# The New Mexico Journal of Science

Kurt S. J. Anderson, Editor

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***The New Mexico Journal of Science***

## EDITOR'S NOTE

The *New Mexico Journal of Science* is a publication of the New Mexico Academy of Science. Each issue of the Journal, which has been published since 1906, contains research papers and articles deemed of interest to the scientists, educators, and citizens of New Mexico. Some volumes have addressed scientific topics of social or economic interest to the state while others have emphasized scientific research in areas where New Mexico is particularly active.

The New Mexico Academy's Science Research Symposium was held in Albuquerque, New Mexico on 14 November 2015. Oral and poster presentations at the Symposium described scientific research being conducted by undergraduate students, graduate students, and faculty at New Mexico's colleges and universities. The New Mexico Academy of Science also presented its annual Outstanding Science Teacher Awards this meeting. Finally, the Academy oversees a New Mexico Junior Academy of Science program that sponsors an annual statewide scientific paper competition for students in New Mexico's high schools. This volume of the *Journal* contains a selection of research papers from that competition.

We wish to acknowledge the several organizations which co-sponsored the 2015 Research Symposium: the New Mexico Experimental Program to Stimulate Competitive Research (NM EPSCoR), and the University of New Mexico's Center for Water and the Environment (UNM CREST). The Editor also wishes to acknowledge the assistance of Ms. Natalie Rogers of NM EPSCoR in preparing this volume of the *Journal*.

The *New Mexico Journal of Science* is published in an electronic-only format; it can be freely downloaded from the Academy's website at http://www.nmas.org. This enables the Academy to reach a much wider readership without incurring the considerable costs associated with the printing and distribution of paper copies.

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*New Mexico Journal of Science*

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# ABOUT THE RESEARCH SYMPOSIUM

The 2015 New Mexico Academy of Science Research Symposium was held in Albuquerque on 14 November 2015. The Symposium was sponsored by the New Mexico Academy of Science (NMAS), the New Mexico Experimental Program to Stimulate Competitive Research (NM EPSCoR), and the University of New Mexico Centers for Research Excellence in Science and Technology (UNM CREST). The Symposium schedule included thirty oral presentations and 59 poster offerings from the students and faculty of New Mexico's universities and colleges. Dr. Vipin Gupta of Sandia National Laboratories provided the luncheon keynote address. Abstracts of these presentations are included in this annual volume of the NMAS *New Mexico Journal of Science*. The Symposium closed with the presentation of awards for what were judged to be the best undergraduate posters, and with the New Mexico Academy of Science's two annual awards for Outstanding Science Teaching.

## Keynote: Power on Demand

The goal of the Power on Demand Research Challenge is to develop new technologies that dramatically improve the size, weight, and power of electrical energy systems at all scales, while maintaining or improving their efficiency, performance, resiliency, robustness, safety, and controllability. By 2025 we will demonstrate a 10X decrease in the size, weight and added power consumption (SWaP) of electrical energy systems for both mobile and stationary applications. Sandia National Laboratories will contribute to a revolution in electrical power technologies by undertaking focused technology campaigns in a small number of key focus areas. Power on Demand's focus areas were selected by a careful consideration of input collected broadly from a diversity of Sandia stakeholders. Accordingly, we have selected the following primary thrust areas: Battery-based electrical energy storage; Power electronics: wide bandgap materials, devices, and power systems; and Energy generation: microsystem-enabled photovoltaics.

## About the Keynote Speaker, Dr. Vipin Gupta

Dr. Vipin Gupta is a systems engineer at Sandia National Laboratories. His work has spanned system design, technology innovation, solar technical assistance, human factors engineering, and team development. Early on, Vipin worked on satellite imaging for monitoring nuclear test sites and the exploration of anti-neutrino detectors for nuclear non-proliferation. Through a Science Fellowship at Stanford University, he developed a workable concept of secure economic zones that straddle two countries; and joined a solar water distillation startup. More recently, he led a project to provide solar technical assistance throughout the United States and innovating with his inventive Sandia teammates in microscale photovoltaics. Vipin earned his PhD in applied physics from Imperial College London and an M.S. in remote sensing from University College London as a US Marshall Scholar.

## About the Sponsors

Founded in 1902, the New Mexico Academy of Science has been in continuous existence since 1915. The Academy is a member of the National Association of Academies of Science (NAAS) and an affiliate of the American Association for the Advancement of Science (AAAS). The New Mexico Academy of Science works with teachers,state agencies, and the legislature to establish appropriate standards for the teaching of the sciences. The Academy can also act as a resource center, providing scientific advice and expertise to these groups and others. The Academy Goals are to foster scientific research and scientific cooperation, increase public awareness of the role of science in human progress and human welfare, and promote science education in New Mexico. Membership is open to any person or organization engaged in or interested in scientific research, scientific education, or the goals and activities of the Academy. Visit www.nmas.org to learn more.

The New Mexico Experimental Program to Stimulate Competitive Research (NM EPSCoR) is funded by the National Science Foundation (NSF) to build the state's capacity to conduct scientific research. Faculty and students from New Mexico universities and colleges are working to realize the state's potential for sustainable energy development, and cultivating a well-qualified Science, Technology, Engineering and Mathematics (STEM) workforce while supporting a culture of innovation and entrepreneurship. The infrastructure and activities of Energize New Mexico are designed to support shared-use equipment, engage new research and community college faculty, and support the STEM pipeline by training teachers, undergraduate and graduate students, and post-doctoral fellows. Research findings are communicated broadly through new partnerships with New Mexico's museum network, a citizen-centric web portal, and vibrant, experiential programs targeting K-12 students. Visit www.nmepscor.org to learn more about NM EPSCoR, and visit www.nsf.gov/epscor to learn more about NSF EPSCoR and other state EPSCoR programs.

The UNM CREST Center is focused on increasing the participation of under-represented minorities (URM) in science, technology, engineering and math (STEM) professions while conducting cutting-edge research into technological and engineering-based solutions to problems with water and the environment. An integral part of the CREST Center is to increase the participation of underrepresented minorities in STEM professions. An integrated, coordinated set of activities to recruit, retain, and graduate students from underrepresented groups will be implemented, as reflected in the diagram below. The Center will leverage existing programs at UNM, including advising, tutoring, scholarships, and multicultural programs. The Center will also developing new capabilities, including the WAVE, a high-school introduction to engineering course, a summer field class, and a water competition. Visit the UNM CREST website for more information.

## Special Chemistry Session from the American Chemical Society

The Symposium did not have enough time to accept all submitted abstracts for presentation. The New Mexico Chapter of the American Chemical Society sponsored a morning session before the start of the Symposium with seven presentations. We have not included their abstracts since they were not part of the Symposium, but the presenters and their institutions are listed below.

- *Brad Watson, University of New Mexico*
- *Wenhan He, University of New Mexico*
- *Mahinda Ranasinghe, New Mexico Tech*
- *Zhen Zhang, University of New Mexico*
- *Jing Yang, University of New Mexico*
- *Martin Kirk, University of New Mexico*
- *Michael Heagy, New Mexico Tech*

# CONCURRENT SESSIONS (I) AT A GLANCE

## SESSION A: FUEL CELLS, BIOFUEL, AND ALGAE

Moderator: Anton Sum, SNL

Jennifer Thompson, University of New Mexico
*The effect of salinity on the growth rate of* Nannochloropsis salina *algae cells*

Sarah Kinter, University of New Mexico
*Temperature effects on biodiesel production an mixed algal community composition grown in a synthetic high saline brine media*

Kodanda Phani Raj Dandamudi, New Mexico State University
*Co-liquefaction of mixed culture micro-algal strains under subcritical water conditions*

Sadia Kabir, University of New Mexico
*Palladium nanoparticles supported on 3D-Graphene electrocatalysts for fuel cells*

Juchao Yan, Eastern New Mexico University
*Algal Turf Scrubber® in treating dairy manure effluents from Eastern New Mexico*

## SESSION B: GEOLOGICAL & GEOTHERMAL PROCESSES

Moderator: Jayne Aubelle, NMMNHS

Jeff Pepin, New Mexico Tech
*The groundwater flow patterns associated with the formation of the Truth or Consequences, NM geothermal resource*

Marisa Repasch, University of New Mexico
*Longevity of northern New Mexico geothermal systems inferred from 40Ar/39Ar dating of Taos Plateau basalts and fault slip history*

Wesley Clary, University of New Mexico
*Glacial and tectonic interactions: Case study in southeast Alaska*

Thomas Luckie, University of New Mexico
*Using ground-penetrating radar to image the near surface deformation of Denali fault zone, central Alaska*

Chris McGibbon, University of New Mexico
*Carbonic springs as distal manifestations of the Jemez geothermal system, San Ysidro, NM, highlighting the importance of fault pathways and hydrochemical mixing*

## SESSION C: BIOLOGY & ECOLOGY

Moderator: David Peters, SNL

Adrienne Hubbard, University of New Mexico
*Study of cave specimen from Cave 12 in New Mexico*

Calvin Vialpando, New Mexico Highlands University
*The effects exerted on garter snake population structure in northern New Mexico by bullfrogs*

Theresa Garcia, University of New Mexico
*Xanthophyll analysis of high desert trees*

Virginia Thompson, University of New Mexico
*Submerged aquatic macrophytes–Ecosystem engineers in New Mexico mountain streams*

Diana Perales, Central New Mexico Community College
*Evaluation of* Arabidopsis thaliana*: photosynthesis*

# CONCURRENT SESSIONS (II) AT A GLANCE

## SESSION D: INFLUENCES ON WATER QUALITY

Moderator: Kurt Anderson, NMAS

Samantha Saville, New Mexico Tech
*Uranium capture on modified inorganic-organic graphite hybrid material to develop a specific uranium binding filtrate for mining reclamation and private water uses*

Natalie Correa, University of new Mexico
*Elemental concentrations in wildfire ash*

Sumant Avasarala, university of New Mexico
*Effect of intermittent flow on metals mobilized from Native American abandoned uranium mine waste sites*

Nabil Shaikh, University of New Mexico
*Spectroscopic investigation of organic compounds and manganese oxides*

Cherie DeVore, University of New Mexico
*The fate of metals near abandoned uranium mine wastes*

## SESSION E: EDUCATION, HEALTH, AND THE ECONOMY

Moderator: Jason Jackiewicz, NMSU

Natalia Sanabria, University of New Mexico
*The economic impacts of wildfires on the built and natural critical civil infrastructure*

JT Goodart, Grants High School
*The Cancer Breathalyzer: Chemical strips that detect chemicals in lung cancer "breathprint"*

Nader Vadiee, Southwest Indian Polytechnic Institute
*Information technology experiences using simulated tele-science exploration of Mars*

Fadi Jamaleddin ahmad, University of New Mexico
*Evaluation of a paraprofessional-delivered diabetes education at a South Valley clinic*

Kip Carrico, New Mexico Tech
*Emerging air quality issues in New Mexico and the West*

## SESSION F: CHEMISTRY & SOLAR POWER

Moderator: Donivan Porterfield, LANL

Chao Dong, New Mexico State University
*Effect of Lewis acid on oxygen atom transfer in molybdenum model complexes*

Ranjana Dangi, University of New Mexico
*Distortion induced acceleration of intersystem crossing*

Alan Thomas, University of New Mexico
*Interchain charge transfer states mediate triplet formation in polymer nanofibers*

Keda Hu, University of New Mexico
*Functional polymers derived from trans-enediyne monomers*

Jianzhong Yang, University of New Mexico
*Molecular breakwater-like tetrapods for organic solar cells*

## POSTER SESSION AT A GLANCE

(01) The effect of salinity on the growth rate of *Nannochloropsis salina* algae cells
JENNIFER THOMPSON / UNIVERSITY OF NEW MEXICO / UNDERGRADUATE STUDENT

(02) Trace element mobility in water and sediments in a hyporheic zone adjacent to an abandoned uranium mine
CLAUDIA ROLDAN / UNIVERSITY OF NEW MEXICO / UNDERGRADUATE STUDENT

(03) Elemental concentration in wildfire ash
NATALIE CORREA / UNIVERSITY OF NEW MEXICO / UNDERGRADUATE STUDENT

(04) When light breaks the long night: stratospheric ozone depletion in the Antarctic
MELISSA MONTOYA / CENTRAL NEW MEXICO COMMUNITY COLLEGE / UNDERGRADUATE STUDENT

(05) Evaluation of a paraprofessional delivered diabetes education project with a South Valley clinic
FADI JAMALEDDIN AHMAD / UNIVERSITY OF NEW MEXICO / UNDERGRADUATE STUDENT

(06) The effects of light and rainwater on the growth and metabolism of *N. salina* and *G. sulphuraria*
SHALEEN EICKHOFF / EASTERN NEW MEXICO UNIVERSITY / UNDERGRADUATE STUDENT

(07) Cultivation of locally adapted algal community on an Algal Turf Scrubber for treatment of dairy wastewater
DAVID ARELLANO / EASTERN NEW MEXICO UNIVERSITY / FACULTY

(08) Assessing uranium contamination in stream sediment on the Navajo Nation
BRIANNE WILLIS / EASTERN NEW MEXICO UNIVERSITY / UNDERGRADUATE STUDENT

(09) Determining chemical composition of wildfire ash particulates
CHRIS HIRANI / UNIVERSITY OF NEW MEXICO / UNDERGRADUATE STUDENT

(10) Hydrothermal liquefaction of various algae in batch and continuous flow reactors
FENG CHENG / NEW MEXICO STATE UNIVERSITY / GRADUATE STUDENT

(11) Evaluating seasonal streamflow forecasts for southwestern snow fed rivers
SHALEENE CHAVARRIA / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(12) Using ground-penetrating radar to image the near surface deformation of a fault zone, Denali Fault, Central Alaska
THOMAS LUCKIE / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(13) Glacial and tectonic interactions: Case study Southeast Alaska
WESLEY CLARY / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(14) Ultra-fast time-resolved fluorescence spectroscopic characterization of rare earth metal-based nanomaterials
RUWINI RAJAPAKSHA / NEW MEXICO TECH / GRADUATE STUDENT

(15) Evaluation of *Arabidopsis thaliana*: Photosynthesis
DIANA PERALES / CENTRAL NEW MEXICO COMMUNITY COLLEGE / UNDERGRADUATE STUDENT

(16) Risk analysis of recycling containment and treatment of produced water from oil and gas production: A conceptual framework
KATIE ZEMLICK / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(17) Modeling bathymetry and topography maps using an Augmented Reality Sandbox
RYAN POTTENGER / MESALANDS COMMUNITY COLLEGE / GRADUATE STUDENT

(18) Experimental Design: Polycultures of 25 common North American freshwater microalgae species
LAURA JACK / NEW MEXICO STATE UNIVERSITY / GRADUATE STUDENT

(19) Using geochemical tracers to understand geothermal flow pathways in northern New Mexico
VALERIE BLOMGREN / UNIVERSITY OF NEW MEXICO / UNDERGRADUATE STUDENT

(20) Effects of silica sol-gel encapsulation on *C. reinhardtii* metabolism
JOHN ROESGEN / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(21) Building a network from two networks: Sucesses and challenges
AYESHA BURDETT / NEW MEXICO MUSEUM OF NATURAL HISTORY & SCIENCE / CURATOR

(22) Palladium nanoparticles supported on 3D-Graphene electrocatalysts for fuel cells
SADIA KABIR / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(23) The effect of biofilm carrier length on nitrification in moving bed biofilm reactors: An examination of mixing intensity, shock loadings, and pH changes on biofilm activity
KODY GARCIA / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(24) Mantle $CO_2$ degassing and fluid migration along fault networks in the northwestern Albuquerque Basin and Valles Caldera
JARED SMITH / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(25) Assessing the geomorphological effects of animal exclosures on a high elevation stream in the Valles Caldera National Preserve
RYAN KELLY / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(26) Algal system for BOD and nutrient removal from urban wastewater: Pilot scale study
SHANKA HENKANATTE-GEDARA / NEW MEXICO STATE UNIVERSITY / GRADUATE STUDENT

(27) Reactor design and operation variables to improve mixed algae biomass production and stability
DEREK WICHHART / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(28) Evaluation of the accumulation of trace metals on iron-manganese couatings on *in-situ* stream pebbles and emplaced substrates
MARGARET TURPIN / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(29) What's inside an invasive frog? Sexual comparison of bullfrog diet of the Mora River
STEVEN SALINAS / NEW MEXICO HIGHLANDS UNIVERSITY / GRADUATE STUDENT

(30) The ecological role of cougars within a multispecies predator-prey system
ARTHUR ANAYA / NEW MEXICO HIGHLANDS UNIVERSITY / GRADUATE STUDENT

(31) Economic impact of natural gas production in the San Juan Basin
JANAK JOSHI / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(32) Xanthophyll analysis of high desert trees
THERESA GARCIA / UNIVERSITY OF NEW MEXICO / UNDERGRADUATE STUDENT

(33) Distortion induced acceleration of intersystem crossing
RANJANA DANGI / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(34) Identification of cold-stress response genes in *Nannochloropsis salina* using RT-PCR
SABA GILL / NEW MEXICO STATE UNIVERSITY / GRADUATE STUDENT

(35) Characterization of physiological response in *Nannochloropsis salina* to cold stress
STEPHANIE WILLETTE / NEW MEXICO STATE UNIVERSITY / GRADUATE STUDENT

(36) Geochemistry of sinkholes in the Santa Rosa, New Mexico area
MARIAH KELLY / UNIVERSITY OF NEW MEXICO / UNDERGRADUATE STUDENT

(37) Stratigraphic relationships and physical properties of young sediment offshore southeastern Asia
RACHEL PRICE / UNIVERSITY OF NEW MEXICO / UNDERGRADUATE STUDENT

(38) Forgiveness aversion: the influence of perceived forgiveness risks on forgiveness motivation
ANGEL DE NIEVES ARELLANO / NEW MEXICO HIGHLANDS UNIVERSITY / GRADUATE STUDENT

(39) Membrane distillation in water treatment
XU WANG / NEW MEXICO TECH / GRADUATE STUDENT

(40) Short duration aquifer test within a fractured crystalline basement reservoir, Truth or Consequences, New Mexico
MICHELLE SHERMAN / SANTA FE COMMUNITY COLLEGE / UNDERGRADUATE STUDENT

(41) Methods for protecting the growth of *G. sulphuraria* as wastewater
ELAN GLENDENING / NMSU: ALAMOGORDO / UNDERGRADUATE STUDENT

(42) The effects of geothermal fluids on surface water quality in the Jemez River system in Northern New Mexico
VANESSA WARD / SANTA FE COMMUNITY COLLEGE / UNDERGRADUATE STUDENT

(43) Alkalic epithermal gold mineralization, southwestern Platoro caldera: An examination of a shallow extinct geothermal system
JEFFREY HRNCIR / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(44) Evaluation of zinc sulfide and copper oxide as catalysts for chemical carbon mitigation
HANQING PAN / NEW MEXICO TECH / GRADUATE STUDENT

(45) The economic impacts of wildfires on the built and natural critical civil infrastructure
NATALIE SANABRIA / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(46) Preferences on energy regulations, tradeoffs and how they vary across New Mexico
KARA WALTER / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(47) Using graphicalanalysis and geothermometry to compare water chemistry among various sites throughout Colorado and New Mexico
TANNER GRULKE / UNIVERSITY OF NEW MEXICO / UNDERGRADUATE STUDENT

(48) Use of chemical and isotopic identifiers to characterize a uranium contaminated groundwater plume in New Mexico
MITCHELL SCHATZ / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(49) Complexation and redox reactions affecting uranium recovery by in situ leaching
OMAR RUIZ / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(50) Beneficial use of produced water in Pressure Retarded Osmosis
STEVEN ALARID / NEW MEXICO TECH / UNDERGRADUATE STUDENT

(51) Water Purification: Insights on the catalytic activity of defect free- and rich-molybdenum disulfide ($MoS_2$) nanosheets for the photocatalytic removal of carcinogenic chromium(VI) ions
SWAGOTOM SARKER / NEW MEXICO STATE UNIVERSITY / GRADUATE STUDENT

(52) Solution processed strontium titanate as a cathodic buffer layer for polymer solar cells
HONGMEI LUO / NEW MEXICO STATE UNIVERSITY / FACULTY

(53) Lipid extraction from algal biomass for biofuel production
TANAKA PFUPAJENA / EASTERN NEW MEXICO UNIVERSITY / GRADUATE STUDENT

(54) Screening test of four low temperatures on a natural mixed algal population preserved with methanol or dimethyl sulfoxide for viability and identification of reconstituted species analysis
SARAH KINTNER / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(55) Growing microalgae in dairy manure effluents for sustainable biofuel production
BIN BAI / EASTERN NEW MEXICO UNIVERSITY / GRADUATE STUDENT

(56) Comparison of evapotranspiration estimates produced by the simplified surface energy balance model and a portable chamber measurement device
IAN HEWITT / NEW MEXICO STATE UNIVERSITY / GRADUATE STUDENT

(57) Imaging geothermal reservoir features with magnetotellurics
MATTHEW FOLSOM / NEW MEXICO TECH / GRADUATE STUDENT

(58) Algal indicators of acidic inputs and intermittent flow in streams in the Valles Caldera National Preserve
APRIL FOX / UNIVERSITY OF NEW MEXICO / GRADUATE STUDENT

(59) Hydrochemistry of Sulphur Springs and Alamo Creek, Valles Calders: Effect of geothermal systems on surface water quality
GRAHAM THOMAS / UNIVERSITY OF NEW MEXICO / UNDERGRADUATE STUDENT

# CONCURRENT SESSIONS ABSTRACTS

## Session A: Fuel Cells, Biofuel, and Algae

Moderator: Anton Sumali, SNL

Room: Enchantment A & B

### The effect of salinity on the growth rate of *Nannochloropsis salina* algae cells

*Jennifer Thompson, University of New Mexico*

Water and land are the largest resources needed in the cultivation of algae for biofuel production. It is necessary to find ways to cultivate algae without impinging on fresh water resources, especially in arid regions. Certain species of algae including ***Nannochloropsis salina*** can be cultivated in hypersaline environments. The purpose of this experiment was to test the effect that salinity has on the growth rate of ***N. salina*** algal cells with the intention of exploring alternative water sources that can be used for the cultivation of algae. ***N. salina*** is a marine algae therefore it was hypothesized that algal cells that were exposed to hypersaline growth media would experience a faster growth rate versus algal cells grown in hyposaline growth media. For this experiment, three ***N. salina*** algal cultures were grown in bioreactors in growth media of a specific salinity. The ***N. salina*** algal cultures were grown in bioreactors that contained growth media of either 50‰ (hypo), 100‰ (control), or 150‰ (hyper) the salinity of seawater. Chlorophyll content, optical density, photosynthetic electron transfer rate, and pH were measured on the cultures during the experiment. Quantitative analysis of experimental data strengthened the hypothesis that algal cells grown in hypersaline media experienced an exponentially higher growth rate. The increased growth rate of ***N. salina*** in hypersaline environments imply that algae may be cultivated for the production of biofuel in non-traditional water sources such as water from oil and gas production, thus limiting competition for fresh water resources in arid regions.

*Keywords: N. salina, algae, biofuel, alternative, water*

### Temperature effects on biodiesel production and mixed algal community composition grown in a synthetic high saline brine media

*Sarah Kinter, University of New Mexico*

Little investigation has been undertaken to determine how wild xenic algal communities adapt to culturing in a laboratory batch reactor and ultimately their ability to produce biodiesel. This study develops a fundamental understanding of how a xenic natural mixed algal community grown under continuous high light in a synthetic brine media at room and high temperature affects algal growth, lipid production, and mixed community composition to improve biodiesel production. A mixed algal population was harvested from the San Acacia Brine Pond, New Mexico. Two sets of three flasks filled with algal culture in synthesized media were sampled every other day for 14 days. Samples analyzed were chlorophyll a, nitrate consumption, fatty acid methyl ester lipids, and pyrosequencing. Light intensity (both studies), light cycle, room and high temperatures were 1400 µmol Photons/$s^2$ $m^2$, 14.5/9.5 hrs Diel, 25/20 °C Day/Night, and 40/35 °C Day/Night correspondingly. The room temperature total identified fatty acid methyl ester lipid curve exceeded that of the high temperature. The top 99‰ room temperature algal population species contained three Chlorophyta species, one Heterokontophyta species, and two Cyanobacteria two species. The top 99‰ high temperature algal population species contained only three Cyanobacteria species. The room temperature algal population produced the most total identified fatty acid methyl ester compared to the high temperature. At the room temperature, the algal population composition contained more species due to the temperature growth range of the Chlorophyta and Heterokontophyta, while the high temperature culture contained only high temperature adapted Cyanobacteria.

*Keywords: Mixed algal community, biodiesel, pyrosequencing*

## Co-liquefaction of mixed culture micro algal strains under subcritical water conditions

*Kodanda Phani Raj Dandamudi, New Mexico State University*

Poly culture micro algal growth attained recent attention to address efficient waste water treatment systems and production of fuel precursors. To estimate the conversion efficiency of such produced biomass, algae samples were processed using hydrothermal liquefaction (HTL) as it is one of the productive thermochemical conversion processes capable of converting wet feedstock into renewable bio-oils. In this study, thermo-acidophilic microalgae Cyanidioschyzon merolae (CM) and Galdieria sulphuraria (GS) were co-liquefied under hydrothermal conditions in a stainless-steel batch reactor. The temperatures and CM/GS mass ratios were varied from 150 to 300°C and 0 to 100% respectively. All the experiments were performed at 20% solid loading and at a reaction time of 30 min. The maximum bio-crude yield was obtained at 300°C and at a mass ratio of 4:1 (CM/GS). A positive synergetic effect is observed for the bio-crude yield, which is dependent on temperature and mass ratio. The bio crude oils were analyzed using Time of Flight Gas Chromatography Mass Spectrometry (TOF-GC/MS) and Fourier Transform Ion Cyclotron Resonance Mass Spectrometer (FT-ICR MS). FT-ICR MS analysis of the bio crude oils indicate that both the co-liquefied and pure individual algal oils are compositionally similar but their relative intensities changed with process parameters. Ultimate and proximate analysis was also performed for the algae biomass, biocrude oil and biochar.

*Keywords: Hydrothermal co-liquefaction; synergetic effect, FT-ICR MS*

## Palladium nanoparticles supported on 3D-Graphene electrocatalysts for fuel cells

*Sadia Kabir, University of New Mexico*

Fuel cells are one of the most promising sustainable energy technologies for energy conversion. However, current fuel cells rely on platinum electrocatalysts, which are expensive and lack long term stability. Alternatively, Palladium (Pd) has been attracting growing interest due to their thermal stability and excellent activity. However, Pd nanoparticles used as catalysts for fuel cells are usually supported on amorphous carbon supports which are prone to corrosion. If has therefore become imperative to develop relatively cheaper catalytic materials with improved performance and durability. In view of that, our present work adopts the Sacrificial Support Method developed at UNM for the synthesis of porous crystalline 3D-Graphene nanosheets. The nanosheets were then utilized as a support material for Pd nanoparticles deposited using the original Pd-precursor based Soft Alcohol Reduction Method. The obtained materials were comprehensively characterized by X-ray diffraction (XRD), transmission electron microscopy (TEM), and scanning transmission electron microscopy (SEM). Our results show that the 3D-Graphene support materials had a high surface area (~300 m2/g) and porosity. The Pd nanoparticles synthesized using ethanol as a reducing agent in the SARM fabrication method had an average size of 4.3 nm as well as the highest electrochemical activity and durability when supported on 3D-Graphene, with a peak current density of over 1550 A/gPd for ethanol electrooxidation. The results from this research will not only lead to the development of highly efficient catalytic materials for fuel cells, but also lead to the advancement and successful commercialization of sustainable emerging energy technologies.

*Keywords: energy, electrocatalysts, fuel cell, graphene*

## Algal Turf Scrubber® in treating dairy manure effluents from Eastern New Mexico

*Juchao Yan, Eastern New Mexico University*

Algal Turf Scrubber® (ATS) uses solar/algal technology to harness attached, primarily filamentous algae for biofuel feedstock, and to simultaneously clean wastewater and impaired water as well. ATS thus offers an economically and environmentally sustainable technology in scaling up algal cultivation in outdoor settings. Funded by the NSF-EPSCoR and Eastern New Mexico University, in 2013 we constructed our outdoor ATS in Portales, New Mexico. Our system has a carbon recovery unit, which contains ca. 10,000 gallons of scrubber effluents consisting of dairy manure effluents

and fresh well water. The effluents are continuously recycled to a floway at precisely controlled flow rates. The floway is 100-feet long and 1-foot wide, and has a surface area of 9.29 m2 and a slope of 0.5%. For more than one and a half years now, our system has been in stable operation. In this presentation, I will focus on the baseline performance of our system, including real-time monitoring of the cultivation broth (pH, temperature, oxidation reaction potential, and conductivity), nutrient analysis, and biomass harvesting, purification and drying. We will also present our preliminary data on biomass productivities, algae strain identification and semi-quantification, ash content, lipid extraction, analysis of carbohydrate and fatty acid methyl ester by Gas Chromatography-Mass Spectrometry.

*Keywords: algae, wastewater, algal biofuel, Algal Turf Scrubber®*

## Session B: Geological and Geothermal Processes

Moderator: Jayne Aubelle, NMMNHS Room: Enchantment C & D

### The groundwater flow patterns associated with the formation of the Truth or Consequences, New Mexico geothermal resource

*Jeff Pepin, New Mexico Tech*

We have investigated two of the most plausible regional groundwater circulation scenarios responsible for the formation of the Truth or Consequences, New Mexico hot springs (~ 41 °C) in the southern Rio Grande rift. The first scenario is that the geothermal anomaly is the result of lateral forced convection associated with a gently-dipping carbonate aquifer. The second scenario is that high permeability of crystalline basement rocks permits circulation of groundwater down to depths of 8 km prior to discharging in Truth or Consequences. We constructed a 2D hydrothermal model of the region using FEMOC to test these hypotheses. Model parameters were constrained by calibrating to measured temperatures, specific discharge rates and groundwater residence times. Hot springs geochemistry is consistent with water/rock interaction in a silicate geothermal reservoir, rather than a carbonate system. Peclet-number analysis of temperature profiles suggests specific discharge rates beneath Truth or Consequences range from 2 to 4 m/year, while geothermometry indicates maximum reservoir temperatures are around 167 °C. We were able to reasonably reproduce observed measurements using the permeable-basement scenario while assigning a uniform effective basement permeability of 10-12 m2. Implementing the exponential decay crustal permeability relationships that are often applied in regional groundwater models was unable to reproduce our field measurements. The carbonate-aquifer scenario failed to match observations. Our findings imply that this geothermal system formed as a result of deep groundwater circulation within permeable crystalline basement rocks. Ongoing work is focused on refining our model using aquifer test results and magnetotellurics.

*Keywords: Geothermal, permeability, hydrothermal modeling, deep groundwater circulation*

### Longevity of northern New Mexico geothermal systems inferred from $^{40}Ar/^{39}Ar$ dating of Taos Plateau basalts and fault slip history

*Marisa Repasch, University of New Mexico*

$^{40}Ar/^{39}Ar$ geochronology of the Taos Plateau Volcanic Field (TPVF) records the spatial and temporal distribution of magmatic activity in northern New Mexico over the last ~5 Ma. Probability density plots and histograms of the data show two major pulses of volcanism: 5.0-4.5 Ma and 3.6-2.9 Ma. Spatial distribution of age data show migration of the heat source beneath northern New Mexico from the earliest TPVF eruptive activity at Cerro Montosa at 5.88 ± 0.18 Ma, the oldest basalts in the vicinity of Cerro Chiflo near the Rio Grande Gorge, the youngest basalts in the northwest TPVF near San Antonio Mountain, and final eruptive events that took place in the northeast TPVF north of

Ute Mountain. Dacites record sub-volcanic intrusions, which were also emplaced during two major pulses: 4.8 Ma and 3.3-2.8 Ma. Stratigraphic relationships among dacites and basalts of the TPVF are well exposed within the Rio Grande Gorge where the Rio Grande has incised into the landscape up to 250 m. The Embudo fault was most active between 3 Ma and 2 Ma, while the La Bajada fault experienced the most displacement within the last 2.5 Ma. Modern hot springs are located along the Gorge fault, where deeply circulated groundwater emerges along intersecting faults near river level. The occurrence of faults along the Rio Grande, and the presence of mantle-derived magmatic volatiles in the hot springs suggest modern hot springs may have been active over the last three million years.

*Keywords: geochronology, geothermal systems, faults*

## Glacial and tectonic interactions: Case study Southeast Alaska

*Wesley Clary, University of New Mexico*

In the last decades research has shown that climate activity can be an important component of large scale tectonics. Glacial erosion and deposition, forced by climate patterns, affect mass balance in large-scale tectonically active regions as well as offshore depositional basins. One ideal natural laboratory to study these climate-tectonic interactions is offshore glacial-marine deposits in SE Alaska where an offshore accretionary wedge records glacial and marine sedimentation as well as faulting. This location is ideal because the offshore depositional basin is near the onshore sediment source which facilitates a short time between erosion and deposition as well as a relatively closed system from source to basin. Thanks to previous research efforts there is extensive data including sediment core, well log measurements, bathymetry, and offshore seismic reflection surveys available to aide in the interpretation of climate-linked glacial activity and fault activity. Detailed stratigraphic and structural interpretation of seismic reflection lines collected off the coast of SE Alaska allow for sequence interpretation of fault activity, glacial deposition, and climate change. Interpretation of sedimentation patterns with special focus on extent and style of glacial sedimentation and fault activity link these processes in space and time. Applied spatial-statistics provides a quantitative link between glacial activity and faulting by testing for shape similarity and proximity of related geologic features.

*Keywords: tectonics, glaciers, seismology, stratigraphy*

## Using ground-penetrating radar to image the near surface deformation of a fault zone, Denali Fault, central Alaska

*Thomas Luckie, University of New Mexico*

The use of ground-penetrating radar (GPR) can provide detailed, centimeter-scale resolution images of the subsurface to a depth of tens of meters. Alaska is one of the most seismically active areas in the United States, but few faults have undergone detailed studies of Quaternary stratigraphy and near-surface structure. In the summer of 2015, a pilot study collected and analyzed 2-D GPR data across the Denali Fault in central Alaska to help constrain near-surface deformation. A basic data processing flow and a 1-D, single-layer velocity model was applied in order to conduct preliminary interpretations. We observed clear reflections to a depth of ~7 m below the ground surface. Data collected at co-located paleoseismic trenching mimic the near-surface reflections and help ground-truth the GPR data. The combined data sets provide insight into the north-south limits of the deformation zone of the fault at this site, along with fault zone morphology at a shallow (<7 m) depth. However, farther from the trenching exposures, the GPR data were less clear as to whether it displayed any reflection patterns indicative of fault zones, which may be due to adverse environmental conditions for GPR implementation. The poor imaging leads to more speculative interpretations, making correlation between the trenching exposures and the GPR data difficult. This pilot study demonstrates the potential use of GPR in the characterization of faults and the advantages and disadvantages of using GPR in conjunction with trenching and outcrop interpretation.

*Keywords: Ground-penetrating radar, active faults, Denali Fault, Alaska*

## Carbonic springs as distal manifestations of the Jemez geothermal system, San Ysidro, New Mexico, highlighting the importance of fault pathways & hydrochemical mixing

*Chris McGibbon, University of New Mexico*

Deeply sourced waters can contribute significant quantities of salinity to groundwater, degrading water quality, with faults acting as conduits for subsurface fluid flow. Understanding source, movement, and chemistry of groundwater is becoming more urgent with changing climate and weather patterns. Sampling was carried out on three groups of carbonic warm/hot springs in New Mexico: Tierra Amarilla, Peñasco springs (San Ysidro), and Soda Dam, Jemez and Indian hot springs. Multiple hydrochemical tracers were applied to quantitatively evaluate possible flow paths and mixing. Three hypotheses were tested for source and transport of waters to these springs: San Juan basin origin, meteoric flow from the Nacimiento Mountains, and/or influence from the Valles Caldera geothermal system. Tracers defining mixing trends are: major ions, stable isotopes, conservative tracers, and helium isotope ratios. Lithium, boron, and bromine values all show the San Ysidro springs to have hydrochemical influence from the Valles Caldera geothermal system. Helium gas data show elevated 3He/4He values consistent with contributions from the Jemez volcanic system. At San Ysidro spring groups, plots of high Lithium/Boron versus chloride suggest geothermal waters acquire chloride from other sources, including salts from the Paleozoic and Mesozoic aquifers. We interpret these carbonic springs to be distal manifestations of fluid circulation along faults with mixtures of Jemez geothermal waters and waters sourced from either/both San Juan Basin aquifers and meteoric sources. Semi-confined fault conduits provide connectivity between spring systems and explain geochemical similarities and mixing trends between Valles Caldera, Soda Dam/Jemez Springs with the more distal San Ysidro springs.

*Keywords: Geochemistry, faults, water, isotopes, spring, Jemez*

## Session C: Biology & Ecology

Moderator: David Peters, SNL

Room: Enchantment E & F

## Study of cave specimen from Cave 12 in New Mexico

*Adrienne Hubbard, University of New Mexico*

Increased diversity of infectious bacteria complicates possible eradication of harmful diseases. Uncovering the mechanisms that enable microorganisms to live in harsh conditions may illuminate effective components for better medicines. Specifically, remote places, like the walls of lava tube caves, can expose relationships between bacterial structures and their survival resources. This study mapped locations of bacteria's possible energy sources along with locations of flowing, standing, and still water in Cave 12. Further, different areas inside and above the lave tube cave were swabbed for bacteria specimens. The microbes were cultivated at room temperature for two days, after which, the mother plates were transferred to a 4°C refrigerator for an additional 12 days. Then, we analyzed the internal cave and surface colonies' morphologies and created subcultures. At three weeks of growth, gram stain, catalase, and oxidase tests analyzed the microbial structures of the subcultures. The morphologies and oxidase test results varied depending on sample origin. Gram stain tests from different subcultures were mostly positive. The catalase test results were all positive. The test results revealed possible correlations between bacterial structures and the originating location of the colony. A thick cell wall is common in the Cave 12 habitat. The cytochrome c oxidase enzyme is not present in all colonies. A surprising result from the catalase test was most microbes have the ability to break down $H_2O_2$. Altogether, these results about the bacterial structures that thrive in harsh environments enable future research to investigate antibacterial applications.

*Keywords: microbiology, microbial structures, antibacterial applications*

## The effects exerted on garter snake population structure in Northern New Mexico by bullfrogs

*Calvin Vialpando, New Mexico Highlands University*

Most studies looking into the effects bullfrogs have on native species have largely focused on the impacts they have on different amphibian species. However, little is known if semi-aquatic reptiles have similar effects. In Arizona and California bullfrogs are known to have a negative effect on the more aquatic Mexican garter snake and giant garter snake populations respectively. In this study, I looked to determine if bullfrogs have an effect on garter snake populations in northern New Mexico. The study took place at the Rio Mora National Wildlife Refuge (RMNWR) in northeastern New Mexico along the Mora River. We placed two boardline transects (n=95 per transect) in two treatment groups, a control (where bullfrogs are left unmanaged) and an experimental (where bullfrogs are managed). The boardline transects were checked from early May to mid-October. Western terrestrial garter snakes were the most abundant species encountered during the duration of the study with the control site having a higher density despite the high abundance of bullfrogs in that area. Plains garter snakes were only detected in the experimental site where bullfrogs are constantly being managed,. Despite being present at the RMNWR, black-neck garter snakes were absent along the two study sites. Bullfrogs do not appear to exert similar effects on the more terrestrial western terrestrial garter snake as they do on more aquatic species as seen in Arizona and California. Few plains garter snakes were detected to make an accurate assessment on how bullfrogs influence their populations.

*Keywords: Garter snakes, bullfrogs, Mora River, RMNWR*

## Xanthophyll Analysis of High Desert Trees

*Theresa Garcia, University of New Mexico*

Xanthophylls are light sensitive plant pigments that help compensate for free radicals by dissipating excess absorbed light energy. Light is a necessity for plant survival, but too much light can generate oxygen reactive species that can damage or even kill a plant. Plants adjust their light harvesting complexes to optimize light utilization, but this process is slow relative to daily environmental variation and the onset of stress. Xanthophylls can convert to light dissipating forms within minutes, so they provide a lot of flexibility plants need. Very little research has been done to explore these compounds in native New Mexican species Juniperus monosperma, and Pinus edulis, which grow in high light, upper elevations, and regularly experience drought. We developed a rapid and improved separation and analysis of the xanthophylls, violaxanthin, antheraxanthin, and zeaxanthin, through ultra-high pressure supercritical fluid chromatography. We then used this method to compare xanthophyll composition of both species grown under heat, drought, and combined heat and drought conditions.

*Keywords: Xanthophylls, chromatography, tree, stress conditions*

## Submerged aquatic macrophytes: Ecosystem engineers in New Mexico mountain streams

*Virginia Thompson, University of New Mexico*

Submerged aquatic macrophytes are ecosystem engineers that can significantly modify abiotic and biotic conditions in their environment. Normally studied in low elevation, low gradient, highly impacted systems, we studied a high elevation, low human impact mountain stream in the Jemez Mountains. Macrophyte species were identified, life history (phenology) observations were taken, instream biomass quantified, and macrophyte effects on water quality and response to disturbance were measured. The four species present were found to be *Elodea canadensis*, *Ranunculus aquitilis*, *Potamogeton richardsonii*, and *Stuckenia pectinata*. Total mean biomass from 2011-2013 peaked at over 1000 g/m2. Biomass measures were sensitive to disturbance events, and continuous measurements of dissolved oxygen at

the site followed similar patterns to macrophyte phenology. This study provides a foundation for understanding the presence and impacts of a specific plant class in a high elevation mountain stream habitat. Mountain headwater areas are key water sources worldwide for cities that depend on surface water for human consumption. As human demands on water resources increase in the face of climate change and growing populations, greater understanding of the impacts these plants have on headwater stream ecosystems enhances our knowledge of the role of these ecosystem engineers in low gradient montane headwater streams worldwide.

*Keywords: Submerged aquatic macrophytes, disturbance, dissolved oxygen, aquatic ecosystems, high elevation*

## Evaluation of *Arabidopsis thaliana*: Photosynthesis

*Diana Perales, Central New Mexico Community College*

*Arabidopsis thaliana* have been transformed to over-express the photorespiratory enzyme, glycine decarboxylase (GDC-L). Our research was to evaluate the photosynthetic activity of *Arabidopsis thaliana*. For more than 30 years, photorespiration has been considered to be a wasteful process, requiring plants to use energy and release $CO_2$ in order to recycle one of the products of oxygen fixation by the photosynthetic enzyme RuBisCO. This side reaction partly reverses the major action of RuBisCO, the capture of $CO_2$ for the Calvin cycle in photosynthesis. Yet, these transformed plants suggest that photorespiration can be beneficial due to the increased expression of the enzyme GDC-L and increased rate of photosynthesis. We investigated how photosynthesis was increased. Specifically, to see if this was achieved through increased expression or activation of RuBisCO in response to the increased expression of GDC-L. Our research was performed by analyzing the RuBisCO activity and measuring the photosynthesis responses under multiple light exposures in both the wild type and the transformed plant (PSL-3). We found during the RuBisCO analysis, the wild type had more activity and higher photosynthesis than PSL-3. This should represent that there is more RuBisCO present in wild type than in PSL-3 but there is other data from our collaborators lab that contradict this idea. Additional data is needed to resolve the discrepancies between the two labs. It is possible that leaf and plant age varied between experiments and is responsible for the different results.

*Keywords: Photosynthesis, enzymes, Arabidopsis thallana, $CO_2$*

## Session D: Influences on Water Quality

Moderator: Kurt Anderson, NMAS Room: Enchantment A & B

## Uranium capture on modified inorganic-organic graphite hybrid material to develop a specific uranium binding filtrate for mining reclamation and private water uses

*Samantha Saville, New Mexico Tech*

Uranium has a significant impact on life in several Western states including New Mexico. The EPA in 1991 proposed the uranium standard for drinking water to be 30 ppb (EPA 1991) but groundwater in uranium-rich areas can range up to 120 ppb (Langmuir 1997). This creates a large problem in New Mexico because most drinking water comes from sources that can be contaminated with high uranium concentrations. Removal of uranium by binding to a subsequently-separable solid is becoming a highly sought technology in industry and uranium research. A new inorganic-organic hybrid material based on carbon for uranium capture has been developed by Dr. Liliya Frolova in the Chemistry Department at New Mexico Institute of Mining and Technology. This material was tested for its percent absorption of uranium, selectivity towards uranium over other common divalent cations, and the materials reusability, durability, and absorption recovery for continued use as filter material. These tests were performed on an inductively coupled plasma mass spectrometer. Surface analysis was accomplished using a scanning electron microscope, particle size analysis was completed with a traditional microscope, and filter prototypes were accomplished with Darcy's Law equation. The

various prototypes can be developed for pressure systems, non-electric systems, larger scale models for industrial use, including remote locations that need it the most. Our hybrid material shows a tenfold increase of uranium absorption over both calcium and magnesium (0% Ca, 0% Mg, 99.96% U) which is a significant increase over the unmodified material (18.14% Ca, 0.32% Mg, 29.34% U).

*Keywords: Water quality, graphite, uranium, filtrate, absorption*

## Elemental Concentrations in Wildfire Ash

*Natalie Correa, University of New Mexico*

Hypothesis: *Metals are concentrated in ash and their presence and speciation varies as a function of different tree species*. Questions: What specific metal and non-metal elements are contained in wildfire ash and how much metal and nonmetal elements do different tree species contain? Long term: What could potentially happen when an excess of metals from wildfire ash enters freshwater ecosystems and what are some toxic metals to humans? Determine the concentration of metals and anions leached from solid ash from the Valles Caldera Natural Preserve. The following six tree species from the Valles Caldera Natural Preserve have been sampled for this study: Quaking Aspen, Blue Spruce, Western Juniper, Ponderosa Pine, Douglas Fir, and Gambel Oak. The ash samples were put through acid digestions (Aqua Regia) and metals were analyzed using Inductively coupled plasma-optical emission spectroscopy and the anions were measured using the mass spectroscopy.

*Keywords: Heavy metals, wildfire ash, pH, water quality*

## Effect of intermittent flow on metals mobilized from Native American abandoned uranium mine waste sites

*Sumant Avasarala, University of New Mexico*

Column experiments were conducted to study the effect of intermittent flow on the mobility of metals from abandoned uranium mine waste sites in Blue Gap Tachee (BGT), AZ and Laguna, NM during surface water infiltration to ground water resources. Intermittent flow represent the rainfall patterns in the southwestern United States, involving alternate wet and dry cycles. In order to simulate these rainfall patterns shorter wet periods of 15, 30, 60, 120 and 360 minutes, followed by longer dry periods of 24 hours, were adopted for the column experiments. The experiment involved sequential leaching of sediments from Laguna and BGT with 18M′Ω water (pH 5.4), Synthetic Rain Water (SRW, pH 5.6), 10mM bicarbonate solution (pH 7.9) and 10mM acetic acid (pH 3.4) solution that represent the environmentally relevant conditions as witnessed in BGT water samples (pH 3.8 and 7.4). With just 18M′Ω water and SRW almost 90 µg/L of U, 4500 µg/L of V and 20 µg/L of As were released from BGT mine waste while the Laguna sample showed the release of 380 µg/L of U, 2 µg/L of V and 40 µg/L of As. The released U concentrations were 3-13 times its EPA MCL for U which under natural circumstances could threaten the proximate communities. Bicarbonate and acetic acid extractions on the other hand released 3500-6000 µg/L of U, 50-3000 µg/L of V and 14-35 µg/L of As from both Laguna and BGT mine waste respectively. A 1D reactive transport model is also being applied to better interpret the role of these interplaying mechanisms.

*Keywords: Uranium, heavy metals, mine waste, Blue Gap, rainfall, intermittent flow*

## Spectroscopic investigation of interfacial interaction of organic compounds and manganese oxides

*Nabil Shaikh, University of New Mexico*

Water reuse has become a necessary practice in semi-arid regions. However, a new generation of emerging organic micropollutants has been increasingly scrutinized in water sources. The oxidation of organic micropollutants by

reaction with manganese oxides [$MnO_x$] has been widely studied but little is known about the changes in chemical characteristics of the $MnO_x$ surfaces. We investigated the oxidation of phenol, aniline and triclosan with $MnO_x$ using X-ray Photoelectron Spectroscopy for surface analysis and ICP-Mass Spectroscopy for liquid analysis. The surface of unreacted $MnO_x$ and reacted $MnO_x$ were examined for variations in Mn oxidation state and carbon/oxygen bonding. The solution were analyzed for soluble Mn. Reaction of phenol with $MnO_x$ resulted in increase in C-OH bonds, indicating the presence of phenol and its polymeric by-products. Detection of chlorine after reaction with triclosan, suggests that triclosan and its by-products are associated to $MnO_x$ surface. The increase in aromatic and aliphatic carbon bonds after reaction with aniline suggests that aniline and its byproducts are also associated to $MnO_x$ surface. An increase of Mn(III) on surface and dissolution of Mn into solution was detected for $MnO_x$ reacted with organics, indicating reduction of $MnO_x$. Different changes in the $MnO_x$ surface was observed among the organic compounds, indicative of differing mechanism or pathways of surface reactions for different organic groups. The results from this research are important towards better understanding biogeochemistry of Mn, and for development of cost-effective water treatment technologies that make use of $MnO_x$ to remove emerging organic micropollutants.

*Keywords: water, emerging contaminants, surface analysis*

## The fate of metals near abandoned uranium mine wastes

*Cherie DeVore, University of New Mexico*

The legacy of uranium mining activities in New Mexico has resulted in a number of abandoned mine sites that have not been adequately managed or remediated. An investigation of the chemical interactions and mobility of uranium (U) near abandoned mine wastes was performed at a site located in Laguna Pueblo, New Mexico. Compared to the U.S. EPA drinking water standard of 30 µg/L, elevated U concentrations (ranging from 65 to 710 µg/L) were observed in surface water below an abandoned uranium mine using inductively coupled mass spectrometry (ICP-MS). These U concentrations seasonally decrease (5.77-10 µg/L) downstream at a reservoir five kilometers below the mine. Our water data suggest that U forms aqueous complexes with carbonate and calcium which could contribute to U mobility. Although U concentrations in stream water are high, acid digestions (performed using hydrochloric and nitric acid) and X-Ray Fluorescence bulk analysis suggest that there is limited accumulation in stream bed and bank sediments. Additionally, individual samples show high U concentrations (20-55 mg/kg) in the roots of salt cedar plants near the mine site and translocation to the stems and leaves is minimal. Our results suggest that uptake by plants, and U sorption to wetland sediments are the dominant factors that help to decrease the U concentrations downstream of the mine. This study contributes to an understanding of the mobility of uranium in surface water and sediments close to the mine waste. This information is essential to determine human health implications resulting from exposure to these metals in neighboring communities.

*Keywords: Metals, uranium, water quality, spectroscopy*

# Session E: Education, Health, and the Economy

Moderator: Jason Jackiewicz, NMSU

Room: Enchantment E & F

## The economic impacts of wildfires on the built and natural critical civil infrastructure

*Natalia Sanabria, University of New Mexico*

The impacts on critical civil infrastructure (e.g., water, telecommunications, transportation, etc.) due to major disaster events, can greatly affect the response times and effectiveness of emergency teams, the proper operation of critical facilities and the recovery time for the community. With natural disasters on the rise and the nation's infrastructure outdated and vulnerable, it is essential for agencies to have a plan of action for the allocation of funds to protect

civil critical infrastructure. Over the past decades, wildfires have increased in severity and frequency in response to changes in climate, especially in the Southwest where the arid climate, heat waves and droughts can have a dramatic effect on the risk of fire. This study explores the economic impacts of wildfire events on critical civil infrastructure and the costs associated to mitigation strategies. The proposed impact assessment framework can be incorporated in the decision making processes of watershed managers in order to consider the proper wildfire risk mitigation strategies that better protect and maintain the functionality of the infrastructure.

*Keywords: wildfire, economic impacts, critical infrastructure*

## The Cancer Breathalyzer: Chemical strips that detect chemicals in lung cancer 'breathprint'

*JT Goodart, Grants High School*

Every year, thousands of people are diagnosed with lung cancer. 85% of patients are diagnosed at a late stage with only a 4% survival rate when diagnosed late. The purpose of this project is to make chemical strips for testing in a modified breathalyzer to detect lung cancer at an earlier stage based on chemicals released in a high concentration in lung cancer 'breathprints'. The experiment was conducted in four phases. Phase I, yeast cultures were grown in lung cancer breathprint chemicals for the chemicals to be released through fermentation combined with $CO_2$. The yeast's ability to survive was measured through density, pH, cell size, and growth. Phase II, chemical strips were made that changed color when exposed to chemicals yeast cultures released by direct liquid contact and constant or alternating aromatic exposure. Color changes, if any, were recorded. In Phase III, further testing was performed using chemicals that modeled aspects of the reaction between the strips and yeast to determine the color-changing agent and increase the rate, concentration, and color change. The color change was recorded. Phase IV, the pH of the strips was measured after exposure to the chemicals in order to determine the reactions occurring. After all data was gathered, color key charts were made that displayed the color change with respect to quantities of chemicals present. The rate of color change was calculated. A cost analysis between the potential breathalyzer and current methods of lung cancer tests was made. In conclusion, the project was successful in making it more possible to develop a breathalyzer for detecting lung cancer.

*Keywords: cancer, cells, health care, breathprint, $CO_2$*

## Information technology experiences using simulated tele-science exploration of Mars

*Nader Vadiee, Southwestern Indian Polytechnic Institute*

To promote the advancement of Native American students in Information Technology (IT) and Science, Technology, Engineering and Math (STEM) careers Southwestern Indian Polytechnic Institute (SIPI) will develop a year-round robotics centered IT immersion program that will provide students a stimulating learning environment to explore their curiosity and creativity in IT and STEM fields. To expand the impact of the program and the number of students reached, SIPI will partner with three regional high schools with predominantly Native American student populations. This project will become a model program through which experience gained can be shared with other Tribal Colleges (TCU) through the TCU Engineering Programs Working Group. The robotic elements of this program will focus heavily on performing remote science operations, akin to the Mars Exploration Rovers, to provide an interesting and technically rich IT environment for student learning. Students will get hands on experience in operating robots from remote locations to emphasize the importance of computers for computation and control, and communication networks to transmit and receive information. Additionally students will work directly with robots to configure and program them with various scientific and technology payloads. The concepts of systems integration will be learned through these experiences to create a big-picture understanding of how IT infrastructure impacts scientific and technology systems.

*Keywords: Robotics, LEGO engineering mechanisms, STEM education, STEM careers, diversity*

## Evolution of a paraprofessional delivered diabetes education project in the South Valley

*Fadi Jamaleddin, University of New Mexico*

Diabetes-related disparities are evident in New Mexico and the South Valley. This study evaluated diabetes patient literacy and medication adherence and the effects of 3 months of telephone support by clinic paraprofessionals. Data were self-reported at baseline and 3 months and compared using the Chi-square test. At baseline (n=37), 37% of patients had low literacy, 50% had possibility of low literacy, and 13% had adequate literacy. Fifty-eight percent of patients (n=33) reported high medication adherence, 24% medium adherence and 18% low adherence. From baseline to 3 months, self-rated health and understanding of benefits of blood sugar control significantly changed.

*Keywords: Diabetes, health care, education, patient literacy*

## Emerging air quality issues in New Mexico and the West

*Kip Carrico, New Mexico Tech*

Despite lingering local problems, U.S. efforts over the past several decades to control air pollution emissions have been strikingly successful in improving ambient air quality. Contrastingly, emerging southwest US regional trends demonstrate increasing, episodic impacts from biomass smoke and soil dust aerosols. Though biomass smoke and dust are traditionally considered from 'natural' sources, stronger links to a changing climate and other human perturbations are becoming increasingly clear. The presentation will discuss such trends and present specific results on the detailed physical properties of smoke and dust aerosols and their significance. The size distribution, light scattering, and light absorbing properties of aerosol particles play a vital role in determining aerosol impacts. Such aerosol physical properties, and their relation to external influences such as humidity and combustion characteristics, determine the resulting aerosol impacts on human health, visibility, atmospheric chemistry and significance to climate.

*Keywords: climate, air quality, climate change, aerosol impacts*

# Session F: Chemistry and Solar Power

Moderator: Donivan Porterfield, LANL

Room: Enchantment E & F

## Contribution of Scys-Mo interaction in sulfite oxidase family enzymes

*Chao Dong, New Mexico State University*

The sulfite oxidase enzymes are important in the metabolism of sulfur for biology systems. The conserved cysteine c207, forming coordination sphere of molybdenum, is vial to the enzyme reactivity. It is proposed to adjust the reduction potential of redox orbital through Mo(dx2-y2)-Scysteine covalency by change in Ooxo-Mo-Scysteine-C dihedral angle. The model complexes that mimic of cysteine ligand in the active site possessing ~90° Ooxo-Mo-Scysteine-C dihedral angle present in the crystal structure of SO enzymes. Electronic absorption, magnetic circular dichroism and resonance Raman spectroscopies in combination with bonding calculations are employed to probe the nature of Mo(dx2-y2)-Scysteine covalency. The results indicates that poor covalency between Mo(dx2-y2)-Scysteine is responsible for gmax<ge in SO enzymes, most of all, which causes no gmax shift to low magnetic field by seleno-subtituted sulfur cysteine in human SO enzyme at high pH.

*Keywords: model complexes, sulfite oxidase, enzymes, chemistry*

## Distortion induced acceleration of intersystem crossing

*Ranjana Dangi, University of New Mexico*

Control of molecular excited state processes is important for understanding how to fully realize the potential of the molecular photonics and electronics fields. In order to obtain insight into atomic and vibronic level control of excited state lifetimes, we have initiated a study of new diimine platinum(II) dichalcogenolenes that possess charge-separated dichalcogenolene --> diimine excited states. Square planar (dichalcogenolene)Pt(diimine) complexes have garnered considerable interest due to their rich photophysical properties, including their photoluminescence behavior. We use a combination of electronic absorption and transient spectroscopies, spectroscopic calculations, and group theoretical arguments to understand the remarkable dependence of excited state lifetimes on (1) the heteroatoms of the dichalcogenolene ligand, and (2) static distortions related to the acceptor ligand. Our results indicate that anisotropic covalency and low-symmetry distortions control spin orbit and vibronic spin orbit coupling, and these are the origin of enhanced $T_1$ --> $S_0$ intersystem crossing in these systems. Of particular interest is (dithiolene)Pt(biquinoline), which possesses a $T_1$ --> $S_0$ lifetime that is nearly two orders of magnitude less than that observed for (dithiolene)Pt(bipyridine). This is due to a strong static distortion driven spin-orbit coupling contribution that can be used to evaluate vibronic spin orbit coupling contributions to the $T_1$ --> $S_0$ lifetimes of other (dichalcogenolene)Pt(diimine) complexes.

*Keywords: dithiolene, diimine, platinum, photoluminescence, electronic structure*

## Interchain charge transfer states mediate triplet formation in polymer nanofibers

*Alan Thomas, University of New Mexico*

Supramolecular aggregates of poly-(3-hexylthiophene) (P3HT) can adopt varying structural conformations with different electronic coupling depending upon aggregation conditions. The electronic coupling between chromophores in these aggregate "nanofibers" ranges from primarily interchain (H-aggregation) to primarily intrachain (J-aggregation) coupling, with a wide range of intermediary or mixed couplings possible. By placing nanofibers of all different types of coupling in an inert matrix at low concentrations and sandwiching this matrix in between conducting electrodes, we are able to monitor the photoluminescence (PL) of individual nanofibers at varying timescales, from ultrafast to steady-state, with and without the presence of an external electric field. We find that J-aggregate nanofibers show a size (molecular weight) dependence on quenching and PL, as well as a susceptibility to an external electric field while H-aggregates do not. We demonstrate that even though J-aggregate nanofibers possess primarily intrachain coupling between chromophores, and these fibers have also been shown to efficiently generate triplets, the primary source of initial triplet generation is due to interchain coupling and charge transfer states between fibers. This knowledge is useful for understanding the relationship between polymer structure and electronic properties in the solid state and can be used to guide the rational design of organic electronic devices.

*Keywords: charge transfer states, polymers, nanofibers, photoluminescence*

## Functional polymers derived from trans-enediyne monomers

*Keda Hu, University of New Mexico*

Conjugated polymers have attracted great research interests due to their tunable optoelectronic properties and increasing applications in organic electronic devices including sensors, diodes and photovoltaics. Among a plethora of examples, non-aromatic all-carbon main-chain polymers including polydiacetylenes (PDAs) and polytriacetylenes (PTAs) represent a unique class of conjugated polymers and have been considered intermediate states transitioning from polyacetylenes (PAs) and the still elusive carbon allotrope, carbyne. We have recently developed facile methods for the synthesis of a series of trans-enediyne (EDY) monomers bearing various functional groups at the double

bonds. These EDYs have been applied in the synthesis of novel PDAs, PTAs and platinum segmented PDAs that are hardly accessible through conventional methods. Physical and electronic properties of these polymers can be easily fine-tuned through varying the substituents that are directly conjugated to the main-chains and their applications in organic photovoltaics (OPVs) have been explored.

*Keywords: enediynes, polydiacetylenes, polytriacetylenes, platinum segmented polydiacetylenes, organic photovoltaics*

## Molecular breakwater-like tetrapods for organic solar cells

*Jianzhong Yang, University of New Mexico*

Most small conjugated molecules applied in solar cells have linear structures containing multiple aromatic groups connected in series. However, unfavorable film forming ability and grain boundaries both originated from high crystallinity of linear small molecules are detrimental to device performances. As a result, 3-D structures, breakwater-like tetrapods are especially interesting owing to their unique ability to mutually interlock, which prevents dislodging and provides high structural stabilities. Herein, we synthesize and characterize two tetrapodal breakwater-like small molecules, SO and SFBTD, as shown below. Absorption, X-ray scattering and differential scanning calorimetry experiments indicate crystalline nature of these compounds but slow crystallization kinetics. Solar cells employing SO or SFBTD and phenyl-$C_{61}$-butyric acid methyl ester (PCBM) were fabricated and evaluated. Relatively low performance was obtained mainly due to the lack of appropriate phase separation, which was caused by molecularly mixed blends with PCBM. Addition of poly(thienylene vinylene) (PTV), a low bandgap highly crystalline conjugated polymer, into the SO/PCBM blend was found to induce appreciable phase separation. Such ternary blend devices showed cooperatively improved performances over binary devices employing either SO or PTV alone. Our findings can give useful insight on the structure-property relationships of such 3-D small molecules and their applications in organic solar cells.

*Keywords: tetrapodal molecule, solar cell, crystallinity and phase separation*

## POSTER SESSION ABSTRACTS

### (01) The effect of salinity on the growth rate of *Nannochloropsis salina* algae cells

*Jennifer Thompson, University of New Mexico*

Water and land are the largest resources needed in the cultivation of algae for biofuel production. It is necessary to find ways to cultivate algae without impinging on fresh water resources, especially in arid regions. Certain species of algae including ***Nannochloropsis salina*** can be cultivated in hypersaline environments. The purpose of this experiment was to test the effect that salinity has on the growth rate of ***N. salina*** algal cells with the intention of exploring alternative water sources that can be used for the cultivation of algae. ***N. salina*** is a marine algae therefore it was hypothesized that algal cells that were exposed to hypersaline growth media would experience a faster growth rate versus algal cells grown in hyposaline growth media. For this experiment, three ***N. salina*** algal cultures were grown in bioreactors in growth media of a specific salinity. The ***N. salina*** algal cultures were grown in bioreactors that contained growth media of either 50‰ (hypo), 100‰ (control), or 150‰ (hyper) the salinity of seawater. Chlorophyll content, optical density, photosynthetic electron transfer rate, and pH were measured on the cultures during the experiment. Quantitative analysis of experimental data strengthened the hypothesis that algal cells grown in hypersaline media experienced an exponentially higher growth rate. The increased growth rate of ***N. salina*** in hypersaline environments imply that algae may be cultivated for the production of biofuel in non-traditional water sources such as water from oil and gas production, thus limiting competition for fresh water resources in arid regions.

*Keywords: N. salina, algae, biofuel, alternative, water*

### (02) Trace element mobility in water and sediments in a hyporheic zone adjacent to an abandoned uranium mine

*Claudia Roldan, University of New Mexico*
*Johanna M. Blake, University of New Mexico*
*Abdul-Mehdi Ali, University of New Mexico*
*Jose M. Cerrato, University of New Mexico*
*Steve Cabaniss, University of New Mexico*

The legacy of abandoned uranium mines lead to community concerns about environmental and health effects. This study focuses on a cross section of the Rio Paguate, adjacent to the Jackpile Mine on the Laguna Reservation, west-central New Mexico. Often, the geochemical interactions that occur in the hyporheic zone adjacent to these abandoned mines play an important role in trace element mobility. In order to understand the mobility of uranium (U), arsenic (As), and vanadium (V) in the Rio Paguate; surface water, hyporheic zone water, and core sediment samples were analyzed using inductively coupled plasma mass spectroscopy (ICP-MS). All water samples were filtered through 0.45µm and 0.22µm filters and analyzed. The results show that there is no major difference in concentrations of U (378-496µg/L), As (0.872-6.78µg/L), and V (2.94-5.01µg/L) between the filter sizes or with depth (8cm and 15cm) in the hyporheic zone. The unfiltered hyporheic zone water samples were analyzed after acid digestion to assess the particulate fraction. These results show a decrease in U concentration (153-202µg/L) and an increase in As (33.2-219µg/L) and V (169-1130µg/L) concentrations compared to the filtered waters. Surface water concentrations of U(171-184µg/L) are lower than the filtered hyporheic zone waters while As(1.32-8.68µg/L) and V(1.75-2.38µg/L) are significantly lower than the hyporheic zone waters and particulates combined. Concentrations of As in the sediment core samples are higher in the first 15cm below the water-sediment interface (14.3-3.82µg/L) and decrease (0.382µg/L) with depth. Uranium concentrations are consistent (0.047-0.050µg/L) at all depths. The over all data suggest that U is mobile in the dissolved phase and both As and V are mobile in the particular phase as they travel through the system.

*Keywords: water, sediment, trace elements*

## (03) Elemental Concentrations in Wildfire Ash

*Natalie Correa, University of New Mexico*
*Jose M. Cerrato, University of New Mexico*
*Johanna M. Blake, University of New Mexico*
*Dr. Rebecca Bixby, University of New Mexico*
*Abdul-Mehdi Ali, University of New Mexico*
*Alexander Clark, University of New Mexico*

Determine the concentration of metals and anions leached from solid ash from the Valles Caldera Natural Preserve. The following six tree species from the Valles Caldera Natural Preserve have been sampled for this study: Quaking Aspen, Blue Spruce, Western Juniper, Ponderosa Pine, Douglas Fir, and Gambel Oak. The ash samples were put through acid digestions (Aqua Regia) and metals were analyzed using Inductively coupled plasma-optical emission spectroscopy and the anions were measured using the mass spectroscopy.

*Keywords: water, sediment, trace elements*

## (04) When light breaks the long night: stratospheric ozone depletion in the Antarctic

*Melissa Montoya, New Mexico Tech and Central New Mexico Community College*
*Dr. Gloria Manney, New Mexico Tech*
*Dr. Ken Minschwaner, New Mexico Tech*

During the winter, Antarctica experiences three to four months of darkness; it is during this time that the ingredients for ozone depletion start gathering. But it isn't until spring, when the sun reappears, that ozone depletion occurs. Stratospheric ozone is important to the global environment since it is responsible for controlling the temperature of Earth's stratosphere and absorbing ultraviolet UV-B radiation from the Sun. UV-B radiation increases the risk of skin cancer and cataracts, damages DNA, and leads to a suppressed immune system. Ozone recovery is happening, but it is a slow process which needs our continued attention; due to the Antarctic ozone hole, there has been significant changes in the Southern Hemisphere surface climate in the summer. Continued monitoring of the ozone hole is important in order to assure its recovery by controlling or completely removing the substances which cause rapid depletion, and to make sure that substances which are being used today won't cause the same amount of damage.

*Keywords: Ozone, Antarctica, climate, health, depletion*

## (05) Evaluation of a paraprofessional delivered diabetes education project in the South Valley

*Fadi Jamaleddin, University of New Mexico*
*Guadalupe Fuentes, South Valley Clinic*
*Elizabeth Yakes Jimenez, University of New Mexico*
*Lorenda Belone, University of New Mexico*
*Camila Romero, University of New Mexico*
*Vanessa Acosta, University of New Mexico*
*Lucinda Johnson, South Valley Clinic*
*Silvia Damron, University of New Mexico*

Diabetes-related disparities are evident in New Mexico and the South Valley. This study evaluated diabetes patient literacy and medication adherence and the effects of 3 months of telephone support by clinic paraprofessionals. Data were self-reported at baseline and 3 months and compared using the Chi-square test. At baseline (n=37), 37% of patients had low literacy, 50% had possibility of low literacy, and 13% had adequate literacy. Fifty-eight percent of patients (n=33) reported high medication adherence, 24% medium adherence and 18% low adherence. From baseline to 3 months, self-rated health and understanding of benefits of blood sugar control significantly changed.

*Keywords: Diabetes, health care, education, patient literacy*

## (06) The effects of light and rainwater on the growth and metabolism of *N.salina* and *G.sulpuraria*

*Shaleen Eickhoff, University of New Mexico*

What causes algal production to crash? What are the stressors that attack the algal cells causing them to die and a new batch to take its place? Isn't there a better way to produce bio-algal oil by re harvesting the same batch? If science

were to find what the stressors of algal cells are and how these stressors affect the cells, then it may be possible to learn how to avoid having algal production batches crash. Instead scientists may be able to in the future harvest the same batch culture, meaning the algal cells can replicate making the cells/mL denser, which predictably produces more oil yield. Currently Microalgae have a dry mass yield of oil production between 30-65%, which is significantly higher than Rapeseed, Soya, Palm, and Jatropha oil production. The focus of this study is to show an increase in cell density and metabolism in both liquid and encapsulated cultures of N. Salina and G. Sulphuraria. This study will also highlight the differences between how a salt water yellow-green algae and freshwater red algae are affected by the same conditions and stressors. G. sulphuraria is expected to show equal to or greater performance at higher temperatures and changes in pH.

## (07) Cultivation of locally adapted algal community on an Algal Turf Scrubber® for treatment of dairy wastewater

*David Arellano, Eastern New Mexico University* *Juchao Yan, Eastern New Mexico University*
*Bin Bai, Eastern New Mexico University*

The pilot application of an Algal Turf Scrubber® at Eastern New Mexico University for treatment of dairy wastewater from a local dairy continues to show promise. Dairies and Cattle Farms make up a significant portion of eastern New Mexico's economy, and they produce millions of gallons of wastewater every year. Utilizing an Algal Turf Scrubber® could help treat millions of gallons of water and produce thousands of pounds of feedstock for cattle or algal biofuel production. Through collaboration with New Mexico State University, we found using oven dry weight and ash free dry weight are accurate ways to track algal growth at the site. By utilizing the data and comparing it with monitoring data collected from the site we can show the continued plausibility of an Algal Turf Scrubber® to treat dairy wastewater, even in a rural desert environment. We are looking further into increasing the effectiveness of the system by increasing the biodiversity of the algal community and finding new ways to manage the algal environment.

*Keywords: algae, wastewater treatment, biofuel production*

## (08) Assessing Uranium Contamination in Stream Sediment on the Navajo Nation

*Brianne Willis, Eastern New Mexico University*

During the summer of 2015 through the EPSCoR funded STEMAP program, a team of hydrologist Dan Cadol, geochemist Bonnie Frey, grad student Reid Brown, myself, and another intern Sherwin Becenti, collected soil samples from streams and washes in the Navajo Nation to measure the heavy metal content washing down from upstream abandoned uranium mines. This STEMAP project was funded because these abandoned uranium mines are still an ongoing health and safety risk to those in the area. Knowing the amount and type of contaminate in these washes and streams could help future cleanup efforts in this area. After sieving, grinding, and then digesting the soil samples in acid, the samples were ran on an ICP-MS for metal content analysis. This machine gives us the data of the element and the amount in each particular soil sample we ran. We also did mass fraction of each sample to get a coarse sand content and finer grain content. Our hypothesis is that Uranium particles adsorbs to finer grain, silt, or clay material more readily than course materials. This is expected since fine grain materials have more pores and larger surface area by mass. We find that there is more Uranium and other heavy metal content in the soil samples we took from the washes that have abandoned Uranium mines upstream of them. Our data also tells us that our hypothesis is supported by the fact that samples with high fine grain material content also hold high levels of Uranium contamination.

*Keywords: Uranium contamination, ICP-MS, Navajo Nation*

## (09) Determining Chemical Composition of Wildfire Ash Particulates

*Chris Hirani, University of New Mexico*
*Johanna M. Blake, University of New Mexico*
*Abdul-Mehdi Ali, University of New Mexico*
*Jose M. Cerrato, University of New Mexico*
*Dr. Rebecca Bixby, University of New Mexico*
*Alexander Clark, University of New Mexico*

Wildfires are known to wreak havoc on ecosystems, both locally and globally. In the southwestern United States, wildfires coupled with intermittent flow from monsoonal moisture create a system where large amounts of ash (up to 3 g/L) can wash into surrounding surface waters. Preliminary data shows that ash exposed to water greatly increases the concentration of redox active metals such as Fe and Mn in water. This may affect dissolved oxygen and pH in surface waters, creating acidic and potentially anoxic conditions. Using characterization methods such as scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM/EDX) and X-ray photoelectron spectroscopy (XPS), we will determine the surface features of ash particulates of spruce, ponderosa, and aspen trees. Understanding the elemental composition and surface characterization of these ash particulates will lead to future research in determining how these redox active metals affect water chemistry over time.

*Keywords: Wildfire, Surface Waters, Dissolved Oxygen, SEM/EDX, XPS, Redox Active Metals*

## (10) Hydrothermal Liquefaction of Various Algae in Batch and Continuous Flow Reactors

*Feng Cheng, New Mexico State University*
*Kwonit Mallick, New Mexico State University*
*Graham Hoffman, New Mexico State University*
*Catherine Brewer, New Mexico State University*
*Nagamany Nirmalakhandan; New Mexico State University*

Algae-based biofuels have attracted attention due to their advantages of not competing with land for food production, fewer terrestrial and weather limitations, higher growth rates, and strong $CO_2$-mitigation abilities. In recent years, there is a surge in research on hydrothermal liquefaction of algae since the feedstock does not need to be dried for processing. Hydrothermal liquefaction uses high temperatures (270 to 300°C) and high pressures (80-100 bar) to produce relatively high yields of bio-oil from algae. This study focuses on hydrothermal liquefaction of various algae under different temperature and pressure conditions in a bench-scale batch reactor and a pilot-scale continuous flow reactor. The composition of algae feedstocks and final products (e.g. aqueous phase, organic phase, and solid char phase) will be characterized to understand the energy balance of the processes. The yield, product distribution and higher heating value of bio-crude oil will be measured to compare the effects of different reactors on hydrothermal liquefaction of algae. The alkali content metal and nitrogen in the liquid slurry need to be reduced to prevent clogging in the hydrothermal liquefaction reactor and to increase final biofuel quality, respectively. In addition, as for the pilot-scale continuous flow reactor, there also must be a trade-off between a narrow reactor diameter to accommodate the high pressures of hydrothermal liquefaction and the tendency of algae particles to create clogs in the reactor plumbing over time.

*Keywords: Hydrothermal Liquefaction; Algae; Bio-Crude Oil; Energy Balance*

## (11) Evaluating Seasonal Streamflow Forecasts for Southwestern Snow Fed Rivers

*Shaleene Chavarria, University of New Mexico*

Seasonal streamflow forecasts issued by the Natural Resources Conservation Service have been used for many years to help make decisions about water resource management in the state of New Mexico. Recent concerns by farmers and state lawmakers about perceived overestimates in forecast predictions have prompted the need to closely examine and identify factors that may aid in forecast improvements where needed. This study looked at the probabilistic distribution of seasonal streamflow forecasts issued by the Natural Resources Conservation Service from 2010-2014, for three sites in the Upper Rio Grande and Pecos River basins, and assessed how effectively forecasts predicted subsequent observed naturalized streamflow. The evolution of seasonal forecast through the forecast period was coupled

with an evaluation of climate anomalies and snowpack for corresponding years. Potentially important links between climate variability and seasonal snowpack were found to have played a role in forecast accuracy. Predictions in the early part of the prediction season rarely captured observed streamflow, and this was linked to anomalously high temperatures and below average precipitation, and snowpack anomalies. We suggest that forecast users consider the entire spread of predicted streamflow values rather than just the 50% exceedance prediction, regarded by the Natural Resources Conservation Service as the best estimate, which had a tendency to overestimate resulting streamflow.

*Keywords: water resource management, streamflow, climate*

## (12) Using ground-penetrating radar to image the near surface deformation of a fault zone, Denali Fault, central Alaska

*Thomas Luckie, University of New Mexico*
*Lindsay Worthington, University of New Mexico*
*Sean Bemis, University of Kentucky*
*J. Kade Carlson, University of Kentucky*
*Wes Clary, University of New Mexico*
*Bradley Bishop, Brigham Young University*

The use of ground-penetrating radar (GPR) can provide detailed, centimeter-scale resolution images of the subsurface to a depth of tens of meters. Alaska is one of the most seismically active areas in the United States, but few faults have undergone detailed studies of Quaternary stratigraphy and near-surface structure. In the summer of 2015, a pilot study collected and analyzed 2-D GPR data across the Denali Fault in central Alaska to help constrain near-surface deformation. A basic data processing flow and a 1-D, single-layer velocity model was applied in order to conduct preliminary interpretations. We observed clear reflections to a depth of ~7 m below the ground surface. Data collected at co-located paleoseismic trenching mimic the near-surface reflections and help ground-truth the GPR data. The combined data sets provide insight into the north-south limits of the deformation zone of the fault at this site, along with fault zone morphology at a shallow (<7 m) depth. However, farther from the trenching exposures, the GPR data were less clear as to whether it displayed any reflection patterns indicative of fault zones, which may be due to adverse environmental conditions for GPR implementation. The poor imaging leads to more speculative interpretations, making correlation between the trenching exposures and the GPR data difficult. This pilot study demonstrates the potential use of GPR in the characterization of faults and the advantages and disadvantages of using GPR in conjunction with trenching and outcrop interpretation.

*Keywords: Ground-penetrating radar, active faults, Denali Fault, Alaska*

## (13) The effect of salinity on the growth rate of *Nannochloropsis salina* algae cells

*Wes Clary, University of New Mexico*
*Lindsay Worthington, University of New Mexico*

In the last decades research has shown that climate activity can be an important component of large scale tectonics. Glacial erosion and deposition, forced by climate patterns, affect mass balance in large-scale tectonically active regions as well as offshore depositional basins. One ideal natural laboratory to study these climate-tectonic interactions is offshore glacial-marine deposits in SE Alaska where an offshore accretionary wedge records glacial and marine sedimentation as well as faulting. This location is ideal because the offshore depositional basin is near the onshore sediment source which facilitates a short time between erosion and deposition as well as a relatively closed system from source to basin. Thanks to previous research efforts there is extensive data including sediment core, well log measurements, bathymetry, and offshore seismic reflection surveys available to aide in the interpretation of climate-linked glacial activity and fault activity. Detailed stratigraphic and structural interpretation of seismic reflection lines collected off the coast of SE Alaska allow for sequence interpretation of fault activity, glacial deposition, and climate change. Interpretation of sedimentation patterns with special focus on extent and style of glacial sedimentation and fault activity link these processes in space and time. Applied spatial-statistics provides a quantitative link between glacial activity and faulting by testing for shape similarity and proximity of related geologic features.

*Keywords: tectonics, glaciers, seismology, stratigraphy*

## (14) Ultra-fast time-resolved fluorescence spectroscopic characterization of rare earth metal-based nanomaterials

*Ruwini Rajapaksha, New Mexico Tech* *Mahinda Ransinghe, New Mexico Tech*

There is an increasing interest in utilizing rare earth based nano-materials for application such as light emitting diode, biomedical applications and other photochemical applications. The photochemical properties of theses materials play a crucial role in determining the feasibility of utilizing these nano-materials in these applications. The trivalent lanthanides Europium (III) doped inorganic lanthanide complexes are well known for high luminescent characteristics of Eu3+ ion and their dual functionality. In order to understand photophysical properties of these materials, we employ femto-second time resolved fluorescence up-conversion spectroscopy and fluorescence time correlated single photon counting spectroscopy. These investigations were supported by steady state absorption and fluorescence spectroscopy. In these investigations, we studied 17 different samples including Europium doped Gadolinium Fluoride (Eu:GdF3), Europium doped Sodium Yttrium Fluoride (Eu:NaYF4), Europium doped Ytterbium Sodium Fluoride (Eu:YbNaF4) coated with different amounts of thionyltrifluoroacetone (TTA), Europium doped ZnO coated with TTA and Eu:GdF3 samples coated with TTA having several Eu3+ doping percentages. These were synthesized by one of our collaborators, Dr. Channa R De Silva. These studies are focused on energy transfer mechanisms, excited state dynamics and fluorescence decay kinetics of these complexes. Absorption spectrum shows strong absorption of all these samples at around 340 nm. Excitation at 350 nm shows emissions for all samples at around 450 nm, 580 nm, 616 nm and 720 nm. The lifetime measurements of these samples using TCSPC data shows nanoseconds (ns) lifetime for all samples. Fluorescence upconversion anisotropy decay studies are underway to understand the energy transfer dynamics in these complexes.

*Keywords: Fluorescence, Upconversion, Anisotropy, Time Correlated single Photon Counting*

## (15) Evaluation of *Arabidopsis thaliana*: Photosynthesis

*Diana Perales, Central NM Community College* *Marissa Horjoe, University of New Mexico*
*Darrell Horton, University of New Mexico* *David Hanson, University of New Mexico*
*Shoshana Jaffe, University of New Mexico*

***Arabidopsis thaliana*** have been transformed to over-express the photorespiratory enzyme, glycine decarboxylase (GDC-L). Our research was to evaluate the photosynthetic activity of ***Arabidopsis thaliana***. For more than 30 years, photorespiration has been considered to be a wasteful process, requiring plants to use energy and release $CO_2$ in order to recycle one of the products of oxygen fixation by the photosynthetic enzyme RuBisCO. This side reaction partly reverses the major action of RuBisCO, the capture of $CO_2$ for the Calvin cycle in photosynthesis. Yet, these transformed plants suggest that photorespiration can be beneficial due to the increased expression of the enzyme GDC-L and increased rate of photosynthesis. We investigated how photosynthesis was increased. Specifically, to see if this was achieved through increased expression or activation of RuBisCO in response to the increased expression of GDC-L. Our research was performed by analyzing the RuBisCO activity and measuring the photosynthesis responses under multiple light exposures in both the wild type and the transformed plant (PSL-3). We found during the RuBisCO analysis, the wild type had more activity and higher photosynthesis than PSL-3. This should represent that there is more RuBisCO present in wild type than in PSL-3 but there is other data from our collaborators lab that contradict this idea. Additional data is needed to resolve the discrepancies between the two labs. It is possible that leaf and plant age varied between experiments and is responsible for the different results.

## (16) Risk Analysis of Recycling Containment and Treatment of Produced Water from Oil and Gas Production: A Conceptual Framework

*Katie Zemlick, University of New Mexico* *Bruce Thomson, University of New Mexico*
*Elmira Kalhor, University of New Mexico* *Janie Chermak, University of New Mexico*

Hydraulic fracturing and enhanced oil recovery (EOR) rely on the application of large volumes of water for energy production. In New Mexico, more than 5,000 acre-feet water was used in oil and gas production in 2014; these volumes are expected to increase over time in accordance with growth in the energy sector. In an effort to reduce impacts on limited freshwater resources, the New Mexico's Energy Minerals and Natural Resources Department (EMNRD) issued rule 19.35.34 to encourage reuse of produced water in oil and gas production by allowing for recycling containment and treatment facilities for produced water. Safeguarding fresh water resources from potential contamination due to siting, construction, and operation of such facilities calls for a risk based suitability analysis. This study describes a conceptual framework for risk assessment and response regarding the transportation, storage, and treatment of produced water. Deterministic and stochastic events associated with both fresh water contamination from recycling containment sites and the costs of construction, operation, and utilization of potential sites will be studied and classified. Probabilistic distribution of the occurrence and impacts from such events on the fresh water quality as well as costs will be derived from historical data and relevant literature. The results of this framework will be a parametric suitability index integrating technical constraints as well as the estimated risks. This suitability index will facilitate informed decision making in planning process for future containment facilities. A byproduct of this research is a map of fresh water vulnerability to contamination.

*Keywords: produced water, recycling containment, risk assessment, suitability index*

## (17) Modeling Bathymetry and Topography Maps Using an Augmented Reality Sandbox

*Ryan Pottenger, Mesalands Community College*

Students enrolled in the Natural Sciences program at Mesalands Community College, study many geographic, geologic, and hydrologic concepts including how to read topography and bathymetry maps. To help students better understand these concepts, Mesalands Dinosaur Museum and Natural Sciences Laboratory became involved in a project to build a 3D visualization tool called an augmented reality sandbox. Using simulation and visualization software designed by Dr. Oliver Kreylos at University of California Davis, the sandbox utilizes a montionsensing input devise (Xbox Kinect 3D camera), and a short-throw data projector mounted above the sand to produce a virtual topography. The Kinect detects the distance to the sand below, and a visualization an elevation model with contour lines and a color map is cast from an overhead projector onto the surface of the sand. As the user moves the sand, the Kinect perceives changes in the distance to the sand surface, and the projected colors and contour lines change accordingly. Users can also create virtual rain, which will help explain catchment areas and watersheds.

*Keywords: Augmented Reality Sandbox, Watershed Modeling, Topography, Bathymetry*

## (18) Experimental Design: Polycultures of 25 Common North American Freshwater Microalgae Species

*Laura Jack, New Mexico State University* *Wiebke Boeing, New Mexico State University*

The purpose of this study is to highlight the importance of an ecological approach in algal cultivation. By pairing monocultures with polycultures, comparing growth, lipid production and relative density, this study aims to identify freshwater microalgae species with positive allopathic interactions for scaled-up microalgal cultivation. The 25 species will be grown in replicate monoculture and in all pairwise biculture combinations. Using a replacement-series design, species will be inoculated at 5,000 cells/mL each within a biculture and 10,000 cells/mL within a monoculture.

Each of the 25 monocultures and 300 bicultures will be replicated twice, resulting in 625 total species/species assemblages. Species/species assemblages are cultured in 48-well plates containing 1 mL of standard Chu growth medium. Species' densities will be enumerated using a hemacytomer and compound microscope. We expect to see evidence of competitive interactions among green algal species. Most bicultures should have reduced cell densities when compared to their monoculture population. We will subdivide species' relative densities of the bicultures into categories to better understand the species interactions and possible competitive asymmetries. Each species in a biculture will either experience strong competition (relative density < 0.5), weak competition (1 > relative density > 0.5), or facilitation (relative density >1). We will plot the joint distribution of species' relative densities for each biculture. Lipid analysis of facilitating bicultures will be compared to monocultures.

*Keywords: Microalgae, Polyculture, Biofuel, Freshwater*

## (19) Using geochemical tracers to understand geothermal flow pathways in northern NM

*Valerie Blomgren, University of New Mexico*
*Laura Crossey, University of New Mexico*
*Karl Karlstrom, University of New Mexico*
*Hyunwoo Lee, University of New Mexico*
*Tobias Fischer, University of New Mexico*

Carbonic warm and hot springs extend NE of the Valles Caldera toward Taos NM. We examined a suite of springs NE of the caldera along the Jemez lineament. Springs were analyzed for the purpose of understanding deep flow pathways of the regional geothermal system. Spring groups differ in the eastern (Taos) versus western (Ojo Caliente and La Madera) regions. Throughout both regions helium isotope analysis reveals the presence of a mantle component; 0.32 Rc/Ra in west and 0.20 Rc/Ra in the east (RA = 3He/4He ratio of air; Rc is air-corrected value). Additional tracers show that Ojo Caliente springs have 87Sr/86Sr ratios of 0.747 and Sr abundances of 1.35 ppm, reflecting water flow through granitic basement rock; the 87Sr/86Sr ratios at La Madera and Statue are 0.718, these values can be explained by mixing basement-influenced Ojo Caliente water and interaction with the less radiogenic limestone aquifer. Ojo Caliente and La Madera also have high $CO_2$ gas concentrations, 7.9 to 30.7‰. These tracers suggest that Ojo Caliente waters travel north to La Madera, and the Jemez volcanic system supplies $CO_2$ leakage along faults of the Jemez lineament. $CO_2$ leakage is not as evident on the east side, which has less radiogenic 87Sr/86Sr ratios of 0.708 and lower $CO_2$, 1.36 to 4.27‰. We conclude that western springs mixed with endogenic fluids derived in part from the Jemez Mountains whereas eastern springs are more meteoric, but still have 3He/4He ratios that suggest magmatic fluid input.

## (20) Effects Of Silica Sol-Gel Encapsulation On *C. reinhardtii* Metabolism

*John M. Roesgen, University of New Mexico*
*David Hanson, University of New Mexico*

With the goal of examining the effect of encapsulation on metabolism in the microalga *Chlamydomonas reinhardtii*, we have created a living hybrid silica sol-gel from encapsulated samples. The encapsulation matrix was formed by the condensation reaction of an alkoxide precursor, tetramethyl orthosilicate (TMOS). The silica sol-gel formed by TMOS, which removes the cytotoxic methanol side chains, is a biologically inert and rigid matrix which physically isolates and constrains cells. Previous research has given evidence of changes in gene expression (Dickson et al 2012) and increases in cellular metabolic products, such as photobiological hydrogen (Dickson et al 2009), when cyanobacterial cells are encapsulated. These results are thought to be due to the physical growth restriction of the matrix on the cells. Here we present physiological measures of cellular viability such as amount of chlorophyll present and photosynthetic oxygen evolution. It is our belief that by finding differences in photosynthetic and respiration rates between encapsulated and liquid cultures, we can support the idea that encapsulation causes cells to divert their energy expenditure from cell growth and division to increased metabolism. To this end, we created treatments that have previously triggered metabolic changes in liquid cultures (DeLong and Hanson 2011). Both the liquid and encapsulated cultures have been subjected to changes in temperature at different densities and then compared the metabolic responses between them.

## (21) Building a network from two networks: successes and challenges

*Ayesha Burdett, New Mexico Museum of Natural History and Science*
*Mary Jo Daniel, New Mexico EPSCoR*
*Selena Connealy, New Mexico EPSCoR*

The New Mexico Informal Science/Current Research Network focuses on two important issues–water and energy. We bring together a network of informal science education institutions (NM ISENet) with a network of researchers (NM EPSCoR) to enhance collaboration that will engage learners of all ages in STEM issues related to water and energy. The goal of this collaboration is to communicate important current research in two ways: (1) a series of statewide and regional meetings connect researchers to educators, the public and policy makers; (2) students and faculty engaged in research provide intellectual and material resources to inform ISE programs and exhibits. We have successfully hosted two annual meetings for the ISE Net community and a third meeting is currently being planned. However, the success of the regional meetings has been patchy; these events have been hosted by one or two core NM ISE Net institutions rather than by many institutions from throughout the state. We are working on the challenge to improve the distribution of regional meetings by developing "mini grants" to host these events. Another ongoing challenge is to improve communication between the two networks, and to understand the priorities and language of each network. Educators face the challenge of developing relationships with individual researchers when their time is already limited, while researchers do not always appreciate the opportunities for broader impact that NM ISE Net can provide. We continue to learn the best way to establish long-term collaborations.

## (22) Palladium nanoparticles supported on 3D-Graphene Electrocatalysts for Fuel Cells

*Sadia Kabir, University of New Mexico*
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Fuel cells are one of the most promising sustainable energy technologies for energy conversion. However, current fuel cells rely on platinum electrocatalysts, which are expensive and lack long term stability. Alternatively, Palladium (Pd) has been attracting growing interest due to their thermal stability and excellent activity. However, Pd nanoparticles used as catalysts for fuel cells are usually supported on amorphous carbon supports which are prone to corrosion. If has therefore become imperative to develop relatively cheaper catalytic materials with improved performance and durability. In view of that, our present work adopts the Sacrificial Support Method developed at UNM for the synthesis of porous crystalline 3D-Graphene nanosheets. The nanosheets were then utilized as a support material for Pd nanoparticles deposited using the original Pd-precursor based Soft Alcohol Reduction Method. The obtained materials were comprehensively characterized by X-ray diffraction (XRD), transmission electron microscopy (TEM), and scanning transmission electron microscopy (SEM). Our results show that the 3D-Graphene support materials had a high surface area (~300 m2/g) and porosity. The Pd nanoparticles synthesized using ethanol as a reducing agent in the SARM fabrication method had an average size of 4.3 nm as well as the highest electrochemical activity and durability when supported on 3D-Graphene, with a peak current density of over 1550 A/gPd for ethanol electrooxidation. The results from this research will not only lead to the development of highly efficient catalytic materials for fuel cells, but also lead to the advancement and successful commercialization of sustainable emerging energy technologies.

*Keywords: energy, electrocatalysts, fuel cell, graphene*

## (23) The effect of biofilm carrier length on nitrification in moving bed biofilm reactors: an examination of mixing intensity, shock loadings, and pH changes on biofilm activity

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*Andrew Schuler, University of New Mexico*
*Patrick McLee, University of New Mexico*

Free-floating attachment surfaces are commonly used in wastewater treatment, but little is known about media geometry affecting biofilm processes. The objective of this study was to compare nitrification and growth of biofilms

grown on different length media in bench-scale moving bed biofilm reactors. The carriers were cut from high density polyethylene tubing with one media type one-third the length of the other, but with inner and outer diameter dimensions identical. Each bioreactor was continuously operated with coarse bubble aeration and provided with a high ammonium loading to promote greatly active nitrifying communities. Biomass measurements were taken regularly to observe growth. A series of variable velocity gradient (G) batch tests was executed to determine the effect of mixing on mass transfer through the biofilms of each media type. High ammonium and variable pH batch tests were also conducted to assess inhibition effects on nitrifiers. Greater biomass was consistently measured on the longer media despite both media types having similar ammonia uptake during continuous operation. Lower G values consistently produced a greater ammonia utilization in the short media biofilm than in the long media biofilm. However, at mid to high range G values, ammonia consumption was similar between both biofilms. Ends of media typically had greater biomass and greater nitrate production than middle sections, while ammonia consumption was similar along carrier length. Abrupt changes in ammonium concentration and pH produced significantly greater inhibition effects in the short media biofilm than in the long media biofilm, suggesting greater protection in the thicker biofilm.

*Keywords: Water, biofilms, bioreactors, nitrification, wastewater*

## (24) Mantle $CO_2$ Degassing and Fluid Migration along Fault Networks in the Northwestern Albuquerque Basin and Valles Caldera

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*Tanner Grulke, University Of New Mexico*
*Graham Thomas, University Of New Mexico*
*Christopher McGibbon, University Of New Mexico*

The Rio Grande rift has active volcanism and faulting providing a field laboratory for examining links between mantle degassing and faults as conduits for fluids and volatiles. $CO_2$ flux measurements were taken at 6 sites in the northwestern Albuquerque basin and Valles caldera. All sites progress to the southwest from the caldera, down the rift-related Jemez fault network, to intersect with the Nacimiento fault. The instrument used to measure $CO_2$ flux was an EGM-4 $CO_2$ gas analyzer (PP systems) with an accumulation chamber. Individual diffuse and spring measurements (n) were obtained from each site at approximately 50 m spacing or less. Carbonic springs at Penasco Springs (n=41) and San Ysidro (n=261), and the carbonate-cemented Sand Hill fault (n=42), were targeted. The Sand Hill fault had the smallest maximum flux (8 g/m$^2$d). The other two sites are approximately equal distance between the Sand Hill fault and caldera sites. Our work suggests these sites reflect intersections of the Nacimiento fault with NE trending faults that connect to the Jemez fault network. The maximum diffuse flux recorded at San Ysidro (434 g/m$^2$d) and Penasco Springs (25 g/m$^2$d) are high, especially along the fault near springs. Maximum diffuse flux measurements of Alamo Canyon (20,906 g/m2d), Sulphur Springs (2,400 g/m$^2$d), and Soda Dam (1,888 g/m$^2$d) at the Valles caldera geothermal sites (n=63, 59, and 92, respectively) are comparable to Yellowstone geothermal systems. Results indicate fault networks allow for volatile transport consistent with the geological occurrence of carbonate accumulations (travertines and cements) along the same structures.

*Keywords: $CO_2$ Flux, Faults, Mantle, Albuquerque Basin, Valles Caldera*

## (25) Assessing the Geomorphological Effects of Animal Exclosures on a High Elevation Stream in the Valles Caldera National Preserve, New Mexico

*Ryan Kelly, University of New Mexico*
*Rebecca Bixby, University of New Mexico*

Livestock grazing near streams can have adverse effects on channel geomorphology, including impacts on bank structure, channel characteristics, and recovery from disturbance. I am examining the effects of the exclusion of both native and domestic grazers on stream geomorphology at 3 animal exclosure locations on San Antonio Creek, Valles Caldera National Preserve, New Mexico. This study is designed to test the hypotheses that: 1) channels are deeper and

narrower in areas where grazers are excluded 2) banks are deeper and bank angle is increased in areas where grazers are excluded 3) over-banking will occur at a lower discharge in areas where grazers are excluded. I used a theodolite to survey stream cross-sections located on San Antonio Creek at the end of grazing season. These cross-sectional coordinate data are being used to create representative 20-foot-long stream sections in the U.S. Army Corps of Engineer program HEC-RAS. I am using the spatial characteristics of the stream sections, such as bank depth, water depth at stream center, channel width, and bank angle, to statistically compare the different sample locations to one another. I am using this information to look for differences in channel and bank characteristics between each surveyed section, and also compare sections where grazers were excluded to sections where there is no exclusion. I am also using geographical information systems software, coupled with HEC-RAS, to construct a flood analysis in surveyed areas. Grazer exclusion as a passive restoration approach may be a cheaper management alternative compared to a more hands-on approach.

*Keywords: Livestock exclusion, Channel morphology, New Mexico, High elevation streams*

## (26) Algal System for BOD & Nutrient Removal from Urban Wastewater-Pilot Scale Study

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Urban wastewater (UWW) treatment plants continue to depend on obsolete, multistage technologies that are energy intensive and unsustainable. UWWs are known to contain internal energy about 6.3 - 7.6 kJ/L, which is about 2-3 times the energy that is currently used for treating them; at the same time, valuable energy, carbon, and nutrient content of the wastewater are dissipated into the environment. The activated sludge process, for example, mineralizes valuable organic content of UWW aerobically to gaseous $CO_2$; the nitrification/denitrification process converts ammonia content of the UWW to gaseous nitrogen and discharges into the atmosphere, instead of harvesting it for use as fertilizers. This study demonstrates a single-step algal system where the selected strain, *Galdieria sulphuraria*, is shown to be capable of mixotrophic metabolism for simultaneous removal of carbon and nutrients from UWWs. The specific advantage of the mixotrophic system in general, and of *Galdieria sulphuraria* in particular, over the traditional heterotrophic bacteria-based systems stems from the fact that stoichiometric carbon-to-nitrogen (C:N) ratio in UWW is closer to that of algal biomass composition than to that of heterotrophic bacteria. Laboratory scale studies have been scaled up to 300L and 700L enclosed photobioreactors for testing under outdoor conditions at the Las Cruces Wastewater Treatment plant. This paper presents the temporal variations of BOD and nutrient removal capability of *Galdieria sulphuraria* from primary-settled UWW and an energetic analysis to demonstrate the net energy advantage of the algal wastewater treatment system over the traditional wastewater treatment process.

*Keywords: Wastewater Treatment, Algal, Single-step, Mixotrophic*

## (27) Reactor design and operation variables to improve mixed algae biomass production and stability

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Imposing selection pressures on mixed communities of bacteria is commonly done to improve performance of activated sludge systems for wastewater treatment. Much less research has been done on reactor design and operation to impose selection pressures in algal polycultures, in part because biofuels research has focused on algal monocultures. It is hypothesized that imposing a selection for algae with good flotation or settling characteristics will enrich for high biomass and/or lipid storage, and that imposing a selection pressure for settling or floating algae will improve solids separation, which is a major challenge in algal cultivation and recovery. The objective of this study is to determine if polycultures of algae can be enriched for useful functions, such as improved solids separation and/or lipid storage, by incorporating settling or floating phases to their operational cycle. This study incorporated three sequencing batch

reactors with defined media, run with a hydraulic residence time of two days, using varied cycle procedures: (1) continuous mixing, (2) wasting from the top after a settling phase (selecting for settled algae), and (3) wasting from the bottom after a settling phase (selecting for floating algae). Initial results indicate that algae favored settling with larger biomass concentration (approximately 4000 mg suspended solids/L after 50 days), including larger flocs of algae/cyanobacteria, in the top wasting reactor after settling, which also yielded a low sludge volume index, indicating a well-settling biomass. Bottom-wasting resulted in low biomass (100 mg/L), indicating that flotation was a poor strategy for selection. Results from Percoll density gradients indicated biomass density was positively correlated with light exposure. These results could indicate that density is not the primary settling/flotation mechanisms and a motility mechanism could be playing a dominant role. Current work is investigating the effects of shorter settling times.

## (28) Evaluation of the accumulation of trace metals (As, U, Cr, Cu, Pb, Zn) on iron-manganese coatings on in situ stream pebbles and emplaced substrates

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*Johanna Blake, University of New Mexico*
*Abdul-Mehdi Ali, University of New Mexico*
*Laura Crossey, University of New Mexico*
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Exposure to trace metals (As, U, Cr, Cu, Pb, Zn) has potential negative health effects on human populations and wildlife. Geothermal waters often have elevated concentrations of trace elements and understanding the geochemical cycling of these elements can be challenging. Previous studies have utilized in situ stream pebbles and glass or ceramic substrates with iron-manganese oxide coatings to understand contamination and or chemical cycling. This project's main focus is to develop an ideal tracing method using adsorption onto substrate surfaces and to define key parameters that are necessary for the phenomenon of adsorption between trace metals and these surface coatings to occur. Sampling locations include the Jemez River and Rio San Antonio in the Jemez mountains, northern New Mexico. Both streams have significant geothermal inputs. Pebbles and cobbles were gathered from the active stream channel. Factors such as leachate type, water pH, substrate type, coating accumulation period and leach time were all considered in this experiment. It was found that of the three leachates (aqua regia, 10% aqua regia and hydroxylamine), hydroxylamine was the most effective at leaching coatings without dissolving substrates. Samples leached with aqua regia and 10% aqua regia were found to lose weight and mass over the following 5, 7, and 10 day measurements. Glass beads were determined to be more effective than in stream pebbles as accumulation substrate: coatings were more easily controlled and monitored. Samples leached with hydroxylamine for 5 hours and 72 hours showed little difference in their leachate concentrations, suggesting that leach time has little impact on the concentration of leachate samples. This research aims to find the best method for trace metal accumulation in streams to aid in understanding geochemical cycling.

## (29) What's Inside an Invasive Frog? Sexual Comparison of Bullfrog Diet of the Mora River

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*Justin Saiz, New Mexico Highlands University*
*Son Tran, New Mexico Highlands University*
*Alfonzo Trujillo, New Mexico Highlands University*
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Invasive species are the single worst conservation problem at the species level worldwide. Invaders can negatively affect the diversity of native species via predation or competition for resources. American Bullfrogs was introduced in Northern New Mexico since the 1940s and because the introduction was so long ago there have been no quantification on the impact bullfrogs' cause on the native aquatic fauna. In this study I analyzed 600 stomach contents of bullfrogs in the Mora River over a four year period. The prey index of the frogs was split into male vs female categories showing the breakdown of diet preference between them. Further analysis showed differences in mass of prey, and comparisons of the most captured food. Most of the stomachs contained Northern Crayfish (*Orconectes virilis*) followed by

whatever insect was abundant at the time. We found often some unidentified white slime that we believe may be from eggs masses of other amphibians or fishes as well as some mixed of stomach acids. Surprisingly, we did not find any leopard frogs in the diet of bullfrogs, however we did find a single Woodhouse Toad (*Anaxyrus woodhousii*).

*Keywords: Invasive Species, Climate Change, Bullfrogs*

## (30) The Ecological Role of Cougars within a Multispecies Predator-Prey System

*Arthur Anaya, New Mexico Highlands University*

Community interactions play an integral part in the study of animal behavior. These interactions both shape and define how species coexist with one another. This creates a network of interconnectedness upon which organisms influence others. Such interactions help wildlife managers understand ecological systems in hopes of developing effective management plans to sustain and conserve both species richness and diversity. A focus on cougars (*Puma concolor*) within the Valles Caldera National Preserve and surrounding Santa Fe National Forest aims to provide information regarding their ecological role as an apex predator. More specifically, the investigation of cougar kill rates, prey composition, and kleptoparasitism by black bears (*Ursus americanus*) will be pursued. We hypothesize kill rates and prey composition are influenced by the degree of kleptoparasitism.

## (31) Economic Impact of Natural Gas Production in the San Juan Basin

*Janak Joshi, University of New Mexico* *Jennifer Thatcher, University of New Mexico*
*Janie Chermak, University of New Mexico*

Natural gas extraction contributes to the economy in many aspects. It creates employment opportunities for local communities and royalties for land owners. It also stimulates economic development in the local economy through revenue recycling. Finally, in New Mexico, the natural gas sector provides significant tax revenues to the local, state and federal governments. However, the true economic impact of natural gas production in the economy is more complicated. For instance, production comes with external costs, such as air pollution, water use, water contamination, and contributes to global warming. At the same time, there are additional positive benefits in terms of demand for additional labor, goods, and services. The objective of this research is to develop an economic assessment of natural gas production in the San Juan Basin considering the broader scope of impacts. The San Juan Basin contains one of the largest conventional fields in the U.S. and is the top natural gas producing region in New Mexico.

*Keywords: Natural Gas, Economic Profits, San Juan Basin, New Mexico*

## (32) Xanthophyll Analysis of High Desert Trees

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*David Hanson, University of New Mexico*

Xanthophylls are light sensitive plant pigments that help compensate for free radicals by dissipating excess absorbed light energy. Light is a necessity for plant survival, but too much light can generate oxygen reactive species that can damage or even kill a plant. Plants adjust their light harvesting complexes to optimize light utilization, but this process is slow relative to daily environmental variation and the onset of stress. Xanthophylls can convert to light dissipating forms within minutes, so they provide a lot of flexibility plants need. Very little research has been done to explore these compounds in native New Mexican species Juniperus monosperma, and Pinus edulis, which grow in high light, upper elevations, and regularly experience drought. We developed a rapid and improved separation and analysis of the xanthophylls, violaxanthin, antheraxanthin, and zeaxanthin, through ultra-high pressure supercritical fluid chromatography. We then used this method to compare xanthophyll composition of both species grown under heat, drought, and combined heat and drought conditions.

*Keywords: Xanthophylls, Chromatography, Tree, Stress Conditions*

## (33) Distortion Induced Acceleration of Intersystem Crossing

*Ranjana Dangi, University of New Mexico* *Martin Kirk, University of New Mexico*
*Jing Yang, University of New Mexico*

Control of molecular excited state processes is important for understanding how to fully realize the potential of the molecular photonics and electronics fields. In order to obtain insight into atomic and vibronic level control of excited state lifetimes, we have initiated a study of new diimine platinum(II) dichalcogenolenes that possess charge-separated dichalcogenolene-->diimine excited states. Square planar (dichalcogenolene)Pt(diimine) complexes have garnered considerable interest due to their rich photophysical properties, including their photoluminescence behavior. We use a combination of electronic absorption and transient spectroscopies, spectroscopic calculations, and group theoretical arguments to understand the remarkable dependence of excited state lifetimes on (1) the heteroatoms of the dichalcogenolene ligand, and (2) static distortions related to the acceptor ligand. Our results indicate that anisotropic covalency and low-symmetry distortions control spin orbit and vibronic spin orbit coupling, and these are the origin of enhanced $T_1$-->$S_0$ intersystem crossing in these systems. Of particular interest is (dithiolene)Pt(biquinoline), which possesses a $T_1$-->$S_0$ lifetime that is nearly two orders of magnitude less than that observed for (dithiolene)Pt(bipyridine). This is due to a strong static distortion driven spin-orbit coupling contribution that can be used to evaluate vibronic spin orbit coupling contributions to the $T_1$-->$S_0$ lifetimes of other (dichalcogenolene)Pt(diimine) complexes.

*Keywords: dithiolene, diimine, platinum, photoluminescence, electronic structure*

## (34) Identification of cold-stress response genes in *Nannochloropsis salina* using RT-PCR

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*Stephanie Willatte, New Mexico State University* *Rolston St Hilaire, New Mexico State University*
*Barry Dungan, New Mexico State University* *Omar Holguin, New Mexico State University*

Marine microalga *Nannocholoropsis salina* is famous for its high oil yield mainly triacylglycerides (TAGs) as neutral storage lipids in response to N deprivation and environmental stresses. One of the response products is polyunsaturated fatty acid (PUFAs), which is derived from lipid metabolism. Recent advances in molecular and genetic analyses of microalgae have uncovered some distinct and unique characteristics of microalgae pointing out towards the necessity to study lipid metabolism and molecular and genetic basis of lipid metabolic pathway. Genes encoding for these lipid biosynthesis enzyme can be found in various microalgae using these analyses. We found out that *Nannochloropsis salina* can accumulate 50% more polyunsaturated fatty acids (PUFAs) under low temperatures as compared to optimum conditions. We carried out a series of experiments to find out the genes, which express more in response to low temperatures through RT-PCR. We also performed a detailed analysis of total lipids extracted using FT-ICR and GC/MS.

*Keywords: Lipid metabolism, RT-PCR, PUFAs, gene expression*

## (35) Characterization of physiological response in *Nannochloropsis salina* to cold stress

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*Saba Gill, New Mexico State University* *Rolston St Hilaire, New Mexico State University*
*Jackie Jarvis, New Mexico State University* *Omar Holguin, New Mexico State University*
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Microalgae have the ability to adapt to several biotic and abiotic stressors that occur within the environment due to their metabolic plasticity. Changes in environmental conditions will mediate physiological responses, such as changes in nutrient uptake and photosynthetic activity, fluctuations in growth parameters, and modulation of lipid production. Exposure to low temperatures contributes significantly to regulating fatty acid pools; however, data are limited on the effects of cold stress on algal metabolism, such as chilling (below 15°C) and freezing (at 0°C). We relate the effects of decreased temperature to lipid production and composition of lipid profiles for *Nannochloropsis salina*, for the following

range of temperatures: 5°C, 10°C, 15°C, 20°C and 25°C. We present a qualitative characterization of physiological changes in response to cold stress by examining the following: fluctuations in growth parameters through optical density (OD) measurements, changes in nutrient uptake by nitrate and phosphate analysis, and changes in photosynthetic activity through use of pulse-amplitude modulated (PAM) chlorophyll fluorometry.

## (36) Geochemistry of Sinkholes in the Santa Rosa, NM Area

*Mariah Kelly, University of New Mexico* *Rebecca Frus, University of New Mexico*
*Laura Crossey, University of New Mexico* *Abdul-Mehdi Ali, University of New Mexico*

In Santa Rosa, NM there are several bodies of water known as sinkholes, fed by an artesian aquifer (the Permian Bernal Formation). The sinkholes are perennial water sources that both host endemic species as well as provide water to the Pecos River. We examine twelve locations, including four sinkholes, three springs, two Pecos River locations, and three water wells to compare the different water chemistries and parameters to identify connections and processes occurring between the diverse water locations. Data collected from the surface water and from wells are acquired by standard water sampling protocols. Samples that are collected from warm water vents at depths lower than 10 meters were taken using an original technique necessitated by the specific condition of the deep locations. We report temperature, pH, conductance, and major ion solute concentrations. All of the waters (sinkhole data (~18 °C, 7.3 pH, 3085µS); spring data (~18 °C, 5.7pH, 2530µS); Pecos River data (~17°C, 6.5pH, 2690 µS)) have a strong geochemical similarity to the regional aquifer (aquifer data (~18 °C, 6.8 pH, 2010 µS)). Additional effects on the waters include evaporation and mineral precipitation/dissolution. We use geochemical modelling codes to indicate the major ions composition and distribution as well as the saturation state with respect to minerals such as calcite and gypsum. The contribution of these artesian groundwater outflows is significant to the Pecos River, and take on additional importance given the projections of diminished stream flows in the future.

## (37) Stratigraphic relationships and physical properties of young sediment offshore southeastern Alaska

*Rachel Price, University of New Mexico* *Harm Van Avendonk, University of Texas, Austin*
*Lindsay Lowe-Worthington, University of NM*

Southeastern Alaska is home to one of the most actively deforming continental margins in the world, and temperate glaciers covering the area contribute to high rates of erosion and offshore sedimentation, making the Neogene sediment covering the offshore continental shelf an ideal location to study interactions between climate and tectonics. We present a high-resolution two-dimensional P-wave velocity model of the glaciomarine sediment and underlying basement in the area and compare to coincident seismic reflection profiles in order to determine lithologic boundaries and correlate with stratigraphic units observed onshore and in offshore boreholes. Data used in this study includes ~115 km of multichannel seismic reflection and coincident ocean-bottom seismometer wide-angle reflection and refraction data. In Yakutat Bay, sediment velocities are high (~ 4 km/s) compared to velocities farther offshore (< 3 km/s), possibly indicating greater compaction of the sediments in the bay. In the central portion of the shelf, three distinct refractions from sedimentary layers are observed and are interpreted as the Yakataga, Poul Creek, and Kulthieth Formations. Northern profiles show only two refractions from sedimentary layers. Basement refractions are observed in the north at close offsets, evidence of shallow basement that could be indicative of uplift in the bay. Our velocity profile used in conjunction with seismic reflection data shows transitions in dominant depositional processes over time in the central portion of the block and helps to provide a regional framework of the geometries of the sedimentary packages and their spatial relationship to major tectonic features.

*Keywords: Offshore sedimentation, glacial sediment, Gulf of Alaska, compaction*

## (38) Forgiveness aversion: the influence of perceived forgiveness risks on forgiveness motivation

*Angel De Nieves Arellano, NM Highlands University  Sierra Fernandez, New Mexico Highlands University*
*Ian Williamson, New Mexico Highlands University*

The attainment of forgiveness maybe hindered even though it is known to provide benefits in psychological, physical, and social ways (p.379). Research by Williamson and colleagues (2015) introduced the concept of forgiveness aversion, which is "an offense-specific motivational state based on perceived forgiveness risks" (p. 378). The dimensions of forgiveness aversion include unreadiness, emotional turmoil that prevents individuals from forgiving; self-protection, concern with how offenders will interpret; and face concerns, or preoccupation with personal reputation which prevents forgiveness. Four studies revealed differential predictors of the three dimensions of forgiveness aversion and found impediments to forgiveness to be situation-specific (Williamsons, Gonzales, Fernandez, & Williams, 2015). The focus of this research is to build on the prior studies by seeing whether the same processes of forgiveness aversion can be triggered in memory. The study had 222 student participants and used a 3 (Aversion Trigger: Rumination, Repeat Offense, or Revenge) x2 (Level: High or Low) experimental design, in which participants' were asked to recall one of six different experiences from their past. Such as, in the high rumination condition they were asked to remember "a time when you kept dwelling on the offense. You kept ruminating about what the person did to you". Individuals, who recalled memories of high rumination, repeat-offending, and/or revenge, were expected to show higher unreadiness, self-protection, and face concerns when respectively considering forgiveness. Individuals by contrast who considered memories that produced fewer thoughts of rumination, repeat-offending, and revenge, were expected to experience less forgiveness aversion and greater forgiveness motivation.

*Keywords: Forgiveness, Motivation, Rumination*

## (39) Membrane distillation in water treatment

*Wang Xu, New Mexico Tech*  *Qu Taoguang, New Mexico Highlands University*

Obtaining fresh water from water desalination is an attractive method to deal with the water crisis. How to achieve this goal efficiently both in technology and economy aspects are challenges to the researchers. Among many treatment options membrane distillation (MD) is a promising one. Driven by the vapour pressure difference between the porous hydrophobic membrane, the MD process has many attractive features. For example the operation temperature is not necessarily heated up to the boiling point, and the operation pressure is much lower than that used in some pressure-driven membrane processes like reverse osmosis (RO). Therefore, MD is expected to be a cost-effective process, and there is less requirement for the membrane too. And as a matter of fact, the MD process can achieve a theoretically 100% salt rejection. However the MD is also attended by some drawbacks such as low permeate flux (compared to other separation process, like RO), and the permeate flux is highly sensitive to the operation conditions, like concentration and temperature. This work demonstrated some efforts in morphology control and operation conditions selection to improve the performance of the MD process.

*Keywords: Water Treatment, Membrane Distillation, Morphology*

## (40) Short Duration Aquifer Test within a Fractured Crystalline Basement Reservoir, Truth or Consequences, New Mexico

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*M. Sherman, New Mexico Tech*
*R. Grano, New Mexico Tech*
*M. A. Person, New Mexico Tech*

Recent 2D hydrothermal modeling efforts published by Pepin et al. (2015) suggest that the low-temperature (~ 41°C) geothermal system in Truth or Consequences, NM is characterized by deep (2-8 km) groundwater circulation within

permeable (10-12 $m^2$) fractured crystalline rocks. Their models were constrained by geochemistry, temperature, flow velocity, and carbon-14 data but lack calibration to aquifer test data. On June 13, 2015, we conducted an aquifer test in a newly drilled 73-meter deep geothermal well within the town's hot-springs district. The production interval of this well is 24 meters long and is within fractured Precambrian metamorphic rocks. We installed pressure transducers in the production well and in two observation wells to monitor water levels during the test. The production rate averaged 1.8 x 10-2 $m^3/s$ (283 gpm) and the two observation wells were located 20 and 38 meters away from the production well, respectively. The two observation wells were shallower and completed in Quaternary alluvium. Production well water levels oscillated during the first two minutes of the aquifer test due to inertial effects. Net drawdown in the production well after 97 minutes of pumping was approximately 0.6 meters, while minimal drawdown was evidenced in the observation wells. Applying the Cooper-Jacob model provided a transmissivity estimate of 1.1 x 104 $m^2$/day and thereby a permeability range of 5 x 10-10 to 2 x 10-12 $m^2$. These results are further evidence that the crystalline basement rocks within the Rio Grande Rift can be remarkably permeable when significantly fractured.

*Keywords: High Permeability, Crystalline Basement, Geothermal, Aquifer Test, Hot Springs*

## (41) Methods for protecting the growth of *G. sulphuraria* as wastewater

*Elan Glendening, New Mexico State University Alamogordo*

The algae strain called *Galdieria sulphuraria* has been used most recently in the treatment of municipal wastewater, reducing the levels of phosphates and nitrogen to comply with EPA regulations so that reintroduction of the wastewater into the ecosystem is energy positive and ecofriendly. This strain has been used because it is an extremophile in that it grows in low pH ranges and high levels of temperature. We have been monitoring the growth of *G. sulphuraria* in outdoor photo bioreactors for identifying crop protection methods and identification of infection sources which could limit the growth and productivity of the algae. While monitoring the algae, a fungal infection took place. We used methods to counter this and to our knowledge have succeeded thus far.

*Keywords: Crop Protection, Algae*

## (42) The Effects of Geothermal fluids on Surface Water Quality in The Jemez River System in Northern New Mexico

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*Rayanna Benally, University of New Mexico*
*Laura Crossey, University of New Mexico*
*Valerie Blomgren, University of New Mexico*
*Jared Smith, University of New Mexico*
*Karl Karlstrom, University of New Mexico*

Geothermal fluids flow into the Jemez River, northern New Mexico, from the Valles Caldera. The river discharge levels (driven by both snowmelt pulses in the spring and monsoons in the summer) greatly influence the local downstream water quality. Water samples have been taken from a 43-kilometer reach of the Jemez River during the summer of 2015 and are compared to results taken along the same reach over the past decade. Methods included 'campaign style' bottle collections for laboratory chemical analysis of cations and metals, anions and alkalinity. Analyses along the studied reach do show three major and distinct geothermal input sites and continuous fluctuations in water quality due to seasonal snowpack melt, seasonal monsoons, and the geothermal fluid inputs. At low river discharges, it is common for many of the constituent concentrations to exceed the Maximum Contaminant Levels, for example sulfate, TDS and arsenic. Alkalinity is also influenced by high $CO_2$ levels of the geothermal discharges. As influences from climate fluctuations continue, the importance of monitoring of the local water systems can be seen, more importantly if temperatures continue to climb and drought conditions persist. Streams of the arid Southwestern US are particularly susceptible to water quality degradation coupled to declines in surface water supply due to the widespread presence of deeply-derived, saline groundwater inputs.

*Keywords: geothermal fluids; discharge levels; water quality*

## (43) Alkalic epithermal gold mineralization, southwestern Platoro caldera: An examination of a shallow extinct geothermal system

*Jeffery Hrncir, University of New Mexico*

The 29.7–28.4 Ma Platoro–Summitville caldera complex is host to a diverse class of polymetallic ore deposits, including the world-class gold deposit at South Mountain. New mapping of andesitic units that have been subjected to widespread epigenetic alteration has revealed a previously unrecognized gold deposit type formed at ~22 Ma hosted within subtle alteration facies at the distal end of an auriferous hydrothermal system. The anatomy of this geothermal system is examined through integration of field mapping and geochemical data. Highly anomalous values of gold, tellurium, antimony, arsenic, and halogens up to 6,000 times background abundance are juxtaposed with remarkably low base metal concentrations and total sulfide content. Together, these metal associations comprise a diagnostic trace element geochemical suite genetically related to low sulphidation epithermal deposits and specifically, the alkaline subclass. Pervasive K-metasomatism, chloritization, and hematization within the mineralized rocks provide additional support for the existence of a hydrothermal system dominated by neutral, low salinity aqueous fluid or vapor contributed from a mafic alkaline magmatic source in the subvolcanic environment. The failure to recognize large-scale disseminated gold deposits in the broader Rio Grande rift by explorationists may be attributed to the historic focus on acid-sulfate alteration styles within extinct geothermal systems rather than subtle alkalic facies that superficially resemble regional propylitic alteration. Predictive hierarchical exploration criteria are developed that suggest broadly favorable environments for further alkaline gold discoveries in other mineralized caldera centers and recently active hydrothermal sites within the influence of the greater Rio Grande rift system.

*Keywords: gold, hydrothermal, rift*

## (44) Evaluation of zinc sulfide and copper oxide as catalysts for chemical carbon mitigation

*Hanqing Pan, New Mexico Tech*

One way to reduce atmospheric $CO_2$ is through chemical carbon mitigation, an approach which traps atmospheric $CO_2$ and converts it to a useful product without the use of additional $CO_2$ generating power sources. This approach can lead to methanol as an end product, a potentially useful fuel. This idea of "methanol economy", pioneered by Chemistry Nobel laureate George Olah, has been highlighted as an alternative to using hydrogen as fuel because methanol is renewable and more readily transportable. The overall goal of this project is to catalytically convert $CO_2$ to formate ($CHOO^-$), and eventually to methanol ($CH_3OH$) using ambient solar energy. This project is focused on evaluating different semiconducting materials as catalysts such as micron- and nano-sized zinc sulfide and copper oxide. Photo-experiments were performed using a buffer system and along with the above mentioned catalysts to test for formate production. Ion chromatography was used to quantify formate concentration. Based on our results, we have demonstrated that nanoparticulate zinc sulfide is a more effective photocatalyst than micron size ZnS in the photoreduction of bicarbonate to formate. The next step is choosing a suitable photosensitizer that is able to donate electrons to an acceptor when exposed to sunlight. Our aims for this project include selecting both a semiconductor catalyst with valence band and conductor bands compatible with the HOMO and LUMO levels of macrocyclic photosensitizers in order to reduce carbon dioxide to formate (and eventually methanol) using ambient solar energy.

## (45) The Economic Impacts of Wildfires on the Built and Natural Critical Civil Infrastructure

*Natalia M. Sanabria, University Of New Mexico* *Vanessa Valentín, University Of New Mexico*

The impacts on critical civil infrastructure (e.g., water, telecommunications, transportation, etc.) due to major disaster events, can greatly affect the response times and effectiveness of emergency teams, the proper operation of critical facilities and the recovery time for the community. With natural disasters on the rise and the nation's infrastructure outdated and vulnerable, it is essential for agencies to have a plan of action for the allocation of funds to protect civil critical infrastructure. Over the past decades, wildfires have increased in severity and frequency in response to

changes in climate, especially in the Southwest where the arid climate, heat waves and droughts can have a dramatic effect on the risk of fire. This study explores the economic impacts of wildfire events on critical civil infrastructure and the costs associated to mitigation strategies. The proposed impact assessment framework can be incorporated in the decision making processes of watershed managers in order to consider the proper wildfire risk mitigation strategies that better protect and maintain the functionality of the infrastructure.

*Keywords: wildfire, economic impacts, critical infrastructure*

## (46) Preferences on Energy Regulations, Tradeoffs and How They Vary Across New Mexico

*Kara Walter, University of New Mexico* *Jennifer Thacher, University of New Mexico*
*Janie Chermak, University of New Mexico*

There are tradeoffs between renewable energy and fossil fuels and within those categories. Recent regulation at the federal level (111D and Clean Power Plan) is creating changes in how states must act regarding carbon dioxide ($CO_2$). These regulations require states to develop a plan to cut $CO_2$ emissions by choosing among plans suggest by EPA. Each of these plans will affect the state and counties to different degrees. This research develops a survey asking about preference for methods for states to meet these goals, examines preferences between renewable and fossil fuels and between natural gas and oil, develops a choice experiment, and asks about preference about hydraulic fracturing, oil and gas development, nuclear energy, infrastructure investment for energy, and regulations in the energy industry. In a state that consistently ranks in the top for fossil fuel production and has a large potential for renewable energy, we expect preferences on plans to vary across the state. This poster will discuss what we have learned thus far from focus groups and debriefings and plans for moving forward with the survey.

*Keywords: energy economics, survey, tradeoffs, CE*

## (47) Using Graphical Analysis and Geothermometry to Compare Water Chemistry among Various Sites throughout Colorado and New Mexico

*Tanner Grulke, University of New Mexico* *Valerie Blomgren, University of New Mexico*
*Laura Crossey, University of New Mexico* *Karl Karlstrom, University of New Mexico*

Graphical analysis can be a useful tool to visualize contrasting features between sets of water chemistries; we are using graphical tools for geothermal sites throughout Colorado and New Mexico. Our first goal was to compare major ions among a sample suite using ternary, Piper and chemical variation diagrams; these diagrams were created with the Geochemist's Workbench and Excel. Our second goal was to represent thermodynamic relationships among solutes using the excel spreadsheet created by Powell and Cumming (2010); this spreadsheet is useful in geothermal environments, as was the case for this study. Another set of tools useful in the assessment of geothermal potential are chemical geothermometers. Chemical geothermometers take advantage of temperature dependent water-rock reactions. The geothermometers applied in this study used concentrations of dissolved silica, Na, K, Ca, Mg, and Li. Geothermometers can be used to assess possible reservoir temperatures from chemical data of surface waters. Geothermometers have some limitations when solute concentrations are affected by processes such as: mixing with other waters, dissolution or precipitation, ion exchange with surrounding materials, and residence time. We again used the Powell and Cumming (2010) spreadsheet application to calculate geothermometry data, and used this data to estimate reservoir temperatures. The graphs and tools assessed for the purpose of our investigation were ternary diagrams ($Cl$-$SO_4$-$HCO_3$ and Na-K-Mg), the Piper diagram and geothermometers. We have found that combining graphical analyses facilitates rapid assessment of the geothermal potential over a wide area.

*Keywords: geothermometry, chemistry, water, graphical analysis*

## (48) Use of Chemical and Isotopic Identifiers to Characterize a Uranium Contaminated Groundwater Plume in New Mexico

*Mitchell Schatz, University of New Mexico*
*Bruce Thomson, University of New Mexico*
*Jose Cerrato Corrales, University of New Mexico*
*Curtis McHaley, U.S. Department of Energy*

Groundwater in shallow aquifers near Milan, NM is the sole source of water for agriculture and human consumption. Beginning in the early 1950's the region experienced extensive mining of uranium and two uranium mills also located nearby. Groundwater in the region has high levels of uranium, selenium, nitrates, and vanadium, and has been found to be too contaminated for human use. Other sources of water have been provided to most residents in the region. Isotopic and chemical identifiers were used to help distinguish contaminants derived from anthropogenic and natural occurring sources near and the two milling sites. Private wells were sampled in the fall of 2015. Principal Component Analysis was used to display similarities and differences in groundwater chemistry for sampled wells, natural sources and uranium mill site groundwater. Several of the private wells had similar levels of contaminants as mill-derived water. Activity ratios (ARs) for uranium-234 and uranium-238 were used to determine the source of groundwater contamination. Dissolved sulfate in mill-derived groundwater was enriched with sulfur-34 whereas, natural occurring groundwater showed a depletion of sulfur-34. Other stable isotopes were used to determine sources of contaminants in the aquifers. The use of chemical and isotopic identifiers in this study help to determine that groundwater contaminants in private wells down gradient from the milling site were most likely derived from the mill site dewatering activities and not the natural occurring contaminants from Morrison formations in the San Mateo Creek basin aquifers.

*Keywords: Groundwater, isotopes, uranium, mining*

## (49) Complexation and Redox Reactions Affecting Uranium Recovery by In Situ Leaching

*Omar Ruiz, University of New Mexico*
*Jose Cerrato Corrales, University of New Mexico*
*Johanna Blake, University of New Mexico*
*Bruce Thomson, University of New Mexico*

From 1950 to the early 1980's New Mexico played an important role in the production of uranium (U) for the nuclear power industry and the nation's weapon programs. Though the U mining and milling industry is largely dormant at present, increased interest in nuclear power as a CO2 free power source has led to proposals for renewed development of U resources. In particular, U mining projects have been proposed using both underground mining and in situ leach (ISL) mining. The objective of this poster is to investigate metal speciation controlled by complexation, and redox reactions resulting from ISL U mining. In principle ISL mining will minimize waste by eliminating mill tailings, mine waste rock, mined dewatering, and radiation exposure. ISL mining has not avoided aquifer contamination and therefore an evaluation of complexation, and redox reactions affecting the interactions between U minerals and co-constituents, which may include but not limited to arsenic, chromium, molybdenum and, vanadium. Batch experiments of low grade ore were conducted and show that U and co-constituents are dissolved and need to be considered for aquifer remediation. Leach tests have been performed both with acids to determine the total metal concentrations, NaHCO3 lixiviant was used to understand U and metal dissolution. The results of these experiments will be presented. The results will be used to develop an understanding of the effectiveness of ISL mining, the potential impacts on ground water quality, and will subsequently be used to develop strategies for mitigating the impacts of these activities.

## (50) Beneficial Use of Produced Water in Pressure Retarded Osmosis

*Adam Martinez, New Mexico Tech*

Produced water is a waste stream from oil production that currently has no method of mitigation. The water is stored in wells, or injected into oil wells for waterflooding to extract more oil. This water is non-potable and has a very high TDS. Pressure retarded osmosis is a method of power generation using the salinity gradient across a membrane. The Hydranautics SWC-50LD membrane was tested for pressure retarded osmosis to generate power. The true permeance

of the membrane was determined to be 0.142 LMHP, and used to properly calibrate the active area of the membrane. Seawater at 3.5‰ was tested to establish a baseline for the membrane power generation. The power for this salinity was found to be 0.5 W/m². Concentrate at 7‰ was also tested, and generated 1.2 W/m². Produced water was assessed using both tap water, and a makeup water with a TDS of 1.5‰. The power generation was found to be lower for the makeup water case at 2 W/m², indicating internal concentration polarization within the membrane. The tap water case generated 3.5 W/m². In this case, this membrane and configuration does not offer optimum power generation, and hollow fiber membranes may be the direction to take for PRO.

## (51) Water Purification: Insights on the Catalytic Activity of Defect Free- and Rich-$MoS_2$ Nanosheets for the Photocatalytic Removal of Carcinogenic Chromium(VI) Ions

*Swagotom Sarker, New Mexico State University* *Hongmei Luo, New Mexico State University*
*Litao Yan, New Mexico State University*

This work highlights an efficient water purification process utilizing cheap and environmentally benign molybdenum disulfide ($MoS_2$) as a (photo)catalyst. By controlling the molar ratio of Mo to S in their precursors, defects can be introduced in the $MoS_2$ nanosheet structures. Defect free- and rich- $MoS_2$ nanosheets are prepared by the one-pot hydrothermal process. Although there is a wide range of reports on the catalytic performance of defect rich-$MoS_2$ and its composites, a correlation between adsorption and corresponding photocatalytic behavior of defect free- and rich-$MoS_2$ is yet to be developed for water purification by removing carcinogenic Cr(VI). However, synthesis parameters and post-synthesis heat treatment offer interesting changes in the crystalline properties as well as the catalytic activities. $MoS_2$ nanosheets are characterized by XRD, BET isotherm, SEM, and TEM. Catalytic performances for Cr(VI) removal is measured at pH=4. Herein, we report (I) the determination of the BET surface area of defect free- and rich-$MoS_2$ to relate to their catalytic activities, (II) the establishment of the adsorption isotherm for Cr(VI) ions, and (III) the comparison of the photocatalytic removal of Cr(VI) for water purification as well as the realization of the influence of the post-synthesis heat treatment on $MoS_2$ nanosheets.

## (52) Solution Processed Strontium Titanate as a Cathodic Buffer Layer for Polymer Solar Cells

*Brian Patterson, New Mexico State University* *Yang Qin, University of New Mexico*
*Jianzhong Yang, University of New Mexico* *Hongmei Luo, New Mexico State University*

Organic photovoltaics present an opportunity for economical, scalable power generation for the ever increasing energy requirements of the developing world. Metal oxides have been investigated as a potential replacement for current buffer layer to alleviate the degradation of the indium tin oxide (ITO) electrode/PEDOT:PSS or poly(ethylenedioxythiophene) poly(styrene sulfonic acid) interface as exposure to air facilitates harmful etching of the glass. Increased stability can be achieved by sandwiching the air-sensitive materials between less air sensitive materials and utilizing an inverted solar cell structure. With collaboration between NMSU and UNM, a thin film of strontium titanate was fabricated using a low cost, scalable polymer-assisted deposition method as an effective cathodic buffer layer utilizing the aforementioned inverted design. The polymer solar cells operating with a poly(3-hexylthiophene) (P3HT) / phenyl-C61-butyric acid methyl ester (PCBM) blend and the strontium titanate cathodic buffer layer exhibited favorable performance with a power conversion efficiency (PCE) of 3.5‰ and fill factor (FF) of 45%, which indicates that such a buffer layer produced through an economical synthesis provides a potentially attractive choice for low-cost organic solar cell fabrication.

*Keywords: solar cell, polymer, strontium titanate*

## (53) Lipid Extraction from Algal Biomass for Biofuel Production

*Tanaka Pfupajena, Eastern New Mexico University* *Juchao Yan, Eastern New Mexico University*

The majority of the fuels we use in our vehicles and other equipment on a daily basis are nonrenewable. As a result,

the world is running out of supplies of fuels. Many alternatives to using natural reservoirs as sources of fuels have been exploited, among which, the use of algal feedstock as a source of biofuel has received enormous attention. Algal biofuel was studied for a long time, and has recently gained popularity again due to the global demand for transportation fuels, the greenhouse gas effects, and the energy security risks. In this project we investigate the use of microalgae cultivated from dairy wastewater to produce biofuels. Algae offer an inexhaustible source of energy, nutrients and raw material. When microalgae are grown and harvested, the biomass obtained contains lipids which can be converted into biodiesels through chemical transformations. In this presentation, I will present my preliminary results on using Sohxlet extraction to extract the lipids, lipids characterizations by Gas Chromatography-Mass Spectrometry, and the separation of algal extracts by a reverse-phase column chromatography.

*Keywords: microalgae, lipids, and chromatography*

## (54) Screening Test of Four Low Temperatures on a Natural Mixed Algal Population Preserved with Methanol or Dimethyl Sulfoxide for Viability and Identification of Reconstituted Species Analysis

*Sarah Kintner, University of New Mexico* *David Hanson, University of New Mexico*
*Andrew Schuler, University of New Mexico* *Abhaya. K. Datye, University of New Mexico*

Understanding the effects of freezing on mixed algal population cultures for later reconstitution is important for long-term culture reproducibility. This temperature screening study freezes a San Acacia Brine Pond mixed algal population with cryopreservants of methanol or dimethyl sulfoxide at four temperatures: 0, -20, -80, and -196 °C, and reconstitutes the frozen algal samples to determine their viability and the species present. One flask was cultivated in the laboratory for 11 days. Each culture sample was mixed with either 5% or 10% methanol or dimethyl sulfoxide. The vials were placed in their respective freezer for 1 week and then reconstituted in 30 mL of media with all vials growing on a rotary table. Temperatures below -196 °C grew only filamentous algae. The culture day growth started by green appearance is: 0 °C- 5% and 10% dimethyl sulfoxide, day 10; -20 °C - 5% dimethyl sulfoxide day 7, 10% dimethyl sulfoxide day 6; -80 °C- 5% dimethyl sulfoxide day 7, 10% dimethyl sulfoxide, methanol 5%, and 10% day 6; -196 °C - 5% and 10% dimethyl sulfoxide, 5% and 10% methanol day 6. Algal (196 °C) species greater than 5% of counts are: Seed Culture: 23% Plectonema Terebrans, 53% Scenedesmus, 19% Chlorosarcinopsis; 5% dimethyl sulfoxide: 60% Plectonema Terebrans, 8% Nitzchia, 21% Scenedsmus, 8% Chlorosarcinopsis; 10% dimethyl sulfoxide: 88% Plectonema Terebrans, 12% Nitzchia, 5% and 10% methanol: 95% Plectonema Terebrans. The best post-reconstitution growth and number of species occurred in 5% dimethyl sulfoxide cryopreservant from the -196 °C reconstituted culture.

*Keywords: Cryogenic freezing, mixed algal populations*

## (55) Growing Microalgae in Dairy Manure Effluents for Sustainable Biofuel Production

*Juchao Yan, Eastern New Mexico University* *Bin Bai, Eastern New Mexico University*

Microalgae hold promise as a sustainable source of biofuels based on their rapid growth and high lipid content. The objective of this study was to adapt microalgae cultivation on an Algal Turf Scrubber® to local conditions (e.g., climate, dairy wastewater characteristics) for maximizing the productivity, which is critical to the future commercialization of algal biofuels. Analysis shows that ethanol, chloroform, and hexane are generally more efficient in the Soxhlet extraction of lipids than other solvents. Thin layer chromatography is used to explore the conditions for the separation of lipids and chlorophyll. For best separation, we have tried mixed solvents with various compositions. We have also used high performance liquid chromatography and gas chromatography-mass spectrometry to characterize the separation fractions.

*Keywords: Algal Turf Scrubber®, productivity, Soxhlet extraction, separation lipids and chlorophyll*

## (56) Comparison of Evapotranspiration Estimates Produced by the Simplified Surface Energy Balance (SSEBop) Model and a Portable Chamber Measurement Device

*Ian Hewitt, New Mexico State University*

In New Mexico, there is currently an effort under the name of the Statewide Water Assessment aimed at producing a water balance for the entire state. A critical, and difficult to measure, component of this is Evapotranspiration (ET). This process is composed of evaporation and transpiration losses to the atmosphere. This component is critical as it is responsible for as much as 90 percent of the precipitation that falls returning to the atmosphere. Though there have been methods produced that accurately measure ET for several decades, none exist that can give continuous estimates across the state in a feasible manner. As a solution to this, researchers for nearly two decades have been working with models that incorporate remotely sensed data from satellites. These have the benefit of producing spatially continuous surfaces of ET for large areas such as the state of NM. The problem is that there have been studies showing that these models have errors in the state upwards of 50 percent. One model has shown promise which is the Simplified Surface Energy Balance Operational (SSEBop) model. Adjustments have been made to the model in the past year and researchers believe it shows promise for use in NM. Here I will show recent estimates produced by the SSEBop in northern NM and comparisons with a portable chamber measurement device over different land cover classes and soil moisture conditions.

*Keywords: Evapotranspiration, SSEBop, New Mexico*

## (57) Imaging geothermal reservoir features with magnetotellurics

*Matthew Folsom, New Mexico Tech*
*Jeff Pepin, New Mexico Tech*
*Mark Person, New Mexico Tech*
*Shari Kelley, Bureau of Geology & Mineral Resources*
*Lucas Blom, New Mexico Tech*
*Dave Love, Bureau of Geology & Mineral Resources*

A comprehensive knowledge of the groundwater flow patterns associated with geothermal resources is critical to sustainable resource management and to discovering blind geothermal systems. Magnetotellurics (MT), which provides subsurface electrical resistivity information, has the ability to image geothermal reservoir features. We have used MT data along with 2D hydrothermal modeling, constrained by temperature, salinity and carbon-14 data, to explore possible deep groundwater circulation scenarios near the Sevilleta National Wildlife Refuge, in the Rio Grande Rift, central New Mexico. The area is underlain by a 100 to 150-m thick molten sill emplaced approximately 19 km below the surface. This sill is referred to locally as the Socorro Magma Body (SMB). Previous studies by Mailloux et al. (1999) and Pepin et al. (2015) suggest that the crystalline basement rocks in this region of the Rio Grande Rift can be significantly fractured to depths of 4-8 km and have permeabilities as high as $10^{-14}$ to $10^{-12}$ $m^2$. The combination of high permeability conditions and the SMB makes this region a promising candidate for discovering a blind geothermal system at depth. We constructed a 2D hydrothermal model that traverses a 64-km zone of active uplift that is associated with the SMB. We also completed a 12-km long, 9-station MT transect across a portion of this profile. Preliminary results suggest a deep convection-dominated system is a possibility. We hypothesize that using hydrothermal modeling in conjunction with MT surveys may prove to be an effective approach to discovering and managing deep regional hydrothermal resources.

## (58) Algal indicators of acidic inputs and intermittent flow in streams in the Valles Caldera National Preserve

*April Fox, University of New Mexico*
*Rebecca Bixby, University of New Mexico*

Biological diversity in aquatic ecosystems can be an indication of structure, function, and stability of the system. Diatoms and other algae often live within narrow environmental conditions, making them important ecological indicators of aquatic ecosystems. Algae respond to these environmental factors with changes in biomass and changes in species assemblages. For example, high conductivities and lower pH, caused by geothermal inputs, can dramatically influence

water quality and biological communities in aquatic systems. Low pH, in combination with intermittent flow, may influence algal diversity in streams. The relationship between pH and intermittent flow in Alamo Canyon (AC) and the Sulphur Creek watershed may be a contributing factor to the diversity of algal assemblages in three AC ponds that are fed by geothermal springs compared to algal assemblages located in downstream reaches of the Sulphur Creek watershed. This connection is likely to influence the chemistry of downstream waters and the composition of algal communities. Low flow, low pH, and high specific conductance can threaten designated uses in New Mexico state waters. Spatial and temporal characterization of the Sulphur Creek watershed through biological data collection and analysis may provide critical data for water quality designation of systems whose current designated use may be threatened due to naturally occurring and unique chemical properties. Utilizing algal assemblage diversity as indicators of water quality in geothermal- influenced waters may assist in the ongoing reclassification of the Sulphur Creek watershed.

*Keywords: algae, water quality, geothermal, intermittent flow*

## (59) Hydrochemistry of Sulphur and Alamo Creek, Valles Caldera: effect of geothermal systems on surface water quality

*Graham Thomas, University of New Mexico*
*Tanner Grulke, University of New Mexico*
*Laura Crossey, University of New Mexico*
*Karl Karlstrom, University of New Mexico*
*Valerie Blomgren, University of New Mexico*
*Jared Smith, University of New Mexico*

The Valles caldera in northern New Mexico is a large, Quaternary silicic volcanic complex (1.25 Ma to 40 ka) containing a liquid-dominated geothermal system. Sulphur Springs and Alamo Canyon in the southwestern part of the caldera contain acidic geothermal features. In this study, we examine the hydrochemistry of the acid-sulfate waters and examine their influence on the surface waters draining the Valles caldera. We sampled waters of Alamo, Sulphur, San Antonio and Jemez rivers during two campaigns in summer, 2015. To obtain pH, temperature and other initial parameters a field probe was placed in streams. After those are recorded two water samples are collected; one for bicarbonate concentrations and another for anion and cation concentrations. With over 23 samples collected, measurements had a wide range results such as pH ranges from 2.5 to 8.5, temperatures from 16 C° to 21 C°, metal concentrations up to 749 ppm. The acidic geothermal contributions have a major effect on the water quality in streams and shallow groundwater systems; especially pH, T, sulfate and metal content in the upper stream reaches of Alamo and Sulphur creeks. The water quality improves as waters from Redondo and the East Fork Jemez enter the stream system. Using solute concentrations (including sulfate, chloride and bicarbonate) we are able to quantify the mass loading of geothermal constituents to the stream system, and predict the consequences of changes to future snowpack and runoff on water quality in the Jemez river system.

*Keywords: Water Quality, Geothermal, Hydrochemistry, Valles Caldera, Jemez River*

# POSTER SESSION AWARDS

Presentations at the afternoon Poster Session were reviewed by an independent panel of judges who scored each undergraduate poster for content and presentation. Awards for the best undergraduate posters were presented at the conclusion of the Symposium.

### First Place : Brianne Willis, Eastern New Mexico University

***Batch extractions of metals from bicarbonate and ascorbic acid solutions***

### Second Place: Vanessa Ward, Santa Fe Community College

***New Mexico geothermal resources: A database compilation for New Mexico EPSCoR***

### Third Place: Mariah Kelly, University Of New Mexico

***Geochemistry of sinkholes in the Santa Rose, NM area***

# OUTSTANDING NEW MEXICO SCIENCE TEACHERS

Each year the New Mexico Academy of Science presents two Awards for Outstanding Science Teaching. Nominations for these awards come from school superintendents, principals, other teachers, parents, and students. An NMAS Awards Committee reviews the nomination materials. The 2015 Awards were presented at the Research Symposium.

## TURTLE HASTE, DESERT RIDGE MIDDLE SCHOOL

Ms. Haste has been teaching science for 25 years and currently teaches 7th and 8th grade science at Desert Ridge Middle School in Albuquerque. She has a B.S. in Physical Geography from the University of Central Missouri and an Masters in Science Education from Oregon State University. She is a National Board for Professional Teaching Standards Certified Teacher in Early Adolescent Science. She holds a NASA Endeavor Fellow STEM Certificate from Columbia University Teacher College. In 2007 she was a NOAA Teacher at Sea, and in 2014-2015 she was named a Teachers For Global Classrooms Fellow. Very recently she was honored as one of the New Mexico Women of STEM for her contributions in motivating young women to pursue education and careers in STEM fields, as well as the NOAA Excellence in Science Education Award for 2015.

Haste is known for her connections with researchers around the world, showing her students how the topics they study are being explored by scientists. Her students have exchanged e-mails, packages, and the occasional video hook-up with researchers in Antarctica. A "sun shadows" project was the first middle school science project ever accepted for presentation at the American Geophysical Union Annual Conference. Her nominator for the NMAS Award said the following about her: "She uses her curiosity, knowledge, and awe of the physical world around her to instill excitement in her students. When she introduces basic and very important scientific concepts, she does so in fun and entertaining ways."

## ANNA SUGGS, ZIA MIDDLE SCHOOL


Anna Suggs has been a sixth grade teacher for 21 years. For the last 15 years, she has been teaching sixth grade science at Zia Middle School in Las Cruces NM. She has a B.S. in agricultural animal science and an M.A. in curriculum and instruction, both from New Mexico State University. During her tenure at Zia Middle School, she has been instrumental in implementing and participating in multiple after school science and technology programs. Her students at Zia also have worked in coordination with Spaceport America to build and launch small rockets carrying payloads.

Her desire to inspire young scientists has led to her (and her students') participation in the NASA Remote Sensing Earth Science Teacher Program in cooperation with Goddard Space F;ight Center. Ms. Suggs and her students have been doing research at White Sands National Monument for 5 years. The research was to determine the impact of human activity on the dune field and the students worked with satellite data and a small UAV flown by the local model airplane club. This research has involved hundreds of students as well as teachers, university personnel, members of the model airplane club, and parents. In 2015, she received the Presidential Award for Excellence in Mathematics and Science Teaching, one of only 102 mathematics and science teachers from all 50 states, the District of Columbia, Puerto Rico and the Department of Defense Education Activity to receive the award.

Ms. Suggs said the award is affirmation and inspiration to her. "The award affirms that the years of hard work, of constantly refining the art of teaching science, have been recognized," she said. "The inspiration is that, now that I have the award, I must continue work to empower my students and colleagues with a love of science and learning."

## 2015 NMAS STUDENT PAPERS

# TESTING AND FINITE ELEMENT MODELING OF HEAD IMPACTS IN SPORTS

Josh Ludwigsen

## ABSTRACT

The purpose of this study was to simulate two typical sub-concussive impacts, one in American football and one in soccer and compare the response of the brain itself during those impacts. The testing was achieved by constructing an instrumented mechanical head and subjecting it to both a helmet-to-helmet football impact and a bare head to soccer ball impact. The speeds of these impacts were representative of typical speeds for 10 to 12 year old males in each sport. The accelerations on the head during these impacts were recorded and used as input into a finite element analysis of a brain model to determine the resulting stresses in the brain. One of the most revealing findings was that the overall severity of the soccer impact was far greater than the football impact. In addition it was seen that the damage that occurs to the brain occurs within the first 0.01 seconds of the impact. This suggests that further research should be conducted into the safety of head impacts in sports other than football.

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Research has shown that the head injury rate for college football players is 0.37 per 1000 athletic exposures where an athletic exposure is considered to be a practice or a game. This is 32% greater than the 0.28 per 1000 exposure rate experienced by men's college soccer players (Daneshevar, et al., 2011). In addition a child's brain is more susceptible to brain injury than an adult brain. This is due to their lack of brain and body development (Cantu, 2015).

Research has also shown that cumulative concussions as well as sub-concussive impacts cause damage to brain tissue and are the cause of brain diseases such at Chronic Traumatic Encephalopathy or CTE. These diseases point to the fact that sub-concussive impacts may also be the cause of severe brain trauma (McKee et. al., 2010). This project attempted to look at the dangers of head collisions in youth sports by simulating head impacts experienced in soccer and football and comparing the impacts effects on the brain through finite element modeling.

## METHODS

In order to measure the accelerations of a youth head during a sports impact, a model wooden head with correct dimensions and weight was constructed. The head was constructed from 3/4" thick layers of pine cut to the shapes of layers of the skull and laminated together. To accurately model the mass of a real head, additional mass was added by replacing one of the wooden layers with a 2.2 kg steel mass, making the total mass of the model 3.6 kg. The neck was simulated with a pair of trampoline springs that were glued into the head. The springs were located side by side to increase lateral stability in the neck during impact, while enabling large movements forward and backwards.

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The following materials were used in the creation of the testing apparatus:

- 2 8ft 1x6 inch pieces of pine
- 1 plastic container.
- Duct Tape
- Screws
- 2 4x4 posts
- 1" thick steel pole

The following materials were used for the model head construction

- 3/4"x12" board of pine
- Calibrated 3 dimensional $\pm$ 200 g accelerometer.
- Screws
- Wood glue
- 2 Trampoline springs
- Measurement Computing 200 series USB Data Acquisition System. This device was capable of recording at 5000 samples a second for each axis.

The model head was constructed by cutting layers from a 3/4" piece of pine. There were 8 layers cut in total, each based on a layer taken from a 3D skull model. The model was available for free at the website http://www.thingiverse.com/thing:43591 and provided an anatomically correct model of the skull. This model was then scaled to size of a child head (Cantu, 2015) After the layers were cut, a space was made for the accelerometer.

Once all layers were cut they were assembled and sanded to create a smooth head shape. The third layer from the base of the skull was replaced with a 2.7 kg steel plate to make the head the appropriate mass. The springs were placed into holes drilled into the head and secured with glue. The accelerometer was placed into the head and secured using a piece of foam to ensure no movement inside the head. The wires were routed through a hole in the layers and through one of the neck springs to the data acquisition system.

To measure the head accelerations, a $\pm$ 200 G accelerometer was rigidly mounted inside the head. The accelerometer was calibrated using a centrifugal. The accelerations were recorded onto a computer using a commercial data acquisition system sampling at 5000 samples per second for each axis. The orientation of the accelerometer's axis's and the overall shape and construction of the head are shown in Figure 1.

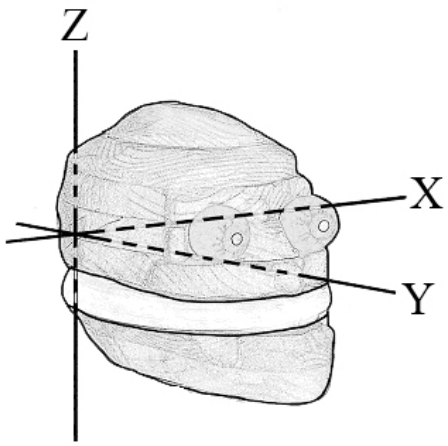


Figure 1 The wooden head simulated the shape and mass of a real head.

This experiment tested two different impacts. The football helmet-to-helmet collision and the soccer ball and bare head collision. For the football collision the colliding helmet was weighted to a mass of 4.08 kg, including a 2.7 kg mass inside the helmet. The soccer ball was inflated to regulation pressure of 83 kPa (12 psi) and had a mass of 0.412 kg.

For the football impacts the chosen speed was based on the state qualifying time for the 7th grade boys 100 m dashes. The qualifying time was 12.8 seconds resulting in an average velocity of 7.8 m/s (IESA, 2015). For soccer impacts the speed was calculated from observations of youth soccer games where kick speeds were roughly 10 m/s. Using these two speeds as maximums, the chosen test speed of 6 m/s was used in all tests. This speed was selected in order to reasonably represent a typical impact that would occur in both sports. A high-speed camera was used in order to verify the speed during testing.

To create an impact similar to those experienced in youth sports, a pendulum was used to accelerate either the helmet or the soccer ball to 6 m/s. This would give the helmet-to-helmet impact roughly ten times the total kinetic energy of the soccer impact. The pendulum was constructed using a wooden frame that held the projectile in a small basket. To ensure that the impacting objects were free flying during impact, the basket and pendulum were stopped to release the ball or helmet just before impact. The testing procedure is shown in Figure 2.

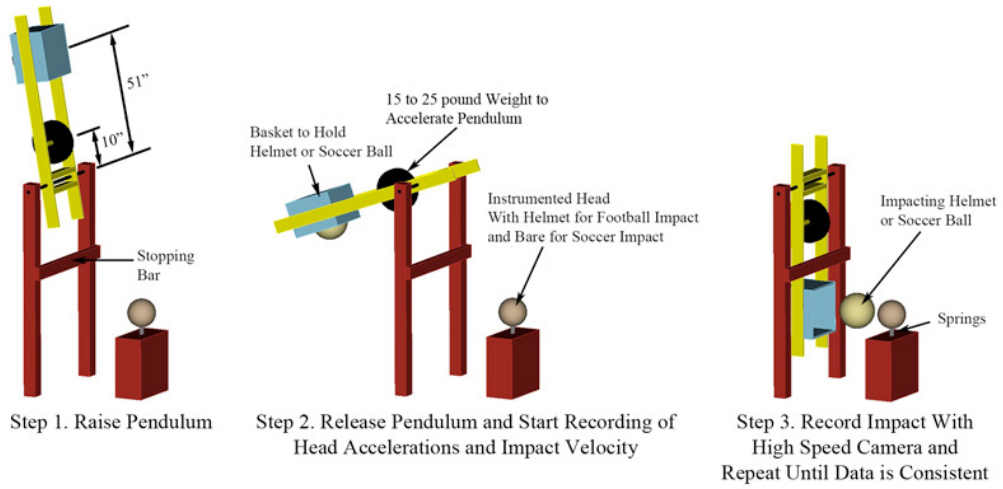


Figure 2 Test set up for the experiment.

The football impact was repeated 5 times. The soccer impact was conducted only 4 times because of the test equipment failure after the 4$^{th}$ soccer test. To evaluate the impact's severity the average measured acceleration versus time data was used as input to a finite element software package, Calcilix, to calculate the stresses on the brain using an implicit solution scheme in a full dynamic analysis (Dhondt, 2015). The brain model, a free-source model created at MIT, simulated three different materials, the cerebral spinal fluid, cerebrum, and skull, using four node tetrahedron solid elements with 127,250 elements in the cerebrum, 61,525 in the cerebral spinal fluid and 54,520 in the skull (Radovitzky, 2015). The freeware software and head model were selected because of their availability and ease of use. For the analysis, the input accelerations were applied to the outside of the skull at the nodes on the surface of the face and base. The values listed in Table 1 were used to define the elastic materials within the head model (Taylor *et. al.*, 2007; Yang *et. al.*, 2014; Taylor *et. al.*, 2014).

Table 1 Material properties used in the finite element model.

| Material | Young's Modulus (KPa) | Poisson's Ratio | Density g/cm^3 |
|---|---|---|---|
| Cerebral Spinal Fluid | 1380 | 0.49 | 1.07 |
| Cerebrum | 6900 | 0.45 | 1.2 |
| Skull | 1.4 E6 | 0.22 | 1.49 |

Young's Modulus is a measure of the elasticity of the material. Poisson's Ratio is the measure of the displacement perpendicular of the axis of compression. Density is the measure of the amount of mass in a unit volume.

The finite element modeling software directly uses the accelerations placed onto the head to predict the displacements of various nodes within the brain during the impact. From these displacements it then calculates the von Mises stresses on each element throughout the brain. The von Mises stress was used as an evaluation of the severity of the impact because it is a measurement of the non hydrostatic distortion energy in the material which can be associated with damage in the material (Lamy, 2013).

## RESULTS

The average acceleration as a function of time is shown in figures 3 and 4.

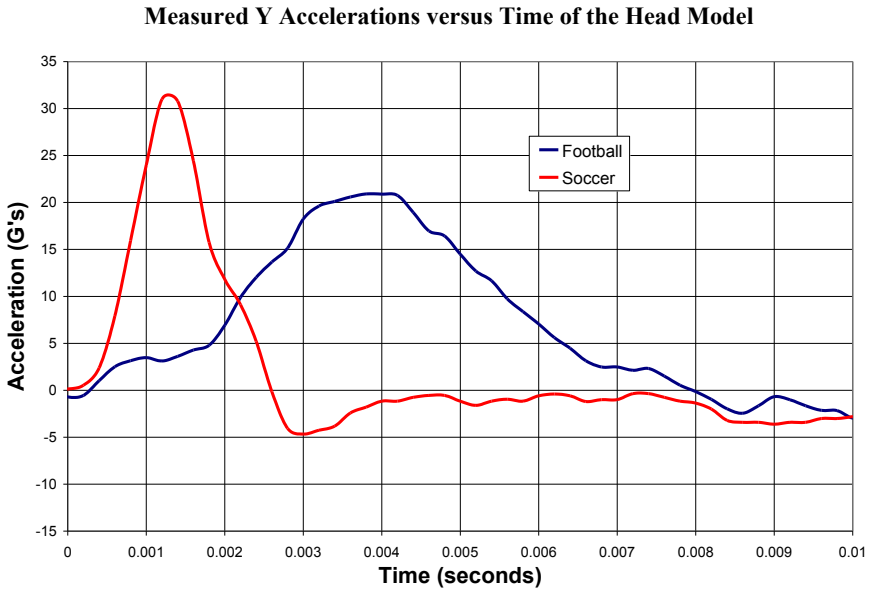


Figure 3 Y axis accelerations versus time for both the soccer and football impacts.

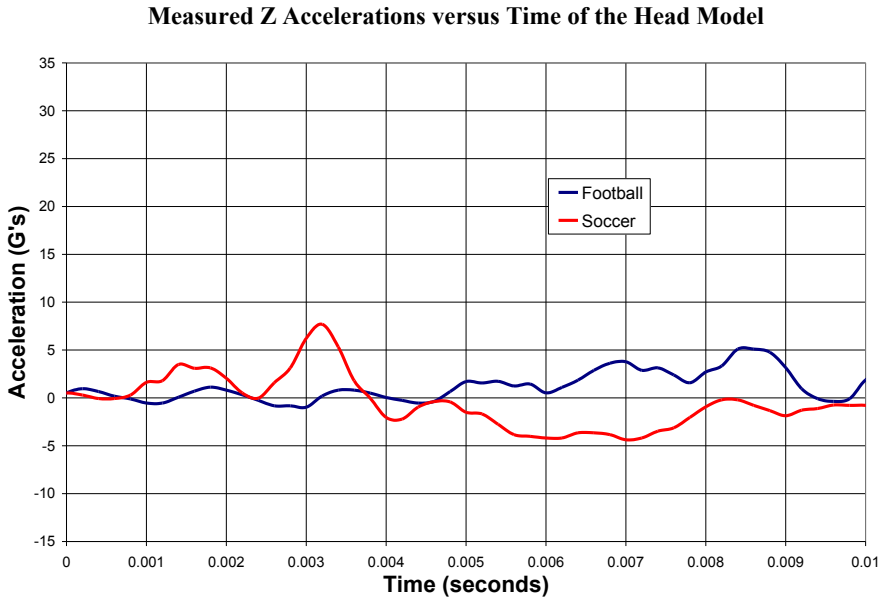


Figure 4 Z axis accelerations versus time for both the soccer and football impacts.

The plots are the average accelerations of the different test curves and already show some of the differences between the soccer and football impacts. The soccer impact has a higher peak acceleration for the y axis. The lower peak acceleration of the football impact lasts a longer time. Another important thing to note is that the accelerations on the head occur within 0.01 seconds from the beginning of the impact. This amount of time is roughly 30 times faster than the human eye can blink (Schiffman, 2001). By 0.01 seconds the model head has moved less than half a centimeter. This is consistent with recent findings on head injuries and accelerations due to blast pressure loads on soldiers heads during exposure to explosions (Taylor *et. al.*, 2014).

These acceleration functions were inputs for the finite element modeling software used to calculate the stresses that occur throughout the brain during the impact. Figure 5 shows the interior of the football brain model at its peak moment of stress 0.0039 seconds into the impact. Figure 6 shows the moment of peak stress for the soccer brain 0.0032 seconds into the impact. The 15 kPa maximum of the scale represents the minimum stresses required for a hit to possibly cause brain damage (Klieven, 2007; Lashkari, 2013).

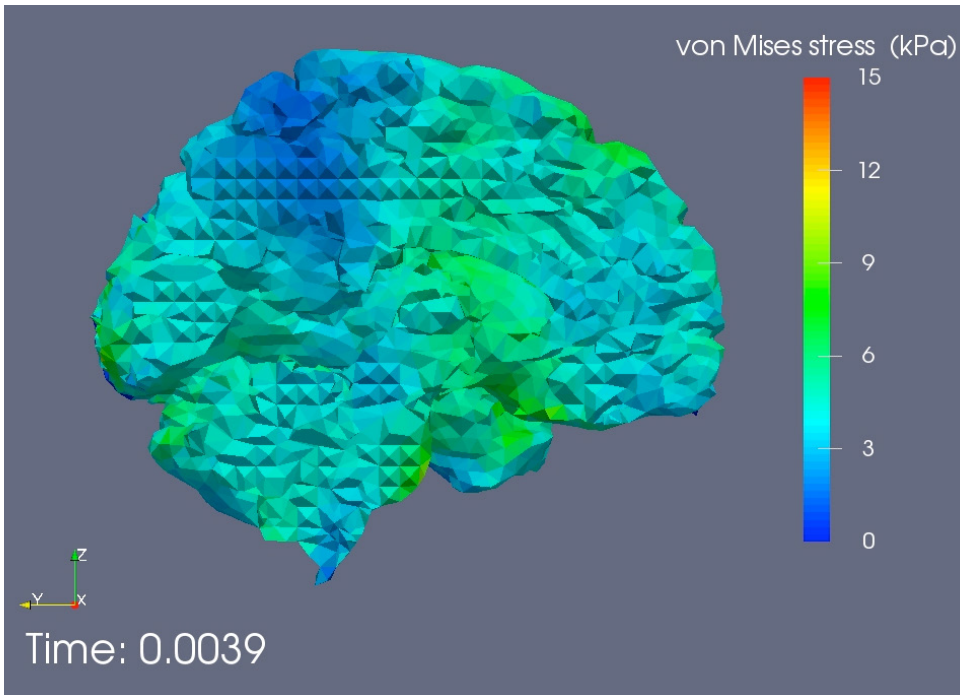


Figure 5 Stresses within the brain 0.0039 seconds into the football impact.

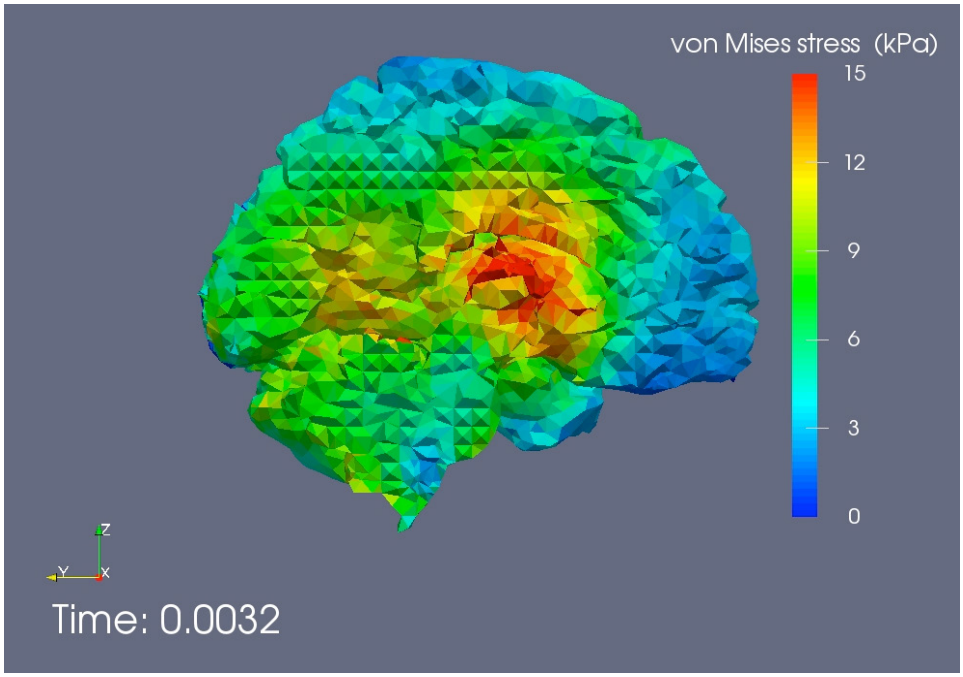


Figure 6 Stresses within the brain 0.0032 seconds into the soccer impact.

Figures 7 and 8 display the calculated von Mises stresses on the outside surface of the brain at 0.0039 seconds after the impact for football and 0.0016 seconds after the impact for soccer.

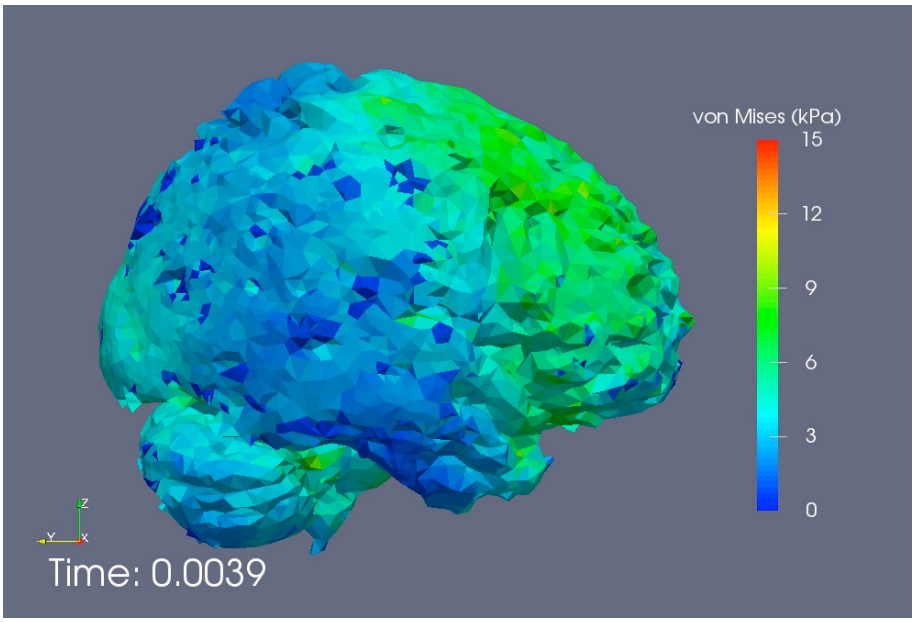


Figure 7 Exterior stresses on the brain during the football impact.

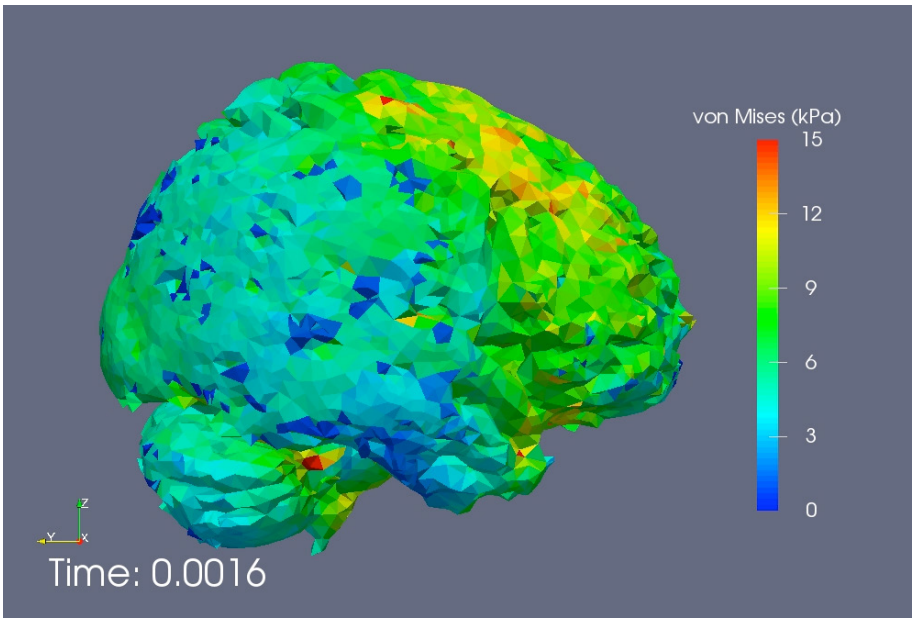


Figure 8 Exterior stresses on the brain caused by the soccer impact. Note that there is a larger region experiencing high stress as compared to the football impact.

In addition to the contour plots of the brain, the peak stress versus time for a representative element inside the areas of maximum stress both the inside and outside of the brains were tracked. These stresses are displayed in Figures 9 and 10

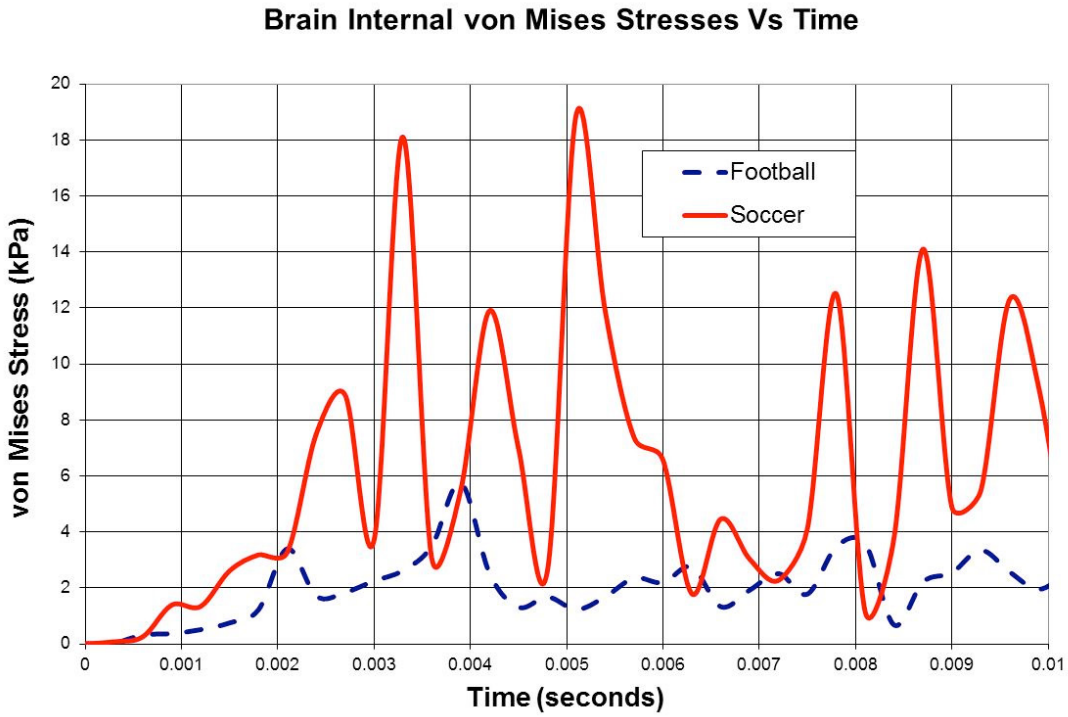


Figure 9 Interior stresses of the brain versus time.

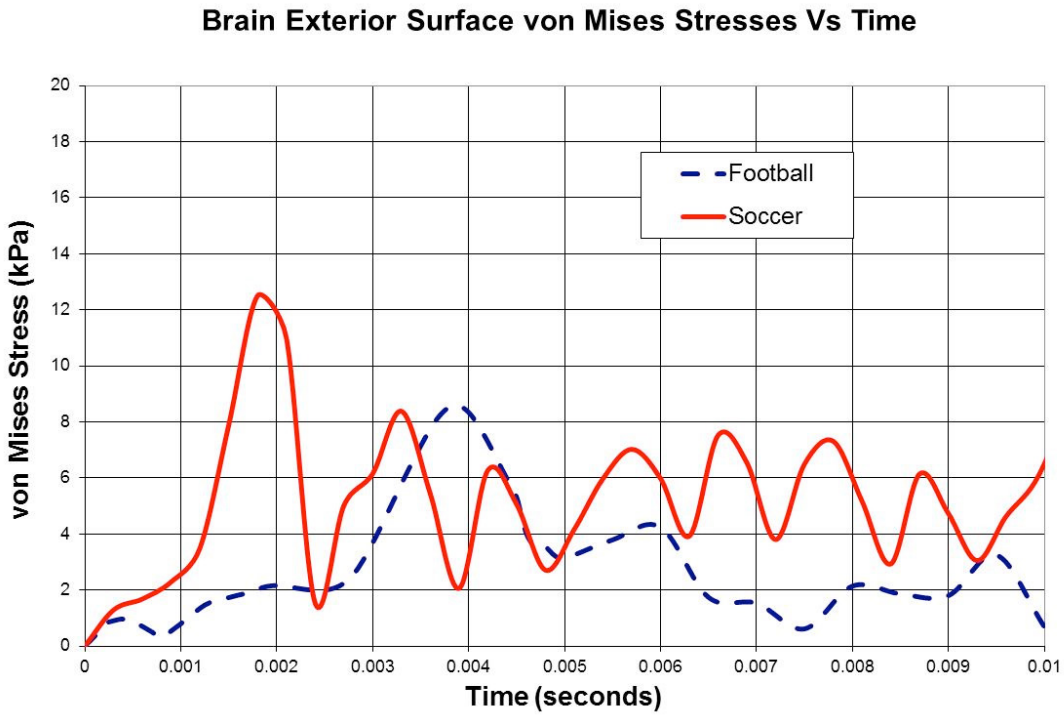


Figure 10 Exterior stresses of the brain versus time.

## DISCUSSION

The results of these experiments demonstrate some of the potential problems that can be experienced in head impacts; however, further research is required in order to substantiate definite conclusions.

It is important to note that these stresses within the brain are occurring before the head has moved half a centimeter. This is contrary to common popular belief as current research has been finding that the damage to the brain occurs well before the brain has moved within the skull and any secondary impacts have occurred. (Taylor *et. al.*, 2014)

Finite element analysis shows that the brain experiences greater stresses during the soccer head impact. The von Mises stresses are significantly greater for the soccer impact than the football impact for both internal and external brain matter. This higher stress may be due to the higher peak acceleration and the shorter duration of the soccer impact. In addition, the exterior of the brain demonstrated a higher amount of stress for a longer period of time for the soccer impact. This indicates that the soccer impact is more severe than the football impact despite the fact that the football impact had roughly ten times the kinetic energy.

One explanation for this difference is the helmet worn during the football impact. High-speed video shows that the helmet collapses and deforms throughout the impact. This deformation indicates that energy from the impact is being absorbed by the helmet and not going directly into the model head. The football helmet therefore significantly reduces the severity of impacts to the head through its ability to deform. This research also indicates that the head

impacts experienced in soccer, even at youth speeds, are worse for the athlete's brain than football. This would then point to the importance in frequency of head impacts and not just the severity of them.

It is possible to conclude from these preliminary finding that the severity of the soccer impact is due to the differences in equipment. Although the football impact features a much harder and more energetic object, the soccer impact still yielded higher stresses on the brain both internally and externally. The only difference between the two is the helmet worn by the dummy head which deformed during the impact. This then justifies further research into equipment for sports outside of football that could help better mitigate the forces experienced during head impacts.

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# Passive Reduction of Involuntary Arm/Hand Tremors

Rusty Ludwigsen[1]

Abstract

In the United States, millions suffer from life-impairing involuntary shaking of limbs and other muscles called tremors. Tremors are caused by a variety of diseases, injuries and conditions, which include traumatic brain injuries, Parkinson's disease, multiple sclerosis, chronic kidney disease, strokes and some medications. Tremors cause difficulty with fine motor control resulting in illegible handwriting. The objective of this project is to help people with tremors by constructing and testing a stabilizing brace that will damp the tremors and allow for controlled hand movements. The brace, worn between the wrist and elbow, is lined with energy absorbing viscoelastic foam, and constructed with a lightweight ridged plastic outer shell that rests on a writing surface. To test the brace's effectiveness, human volunteers performed tasks that required fine motor control with and without the brace. The tasks revealed how much the tremor in their hand was reduced both numerically, by analyzing the data from an instrumented pen, and visually, through inspection of the test results. Results showed that the brace is effective for the majority of the group, which suggests further research is warranted into the concept of hand stabilizing equipment.

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In the United States alone, millions of people suffer from life-impairing involuntary muscular movements that result in shaking of extremities, called tremors (Pressman 2014). Disorders or conditions that can produce tremors include Parkinson's disease, multiple sclerosis, stroke, traumatic brain injury, medications, alcohol abuse, mercury poisoning, overactive thyroid, liver failure or neurodegenerative diseases (Tremor Fact Sheet 2014). One of the many problems tremors cause is difficulty with fine motor control. During a scientific meeting, the author witnessed two gentlemen with obvious tremors in their hands and arms. The act of writing required a great amount of effort and the notes were illegible. Last year research was done to test if a motion damping brace could reduce the tremor on a shaking, wooden, surrogate arm. Results found that the brace reduced the tremor by about 90%. This year's project is an extension of that research. A newly designed brace was printed on a 3D printer and tested on human subjects. It was hypothesized that the use of a, simple and passive brace would significantly reduce the tremors experienced by test subjects, enabling greater fine motor control.

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## Methods

The brace shown in Figure 1 was constructed of a hard 0.5cm thick plastic outer shell, hinged on one side and clasp with Velcro on the other. It was lined with a 1.5cm thick layer of closed cell viscoelastic foam chosen for its high viscoelasticity and firmness. Viscoelastic foam takes time to return to its original shape after being deformed. The base of the brace was a 0.5cm layer of rubber to grip the writing surface and help stabilize the arm. The idea behind the brace was that energy from the tremor would be absorbed by the foam while the brace was stabilized by the table. The brace was worn between the wrist and the elbow as shown in Figure 2.

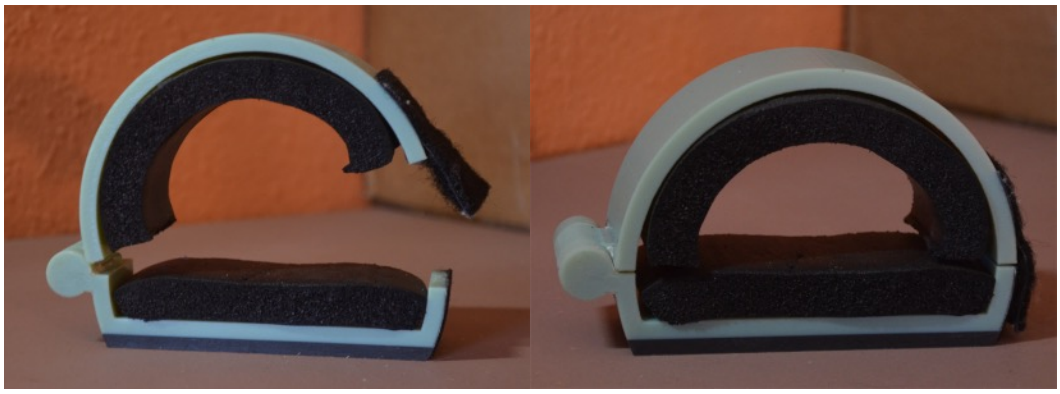

Figure 1 Brace Construction showing interior foam and non slip base.

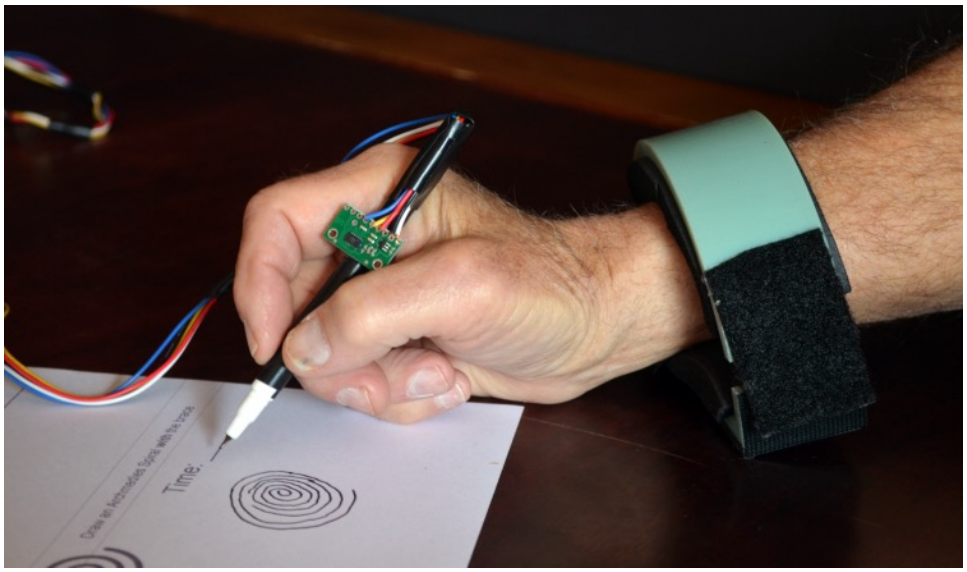


Figure 2 Brace being worn on a volunteer.

To test the brace, human volunteers were recruited from The NM Parkinson Disease Coalition, The International Essential Tremor Foundation, friends and acquaintances. The

diversity of the group allowed testing on a variety of tremors. Eight experienced tremors due to Parkinson's disease, eight experienced tremors due to essential tremors, two experienced tremors due to medication, and three were unknown. A total of 21 subjects participated. All had active tremors except two and their data was not used.

To test the brace's effectiveness, tasks were devised to measure tremor reduction both visually and numerically. After filling out an initial questionnaire, three tasks were administered to each subject, with and without the brace, six tests total. Tasks to visually evaluate the tremor reduction included, drawing a spiral (Haubenberger et al. 2011, Diagnostic Tests of Motor Function 2014) and two sets of mazes of varying difficulties. To quantify data on the brace's effectiveness, subjects used a pen instrumented with a 3-axis accelerometer, shown in Figure 3, when drawing the spirals. The accelerometer measured the shaking of the hand while drawing. Appendix C shows correlation between acceleration data and visual appearance of the spiral. To show reduction of the tremor visually, subjects performed a task that was similar to a maze with only one path to follow. Two sets of mazes were used. In the first set, mazes 1 and 2, shown in Figure 4, were a lower difficulty with lines 2.54 cm apart and a path length of 40.64 cm. The second set, mazes 3 and 4, shown in Figure 5, were more difficult with lines 1.27 cm apart and a path length of 60.96 cm. Subjects did not have the stamina to complete all four maze tests with and without the brace, so only one maze from each set was chosen. To visually see differences in their fine motor control the spirals, drawn with the instrumented pen, were examined.

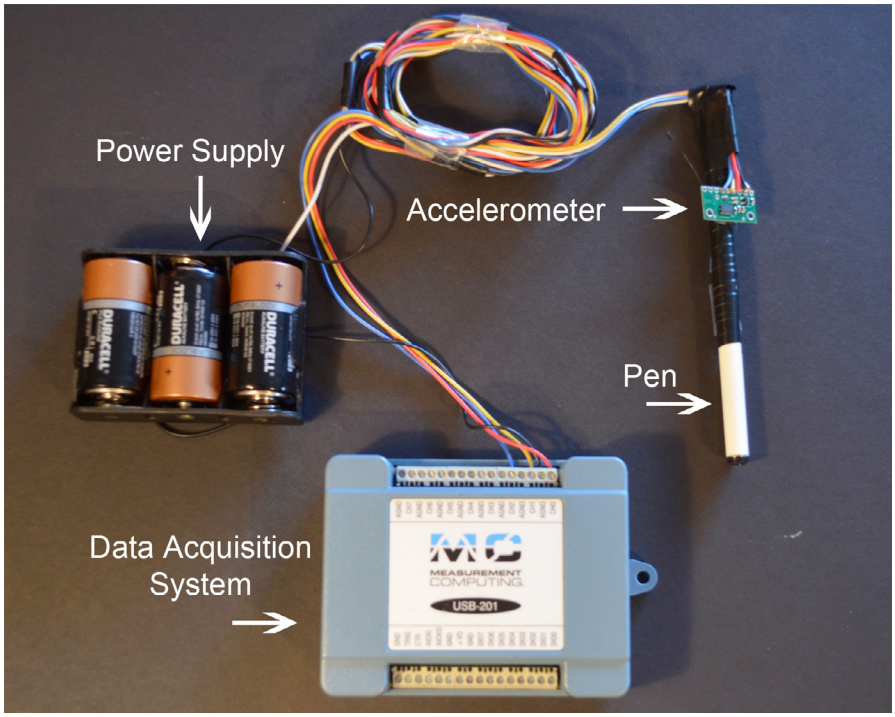


Figure 3 Instrumented Pen and data acquisition system.

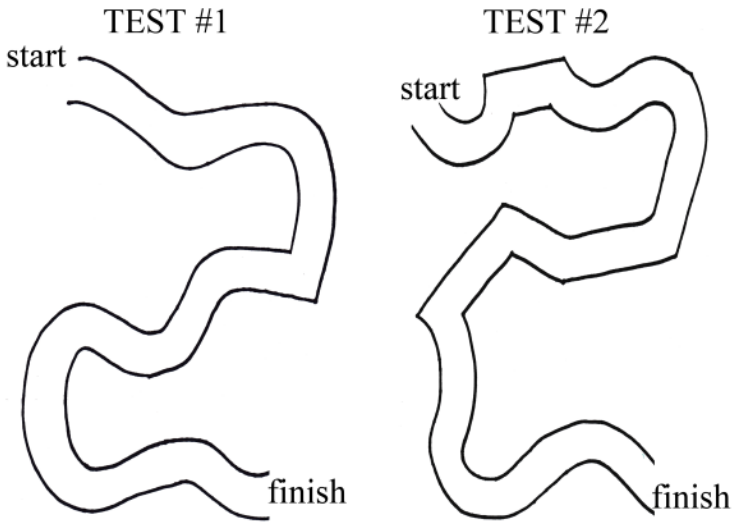


Figure 4 Test mazes #1 and #2.

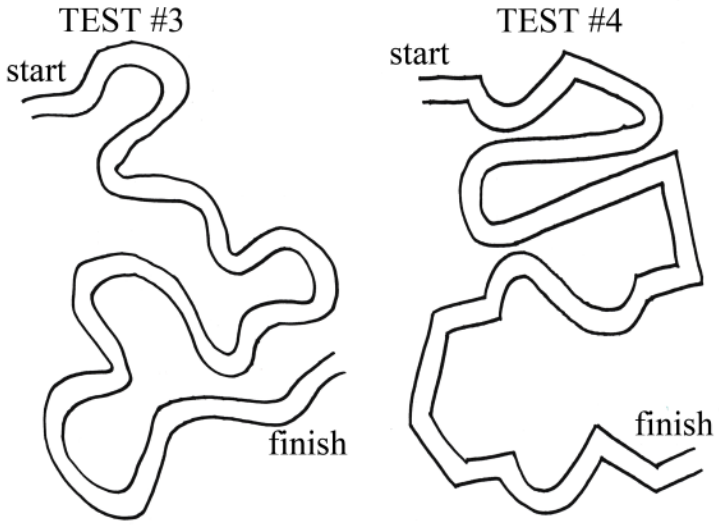


Figure 5 Test mazes #3 and #4.

## Results

After concluding testing, results were separated into four categories based on visual interpretation of the individual tests. The first category included test results that showed significant improvements. This meant a large reduction of tremors for both the drawings of spirals and mazes with the brace. The second category included test results that showed a

moderate improvement when the brace was worn, but the tremors were still visually present in the results. The third category included results that showed minor improvements where there was little or no difference when wearing the brace. The fourth category of subjects was not experiencing tremors at the time of testing. See Appendix B for more detailed information. Individuals did not necessarily show an equal level of improvement through all tests. Table 1 shows qualitative test results.

Table 1 Listing of test visual evaluations.

| Subject Number | Spiral Test | Mazes 1 and 2 | Mazes 3 and 4 | Cause of Tremor | Persistence of Tremor |
|---|---|---|---|---|---|
| #1 | Moderate | Moderate | Minor | Medication | Constant |
| #2 | NAT* | NAT* | NAT* | Parkinson | Sporadic |
| #3 | NAT* | NAT* | NAT* | Unknown | Sporadic |
| #4 | Moderate | Minor | Moderate | Essential tremors | Constant |
| #5 | Minor | Minor | Minor | Unknown | Constant |
| #6 | Moderate | Moderate | Moderate | Essential tremors | Constant |
| #7 | Minor | Minor | Minor | Essential tremors | Sporadic |
| #8 | Significant | Moderate | Minor | Essential tremors | Sporadic |
| #9 | Significant | Minor | Minor | Essential tremors | Sporadic |
| #10 | Moderate | Moderate | Significant | Parkinson | Sporadic |
| #11 | Significant | Moderate | Moderate | Essential tremors | Sporadic |
| #12 | Minor | Minor | Minor | Parkinson | Sporadic |
| #13 | Significant | Significant | Significant | Parkinson | Sporadic |
| #14 | Moderate | Significant | Moderate | Essential tremors | Sporadic |
| #15 | Significant | Minor | Minor | Parkinson | Sporadic |
| #16 | Minor | Moderate | Minor | Essential tremors | Sporadic |
| #17 | Moderate | Minor | Minor | Parkinson | Constant |
| #18 | Minor | Minor | Moderate | Unknown | Sporadic |
| #19 | Significant | Moderate | Minor | Parkinson | Constant |
| #20 | Significant | Significant | Significant | Parkinson | Sporadic |
| #21 | Moderate | Moderate | Moderate | Medication | Sporadic |

*NAT = No Active Tremors

One of the most dramatic differences was seen in Subject #8, who showed significant improvement in the spiral test but moderate and minimal improvement in the maze tests. Figure 6 shows the results for subject #8. Without the brace the tremors were very apparent, producing an irregular, wavy and very large spiral. When the brace was used, the spiral became more regular, smoother, and compact showing more control of the hand and thus more fine motor control. The maze tests displayed much smaller improvements than the spiral test. There was only moderate improvement for maze #1 and minor improvement for maze #4. The instrumented pen data, shown in Figure 7, shows that the tremor was damped but still very present which does not match with the visual appearance of the spiral.

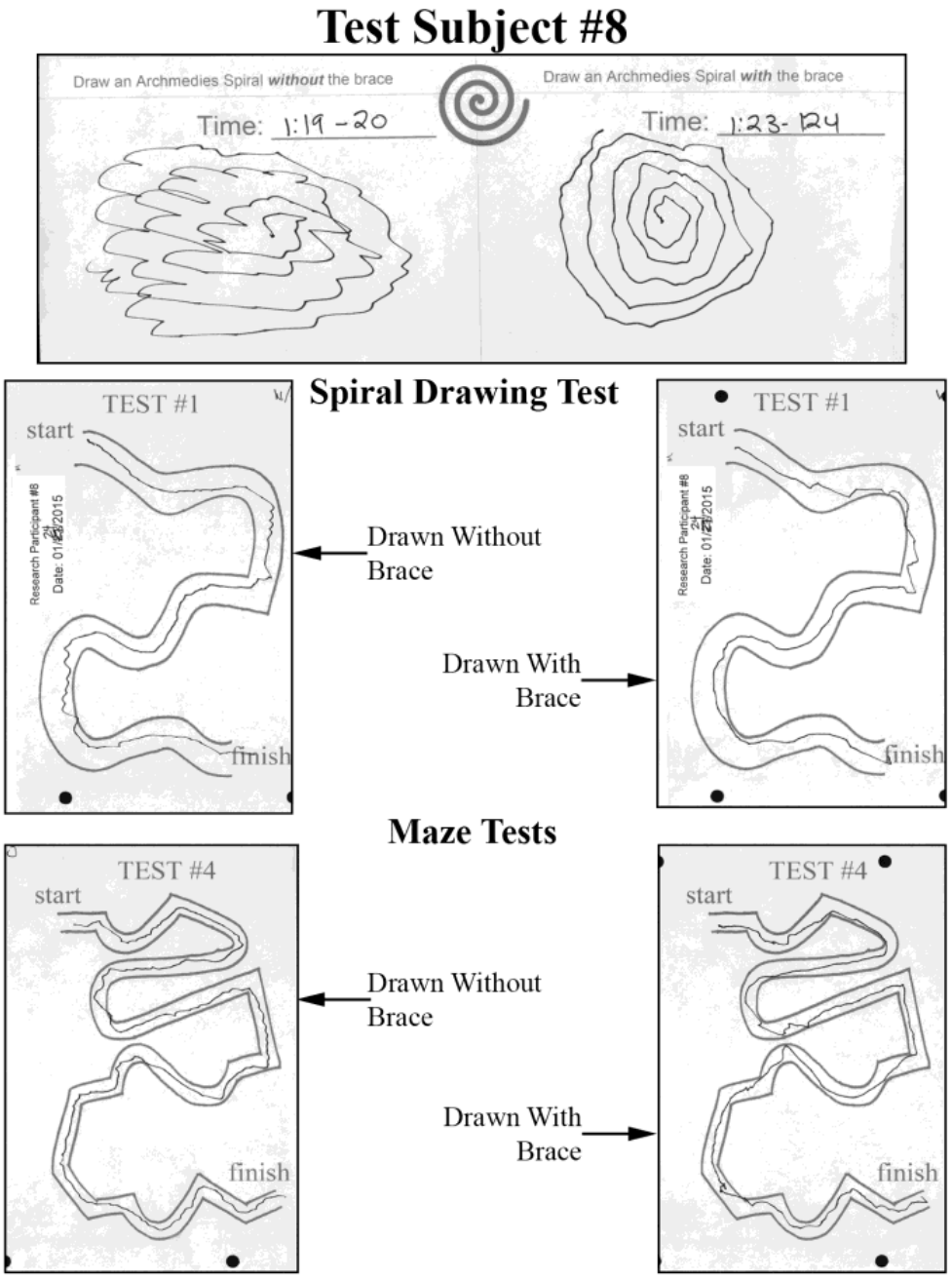


Figure 6 Subject #8 showed significant improvement in the spiral, and moderate improvement in maze test #1 and minor improvement in maze test #4.

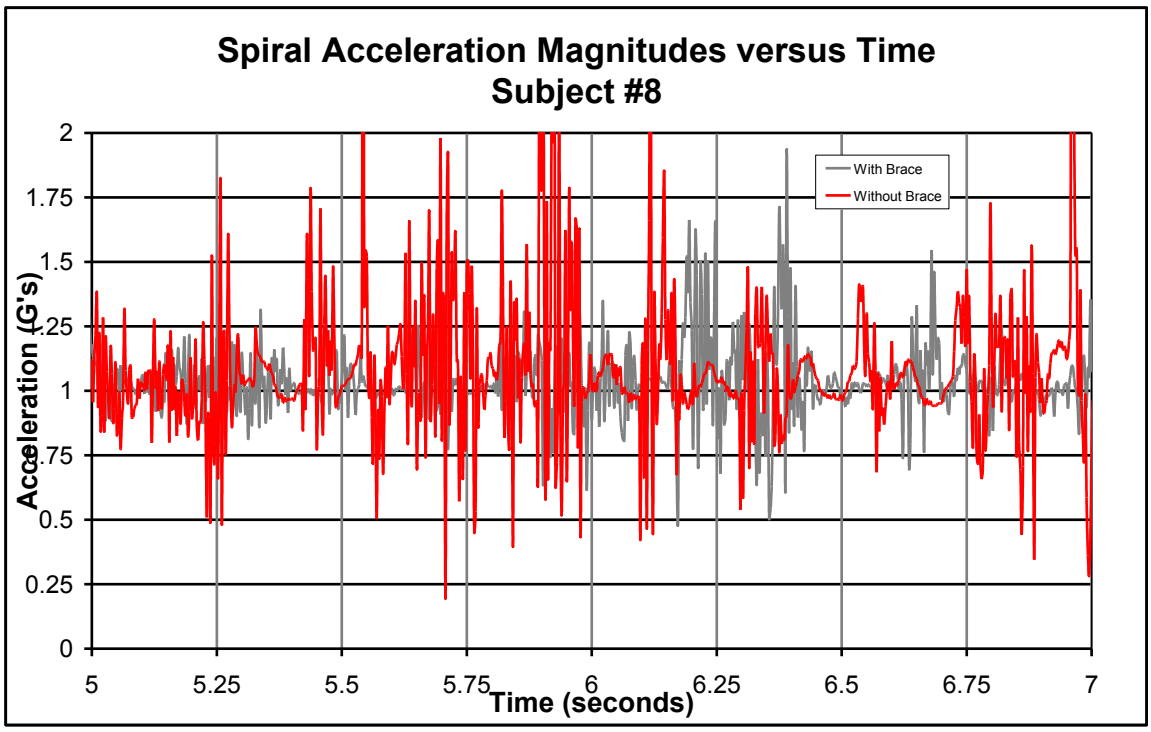


Figure 7 This plot shows the reduced accelerations during the spiral drawing test for Subject #8.

When subject #20 was not wearing the brace the spiral test was very lopsided and erratic. The mazes showed similar results. The lines were irregular with dramatic, intermittent movements off the path throughout the maze. When the brace was used the spiral became more regular and stable and the lines became closer together without overlapping. This clearly shows that subject #20 had greater fine motor control with the brace. The mazes showed significant improvement as well. The lines became smoother and centered with near elimination of tremors when wearing the brace, as shown in Figure 8. The instrumented pen data is shown in Figure 9. The data suggests that subject #20 experienced minor damping of the small, high frequency tremors but a significant damping or near elimination of the large, sporadic tremors.

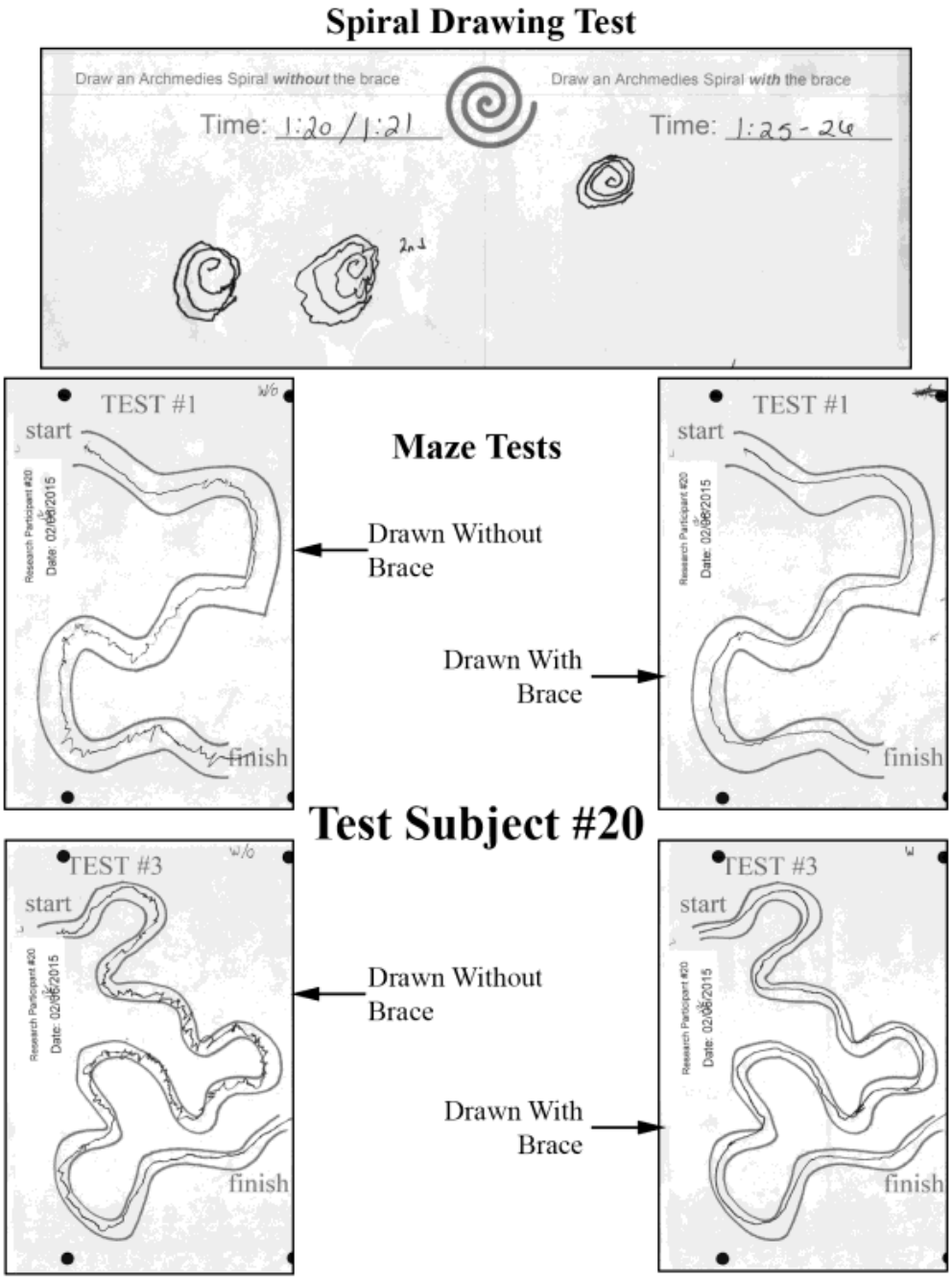


Figure 8 Subject #20 showed significant improvement in both the spiral and maze tests.

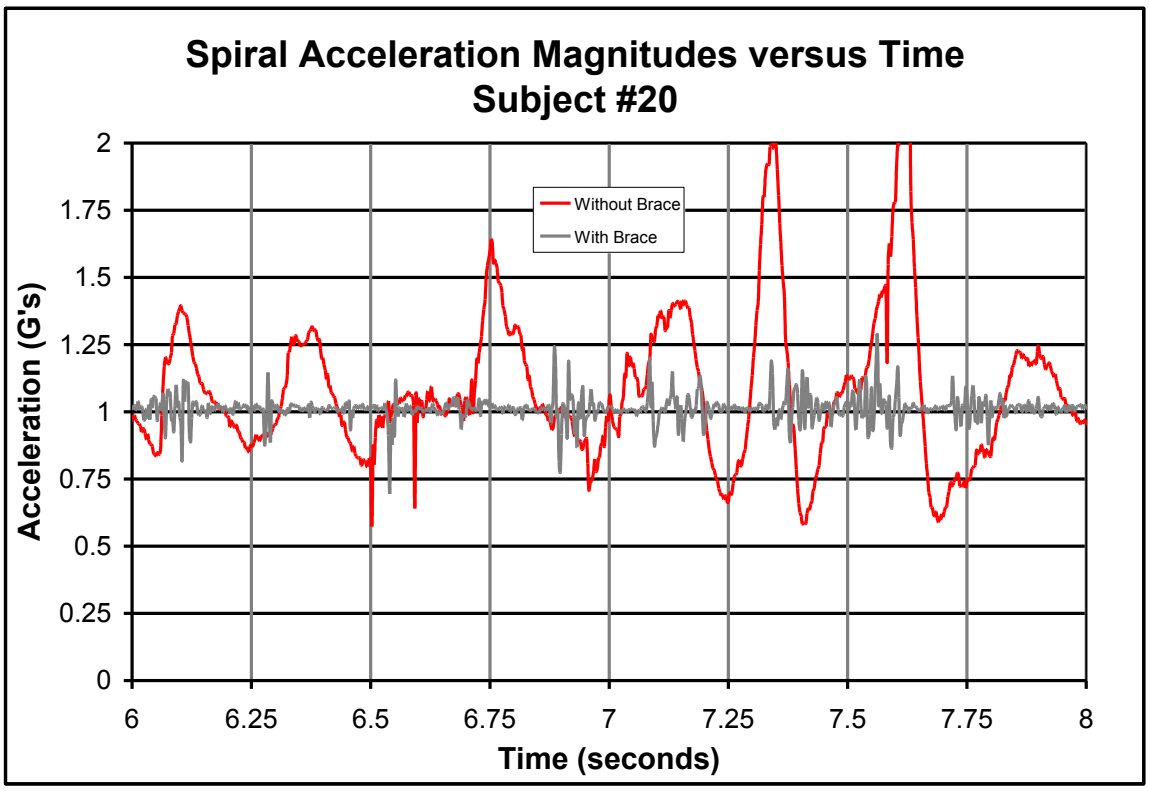


Figure 9 This plot shows the reduced accelerations during the spiral drawing test for Subject #20.

Subject #11 is an example of someone who experienced significant improvement in the spiral test and moderate improvement in both maze tests shown in Figure 10. This subject had very large jerking movements instead of the small rapid tremors experienced by subject #8. For the spiral test the brace was able to reduce the jerking of the arm to a point where they could draw a cohesive spiral. The maze tests were similar in the fact that the lines were smoother but the large tremors were still very visible. The data from the instrumented pen, shown in Figure 11, indicates that there were still very large peaks of acceleration when wearing the brace yet the spiral visually showed a significant improvement. There was no correlation between the acceleration data and spiral appearance for this subject.

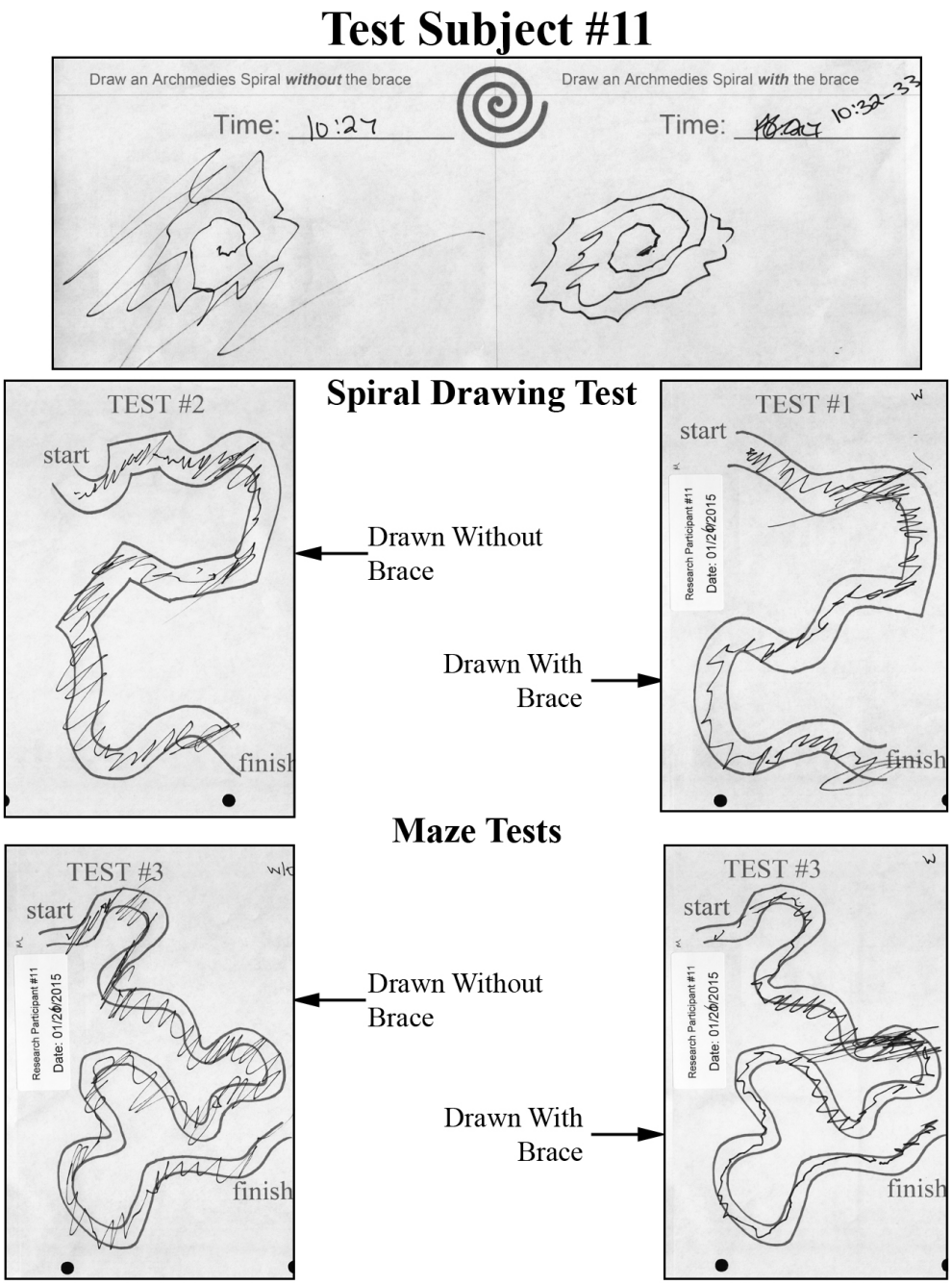


Figure 10 Subject #11 showed significant improvement in the spiral and moderate improvement in the maze tests.

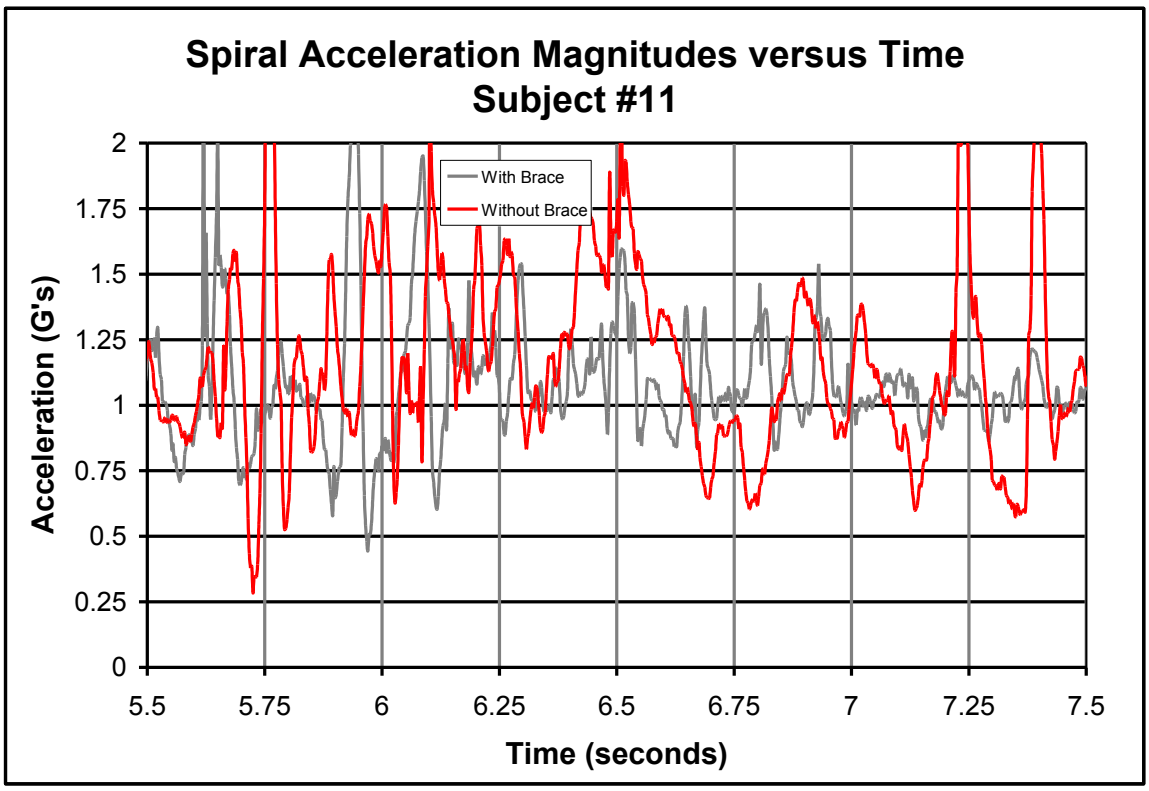


Figure 11 This plot shows the accelerations during the spiral drawing test for Subject #11.

Subject #13 demonstrates significant improvement in all tests. The spiral test, without the brace, is very large, wavy and erratic. However, when the brace was used, the spiral became more compact and smoother. This demonstrates that the subject had more control of their hand and thus more fine motor control. Both maze tests show a significant amount of improvement when the brace was worn. The lines became more regular and smooth. In addition, the lines were closer to the center of the maze showing more control of the hand as shown in Figure 12. The data from the instrumented pen confirms that the tremor was damped with the brace as shown in Figure 13.

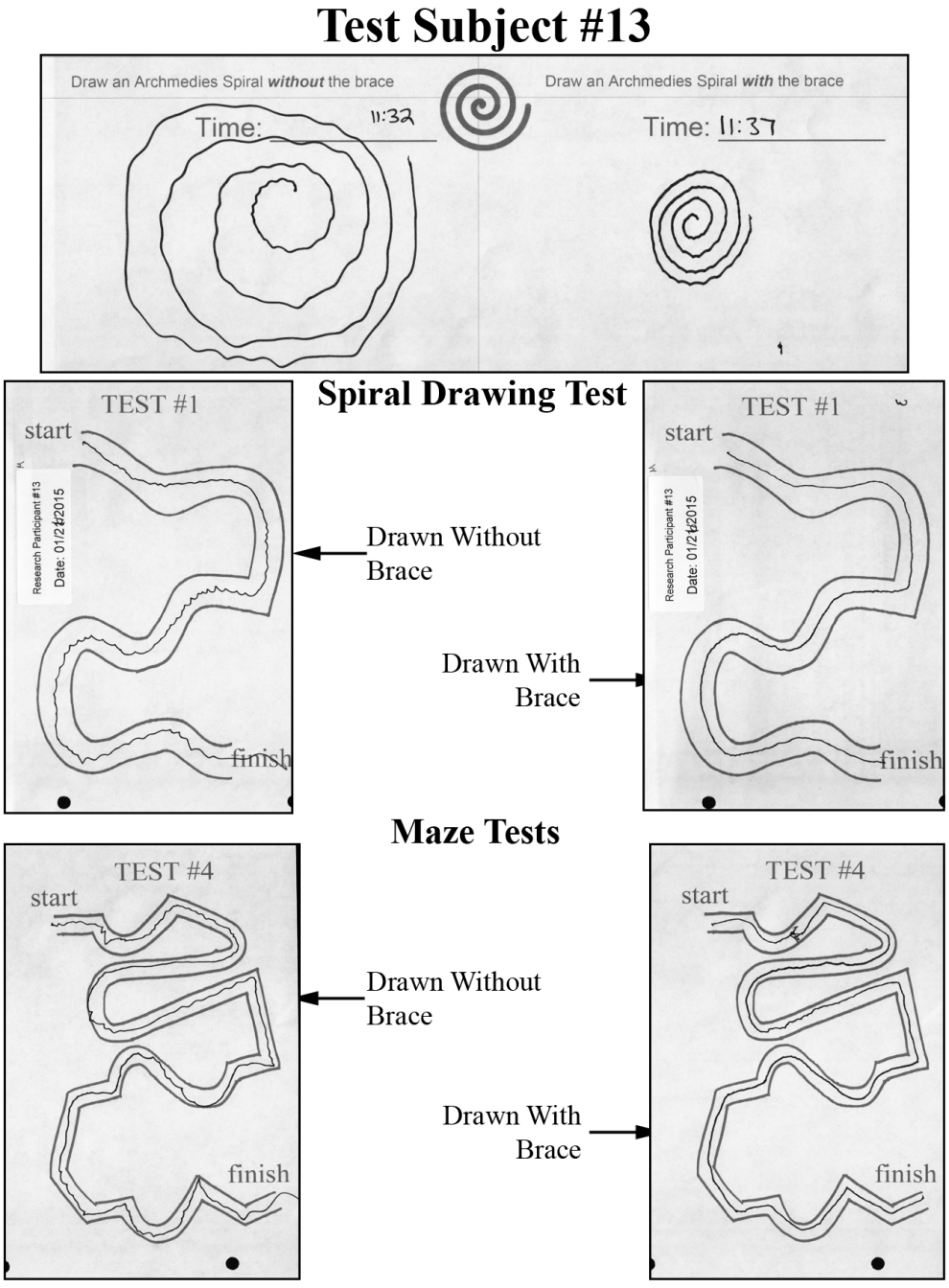


Figure 12 Subject #13 showed significant improvement in both the spiral and maze tests.

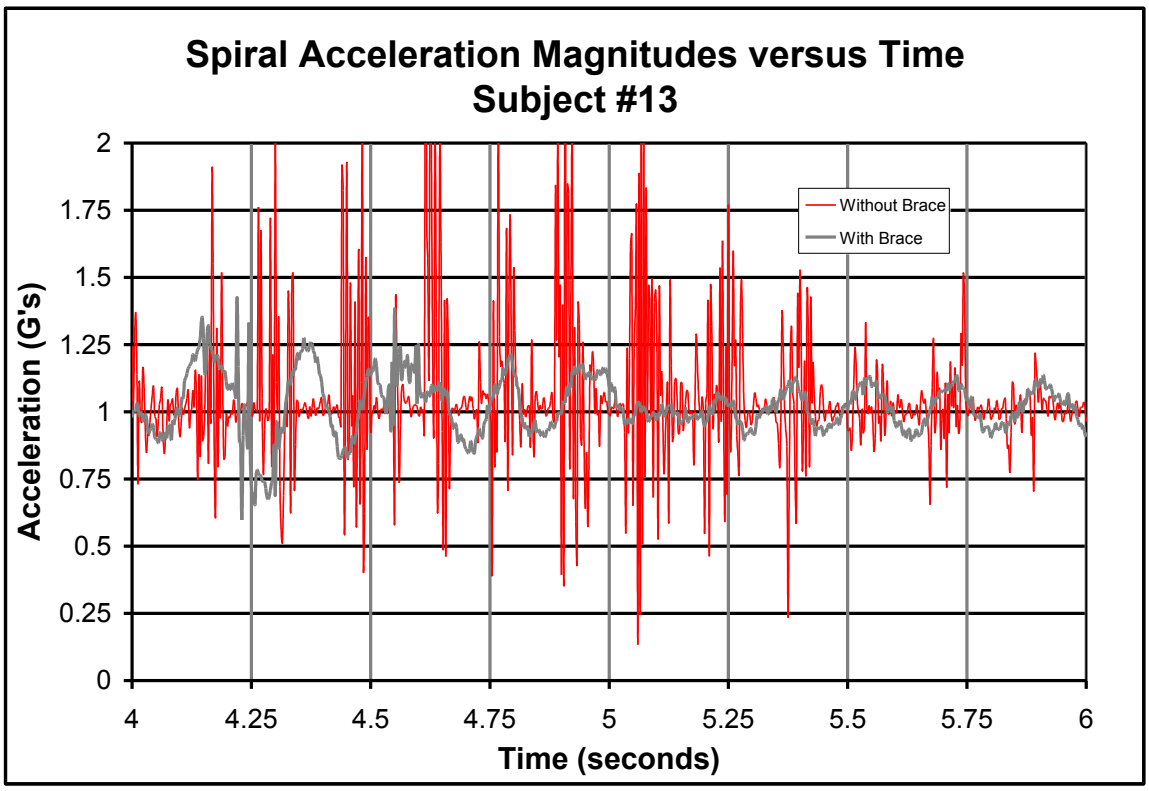


Figure 13 This plot shows the accelerations during the spiral drawing test for Subject #13.

Examining the data of all 19 actively tremoring subjects showed the following. Analysis of the spiral tests revealed that 37% of the subjects experienced significant improvement, 37% experienced moderate improvement and 26% experienced minimal improvement. Analysis of the first set of maze tests showed that 16% experienced significant improvement, 42% experienced moderate improvement and 42% experienced minimal improvement. When the second set of maze tests were analyzed results showed that 16% experienced significant improvement, 32% experienced moderate improvement and 52% experienced minimal to no improvement. Figures 14 to 16 graphically show these results.

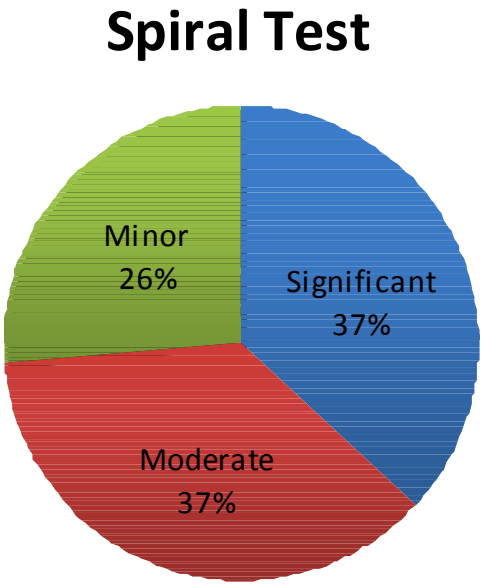


Figure 14 Pie chart showing the percentages of the level of improvement when using the brace for the spiral test.

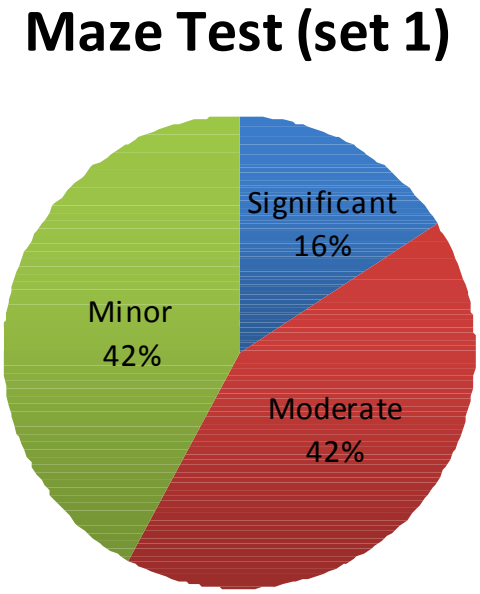


Figure 15 Pie chart showing the percentages of the level of improvement when using the brace for set 1 of the mazes.

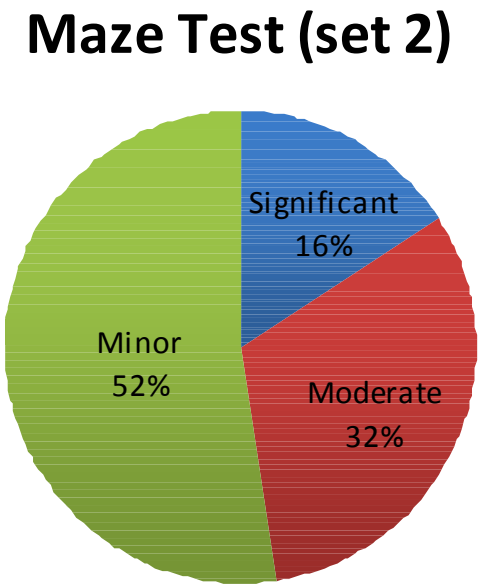


Figure 16 Pie chart showing the percentages of the level of improvement when using the brace for set 2 of the maze tests.

## Discussions

Results show that effectiveness of the brace varied between subjects and tests helping either significantly or moderately for 84% of subjects in at least one test and in 60% of the 57 individual tests. Although it was not a universal solution, the results show the hypothesis is correct because the brace did reduce tremor severity and helped subjects regain some fine motor control.

This research warrants further work to include testing variations of the brace design, larger clinical trials to gather more data on the brace performance, and testing different kinds of foams to use in the brace. A patent has been filed and is currently pending.

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NASA, (2005), Forty-Year-Old Foam Springs Back With New Benefits, Retrieved from http://spinoff.nasa.gov/Spinoff2005/ch_6.html viscoelastic by NASA

## Acknowledgements

I would like to thank Dr. Marybeth Barkocy, my qualified scientist, for her insight into the causes and problems associated with tremors and supporting my research. In addition, I would like to thank Ms. Karen Wingrove of The NM Parkinson Disease Coalition and Mr. Ken Whiton of The International Essential Tremor Foundation for helping to arrange volunteers for testing, and finally, I especially want to thank all of the volunteers who graciously donated their time.

## Appendix A – Selected Test Results

Examples of drawing tests and accelerations from subjects that exhibited varied amounts of help with their tremors from the brace.

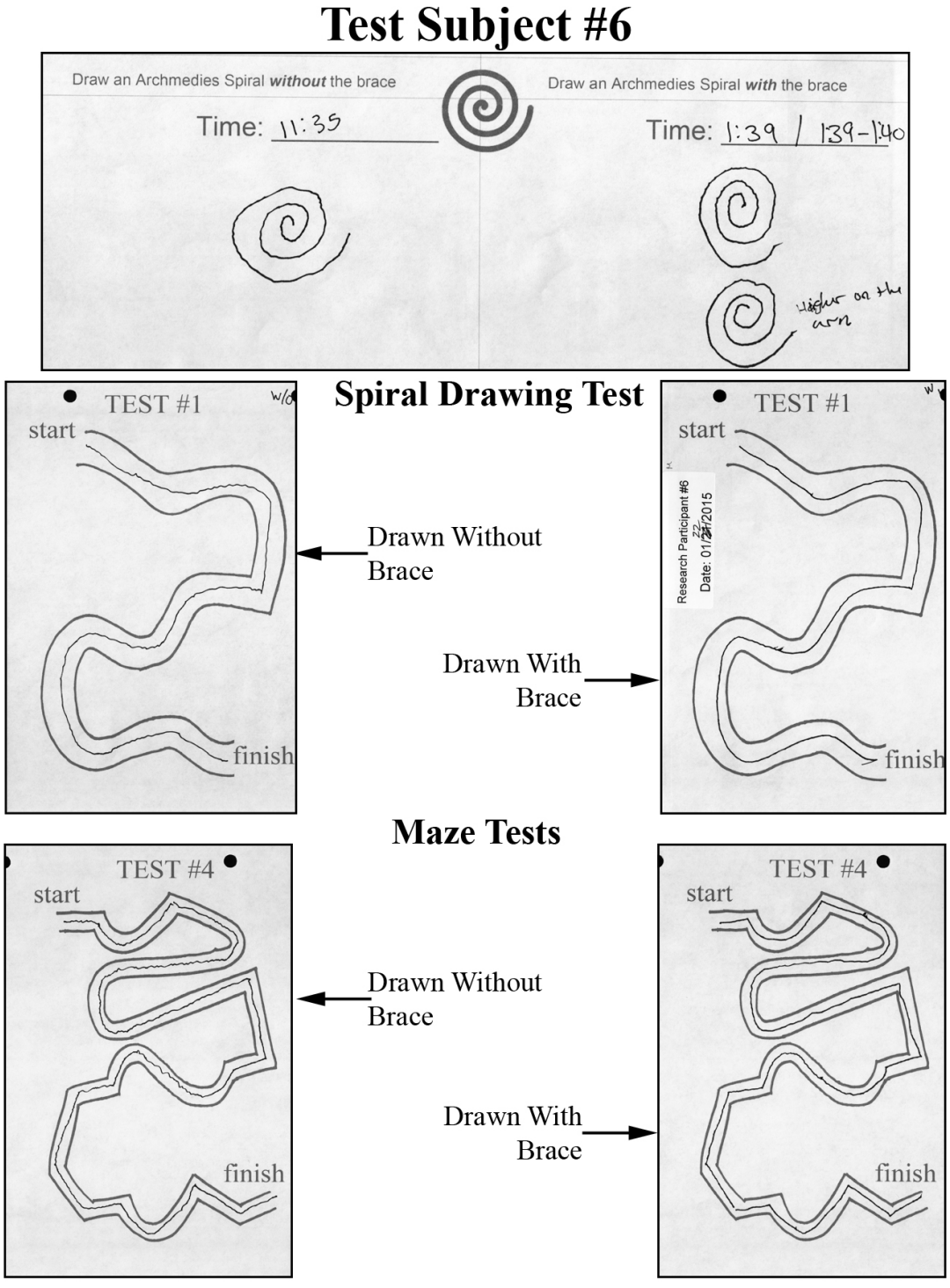



Figure A1 Subject #6 showed moderate improvement in both the spiral and maze tests.

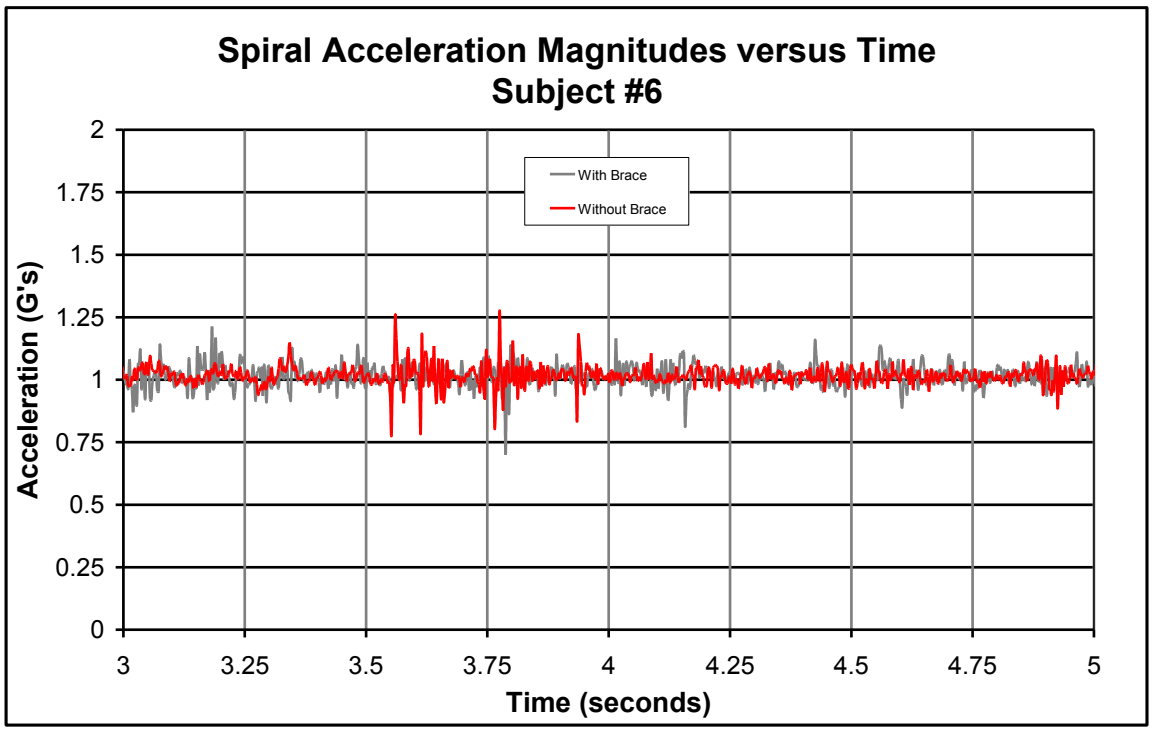



Figure A2 This plot shows the accelerations during the spiral drawing test for Subject #6.

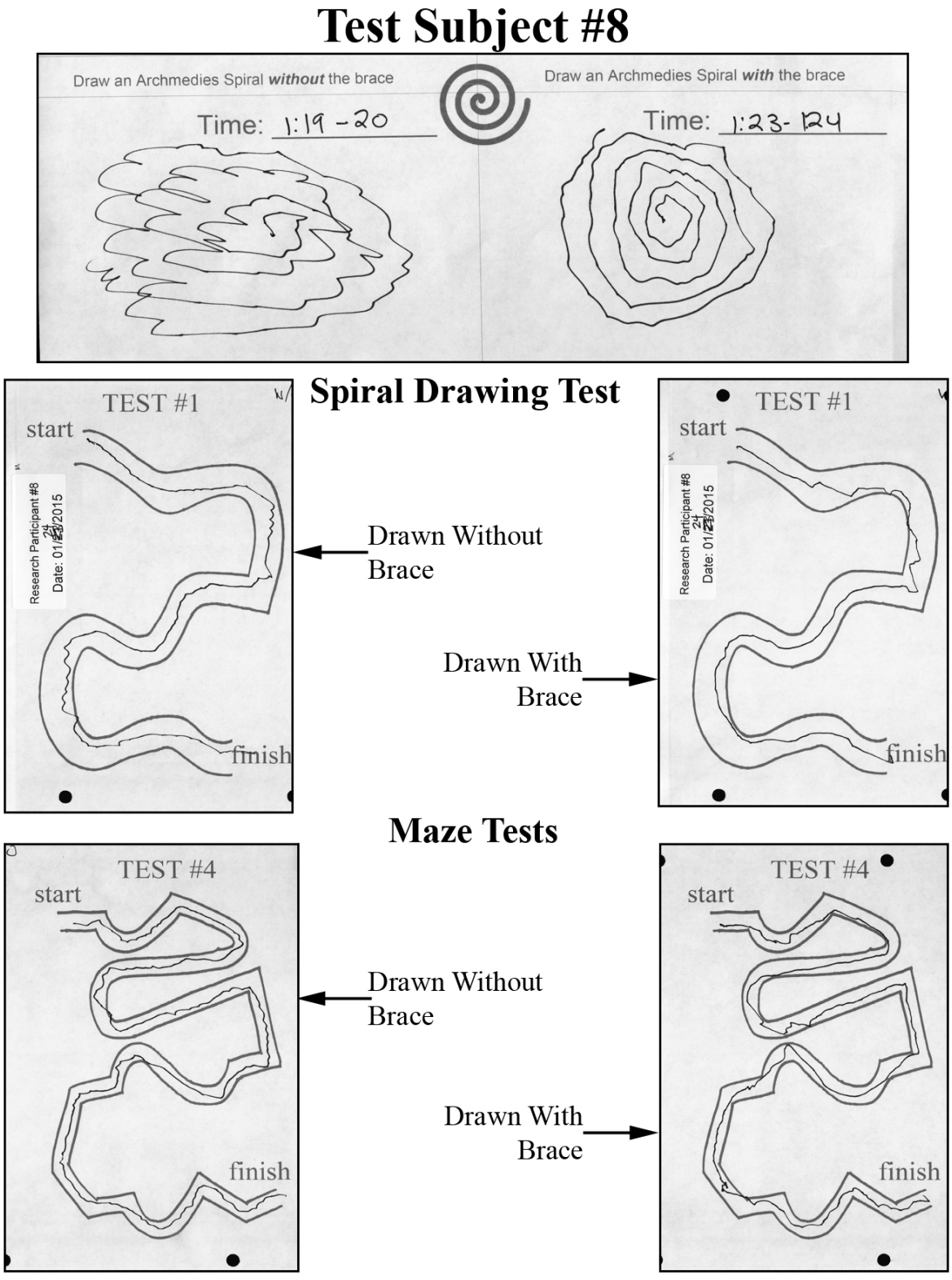



Figure A3 Subject #8 showed significant improvement in the spiral test, moderate in maze #1, and minor in maze #4.

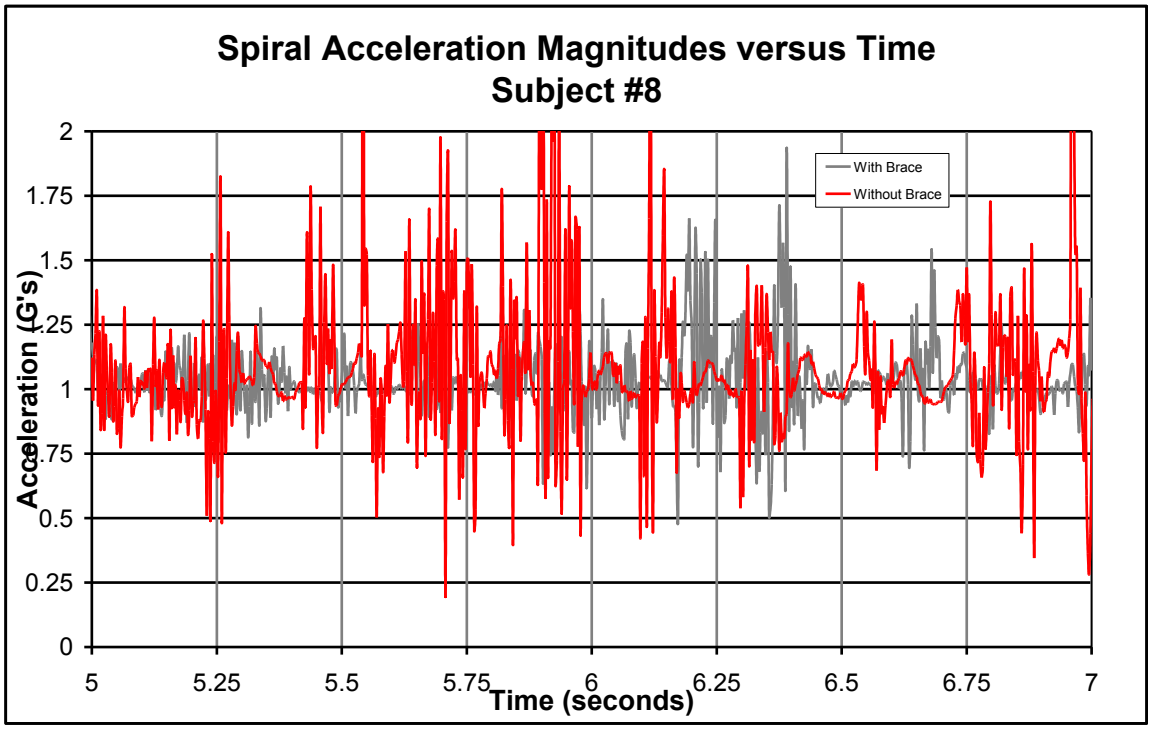



Figure A4 This plot shows the reduced accelerations during the spiral drawing test for Subject #8.

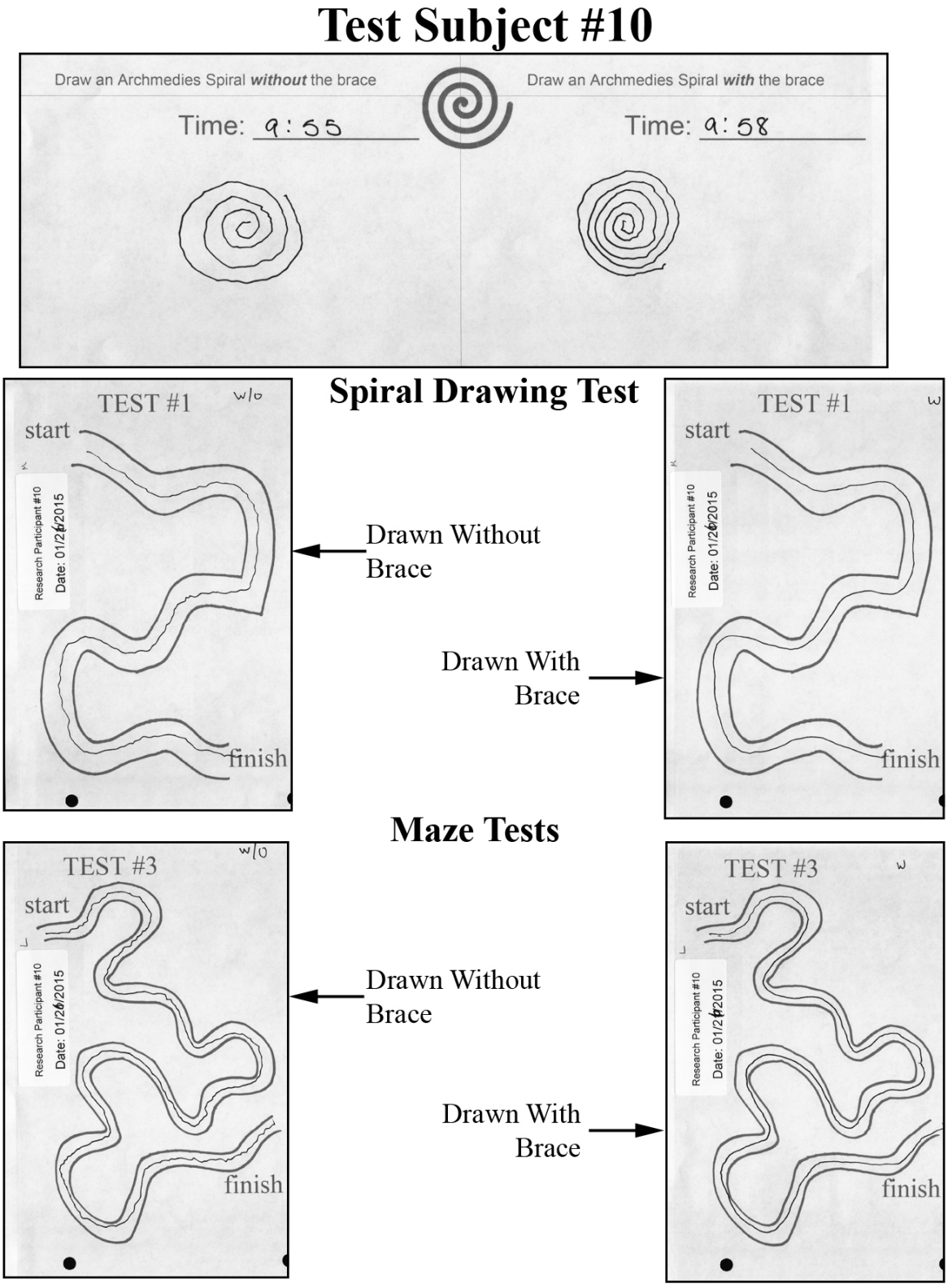



Figure A5 Subject #10 showed moderate improvement in both the spiral and maze #1, and minor improvement in maze #3.

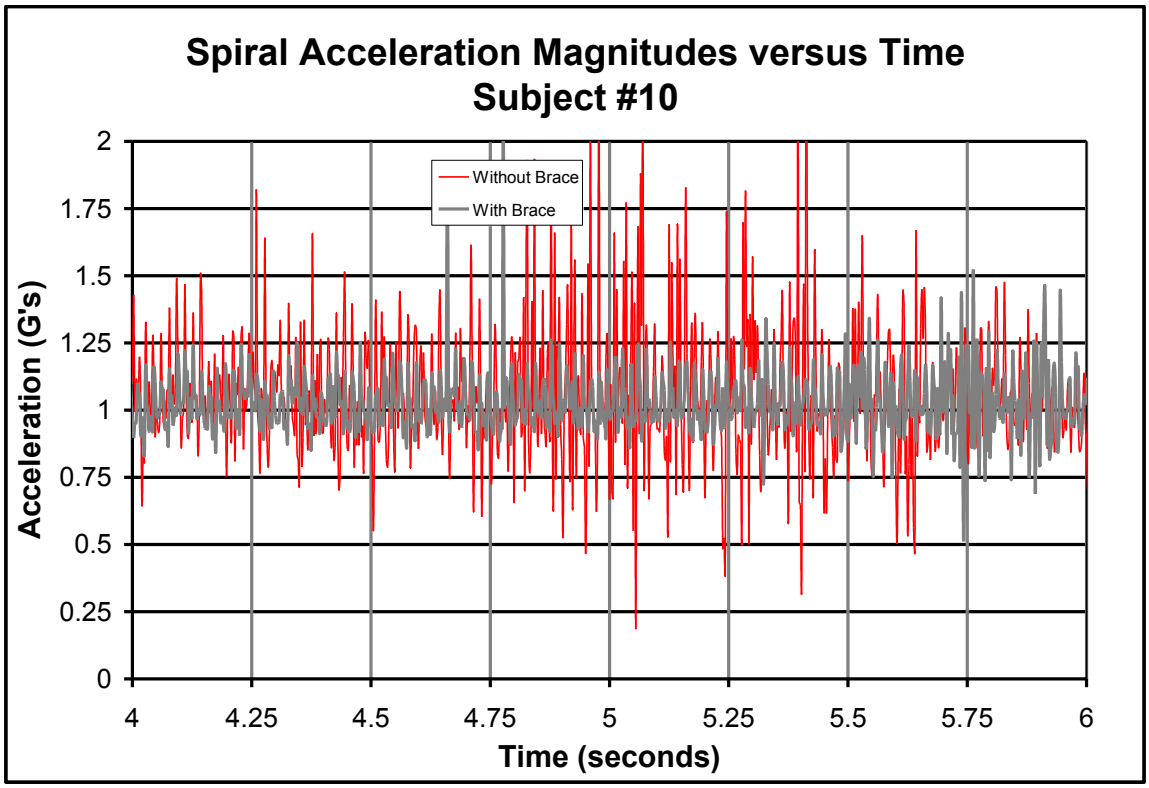



Figure A6 This plot shows the accelerations during the spiral drawing test for Subject #10.

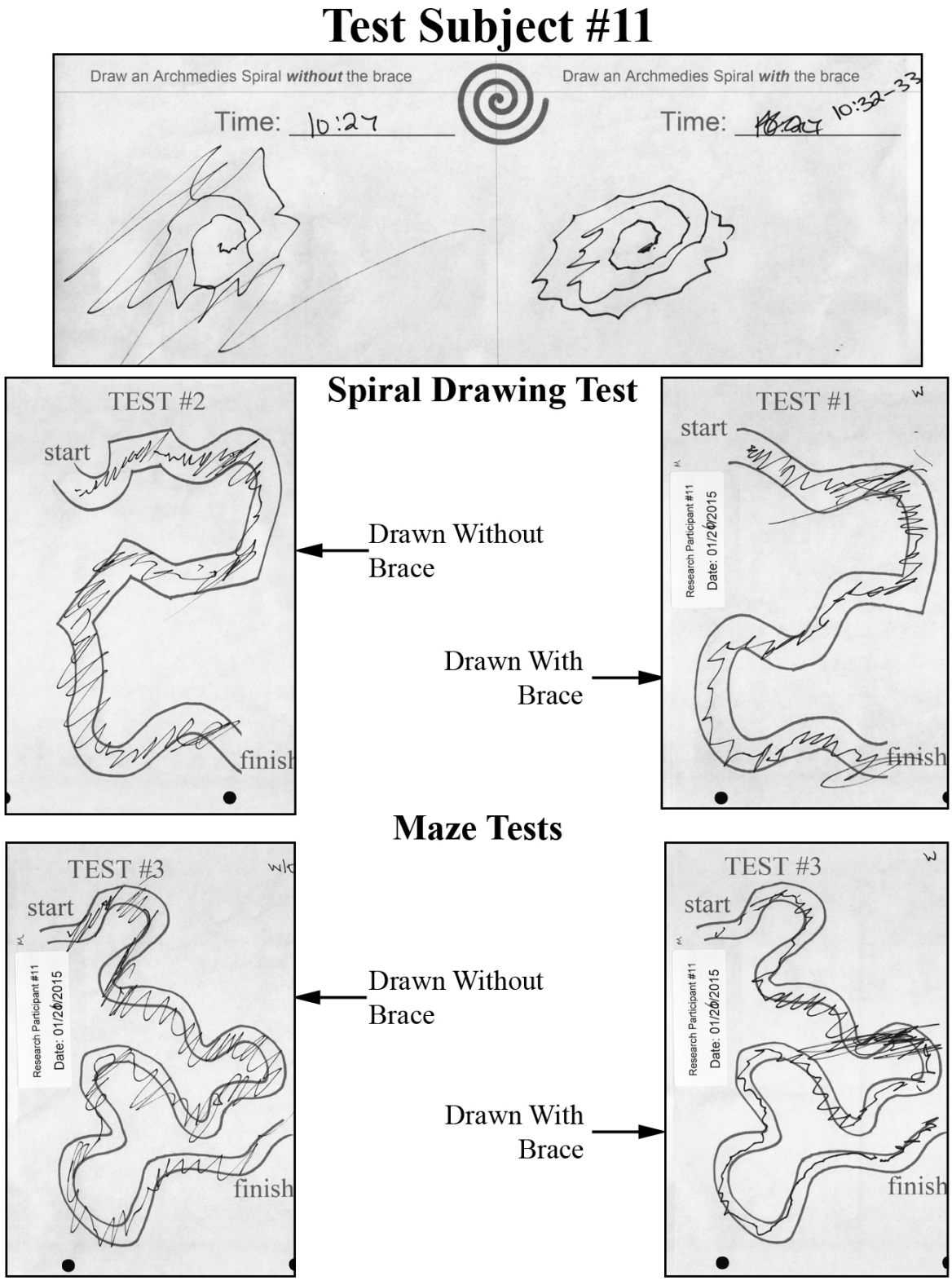



Figure A7 Subject #11 showed significant improvement in the spiral test and moderate in the maze tests.

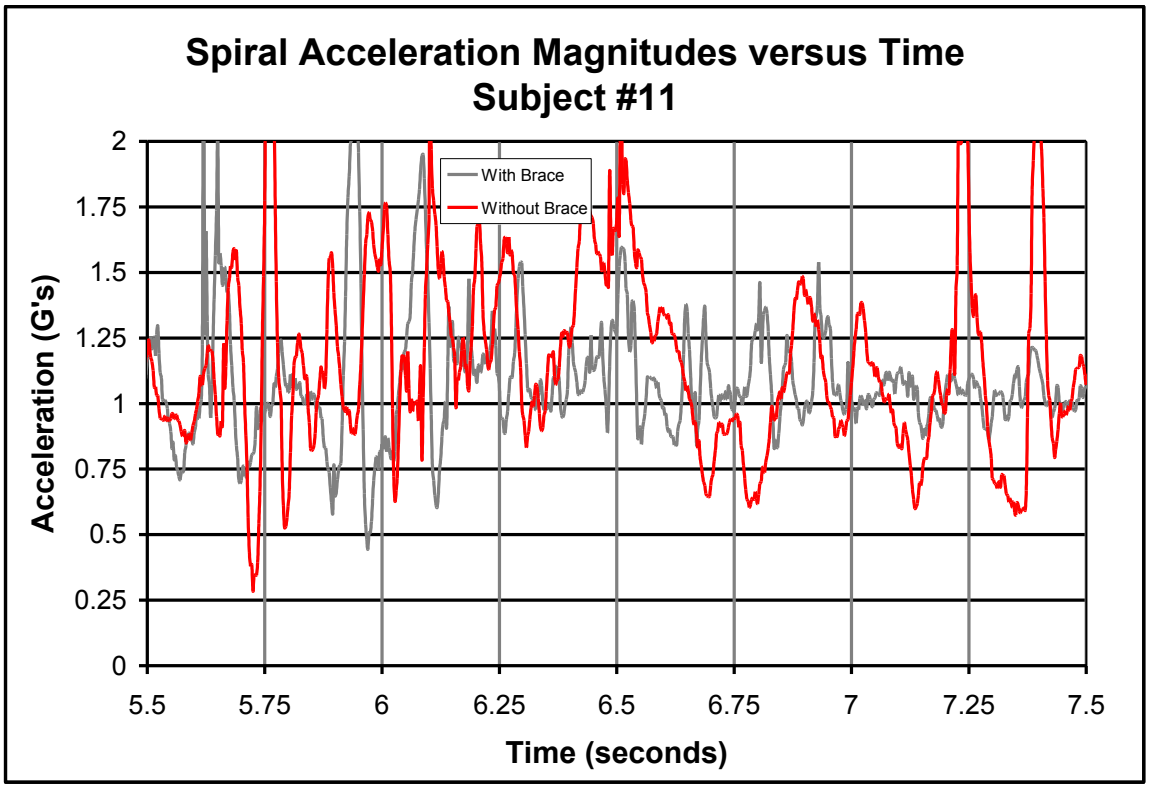



Figure A8 This plot shows the accelerations during the spiral drawing test for Subject #11.

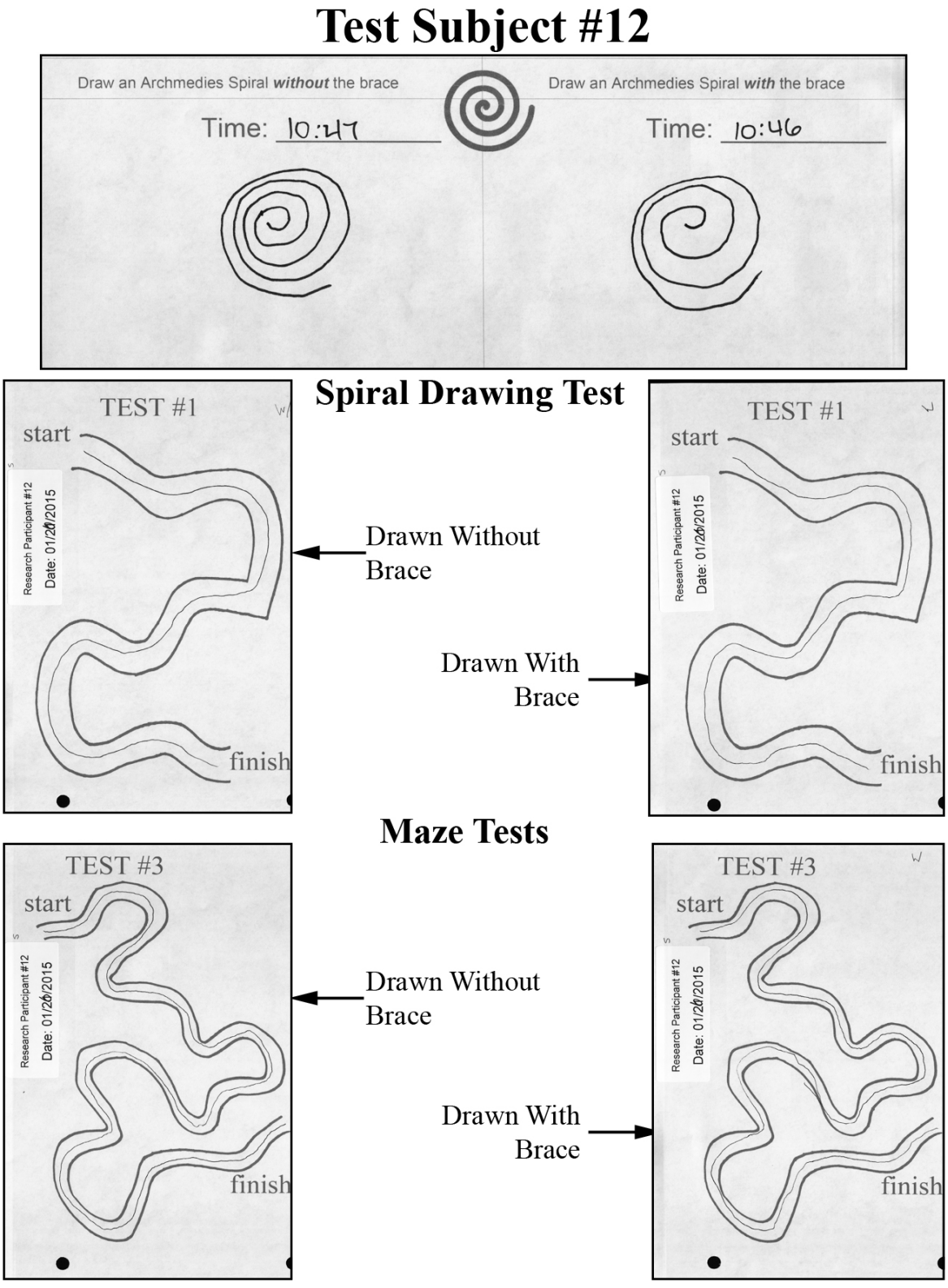



Figure A9 Subject #12 showed minor improvement in both the spiral and maze tests.

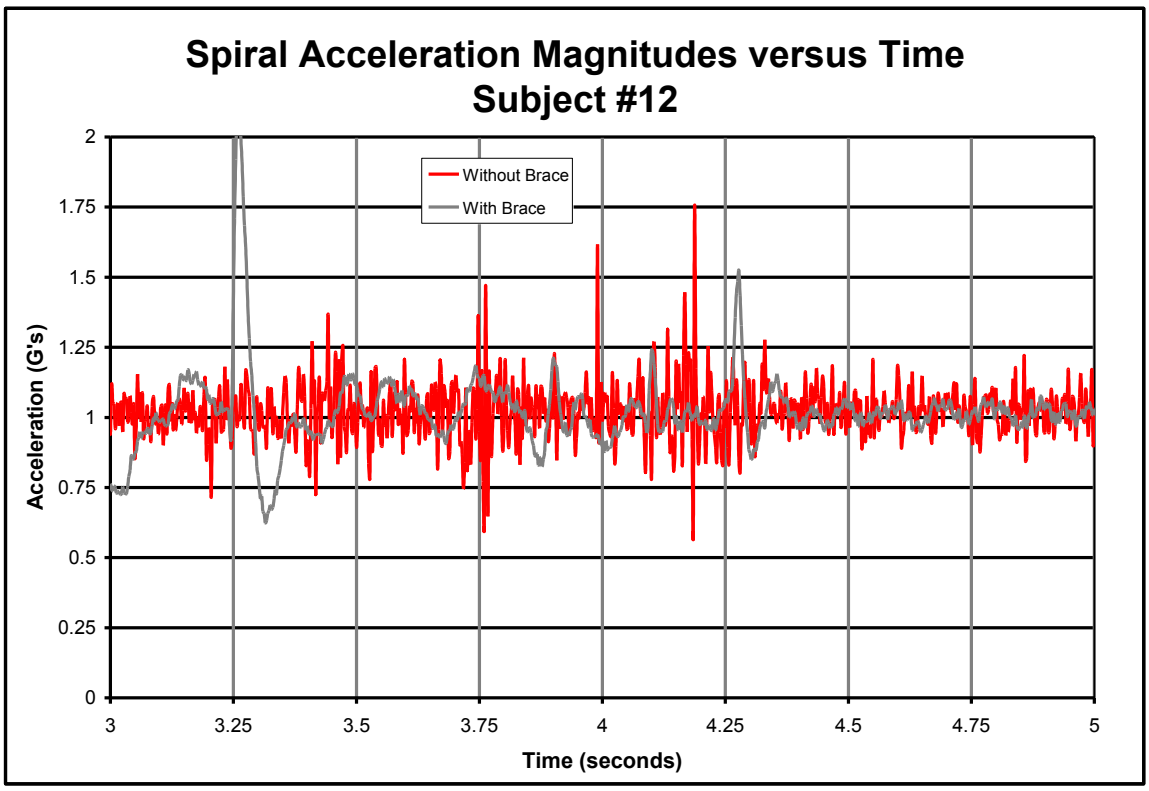



Figure A10 This plot shows the accelerations during the spiral drawing test for Subject #12.

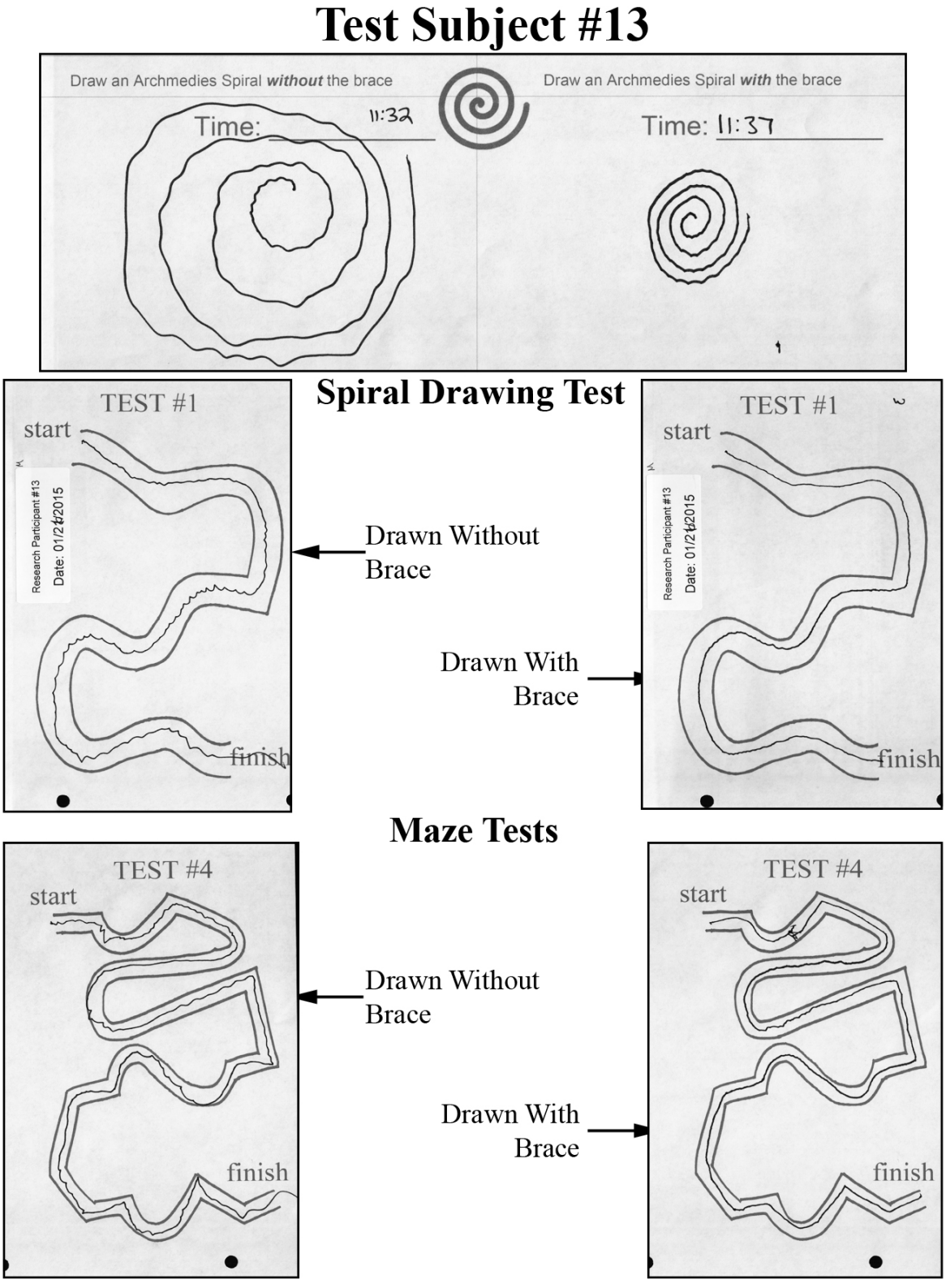



Figure A11 Subject #13 showed significant improvement in both the spiral and maze tests.

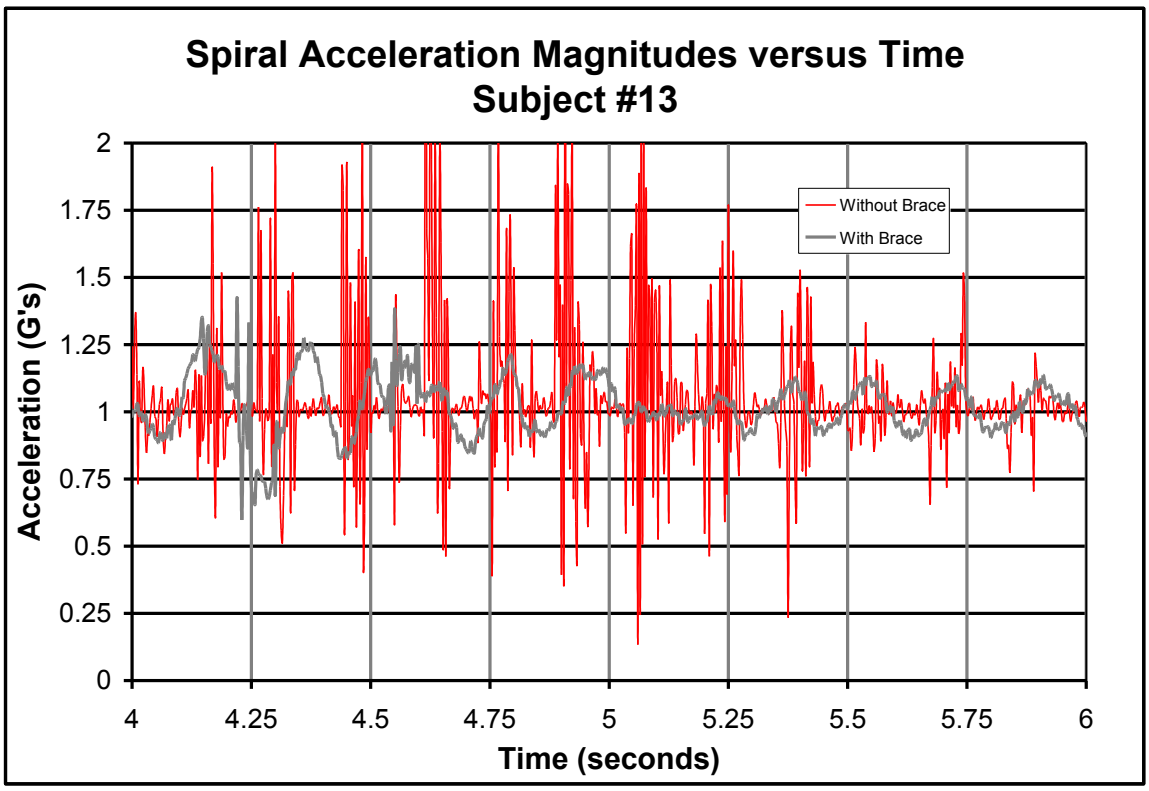



Figure A12 This plot shows the accelerations during the spiral drawing test for Subject #13.

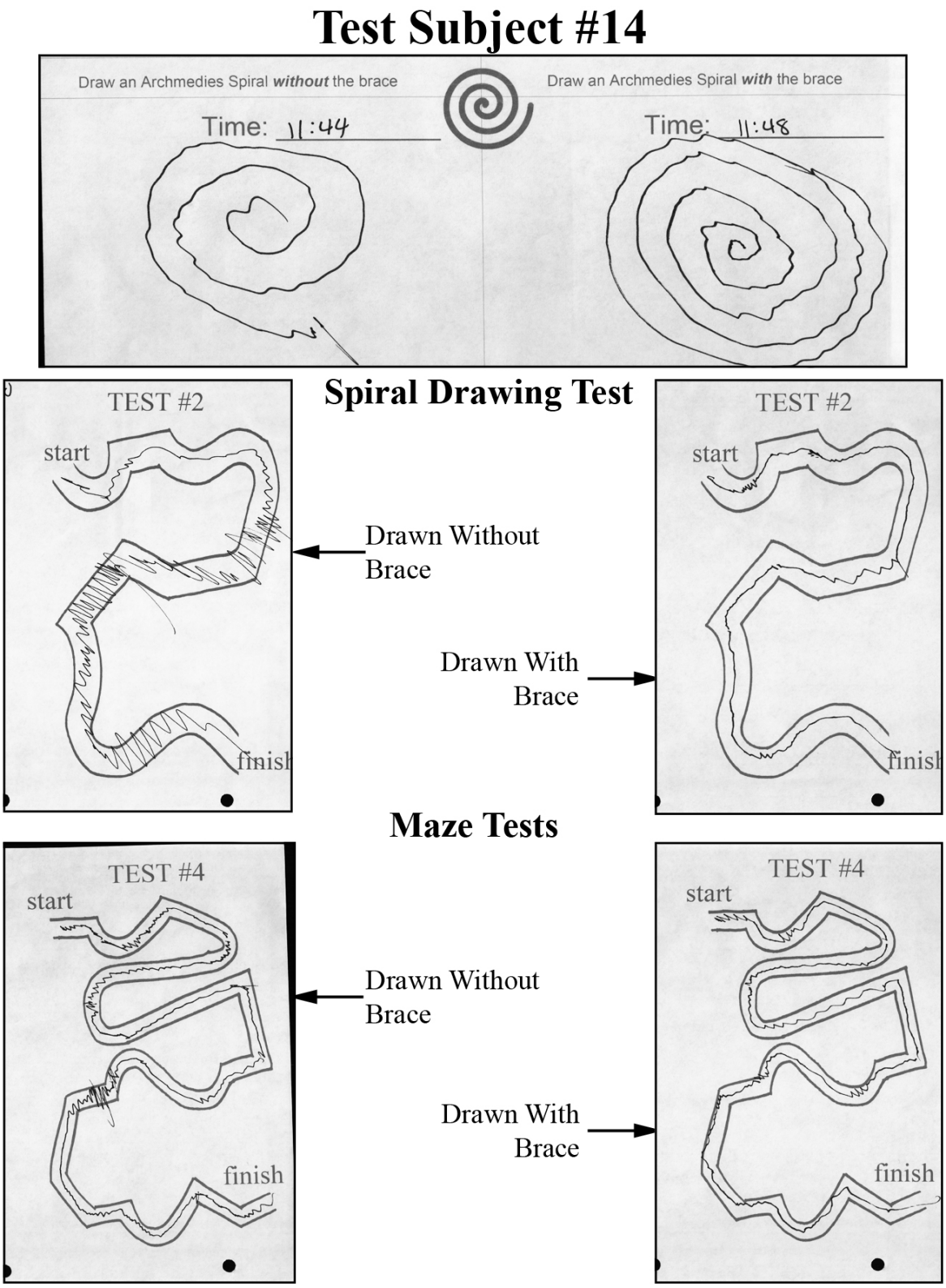



Figure A13 Subject #14 showed moderate improvement in the spiral test, significant improvement in maze #2 and moderate improvement in maze #4.

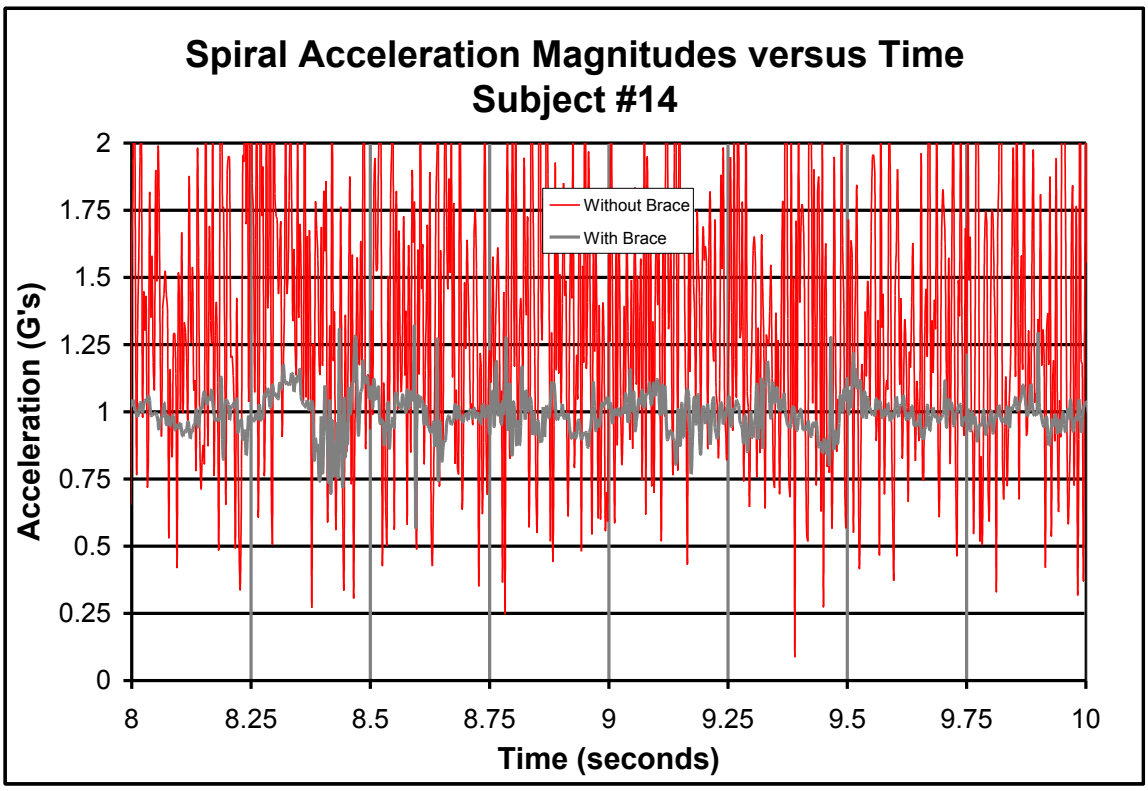



Figure A14 This plot shows the reduced accelerations during the spiral drawing test for Subject #14.

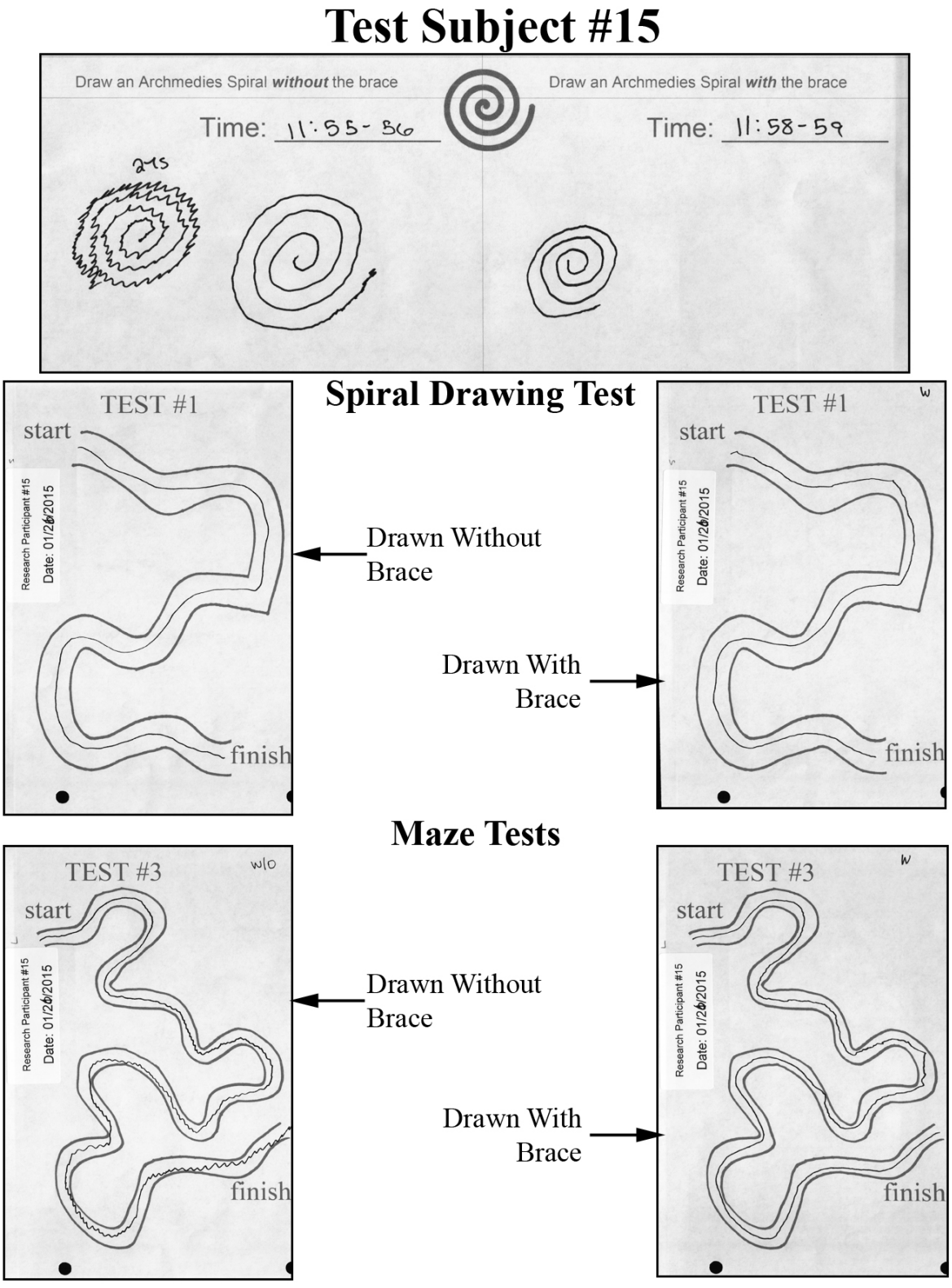



Figure A15 Subject #15 showed significant improvement in the spiral test and minor improvement maze tests.

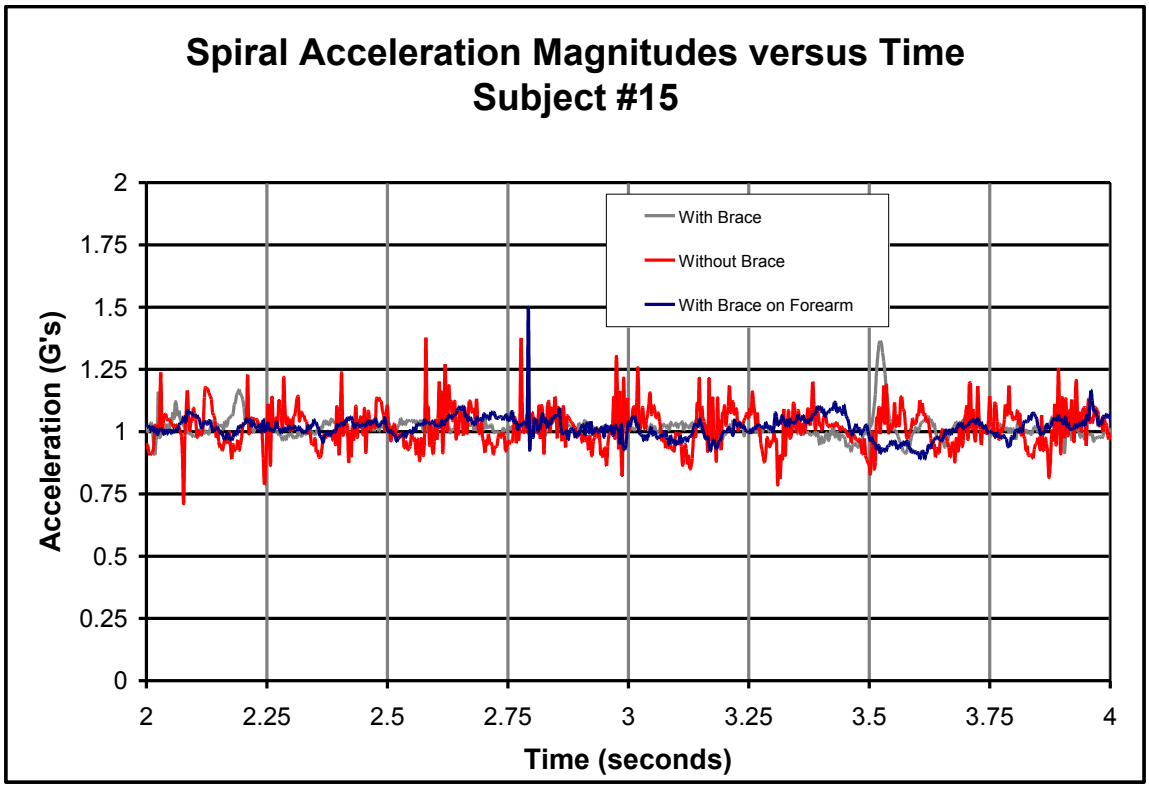



Figure A16 This plot shows the reduced accelerations during the spiral drawing test for Subject #15.

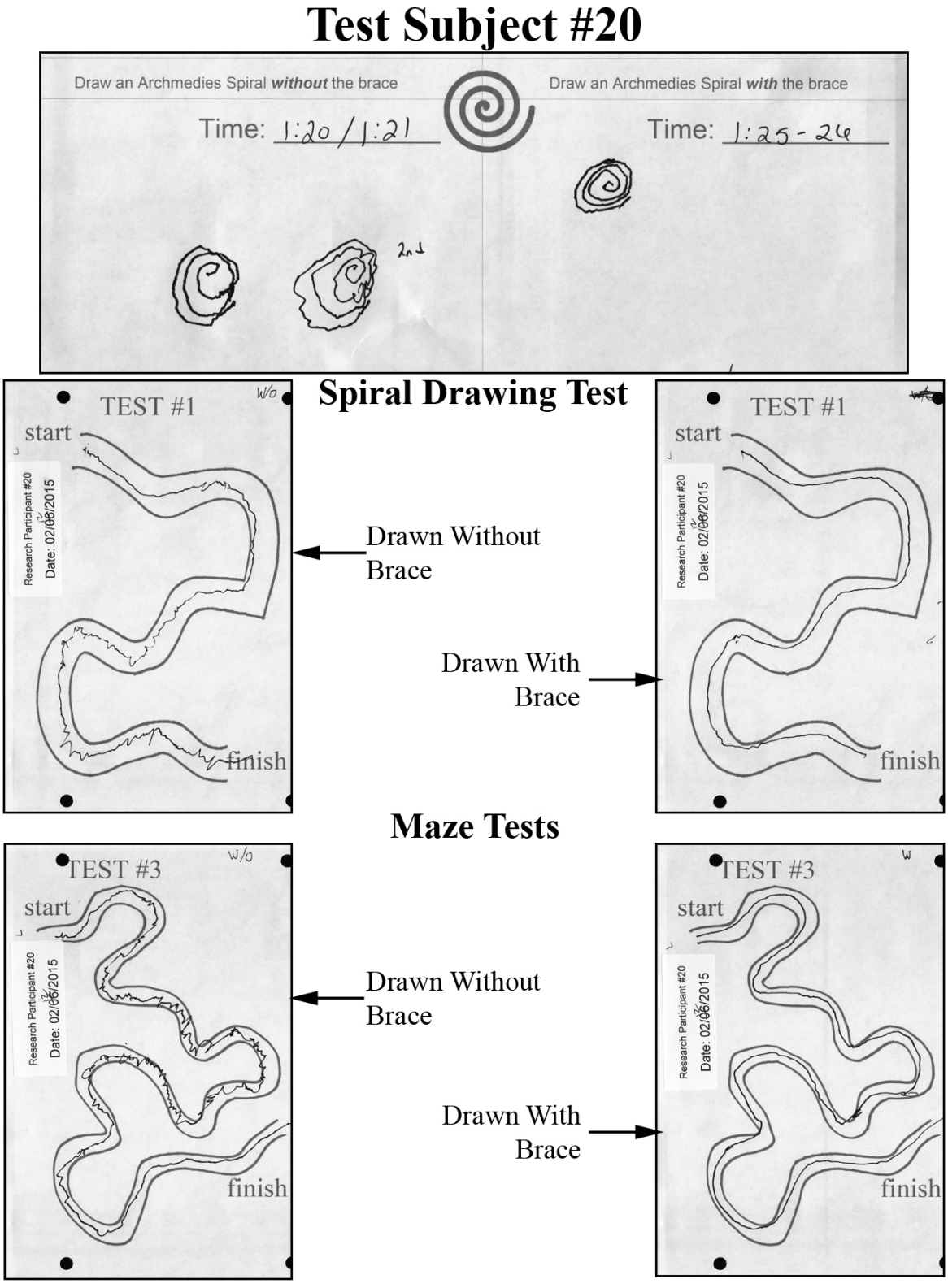



Figure A17 Subject #20 showed significant improvement in both the spiral and maze tests.

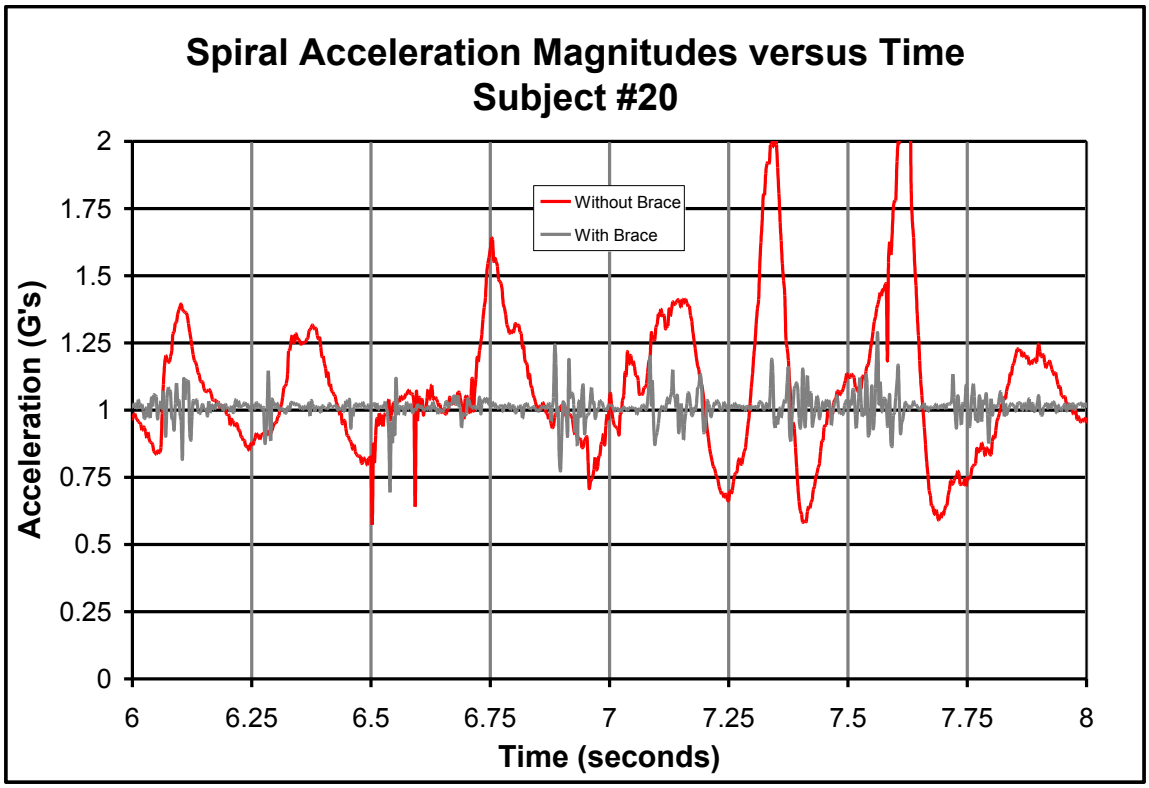



Figure A18 This plot shows the reduced accelerations during the spiral drawing test for Subject #20.

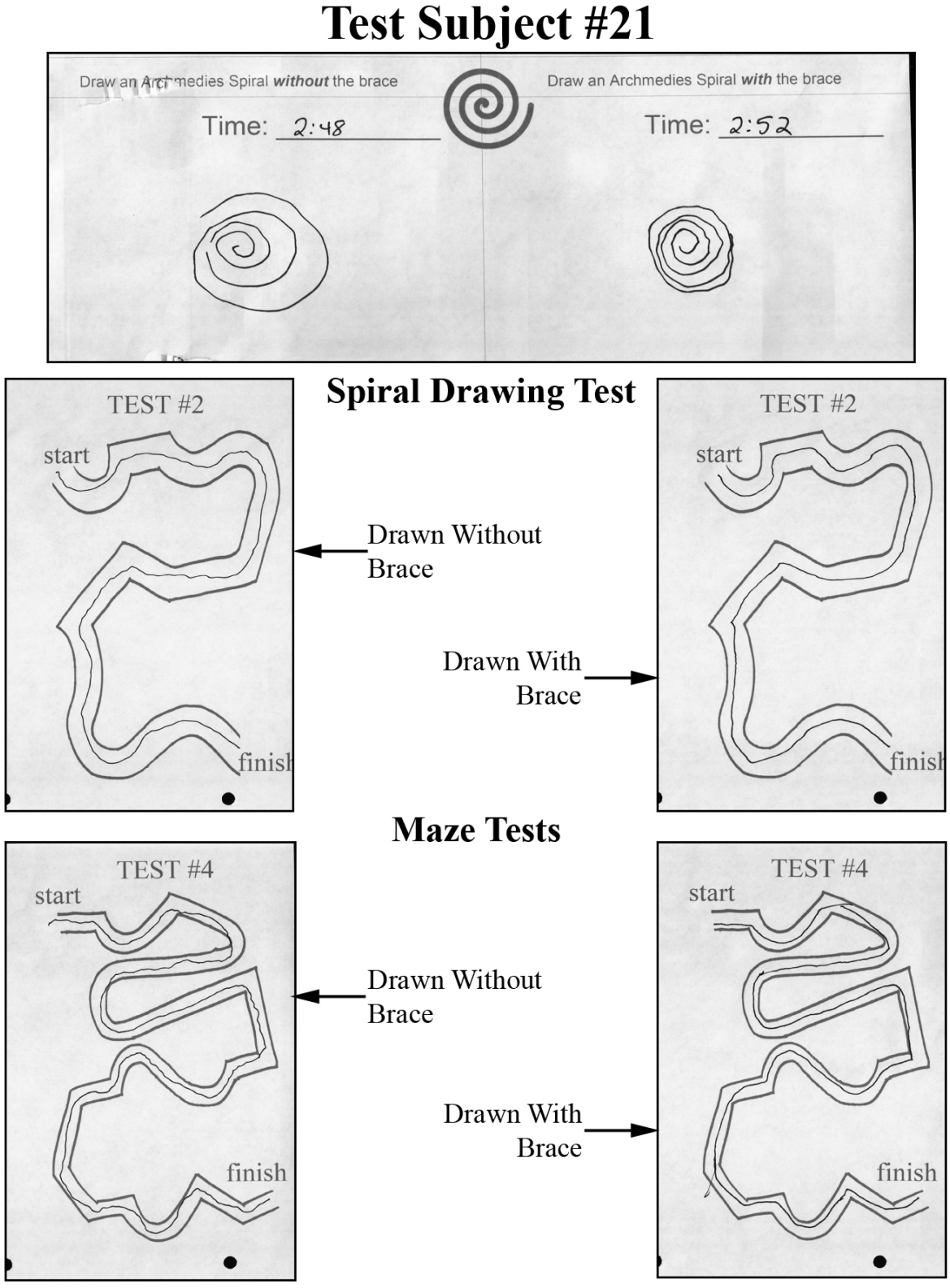



Figure A19 Subject #21 showed moderate improvement in both the spiral and maze tests.

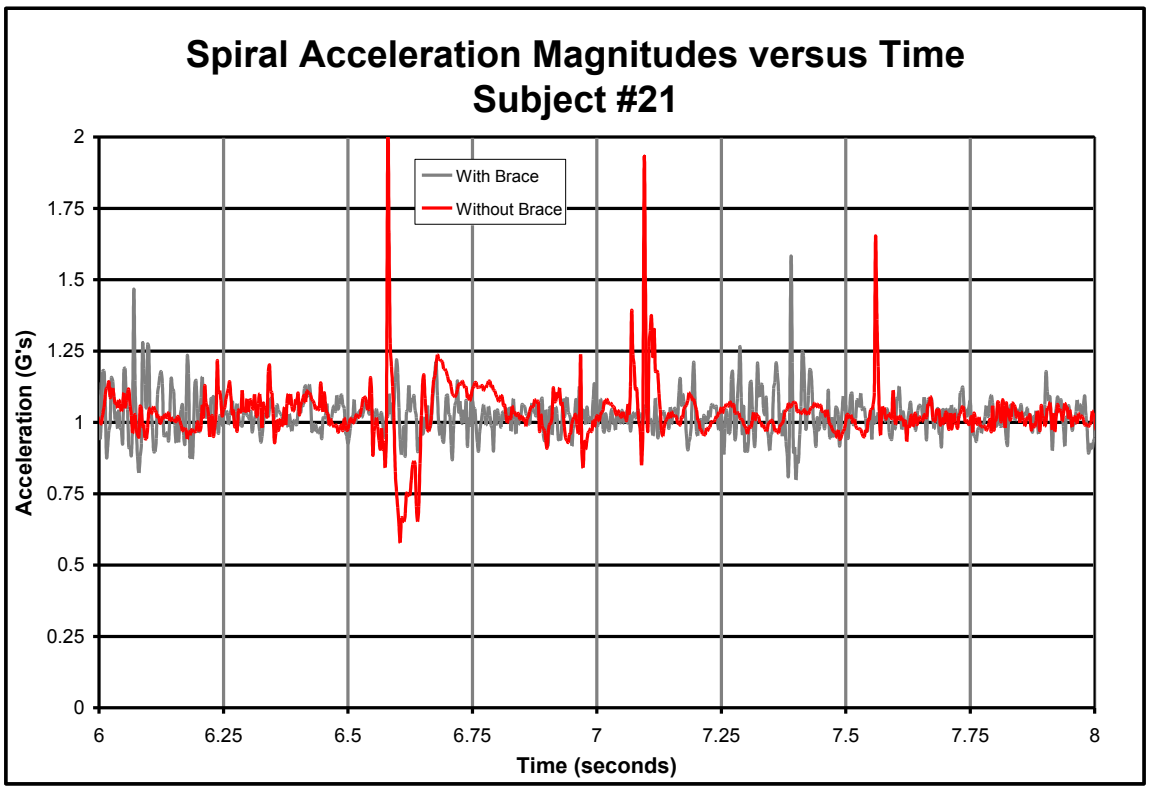



Figure A20 This plot shows the accelerations during the spiral drawing test for Subject #21.

Appendix B – Subjective Classification of Maze and Spiral Tests

A set of guidelines was developed to classify individual test results into significant, moderate and minor categories. In the Maze tests, to be classified as significant improvement, subject needed to have a very apparent tremor, shaky and irregular lines in the maze. When the brace was worn lines had to become smoother resulting in points where the tremor was barely visible such as subject #14. To be classified as moderate improvement, subject needed to have a visible tremor. When the brace was worn, areas of visible reduced were apparent with some remaining points in the maze line test where the lines drawn looked very similar with and without the brace, such as subject #21. A classification of minor was given when subject showed very little or no improvement with and without the brace, such as subject #15. Figure B1 shows examples from all three classifications.

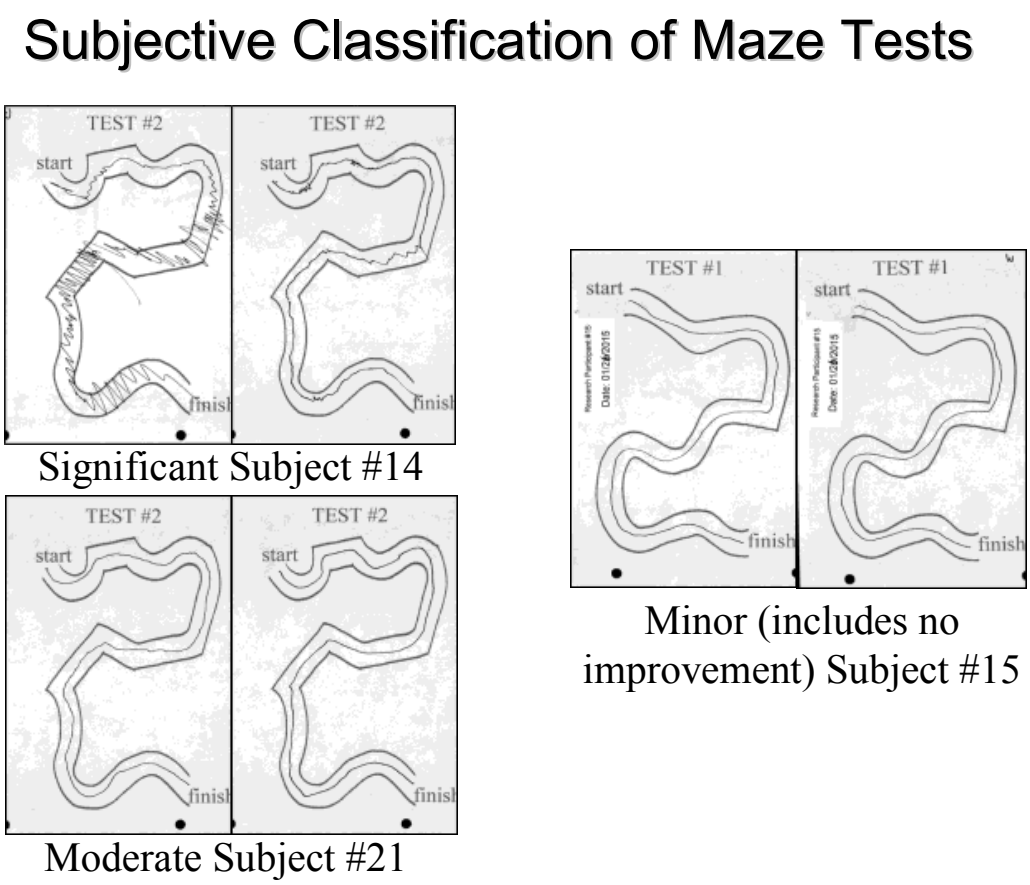



Figure B1 Examples of the three levels of classification for the maze tests.

In the Spiral testing, to be classified as significant improvement, subject needed to have a very apparent tremor that deformed the spiral greatly and when the brace was worn the spiral became more regular and circular such as subject #8. To be classified as moderate improvement, subject needed to have a visible tremor in the initial spiral and when wearing the brace the lines of the spiral became smoother and closer together showing more fine motor control such as subject

#10. To be classified as minor improvement, subjects' two tests looked very similar showing little to no improvement such as subject #12. Subjective classifications of spiral tests are shown in Figure B2.

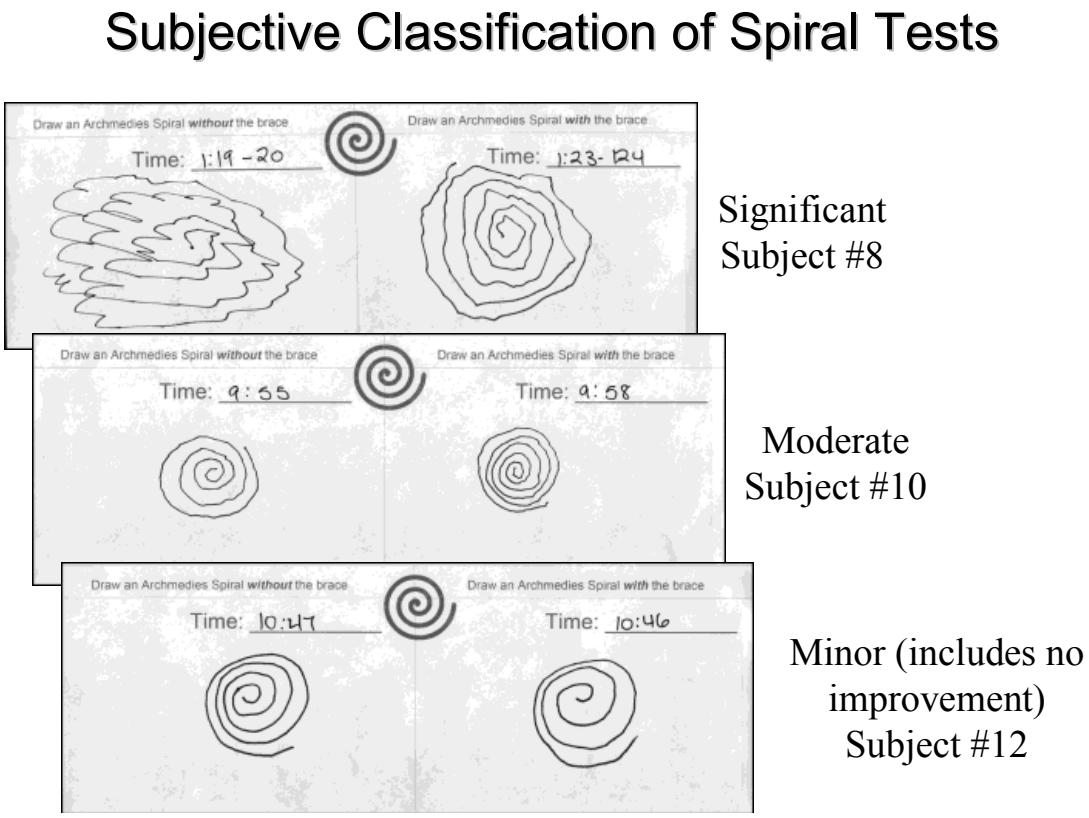
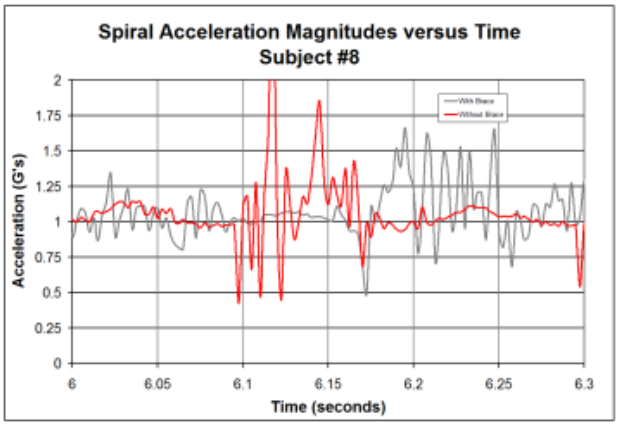


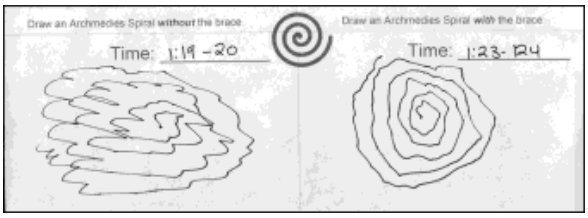

Figure B2 Examples of the three levels of classification for the spiral test.

Appendix C – Correlation between Acceleration Magnitudes and Visual Appearance of Spiral Test

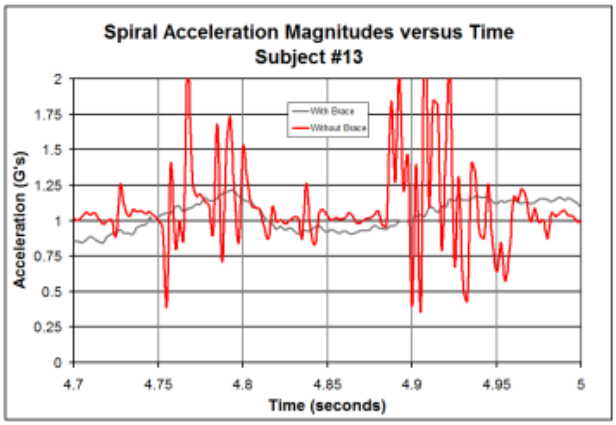
When the graphs of acceleration magnitude were compared to the visual appearance of the spiral there was no consistent correlation observed. For subject #8 there was a significant reduction in the tremor visually, but when examining the instrumented pen data, large peaks of accelerations were observed that were not visually present in the spiral. This is an example where a correlation was not found. For subject #13 the tremor was significantly reduced visually with almost complete elimination of the tremor. The acceleration data supports this finding and shows a large reduction of the tremor. This is and example where a correlation was observed. When examining all 19 subjects' results, no consistent correlation was found.



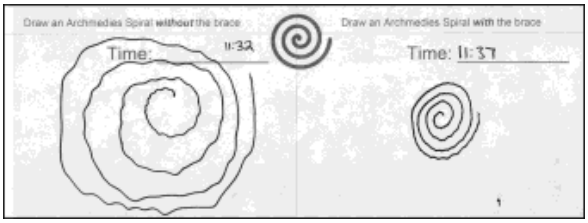

No visible correlation




Subject #8




Visible correlation




Subject #13

Figure C1. Two examples of comparing the acceleration data with the visual results. One shows poor correlation and the second shows good correlation.

Appendix D - Converting Voltages to Accelerations

The accelerometer used in the experiment can measure accelerations from approximately negative 4 G's to approximately positive 4 G's. It does this by using a known input voltage of 3.3 volts which stays constant because the accelerometer circuit board has a built in voltage regulator. The accelerometer works by setting ½ of the input volts to a zero G state. If the accelerometer is free falling or in a zero G condition, the output of the accelerometer would be 1.65 volts. As the accelerometer experiences more G loads, the voltage changes by a known factor of approximately 2.42 G's/volt. The plot of the G's versus voltage for each axis after calibration is shown in Figure B1.

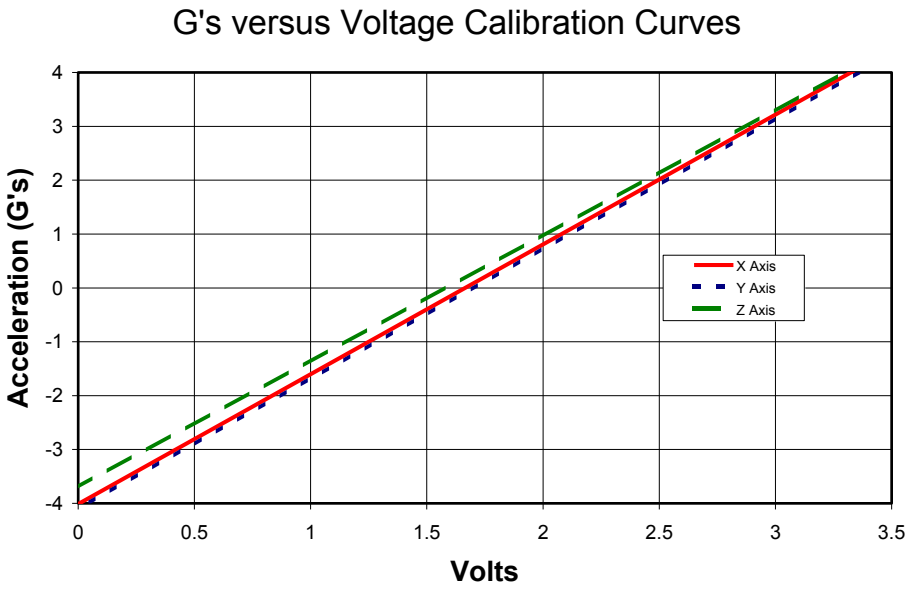
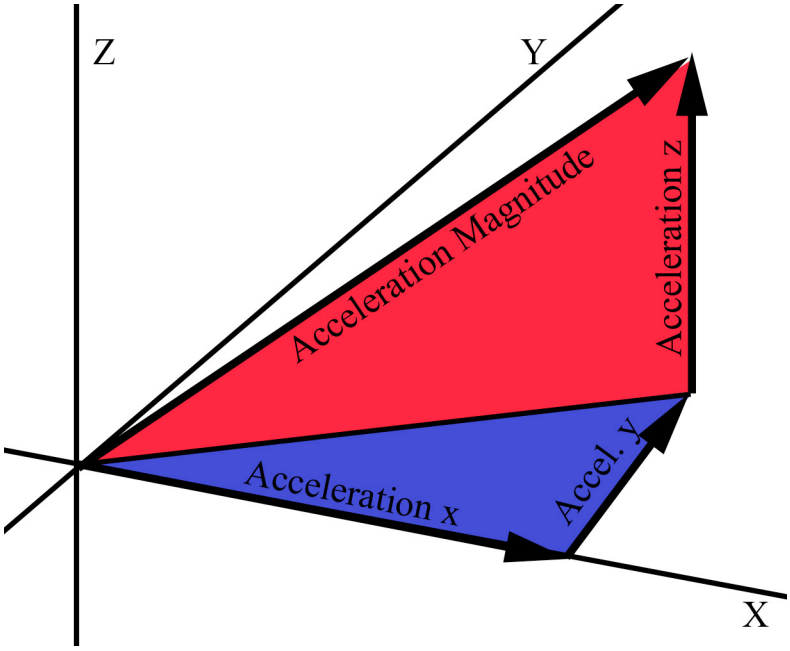



Figure D1. Simple linear relationship between voltage and acceleration in G's.

Appendix E – Calculating Acceleration Magnitude

To represent data in a clean an orderly way, the data from the instrumented pen was converted into acceleration magnitudes. This was chosen because every person holds a pen slightly different which makes direct comparisons impossible. The accelerations magnitude shows the maximum acceleration component from the three recorded accelerations. The acceleration magnitude is found by taking the square root of the sum of the squares of the acceleration components. This is simply Pythagorean theorem in 3 dimensions. Figure C1 is a graphical representation of acceleration magnitude.




$$Acceleration\ \ Magnitude = \sqrt{AccX^2 + AccY^2 + AccZ^2}$$

Figure E1 Graphical representation of the acceleration magnitude.

# Will it be a Good Ski Season? Correlation between El Niño and U.S. Weather

Lillian Petersen[1]

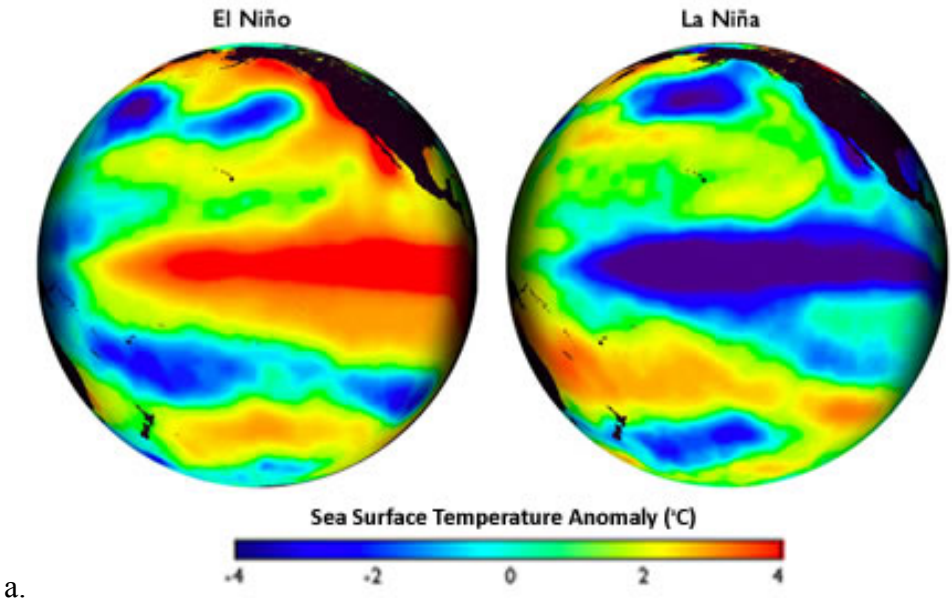
**Abstract**

This study investigates the correlation between El Niño and the weather across the U.S. El Niño is defined as warmer waters in the equatorial Pacific. La Niña is colder waters in that same area. The correlation between El Niño index and weather station data from 25 U.S. cities was computed for three variables: precipitation, snowfall and temperature. Daily weather data was averaged by month and year. It was found that El Niño correlates differently for different regions of the U.S. From New Mexico to the east coast, the weather is colder and wetter during El Niño and warmer and drier during La Niña (statistically significant and highly significant correlations). The whole southern half of the U.S. is wetter during an El Niño. The north-western U.S. is warmer, and areas near Ohio are drier. However, the correlation is not immediate. The data shows about a five month time lag between El Niño and the wintertime snowfall. The previous August El Niño index is the best predictor of total winter snowfall for most U.S. cities. El Niño is a good predictor of seasonal weather, but not perfect. The difference between strong El Niño and strong La Niña snowfall in Los Alamos, New Mexico, is 30 in. on average, while the standard deviation of the error of the best fit line is 27 in. This means that the prediction is almost as large as the variability.

---

El Niño is an oscillation in the earth's climate that influences weather around the world (Brown et al. 2002, Knauss 1997, Talley et al. 2011). El Niño is classified as warmer waters (>28$^{o}$C) in the equatorial Pacific, and La Niña is colder waters (<25$^{o}$C) in that same area (Figure 1a, Talley et al. 2011, p. 346). The El Niño index ranges from -2.5 to 2.5. If the index is positive, it is an El Niño, and if it is negative, it is a La Niña. If it is at zero, it is neutral. If the index is one, that means the sea surface temperature of the Nino 3.4 region (Figure 1b) is one degree warmer than average, and if it is negative one, it is one degree colder.

[1] Corresponding Author: lilliank.la@gmail.com




a.


b.

**Figure 1.** Sea surface temperature anomaly (difference from the average) of El Niño (left) and La Niña (right) in the equatorial Pacific (a) (Fiondella 2015). The Nino 3.4 region (b) (Dahlman 2009).

El Niño affects the jet stream (Figure 2). When there is an El Niño, the jet stream is further south, causing more storms and colder temperatures in the southern U.S. and northern Mexico. When there is a La Niña, the jet stream moves further north giving more storms to Alaska, Canada, and the northern U.S. (NOAA 2015c). El Niño-related temperature and precipitation impacts across the United States occur during the cold half of the year (Halpert 2014).

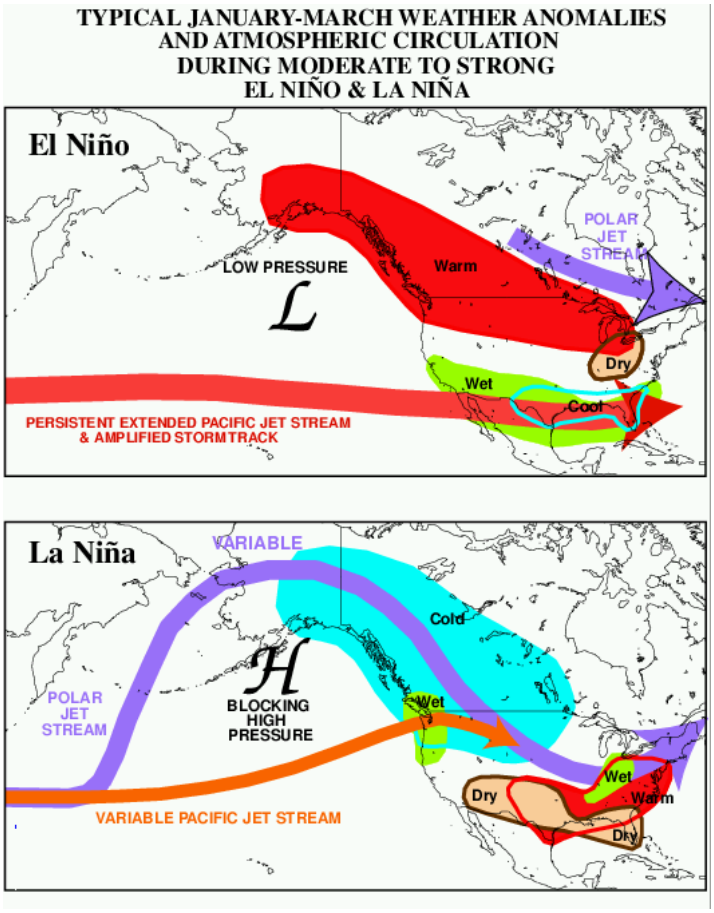



**Figure 2.** Typical weather patterns for El Niño and La Niña during the winter months (NOAA 2015c).

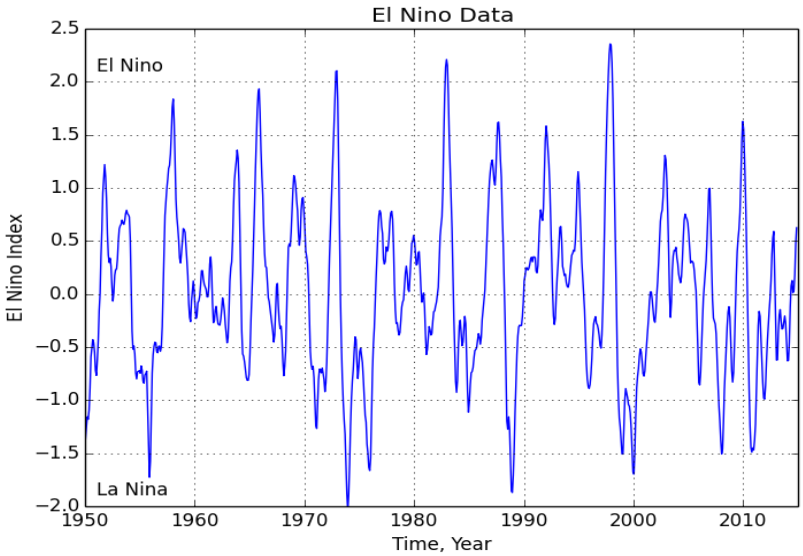
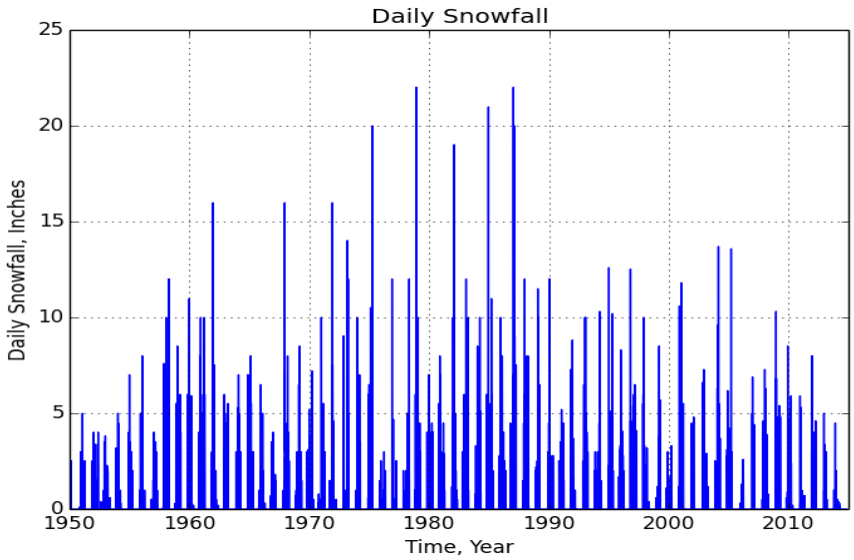


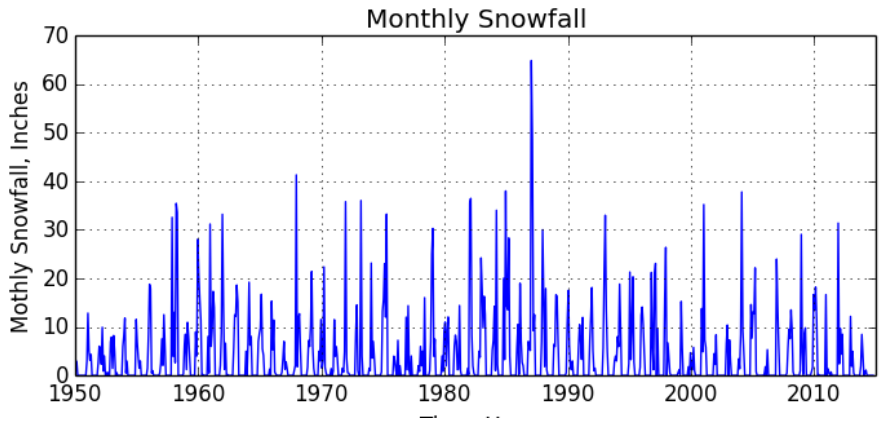

**Figure 3.** El Niño 3.4 index since 1950. This is the temperature anomaly in the equatorial Pacific in $^{o}$C (NOAA 2015b). This and all following plots made by author.

## Methods

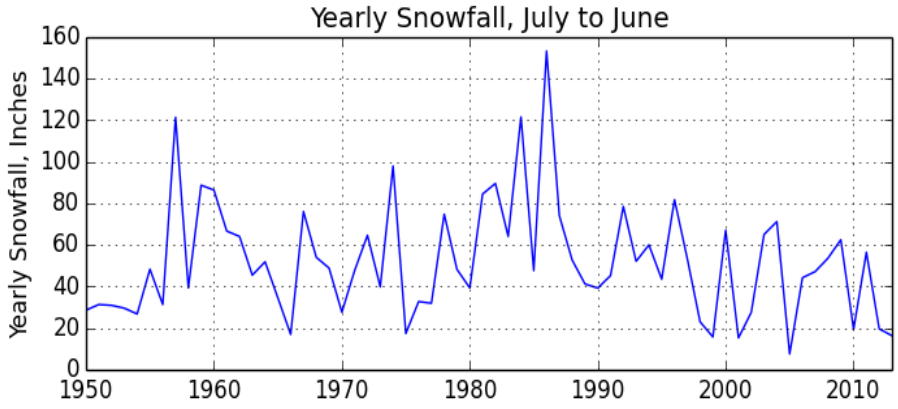
This section will explain how data and graphs were plotted. First, El Niño Index 3.4 data from NOAA was downloaded (NOAA 2015b), as shown in Figure 3. Daily maximum temperature, minimum temperature, precipitation, and snowfall was downloaded from NOAA for 25 cities across the U.S. (NOAA 2015a). Daily data was averaged for each month and year (Figure 4). Python code was written to compute the correlation of the El Niño index and the monthly average weather. Month by month, for example the January El Niño index to January's snowfall, the correlation was very low at 0.01. However, when weather data was averaged over the winter months, the correlation with the yearly El Nino index was a lot higher.




a.




b.




c.

**Figure 4.** Los Alamos snowfall data since 1950 for every day (a), summed for every month (b), and the total snowfall for each year (c). (NOAA 2015b).

The formulas used are as follows:

The *average* of $N$ numbers, $x_1$, $x_2$, $x_3$, ..., $x_N$, is:

$$\mu_x = \frac{1}{N}\sum_{i}^{N} x_i$$

The python code to compute the average is:

```
def AvgList(x):
        xAvg=0.
        for k in range(len(x)):
                xAvg=xAvg+x[k]
        xAvg=xAvg/(k+1)
        return xAvg
```

The *standard deviation* measures the spread of the data:

$$\sigma_x = \sqrt{\frac{1}{N}\sum_{i}^{N}(x_i - \mu_x)^2}$$

The python code for the standard deviation is:

```
def stdDev(x): #function to compute standard deviation
        xAvg=AvgList(x)
        xdev=0.
        for k in range(len(x)):
                xdev=xdev+(x[k]-xAvg)**2
        xdev=xdev/(k+1)
        xdev=sqrt(xdev)
        return xdev
```

The *correlation* between two data sets may be between negative one and one, where one means they are 100% correlated, and negative one means they are oppositely correlated. When the correlation is zero, it is completely random. The correlation between a dataset x and a dataset y is:

$$r_{xy} = \frac{\frac{1}{N}\sum_{i}^{N}(x_i - \mu_x)(y_i - \mu_y)}{\sigma_x \ \sigma_y}$$

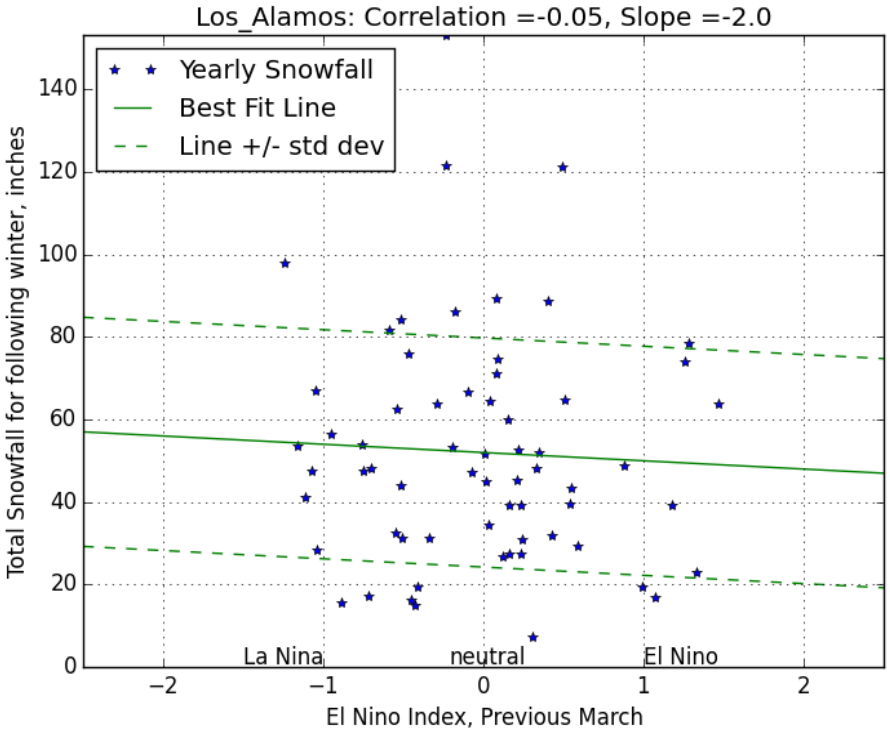
The python code for the correlation is:

```
def corr(x,y):
        xAvg=AvgList(x)
        yAvg=AvgList(y)
        rxy=0.
        n=min(len(x),len(y))
        for k in range(n):
                rxy=rxy+(x[k]-xAvg)*(y[k]-yAvg)
        rxy=rxy/(k+1)
        stdDevx=stdDev(x)
        stdDevy=stdDev(y)
        rxy=rxy/(stdDevx*stdDevy)
        return rxy
```

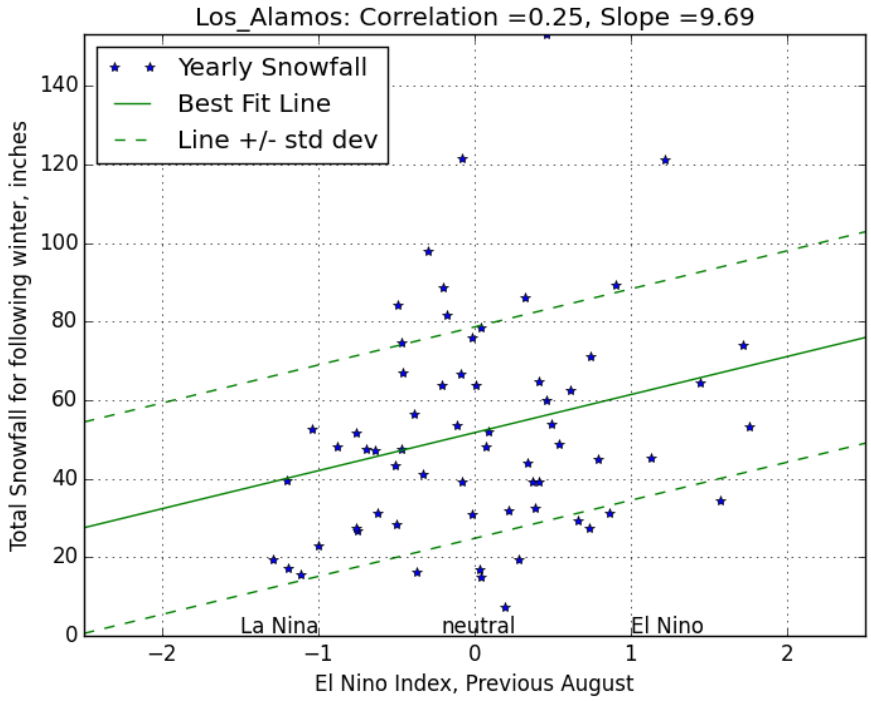
The best fit line was also added to all the plots. The best fit line is the line that best fits the data. In other words, it is the line that is the least possible distance squared to all the points. The equation of a line is $y=mx+b$. A python library was used to compute the best fit line. The 500 lines of python code is available upon request from the author, which also shows how data was read in and how plots were made.

## Results

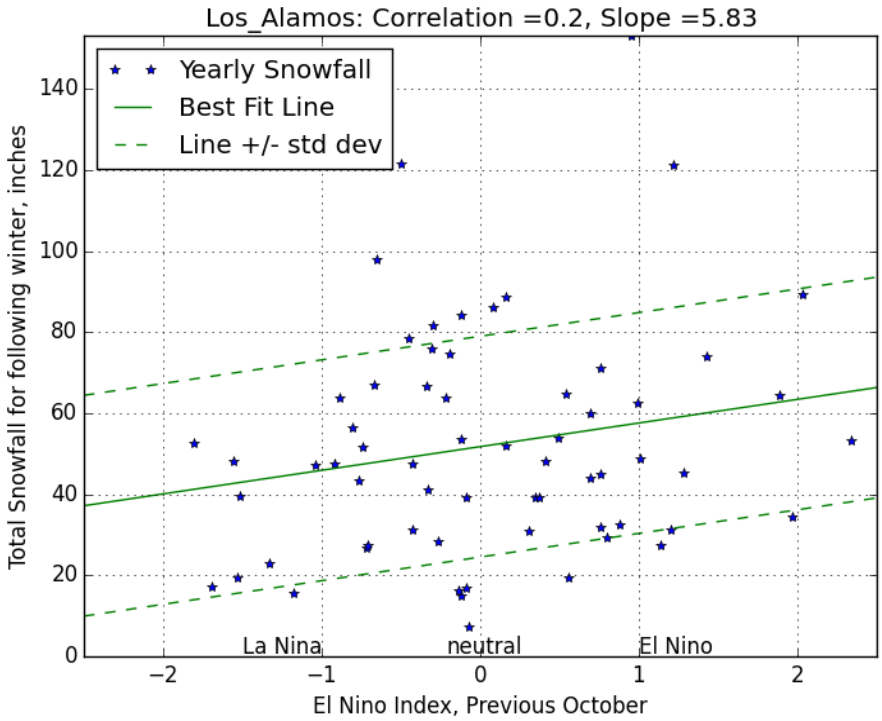
For this project, correlations between the El Niño index and temperature, precipitation, and snowfall were evaluated. For the same month, the correlation was very low—0.01 or lower. Therefore El Niño and weather do not correlate during the same month. After summing the snowfall for every year, there was a higher correlation with the El Niño index from previous months. As seen in Figure 5, the amount of snowfall in winter in Los Alamos has the highest correlation with the El Niño index from the previous August. This is true for most of the cities across the U.S., and the ones with the highest correlations were the cities that were colder and wetter during an El Niño. The only places where the highest correlation wasn't with August were Oregon (October) and northern California (June). This shows that there is about a five-month time lag between El Niño and the weather that follows for most of the cities across the U.S.




a.




b.




c.

**Figure 5.** Total snowfall for the following winter as a function of the El Niño index for the previous March (a), August (b), and October (c). Each dot is for a winter in Los Alamos from 1950 to 2015. The dashed lines show the standard deviation of the error of the best fit line.

A correlation is considered *statistically significant* if there is less than one in 20 chance (five percent) that it happened randomly. It is considered *highly significant* if there is less than one in 100 chance (one percent) that it happened randomly. For 60 points, a significant correlation is above 0.25 and a highly significant correlation is above 0.32 (Crow et al. 1960, p.241). The correlation in August is considered statistically significant.

The best fit line in Figure 5 is a simple model to predict snowfall. For August in Los Alamos, this model predicts 70 inches during a strong El Niño and 40 inches during a strong La Niña, a difference of 30 inches. To measure the accuracy of the best fit line, the standard deviation of the error of the best fit line was computed. This was 27 inches for August, showing that the variability in winter snowfall is almost as big as the difference between El Niño and La Niña.

Next, data was binned into the years classified as a strong, moderate and weak El Niño or La Niña, as seen in Figure 6. First, the El Niño index was smoothed by averaging over consecutive three-month intervals. For a year, spanning from July to June, to be classified as a strong El Niño, the smoothed index has to be over 1.5 for at least three months in a row, as described in Null 2015. These years are circled in red. The values for weak and moderate El Niño's are 0.5 and 1. La Niña classification is the same but negative. Next, the average was taken for the precipitation, snowfall, and temperature of all the years classified as a strong El Niño (Figure 7). This was then done for all the different categories of El Niño.

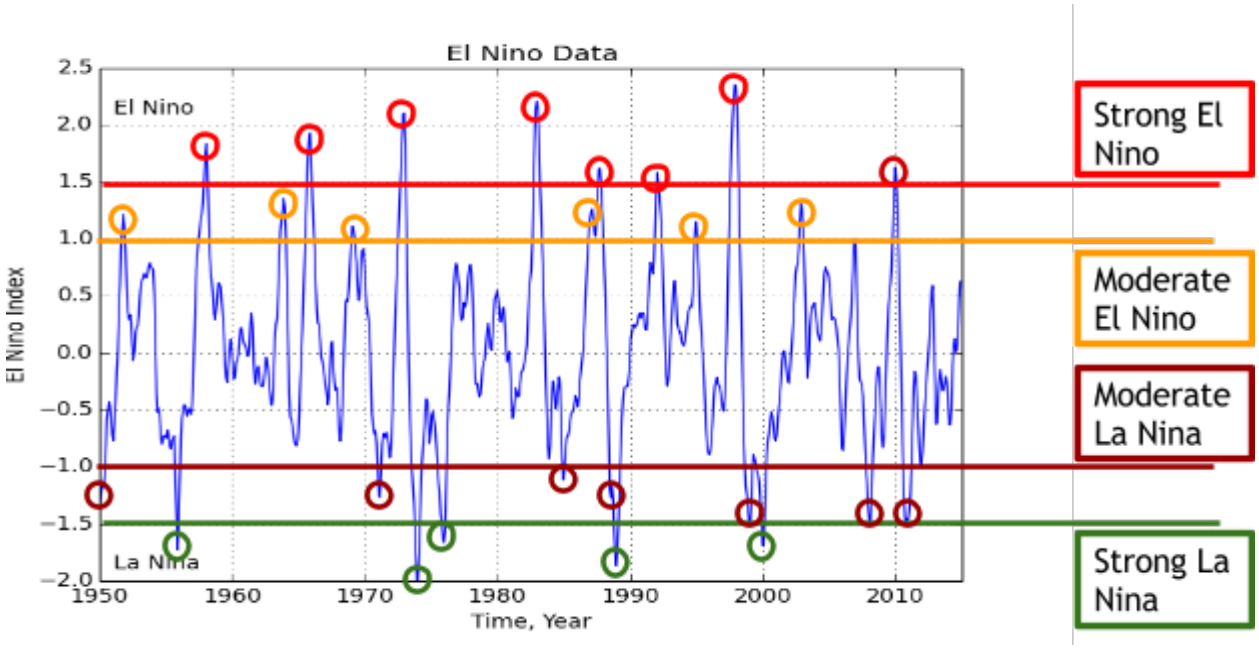
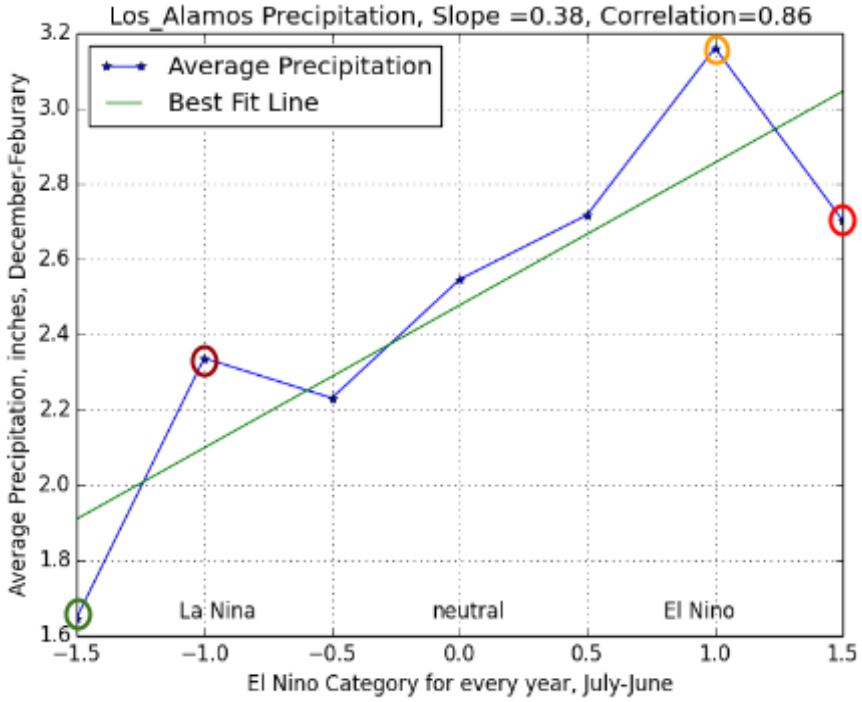
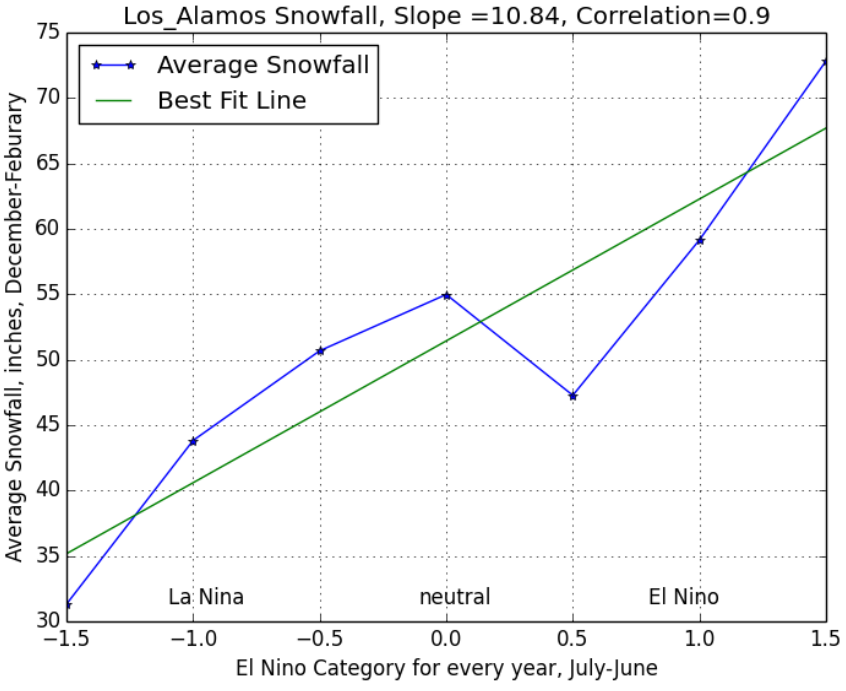


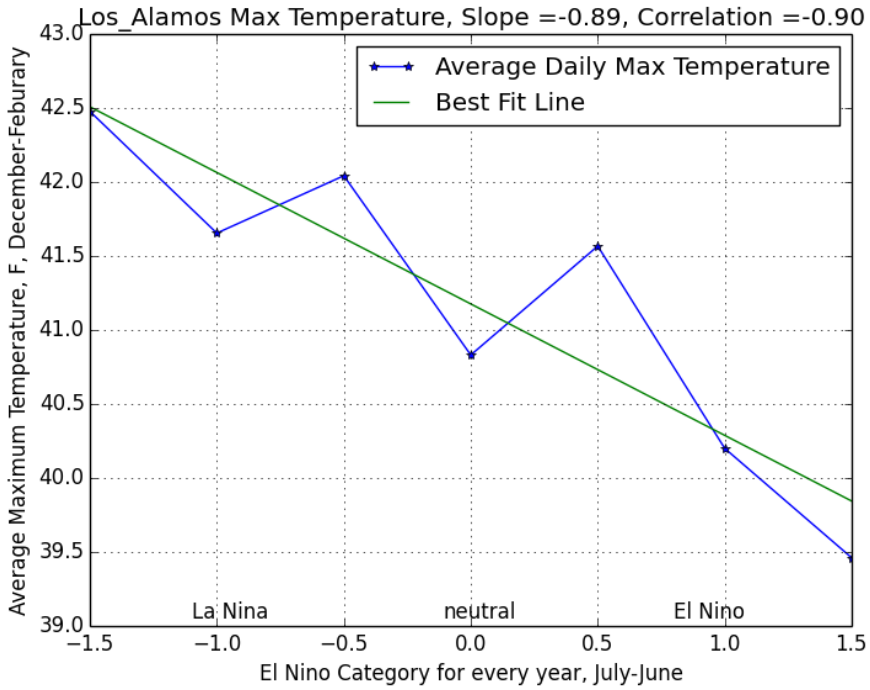

**Figure 6.** For a whole year to be classified as a strong El Niño, the index of that year has to be above 1.5 for at least three months in a row. Likewise is for strong La Niña, moderate El Niño, moderate La Niña, weak El Niño, and weak La Niña, using values of -1.5, 1.0, -1.0, 0.5, and -0.5, respectively.


Los_Alamos Precipitation, Slope =0.38, Correlation=0.86
Average Precipitation
Best Fit Line
Average Precipitation, inches, December-Feburary
La Nina
neutral
El Nino
El Nino Category for every year, July-June

a.


Los_Alamos Snowfall, Slope =10.84, Correlation=0.9
Average Snowfall
Best Fit Line
Average Snowfall, inches, December-Feburary
La Nina
neutral
El Nino
El Nino Category for every year, July-June

b.




c.

**Figure 7.** The average was taken of the precipitation, snowfall, and temperature for all of the categorized years (strong, moderate, and weak El Niño and La Niña). During a stronger El Niño, Los Alamos is wetter (a), gets more snow (b), and has colder temperatures (c). The circles on (a) correspond to the average of the years in Figure 6 with the same color.

In the town of Los Alamos, the weather is cooler and wetter during an El Niño. During a La Niña, it is warmer and drier. This is also true for multiple towns across New Mexico and Colorado. As seen in Figure 8, from New Mexico to the east coast, the weather is colder and wetter during an El Niño and opposite during a La Niña. West of New Mexico, it is wetter during an El Niño, but temperature effects have a low correlation. The north-western U.S. is warmer and areas near Ohio are drier. Some examples of this are Louisiana, which is colder and wetter (Figure 9), and Cincinnati, which is drier (Figure 10). If the correlation was between -0.5 and 0.5, the location was categorized as a low correlation. In Figure 7, the correlation is shown in the top of each panel. For seven points, a significant correlation is above 0.67, and a highly significant correlation is above 0.8 (Crow et al. 1960, p.241).

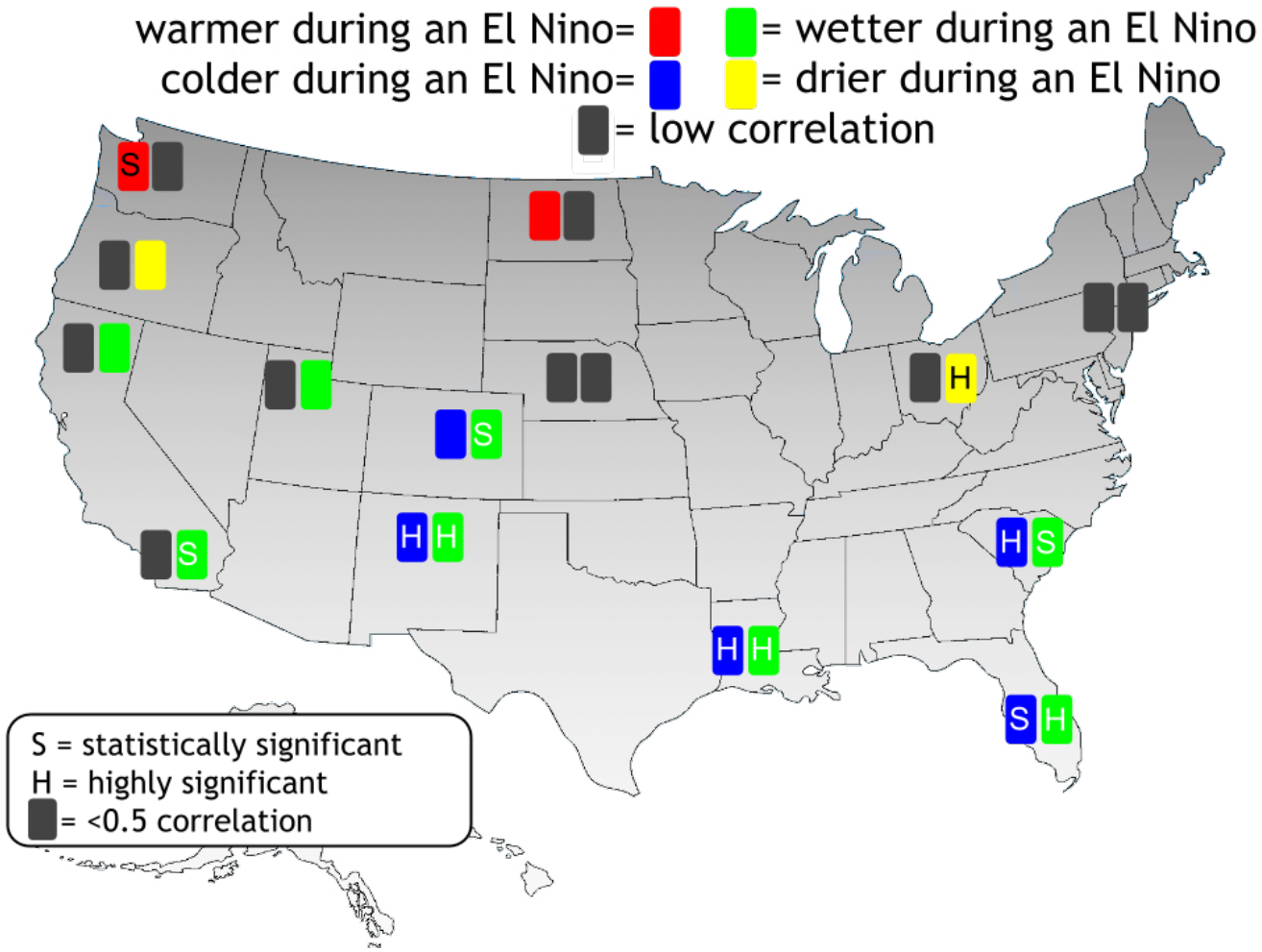
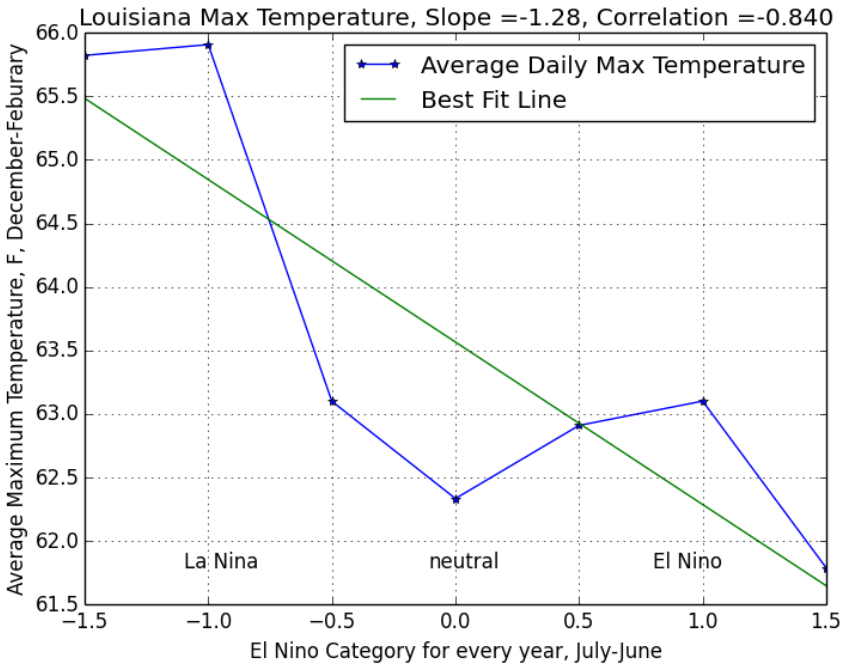
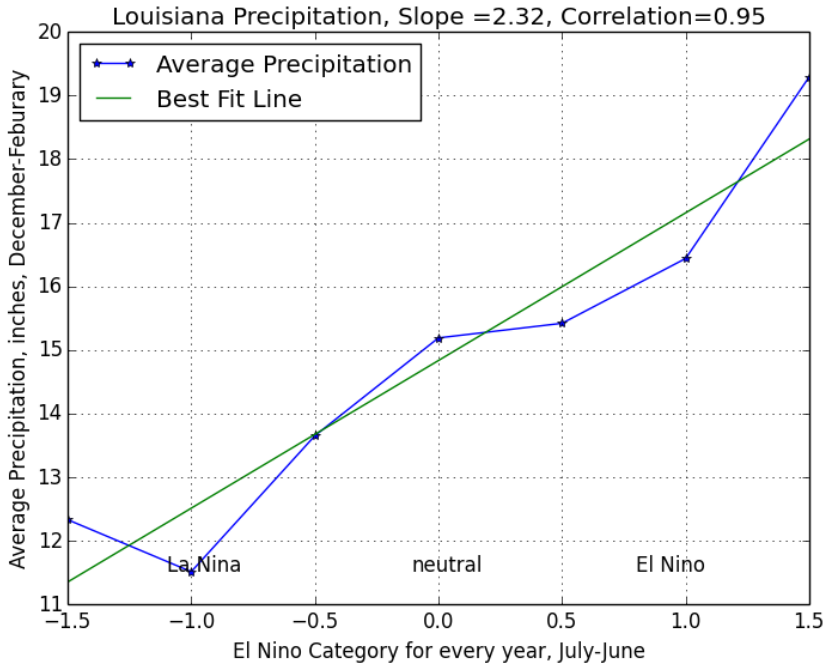



**Figure 8.** Effects of El Niño across the U.S. A graph with seven points is considered significant if the correlation is above 0.67. It is considered highly significant if the correlation is above 0.8. If the correlation was between -0.5 and 0.5, that location was classified as a low correlation.

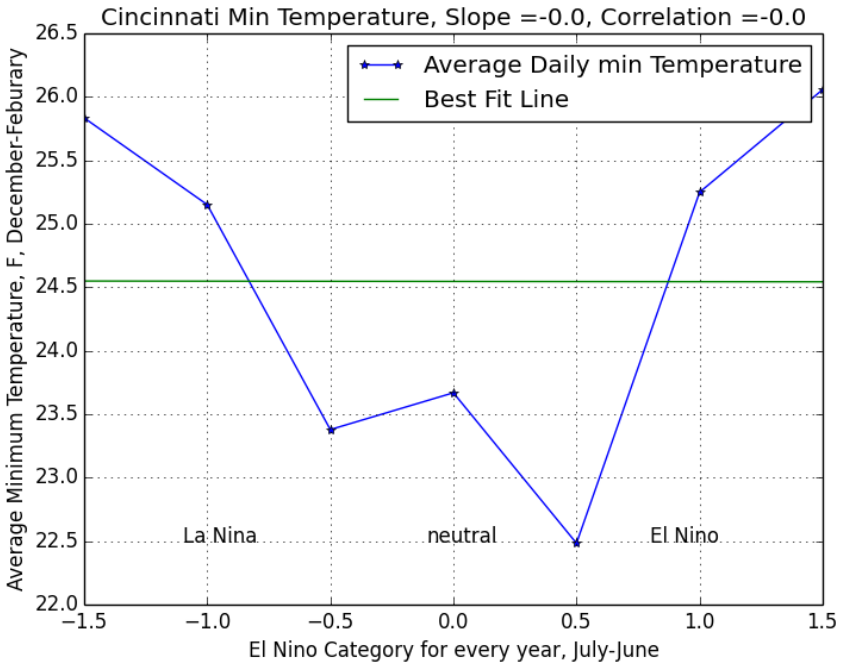



a.

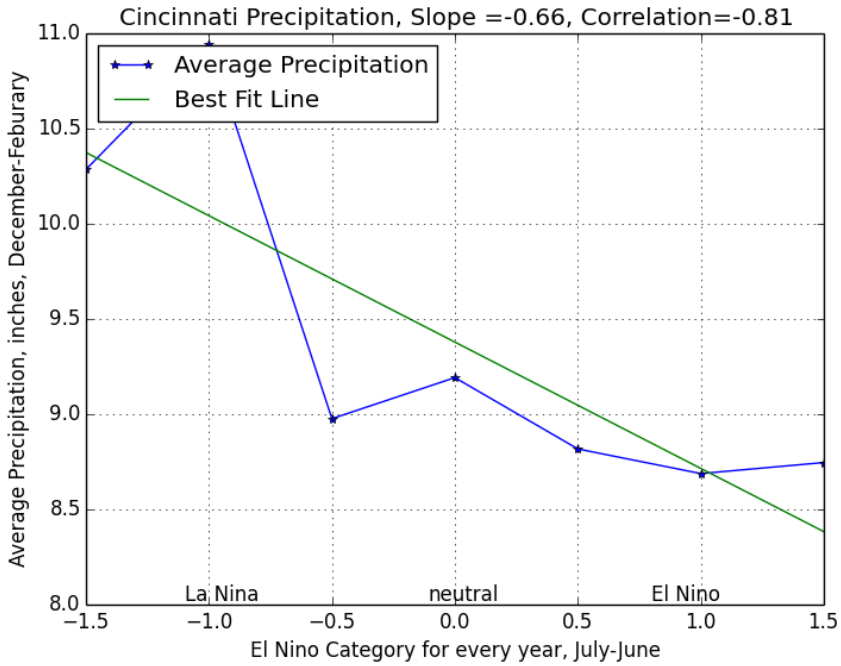



b.

**Figure 9.** Effects of El Niño for Louisiana. Louisiana is colder and wetter during an El Niño. Both of the correlations are highly significant.




a.




b.

**Figure 10.** Effects of El Niño for Ohio. Ohio is drier during an El Niño with a high significance

## Conclusions

El Niño has different effects on the weather for different locations across the U.S. In New Mexico, it is colder and wetter during an El Niño. Significant and highly significant correlations were found between the El Niño index and temperature, precipitation, and snowfall, particularly in the Southern U.S. There was a five month time lag between El Niño and the weather that follows. This study shows that the El Niño index is a weak predictor of the next season's weather. This could be used for agriculture, drought prediction, snow removal planning, fire preparedness, and even deciding whether to buy a ski pass for the next ski season.


## Acknowledgements

Over the past year, I learned how to program in python from Mark Petersen of Los Alamos National Laboratory. He taught me how to download data, make plots, and explained statistics such as correlation. Kimberly Petersen reviewed my writing and helped me improve my paper. Phillip Wolfram of Los Alamos National Laboratory suggested improvements. I also want to thank all of the judges at the NMAS paper competition and the Science Fairs, who gave advice on how to improve my project.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# A Farewell to Thermal Expansion

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## Abstract

This work is motivated by an increasing demand for materials that do not change their volume in response to temperature. Aerospace vehicles, high precision optics (notably telescopes), and various electronics all have significant reactions to even moderate thermally induced expansion, especially in temperature volatile environments such as space. In the framework of this project, new bulk materials with zero and negative isotropic thermal expansions have been created. First, Cobalt Hexacyanocobaltate $Co_3[Co(CN)_6]_2$ was synthesized. This material has negative thermal expansion but can only be obtained in the form of a powder. Then, a composite material consisting of this powder and an epoxy matrix was formed and found to display zero thermal expansion. The same powder was also sintered under high pressure in order to produce specimens with negative thermal expansion. For sintering, a special furnace capable of 2000 psi pressurization has been designed and built. The purity and crystallinity of Cobalt Hexacyanocobaltate has been validated through X-ray diffraction, and the shape and size of the particles through SEM and confocal microscopy. Thermal expansion of the bulk specimens was measured using the extensometer of an Instron testing machine (at elevated temperature) and micrometer (at low temperatures).


## Introduction

*1.1. Motivation.*

Expansion or contraction of materials due to temperature changes is a primary cause of structure failures. Due to higher energies, materials at higher temperatures expand because of greater atomic vibration. Likewise, materials at lower temperatures contract due to lesser atomic vibration. If a structural element is heated non-uniformly (cold in one place and hot in another), significant thermal stresses may take place that lead to fracture.

The most dramatic recent examples of failure due to thermal expansion in materials are the collapse of the Twin Towers during the 9/11 terrorists attack in 2001 (figure 1) [1] and the explosion of the *Columbia* Space Shuttle in 2003 (figure 2) [2], [3].

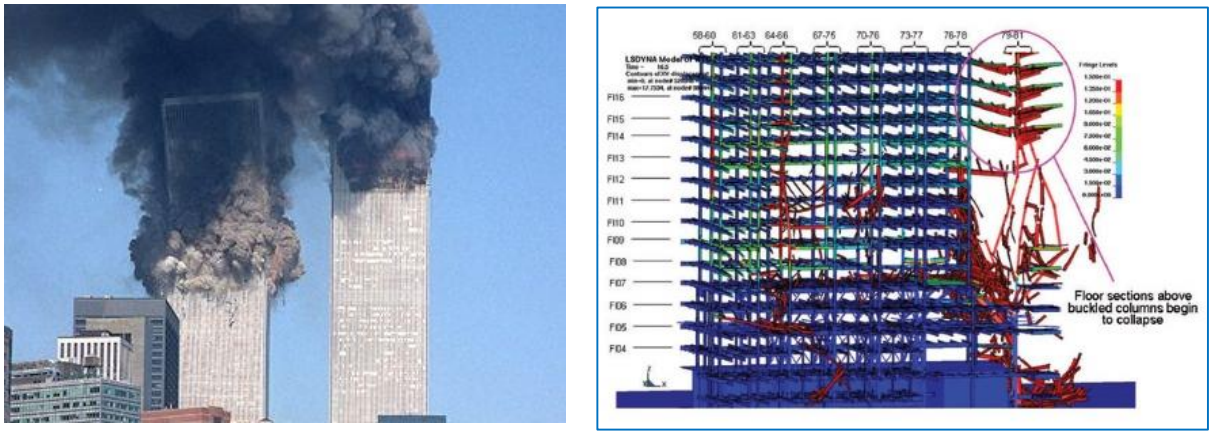



**Figure 1.** The collapse of the twin towers occurred mainly due to thermal damage, leading to buckling in the main support beams from uneven thermal expansion [4] (left), [5] (right).


**Figure 2.** The loss of the space shuttle *Columbia* was partly induced by damages related to thermal expansion [6] (left), [7] (right).

Telescopes in outer space incur substantial distortions to their mirrors due to temperature fluctuations [8]. This results in a loss of precision, lower quality images, and distorted readings.

Various monuments, landmarks, and buildings exhibit visible cracking and destructive microstructure changes as well, with notably oil and gas pipelines [9], [10], motor turbines [11], and high precision optics [8] all significantly affected by thermal expansion. It is estimated that 52 million barrels of oil are leaked in marine waters alone worldwide annually, largely in part due to thermal damage of pipes [13], [14], [15], [16].

**Figure 3.** Abnormal linear expansion of railway tracks due to the hot climatic conditions (left) [12] and buckling of an oil pipe-line due to thermal expansion (right) [10].

Existing solutions utilize carbon fiber (figure 4), which exhibits negative thermal expansion (NTE), though only in one direction, with positive thermal expansion still occurring in the two perpendicular directions.

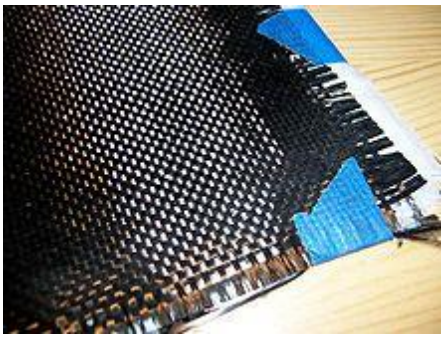


**Figure 4.** Carbon fiber exhibits negative thermal expansion in one direction and positive thermal expansion in the other two perpendicular directions [17].

The main objective of the present work is to develop a composite material with an isotropic thermal expansion coefficient of zero, to produce a material with isotropic negative thermal expansion, and to prove such works experimentally. For this goal, powder showing negative thermal expansion has been used.

### *1.2. Negative Thermal Expansion (NTE).*

The vast majority of materials that exhibit NTE behavior have one thing in common; namely, they can be viewed as relatively open framework structures (Roy, 1995). No bond shortening

upon heating has been seen in any material. Framework materials usually consist of edge or corner sharing metal coordination polyhedrals, which form a three-dimensional network. In most cases, those polyhedrals are extremely rigid, while the coupling between them is somewhat weaker. This opens up the possibility of an appearance of total macroscopic decrease of the specimen's size due to the collective motion of the polyhedral, like in Prussian Blue, which crystallizes in a cubic structure, consisting of alternating $Fe^{2+}$ and $Fe^{3+}$ ions located on an face-centered cubic lattice in such a way that $Fe^{3+}$ is octahedrically surrounded by N atoms and $Fe^{2+}$ is surrounded by C atoms. Prussian Blue Analogs (PBAs) form when either one or both Fe ions are replaced with other atoms, but the main features of the basic structure remain the same.

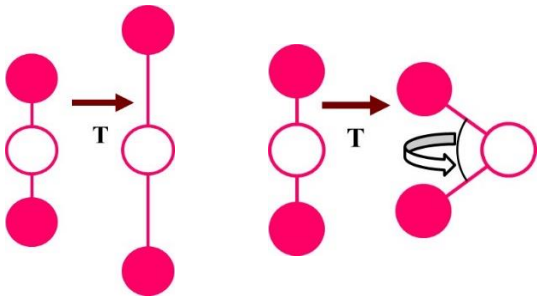



**Figure 5.** Longitudinal (left) and transverse (right) vibrations. Dominant transverse vibrational modes can provide a mechanism for NTE in some solids.

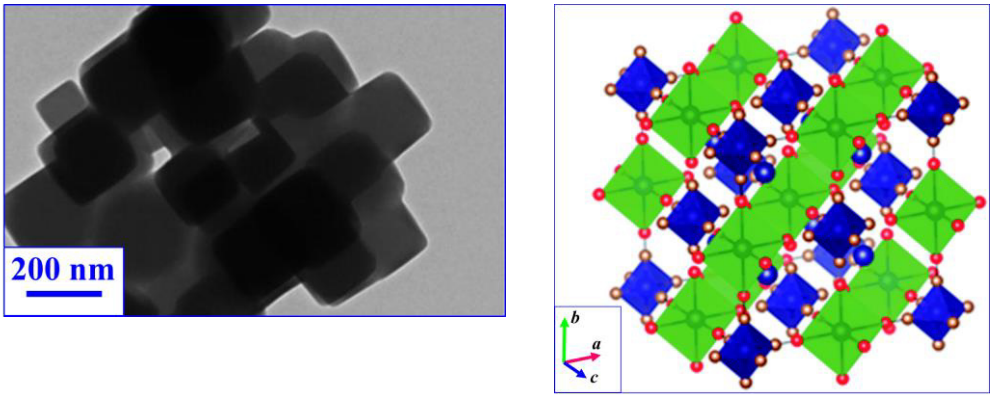



**Figure 6.** Typical TEM image of $Co_3[Co(CN)_6]_2$ nanocubes (left) (from Nie et al, 2014). Crystal structure of Cobalt Hexacyancobaltate (right) (from Adak et al, 2011). The blue and dark yellow balls stand for Co and C atoms and the red balls represent N atoms, respectively.

| *M* | *$M_2[Fe(CN)_6]$* | *$M_3[Co(CN)_6]_2$* | *$M_3[Fe(CN)_6]_2$* | *$M_3[Cr(CN)_6]_2$* |
|---|---|---|---|---|
| ***Mn*** | ***+0.9*** | ***-22.4*** | ***+18.1*** | ***-12.5*** |
| ***Co*** | ***+12.4*** | ***-39.7*** | ***-7.6*** | ***-13.9*** |
| ***Ni*** | ***+18.1*** | ***-3.6*** | ***+40*** | ***+30.0*** |
| ***Cu*** | ***+1.7*** | ***-23.6*** | ***-23.4*** | ***No data*** |
| ***Zn*** | ***No data*** | ***-2.2*** | ***-31.1*** | ***No data*** |

**Table 1.** All hexacyanocobaltates exhibit negative thermal expansion. Cobalt Hexacyanocobaltate (highlighted in yellow) exhibits the greatest negative thermal expansion (from Adak et al., 2011).

Coefficients of thermal expansion ($\alpha$, in units of $10^{-6}$ $K^{-1}$) for the PBAs determined from X-ray data have been reported by Adak et al (2011). Both negative and positive thermal expansion has been observed. All the hexacyanocobaltates show negative thermal expansion. The greatest negative thermal expansion is demonstrated by Cobalt Hexacyanocobaltate $Co_3[Co(CN)_6]_2$. The reported data constitute the highest negative thermal expansion, and thus this material was chosen as a component for the designed composite. Design has been done using theoretical models of the effective thermal expansion available in literature.

One of the earliest models for the effective thermal expansion coefficient $\alpha$ of an isotropic two-phase composite of arbitrary microstructure was proposed by Turner (1946):

$$\alpha = \frac{c_1\alpha_1 K_1 + c_2\alpha_2 K_2}{c_1 K_1 + c_2 K_2} \qquad (1)$$

where $c_1$ and $c_2$ are volume fractions of the two phases, $K_1$ and $K_2$ are bulk moduli, and $\alpha_1$ and $\alpha_2$ are the thermal expansion coefficients of the phases.

Kerner (1956) developed a so-called three-phase model for thermomechanical properties of composites:

$$\alpha = \frac{c_1\alpha_1 K_1(3K_0 + 4G_0) + c_0\alpha_0 K_0(3K_1 + 4G_0)}{c_1 K_1(3K_0 + 4G_0) + c_0 K_0(3K_1 + 4G_0)} \quad (2)$$

where subscripts "0" and "1" corresponds to the matrix and the inhomogeneities and $G$ is the shear modulus.

Arthur and Coulson (1964) used the Blackburn equation that isgiven as a private communication without derivation. Holliday and Robinson (1973) mentioned a misprint. After the corrections, the Blackburn equation has the following form:

$$\alpha = \alpha_0 - c_1\theta(\alpha_0 - \alpha_1)$$

$$\theta = \frac{3E_1(1-\nu_0)}{[(1+\nu_0) + 2c_1(1-2\nu_0)]E_1 + 2c_0E_0(1-2\nu_1)} \quad (3)$$

where $E$ is Young's modulus and $\nu$ is Poisson's ratio

Tummala and Friedberg (1970) considered a single spherical inclusion and derived the thermal expansion coefficient as:

$$\alpha = \alpha_0 - c_1\theta(\alpha_0 - \alpha_1)$$

$$\theta = \frac{E_1(1+\nu_0)}{(1+\nu_0)E_1 + E_0(1-2\nu_0)} \quad (4)$$

Predictions with different models are compared in Figure 7. For calculations, material constants were used for Cobalt Hexacyanocobaltate and epoxy as available in literature (Table 2).

| | ***Thermal expansion*** | ***Bulk modulus*** | ***Poisson's ratio*** |
|---|---|---|---|
| ***Particles*** | ***-39.7x10$^{-6}$*** | ***30 GPa*** | ***0.25*** |
| ***Epoxy*** | **50x*10$^{-6}$*** | ***5 GPa*** | ***0.4*** |

**Table 2.** Material Constants for Cobalt Hexacyanocobaltate and epoxy (from Wong et al, 1999).

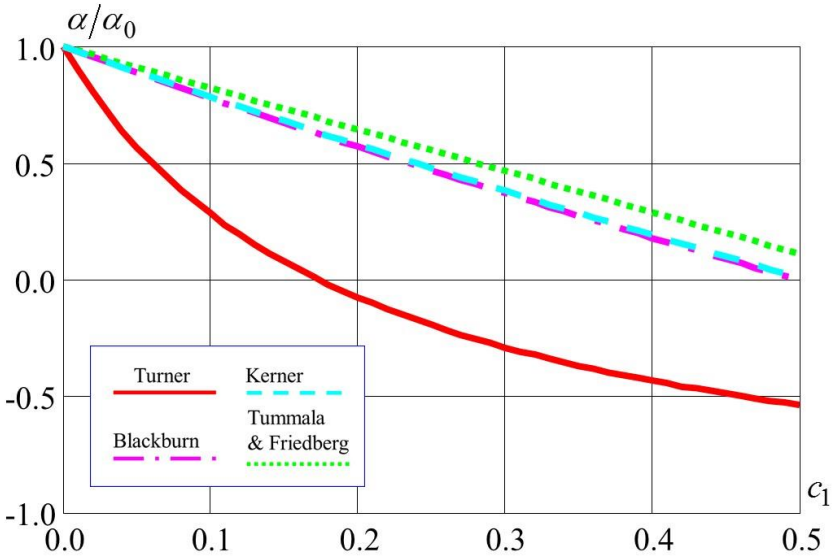



**Figure 7.** Comparison of different theoretical model predictions for effective thermal expansion of Cobalt Hexacyanocobaltate.

## Materials and Methods

*2.1. Cobalt Hexacyanocobaltate.*

The preparation of the Prussian Blue Analog (PBA) samples under study was done via standard chemical precipitation techniques. The reagents $K_3[Co(CN)_6]$ and $CoCl_2$ with 98% purity [18] were used as-received without further purification. The samples were prepared in the chemistry laboratory of Las Cruces High School. The chemical reaction for preparing the PBA is (Adak et al, 2011):

$$2\ K_3[Co(CN)_6] + 3\ CoCl_2 \longrightarrow Co_3[Co(CN)_6]_2 + 6\ KCl$$

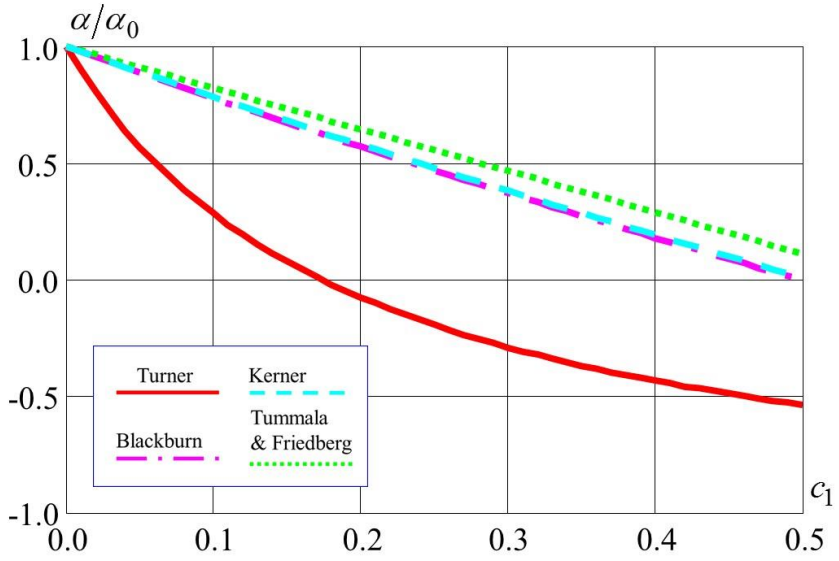


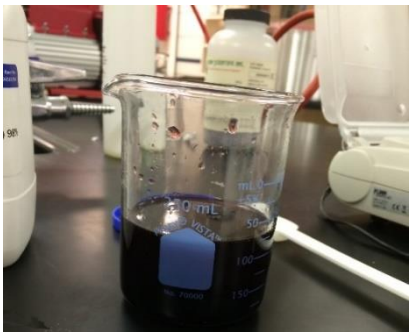

**Figure 7.** Comparison of different theoretical model predictions for effective thermal expansion of Cobalt Hexacyanocobaltate.

## Materials and Methods

*2.1. Cobalt Hexacyanocobaltate.*

The preparation of the Prussian Blue Analog (PBA) samples under study was done via standard chemical precipitation techniques. The reagents $K_3[Co(CN)_6]$ and $CoCl_2$ with 98% purity [18] were used as-received without further purification. The samples were prepared in the chemistry laboratory of Las Cruces High School. The chemical reaction for preparing the PBA is (Adak et al, 2011):

$$2\ K_3[Co(CN)_6] + 3\ CoCl_2 \longrightarrow Co_3[Co(CN)_6]_2 + 6\ KCl$$



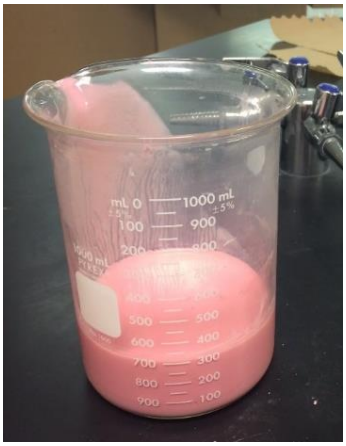


**Figure 8.** $K_3[Co(CN)_6]$ in solution (left, above). $CoCl_2$ in solution (center, above). $Co_3[Co(CN)_6]_2$ and KCl not yet filtered and separated physically (though separation between pink-tinted clear liquid and slightly darker pink solid particles towards the bottom is visible) (right, above). Purified and separated $Co_3[Co(CN)_6]_2$ awaiting to be dried (left).

To analyze the purity and crystallinity of the PBA powder obtained an X-ray technique was employed. X-ray diffraction was measured at room temperature in air on an Empyrean Industrial X-ray diffractometer with monochromatic CuKα (λ = 1.54 Å) radiation at New Mexico State University's (NMSU) Physics department.

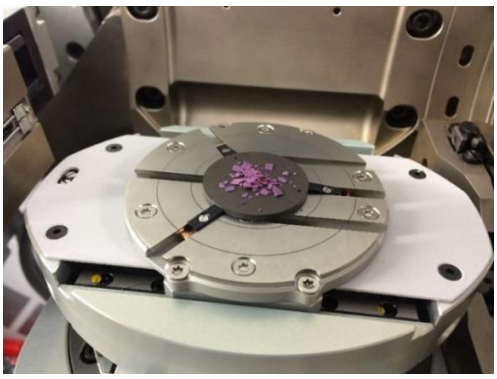
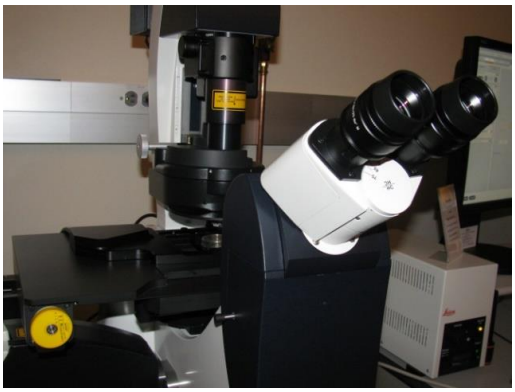



**Figure 9.** The Prussian Blue Analog on a zero background disk in the X-ray diffractometer (left). The X-ray diffractometer in full view (right).

The shape and size of $Co_3[Co(CN)_6]_2$ particles as well as the microstructure of the PBA epoxy composite were evaluated with SP5II confocal microscope and S3400N scanning electron microscope in the NMSU Core University Research Resources Laboratory.



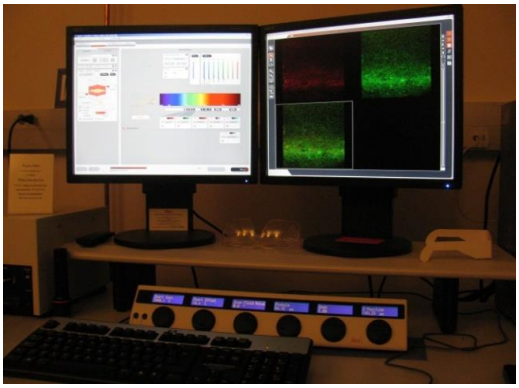


**Figure 10.** SEM Hitachi S3400N microscope (left). SP5II Confocal microscope (below, left and right)

*2.4. Sintering.*

The main method to produce bulk ceramics from powder is sintering (see, for example, Rice, 1998). PBAs cannot sustain high temperatures (the temperature of crystalline structure degradation is between 600 and 700 K). This means that the sintering of PBA should be performed at low temperatures and, therefore, has to be supplemented by high pressure.

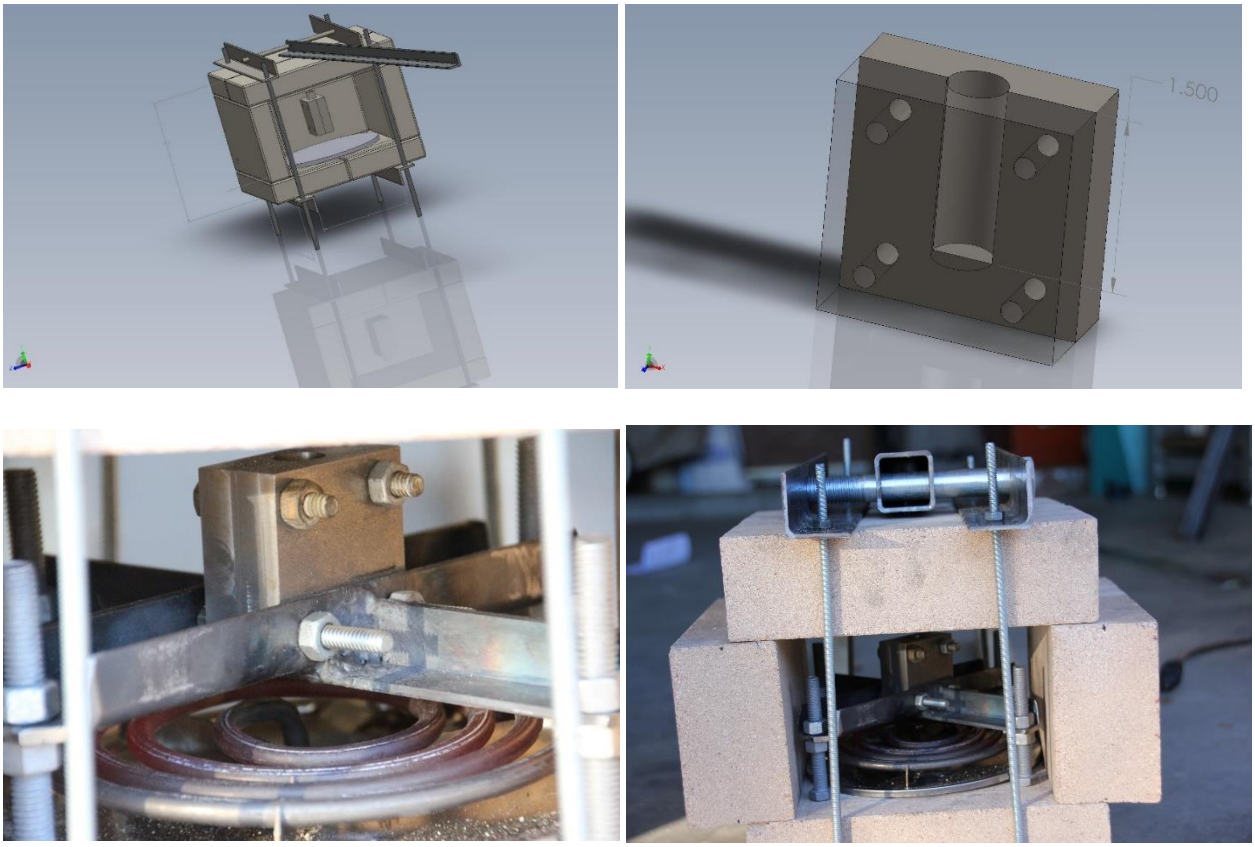



**Figure 11.** Solidworks representation of the sintering furnace (top, left). Solidworks representation of the PBA steel mold in the furnace (top, right). Built steel mold positioned over the furnace's heating element (bottom, left). Completed furnace with view showing firebrick frame (with side bricks removed for observability), pressure mounting mechanism (top of image), heating element, and steel mold (bottom right).

A special furnace that allows for such a process has been designed and built. The design was done using Solidworks software. The welding was performed in the garage of Mr. Fritz Wagoner. The thermal expansion coefficient was measured through two different methods. At high temperature (300K-350K), an extensometer of an Instron testing machine with an oven was used. At low temperatures (250K-300K), the specimens' sizes were measured by micrometer before and after being kept in a freezer.

**Figure 12.** The Instron Machine with oven (left). The extensiometer with secured specimen in place in the oven (right).

## Results and Discussion

*3.1. PBA Powder.*

0.5 Molar solutions of $K_3[Co(CN)_6]$ and $CoCl_2$ were prepared and reacted. Twice the resulting solution's clear liquid layer of $H_2O$ and KCl was siphoned off after being diluted in 1 L of deionized water. The remaining solution was then spread thinly over a ceramic drying surface, and $Co_3[Co(CN)_6]_2$ in powder form was collected.

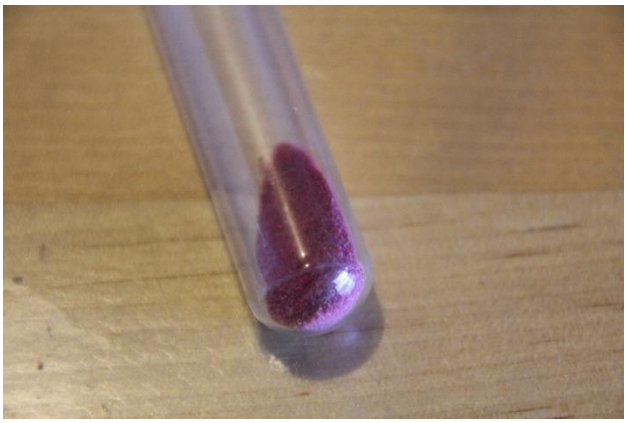


**Figure 13.** The first Prussian Blue Analog successfully synthesized.

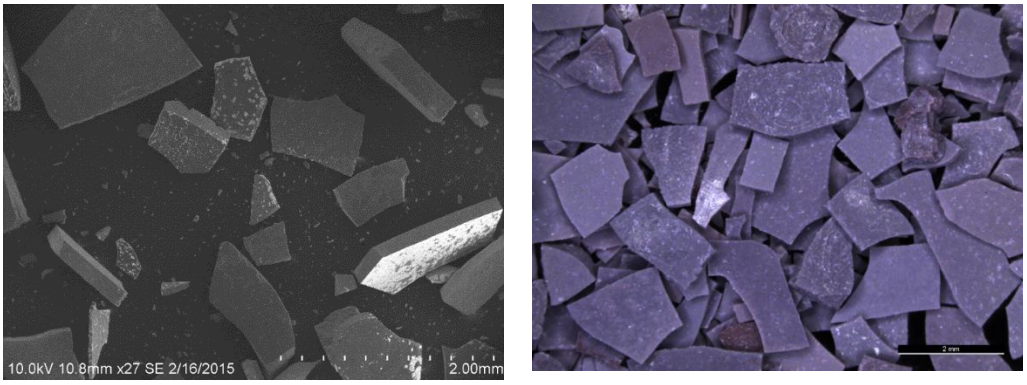



**Figure 14.** SEM (left) and optical microsope (right) imageing of the synthesized PBA. the PBA has been obtained in the form of platelets of a thickness of about 0.1 mm and a planar size of up to 1 mm.

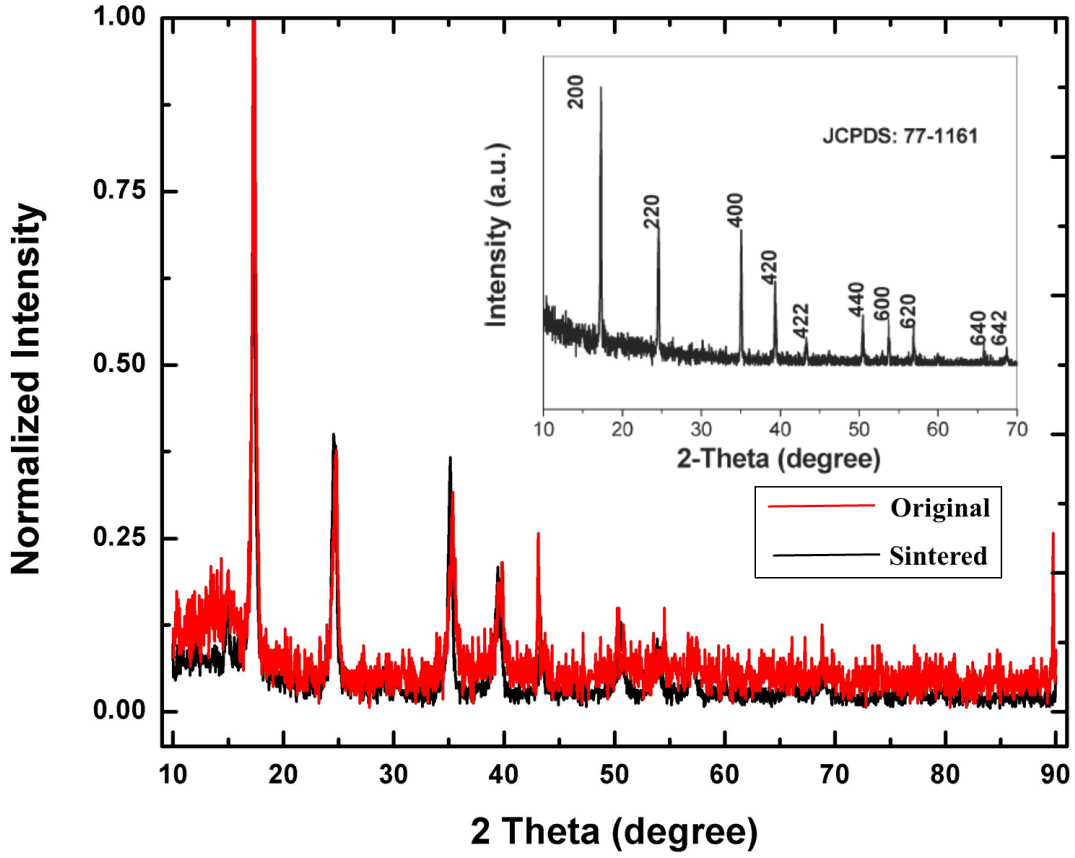



**Figure 14.** Comparison of the X-ray diffraction pattern from the synthesized PBA (shown in the bottom graph) with the standard one from the Joint Committee on Powder Diffraction Standards, Card # 77-1161 (shown in the inset, Hu et al, 2011).

The dry material was then studied using SEM and confocal microscopes and an X-ray diffractometer. X-ray diffraction patterns of the as-prepared and thermally treated powders were taken and compared with the standard pattern for bulk cubic $Co_3[Co(CN)_6]_2$ (Joint Committee on Powder Diffraction Standards, Card # 77-1161, taken from Hu et al, 2011). The main peaks corresponding to 2θ are 17, 24, 35, 38, and 43 degrees. All the reflections can be readily indexed as a pure face-centered cubic phase of the material with a lattice constant of a = 10.2 Å. These results confirm that the described precipitation method allows one to obtain the relatively pure Cobalt Hexacyanocobaltate of high crystallinity.

*3.2. Specimen Preparation.*

Two types of specimens have been made: a PBA-epoxy composite and a pure sintered PBA. Sintering was the most challenging aspect of the project, as no information about sintering of Cobalt Hexacyanocobaltate is available in literature. Numerous initial attempts were not successful – the powder was completely destroyed at a temperature of about 800 K (setting of "high"), with the carbon portion of the PBA combusting. Other unsuccessful attempts were done using a microwave oven. The successful result was obtained at a temperature about 450 K (setting of "low") under an applied pressure of 2000 psi.

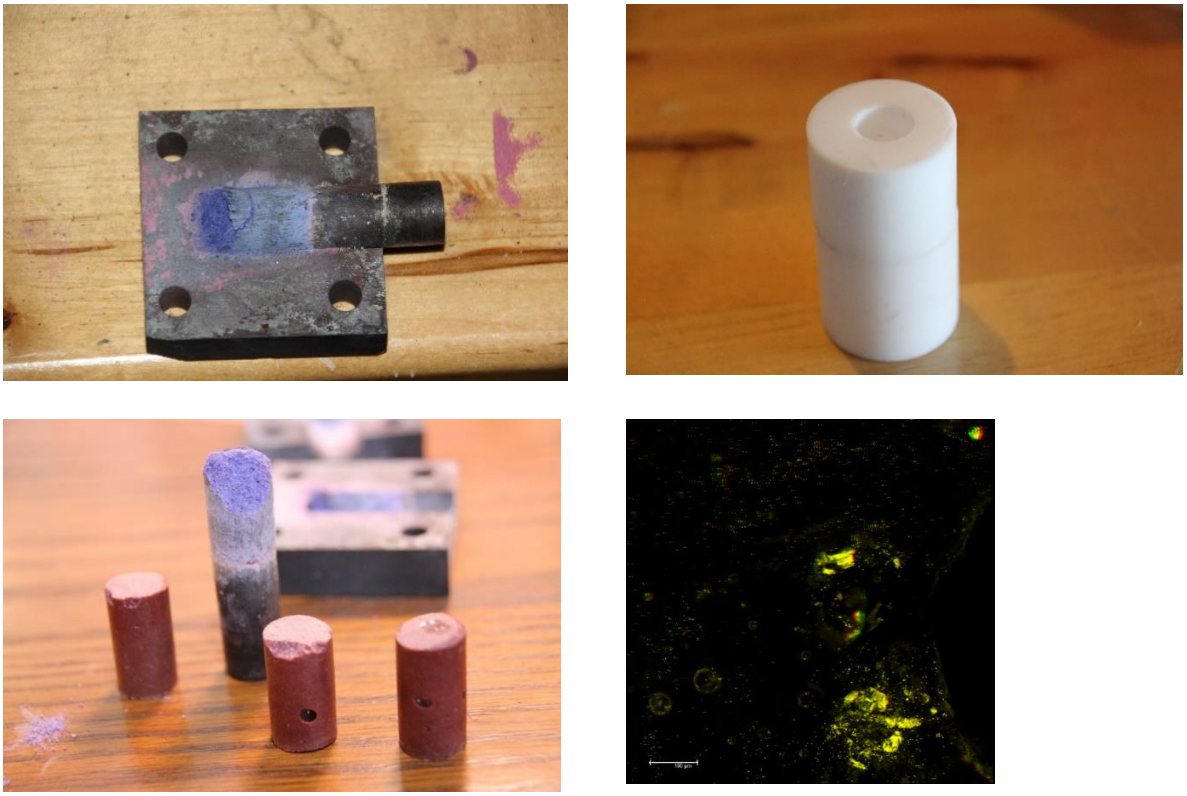


**Figure 16.** The successfully sintered PBA. Note the clear difference in color from the formed blue PBA to the purple-pink PBA on the table (top left); the Teflon molding used for formation of PBA-Epoxy composites (top right). PBA-Epoxy composites (purple) and sintered PBA together (blue) The specimens were of cylindrical shape, 0.5 inches in diameter and 1 inch in length. (bottom left). Confocal imaging of the PBA Epoxy composite (bottom right).

*3.3. Thermal Expansion.*

The coefficient of thermal expansion of the epoxy resin varies from $45x10^{-6}\,K^{-1}$ to $60x10^{-6}\,K^{-1}$. In the experiments, a value of approximately $50x10^{-6}\,K^{-1}$ has been obtained. Adding PBA powder to the epoxy leads to a decrease of this value. In specimens with a volume fraction of PBA particles of about 50%, it practically vanishes. Measurement of the diameter of cylindrical specimens shows that at the range of temperatures from 220 K to 300 K it is practically unchangeable.

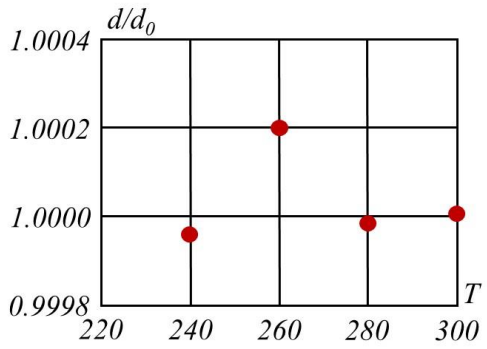



**Figure 17.** The coefficient of thermal expansion with regard to temperature for the PBA-epoxy composite measured by the micrometer at low temperatures.

More accurate measurements using the extensometer of the Instron testing machine show similar results. Temperature in the test varied linearly with time. The plots for the length change of the specimen with the attached extensometer and thermal expansion of the extensometer itself practically coincide. Subtracting one from another gives the change in length of the specimen. The plot is rebuilt in dependence on temperature.

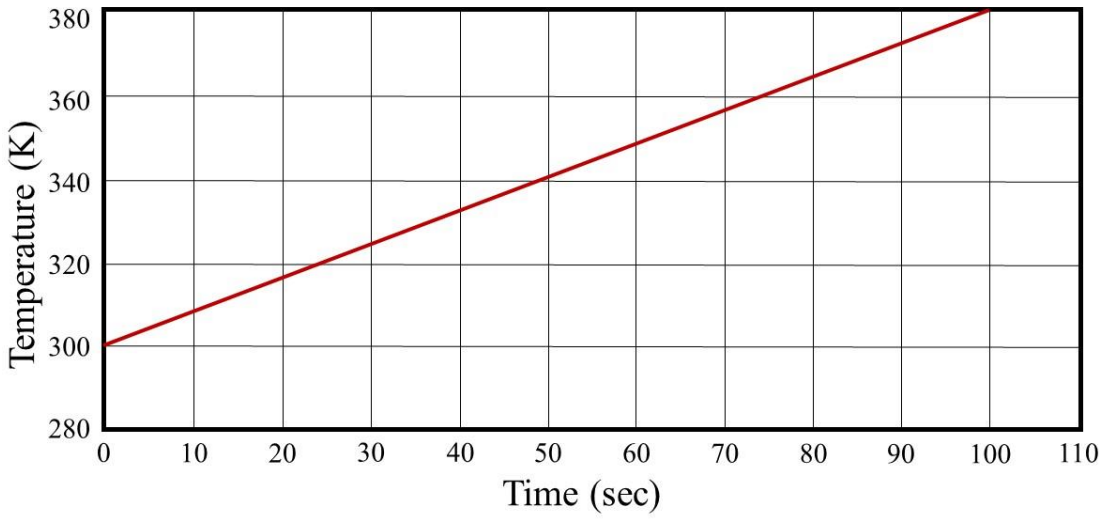



**Figure 18.** The relationship between time and temperature is linear.

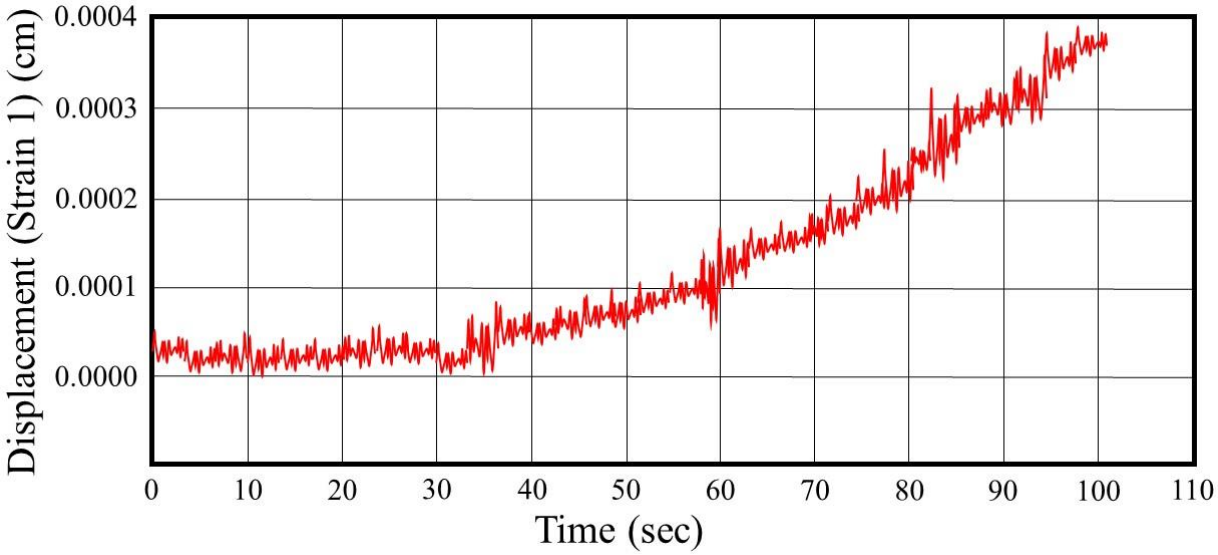



**Figure 19.** The relationship between strain and time of the PBA-epoxy composite during heating.

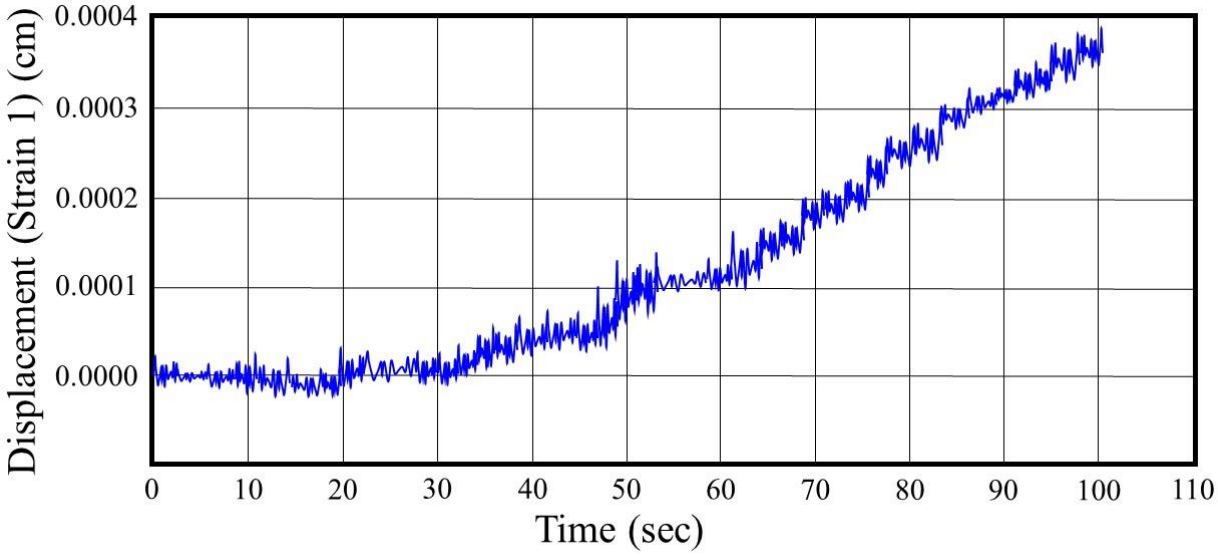



**Figure 20.** The relationship between strain and time of the extensometer during heating. Note the similarity of the graph to Figure 19.

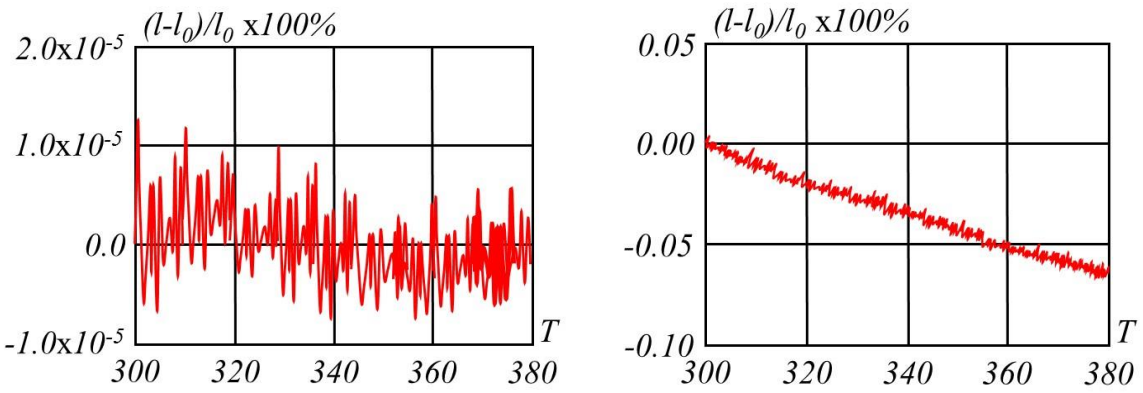



**Figure 21.** Thermal Expansion coefficient with regard to temperature for the PBA-epoxy composite (left) and for the sintered PBA specimen (right).

A similar procedure has been applied to measure thermal expansion of the sintered specimen. Slight shortening of the specimen was observed as temperature increased.

## Conclusions

In this project, a new composite material with zero thermal expansion has been developed. It consists of two phases – an epoxy matrix and Cobalt Hexacyanocobaltate (PBA) particles. PBA has been synthesized using standard chemical precipitation techniques. Its high purity and crystallinity is confirmed by X-ray diffraction. Cobalt Hexacyanocobaltate exhibits negative thermal expansion. Its particles were used to build (1) a composite with zero thermal expansion and (2) sintered bulk material with negative thermal expansion. Sintering was done in a specially designed and built electrically heated furnace with an applied pressure of 2000 psi. Thermal expansion of the specimens was measured using an Instron extensometer at elevated temperatures and via measurement of diameter change at low temperatures.

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