COLLEGE OF NATURAL RESOURCES AND ENVIRONMENT
SUSTAINABLE BIOMATERIALS
VIRGINIA TECH

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Center for Packaging and Unit Load Design

CPULD News

Quarterly Newsletter

The current edition of the newsletter contains the following exciting topics from CPULD:

- Investigation into the effect of forklift type, pallet design, entry speed, and top load on the horizontal shock impacts exerted during the interactions between pallet and forklift
- Evaluating the correlation of the containment force of stretchwrap: corners v. sides of unit loads
- Testing a sustainable alternative to plastic stretch film
- Evaluating the packaging systems of window AC units
- Other graduate and undergraduate research project info
- Alumni spotlight: Jayne Little
- Graduate student spotlight: Joe Keller
- Summaries and updates on CPULD events, conferences, and publications
- Congratulations to Mary Paz Alvarez and Saewhan Kim on their 2022 awards

Featured Research – The effect of forklift type, pallet design, entry speed, and top load on the horizontal shock impacts exerted during the interactions between pallet and forklift

Image 1. Forklifts used in the study (left to right: gas, electric, reach).

Shock impact damage is a distribution hazard that affects all pallets and unit loads, resulting in significant damages. Testing sequences have been developed to assess the resistance of pallets and unit loads to shock impact damage, and this information has been used to improve pallet design. As forklifts are widely used in the industry, common factors in these testing sequences are the simulations of forklift damage through incline impacts and free-fall drops.

The objective of this research was to investigate the effects of forklift type (Image 1), pallet design, entry speed, and top load on the horizontal shock responses. Two pallet designs were investigated during this study including a wooden and a plastic pallet design. Because the friction between the pallet and the floor could influence results, the static coefficient of friction (COF) between the bottom of the pallet and the concrete floor was measured for both pallet designs.

Two data loggers were used to measure acceleration and the horizontal shock impacts experienced during the same event on both the pallet and the forklift (Image 2). The SAVER 3X90 datalogger was mounted to the back of the fork tine carriage using Scotch permanent outdoor/exterior mounting tape. The measurements on the pallet were recorded by a SAVER 3D15 datalogger, positioned on the top lead deckboard on both pallet designs using Scotch permanent outdoor/exterior mounting tape. Data was collected from all three axial directions from both the pallet and the fork tine carriage.

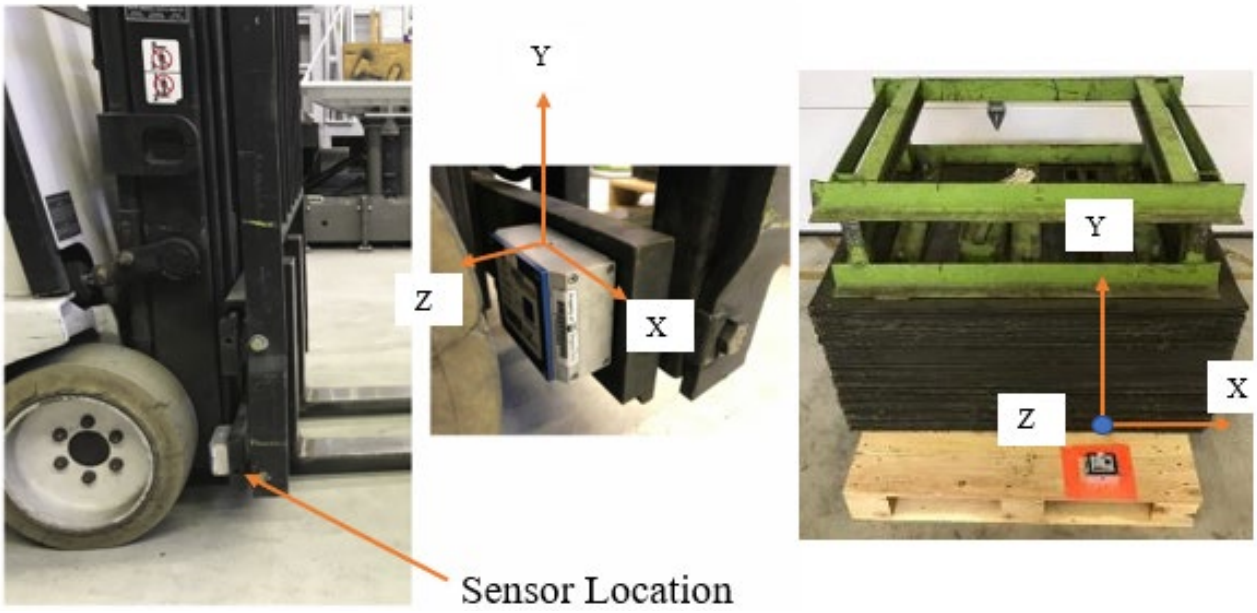

Image 2. Representative picture of: (a): sensor location, and (b): sensor orientation on the forklift; (c): sensor location and orientation on the pallet.

The acceleration, duration, and delta velocity responses registered for each forklift were recorded. The average acceleration measured on the forklifts was 2.98 G. The coefficient of variation obtained for these measurements was 37%, reflecting values as low as 1.38 G (for the reach truck) or as high as 5.1 G (for the gas forklift). The average event duration recorded was 13.6 ms. The coefficient of variation obtained for that event duration was 23%. While high, the variations found were considered acceptable as shock is traditionally considered a difficult parameter to characterize.

The acceleration measured in the forklifts was then used as the main response for further analysis. The p-values obtained in the analysis showed that all of the main factors (forklift type, pallet design, entry speed, and top load) significantly affect the acceleration experienced by the forklift during its interaction with the pallet. Similarly, the researchers found two-way interactions between most variables, and one three-way interaction was found to be significant as well, corresponding to the forklift, pallet design, and top load.

The measured acceleration response was significantly higher (15%) when the gas forklift was used, while the reach truck and the electric forklift were not significantly different from each other. However, event durations with the reach truck were 50% longer than with the electric forklift. When wood pallets were used for testing, the acceleration levels were significantly higher (20.7%). This result could be explained by the greater coefficient of friction between the pallet and the laboratory floor, which increased the resistance of the pallet to impact. When the impact speed was increased, the measured acceleration increased by as much as 32%, but entry speed did not affect the duration response.

The results showed that there was no significant difference in acceleration when the top load was increased from 227 kg to 680 kg. However, when the top load was further increased to 1,134 kg, the measured acceleration increased by 22%. This result indicates that, at least for heavy top loads, the weight of the top load needs to be tracked during data collection. Due to the changes in mean acceleration, pallet design and entry speed were found to be the most influential factors on the acceleration measured on the forklift at the moment of impact (Image 3).

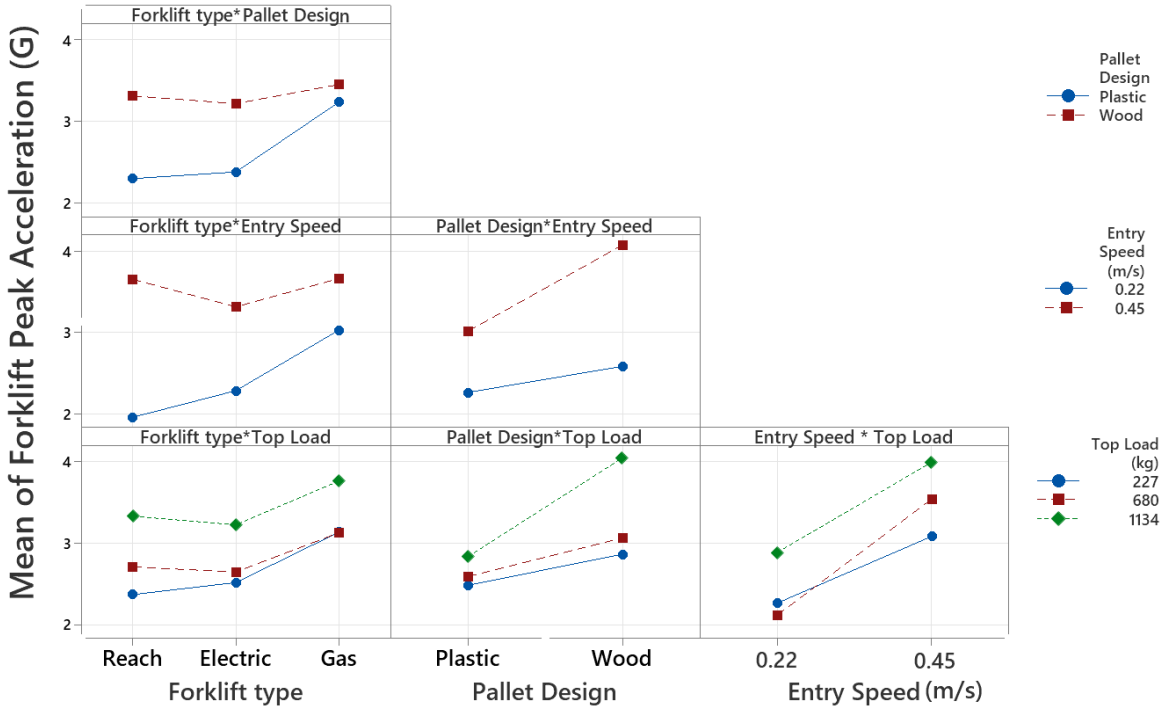

Image 3. Interaction plot for Forklift Peak Acceleration response.

This research concluded that the intensity of the horizontal shock response exerted on the pallet varies approximately 16% depending on the type of forklift used. Therefore, it is necessary to consider the type of forklift used in a warehouse when comparing acceleration intensities and their effect on your pallet durability. They also found that a plastic pallet design is associated with a 20% lower horizontal shock response in the forklift. So, caution needs to be taken during data collection in a warehouse environment because the pallet design will have a significant effect on the shock results measured. The researchers summarized that the 14% higher acceleration response that was obtained for the pallet when the speed was increased was due to increased kinetic energy during impact. An increase in the acceleration response was also found with the change in top load; however, the effect of this change was dependent on other factors such as entry speed and forklift type. The acceleration measured on the pallet is approximately 4.4 times greater than the acceleration measured on the forklift for the same impacts.

Alumni Spotlight – Jayne Little

Image 1. (left) Jayne Little, as a CPULD Intern, 2017, and (right) as a Packaging Engineer at Newell Brands, 2021.

Jayne Little came to Blacksburg from South Riding, VA. She graduated in May 2018 with a B.S. in Packaging Systems & Design and minors in both Psych & Communication. Virginia Tech had seemed like the obvious choice as her dad, aunt, and uncle all attended. Jayne told us that "I came into VT undecided, and soon switched to major in Psychology with hopes to pursue grad school following undergrad. However, I wasn't feeling challenged enough by the major and it didn't have the hands-on experience that I was looking for in college. I've always wanted to do something in design (as a kid, I went through a phase of wanting to be an interior designer) so I started to dig into packaging. The career opportunities and pathway to a career drew me in. It was very apparent to me that packaging is vital in almost every industry and I'd be able to choose which path to pursue, whether that be food packaging, CPG, industrial, etc. I didn't necessarily have a "dream job" that I was hoping to come out of undergrad with, but I knew I would have options."

Jayne enjoyed many of her courses once she switched to the packaging program. She said "the in-major classes of the PS&D program were all valuable in their own regard - but those that were most interesting to me were Packaging Polymers & Production, and Packaging Design for Global Distribution. The polymers course gave me a great first hand understanding of different packaging materials, while the design project in Packaging Design for Global Distribution was closest to a real-world project in the packaging industry. In my opinion, one of the most beneficial aspects of the packaging program at Tech was the professors & students in the major. Everyone was passionate about packaging & seeing each other succeed. This was apparent in the coursework and the guest speakers that were brought in for students to learn more about the industry."

Through her work at CPULD, Jayne learned valuable information about the ISTA testing processes and common failures that are often seen in testing. She went on to explain that "though I'm not conducting testing first-hand at my current job, it is still good to know the background & why of the testing process - especially

taking these factors into consideration when designing new packaging." She also enjoyed the variety of tasks she was assigned while working in the pallet lab. "Working at the CPULD was honestly challenging some days, as you never knew what new project to expect when showing up for work. But, this was also one of my favorite parts. Whether it was inspecting unit loads of tile, or testing a truck load of paper towels - each project presented its own learnings & takeaways that I still keep in the back of my mind today!"

After graduating, Jayne found work as a Packaging Engineer at Newell Brands in NC. She explained that "in my role, I am responsible for leading packaging development for new products launching in Europe. I work on the Writing division, so most of my work is with brands such as Sharpie, PaperMate, and Elmers. My day-to-day responsibilities include collaborating with cross-functional teams to ensure all project must-haves are met, creating specs and bill of materials for new products, and collaborating with the Newell Packaging test lab to validate any new designs through ISTA testing. I also work on cost-savings initiatives to be implemented for new/existing products at Newell. There are many ongoing sustainability initiatives in Europe, so I also work to make sure those are understood and met in all new packaging designs - this often includes ideating on new packaging designs to make sure they are plastic-free, or contain recycled content if plastic must be used."

For a while, during to the pandemic, Jayne worked 100% from home. However, she is now only working part-time from home. "I am now going into the office three times a week, along with the rest of the packaging team at Newell. Since COVID has become less prominent in the community, we've adopted a hybrid model of three days in the office with two days working from home during each week."

She has enjoyed living in North Carolina. Jayne "has found a great social circle in Charlotte to spend time with, a mix of some VT alum and new friends. Since quarantine started, I have definitely learned to appreciate the neighborhood I live in so much more by taking long walks and working out outdoors whenever possible. I love to try new restaurants in the area, but also love to experiment in the kitchen with different healthy recipes as I am also trying to maintain a healthy lifestyle by fitting in time to go to the gym after work every day."

Jayne had the following advice to offer others who attend VT. "One of the most valuable takeaways from my college experience is to never turn down an opportunity to get involved. When I transferred into the packaging major, I truly tried my best to go all-in and joined the packaging club, applied to work at the CPULD, connected with other students. Not only did this help me to make new friends in the major, but also opened up the door to so many opportunities for my career and connections that I might have otherwise missed."

Research Update – New grant from the Pallet Foundation for Sean Hobb's pallet market study

Image 1. a). Pallet Foundation and b). NWPCA logos

There are 2.6 billion pallets in circulation in the United States out of which wood pallets constitute 95% of the market. However, the pallet industry in the U.S changes continually: companies consolidate, new and sometimes quite different players enter the market, and alliances or partnerships are formed. To ensure the continued leading position of the wood pallet manufacturing segment in the U.S., it is essential to have up-to-date information regarding the current status of the industry encompassing new wood pallet manufacturing and the recycling of used wood pallets.

Our director, Dr. Laszlo Horvath, has received a new grant from The Pallet Foundation to investigation of the current status of new wooden pallet manufacturing and pallet recycling in the U.S. A comprehensive survey will be used to gain important insights to the pallet market. The survey will also be used to investigate the effect of COVID-19 pandemic on the industry. The Pallet Foundation has historically funded survey projects like this for the wooden pallet market every 5-10 years with the last market survey being conducted for 2016.

Sean Hobbs, who is a recent graduate of the Packaging and Systems Design program at Virginia Tech was selected to work on the project. Hobb's will work through the summer to develop the survey. Data collection will start in September 2022 with the survey being deployed to collect detailed trends for the calendar year 2021. In particular, this study will investigate new pallet production estimates as well as collecting info about recovered pallets and what is done with them. Hobb's will study repair and resale numbers as well as collecting data about pallet material choices. Hobbs will analyze long-term trends by comparing his 2021 results to the results of previous market studies - especially the research conducted in 1996, 2006, 2011, 2016 (by previous Pallet Foundation / NWPCA grants).

The results of the survey will be disseminated first in Pallet Central for the members of NWPCA to review. The results will also be published in an international, peer-reviewed, research journal one year after the end of Hobb's study.

Research Update – New funding from FBA and ICPF to investigate box compression strength

Image 1. Project sponsors, ICPF and FBA, logos.

Dr. Laszlo Horvath and Dr. Eduardo Molina has received new funding from the Fibre Box Association (FBA) and the International Corrugated Packaging Foundation (ICPF) for a research project focused on the investigation the effect of pallet overhang on box compression strength.

Undergraduate students, Matt Simonson (rising junior, Franklin Lakes, NJ), Alonda Johnson (rising senior, Newport News, VA) and Kyle Main (rising junior, Newport News, VA), and graduate student, Saewhan Kim (Ph.D., South Korea), have been selected to work on the project. The research will involve the testing of more than 1,900 corrugated boxes to evaluate the effect of different levels of overhang on the strength of corrugated boxes. The investigated overhang values will range from 0.25 in. to 3 in. and also evaluate multiple box locations on pallets.

The packaging industry relies on a series of factors to calculate a box's compression strength and its expected performance in the field. These parameters fall into two generalized categories: those impacting box performance because of their environment, and those impacting box performance because of how the box is being used. Current industry realities raise questions about how to truly represent what happens in a modern unit of stacked boxes. The results of the experiments conducted during this research project will be used to update the safety factors listed in the Fiber Box Handbook.

Research Update – New grant for Joe Keller's fastener study

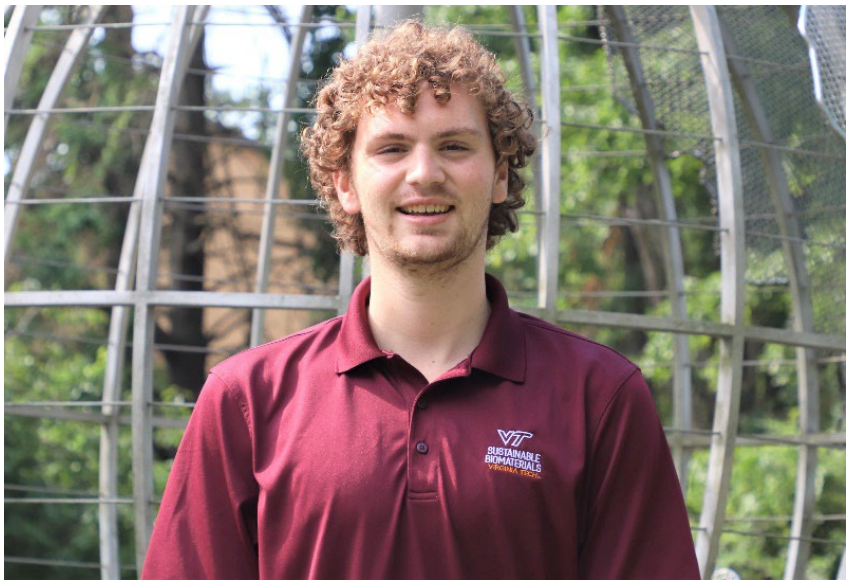

Image 1. (left) Joe Keller, M.S. student and (right) The Pallet Foundation, sponsor of this research.

Our director, Dr. Laszlo Horvath, has received a new research grant from The Pallet Foundation to investigate to predict the rotational stiffness of pallet joints made using alternative fasteners including lag screws and carriage bolts. This project will investigate and validate the applicability of the findings of previous researchers, Loferski and Gamalath, who designed a model to predict the rotational stiffness of pallet joints based on the traditionally used fasteners such as pallet nails.

Although wood pallets are most-commonly assembled with nails, heavy-duty pallets and special-purpose pallets are often assembled with other fasteners such as lag screws and carriage bolts. The strength of these types of alternative fasteners has been well documented in the literature and design codes, but the stiffness of the resulting pallet joints has never been evaluated. The model developed by Loferski and Gamalath to predict joint stiffness was never validated for pallet joints made with alternative fasteners. Therefore, the goal of this project will be to investigate the rotational stiffness of pallet joints made with lag screws and carriage bolts and to evaluate the applicability of the model developed by Loferski and Gamalath to predict the rotational stiffness of these pallet joints.

A total of six, alternative fastener designs will be investigated including lag screws (sizes 0.25", 0.375", and 0.5") and carriage bolts (sizes 0.25", 0.375", 0.5"). In order to simulate a range of wood density values, wood species with various specific gravity values will be investigated including: kiln-dried softwood, green softwood, and green hardwood. All wood samples will be measured and conditioned to make sure that the dimensions and the moisture content of the wood is known and consistent. Head embedment stiffness tests, shank withdrawal

stiffness tests, as well as moment-rotation tests will be conducted on multiple samples of the alternative fasteners.

Joe Keller (Charlottesville, Virginia), a recent graduate of the Packaging Systems and Design program at Virginia Tech, has been selected to work on the research project. Joe started his Master's research project during the Fall of 2021 and expected to graduate by May 2023. The information obtained from Keller's research project will be built into The Pallet Design System, so it will allow future pallet designers to better design wood pallets using lag screws and carriage bolts.

Grad Student Spotlight – Joe Keller

Image 1. Joe Keller

Joseph Keller came to Virginia Tech from Charlottesville, VA where he lived with his family and three sisters. He was a competitive swimmer and has run half-marathons. Joe came to the SBIO department in 2017 for a Packaging Systems and Design degree. In the spring of 2021, as he was almost done, he was convinced to pursue a graduate degree after speaking with Dr. Laszlo Horvath about the Masters research topics that were currently available to him. Joe told us that "after talking with Dr. Horvath and the other graduate students, I decided to join the program and not looked back since!"

When asked to simplify it, Joe explained the subject that he chose for his graduate research this way: "I am investigating the stiffness of a wooden pallet when using lag screws and carriage bolts to hold them together. Most pallets have nails holding them together but some companies need stiffer pallets or stronger fasteners like lag screws and carriage bolts. I am testing the exact values companies should expect from these fasteners."

We asked Joe what he felt would be one of his greatest benefits from attending graduate school, he told us, "I am hoping to gain a better understanding of the research process from writing research papers, to all of the different steps involved in research. I find it very fascinating starting out with a hypothesis for an unknown question and then through hard work finding the answer. I am currently analyzing my results that I have gathered from my research, and the results will be put into PDS which is a software owned by my sponsor NWPCA."

When asked about what other classes he felt may be helpful in his graduate curriculum, Joe initially felt "there was a big hole for me in the use of accelerometers and shock sensors, but now that I have taken Dr. Horvath's

new packaging dynamics class, that gap has been filled, and I am more confident in using those devices and the analysis that goes along with them."

Regarding his future career plans, and whether working in the pallet lab has helped him prepare for a career, Joe said "I am hoping to get a job with a large company working in a lab or as a packaging engineer. I think working in the pallet lab has set me up to go into either of these positions with a great foundation of knowledge that I can bring to a company. Learning all of the different testing standards in the lab and testing a lot of different products has prepared me well for work in the industry where I know I will be designing and testing similar products and to the same standards that I've used in the lab."

Research Summary – Undergrad research project evaluating the correlation of the containment forces of stretchwrap at the corners versus the sides of unit loads

Image 1a. Gabby Brophy (Junior) and Michael Harris (Junior) are measuring the containment force of a unit load

The movement of products has created a single world market connecting developing countries to first world nations. One of the problems that has arisen is making sure products arrive undamaged. When transporting products, they are commonly bundled together and placed on a pallet, which is called a unit load; unit load stability is crucial for the safe transit of goods. To this end, 65% of unit loads are commonly wrapped with stretch film.

The current standard for selection and use of stretch films is ASTM D 4649, which is one of the only regulated ways to compare one stretch wrap to another. The only test that reflects containment force on a unit load requires the user to pull a plate that was placed behind the stretch film outward. The stretch film itself provides the unit load with containment force, which is the technical term for how much force is required to maintain stability. Containment force is measured in pounds and there are different ranges of containment force needed depending on the unit loads' weight.

This research project was designed to evaluate how the containment forces measured at the corners of a unit load correlate to the containment forces measured at the sides of a unit load, based on various stretch wrap factors such as pre-stretch, overlap, and number of layers – and how these variables impact the amount of film needed to stabilize the unit load. This undergraduate research project was sponsored by White and Company

and the students selected to work on this project were Gabby Brophy (Junior) and Michael Harris (Junior). Both of these students are studying Packaging Systems and Design at Virginia Tech.

Image 2. Rigid test unit load with a length and width of 48 inches and a height of 50 ¼ inches constructed of plywood and lumber. Shows load cell located on side of unit load.

The researchers created a rigid test unit load constructed out of plywood and lumber. This test unit load was built as a one-piece structure designed to allow forklift handling (Image 2). To measure the containment forces provided by stretch wrap, the researchers utilized a Highlight Industries portable film cell testing kit comprising of three 100 lbs. max load cells. Two of the load cells were installed under the detached freestanding corner of the cube (Image 3) to measure the corner containment force. The third load cell was positioned to the side of the unit load, 10 inches from the top and 18 inches from the back of the cube. (Image 2). The data was recorded and analyzed using the Highlight Industries portable film force system.

Image 3. View of corner containment testing area - the 2 load cells are located 10" from the top and bottom of the unit load.

The results of the collected data demonstrated a correlation between multiple factors. The testing variables of the experiments were: the effect of layers, the effect of overlap, the effect of pre-stretch, and the effect of the overall stretch. The students evaluated how each these affected containment force and how each variable affected the total amount of stretch wrap used.

When the number of layers increased, the measured containment force increased for all scenarios. The greatest increase, of 19.69%, was found for the corner containment when the number of layers increased from 1 to 3. When the percentage of overlap between the different film layers increased, the amount of containment force also increased. The greatest increase, of 19.61%, for the corner force measurement, was found when the overlap was increased from 29% to 74.6%. This shows that as more layers are added to the unit load, the containment force will increase exponentially.

However, as the pre-stretch setting on the machine increased, the containment force decreased. This makes sense because, as the film gets thinner through the pre-stretch process, less containment force can be applied to the unit load. While the overall stretch had a negative effect, it was minimal.

From all of the testing done, one of the most significant findings was the correlation of 1 lb. of compression force measured on the side, from the ASTM pull plate method, correlated to 8 lbs. of containment force on the corner load cells. This project allowed the packaging students to gain more experience with the stretch wrapping equipment and get hands-on experience in determining the effect that the various factors had on containment force. The results of these experiments will be used by the sponsor to expand the capabilities of their unit load design software called Best Load.

Research Summary – Undergrad research project testing a sustainable alternative to plastic stretch film

Image 1(left). Highlight Brands Synergy 4 High Profile Wrapping Machine applying new, sustainable, paper stretch film and (right) unit load wrapped with typical plastic stretch film.

The packaging industry has recently started to take steps to address concerns about the environment regarding waste and pollution because packaging is estimated to make up 40% of the 250 million tons of total annual waste, and it makes up 50% of the total plastic waste globally. Packaging companies are trying to create eco-friendly packaging, which includes edible, bio-based, and biodegradable materials obtained from renewable resources. Although, the industry created 125,000 tons of bio-based packaging materials in a recent year, the majority of the 100 million tons of packages were still made from petrochemical-based plastics.

To exemplify tangible advances in sustainable packaging development, packaging companies have taken strides to alter plastics and focus on similarly functioning alternatives. In particular, the international packaging world has taken an active interest in sustainable stretch films. This research project was sponsored by Westrock. Undergraduate students, Gracie Dixon (Junior) and Shak Kataev (Senior) were selected for the project. The students were supervised by Saewhan Kim who is an MS student studying sustainable packaging. The goal of the project was to evaluate the potential of an alternative type of sustainable paper wrap to be used as a load stabilizer.

This series of experiments focused on testing unit load stability with two different wrapping materials: typical plastic LLDPE stretch film and a new, stretchable, paper film. The tests conducted during this experiment were

an incline impact sway test, a 22-degree tip test, a rotational edge drop test, and a series of tests within the ISTA 3E standard of testing unit loads.

Different wrapping patterns were used to determine how the films would be applied to the unit loads. These patterns are called recipes. The chosen recipe is determined by the vertical speed of the spinning carriage, the amount of overlap, the amount of pre-stretch, the number of wraps on top and bottom, and a film force multiplier. These variables factor into the unit load's stability after it is wrapped.

Identical unit loads were wrapped with four different recipes of the new paper film, and as a control, another unit load was wrapped with a plastic stretch film, and they were all tested the same. The unit loads that were wrapped with the paper film were evaluated for the new film's potential as a viable alternative to the plastic stretch wrap. Measurements of the total sway and total slip were taken throughout the entire experiment. During the impact tests, the unit load's sway and slip increased with each impact until the plastic wrap failed to contain the unit load. At that point, product trays ripped through the plastic wrap and fractured the stacked unit load. Comparatively, the plastic film stretched but suffered no corner damage, while the paper wrap tore at the corners of the pallet where the paper wrap overlapped the products trays and the pallet, but it did not fail entirely as the plastic-wrapped unit load did. Ultimately, the plastic wrapped unit load failed at the 4.12 ft/s impact speed while the paper wrapped unit load remained mostly intact, except with the bottom corner tear (Image 2).

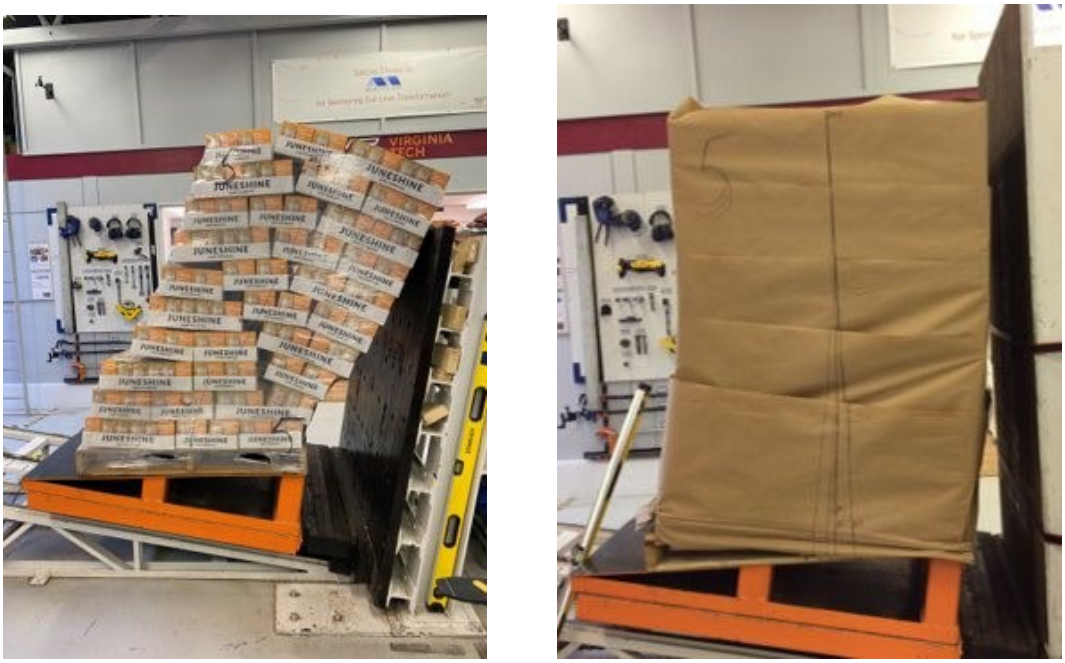

Image 2. Showing plastic-wrapped unit load failure (left) versus paper-wrapped unit load's performance (right) during incline impact tests.

This study showed that during the Incline Impact and 22-Degree Tilt Tests, the paper wrap performance was superior to plastic stretch film. This indicates that sudden stops are better-sustained by the paper film than plastic film. However, the Rotational Edge Drop Test results indicate the plastic film can handle more limited drops. The overall unit load was very slippery, which resulted in sliding during certain tests. Ultimately, this could have been one of the biggest factors in this research. If the product trays had been manufactured from a different material, there would have been a different coefficient of friction.

Once the paper film began to tear on the corners, the unit load became unstable. The tears increase in length and spread over repeated impacts as the tension acquired during the wrapping procedure is lost. Since the corners were the biggest failure during the paper film testing. This could be prevented by adding corner stabilizers to give more protection.

Although the paper wrap has a potential to be an effective load stabilizer for certain types of unit loads, further research will have to be conducted to fully understand the limitations of this technology.

Research Summary – Undergraduate research project testing the packaging systems of window AC units

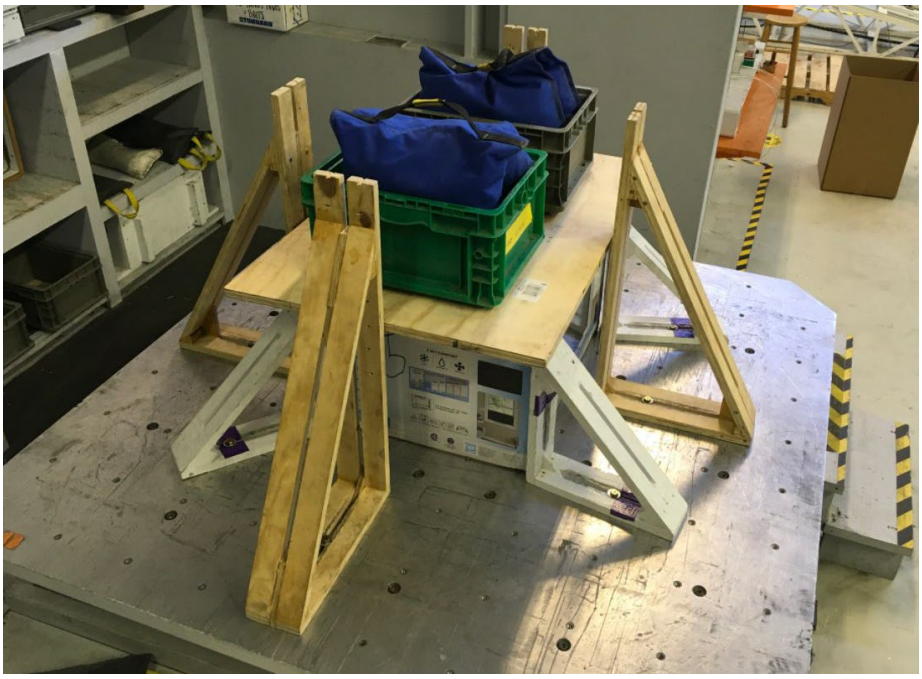

Image 1. Vibration testing of one of the AC units

One of the largest appliance manufacturers sponsored an undergraduate research project during the 2021-2022 school year. They asked their assigned student group to investigate the packaging systems for their window AC units as compared to many of their competitor's packaging versions. Rosa Williams (Sophomore) and Rohan Sarathy (Senior) were selected to work on the project.

Many international companies suffered from the increased supply chain costs and delays due to the COVID-19 pandemic and were forced to deal with the repercussions of the escalating US-China trade conflict; however, this project's sponsor actually saw an increase in export sales due to the increased demand for sterilization features in home appliances such as air conditioners, humidifiers and washing machines which were already built-in features in their brand.

There were 11 different air conditioning units, each of them produced by a different company, that were sent to the testing facility. Most units were packaged into corrugated boxes and protected with molded Styrofoam cushion. Some designs had additional straps that provided added containment and one unit was secured with a stretch wrap.

The students received two packages from each AC design. The first package was used for a packaging performance evaluation using the ISTA 6 Amazon Type B testing standard. This testing sequence included a drop test, a horizontal compression test, vertical compression, four vibration sequences (Image 1), and finally a second drop sequence. Each design that completed testing underwent a thorough inspection to determine any internal damages, structural or cosmetic, to either the product or the packaging materials, that was not visible during the testing sequence. Depending on the performance throughout the testing sequence and inspection, each design was given a grade of Pass or Fail.

The second package was used to create a detailed bill of materials for each product. The goal was to understand the different packaging approaches that the different companies are employing to protect their products.

Sustainability is rapidly becoming more meaningful to consumers. In order to assess the units based on their sustainability, two ratios were used. Packaging efficiency was calculated through the ratio of product weight to packaging weight. Another ratio used the ratio of recyclable packaging materials to total packaging material

weight. A sustainability score was calculated by adding these two ratios together, with higher numbers being more sustainable (Image 2). Design 5 ended up being the most sustainable package, with a sustainability score of 13.77. However, there was no relationship between the packages' sustainability and their ability to pass the testing; all package designs ultimately failed due to vent damage and other failure modes.

Design #	Total Weight (lb)	Recyclable (lb)	Non-recyclable (lb)	Product (lb)	Product: Packaging Ratio	Recyclable: Total Ratio	Sustainability Score	Ranking
I0005- D1-2	82.0	9.886	1.610	70.5	6.13	0.860	6.99	11
I0005- D2-2	69.8	7.689	3.702	58.4	5.13	0.675	5.80	10
I0005- D3-2	55.2	3.002	1.742	50.5	10.64	0.633	11.27	2
I0005- D4-2	54.8	3.2	1.984	49.6	9.54	0.618	10.16	4
I0005- D5-2	54.0	2.695	1.145	50.2	13.06	0.702	13.77	1
I0005- D6-2	53.6	2.8810	1.819	48.9	10.40	0.613	11.02	3
I0005- D7-2	53.6	3.391	2.688	47.5	7.82	0.558	8.38	7
I0005- D8-2	53.0	4.090	2.914	46.0	6.57	0.584	7.15	9
I0005- D9-2	53.4	2.317	2.878	48.2	9.28	0.446	9.72	5
I0005- D10-2	53.6	3.277	2.652	47.7	8.04	0.553	8.59	6
I0005- D11-2	53.2	3.706	2.976	46.5	6.96	0.555	7.52	8

Image 2. Sustainability ratios and ratings of AC packaging designs 1-11

Although most of the designs failed the test, the students got valuable information on the model of failure that helped the company improve the packaging design. One of the interesting failure mode that the students observed was the failure of the tape that sealed the flaps of the package. A tape failure causes the box to lose containment and thus compromising its ability to protect the product. Amazon considers this damage as an automatic failure. Tape failure is a common failure mode during the Amazon testing thus packaging engineers are encouraged to use higher quality tape to avoid the expensive retesting cost and also damages during actual shipping.

The following semester, the students will work on redesigning the packaging system for one of the AC units with the goal to create a fully curbside recyclable packaging.

Research Highlight – Undergraduate exploration of insulated shipping containers for cold chain

Image 1. Mark Brumnbaugh measuring a Home Chef meal kit box.

A partner company of CPULD recently sponsored a project for the undergraduate students in the Packaging Systems and Design major. The project was to investigate multiple major meal kit companies to assess their packaging in terms of effectiveness and sustainability. Mark Brumbaugh (xyz from abc) and Livvy Do (xyz from abc) were selected to research meal kits from Dinnerly, HomeChef, and Blue Apron, as well as meal kit specific packaging from Smurfit Kappa, Daily Harvest, PaperLiners, KodiaKotton. These particular kits and packaging were selected in order to provide a wide range of packaging/insulation types for this research project (Image 2).

Image 2. Types of insulation/packaging being evaluated for meal kit and packaging companies.

The students measured (Image 1) and recorded (Image 3) everything that belonged in the meal kits, then repacked it all with the applicable insulation/packaging combinations and included a datalogger, Easy Log-USB-2-LCD, in each box as well as cold packs to fill the remaining space in each box. The boxes were sealed with one strip of tape across major box flaps and monitored for 2-3 days or until fully equilibrated with room temperature. The testing procedures used were based on the ISTA 7D Temperature tests for transport which included preconditioning, testing in a moisture-controlled chamber, and constant temperature measuring. The average performances of three or four samples of each brand/packaging combination were recorded and analyzed for their temperature performance, weight and volume efficiency, and sustainability level.

Image 3. Livvy entering data from testing meal kits.

The various meal kits maintained their temperature under 5 degrees Celsius for 30.1-54.1 hours with an average 41.7 hours. The weight efficiency was found by dividing the total weight of the package by the weight of the insulation only – a lower percentage is a better rating as it means they needed less insulation weight to keep their meals at the desired temperature. The meal kits tested showed weight efficiency ratings of 33.3% to 71.4% with an average of 52.28%. The volume efficiency is a slightly different way of measuring basically the same thing. In this case, the volume of the insulation is divided by the volume of the container. For volume efficiency, a higher percentage is better, as it means the whole meal kit is more efficiently packed which means it will be less expensive to distribute. The meal kits tested ranged from 51.1%-97.3% with an average of 77.12%.

Sustainability is a major concern with most modern companies, and the packaging field is no different. The various types of packaging/insulation tested in this project were given a sustainability rating based on their recyclability and biodegradability. In this area, the foil liners used by the Blue Apron brand received the lowest

sustainability score as their foil is neither recyclable nor biodegradable. The Smurfit Kappa and the PaperLiner brands received the highest ratings as their packaging/insulation combo is both recyclable and biodegradable.

Overall Ranking

Solution	Temperature Performance	Weight Efficiency	Volume Efficiency	Sustainability	Ranking Total
Home Chef	4	1	2	4	11
Blue Apron	2	2	1	7	12
Daily Harvest	3	4	4	3	14
Dinnerly	1	3	5	5	14
Paper Liner	5	5	7	1	18
Thermobox	6	6	6	1	19
Kodiakotton	7	7	3	5	22

Table 1. Overall ranking of the various packaging/insulation combinations tested.

All data was combined to create an overall ranking of all packaging/insulation combinations that were tested (Table 1). The best temperature-controlled meal kit was the Dinnerly brand (Image 4) which stayed at 5 degrees Celsius for 54.1 hours. Dinnerly used encapsulated cotton liners and a polymer made from LDPE. The best meal kit, in terms of sustainability, was the Daily Harvest brand which used insulation made from paper and inflated plant-based starch which resembles Styrofoam but is 100% recyclable. However, the best ranking overall went to the Home Chef brand (Image 5) which used PET fiber sheets and #1 plastic, both of which are recyclable and helped maintain temperatures while having good volume and weight scores.

Image 4. A.) Dinnerly brand, the best temperature-controlled meal kit in packaging and B.) HomeChef brand, the best overall scored meal kit in packaging.

Employee Spotlight – Nicolas “Nico” Navarro

Image 1. Nicolas Navarro, Project Manager

Our packaging team at the Center for Packaging and Unit Load Design has been expanded with a new project manager. Nicolas Navarro is a CPULD alumni who is originally from Costa Rica. Nico works in the pallet testing lab, taking over more and more of the daily running activities of a busy laboratory. He manages the student workers, organizes daily tasks, plans project with our outside customers, among many other responsibilities. He has already proven himself a great new asset for Center!

Nico always wanted to travel and pursuing higher education gave him a good excuse to follow that dream. He told us that he “had always wanted to pursue university studies outside of my home country, and at the time of my graduation from Costa Rica Tech, Virginia Tech provided me with an excellent opportunity to fulfill this dream given VT’s strong academic reputation, benefits, and college campus. I initially chose to study industrial engineering because it provided a blend between management and engineering concepts. The idea of developing competence in a technical subject and then applying management skills to lead change appealed to me.”

“I graduated in the summer of 2020 after completing two master degrees in both Packaging and Industrial Engineering. During my time as a graduate student, I conducted exploratory research about the use of Internet-of-Things technology in pallets. After my graduation, I worked as a Field Application Engineer at JFR Holdings in Hanover, and Auburn, Pennsylvania.”

“I came back to Blacksburg on February 2022, to join the Center for Packaging and Unit Load Design as a project manager. I am very excited and happy to be back. One of the best parts of working at the Center is learning to deal to a wide variety of different engineering and management challenges during the projects that we conduct for our clients. Our labs are all about hands-on engineering, where you can actually see the how the

material learned in classes translates to a practical and real application. Our students acquire valuable skills in understanding problem fundamentals, and project management."

Nico finished up by sharing a little about himself personally. "When I am not at work, I am usually working out at the gym, running on the Huckleberry trail, or reading at home. I enjoy reading philosophy, history of philosophy, politics, science, and also fiction novels. Other hobbies include hiking, visiting museum and art galleries, traveling, and hanging out with friends."

News – Saewhan Kim wins H.E. Burkhart Outstanding Masters Student award.

Image 1. Saewhan Kim with the H.E. Burkhart Outstanding Masters Student award.

CPULD is proud to announce that our graduate student, Saewhan Kim. was awarded the H. E. Burkhart Outstanding Masters Student award for 2022. At the time of his award, Saewhan was pursuing an M.S. degree in Forestry and Forest Products. His major professor, Dr. Laszlo Horvath, told us that he "has had the chance to work with Saewhan since 2020 when he was accepted into the graduate program in my department. His research focuses on understanding and investigating the environmental impacts of a novel unit load design method that uses the stiffness of a pallet top deck to optimize the corrugated box design. The results will be built into a commercial computer software which will allow companies to reduce the amount of corrugated board needed by designing boxes and pallets holistically."

In addition to his own research, Saewhan has been working at the Center for Packaging and Unit Load Design two days a week as a Graduate Laboratory Manager for the pallet lab. He has been responsible for ensuring that our testing and design projects are completed on time and with the required accuracy. Saewhan has also mentored five undergraduate students through their senior design projects. And he is already actively involved in the packaging community. Saewhan has been a member of the International Safe Transit Association (ISTA) since his first year at Virginia Tech. And, he also successfully obtained two major industry certifications: ISTA CPLP Technician and Technologist levels, which are generally reserved for industry professionals with multiple years of experience.

Dr. Horvath told us that Saewhan's "research progress is exceptional. He already has two conference proceedings and two conference presentations. In addition, he has one peer-reviewed article published and two under preparation. He is a natural leader and a great mentor for undergraduate students. Based on his academic and research performance, I would categorize him into the top 5% of students I had a chance to work with."

Due to his outstanding research, Saewhan was accepted to continue his studies as a Ph.D. student under DR. Horvath's mentorship, working towards achieving his final goal of being a faculty member in a major research university.

News – Mary Paz Alvarez wins Outstanding TA award from our college

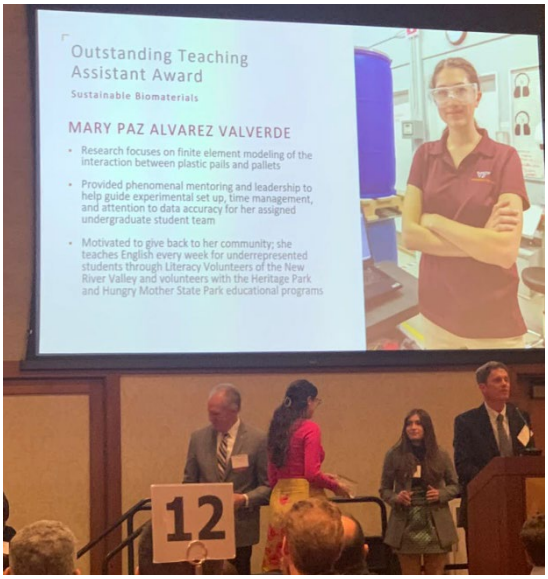

Image 1. Mar Paz Alvarez (left) walking across the stage to accept her Outstanding Teacher's Assistant Award and (right) holding the award plaque.

CPULD is proud to announce that our graduate student, Mary Paz Alvarez was awarded the Outstanding Teacher's Assistant Award for 2022. Mary has been with our department since 2019 when she was accepted as an M.S. student. Her research focuses on the interactions between plastic pails and pallets. Her results will be built into a commercial computer software which will allow companies to design safer and more sustainable unit loads by designing pallets specifically to optimize the plastic materials used in pails. Mary told us "now that I have successfully defended and published my master's thesis, I have begun my work on my PhD, working side by side with the National Wooden Pallet and Container Association to create a finite element analysis model based on my previous work."

But parallel to her research projects, Mary spends days each week as a Graduate Laboratory Manager coordinating the day-to-day operations and supervising the undergraduate students in the Pallet Lab. She has also assisted in the teaching of multiple undergraduate classes each semester, and she has been responsible for mentoring undergraduate student teams and guiding them through research projects. Her major professor, Dr. Laszlo Horvath told us that "Mary did a phenomenal job helping the students with their experimental setup, keeping them on track, and ensuring the accuracy of the generated data."

To gain additional experience, Mary took on more than just teaching responsibilities. She has designed and taught multiple laboratories related to ISTA testing. She taught a module related to the effect of atmospheric conditions on packaging performance and developed a new lecture on the use of packaging standards. She was responsible for another module related to unit load interactions which included the development and administration of an exam to assess how well the students understood the topics she'd taught them. She has also worked to coordinate laboratory exercises, helped students during their industry-sponsored class projects, and graded exams and homework.

Regarding her teaching experiences, Mary told us, "My favorite class to help out with was global distribution since the students are not only learning incredibly relevant information, but they're also working on projects that go into their permanent portfolios. I love seeing students experience the engineering design process - they

have to sit down and think about where their packaging went wrong and how it could be better. Every year I've been impressed by how creative some of our students can be when they're given an opportunity to show it off."

And, in reference to her work with undergraduate student teams, Mary told us that "my role in their work is to be a point of contact and the person that trains them on equipment. More importantly, I am their mentor which means I am to be supportive and guide them through the research process. It has been fulfilling to see students succeed and understand the importance of their work while also having to work through the difficulties of research. I worked closely with my students since they began their research under my supervision and training. As time progressed and their comfort grew with the equipment, they earned their independence, and we began to work more closely as colleagues instead of a student and teacher. Mentoring students has been one of my favorite experiences since I am able to communicate with my students and spend more time with them more personally."

According to Dr. Laszlo Horvath, "Mary completely exceeded our expectations by assisting the students during their design projects and mentoring them throughout the project. She both encouraged and helped the students. Despite her high workload, she did a great job, and the students highly praised her work and dedication. She is a natural leader and has been a great mentor for many undergraduate students."

Mary is already active in the packaging community; she is a member of the International Safe Transit Association (ISTA). She has also successfully obtained two major industry certifications: ISTA CPLP Technician and Technologist levels, which are generally reserved for industry professionals with multiple years of industry experience. She is also committed to becoming the best teacher possible; thus, she has already completed the Future Professoriate certificate offered by the graduate school and is currently beginning coursework to earn an Engineering Education certificate. Mary is actively involved in two service fraternities, and she has been a graduate student coordinator for the Graduate Research Symposium. She is also motivated to give back to her community; thus, she teaches English every week for underrepresented students through New River Literacy.

Mary is also passionate about educating young kids about environmental topics. Through her service fraternities, Mary has helped local school teachers as well. She explained that "I have worked extensively with the Blacksburg public school system and parks system, mainly Kipps elementary school and parks around the New River Valley. My work with the elementary school revolves around general STEM education, so I go to the elementary schools and help science teachers with the hands-on activities that she has planned for her class. My fraternity also plans and coordinates STEM classroom days where we develop and teach our own lesson plans."

Due to her outstanding research progress, Mary decided to continue her studies as a Ph.D. student under Dr. Horvath's mentorship in order to achieve her final goal of becoming a faculty member at a major research university. Throughout all of these experiences, Mary believes that her coursework "led to me gaining a better understanding of higher education and what type of teaching strategies can help my students. Part of being a good teacher and mentor is being able to learn and change as time goes by to make sure that my students are succeeding and enjoying the coursework. I not only teach and mentor my students, but I am constantly looking at how to improve on my own skills to create better student experiences."

News – Saewhan Kim presented for CPULD at national ISTA conference

Image 1. Saewhan Kim presenting at ISTA TransPack conference.

CPULD was proud to have graduate student, Saewhan Kim, present his research findings at the ISTA TransPack global industry conference and forum in 2022. This is ISTA's signature, annual event where the packaging community comes together to tackle today's challenges and shape the future of transport packaging.

Saewhan shared the findings of a research project that he led and oversaw during the 2021-2022 school year about a new type of sustainable, paper-based, stretch film that can be used for unit load stabilization. Although the properties of the usual plastic stretch film make it an excellent material to effectively stabilize unit loads, the fact it is derived from fossil fuels and difficulties in recycling plastic stretch film creates a significant environmental burden.

Due to environmental concerns and in order to try and reduce the effects on global warming, major companies are showcasing their commitment to sustainable packaging by looking into other unit load stabilizers. Recent developments in paper science have allowed for the creation of a stretchable paper that can be used as a more sustainable alternative to plastic stretch films. The goal of the current project was to investigate the applicability of this new paper wrap to stabilize a unit load of carbonated beverages.

Saewhan's series of experiments focused on the comparative testing of the unit load's stability while contained by the two different wrapping materials: plastic LLDPE stretch film and a stretchable paper film. The unit load was wrapped with the paper film and then tested. The paper film was evaluated for its potential as a viable alternative to the also-tested, plastic-wrapped, control unit load. The total slip and sway were measured throughout the experiment.

The control unit load's slip and sway increased with each impact until the plastic wrap failed to contain the unit load. Compared to that control unit load, the unit load wrapped with paper wrap, recipe 1 slipped 99% to 200% more. This was mainly due to the torn corners of the paper wrap at the point of contact with the pallet corners, which caused the paper's failure to hold the unit load from slipping. However, the degree of product slip was not enough to affect the unit load stability since ample bottom-surface of the product was still sitting on the pallet. The slip results showed that paper wrap could be used on unit loads with a small underhang without film failure. On the other hand, the control unit load consistently experienced from 20% to 161% more sway than the paper wrap, recipe 1 unit load after each impact. Excessive sway on the control unit load led to unit load collapse, whereas the paper wrapped unit load remained stable after same speed impact.

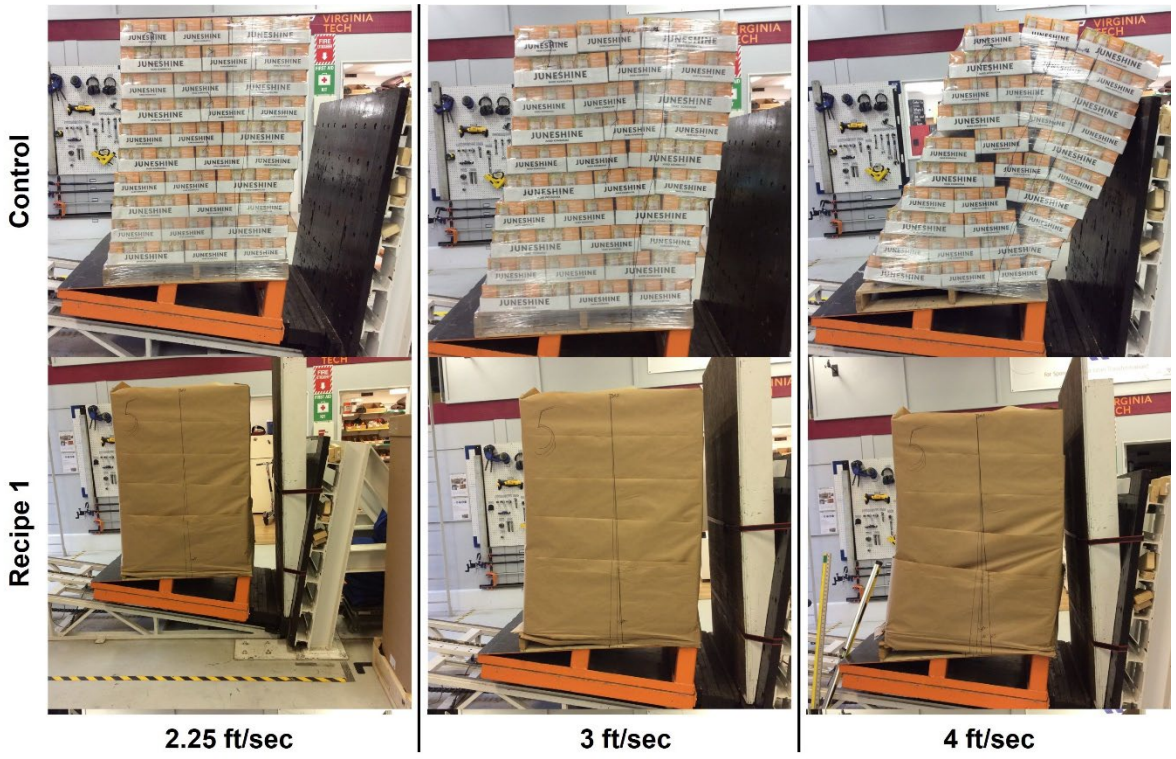

Image 2. Plastic versus paper wrapped unit loads during incline impact tests.

In short, the paper wrapped unit load showed exceptional load stability performance. It was inevitable that a unit load would need to use more paper materials to get the same or better performance compared to plastic stretch film because paper wrap was not initially engineered for unit load stabilization purposes. It was found that paper wrap requires from 5.92 times to 8.55 times more material in terms of weight to reach the same or better stability performance on a unit load.

However, the new paper wrap can still be an effective alternative to plastic stretch film if the industry aims to eliminate fossil fuel-based materials from its supply chain since the paper wrap can provide superior performance for stabilizing unit loads. Many other load stabilizer options exist in the industry, but they are mostly fossil fuel-based products or unit loads need to meet specific circumstances to use them. In contrast, paper wrap could be widely applied to most unit load configurations with similar or better performance.

News – Mary Paz Alvarez traveled to Europe as a Global Perspectives Program scholar

Image 1. a). Mary Paz Alvarez during her travels to Europe and b). posing on an art installation and seating area made from used pallets.

CPULD is proud of PhD student, Mary Paz Alvarez, for being selected for the Global Perspectives Program here at Virginia Tech. Along with fifteen students, and two VT faculty members, Mary traveled to Switzerland, France, and Italy during May 2022. Per the graduate school website, the Global Perspectives Program (GPP) is an example of a program through which VT graduate students are prepared to be global citizens. The purpose of GPP is to enable VT's graduate students to "examine differences in academic practices and to develop innovative and effective approaches that foster international awareness and education. The program provides firsthand experiences that help each participant acknowledge the differences around the world and embrace a perspective beyond their own country of origin."

Mary told us that all of her colleagues on the trip were from different academic backgrounds, but that all have an interest in working in higher education. She went on to explain that "the main goal of the trip was to learn about the higher education structure and differences between higher education within Europe and comparing it to the United States. We also wanted to expand our views of higher education beyond the scope of Virginia Tech and think about ways to incorporate what we saw into our own teaching experiences. Additionally, we each have our own individual learning goal - mine was learning about students with disabilities and their experiences in higher education in Europe."

Through these travels, Mary quickly recognized many differences in the European higher education. "There are differences in higher education before higher education even begins," she told us. "Europe has a different system for their students while they're still navigating high school - they can begin learning about vocational or

University subjects and begin specializing at a younger age. In the US, students are not provided a specialized education until they are in College. One of the largest differences is that Europe has the Bologna Process where students go through 3 years to earn their Bachelors, 2 years for their Masters and 3 years for their PhD - and students have to complete their masters in order to move into a PhD."

Mary further explained that "in the United States we typically expect 4 years to complete a bachelors, 2 years for the masters, and an undefined amount of time for the PhD. In Europe, PhD students are also seen more as instructors and workers at the university instead of students. They have a different balance between research and teaching than what we see in the US. Also, in the US, PhD students have to take course work which is not the norm in Europe. In the US, PhD students have different levels of involvement, and there is no standardization of these engagement levels; it fully depends on the individual student."

Image 2. Mary attending a lecture by Dr. Alexander Hasgall, Head of the European Union Association's Council for Doctoral Education on the future of "Higher Education in 2030."

Her GPP travel included visits to universities, laboratories, libraries and more. Mary especially enjoyed her visit to SUPSI in Switzerland because it reminded her of the Pallet Lab in CPULD where she works. In her words, "visiting SUPSI in Switzerland was especially impactful since the institution focuses on applied sciences where students can work hands-on in labs and there is a blend of industry, student research, and learning. Our own packaging program would fall into a similar category since students have to take labs and do relevant industry projects in order to earn their degree - other European universities had a more theoretical approach to their programs, but I personally enjoy teaching and learning in labs so seeing those types of spaces is always motivating."

Mary also enjoyed her visit to the University of Basel's library. She told us that visiting the "library was super interesting - the library and conservation team pulled out some incredibly significant documents that are being stored at the University such as original hand-written Bible annotations by Erasmus, original maps of Paris from the 1600's, and many more documents. It was interesting from the standpoint that these documents are older than the United States and each documents impact on our world's history. The role of libraries are unique at each institution, and I had never been to a library that was dedicated to document conservation and preservation before."

Image 3. Mary attending a tour of the University of Basel's newly constructed Biozentrum, a leading, worldwide institute for molecular and biomedical research.

Mary learned a lot from the Global Perspectives Program. However, meeting others with the same passion for higher education and realizing that all issues are global issues are what she valued most about her travels. "The best part of the trip was establishing and growing my own global network. It's refreshing to leave your institution and see that your institution is not the only group struggling with modern issues; most issues are truly universal and global. Talking with faculty, law makers, and other students reinforced how universal higher education is. Talking with students and exchanging our stories and goals was a priceless experience. It's exciting to come out of a trip with so many new friends and colleagues from all around the world all being united by one topic: wanting to teach our future generations. It definitely reinvigorated my own vision in academia and the impact that we can individually have."

News – CPULD faculty and students have had nine articles published so far during 2021-2022

Image 1. Industry journals with CPULD members' articles

CPULD is excited to announce that our graduate students have gotten nine articles published in peer-reviewed industry journals over the last year and a half! The journals that our students published in encompasses the best journals related to packaging distribution including Applied Science and Packaging Technology and Science. Disseminating research findings in international peer-reviewed journals is a great experience to graduate student. "Our students learn how to cohesively but concisely explain the results of their experiments and the methods that were used for obtain them" said our director, Dr. Horvath. "It is also a great opportunity to our graduate students to get name recognition from the international packaging community."

Below you will find the summaries and the links to CPULD's published articles.

The effect of plastic pails on pallet deflection and pressure distribution for stringer class wooden pallets.

- Written by Mary Paz Alvarez, Laszlo Horvath, John Bouldin, and Farhad Shahabi
- Journal: Packaging Technology and Science, 2021, Volume 34, Issue 7, Pages 423-434
- Abstract snippet: Although pails are an essential packaging solution used to transport smaller amounts of liquids (1–40 L), there is a lack of understanding about the effect of load bridging on unit loads of pails. The objective of this research was to understand the differences in pallet bending and pressure distribution across the top of the pallet when pallets are loaded with plastic pails compared with a flexible airbag. The results revealed that pallets deflect 32%–89% less when loaded with plastic pails. The load predominantly distributes down the bottom perimeter of the pail, indicating that the design of the bottom of the pail could have a major effect on pallet performance. The effect of plastic pails was dependent on pallet design, indicating that the stiffness of a pallet could have a major effect on load bridging experienced by plastic pails.

Measurement and analysis of industrial forklifts vibration levels for unit load testing purposes.

- Written by Yu Yang Huang, Laszlo Horvath, and Peter Borocz
- Journal: Applied Sciences, 2021, Volume11, Issue 7, Page 2901
- Abstract snippet: Forklifts are one of the most common types of material handling equipment used in warehouses and distribution centers. Vibration generated by forklifts may have an effect on the performance of unit loads and product damage rates. Historical research projects have focused predominantly on the measurement of vibration for over-the-road transportation. Thus, there is still a lack of understanding of the level of vibration caused by forklifts. The goal of this study was to understand how the vibration that is experienced by unit loads while being transported by forklifts is affected by factors such as speed, road condition, unit load weight, type of forklift, and sensor location. For this study, power spectral density (PSD) measurements were collected using a Lansmont Saver 9X30 data logger. Vibration levels were measured for three different industrial forklifts on two different surface types. The forklifts were driven at two different speeds while carrying two different unit load weights. For all of these conditions, the vibration levels were measured at the forklift carriage, at the back of the fork tine heel, and at the fork tine tips.

Development of a friction-driven finite element model to simulate the load bridging effect of unit loads stored in warehouse racks.

- Written by Eduardo Molina, Laszlo Horvath, and Robert West
- Journal: Applied Sciences, 2021, Volume 11, Issue 7, Page 3029
- Abstract snippet: Current pallet design methodology frequently underestimates the load capacity of the pallet by assuming the payload is uniformly distributed and flexible. By considering the effect of payload characteristics and their interactions during pallet design, the structure of the pallets can be optimized, and raw material consumption reduced. The objective of this study was to develop and validate a finite element model capable of simulating the bending of a generic pallet while supporting a payload made of corrugated boxes and stored on a warehouse load beam rack. The model was generalized in order to maximize its applicability in unit load design. Using a two-dimensional, nonlinear, implicit dynamic model, it allowed for the evaluation of the effect of different payload configurations on the pallet bending response. The model accurately predicted the deflection of the pallet segment and the movement of the packages for a unit load segment with three or four columns of boxes supported in a warehouse rack support. Further refinement of the model would be required to predict the behavior of unit loads carrying larger boxes. The model presented provides an efficient solution to the study of the affecting factors to ultimately optimize pallet design. Such a model has not been previously developed. The model successfully acts as a tool to study and predict the load bridging performance of unit loads requiring only widely available input data, therefore providing a general solution.

Development of a Gaussian Process Model as a surrogate to study load bridging performance in racked pallets.

- Written by Eduardo Molina and Laszlo Horvath
- Journal: Applied Sciences, 2021, Volume 11, Issue 24, Page 11,865
- Abstract snippet: The objective of this study was to develop a full description of how payload characteristics affect load bridging on unit loads of stacked corrugated boxes on warehouse racking support. To achieve this goal, the authors expanded on a previously developed finite element model of a simplified unit load segment and conducted a study to screen for the significant factors and interactions. Subsequently, a Gaussian process (GP) regression model was developed to efficiently and accurately replicate the simulation model. Using this GP model, a quantification of the effects and interactions of all the identified significant factors was provided. With this information, packaging designers and researchers can engineer unit loads that consider the effect of the relevant design variables and their impact on pallet performance. Such a model has not been previously developed and can potentially reduce packaging materials' costs.

Investigation of the effect of pallet top-deck stiffness on corrugated box compression strength as a function of multiple unit load design variables.

- Written by Saewhan Kim, Laszlo Horvath, Jennifer Russell, and Jonghun Park
- Journal: Materials, 2021, Volume 12, Issue 21, Page 6613
- Abstract snippet: Unit loads consisting of a pallet, packages, and a product securement system are the dominant way of shipping products across the United States. The most common packaging types used in unit loads are corrugated boxes. Due to the great stresses created during unit load stacking, accurately predicting the compression strength of corrugated boxes is critical to preventing unit load failure. Although many variables affect the compression strength of corrugated boxes, recently, it was found that changing the pallet's top deck stiffness can significantly affect compression strength. However, there is still a lack of understanding of how these different factors influence this phenomenon. This study investigated the effect of pallet's top-deck stiffness on corrugated box compression strength as a function of initial top deck thickness, pallet wood species, box size, and board grade. It found that, for a company using lower stiffness pallets or heavy corrugated boxes for their unit loads, this study suggests that they will find more opportunities to optimize their unit loads by increasing their pallet's top deck thickness.

An investigation of wood pallets landfilled and recovered at US municipal solid waste facilities.

- Written by Zachary Shiner, Laszlo Horvath, Phillip Araman, and Brad Gething
- Journal: BioResources, 2021, Volume 16, Issue 1, Pages 1496-1522
- Abstract snippet: The purpose of this research was to investigate the total number of pallets that end up in landfills in the United States as well as to gain a better understanding of the overall waste stream. The results indicated that an estimated 249 million tons of MSW was received at landfills nationwide. This was an increase from the 239 million tons of MSW in 1998. Only 13.1 million pallets were landfilled in 2016, which was over a 90% decrease from the 138 million pallets landfilled in 1998. At the same time, approximately 15.9 million pallets were recovered, repurposed, or reused at the surveyed MSW facilities, which was a decrease from the 22 million pallets recovered in 1998. The results of this research indicate that fewer pallets are making their way to landfills, and a greater proportion of pallets reaching MSW facilities are being recovered.

Vertical random vibration test spectrum to simulate the forklift handling environment.

- Written by Peter Borocz, Laslo Horvath, and Yu Yang Huang
- Journal: ASTM Journal of Testing and Evaluation, 2021, Volume 50, Issue 2
- Abstract snippet: Analyzing and measuring the vibration environment during distribution is fundamental to understanding and simulating the ability of a packaged-product system to avoid any damages from transportation hazards. During distribution, various vehicles, including forklifts, are used to perform shipping and handling tasks such as loading, unloading, and warehouse organizing processes. The aim of this paper was to provide an understanding of the average vibration levels that occur during handling so they can be used in pre-shipment testing. Various forklifts were observed, measured, and analyzed to obtain information about their average vibration levels while performing recommended tests. The measured acceleration-time data were analyzed in terms of power spectral densities (PSD) and presented with statistical data that provided an understanding of the variability of intensity.

Design of an IoT system for the palletized distribution supply chain with model-based system engineering tools.

- Written by Nicolas Navarro, Laszlo Horvath, and Alejandro Salado
- Journal: Systems, 2022, Volume 10, Issue 1, Page 4
- Abstract snippet: In recent years, Internet-of-Things technology (IoT) has been the subject of research in diverse fields of applications. IoT plays an essential role in transitioning enterprises towards a more interconnected paradigm of manufacturing, logistics, services, and business, known as Industry 4.0. This paper presents an operational concept for a system that implements IoT technology in pallets, which are used to move products along supply chains. These sensors will help us gain insight into the conditions experienced by products and unit loads. Having this capability will allow us to obtain the information

necessary for better control of product distribution along the supply chain, and to design packaging that is more efficient and effective in protecting products during distribution. In this paper, we show how Model-Based Systems Engineering (MBSE) can be leveraged to create models that capture the required system behaviors, and we address the complexity of an IoT system within the domain of packaging and logistics applications.

Effect of wooden pallets characteristics on the compression strength of palletized plastic pails.

- Written by Mary Paz Alvarez and Laszlo Horvath
- Journal: Packaging Technology and Science, 2022, June 15th
- Abstract snippet: The objective of this study was to understand how plastic pails are affected by the pallet's top deckboard thickness and the effect of the pail's location on the pallet. The first phase of testing investigated the pail location effect in five different locations on a small-scale pallet segment. The second phase further investigated the two locations that had the best and worst performances in terms of pail strength. One additional location was chosen based on a previous study on corrugated boxes. It was found that the pallet's top deckboard thickness and the location of the pail both had significant impacts on pail deformation, pallet deflection, and pail compression strength. This study also indicated that symmetrical and asymmetrical loading created different trends when comparing pail deformation, pallet deformation, and pail compression strength. It was found that the thickness of the deckboards is relevant when investigating pail failure but the experiments were unable to find a consistent trend between pallet deflection and pail failure load. These factors can all be taken into account by unit load designers in order to create safe and sustainable pallets.

https://bioresources.cnr.ncsu.edu/resources/wood-pallet-performance-analysis-with-palletized-drums-in-distribution-and-warehousing/

https://www.mdpi.com/2076-3417/12/14/7035

News – CPULD graduate students get writing help

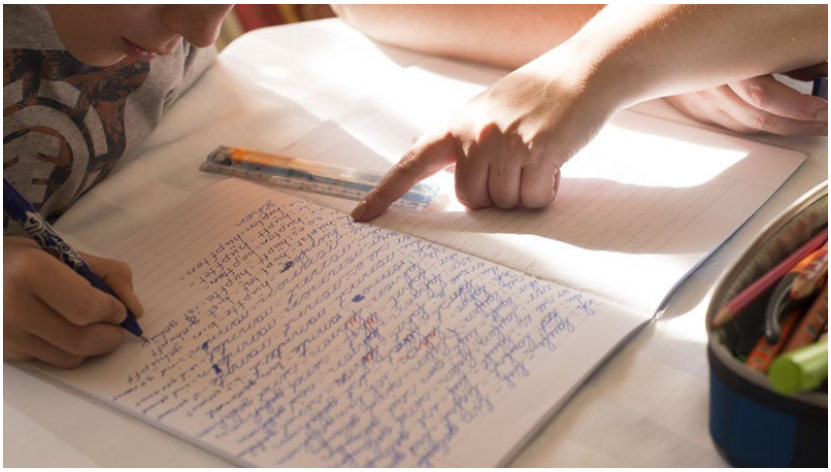

Image 1. Writing help

CPULD is offering new assistance for its graduate students! Writing is a major challenge for any college student. Whether it's lack of or inadequate coursework, English as a second language, or just lack of knowledge of the rules of grammar, many of the students entering our programs need help with their professional writing capabilities. Even if a student is planning to go into a job that may seem like writing wouldn't be an issue, good writing skills can help anyone stand out and succeed – because good writing skills translate to good communication skills, which everyone needs.

As necessary as communication skills are, the vast majority of public colleges report enrolling students who are not ready for college-level work. Per the Hechinger Report, which studied data from over 900 universities, 96% had to put incoming high-school students into remedial writing classes. In fact, almost 25% of the universities studied had to place over 50% of incoming students into remedial classes.[1] "Three-quarters of 12th graders lack proficiency in writing, according to the most recent National Assessment of Educational Process. And, a full 40% of those who took the ACT exam in high school lacked the reading and writing skills needed to successfully complete an entry-level, English composition class in college."[2]

CPULD is lucky to have a very international cohort of graduate students. However, English is a funny language and we've found it helpful to focus on some of the more irregular English grammatical issues. There are many English rules that don't exist, or are actually the opposite, of other languages' rules. Also, we've learned that while some students have taken college writing classes, they're still lacking in the professional writing arena. Professional and/or technical writing requires the use of different language – personalized language such as "I" or "me" is to be avoided, and more attention is paid to the formalities. Generally, students are encouraged to use many different words to avoid being boring, but in technical writing, they are required to use the same exact

word choice throughout a document to avoid confusion. It is also has been hard for the students to learn how to explain their research, with the required amount of detail, in order to make the work repeatable, and yet not have the description too long or share unnecessary details.

Due to recognizing this need, CPULD offers one-on-one editing and tutoring to all of its graduate students who want help. CPULD's administrative assistant, J. Kate Bridgeman, loves writing and has many, many years of classes and experience in writing everything from news articles, to interviews, to research papers, to blogs with hundreds of regular readers. Kate enjoys all aspects of the writing process and regularly writes and edits for CPULD's website, newsletters, and social media. Since she came to CPULD, the graduate students have been encouraged to reach out to Kate for any writing help they may want or need.

Dr. Laszlo Horvath has been working on setting up a new system/process that will ensure his graduate students participate in and benefit from the writing help being offered. The current plan is for the students to write short papers and turn them in for editing. Once edited, the student will have the chance to sit down with Kate for a private session going over any overarching issues that have been noticed in their writing. One of CPULD's Master's students has already gone thru this process, and we were very pleased when the articles he turned in after his tutoring session showed a marked improvement over his initial writing samples.

Some helpful links!

- Make sure you know how and where to use commas.
    - This website outlines the main rules of commas and gives great examples of how and where to use commas in your writing. https://owl.purdue.edu/owl/general_writing/punctuation/commas/extended_rules_for_commas.html

- Citations must be consistently formatted and reference pages need all of the info in the right order. Most faculty and industry journals generally request MLA or APA formatting for references, but occasionally other formats are chosen.
    - We recommend the Purdue University website for reference formatting help – and it provides examples of how to cite almost any source you can find. https://owl.purdue.edu/owl/research_and_citation/apa_style/apa_formatting_and_style_guide/reference_list_basic_rules.html

References:
1. https://hechingerreport.org/colleges-enroll-students-arent-prepared-higher-education/
2. https://demmelearning.com/college-level-writing/

News – Upgrades and updates at CPULD

Image 1. a). Unit load tester in the distribution lab and b). upgraded software for the unit load tester

CPULD has been able to upgrade and/or replace many pieces of equipment over the last year.

One of the major upgrades has been to the software running our unit load testing equipment. Our unit load tester was built in the 1950s by the Tinius Olsen company (Image 1), and it has been updated electronically a few times over the years. However, it has always been something we physically built or developed. Now, we've partnered with MTS to retrofit the whole control system with new, state-of-the-art capabilities. This new software has more built-in analysis capabilities. We'll be able to conduct much more detailed analysis because the software is collecting more data, reporting more data, and can process all of the collected data itself, which will reduce the post-processing time.

The equipment was expanded our capabilities to monitor up to deflection points on the pallet without string potentiometers and the system has the ability to receive signals from up to 52 deflection monitoring devices. We've also added a camera to the equipment to record exactly what's happening while tying it directly to the data being collected. Historically, when we built the software ourselves, we have to do all the data crunching ourselves. Now we have MTS backing the software, we are exchanging the electric motor for a new one with better, fine-tuning capabilities, and while there were only two speeds available before, now we will be able to dial in any exact speed we need for testing. Another large change is that the current equipment wasn't designed to conduct creep tests with its rigid platen, but now we'll have software that controls the part of the equipment that produces constant pressure as needed for the creep tests which reduces the test setup time.

CPULD was also able to purchase a new PDT-80 drop tester from Lansmont Corporation (Image 2). The new drop tester has a lot of fully automated capabilities which allows us to conduct drops on small packages faster

and with greater accuracy. The lab also acquired high speed cameras with ProAnalyst video analyzer software that allow us to accurately record the orientation of the package when it hits the ground and also get information on the deformation of the box during the drop.

To expand our data analysis capabilities that lab acquired two Saver 3x90 and two 3D15 data loggers from Lansmont Corporation and purchased multiple go-pro's gps units and night-vision cameras. These new capabilities allow our students to collect data from different transportation modes and conduct state-fo-the-art research on this field.

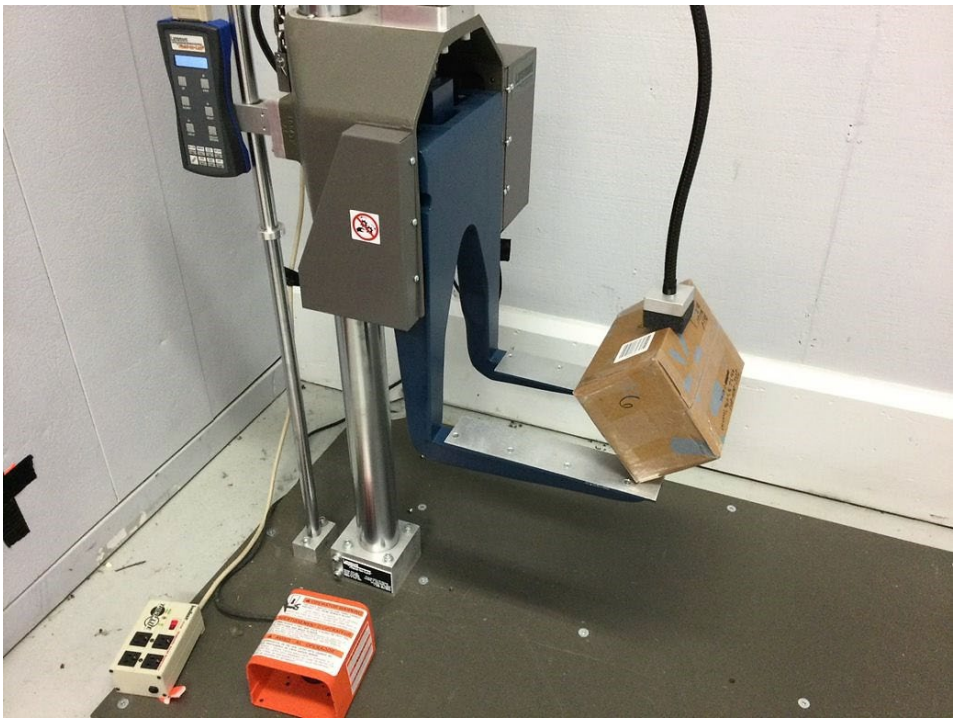

Image 2. New drop tester in CPULD's distribution lab.

Another change around CPULD is the upgrade to the lighting in the FasTrack area of the lab. CPULD developed a unique, accelerated pallet durability simulation called FasTrack in 2000. This test can simulate decades of use to a pallet in a matter of months. To test a palletized unit load for durability and economics of use, we simulate rough handling. This accelerated rough handling can be achieved by using multiple devices employed in actual material handling systems. The protocol used is a modification of testing developed to simulate the use of pallets by the grocery dry goods industry. This portion of the lab used to be a dark, storage area, but due to the fact that FasTrack projects now make up twelve percent (12%) of CPULDs work, we decided to update the area in which these tests are conducted (Image 3). Other than making the space more functional, this change is also in-line with Virginia Tech's long term sustainability mission and will significantly reduce our energy consumption and improve our environmental footprint.

Image 3. FasTrack area of the distribution lab.

Finally, CPULD is currently working on establishing a new IAP membership related to unit load stability. Last year, the Center acquired a Lansmont TruMotion Horizontal Stability Testing equipment that will be the first unit load stability tester in any U.S. academic institution. This new equipment will allow us to lead the development of the first unit load stability testing methods in the U.S. This new capability and connected research will position the Center and Virginia Tech as global leaders in this area.

The share and importance of sustainable packaging is growing in the U.S. The Center and our packaging program are uniquely positioned to capitalize on this interest. Our long-term goal is to develop a new professional M.S. degree in Sustainable Packaging Design. The degree development will be completed by the end of 2022, so we hope to submit the new degree proposal by the end of the year.

As part of this degree's development, a new advisory group was assembled that included major corporations such as General Mills, Seventh Generation, Pepsi Co, Loop, Pergis, and Atlantic Packaging, among many others. In the short term, the Center is working with the VT SBIO department to acquire technologies that will give our students the ability to design with novel packaging materials. We are also developing continuing education courses that we will be able to offer to the industry even before the approval of the degree.

News – Jorge Masis graduated with his Masters degree and worked for CPULD last semester

Image 1. Joe Keller

Alumni Jorge Masis, graduated with his Master's degree in December 2021. His research project looked into the damages that pallets sustain during their trips through the distribution supply chain, and how closely these damages match those created during CPULD's accelerated pallet durability testing called FasTrack. Jorge's research has been used to help update the FasTrack simulation to better represent the 20th century supply chain.

After graduating Jorge stayed another semester working for CPULD on various packaging design projects where the goal was to create e-commerce ready packaging solutions. Jorge has now taken a job with Red Sun Farms and moved to Texas to start his professional career as a packaging engineer. He was a great students and we are sure that he will be really successful.

News – Outside articles about CPULD and its faculty / students

Dr. Horvath was interviewed by WDBJ7 on supply chain issues: https://www.wdbj7.com/2022/05/23/virginia-tech-professor-hopes-shortage-woes-can-fuel-change/

Dr. Horvath was interviewed by WJLA on the baby formula shortage: https://wjla.com/features/7news-mornings/baby-formula-shortage-06-01-2022

Dr. Horvath interviewed by Modern Materials Handling about supply chain issues in June 2022: https://www.mmh.com/article/pallets_keep_the_supply_chain_moving

Pallet Enterprise interviewed Dr. Horvath on circular economies and pallets in June 2022: https://palletenterprise.com/view_article/5715/Pallets-Make-the-World-Go-'Round:-Circular-Versus-Linear-Economies-and-Their-Effects-on-the-Pallet-Industry

Improve Sales and Customer Service with Better Designs: Best Pallet™ & Best Load™ Software Provide the Right Solution for Challenging Supply Chains

By Chaille Brindley
Date Posted: 2/1/2022

Even Better: Software developed by Dr. Mark White enables pallet companies to find the best packaging solution for customers. Best Pallet is a user-friendly, inexpensive computer modeling program designed for the fast-paced pallet salesperson or designer. Best Load is the next generation of unit load design today.

Pallet Enterprise article about Best Load and Best Pallet softwares mentions and quotes Dr. Horvath in February 2022: https://palletenterprise.com/view_article/5672/Improve-Sales-and-Customer-Service-with-Better-Designs:-Best-Pallet%E2%84%A2-&-Best-Load%E2%84%A2-Software-Provide-the-Right-Solution-for-Challenging-Supply-Chains-

Alonda Johnson, a PSD major, was interviewed for a SBIO undergraduate student showcase article: https://sbio.vt.edu/about-us/student-showcase/alonda-johnson.html

Trey Good, CPULD alumni was interviewed by CNRE and spoke about Dr. Horvath as his mentor: https://cnre.vt.edu/about/newsmagazine/articles/summer-2022/alumna-remembers-charisa-morris.html

~ Continuing Education Opportunities ~

2022 Webinars

CPULD is pleased with the response to our webinars. Over 2021, Director Laszlo Horvath gave multiple separate lectures, which were free to our members. In 2020, CPULD partnered with NWPCA in offering a series of webinars designed to help train the industry on various new aspects of NWPCA's Pallet Design System (PDS) software which is regularly updated with research findings from CPULD projects. Overall, our webinars have reached over 680 attendees in 17 countries. If there are any topics in particular that you or your company would be interested in, please feel free to suggest them to us! Stay tuned to learn when 2022 webinars are announced!

Wood Pallet Design and Performance Short Course, Nov. 8th-10th, 2022

Pallet design is an integral part of the material handling system. Wood pallet suppliers, sales professionals, professionals responsible for pallet purchases, packaging engineers, and pallet specifiers will all benefit from an understanding of how to design pallets that will last longer and perform better.

This intensive three-day short course will teach techniques that pallet designers can use to save money when designing pallets by considering the interactions between all of the components of the material handling system. The course will use state-of-the-art pallet design software called the Pallet Design System (PDS) to better demonstrate the steps that go into the pallet design process. You will also be taken on a tour of a working, state-of-the-art, pallet testing laboratory!

Unit Load Design and Performance Short Course, TBD 2022

Unit load design is a revolutionary, systems-design approach that significantly reduces the cost of distributing products to consumers by understanding how pallets, packaged products, and handling equipment mechanically interact. Unit load design is a new and valuable service that pallet, packaging, and handling equipment suppliers can offer their customers.

This intensive three-day short course will teach techniques that pallet and packaging designers can use to save money on corrugated board and plastic packaging materials when designing pallets and packages by considering the interactions between all of the components of unit loads. The course will use a state-of-the-art unit load design software called Best Load to better demonstrate the steps of the unit load design process. You will also be taken on a tour of a working, state-of-the-art, packaging and pallet testing laboratory!

To learn more or register for these courses, visit:
www.unitload.vt.edu/education/continuing-education/

COLLEGE OF NATURAL RESOURCES AND ENVIRONMENT
SUSTAINABLE BIOMATERIALS
VIRGINIA TECH

Spring/Summer 2022

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Quotes for new testing projects, distribution packaging projects, unit load design projects, membership with the center, new research projects

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