The Hughes Danbury Technology Transfer Program

Alfonse G. Antonelli

Hughes Danbury Optical Systems, Inc.
100 Wooster Heights Road, Danbury, Connecticut 06810-7589

ABSTRACT

This paper describes how our Technology Transfer Program (T^2P) contributes to the continuing education of our technical staff. It describes the process employed from the guiding philosophy through instructor selection to program execution, including the role performed by members of the technical staff in the process. The various types of training offered and program delivery modes are described. Programs specific to optics training (including an optics core curriculum) are discussed, as are relevant non-optics courses.

Keywords: technology transfer, guiding philosophy, course selection, optics and non-optics subject matter

1. INTRODUCTION

The guiding philosophy of employee development at Hughes Danbury is straightforward. It is a shared responsibility between the employee and the company that requires planning. To facilitate the planning process for our technical staff, we ask:

1. What are our core products?
2. What technologies are employed to produce these products?

The planning process includes a discussion between employee and supervisor, not only on technical discipline, but also on non-technical subjects such as communications and personal management skills.

Our Technology Transfer Program has become the vehicle to focus and implement much of our technical professional development activities. The intent of the Technology Transfer Program is to offer in-house courses and programs that cannot be obtained at a local college or university. To this end, the program draws heavily upon our "resident technical experts" for the instruction of those technologies employed at Hughes Danbury.

The Technology Transfer Program is not a panacea. Most employees must fulfill development plans by supplementing in-house offerings with outside courses, workshops, seminars, and through professional affiliations.

2. ELEMENTS OF THE PROGRAM

Each spring and fall, four to six in-house courses are available to qualified employees. The offerings are detailed in a brochure distributed to all members of the technical staff. In addition to content, instructor, dates, and times, the course write-up states needed prerequisites and any associated fees. Quite often, the course offering also contains two to three non-technical programs.

Although the average course duration is 20 hours, some are as short as four hours while others are as long as 24 hours. Courses taught by Hughes Danbury employees generally meet once a week for two hours in the evening. Courses taught by instructors who are not within the Danbury, Connecticut area are held over a two or three day period and run during business hours.

The spring and fall programs are supplemented by "on demand" program offerings to meet special needs. Because special requests usually require quick action, these programs seldom appear in a brochure and are usually for a specific audience.

Other elements of the Technology Transfer Program include lunch-time seminars, our Distinguished Speaker Program, and Rensselaer Polytechnic Institute's Satellite Video Program. Almost all of the lunch-time seminars are given by employees who are about to present a paper at a conference or who have recently attended a conference. From time to time, a series of lunch-time seminars are conducted by several individuals on various aspects of a specific technology or product.

The Distinguished Speaker Program utilizes outside speakers, university personnel, or researchers from other institutions who are well regarded by the scientific community.

3. COURSE AND INSTRUCTOR SELECTION

All in-house programs are offered under the auspices of the Center for Professional Development (the Development Center), whose mission is the promotion and sponsorship of continuing education activities that meet the needs of the company and of the individual so that both can grow and prosper. The Development Center is directed by a governing board comprised of employees from a cross-section of our professional, business, and technical disciplines. Offerings within the Technology Transfer Program are effected by a technical subcommittee of the governing board.

The technical subcommittee meets periodically during the year to plan the spring and fall offerings. Once potential topics have been identified, subcommittee members recommend and approach the most qualified instructor(s). Then, if the person is willing to teach, a preliminary course description is submitted. Any material such as textbook or required software must also be identified so it can be included in the published course fee.

Because most Technology Transfer Program courses are taught by employees and are held after business hours, an honorarium is paid to the instructor. The honorarium is compensation for the after-hours teaching time with the amount being based upon course length. The instructor is not compensated for course development that is done on his/her time.

4. COURSE EXECUTION

Enrolling in a course requires the completion of a registration form that must be signed by the participant's management. The registration form also serves as the basis to charge back the course fee to the appropriate department section number at course completion. If a registered candidate cancels at the last minute, is a "no show" or fails to complete the course, his/her section is still charged the full course fee. Most courses have enrollments of 12 to 20 students. A course with fewer than 10 registrants is usually canceled, unless the respective department managers agree to pay a higher course fee.

The majority of courses are taught using a lecture format in combination with visual aids, usually overhead transparencies. Some courses use both a classroom and laboratory environment. If a videotape program is used, the instructor is required to "add value" to what is usually generic information by making the tape content specific to Hughes Danbury practice.

As part of course execution, all instructors, including non-employees, are required to incorporate principles of continuous measurable improvement (the Hughes Aircraft system of total quality management) into the course. Non-Hughes instructors are sent a booklet that describes the principles and other aspects of our quality system to help them point out how the course content is an application of one or more of the principles.

5. COURSES OFFERED

Courses offered in the Technology Transfer Program are not intended to duplicate course-work that an employee may have taken in college. Therefore, our Core Optics Curriculum caters to those members of the technical staff who do not have a formal optics education. Because of the nature of the work at Hughes Danbury, such employees often find themselves working side by side with optical engineers or with an optics subsystem. Thus, knowledge and familiarity with various optical disciplines is needed. The Core Optics Curriculum is shown in Table 1.

Table 1. Core Optics Curriculum.

Course	Duration
Optical Principles	20 hours
Optical Alignment Laboratory	20 hours
Practical Optical Engineering	24 hours
Optical Fabrication Technology	20 hours
Introduction to Physical Optics and Diffraction Phenomena	24 hours
Introduction to Optical Testing	10 hours

For those employees who have degrees in optics or optical engineering, the Technology Transfer Program offers course-work in advanced optical topics and non-optical technical disciplines. The optical engineer or optical scientist often requires an understanding of subjects such as mechanics and control systems to appreciate how the optical component is integrated within the total system.

Again, keep in mind that it is not the intent of the program to offer course-work available at a local college or university, but knowledge on the subject relative to its practice at Hughes Danbury.

Tables 2 and 3 show courses in advanced optical topics and other technical disciplines, respectively, that have been offered within the Technology Transfer Program.

Table 2. Advanced Optical Topics.

Course	Duration
Topics in Physical Optics	20 hours
Fourier Optics	20 hours
Thin Film Optical Coatings	20 hours
Statistical Characterization of Optical Surfaces	16 hours
Optical Systems Analysis	14 hours
Factors Important to the Conceptual Design or Selection of Optical Systems	20 hours
Materials and Processes for Dimensionally Stable Mirrors	10 hours
Imaging Systems	7 hours

Table 3. Courses in Other Technical Disciplines.

Course	Duration
Systems Engineering Overview	6 hours
Feedback and Control Systems	24 hours
Precision Mechanics	24 hours
Electromechanics	24 hours
Optomechanics	14 hours
Advanced Optomechanics	7 hours
Optomechanical System Design	12 hours
Analysis of Optomechanical Interface	6 hours
Cryogenic Engineering for Optical Systems	20 hours
Silicon Carbide Technology	4 hours
Materials Science	24 hours
Solid State Detectors	20 hours

6. CONCLUSION

The Technology Transfer Program has served as the focal point for the in-house professional development of our technical staff since 1989. To date, 58 technical courses have been offered, accounting for an enrollment of over 1,000.

In terms of cost effectiveness, measured in dollars spent per student per course, the Technology Transfer Program is a bargain. It has the lowest cost when compared to all other types of professional development course-work: $131 per person for an average of 18 hours of training.

The program has endured, even in times of uncertainty, because of the value our technical staff places on maintaining technical competency. Thus, each spring and fall, there is a demand for new offerings and an anticipation of the course brochure.

7. APPENDIX: SAMPLE COURSE OFFERINGS/CONTENT

OPTICAL PRINCIPLES

This course is a non-mathematical introduction to the phenomena of optics and manufacture of optical products. Major topical areas covered are electromagnetic radiation, how light is generated, image formation, typical optical components, photographic effects, interference effects, the eye as an optical instrument, optical instrumentation, chronology of optical instrument evolution, and the electro-optical mechanical design process.

PRACTICAL OPTICAL ENGINEERING

This course examines first-order optical system layout techniques, analytical design tools, typical optical instruments, materials choice considerations, optical component manufacture and testing, mounting optical components and structural considerations, adjustment mechanisms, minimizing environmental effects, system alignment techniques, and system performance testing techniques.

INTRODUCTION TO PHYSICAL OPTICS AND DIFFRACTION PHENOMENA

This course provides a basic understanding of the fundamental principles of physical optics. Topics include basic properties of the electromagnetic field, polarization effects, basic coherence theory, interference phenomena, scalar diffraction theory, a review of geometrical optics, a review of Fourier theory and linear systems, and an introduction to aberration theory, image formation, spatial filtering and holography.

OPTICAL ALIGNMENT LABORATORY

This is a hands-on laboratory course. Major content areas are introduction to optical instrumentation, brief history of optics and some basic image position formulae, use of auto-collimators to determine flatness of surface plate, data from earlier sessions and method of calculation flatness, use of alignment telescope to determine deviations from a straight line, measuring angles with theodolite, co-aligning two instruments, discussion of lasers as alignment devices and interferometry (in particular, the H-P Laser Gauge). The course will conclude with a question and answer period of topics discussed throughout the course.

OPTICAL FABRICATION TECHNOLOGY

This course describes the fabrication of optical components including lenses, prisms, mirrors and windows, from ordering the optical glass to coating. Techniques used for high-volume production as well as one-of-a-kind prototypes are discussed.

INTRODUCTION TO OPTICAL TESTING

This course introduces the rudiments of interference, fundamental interferometer types (Twyman-Green, Fizeau, and Mach-Zehnder), and typical optical testing applications (windows, prisms, flats and spheres). Then, it builds a foundation of understanding concerning conventional interferogram interpretation and analysis from which the advantages of phase measuring interferometry (PMI) can be explained. It also covers concepts of aspheric testing and absolute calibration.

TOPICS IN PHYSICAL OPTICS

A selective set of fundamental problems in physical optics is studied. These problems involve the specialized subjects of diffraction, stray light and particle scattering; beam propagation in multilayer media and through atmospheric turbulence; and the analysis of gratings and waveguides.

THIN FILM OPTICAL COATINGS

This course focuses on the use of thin films in optical applications, Maxwell's equations and propagation of light in homogeneous and inhomogeneous media, isotropic and anisotropic materials, reflection and refraction, anti-reflection films, metal and dielectric mirrors, bandpass and edge filters, beamsplitters and polarization selective filters. The course also covers computer algorithms for designing devices, synthesis and optimization techniques, as well as deposition technologies with emphasis on resultant optical, electronic, and mechanical properties on films. Analysis techniques used in characterizing the properties of thin films are introduced. In addition, the course describes nonlinear materials and properties of surfaces and system design aspects of coating for error budget and throughput considerations.

OPTICAL SYSTEMS ANALYSIS

This course focuses on two major subject areas: the analysis of imaging characteristics and the analysis of the effect of stray light. Specific topics include linear systems with respect to frequency domain analysis and Fourier transforms, analysis of aberration-free optical systems, analysis of systems having statistically described aberrations, measures of optical system quality, systems analysis using the Sampling Theorem and the Fast Fourier Transform, basic principles of stray light analysis, surface scatter and models of surface roughness, diffraction with respect to its suppression, and systems analysis with respect to optical design for the reduction of stray light.

FOURIER OPTICS

This course includes representation of physical quantities by mathematical function, review of Fourier theory and linear systems, Fourier treatment of near-field scalar diffraction theory, Fourier transforming and imaging properties of lenses, transfer function characterization of imaging systems, spatial filtering and optical information processing, holography, and applications.

STATISTICAL CHARACTERIZATION OF OPTICAL SURFACES

The following topics are covered: interferometry, including a classical two-armed interferometer, common path and self-referencing interferometers, reference surfaces, and null correctors; optical surface descriptions, including the Zernike polynomials, the Fourier-Legendre polynomials, power spectra, and autocovariance functions; scatter from optical surfaces, including scatter in the geometric limit, scatter in the smooth surface limit, and the scatter MTF – the gemera case; and scatter and optical performance, including encircled energy, stray light, and MTF.

CONCEPTUAL DESIGN OR SELECTION OF OPTICAL SYSTEMS

This course covers several key topics that are important for the conceptual design or selection of optical systems. Detailed design techniques and aberration theory are not discussed. Instead, several useful ways of thinking about optical systems, at the conceptual level, are explored and illustrated with many examples. Topics include: showing how certain ways of thinking, which can be reduced to several powerful rules and "tricks," can be used to optimize the process of selecting an optical system and to minimize its complexity; discussing the limitations and potential of the new "automatic" optical design computer programs; deciding what is reasonable in terms of time and cost to expect from human-guided optical design; how new technologies, like binary optics, will impact optical systems in the near future; and a review of particular types of optical systems (like telescopes) of interest to the class.

MATERIALS AND PROCESSES FOR DIMENSIONALLY STABLE MIRRORS

Topics covered give a solid background in the properties, microstructure and fabricability of mirror materials, a background in the causes and prevention of dimensional instability, and options in materials and processes selection to meet the requirements. Mirror design is not addressed, except in terms of fabrication limits for specific materials. Material and process trades are addressed in terms of availability, risk, performance goals and, of course, cost. Specific attention is given to fused silica/quartz, ULE and Zerodur, beryllium, aluminum, Invar and copper, silicon and the silicon carbides.

SYSTEMS ENGINEERING OVERVIEW

Topics covered include system design and analysis, system requirements and verification, system integration, software system design, mission operation and planning, system effectiveness, and system test planning and audit.

PRECISION MECHANICS

This course covers kinematic relationships, degrees of freedom, geometry, tribology, ball and flexure bearings, micropositioning, materials, resonance, Hertzian stresses, fatigue, optical component mounts, and thermal and environmental considerations in precision instrument design. Emphasis on practical devices, mechanisms, and concepts.

UNDERSTANDING IMAGING SYSTEMS

After a brief historical background of the astronomical telescope and the photographic lens, the essential fundamentals of geometrical optics are reviewed. The geometric theory of image formation includes discussions of the six cardinal points, transverse and longitudinal magnification, graphical ray tracing, angular magnification (the Helmholtz Invariant) stops and pupils (vignetting), and marginal and chief rays (the Lagrange Invariant). Diffraction theory and aberrations are presented, with particular emphasis placed upon obtaining physical insight.

FEEDBACK AND CONTROL SYSTEMS

The topics include the motivation for the general approach; review of complex variables, ordinary differential equations and difference equations; linearity, impulse response and convolution; sampling; Fourier transform, Laplace transform, Z-transform and bilinear transform; transfer functions, Bode plots, Nyquist plots, poles and zeros; stability criteria; characterization of electro-mechanical and electro-optical subsystems (typical actuators and sensors, structural modes); characterization of noise and disturbance sources; A/D, D/A and microprocessor implementation; servo performance parameters; analog and digital controller designs; feed forward techniques; basics of non-linearities and their effects; and state space.

ELECTROMECHANICS

This course follows the development of the previously offered Precision Mechanics course: practical aspects of many sensors, actuators and controls are discussed. A wide range of devices and instruments are described and analyzed. Dynamic aspects of mechanisms and servo controls are explored. Bode graphs are introduced and used to illustrate behavior.

OPTOMECHANICS

This course addresses optical fundamentals including geometric optics, optical drawings and the influences of tolerances on cost, with emphasis on optical parameters that affect optomechanical design. A discussion of optical material properties covers the control of optical surface distortion, thermal distortion properties, dimensional instability and strength of glassy optical materials. This course describes the control of deflection, principles of kinematic design, athermalization of optical systems, and vibration isolation systems. In addition, lens mounting covering windows and prism mounting are covered. Also, the course describes mirror mounting of small and large mirrors with emphasis on rapid analytical methods of calculating mirror deflections.

OPTOMECHANICAL SYSTEM DESIGN

This course addresses key optomechanical issues in optical system and optical instrument design. It demonstrates the close interrelationships between structural mechanics, materials and optical engineering technologies. Major topics include 1) the optomechanical design process; 2) environmental effects on optical components and systems and environmental testing; 3) mechanical properties of refracting, reflecting and structural materials as well as of adhesives and sealants as used in optical applications; 4) mounting individual lenses and windows; 5) examples of multi-component lens, mirror and catadioptric assemblies; 6) mounts for small mirrors and prisms; 7) examples of non-metallic and metallic mirror substrates; 8) comparisons of various mountings for larger mirrors; and 9) general optical instrument structural design considerations.

CRYOGENIC ENGINEERING FOR OPTICAL SYSTEMS

This course is designed to give an overview of the engineering issues that differentiate cryogenic optical systems from more typical room temperature systems. It covers thermal, electrical, and mechanical cryogenic properties; conductive and radiative heat transfer; low temperature instrumentation; cryogenic safety; vacuum techniques and materials; and refrigerators, dewars and test chambers. Course material is derived from a variety of sources.

ADVANCED OPTOMECHANICS

The course is divided into four major sections: control of deflection, precision motion, dynamic optics, and mirror design. Specific topics include structural considerations in design of optomechanical systems; semi-kinematic configurations and connections; stabilization methods for metals; analysis and control of motion; precision actuator designs and precision bearings; scanning mirror systems, including both oscillating scan mirrors and rotating polygon mirrors; fracture statistics and fracture mechanics; mirror deflections, including thermal gradients, self-weight and bimetallic bending effects; and optimization of lightweight mirror structures and shapes.

ANALYSIS OF THE OPTOMECHANICAL INTERFACE

This course addresses, in detail, a variety of techniques commonly used to mount optical components and assemblies in optical instruments. Topics include 1) estimation of axial stresses in individual lens-type components due to mechanical preload at assembly; 2) effects of applied acceleration forces; 3) effects of temperature changes; 4) estimation of radial stresses;

5) parametric comparisons of the above effects with different mounting interface configurations; and 6) designing the optic-to-mount interface for small mirrors and prisms using clamps, adhesives and flexures. Examples of typical refracting and catadioptric assemblies are used to illustrate multiple component mounting designs.

SILICON CARBIDE TECHNOLOGY

This introductory course provides a roadmap of SiC fabrication methods, their differences, and suitability for precision applications. The characteristics of pure SiC are discussed as are the effects of the fabrication methods on composition and properties. The degree of attainable near-net-shape is covered in depth. Optical fabrication methods are described, including methods of cladding to enhance polishability.

MATERIALS SCIENCE

This course covers physical metallurgy and microstructures; heat treatment; steels, irons, cast irons, stainless steels, inconels, Invar and super Invar; beryllium; dimensional stability; aluminum, magnesium and titanium; materials in the electronics industry; materials problems (fatigue, corrosion, wear and fracture); castings and forming processes (forging, extrusion and rolling); platings and other coatings; welding, brazing and soldering; and testing, radiography, hardness testing, tensile testing and metallography.

SOLID STATE DETECTORS

This course is an introduction to basic detector types, radiometry, detector amplifiers, noise, design of visible radiometer, design of a position sensor (Quad Cell), introduction to charge coupled device detectors, introduction to charge injection device detectors, and design of a star tracker.