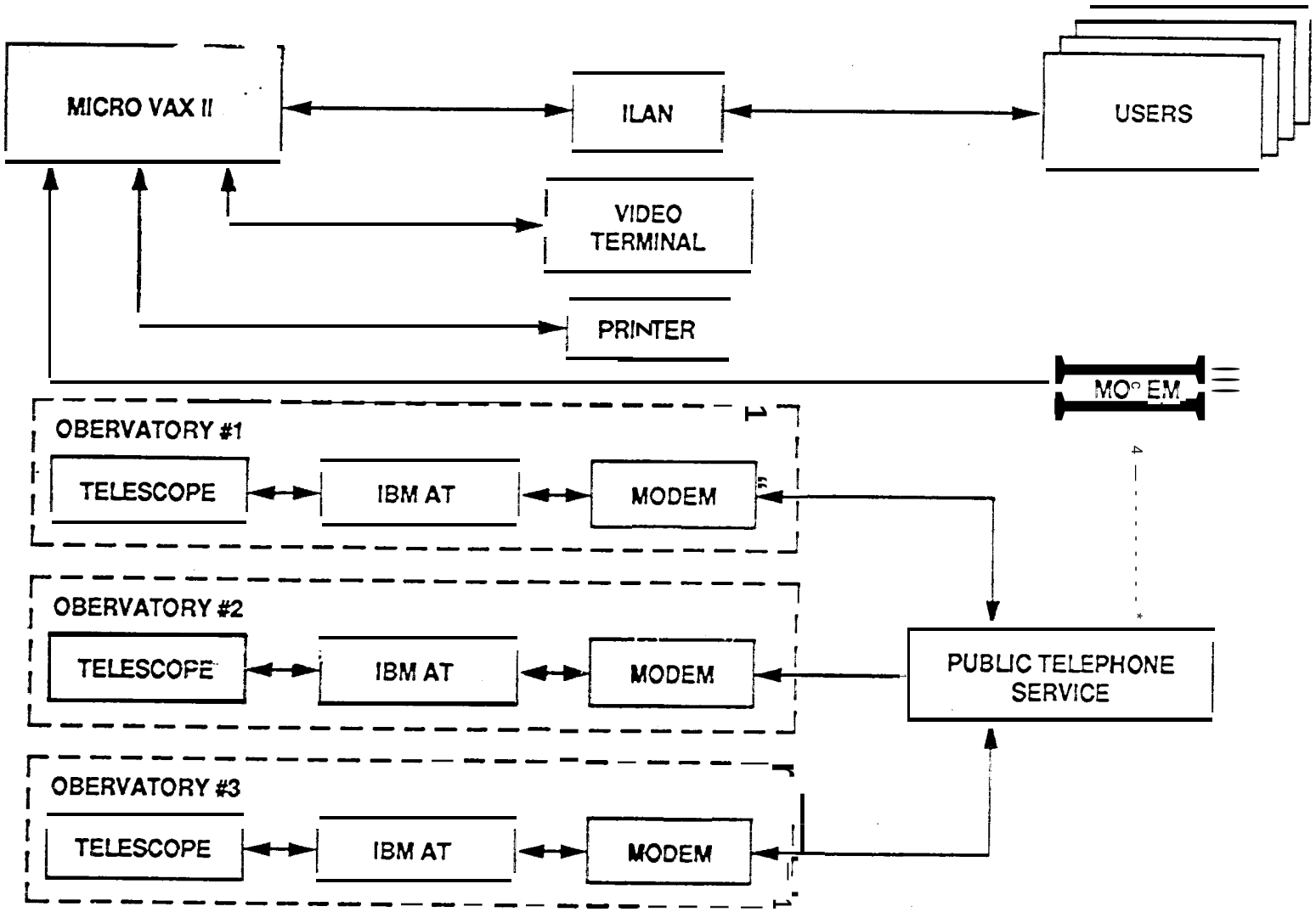
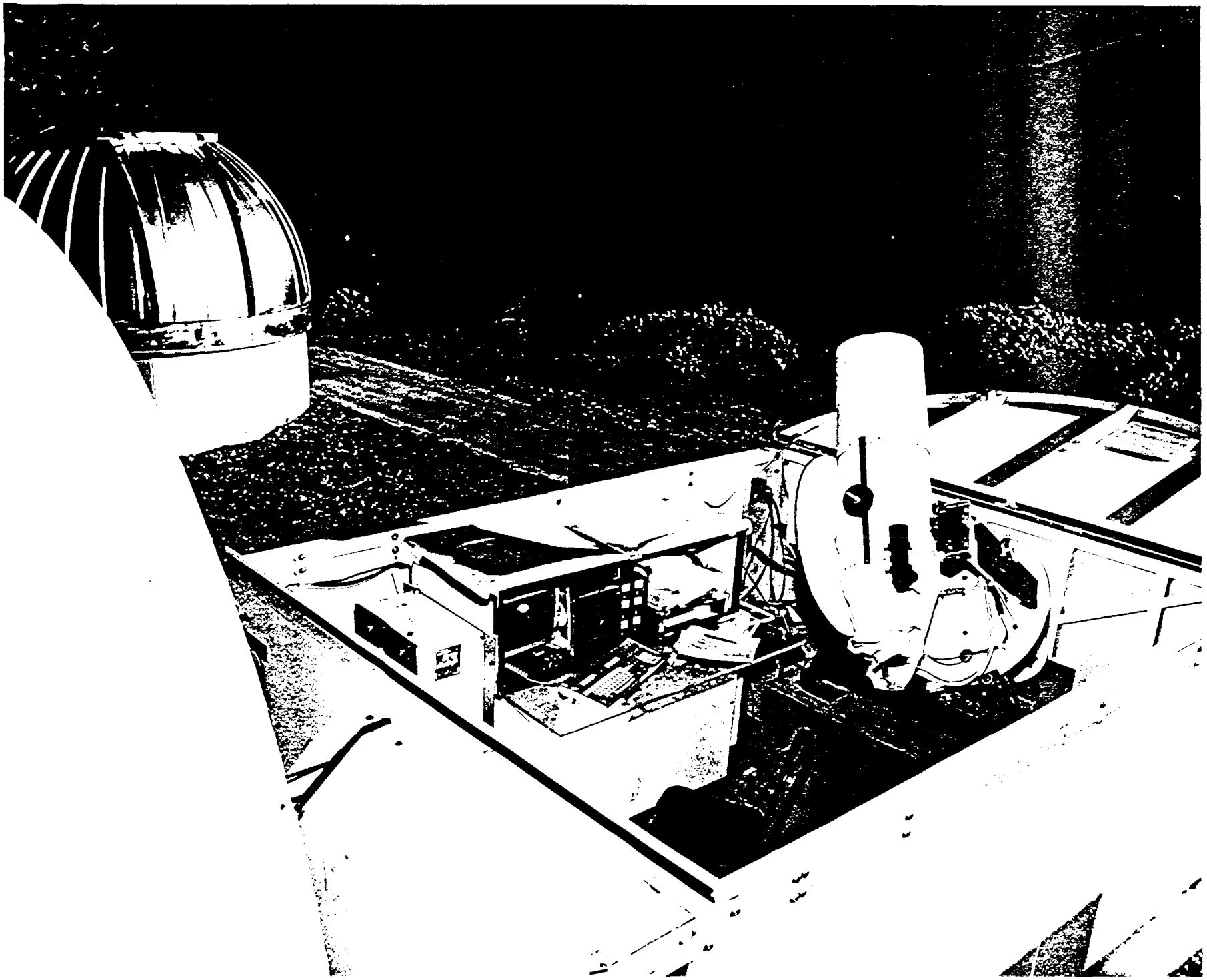
ACCOMPLISHMENTS (Cont'd)

AVM SYSTEM FUNCTIONAL DIAGRAM





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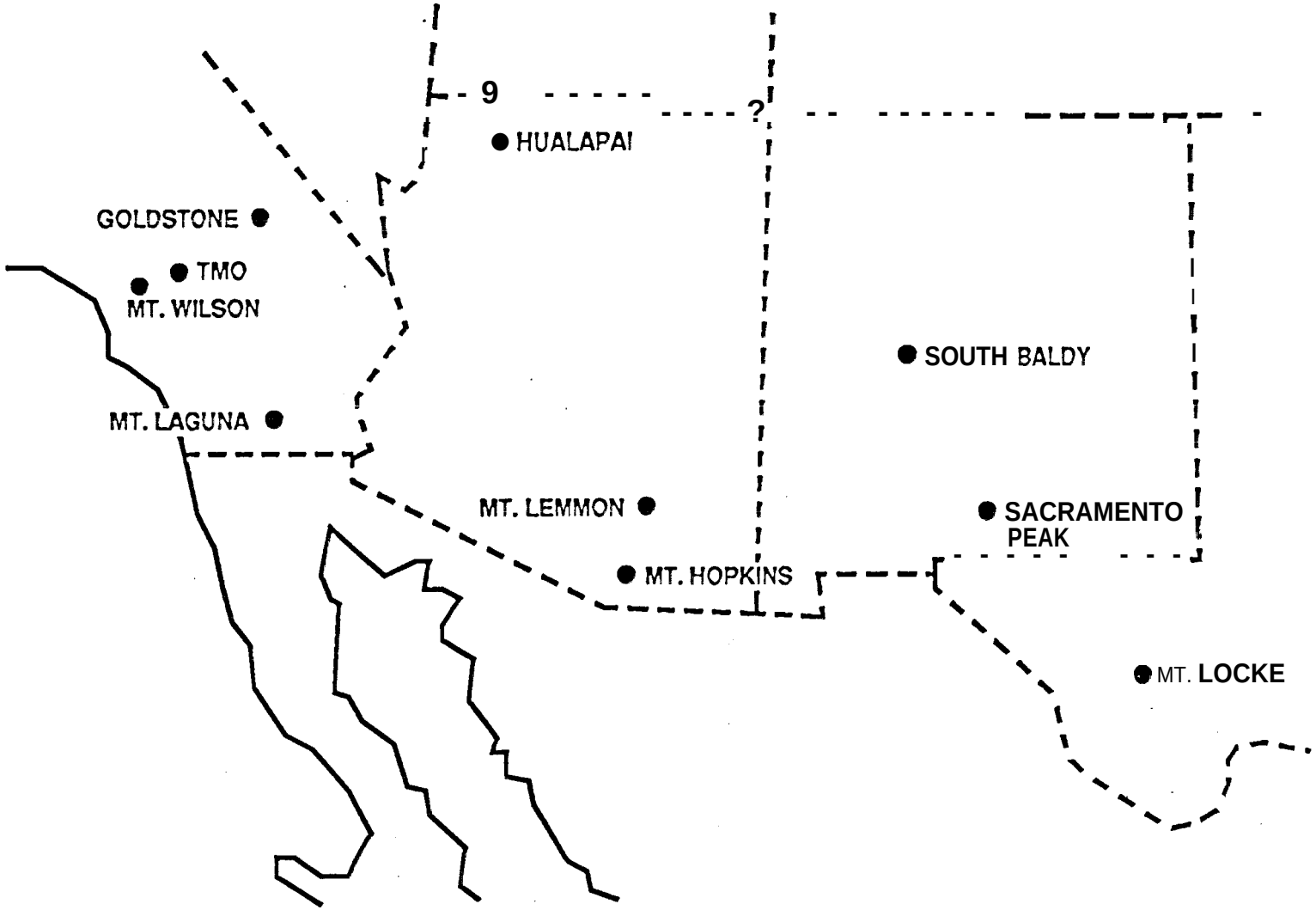
ACCOMPLISHMENTS (Cent'd)

- IDENTIFIED CANDIDATE SITES FOR AVM DEPLOYMENT



OPTICAL COMMUNICATIONS TECHNOLOGY DEVELOPMENT

ACCOMPLISHMENTS (Cent'd)

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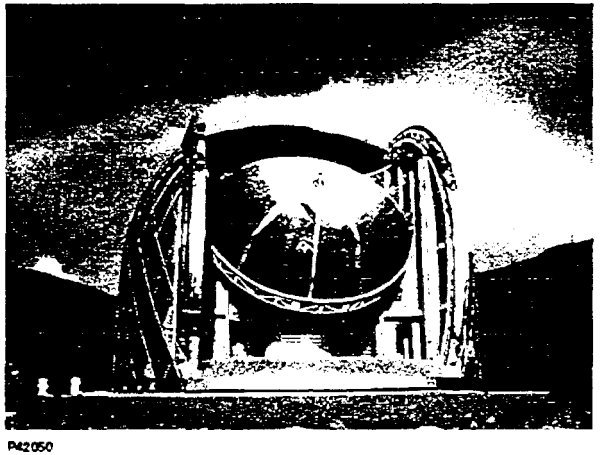
OPTICAL COMMUNICATIONS SYSTEM STUDIES

- IDENTIFIED POSSIBLE ALTERNATIVE ANTENNA DESIGN TO DSORA: CALTECH LEIGHTON DISH
  - . 10.4 m DIAMETER/PRIMARY MIRROR, 84 PANELS
  - . SURFACE FLATNESS: 80 µM OVER 10 m - DAYTIME
    40 µM OVER 10 m · NIGHTTIME
- CALTECH COST TO BUILD ~ $2 M
- MEASURED MIRROR SUBSTRATE CHARACTERISTICS AND FIGURE MAKE MODIFIED LEIGHTON DISH A POSSIBLE CANDIDATE FOR PROTOTYPE OPTICAL RECEIVER



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- NEXT STEPS
  - RESEARCH OTHER LARGE APERTURE STRUCTURES AND SELECT Candidates FOR FURTHER STUDY
  - PERFORM DETAILED STUDY OF LEIGHTON DISH AND OTHER SELECTED ANTENNAS
    - DETERMINE MODIFICATIONS NEEDED TO ACHIEVE REQUIRED PERFORMANCE
    - DETERMINE COSTS OF MODIFICATIONS AND ESTIMATE TIME TO COMPLETE BUILD

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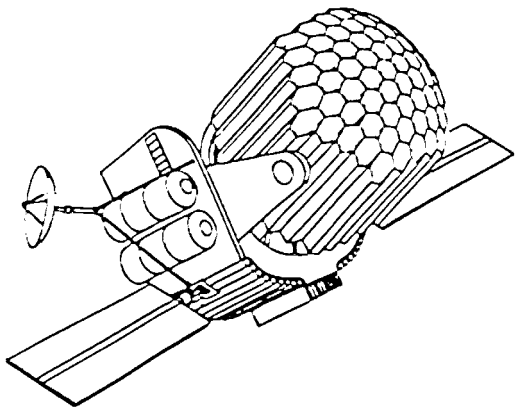
Deep Space Relay Satellite System (DSRSS)



SPACEBORNE RECEPTION **STATION**

STUDIES COMPLETED AT:

TRW

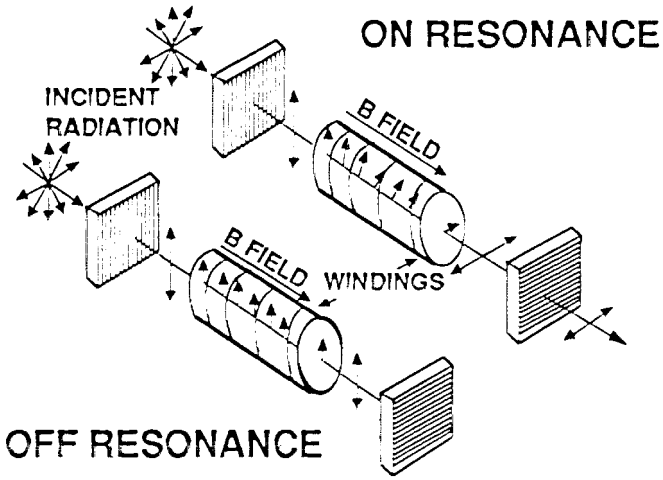
Stanford Telecommunications

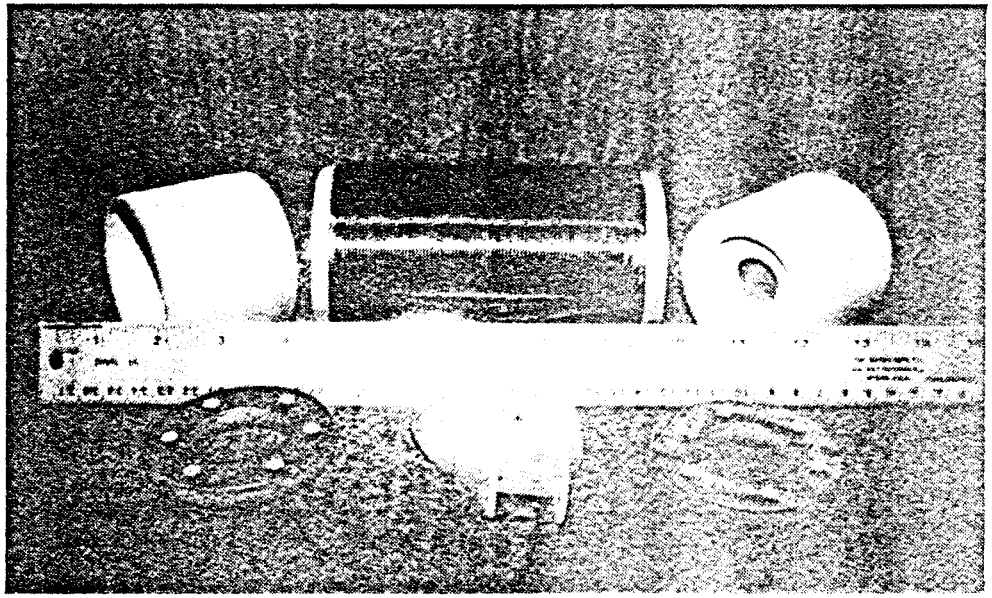
BOTH CONTRACTORS FOUND OPTICAL COMMUNICATIONS TO BE MORE COST EFFECTWE THAN RF FOR ORBITING RECEPTION

ACCOMPLISHMENTS SINCE JUNE 1991

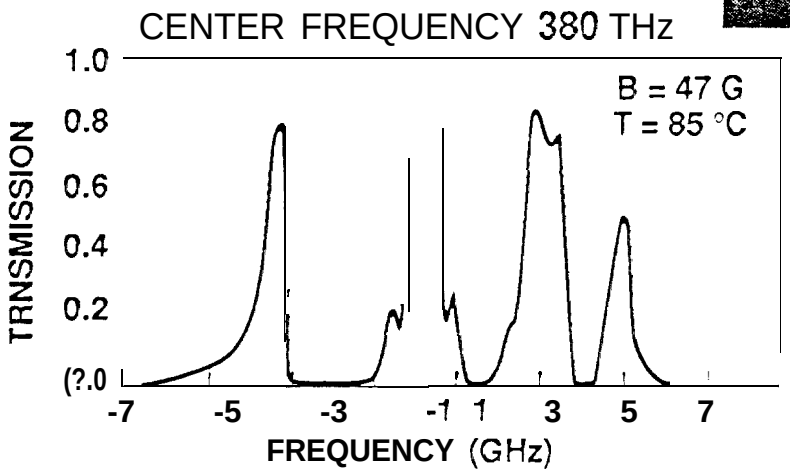
NMSU OPTICAL FILTER RESEARCH

- DESIGNED, CONSTRUCTED AND TESTED 780 nm FADOF FILTER





FADOF FILTER



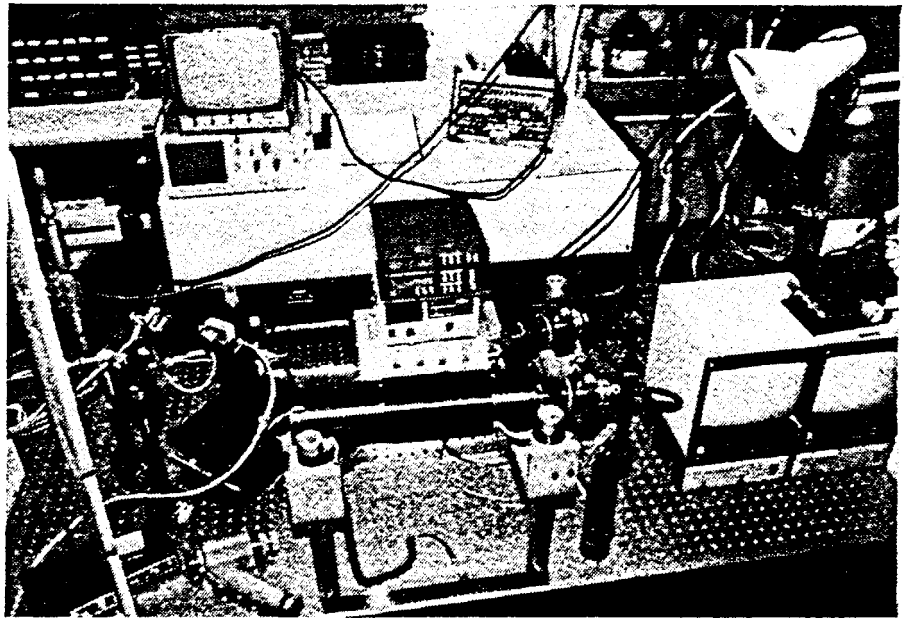
- PERFORMANCE (MEASURED)
  - 50 dB OUT-OF-BAND REJECTION
  - 90% RELATIVE TRANSMISSION
  - 63% ABSOLUTE TRANSMISSION (80% POSSIBLE WITH ANTI-REFLECTION COATINGS)

- PERFORMANCE AGREES WITH THEORY AND CAN BE EXTENDED TO OTHER WAVELENGTHS

ACCOMPLISHMENTS (CONT'D)

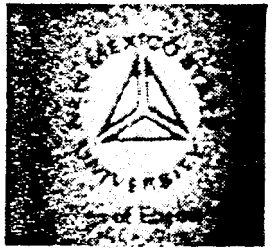
NMSU OPTICAL FILTER RESEARCH

- DEMONSTRATED IMAGE PRESERVATION FEATURE OF FADOF (IMPORTANT FOR FILTERING RECEIVED SIGNALS PRIOR TO ACK/ TRK DETECTION)

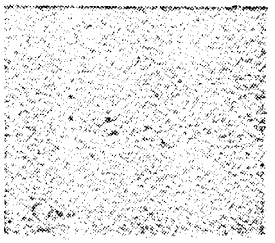


TARGET IMAGES (WITHOUT FADOF)

W! THOUT BACKGROUND

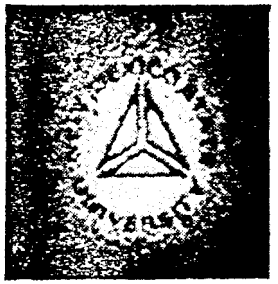


WITH BACKGROUND



TARGET IMAGES (WITH FADOF)

WITH BACKGROUND



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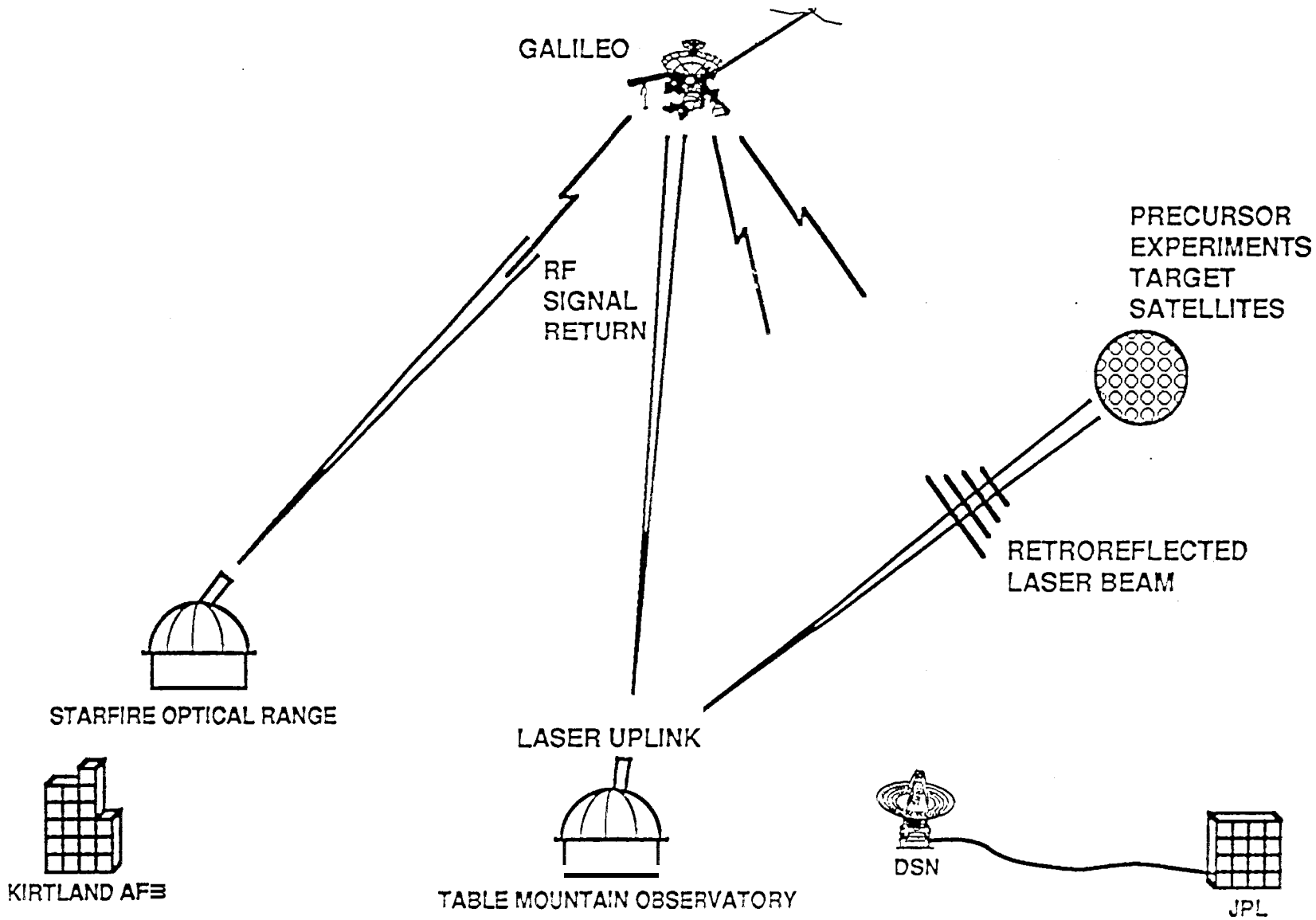
DEMONSTRATIONS

GOPEX DEMONSTRATION

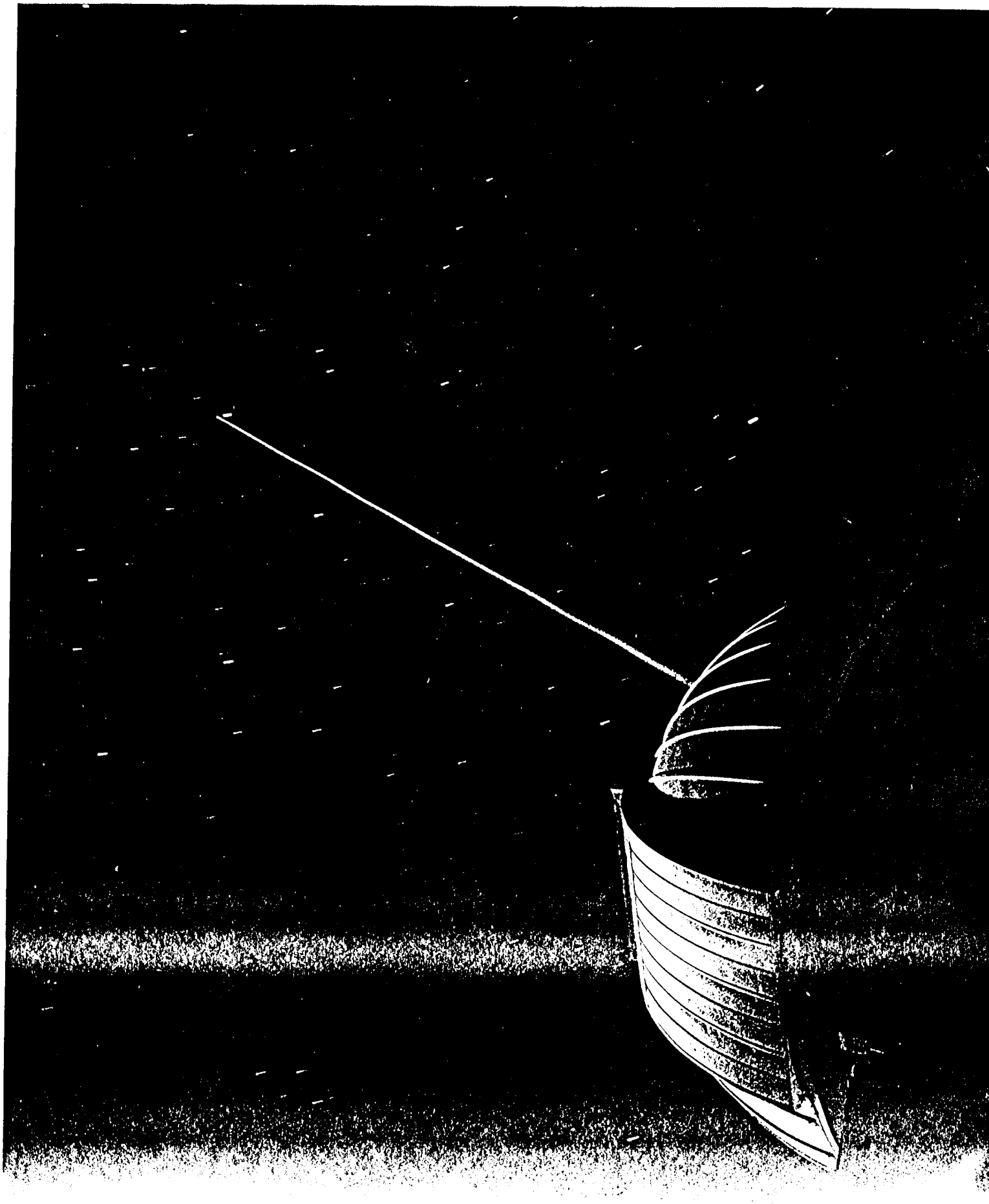
OVERVIEW

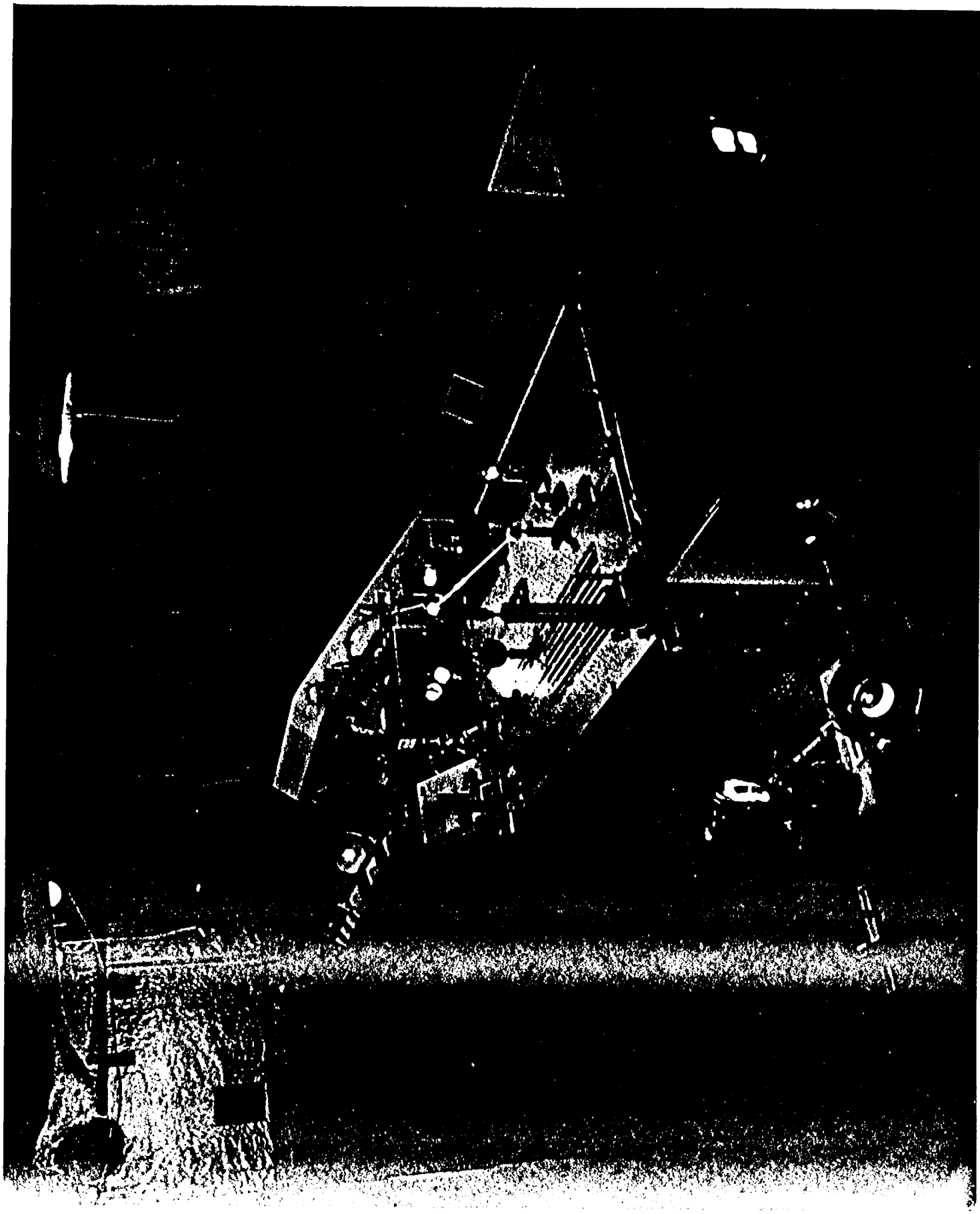


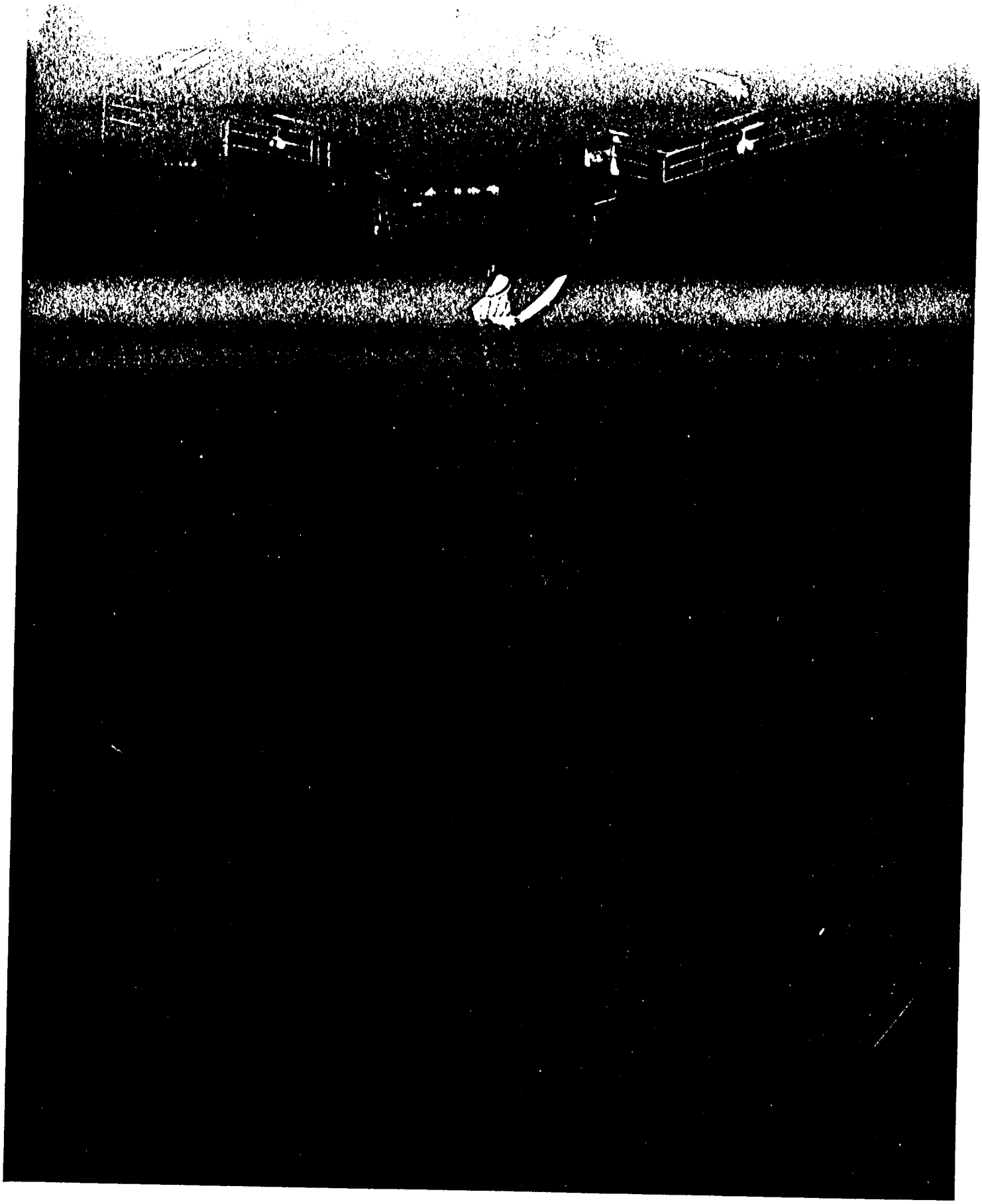
GALILEO OPTICAL EXPERIMENT (GOPEX)

OBJECTIVES

- DEMONSTRATE OPTICAL COMMUNICATIONS OVER DEEP SPACE DISTANCES
- VERIFY FEASIBILITY OF UPLINK OPTICAL BEAM POINTING BASED ON TRAJECTORY PREDICTS ONLY
- VALIDATE OPTICAL TELECOMMUNICATIONS PERFORMANCE PREDICTION MODELS







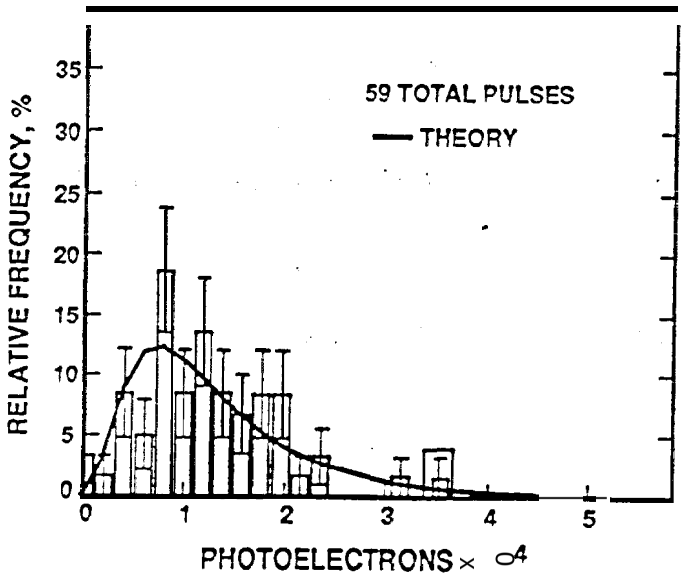
GOPEX

EXPERIMENTAL RESULTS

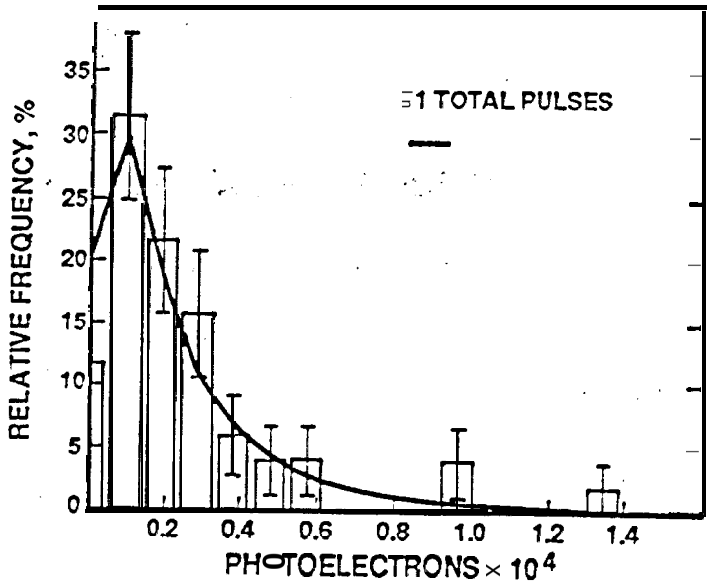
COMPARED THEORETICAL AND EXPERIMENTAL LASER INTENSITY DISTRIBUTIONS USING WEAK AND STRONG TURBULENCE MODELS

- ATMOSPHERIC TURBULENCE ESTIMATED FROM SEEING CONDITIONS MEASURED AT STATIONS

TRANSMISSION FROM TMF DAY 2
WEAK TURBULENCE MODEL



TRANSMISSION FROM TMF DAY 8
STRONG TURBULENCE MODEL



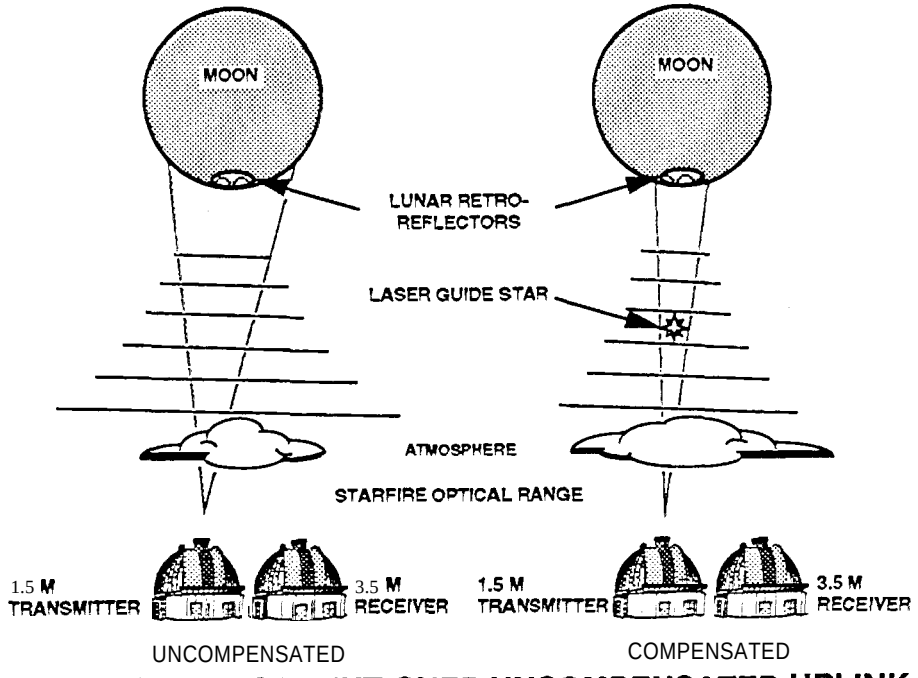
ACHIEVED GOOD AGREEMENT BETWEEN PREDICTED AND MEASURED INTENSITY DISTRIBUTIONS

- VALIDATED GOPEX OPT CAL LINK PERFORMANCE MODELS

ACCOMPLISHMENTS (Cent'd)

LITES

- pLANNED COMPENSATED EARTH-MOON-EARTH RETROREFLECTOR LASER LINK (CEMERLL) OCTOBER - DECEMBER 1993
- DEMONSTRATION WILL:
  - COMPARE COMPENSATED AND UNCOMPENSATED LASER TRANSMISSIONS
  - ASSESS RELEVANCE OF RECENTLY DECLASSIFIED ATMOSPHERE-COMPENSATED LASER PROPAGATION WORK TO OPTICAL COMMUNICATIONS



- EXPECT UP TO 20 dB ENHANCEMENT OVER UNCOMPENSATED UPLINK
  - up TO 40 dB OVER EXISTING LUNAR LASER RANGING FACILITIES
- COST SAVINGS FOR UPLINK BEACON OPTICAL TRAIN
  - RELAXES Requirement FOR COSTLY HI GH DAMAGE-THRESHOLD OPTICS

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SUMMARY

- OPTICAL COMMUNICATIONS IS READY FOR SERIOUS DEVELOPMENT AND IMPLEMENTATION

- NASA's MISSIONS NEED THE CAPABILITIES AND BENEFITS ENABLED BY OPTICAL COMMUNICATIONS