Mr. M. J. Aucremanne

PRINCETON UNIVERSITY OBSERVATORY
Princeton, New Jersey

FINAL REPORT

NSr-31-001-127

"DEVELOPMENT AND EVALUATION OF TELEVISION TUBES FOR SPACE ASTRONOMY"

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C.
May 10, 1974

PURPOSE

Develop television type image sensors, sensitive in the visible and ultraviolet, capable of long exposures at high spatial resolution, and otherwise suitable for space astronomy applications.

PERSONNEL

Principal Investigator	-	Prof. Lyman Spitzer
Research Staff	-	Mr. John L. Lowrance Mr. Paul Zucchino Mr. John Opperman Mr. Patrick Murray

FISCAL STATUS

Value of Contract	464,958
Expenditures as of March 31, 1974	464,958
Balance	-0-

I. BACKGROUND

In 1964 Princeton University began a study of the best type of television type image sensor for future space astronomy missions in the visible and ultraviolet spectrum. This study concluded that the SEC-vidicon offered the most overall potential. This was largely based on its ability to integrate the photoelectron image for long periods of time as required in many astronomical observations. This study was followed by a program to make ground based observations using an SEC-vidicon camera on the 36" telescope of the Princeton University Observatory in order to indicate whether the SEC vidicon camera had the operational characteristics required for spectrophotometry and imaging. These tests were encouraging and the program was continued to make improvements to the television tubes that would make them more suitable for astronomical observations.

These improvements included reducing the internal background of the tube, removing a mesh used to stabilize the KCl target and working out a mode of sequential operation that would still be safe. Considerable work was done to develop a reliable way to seal the ultraviolet transmitting windows to the tube and to achieve acceptable photocathode quantum efficiency on these MgF_2 windows. The tubes were redesigned to make them rugged enough to survive a rocket launch. There was also considerable work on the magnetic deflection and focus coils for the tubes. New preamplifier designs were developed to improve the dynamic range by reducing the readout noise. The target assembly was redesigned to reduce the microphonic signals and reduce the shunt capacitance to the rest of the tube since this also affected the readout noise.

Figure 1 gives an overview of the chronological improvement in resolution through the program.

As the tubes improved, it became clear that they were not only good for space applications but could be used to good advantage for some ground-based observations. The camera was used on the Mt. Wilson 60" and the Mt. Palomar 200". It has also been used on a 36" at Kitt Peak and the 106" at McDonald Observatory.

A substantial number of technical and scientific papers have resulted from the program as noted in the attached bibliography.

The WX-31718 (40 mm, UV sensitive) has been flown in an Aerobee sounding rocket and performed well, even after a parachute landing. The WX-31958 (7056 glass window version) has been used extensively by Princeton and others for ground-based observing and is currently being incorporated in a balloon-borne telescope that is a joint venture of the Netherlands and the NASA Johnson Spaceflight Center.

This program has been superseded by a program to develop a 70 mm version of the tube for the Large Space Telescope.

II. STATUS OF SEC-VIDICON DEVELOPMENT

Figure 2 shows in schematic form the SEC-vidicon. A photoelectron from the photocathode is accelerated by 8000 volts; strikes a target causing a charge transfer across the target of approximately 50 electrons. The optical image is integrated as an electrical charge pattern on the target. Following an exposure the electron gun is turned on and the electron beam is scanned across the target depositing electrons in those areas where electrons have been depleted by the exposure. The image section and the electron gun are focused by a magnetic field. Further details of the operation may be found in the references listed in the bibliography.

Figure 3 shows the WX-32192 and WX-31718 which has a magnesium fluoride window sealed to gold foil by frit glass. Table I lists the characteristics of these tubes, as well as a smaller version developed for possible use on the International Ultraviolet Explorer satellite. The photoelectric transfer function for the WX-31718 is shown in Figure 4.

Under NGR-31-001-236 and NAS5-20069 work is continuing to increase the resolution and extend the dynamic range of these sensors.

BIBLIOGRAPHY

PUBLICATIONS

1. "Integrating Television Sensors for Space Astronomy," J. L. Lowrance and P. Zucchino. Adv. in Electronics and Electron Physics, Vol. 28B, p. 851.
2. "Report on Evaluation of Television Tubes for Space Astronomy," J. L. Lowrance and P. Zucchino. Dept. Publication: NASA RESEARCH CONTRACT: NSR 31-001-127 (1969).
3. "A Study of Telescope Maintenance and Updating in Orbit," W. Grantz, W. Wetherall, N. Molesko and J. L. Lowrance. S.P.E.E. Seminar Proceedings on Space Optics, Vol. 19, 1970.
4. "Progress Report on Development of the SEC-Vidicon for Astronomy," P. Zucchino and J. L. Lowrance. Pub. Astronomical Use of Television-Type Image Sensors, Symposium Proceedings, NASA SP-256, 1971.
5. "Development of Television Tubes for the Large Space Telscope", J. L. Lowrance and P. Zucchino, Space Applications of Camera Tubes, International Colloquium sponsored by Centre National D'Etudes Spatiales, Paris, Nov. 1971.
6. "Recent Developments and Applications of the SEC Vidicon for Astronomy," P. Zucchino and J. L. Lowrance. Adv. in Electronics and Electron Physics, Vol. 33B, p. 801, Academic Press, London 1972.
7. "An Integrating Television System for Astronomy", D. C. Morton. Proceedings of ESO/CERN Conference on Auxiliary Instrumentation for Large Telescopes, Geneva, Switzerland, May 2, 1972.
8. "Large Space Telescope Television Sensor Development," J. L. Lowrance. Advanced Electro-Optical Imaging Techniques, Proceedings of NASA HQ Symposium, Washington, D. C. Sept. 22, 1972. NASA SP-338.
9. "The Use of Television Type Sensors in Astronomy," Astronomical Observations with Television Type Sensors. Proceedings of a Symposium held by Institute of Astronomy and Space Science at University of British Columbia, Vancouver, Canada, May 1973.

10. "Astronomical Television Development at Princeton University Observatory," presented at IAU Commission 9 Working Group on Astronomical Use of Image Tubes, Sydney, Australia, 1973.

11. "Television Systems for Astronomical Applications," J. L. Lowrance with P. Zucchino. Methods of Experimental Physics, Vol. 11, Academic Press, February 1974.

SCIENTIFIC PAPERS BASED ON ASTRONOMICAL OBSERVATIONS WITH THE TELEVISION SENSORS DEVELOPED UNDER THIS CONTRACT.

1. Bernat, A., Ferland, G., Robbins, R. R., and Crane, P. 1973, "SEC-Vidicon Slitless (O II) Image of NGC 2440", BAAS 5, 423 and Ap.J. (in prep.).
2. Crane, P. 1971, "Photometry of Galaxies with Integrating Television", BAAS 3, 399.
3. Crane, P. 1973a, "Surface Photometry of SBO Galaxies", BAAS 5, 349.
4. Crane, P. 1973b, "The SEC-Vidicon as a Photometer in Astronomical Observation with Television Type Sensors, ed. by J. W. Glaspey and G. A. H. Walker (Vancouver, B.C.) pp. 391.
5. Davidson, K., Crane, P., and Chincarini, G., "TV Photometry of Filaments in the Crab Nebula (in press).
6. Lowrance, J. L., Morton, Donald C., Zucchino, Paul, Oke, J. B., and Schmidt, Maarten, "The Spectrum of the Quasi-Stellar Object PHL 957", Ap. J. 171, January 15, 1972, pp. 233-251.
7. Morton, Donald C. and Morton, Winifred A., "Absorption-Line Profiles in the Quasi-Stellar Object PHL 957", Ap.J., Vol. 174, June 1, 1972, pp. 237-252.
8. Morton, Donald C. and Chevalier, Roger A. "Velocity Dispersions in Galaxies I. The E7 Galaxy NGC 7332", Ap. J. 174, June 15, 1972, pp. 489-498.
9. Morton, W. A. and Morton, Donald C. "Absorption Lines in the Spectrum of the Quasar Ton 1530", Ap.J., Vol. 178, No. 3, Pt. 1, December 15, 1972.
10. Morton, D. C. and Chevalier, Roger A.,"Velocity Dispersions in Galaxies. II. The Ellipticals NGC 1889, 3115, 4473, and 4494.", Ap. J., Vol. 179, No. 1 Pt. 1, January 1, 1973.
11. Morton, D. C. and Thuan, T. X., "Velocity Dispersions in Galaxies. II. The Nucleus of M31". Ap.J., Vol. 180, No. 3, Pt. 1, March 15, 1973.
12. Morton, D. C. and Richstone, D. O., "Absorption Lines in the Spectrum of the Quasar Markarian 132", Ap.J., Vol. 184, No. 1, Pt. 1, August 15, 1973.

CHRONOLOGY OF SEC-VIDICON RESOLUTION IMPROVEMENT AT PRINCETON UNIVERSITY OBSERVATORY

Year	No. of picture elements at 50% MTF
1968	1.6×10^4
1969	4×10^5
1971	1×10^6
1972	4×10^6

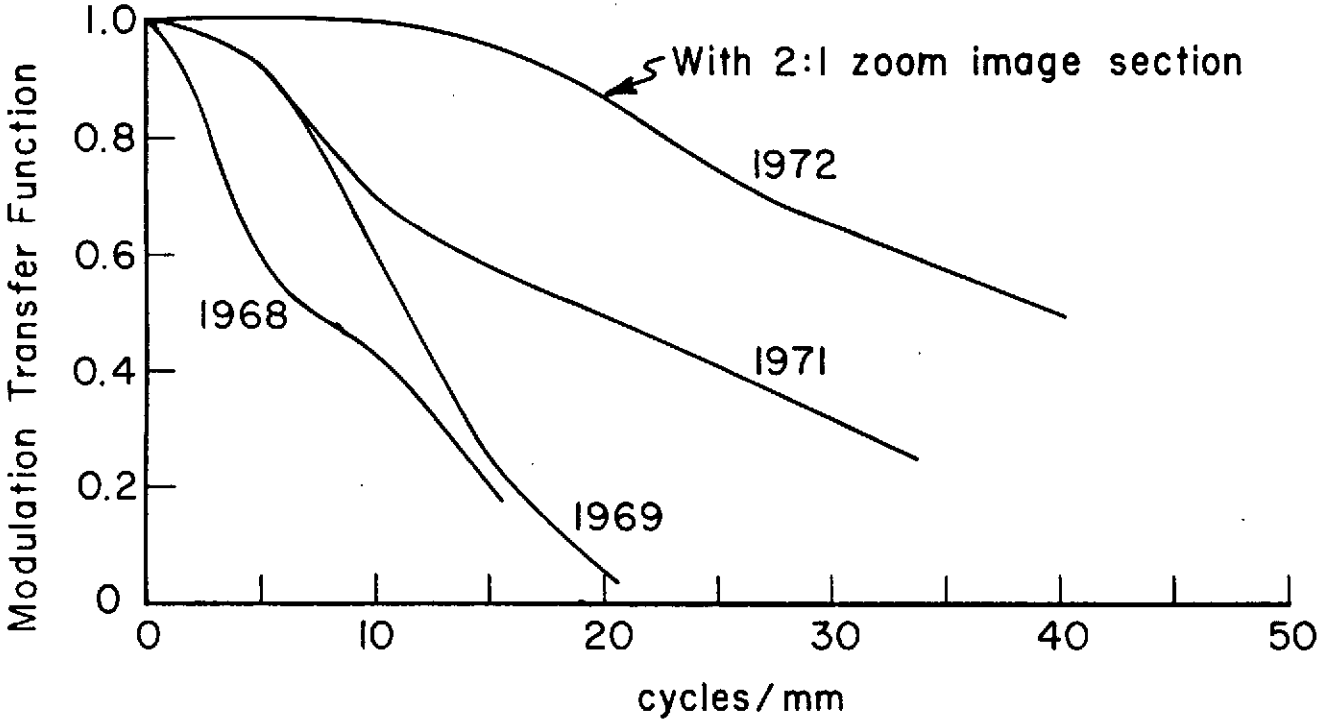

Figure 1

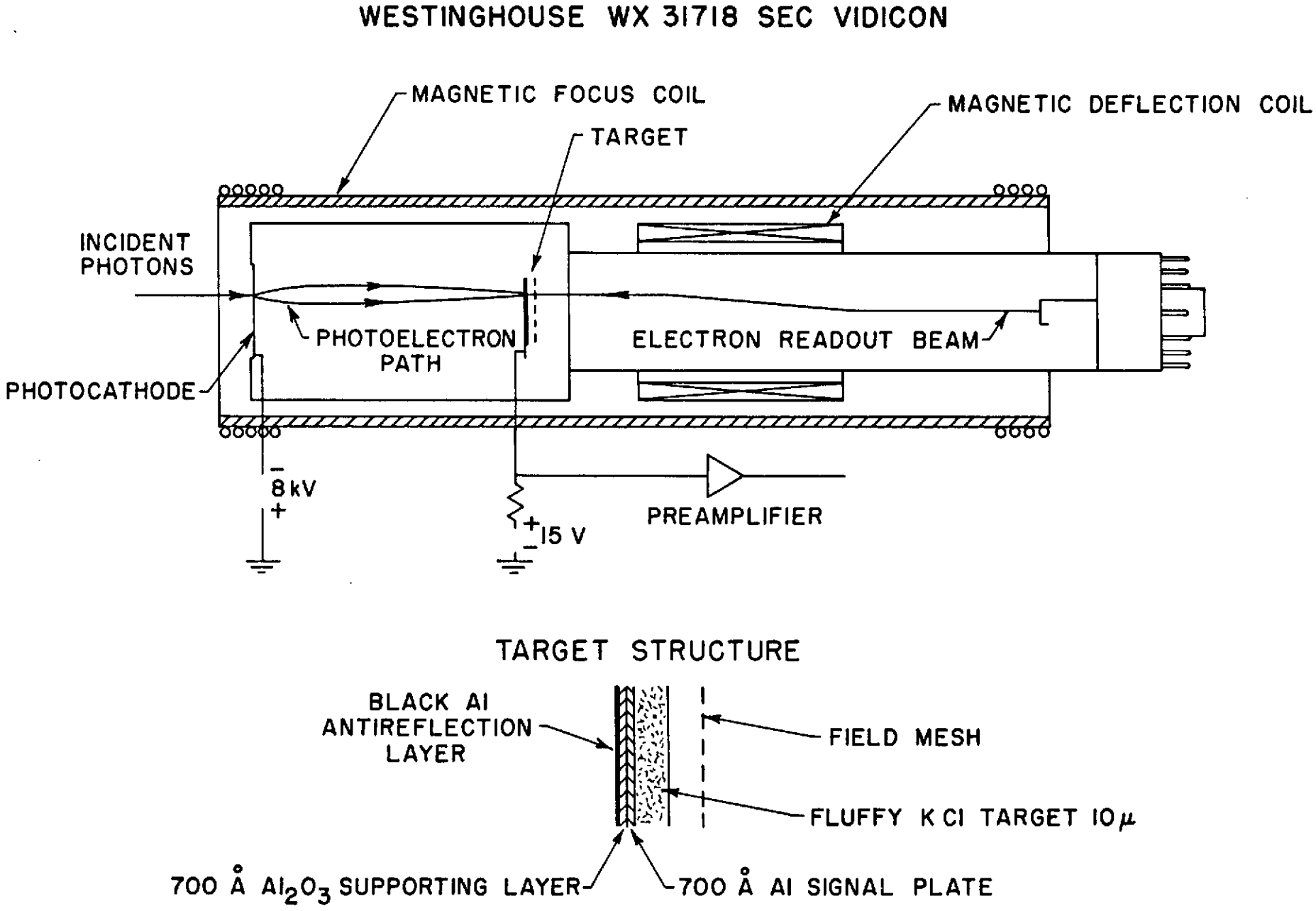
WESTINGHOUSE WX 31718 SEC VIDICON
MAGNETIC FOCUS COIL
TARGET
MAGNETIC DEFLECTION COIL
INCIDENT PHOTONS
PHOTOELECTRON PATH
ELECTRON READOUT BEAM
PHOTOCATHODE
8 kV
+15 V
PREAMPLIFIER
TARGET STRUCTURE
BLACK Al ANTIREFLECTION LAYER
FIELD MESH
FLUFFY K Cl TARGET 10 μ
700 Å Al_2O_3 SUPPORTING LAYER
700 Å Al SIGNAL PLATE

Figure 2

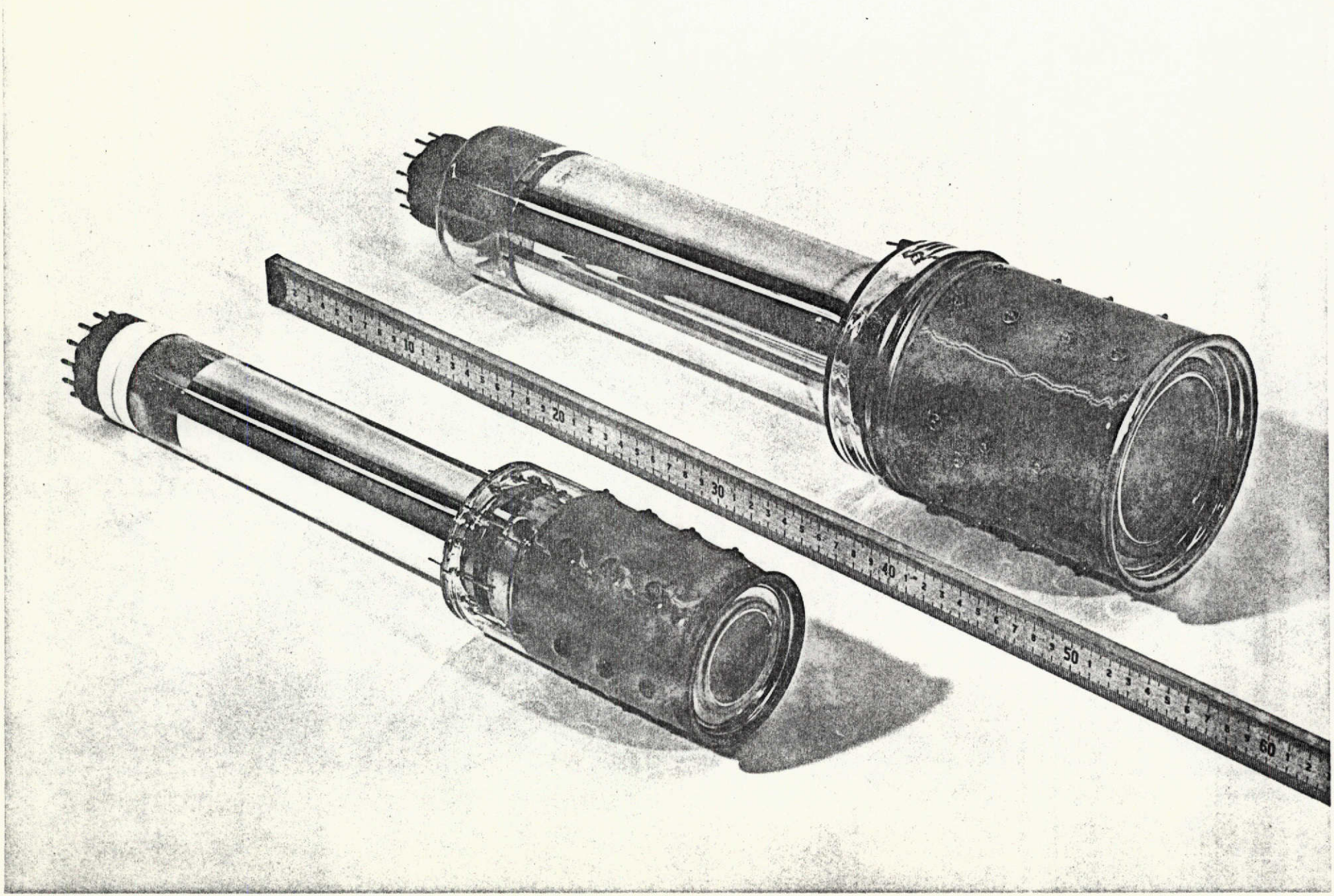

Figure 3
SEC-VIDICONS

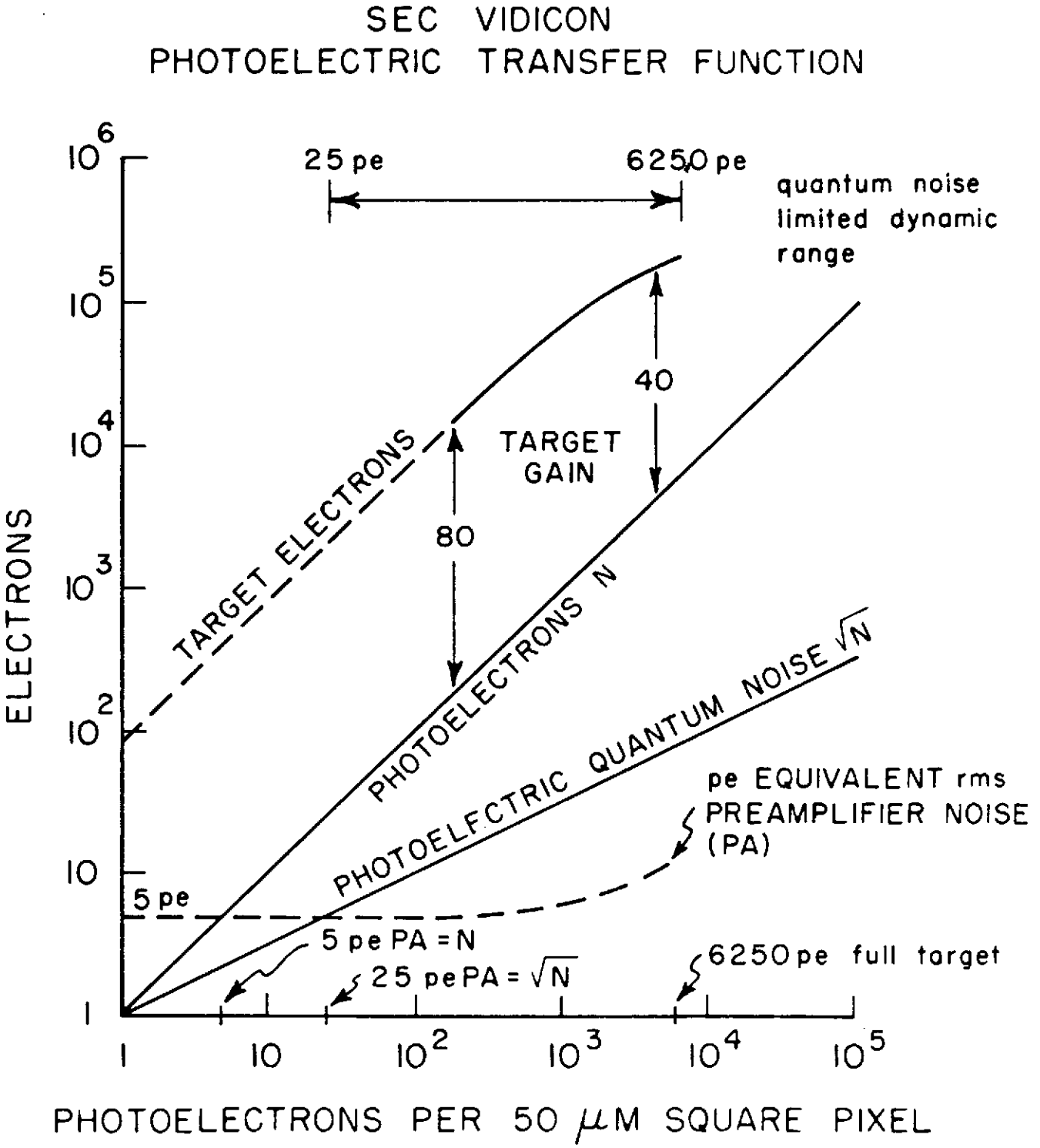
SEC VIDICON
PHOTOELECTRIC TRANSFER FUNCTION
25 pe
6250 pe
quantum noise limited dynamic range
40
TARGET GAIN
80
TARGET ELECTRONS
PHOTOELECTRONS N
PHOTOELFCTRIC QUANTUM NOISE √N
pe EQUIVALENT rms PREAMPLIFIER NOISE (PA)
5 pe
5 pe PA = N
25 pe PA = √N
6250 pe full target
ELECTRONS
10^6
10^5
10^4
10^3
10^2
10
1
1
10
10^2
10^3
10^4
10^5
PHOTOELECTRONS PER 50 μM SQUARE PIXEL

Figure 4

Table 1

	WX-32192 Large SEC-vidicon	WX-31718 Medium SEC-vidicon	WX- Small SEC-vidicon
Photocathode Diameter	76 mm 110 mm	38 mm	25 mm
Target Size	56 x 51 mm	25 x 25 mm	15 x 15 mm
Overall Length	487 mm	432 mm	240 mm
Maximum Diameter	128 mm	80 mm	58 mm
Window	MgF_2 Glass	MgF_2 Glass	MgF_2 Glass
Focus Field	80 gauss	80 gauss	80 gauss
Resolution (50% modulation)	20 cycles/mm	20 cycles/mm	20 cycles/mm(?)
No. Picture Elements	4×10^6	10^6	3.6×10^5
Photocathodes	NaK Sb S-20 ER	NaK Sb S-20 ER	NaK Sb CsTe S-20 ER

I. BACKGROUND

In 1964 Princeton University began a study of the best type of television type image sensor for future space astronomy missions in the visible and ultraviolet spectrum. This study concluded that the SEC-vidicon offered the most overall potential. This was largely based on its ability to integrate the photoelectron image for long periods of time as required in many astronomical observations. This study was followed by a program to make ground based observations using an SEC-vidicon camera on the 36" telescope of the Princeton University Observatory in order to indicate whether the SEC vidicon camera had the operational characteristics required for spectrophotometry and imaging. These tests were encouraging and the program was continued to make improvements to the television tubes that would make them more suitable for astronomical observations.

These improvements included reducing the internal background of the tube, removing a mesh used to stabilize the KCl target and working out a mode of sequential operation that would still be safe. Considerable work was done to develop a reliable way to seal the ultraviolet transmitting windows to the tube and to achieve acceptable photocathode quantum efficiency on these MgF_2 windows. The tubes were redesigned to make them rugged enough to survive a rocket launch. There was also considerable work on the magnetic deflection and focus coils for the tubes. New preamplifier designs were developed to improve the dynamic range by reducing the readout noise. The target assembly was redesigned to reduce the microphonic signals and reduce the shunt capacitance to the rest of the tube since this also affected the readout noise.

Figure 1 gives an overview of the chronological improvement in resolution through the program.