

UNCLASSIFIED

AD 404 068

*Reproduced
by the*

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

63-3-4

NAVWEPS REPORT 7966
Supplement
NOTS TP 3163
COPY 93

**MODIFICATIONS AND ADDITIONS TO THE NOTS GENERAL
OPTICAL RAY TRACING COMPUTER PROGRAM**

SUPPLEMENT

by

G. W. Shavlik
Test Department

MAY 14 1963

ABSTRACT. Additional modifications to the general optical ray tracing computer program at NOTS are presented. This material is supplemental to NAVWEPS Report 7966 (NOTS TP 3011), dated September 1962.

Released to ARIA for further dissemination with
out restriction beyond their security security
regulations.



U. S. NAVAL ORDNANCE TEST STATION

China Lake, California

March 1963

CLASSIFIED BY ARIA

404 068

404068

AD NO.

U. S. NAVAL ORDNANCE TEST STATION

AN ACTIVITY OF THE BUREAU OF NAVAL WEAPONS

C. BLENMAN, JR., CAPT., USN
Commander

WM. B. MCLEAN, PH.D.
Technical Director

FOREWORD

Additional modifications and changes in the NOTS general optical ray tracing computer program are reported. This material supplements that appearing in NAVWEPS Report 7966 (NOTS TP 3011) of the same title, and is intended for use with that report. It has been reviewed for technical accuracy by John R. Snyder.

Released under
the authority of
IVAR E. HIGHBERG
Head, Test Department

F. M. ASHBROOK, Head
Instrument Development Division

NOTS Technical Publication 3163
NAVWEPS Report 7966
Supplement

Published by Test Department
Manuscript 30/MS-563
Collation. Cover, 3 leaves, abstract cards
First printing 230 numbered copies

- 1 Tactical Air Command, Langley Air Force Base (TPL-RQD-M)
- 2 Aeronautical Systems Division, Wright-Patterson Air Force Base
Member, Optical Systems Working Group, IRIG (1)
- 4 Air Force Flight Test Center, Edwards Air Force Base
Members, Optical Systems Working Group, IRIG (3)
- 1 Air Force Missile Development Center, Holloman Air Force Base
- 8 Air Force Missile Test Center, Patrick Air Force Base
Steering Committee Member, IRIG (1)
Members, Data Reduction and Computing Working Group, IRIG (2)
Members, Optical Systems Working Group, IRIG (4)
- 4 Air Proving Ground Center, Eglin Air Force Base (Members, Optical
Systems Working Group, IRIG)
- 3 Eglin Air Force Base
Steering Committee Member, IRIG (1)
Members, Data Reduction and Computing Working Group (2)
- 3 Holloman Air Force Base
Steering Committee Member, IRIG (1)
Members, Optical Systems Working Group, IRIG (2)
- 1 Rome Air Development Center, Griffiss Air Force Base
- 10 Armed Services Technical Information Agency (TIPCR)
- 1 Langley Research Center (Member, Steering Committee, IRIG)
- 2 National Bureau of Standards
Steering Committee Member, IRIG (1)
Office of Basic Instrumentation (1)
- 1 Australian Joint Service Staff (Australian Weapons Research Establish-
ment), via BuWeps (DSC)
- 1 Applied Physics Laboratory, JHU, Silver Spring (Technical Document
Center)
- 1 AVCO Research Laboratory, Everett, Mass. (Document Control Center)
- 1 California Institute of Technology, Pasadena (Library)
- 1 Convair, Fort Worth (Henry S. Wolanski)
- 1 Douglas Aircraft Company, Inc., Long Beach
- 1 Douglas Aircraft Company, Inc., Santa Monica, Calif. (John R. Lowe)
- 1 General Electric Company, Numerical Analysis, Cincinnati
- 1 General Motors Corporation, Research Laboratories Division, Special
Problems Department, Warren, Mich. (Donald E. Hart)
- 1 Harvard College Observatory, Cambridge
- 1 Hughes Aircraft Company, Culver City, Calif. (Research and Development
Library)
- 1 International Business Machines Corporation, New York (Charles R. DeCarlo)
- 1 Jet Propulsion Laboratory, CIT, Pasadena (Dr. W. H. Pickering)
- 1 Lick Observatory, Mt. Hamilton, Calif.
- 1 Lockheed Aircraft Corporation, Burbank (Leland H. Amaya)
- 1 Los Alamos Scientific Laboratory (Edward A. Voorhees)
- 1 Lowell Observatory, Flagstaff, Ariz.
- 1 Mt. Wilson Observatory, Pasadena
- 1 New York University, College of Engineering (Dr. Emanuel Mehr)
- 1 North American Aviation, Inc., IBM Computing Group, Los Angeles
(Jack A. Strong)

- 1 Northwestern University, Evanston, Ill.
- 2 Sandia Corporation, Albuquerque (Members, Optical Systems Working Group, IRIG)
- 1 The Boeing Company, Seattle (Applied Mathematics Section, John F. Stockman)
- 2 The Rand Corporation, Santa Monica, Calif. (Paul Armer)
- 1 The University of Michigan, Ann Arbor
- 1 United Aircraft Corporation, East Hartford, Conn. (Walter A. Ramshaw)
- 1 University of California Lawrence Radiation Laboratory, Livermore (C. G. Craig for Sidney Fernbach)
- 1 Yerkes Observatory, University of Chicago

INTRODUCTION

Previous modifications and additions to the NOTS General Optical Ray Tracing Computer Program were reported in NAWEPs Report 7966 (NOTS TP 3011). Since the publication of that report, the following additional changes have been made in the ray tracing program.

MODIFICATIONS AND ADDITIONS TO ABERRATIONS

The equation for Petzval sum has been changed from

$$PTZ = - \sum_{i=1}^m \left(\frac{N'_{10} - N_{10}}{N'_{10} N_{10}} \right) c_i, \text{ to}$$

$$PTZ = - \sum_{i=1}^m \left(\frac{N'_1 - N_1}{N'_1 N_1} \right) c_i$$

Since another aberration has been added to the first eight already computed, another ray must be traced with the first nine rays. This ray, numbered 9A, is the marginal sagittal ray. The aberration XSR, the distance from the focal plane to the intersection point of the marginal sagittal rays, is given by the equation

$$XSR = -T'_{z9A} \frac{q'_{x9A}}{q'_{z9A}}$$

Ray number 9A and the aberration XSR are shown in Fig. 1.

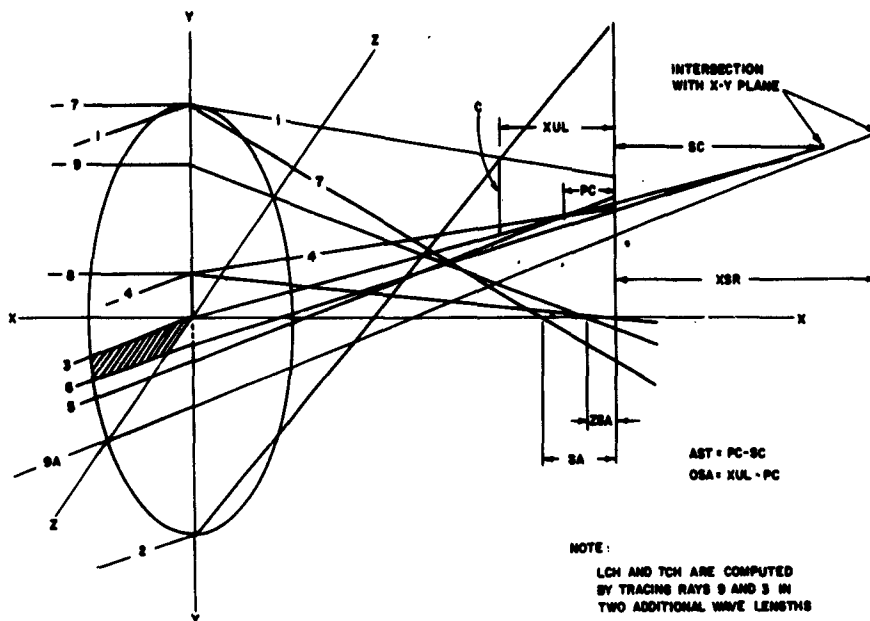


FIG. 1. Aberration Diagram.

TRACING THROUGH ASPHERIC CYLINDRICAL INTERFACES

The equation for the interface is

$$f(x, y, z) = A (-y \sin \alpha + z \cos \alpha)^8 + B (-y \sin \alpha + z \cos \alpha)^6 \\ + C (-y \sin \alpha + z \cos \alpha)^4 + D (-y \sin \alpha + z \cos \alpha)^2 - x = 0$$

where A, B, C, D are the aspheric coefficients, α is the angle between the axis of the cylinder and the positive x-y plane (the positive direction of rotation for α is from the positive x-y plane to the positive x-z plane), and $x, y, z = T'_x, T'_y, T'_z$, respectively. The equation for the ray is

$$\frac{x - T_x}{q_x} = \frac{y - T_y}{q_y} = \frac{z - T_z}{q_z}$$

therefore, $y = \frac{q_y}{q_x} (x - T_x) + T_y$ and $z = \frac{q_z}{q_x} (x - T_x) + T_z$

where $T_x = T'_x(1-1) - \frac{q_x}{q_x} t_1$; $T_y = T'_y(1-1)$; $T_z = T'_z(1-1)$.

$$\begin{aligned} \text{Now } f(x) = & A \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^8 \\ & + B \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^6 \\ & + C \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^4 \\ & + D \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^2 \\ & - x = 0 ; \end{aligned}$$

and

$$\begin{aligned} f'(x) = & 2 \left(-\frac{q_y}{q_x} \sin \alpha + \frac{q_z}{q_x} \cos \alpha \right) \left\{ 4A \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^7 \right. \\ & + 3B \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^5 \\ & + 2C \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^3 \\ & \left. + D \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right] \right\} \\ & - 1 = 0. \end{aligned}$$

To solve $f(x)$ for x , the Newton-Raphson method is used. Once x is found, y and z can be found from the ray equation.

The partial derivatives of the interface equation are

$$H_x = -1$$

$$H_y = -2 \sin \alpha [4A(-y \sin \alpha + z \cos \alpha)^7 + 3B(-y \sin \alpha + z \cos \alpha)^5 \\ + 2C(-y \sin \alpha + z \cos \alpha)^3 + D(-y \sin \alpha + z \cos \alpha)]$$

$$H_z = 2 \cos \alpha [4A(-y \sin \alpha + z \cos \alpha)^7 + 3B(-y \sin \alpha + z \cos \alpha)^5 \\ + 2C(-y \sin \alpha + z \cos \alpha)^3 + D(-y \sin \alpha + z \cos \alpha)]$$

where H_x must have the same sign as q_x . Now use equations 96-107 of "Ray Tracing Through Uncentered and Aspheric Surfaces", by William A. Allen and John R. Snyder, OPT SOC AM, J, Vol. 42, No. 4, pp. 243-249, April 1952, reprinted as the appendix to NAWEPS Report 7966 (NOTS TP 3011), pp. 26-32.

AN ADDITION TO AUXILIARY PROGRAM NO. 20501

The square lattice input for spot diagram computation program has been modified so that spot diagrams may be computed automatically for cylindrical interfaces. The equation for the number of points, N_p , inside the rectangular pupil is

$$N_p = \left(\frac{L + W}{2\delta} + 1 \right)^2$$

Solving for the increment, δ , we have

$$\delta = \frac{L + W}{2(\sqrt{N_p} - 1)}$$

where L and W are the length and width, respectively, of the cylindrical interface as shown in Fig. 2. No obstruction is permitted for spot diagrams for cylindrical interfaces.

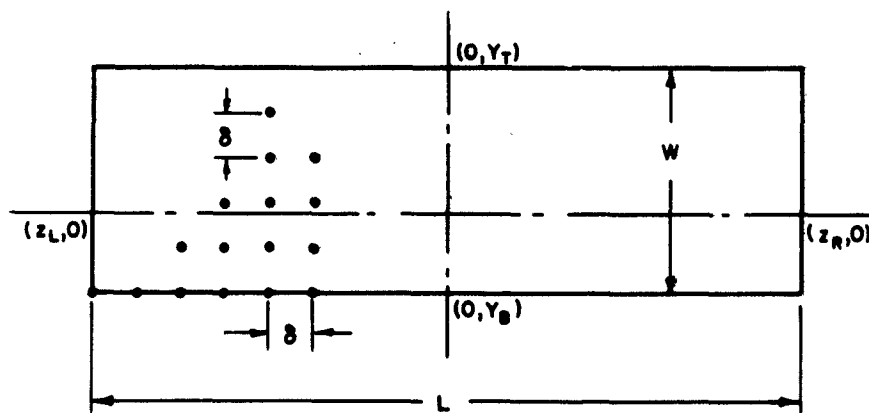


FIG. 2. Square Lattice for Cylindrical Lens Spot Diagram Computation.

INITIAL DISTRIBUTION

- 9 Chief, Bureau of Naval Weapons
 - DLI-31 (2)
 - R (1)
 - R-14 (1)
 - R-3 (1)
 - RMGA-53 (1)
 - RRRE-3 (1)
 - RRRE-41 (1)
 - RTMS-21 (1)
- 2 Special Projects Office
 - SP-271 (1)
 - SP-2722 (1)
- 1 Chief of Naval Research (Code 104)
- 2 Naval Air Development Center, Johnsville
- 1 Naval Air Test Center, Patuxent River (Aeronautical Publications Library)
- 6 Naval Missile Center, Point Mugu
 - Steering Committee Member, IRIG (1)
 - Members, Data Reduction and Computing Working Group, IRIG (2)
 - Members, Optical Systems Working Group, IRIG (2)
 - Technical Library (1)
- 1 Naval Ordnance Laboratory, Corona
- 1 Naval Ordnance Laboratory, White Oak (Library)
- 1 Naval Ordnance Missile Test Facility, White Sands Proving Ground
- 2 Naval Research Laboratory (Code 2021)
- 4 Naval Weapons Laboratory, Dahlgren
 - Members, Optical Systems Working Group, IRIG (3)
 - Technical Library (1)
- 2 Naval Weapons Services Office
- 1 Navy Electronics Laboratory, San Diego
- 2 Aberdeen Proving Ground
 - Ballistic Research Laboratories (1)
 - Development and Proof Services (1)
- 4 Army Ordnance Missile Command, Redstone Arsenal (Technical Library)
- 2 Frankford Arsenal
 - Pitman-Dunn Laboratory (1)
 - Library (1)
- 1 Signal Corps Engineering Laboratories, Fort Monmouth
- 11 White Sands Missile Range
 - Steering Committee Member, IRIG (1)
 - Secretariat, IRIG (1)
 - Members, Data Reduction and Computing Working Group, IRIG (3)
 - Members, Optical Systems Working Group, IRIG (3)
 - Technical Library (3)
- 1 Air Force Systems Command, Andrews Air Force Base (Member, Steering Committee, IRIG)

ABSTRACT CARD

U. S. Naval Ordnance Test Station

Modifications and Additions to the NOTS General Optical Ray Tracing Computer Program, Supplement, by G. W. Shavlik. China Lake, Calif., NOTS, March 1963. 6pp. (NAWWEPS Report 7966, Supplement; NOTS TP 3163), UNCLASSIFIED.

ABSTRACT. Additional modifications to the general optical ray tracing computer program at NOTS are presented. This material is supplemental to NAWWEPS Report 7966 (NOTS TP 3011), dated September 1962.

1 card, 4 copies



U. S. Naval Ordnance Test Station
Modifications and Additions to the NOTS General Optical Ray Tracing Computer Program, Supplement, by G. W. Shavlik. China Lake, Calif., NOTS, March 1963. 6pp. (NAWWEPS Report 7966, Supplement; NOTS TP 3163), UNCLASSIFIED.

ABSTRACT. Additional modifications to the general optical ray tracing computer program at NOTS are presented. This material is supplemental to NAWWEPS Report 7966 (NOTS TP 3011), dated September 1962.

1 card, 4 copies



U. S. Naval Ordnance Test Station

Modifications and Additions to the NOTS General Optical Ray Tracing Computer Program, Supplement, by G. W. Shavlik. China Lake, Calif., NOTS, March 1963. 6pp. (NAWWEPS Report 7966, Supplement; NOTS TP 3163), UNCLASSIFIED.

ABSTRACT. Additional modifications to the general optical ray tracing computer program at NOTS are presented. This material is supplemental to NAWWEPS Report 7966 (NOTS TP 3011), dated September 1962.

1 card, 4 copies



U. S. Naval Ordnance Test Station

Modifications and Additions to the NOTS General Optical Ray Tracing Computer Program, Supplement, by G. W. Shavlik. China Lake, Calif., NOTS, March 1963. 6pp. (NAWWEPS Report 7966, Supplement; NOTS TP 3163), UNCLASSIFIED.

ABSTRACT. Additional modifications to the general optical ray tracing computer program at NOTS are presented. This material is supplemental to NAWWEPS Report 7966 (NOTS TP 3011), dated September 1962.

1 card, 4 copies

