a. Project Title

Quantifying and prioritizing the determinants of wood quality in chestnut variants

b. Summary (not more than 100 words)

Interested parties have considered wood quality, such as timber value and appearance, in back-crossed and genetically-modified chestnut variants. Until now, such considerations have been anecdotal and based on limited samplings of stems, most of which are apparently juvenile wood. This proposal, which offers a methodology for sampling and analyzing chestnut wood, is a preliminary study to determine and define appropriate parameters to enable future research on the impacts of chestnut breeding on wood properties. Its focus is on American and Chinese chestnut (*Castanea dentata* and *C. mollissima*) to bracket the range of properties that relate to restoration chestnut wood quality.

c. Principal Investigator(s) and Institutional Affiliation(s)

Charles D. Ray, Ph.D. - Associate Professor, Wood Science and Operations, The Pennsylvania State University

Gary P. Carver, Ph.D. Physicist (retired) and woodcarver, TACF board of directors (emeritus), Maryland chapter board member, past president and vice president of the Maryland chapter (multiple times)

d. Duration of project

Twelve months from the awarding of the grant.

e. Total amount requested. Please list sources and amount of matching funding for the same project.

<u>Requested funds</u>

Total = $7,775 (Quote attached as Appendix 1)

Consisting of:

Laboratory microscope, stand, lighting, and camera for wood specimen macroscopy (Bid attached) = $5775

Microscopic controller interface and computer = $1500

Travel and shipping for log specimens = $500

<u>Matching funds</u>

12 Weeks of Dr. Ray's time = $41,796

3 Weeks of Dr. Carver's time

f. Short and long-term goals of the project

<u>Short term</u> – 3 months (but may extend longer to collect all samples, especially mature Chinese chestnut) Establish sources of specimen logs. Collect specimens and deliver to Penn State. Install laboratory equipment and calibrate to chestnut specimens from Penn State Xylarium.
<u>Long term</u> – 12 months

Determine which wood properties in chestnut variants result in statistically significant differences between variants. Based on these findings, prioritize these properties and the statistical parameters of investigation for future, long-term chestnut wood studies. The criteria for prioritization will include importance to wood quality for commercial applications and relationship to desirable growth characteristics. Begin a macro- and micro-photographic collection of wood specimens with identifying properties labeled. Write and post on agreed-upon website the findings of the study with detailed images. Author and submit a scientific paper on the study for peer-reviewed publication.

g. Narrative

Wood quality and variability

In their landmark work on wood variation, Zobel and van Buijtenen (1989) reference an earlier observation that "breeding for wood is a secondary effort, within the primary effort of getting faster growing, better formed, well adapted, pest-resistant trees. It can be super-imposed on the regular program with the major extra effort required being a greater number of parent trees to satisfy the wood requirements." (Zobel, 1971)

Most work on wood quality over the decades has focused primarily on specific gravity, since it is this property that has the most direct and significant impact on wood product yield, whether that product be lumber, pulp and paper, or energy. It is well known that differences in wood across species, provenances, environmental conditions, earlywood and latewood, sapwood and heartwood, and juvenile wood and mature wood will produce differences in specific gravity. Therefore, the bulk of wood science has focused on specific gravity with respect to tree improvement programs.

However, for the specific category of fine hardwoods, those used primarily for quality furniture and cabinet production and woodworking, many other wood properties have as significant, or more significant impact on the utilization potential of the wood. Cell length, cell thickness, cell width, the presence and size of ray or parenchyma cells, grain characteristics, cell collapse, and fibril angle can all impact the visual or mechanical desirability of specific woods. In addition, color variation can be a key determinant of market value; for instance, color of hard (sugar) maple has been a quality determinant in cabinetry applications for decades.

The issue of chestnut wood quality

Of these fine hardwoods, American chestnut holds a somewhat unique position. While historically used in rough, structural applications and inside veneers, it is now commonly coveted by woodworkers for its smooth yet rugged appearance. It was extensively used for outdoor structures, such as sheds, barns and fences, because it has a high resistance to decay. Today, with the environmental concerns that have reduced the rot resistance of pressure-treated wood, chestnut wood could find a ready market for such uses as decks, outdoor furniture, and playground equipment. In fact, the rebirth of a chestnut wood industry will be fostered by commercial interests that desire to produce such products using natural chestnut wood. This could result in substantial financial support for TACF's restoration efforts.

Compared to other hardwoods, American chestnut wood is of medium density and hardness. The heartwood is light brown, often with a reddish or cocoa tinge. Since it is a ring-porous wood, the "grain," i.e., the visible growth ring structure, is prominent. The earlywood (spring growth) has large pores. The latewood (summer growth) has small pores that are not easily visible without magnification. Therefore, to the unaided eye, the latewood appears to have no pores.

In chestnut, the rays, bands of tissue that are radial and cross the annual rings, are very narrow and are difficult to see even with magnification. The result is that American chestnut wood is "clean" looking, that is, there are hardly any figure and/or markings in the wood between the layers of pores. See Figures 1 and 2.

Figure 1. Face grain of American chestnut wood.   All four samples are made from recycled barn wood. The dark spot on the second-from-left sample is the iron stain from a nail.

Figure 2. Close-up of American chestnut wood face grain.

Chinese chestnut wood, by comparison, has a light greenish or olive-brown color. It has less prominent grain and has irregular, random markings in its latewood. See Figure 3.

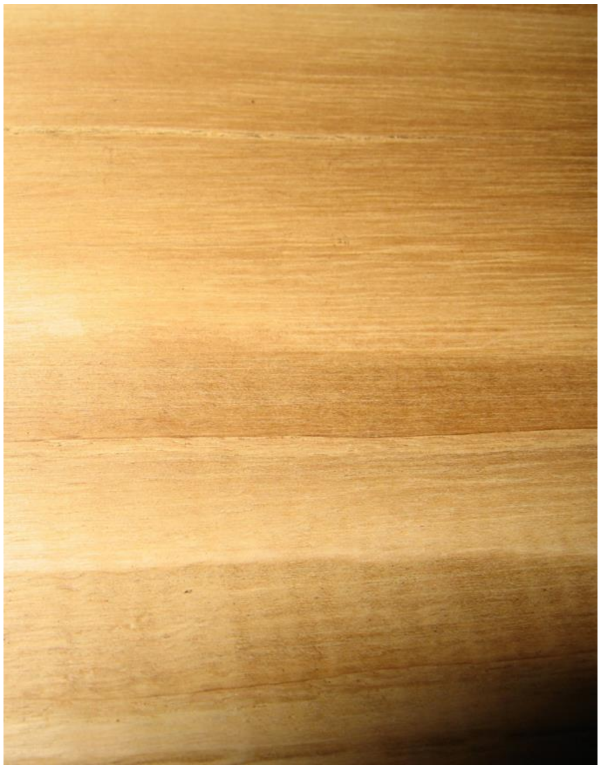

Figure 3. Face grain of Chinese chestnut wood. Notice the less pronounced earlywood and slightly different color.

This observed difference is of concern to some in the field of American chestnut restoration. Will the chestnut that is restored to American forests produce wood that resembles the attractive, clean, historical chestnut wood with its warm, reddish tones…or will it more closely resemble the less desirable Chinese chestnut wood? Early observations at least hint at the possibility that the wood produced from back-cross efforts may produce wood more closely resembling the Chinese chestnut ancestors.

However, these early observations have all been empirical and anecdotal. What has been lacking is a well-designed approach to categorizing chestnut wood properties regarding their impact on wood desirability, and statistical differences between defined properties of American and Chinese chestnuts, and their cross-bred descendants.

<u>Juvenile vs. mature wood</u>

In considering the empirical observations of chestnut wood variation made to date, we notice that there has not been clear distinction between juvenile wood and mature wood when making comparisons. Cross-sections obtained from plantation thinning less than ten years old will be almost entirely juvenile wood; and rogued trees from plantations from ten to twenty years will still contain a large percentage of juvenile wood in the stem. In addition, wood specimens produced from branches of mature trees will contain a large percentage of juvenile wood. Observation of this juvenile wood may lead to mistaken assumptions about mature wood properties.

Juvenile wood in hardwoods has typically not been considered of high scientific interest (Boyd, 1968), since it is typically less significant in hardwoods than softwood with respect to difference in specific gravity. Diffuse-porous hardwoods, in particular, exhibit very little difference between juvenile wood and mature wood (Zobel and van Buijtenen, 1989). However, Fukazawa (1984) was able to differentiate between four different growth type variations in hardwoods with respect to juvenile wood, and concluded that juvenile wood in hardwood differs from mature wood in specific gravity, strength, shrinkage, cell dimensions, and microfibrillar angle. More specifically, and more importantly to the issue of chestnut wood quality, Wheeler (1987) made a generalized assessment that juvenile wood in ring-porous woods (such as chestnut) had a *higher* specific gravity than mature wood and stated: “The rings closest to the pith lack the characteristic…of large-diameter earlywood vessels.” This general observation is confirmed by observation in juvenile chestnut wood that the annual rings are not as well-defined in specimens culled from back-crossed chestnut plantations;

the blurring of these distinctive rings is therefore more likely a function of the juvenile wood itself, rather than an indicator of difference in wood due to the genetic cross-breeding.

One of our hypotheses, then, is that we will find wood quality differences between juvenile and mature wood specimens in chestnut, and that we will be able to quantify these differences and compare them for statistical difference between mature American chestnut wood and the back-crossed variants.

<u>Color variation</u>

One concern of woodworkers is that the wood of the replacement chestnut forest may have more of a gray-green color typical of Chinese chestnut, than the warm red-brown color of American chestnut. Specimen color will be one of the properties we examine in the study. The new equipment being purchased with the project funds will allow us to do this quantitatively. The software will come with a “line profile” tool (Figure 4). This will allow us to draw a line across the sample image, providing us with the intensity profile for RGB (red-green-blue). This will quantitatively differentiate the intensity profile of the sample images, providing us with data upon which we can perform statistical tests of differences.

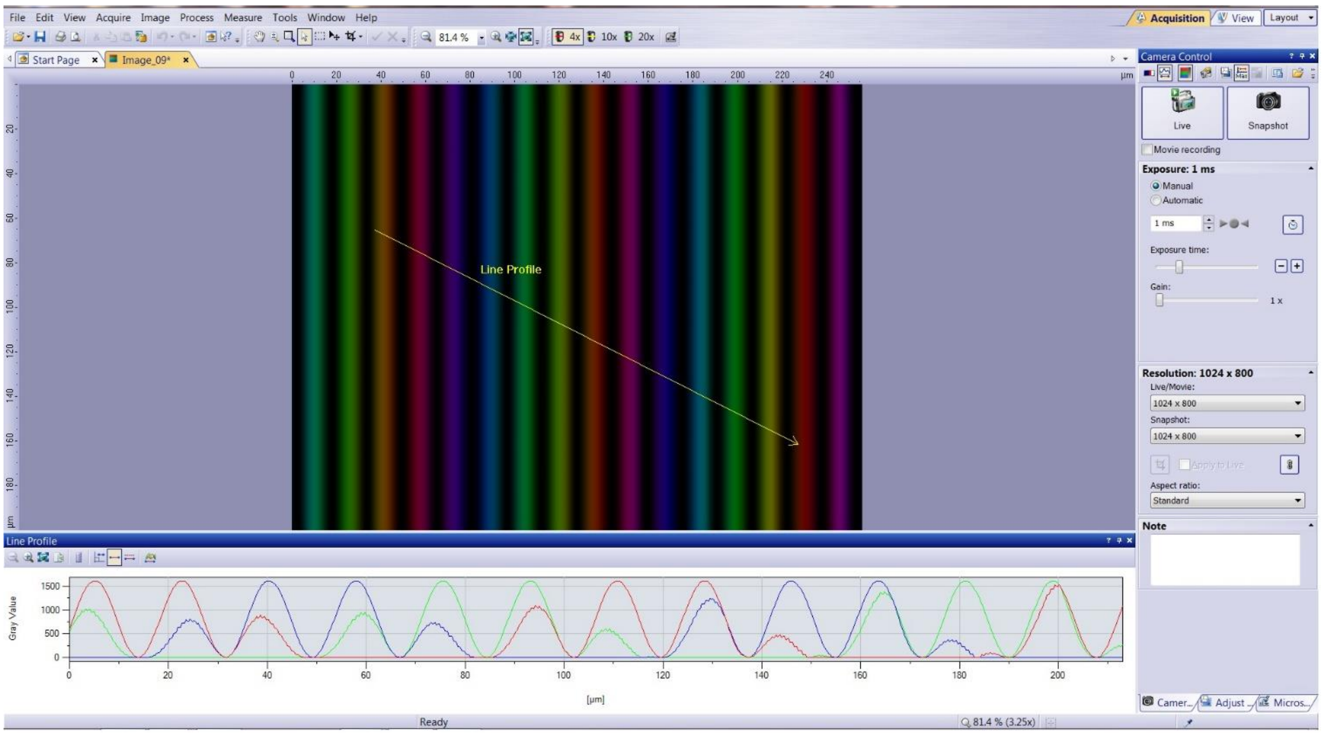

Figure 4. Screen shot of system Line Profile Tool that will produce data for color differentiation.

<u>Methodology</u>

For this preliminary study, we will focus on exploratory statistics and data analysis tools. First, we will decide on the six most identifiable and quantifiable wood quality variables provided by all of the specimens. We don’t know at this point what those six variables will be, but certainly, specific gravity and color code will be two of them. For each of these variables, we will produce histograms of the data sets to satisfy assumptions of the normality of the data. This assumption is based on the proven normality of natural systems; it will allow us to justify a sample size of n=30 specimens per type in accordance with the Central Limit Theorem. Dr. Carver will organize and facilitate the collections of all specimens, using a network of TACF partners.

Assuming these findings of normality to be apparent in the data, we will be able to statistically justify our conclusions on a sample of 30 specimens per category, for a total of 120 log specimens collected. Since we will be attempting to establish differences in two main categories of effects - juvenile wood vs. mature wood, and American chestnut vs. Chinese - we will collect 30 specimens of each of the four. The sample design will be as shown in Table 1.

Table 1. Statistical design of exploratory experiment.

	American	Chinese-cross
Juvenile	N=30; x1….x6 (with replication)	N=30; x1….x6 (with replication)
Mature	N=30; x1….x6 (with replication)	N=30; x1….x6 (with replication)

All data collection on the wood properties of the specimens will be performed in the Penn State Xylarium in State College, Pennsylvania. In addition to specific gravity and color, focus will be on anatomical and physical variables that can be determined and quantified microscopically. Mechanical properties that require testing in engineering labs will be left for future studies, where larger sample sizes and specimen sizes will be required.

Statistical tests of significance will be performed once all the data is collected, and determination will be made as to whether which, if any, of the wood quality variables can be used in future studies to monitor wood quality as chestnut plantations are harvested at different stages. Depending on the results of the study, we may be able to draw a conclusion on whether the back-propagation cross-breeding of American chestnut with Chinese chestnut results in a real wood quality issue. And while this exploratory statistical design will not provide us conclusive results on which backcrossed variants produce wood more like American chestnut, it may provide us with clues to focus on for specific wood qualities.

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Wheeler, E.A. 1987. Anatomical and biological properties of juvenile wood in conifers and hardwoods. For Prod Res Soc Session IV A. Louisville, Kentucky. 3 pp (Summary).

Zobel, B.J. 1971. Genetic manipulation of wood of the southern pines including chemical characteristics. Wood. Sci. Tech. 54:255-271.

Zobel, B.J., and J.P. van Buijtenen. 1989. Wood Variation – Its Causes and Control. Springer-Verlag, Berlin Heidelberg, Germany. 355 p.

h. Timeline, showing start and completion dates for each goal.

Month	Activity
1	Establish sources of specimen logs
2	Install laboratory equipment in Penn State Xylarium
2-3	Collect and deliver specimens to Penn State
2-3	Calibrate lab equipment to chestnut specimens from Xylarium collection
3	Make preliminary determination of wood quality variables to include in study
4-9	Perform studies on collected specimens, including photography
7-9	Compile statistics and create exploratory graphics
8-12	Create website material and post to chosen website(s)
10-12	Produce and submit scientific paper to refereed journal of choice

i. How results will be measured and reported.

Specific gravity measurements will be made from sub-samples cut to required size from the specimen logs, dried to oven-dry moisture content (0% MC), and weighed on a laboratory scale. Color measurements and anatomical measurements will be made on the newly-acquired Olympus SZ-61 microscope and accompanying computer and imaging software.

Results will be reported for the public in a website of choice of TACF, and for scientific publication in a peer-reviewed journal of choice of TACF. Dr. Ray has extensive experience in both types of reporting.

j. Breakdown of how and when funds will be spent

The laboratory equipment will be acquired and funds spent immediately upon award of the grant. The travel/shipping expenses will be spent as necessary for specimen collection.

k. Brief Curriculum Vitae (CV) for each Principal Investigator, including recent publications and grants received. Please restrict each CV to two (2) pages.

Charles David Ray
Associate Professor, Wood Science and Operations
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The Pennsylvania State University
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University Park, PA 16802
Office: (814) 865-0679 FAX: (814) 863-7193 email: cdr14@psu.edu
Web page: http://www.sfr.cas.psu.edu/Faculty/ray.htm

Education

B.S.F, 1986 Stephen F. Austin State University, Nacogdoches, TX (Forest Management) *Magna cum laude.*

Ph.D., 1991 Texas A&M University, College Station, TX (Forest Science); Operations Research concentration. "A Prescriptive Methodology for Comprehensive Evaluation of Manufacturing Expert System Projects."

Professional

Partner, Scientific Management Solutions, LLC (2004-present)
Truss Plant Inspector (Sub-contractor), Structural Building Components Association (2007-present)
Board of Directors, Education Committee, Northeastern Lumber Retailers Association (2018-present)
Board of Directors, Pennsylvania Biomass Energy Association (2011 – 2012)
Board of Directors, Forest Products Society (1998 - 2000)
Corporate Quality Assurance Manager, Louisiana-Pacific Corporation, Portland, OR. (1999-2002)
Technical Research Director, Temple-Inland Forest Products Corporation, Diboll, TX. (1994-1999)
Adjunct Professor, Department of Forest Science, Texas A&M University, College Station, TX. (1995 – 1997)
Process Development Manager, Building Products Group, Temple-Inland, Diboll, TX. (1992-1994)
Special Projects Manager, Building Products Group, Temple-Inland, Diboll, TX. (1990-1992)

Selected service to business and industry (13 total)

1. Ciolkosz, D. and C. Ray. "Status and Needs of the Wood Pellet Industry in Pennsylvnaia – 2009." March, 2009. Submitted as a white paper report to former US Congressman John Peterson and PA-Pellet.org as support for their consulting work to the wood pellet industry.
2. Ray, C.D. and V. Wadhwa. "Optimization of Sawmill Efficiency Measures." March, 2004. Linear programming model and user manual developed for Pine Creek Lumber, Mill Hall, PA for use in research study. Model demonstrates potential doubling, and more, of Pine Creek's monthly profits from log grade mix and pricing improvements.
3. Ray, C.D. "Analysis of Variation in Orientation at Jasper OSB." November, 2003. Review, with recommendations, of a study performed by Louisiana-Pacific technical staff on the performance capability of an OSB forming machine with respect to the angle of orientation of wafers through the thickness of the board. Louisiana-Pacific Corporation, Conroe, TX.
4. Gattani, N. and C.D. Ray. "Time Series Modeling and Analysis of the Hardwood Kiln Drying Process". September, 2003. Thesis research summary presentation given to the management of Bradford Lumber, Bradford, PA.
5. Ray, C.D., and L. Stover. "Investigation of Step Joints in Table Tops." Technical Service Report submitted to Catawissa Lumber and Specialty Company, Inc., Catawissa, PA. December, 2002. This report helped Catawissa resolve a quality issue with a major customer and re-establish the account.

Selected refereed journal articles and proceedings (39 total)

1. Mysyk, M, Y, Matsyshyn, V. Mayevskyy, C. Ray, R. Kurka, and I. Sopushynskyy. 2017. "Identification of the length distribution of lumber defect-free areas." Wood and Fiber Science 49(4), 2017, pp 396-406.

2. Wiedenbeck, J., M. Scholl, P. Blankenhorn, and C. Ray. 2017. "Lumber volume and value recovery from small-diameter black cherry, sugar maple, and red oak logs." BioResources. 12(1), 853-870.
3. Ray, C.D., L. Ma*, T.Wilson, D. Wilson, L. McCreery, and J. Wiedenbeck. 2014. “Biomass boiler conversion potential in the eastern United States.” Renewable Energy 62(2014):439-453.
4. Ray, C.D. 2013. “On calculating the green weight of wood.” World of Wood 66(6):16-21.
5. Ray, C.D. 2013. “Soft hardwood, hard softwood, and vice versa.” World of Wood 66(5):5-7.
6. Scholl, M.S., J.K. Wiedenbeck, P.R. Blankenhorn, C.D. Ray, L.R. Stover, and B.W. Beakler. 2008. “A comparison of kiln-drying schedules and quality outcomes for 4/4-thickness black cherry lumber sawn from small-diameter logs.” Forest Prod. J. 58(12):41-48.
7. Ray, C.D., J. Janowiak, J. Michael, and H. Bachev. 2007. “Economic and Environmental Impact Assessment of Proposed Bark-Free Requirements for Wood Pallets in International Trade.” J. Forest Prod. Bus. Research 4(6).
8. Ray, C.D., N. Gattani*, E. del Castillo, and P.B. Blankenhorn. 2007. “Identification of the relationship between equilibrium moisture content, dry bulb temperature, and relative humidity using regression analysis.” Wood Fiber Sci. 39(2):299-306.
9. Ray, C.D. 2007. “The Virtual Extension Specialist.” Journal of Extension 45(2).
10. Ray, C.D., V. Wadhwa*, and J.H. Michael. 2007. “Impact of Overrun on Optimal Performance of Hardwood Sawmills.” Wood Fiber Sci. 39(2):291-298.
11. Ray, C.D. and E. Deomano. 2007. “Bark occurrence in U.S. and Canadian wooden pallets and containers.” Forest Prod. J. 57(3):84-88.
12. Ray, C.D., E. del Castillo, N. Gattani*, and P.R. Blankenhorn. 2005. “Time Series Techniques for Dynamic, Real-Time Control of Wood Drying Processes.” Forest Prod. J. 55(10):64-71.
13. Beakler, B.W., P.R. Blankenhorn, L.R. Stover, and C.D. Ray. 2005. “Total organic compounds released from dehumidification drying of air-dried hardwood lumber.” Forest Prod. J. 55(2):57-61.
14. Zhang, J. and C.D. Ray . 1995. "Modified Multivariate Evaluation Techniques for Industry-Wide Product Surveys." Conference Proceedings, The Third International Applied Statistics in Industry Conference. Dallas, TX.

Other selected publications (97 total)

1. Ray, C. D. 2010. “Finishing the Quality Circle: Quality Control Strategies for Lumber and Wooden Pallet Companies. Part 2.” Pallet Enterprise, February, 2010.
2. Ray, C. D. 2009. “Quality Control Strategies for Lumber and Wooden Pallet Companies. Part 1.” Pallet Enterprise, December, 2009.
3. Ray, C.D., and B. Diehl. “Toxicity of Yew Wood and Roots.” Posted on Penn State Extension website, November 17, 2014. https://extension.psu.edu/toxicity-of-yew-wood-and-roots
4. Ray, C.D. “Calculating the Green Weight of Wood Species.” Posted on the Penn State Extension website, June 30, 2014. https://extension.psu.edu/calculating-the-green-weight-of-wood-species

Other

Journal articles refereed and proposals reviewed by Dr. Ray (41 total)
News releases quoting Dr. Ray (40 total)
Funded projects, grants, commissions, and contracts (24 completed, total funding of $3,482,279)
Penn State Extension Programming (38 programs, 108 presentations, 3831 attendees)
Penn State Online websites (4 sites since 2002; over 1,031,000 views to date), including
http://pennstatexylarium.blogspot.com/

Gary P. Carver
Physicist (retired), Woodworker, TACF Board Member (emeritus)
Carverscarvings
3501 Big Woods Road, Ijamsville, MD 21754
301-831-9151

Gary received his BS in physics from Clarkson University in Potsdam, NY and his Ph.D. in solid state physics from Cornell University in Ithaca, NY. He began his professional career as a research scientist studying the electronic properties of semiconductor materials at the Naval Ordnance Laboratory. On a special assignment, he spent three months at sea in the South Pacific studying atmospheric effects near nuclear bomb airbursts. He spent a sabbatical year working in the Clarendon Laboratory at Oxford University before joining the National Institute of Standards and Technology (NIST).

At NIST, he became manager and lead scientist of a research group that developed materials characterization tests for semiconductors. Using a unique semiconductor metrology clean room facility that he designed, he led a research program on techniques for measuring and controlling the materials and processes used to make computer chips. Ultimately, he migrated from physics to manufacturing engineering and transitioned his professional activities from research to technical management. He spent a year as the scientific adviser to the assistant secretary for technology at the U.S. Department of Commerce and returned to NIST as scientific advisor to the director of the Manufacturing Engineering Laboratory.

On a special three-year assignment for the U.S. Department of Commerce, he was director of the Federal Government's Metric Program. As "Mr. Metric," he coordinated metric conversion at all executive branch agencies, helped industrial firms use metric standards, and provided information about the metric system to U.S. industry.

In 1998, he joined the Jet Propulsion Laboratory as Manager of the Intelligent Transportation Systems Standards Program. In 2003, Gary retired from JPL and became a full-time woodcarver, a passion he had pursued as a hobby

While he was working for others, Gary authored over 50 reports and journal articles and gave many professional presentations. He wrote numerous reports for government officials, including reports sent by the Secretary of Commerce to the President and the Secretary of Transportation to the Congress.

Gary's "left-brain, right-brain" transition turned him into woodcarver, in accord with his name. Now that he is working for himself, Gary has combined his love of carving and of the American chestnut tree by carving reclaimed chestnut wood from old cabins and barns. His chestnut carvings are featured on the website of The American Chestnut Foundation and on his own Web site, www.carverscarvings.com.

EMPLOYMENT (During career as a physicist at the National Institute of Standards and Technology)

Senior Management Advisor, Manufacturing Engineering Laboratory
Assocate Director of Technology Services for Metric Activities And Director of the Metric Program, Technology Services
Technical Assistant to Assistant Secretary for Technology Policy, Technology Administration, Department of Commerce
Program Manager and Deputy Division Chief, Factory Automation Systems Division
Program Manager, Manufacturing Technology Centers Program, Center for Manufacturing Engineering
Project Coordinator, Quality Control Metrology, Semiconductor Electronics Division
Deputy Division Chief and Group Leaoer, Semiconductor Materials and Processes Division
Visiting Scientist, Clarendon Laboratory, Oxford University, Oxford, England

EDUCATION

Batchelor Of Science (cum laude) in Physics, Clarkson University
Doctor of Philosophy in Physics, Cornell University
Sabbatical Year, Clarendon Laboratory, Oxford University, England

SELECTED PROFESIONAL PUBLICATIONS IN PEER-REVIEWED JOURNALS

High Spatial Resolution Mapping of Resistivity Variations in Semiconductors, J. J. Kopanski, J. R. Lowney, D. S. Miles, D. B. Novotny, and G. P. Carver, Solid-State Electronics, Vol. 35, 423-433 (1992).

High Spatial Resolution Mapping of Semiconductor Resistivity, J. J. Kopanski, G. P. Carver, J.R. Lowney, D. S. Miles, and D. B. Novotny, Extended Abstracts of the Electrochemical Society, Vol. 91-1, 698-699 (1991).

Verification of the Relationship Between Two-Probe and Four-Probe Resistances as Measured on Silicon Wafers, J. J. Kopanski, J. Albers, G. P. Carver, and J. R. Ehrstein, J. E/ectrochem. Soc., Vol. 137, 3935-3941, (Dec. 1990).

High Mobility CMOS Transistors Fabricated on Very Thin SOS Films, D. J. Dumin, S. Dabral, M. Freytag, P. J. Robertson, G. P. Carver, and D. Novotny, IEEE Trans. On Electron Devices, Vol. 36, 596-598 (Mar. 1989).

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Well-Defined Contacts Produce Accurate Spreading Resistance Measurements, G. P. Carver, S. S. Kang, J. R. Ehrstein, and D_. B. Novotny, J. E/ectrochem. Soc., Vol. 134, 2878-2882, (1987).

An Innovative Measurement of Specific Contact Resistivity Confirms Lower Aluminum-Silicon Contact Resistance, G. P. Carver, D. B. Novotny, and J. J. Kopanski, Proceedings of the 1987 IEEE VLSI Multilevel Interconnection Conference, Santa Clara, CA, June 15-16, 1987, 337-343.

Silicon Quality Versus Thickness for Novel Silicon on Boron Phosphide SOI Process, P. J. Robertson, D. J. Dumin, G. P. Carver, D. B. Novotny, and M. Freytag, Proceedings of the Spring Meeting of the Materials Research Society, Anaheim, CA, April 21-25, 1987.

Influence of Short-Channel Effects on Dopant Profiles Obtained from the dc MOSFET Profile Method, G. P. Carver, IEEE Trans. Electron Devices, Vol. ED-30, 948-954 (1983).

An Analytical Expression for the Evaluation of Leakage Current in the Integrated Gated-Diode Electrometer, G. P. Carver and M. G. Buehler, IEEE Trans. Electron Devices, Vol. ED-27, 2245-2252 (1980).

Magnetophonon and Shubnikov-de Haas Oscillations in N-type PbTe Epitaxial Films, J. R. Burke and G. P. Carver, Phys. Rev., Vol. B17, 2719-2727 (1978).

A Corbino Disc Apparatus to Measure Hall Mobilities in Amorphous Semiconductors, G. P. Carver, Rev. Sci. lnstrum., Vol. 43, 1257-1263 (1972).

P3' Spin Echoes in Metallic Phosphorus-Doped Silicon, G. P. Carver, D. F. Holcomb, and J. A. Kaeck, Phys. Rev. Vol. B3, 4285-4286 (1971).

Nuclear Magnetic Resonance in the Cesium-Graphite lntercalation Compounds, G. P. Carver, Phys. Rev., Vol. B2, 2284-2295 (1970).

A Sophomore Course in Experimental Physics, G. P. Carver and D. B. Scarl, Am. J. Phys. Vol. 36, 361-365 (1968).

Nuclear Spin Relaxation in Cs and Rb Metals Below 77°K, G. P. Carver, D. F. Holcomb, and J. A. Kaeck, Phys. Rev. Vol. 164, 410-412 (1967)**l.**

A Conflict of Interest or Commitment (COI or COC) statement. If a COI or COC is known, please document them here. If there is no known COI or COC, please certify as such with a statement in this section.

Dr. Ray has no known COI with any party affiliated with TACF or other researchers in the field.

Dr. Carver has been a member of the Maryland Chapter of TACF almost since its inception. He has served the chapter as president and vice president multiple times. He served on the TACF board of Directors. Currently he is an emeritus board member of TACF and a board member of the Maryland Chapter.

Appendix 1. Quote for laboratory equipment to be purchased for performance of the study.

B&B MICROSCOPES LIMITED

*Optics*Imaging*Confocals*

490 Lowries Run Rd
Pittsburgh, PA 15237

Phone 800-433-1749 **Fax:** 877-768-1984

Quote No: 2018-WCH-1154 - 2 ***8/10/2018***

Charles Ray PHD
Penn State University
205 Forest Resources Building
University Park, PA 16802

Phone: (814) 222-1345
Fax:
E-Mail: cdr14@psu.edu

Sales Rep: William Hilinski
Phone: (814) 573-3301 Ext. 175
Email: William.Hilinski@BBMicro.com

Email all Purchase Orders to Orders@BBMicro.com

Olympus SZ61 on Boom Stand with Camera & Software

	Catalog No.	Product Description	Qty	Price	Extension
1		Microscope & Stand	1	$0.00	$0.00
2	SZ-6145TR	SZ6145TR;MICROSCOPE BODY W/67. 45X ZOOM OPTICS & 45DEGREE C M	1	$2,102.00	$2,102.00
3	2-S110H	WHSZ10X-H;EYEPIECE 10X WITH ES D CAPABILITY, FN22, FOCUSABLE	2	$141.00	$282.00
4	S-02672	SZ2-STB2;BONDER ARM WITH ESD CAPABILITY	1	$269.00	$269.00
5	DI-SMS16B	SMS16B;STD BOOM STAND W/ 24" V ERTICLE POLE	1	$599.00	$599.00
6	DI-126	126;NON-TILT MOUNT FOR 24.5MM	1	$275.00	$275.00
7		Lighting	1	$0.00	$0.00
8	SCH-A20500	A20500; LIGHT SOURCE, ACE, EKE, 115V	1	$399.00	$399.00
9	SCH-A0852060	A08520.60; GOOSENECK, DUAL,FLEXI, 60 COMM	1	$293.00	$293.00
10	SCH-A08591	A08591; CLAMP, M6, SINGLE V	1	$64.00	$64.00
11		Camera / Software	1	$0.00	$0.00
12	CS-EN-V2	CS-EN-V2; cellSens Entry Version 2	1	$717.00	$717.00
13	SIS-LC30	CAM-LC30; LC30 3.2MP CMOS Color Camera, USB2.0	1	$1,348.00	$1,348.00
14		Shipping	1	$0.00	$0.00
15	SHIPBX41/45-1 Box	1 Box	1	$69.00	$69.00
16	IA-Computer-Demo	Demo - Dell Imaging PC w/ Monitor, Mouse & Keyboard	1	$1,500.00	$1,500.00

Hunt Optics Imaging D/B/A BB Microscopes, Ltd.

B&B MICROSCOPES LIMITED

*Optics*Imaging*Confocals*

490 Lowries Run Rd
Pittsburgh, PA 15237

Phone 800-433-1749 **Fax:** 877-768-1984

Quote No: 2018-WCH-1154 - 2 ***8/10/2018***

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University Park, PA 16802

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Sales Rep: William Hilinski
Phone: (814) 573-3301 Ext. 175
Email: William.Hilinski@BBMicro.com

Email all Purchase Orders to Orders@BBMicro.com

Olympus SZ61 on Boom Stand with Camera & Software

Catalog No.	Product Description	Qty	Price	Extension
			Subtotal:	$7,917.00
			Discount:	$641.97
			TOTAL:	**$7,275.03**

Terms & Conditions: 9.23c

PLEASE NOTE:

Price is Valid for 30 Days.
Payment Terms - Net 30 days Unless Different Terms Listed Above.
Price Does Not Include Shipping, Handling or Taxes Unless Quoted Above.
Please Add Where Applicable.
A Minimum of 20% Restocking Fee May Apply on Any Returned Items.

OLYMPUS WARRANTY:
Five Years on Mechanics and Optics.
One Year Electrical.
As Specified by the Olympus Manufacturers Warranty.

This is an official price quotation for the products which you have shown an interest to purchase. The prices listed in this quotation as well as any package pricing, apply to the entire quote as presented. Changes, additions or deletions from this quotation may result in pricing adjustments. Catalog numbers may change from time to time.

This quotation is valid until 9/20/2018