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 online edition of the newsletter contains the following exciting topics from CPULD:

- Investigation into the effects of various factors on the vibration levels experienced by unit loads under forklift handling conditions.
- Results of recent graduate research projects.
- Alumni spotlight: Alina Mejias Rojas.
- Student spotlight: Victoria Dashevsky.
- Summaries of short courses and webinars hosted by CPULD.
- Interviews conducted with CPULD faculty and staff.

Research Highlight — Investigation into the effects of various factors on the vibration levels experienced by unit loads under forklift handling conditions

Image 1. Yu Yang Huang attaching sensors to the electric powered forklift.

Forklifts play an important role in the global distribution of packaged products. They are commonly used to move and lift materials and products throughout the supply chain and offer load capacities from a few thousand pounds up to 180,000 pounds. Forklifts are one of the most common types of material handling equipment used in warehouses and distribution centers.

Forklifts experience vibration during operation. Vibration is a mechanical phenomenon that is very common in transport vehicles and affects every packaged product during the handling and transportation process. Forklifts experience different vibration levels under different conditions, such as speed, road conditions, and unit load weight. The vibration produced is not a smooth, oscillatory motion; it is a shaped mix of various frequencies and amplitudes, and it is constantly changing.

Forklifts are the most common material handling method used to move pallets through the supply chain. While being transported on a forklift, pallets have a different load capacity, commonly referred to as dynamic load capacity. Despite the term “dynamic,” current testing standards only use static load tests to measure this value. Master’s student Yu Yang’s research focuses specifically on developing a true dynamic load testing method for pallets and then using this new method to revise the ISO 8611 testing standard.

While many studies have been done analyzing the vibration levels of forklifts, not much research has been conducted to analyze how various factors affect vibration. The goal of the first phase of Yang’s research was to understand how the vibration experienced by unit loads while being transported on forklifts is affected by speed, road conditions, unit load weight, forklift type, and sensor location. For this research, several power spectral densities (PSD) were obtained and analyzed for different types of commonly used industrial forklifts in a laboratory environment.

Image 2. (Left to right) Gas- powered forklift, electric-powered forklift, and reach truck.

Three types of forklifts were investigated (gas-powered, electric-powered, and a reach truck) on two different types of road conditions (concrete and asphalt) while carrying two different load weights (1,500 lbs. and 2,500 lbs.). The intensity of vibrations caused by the forklifts was measured using a Lansmont SAVER 9X30 data logger under the various handling scenarios. Two three-axis accelerometers were also connected to the data logger to record data from three different positions of the forklift.

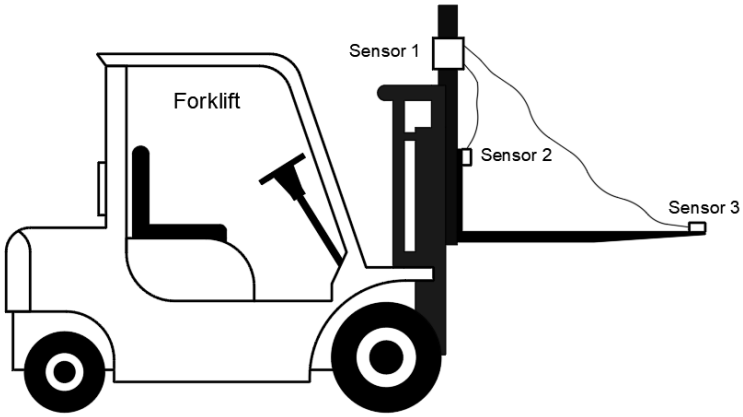

Image 3. Sensor positions for the vibration data collection.

An analysis of vibration levels was conducted using Grms (root-mean-square) values and power spectral density plots. An initial analysis using Grms values was conducted to compare the vibration levels that were generated by the three forklifts under the different handling scenarios. A second analysis used the power spectral density plots to analyze in more detail the effects of speed, road condition, forklift type, unit load weight, and sensor location on forklift vibration levels. Furthermore, a comparison of vibration levels was performed between an ISTA trailer truck and the forklifts.

It was observed that the gas-powered forklift presented the highest vibration intensity while the reach truck showed the least. The highest peaks were observed on low frequencies, around 3.5 Hz. The gas and electric forklifts presented peaks near the same frequency, while the peaks for the reach truck shifted towards higher frequencies.

It was discovered that forklifts on asphalt experienced a higher level of vibration compared to forklifts on concrete. The results also revealed that the sensors, at both the carriage and the tip, measured increasing vibration levels with increasing speed. The change in speed represented an increase in vibration levels of 41.6% on asphalt and a 38.4% on concrete. Vibration levels at the tip of the tines were higher than those at the forklifts' carriage.

Additionally, it was observed that, on all three forklifts, the vibration levels decreased with an increase in the weight of the unit load. For the gas and electric forklifts, the highest peaks occurred at low frequencies around 2.0-4.0 Hz. For the reach truck, the highest peaks occurred around 3.0-5.0 Hz. The peaks of vibration shifted towards lower frequencies with increasing weight. The change in the weight represented an increase of 26.0% on asphalt and 7.2% on concrete.

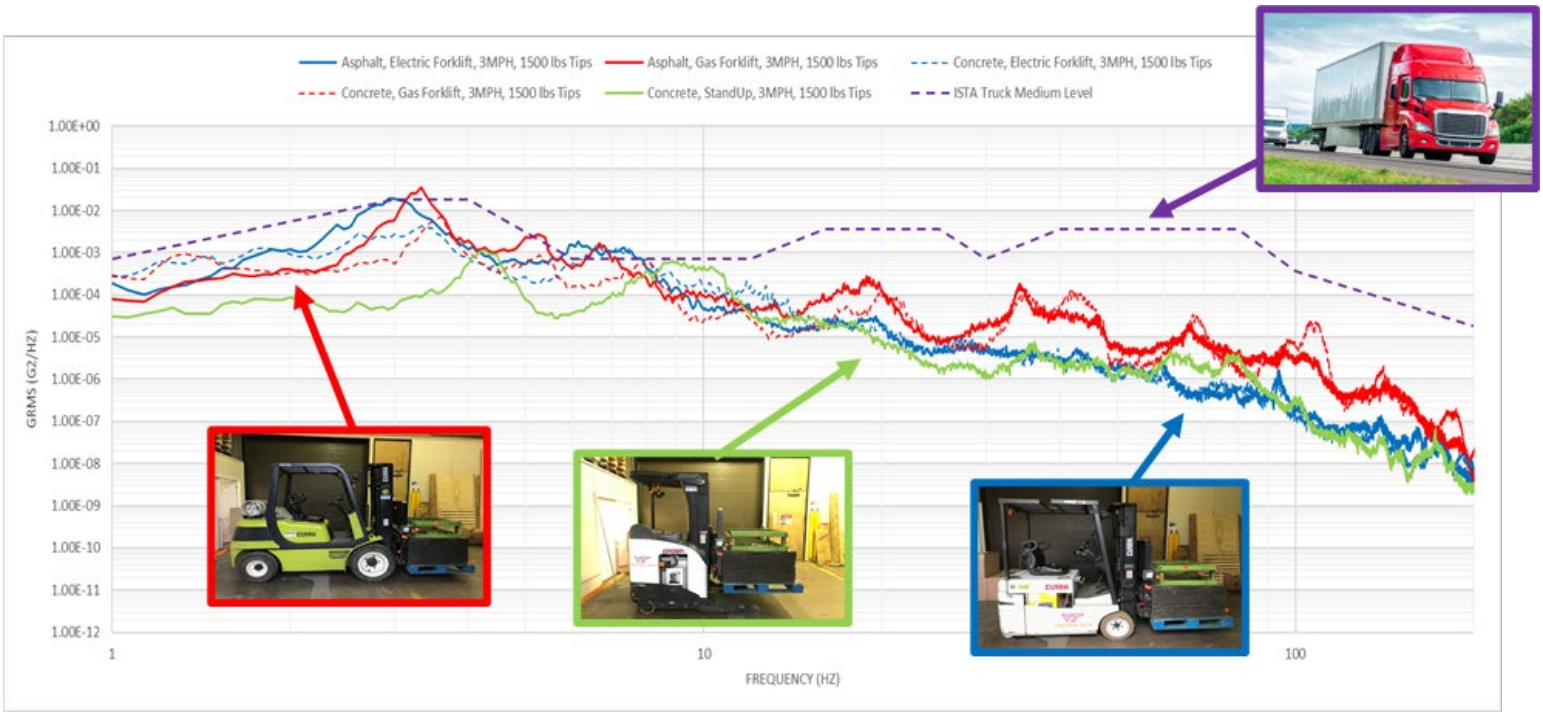

Image 4. Comparison between ISTA truck and forklifts in vibration levels experienced.

Finally, it was found that ISTA trailer trucks experience higher vibration levels compared to forklifts. Vibration levels are affected by the suspension system of the vehicle. The suspension system is connected to the wheels, which provide contact between the road and the vehicle. The type of suspension and the speed of the vehicle affect vibration levels. In previous studies, researchers concluded that air-suspended trailer trucks experience the lowest level of vibration on a continuous road surface which, in turn, transmits the lowest level of peak accelerations to the cargo. In addition, they mentioned that the damping of this vehicles' suspension is superior to trucks having steel spring suspensions, resulting in a quicker recovery from severe shocks.

In short, the results showed that an increase in forklift speed increases vibration intensity. On the other hand, an increase in the forklift load weight decreases vibration intensity. Among the three forklifts studied, the gas-powered forklift has the highest Grms values on an asphalt road surface.

The next phase of this research will focus on using the obtained information to create a dynamic pallet bending measurement method on our vibration table.

Alumni Spotlight — Alina Mejias Rojas

Image 1. Alina Mejias Rojas' graduation day picture.

Alina Mejias Rojas came to the Center for Packaging and Unit Load Design from the Costa Rica Institute of Technology. She grew up in San Carlos, Costa Rica, and started an internship with CPULD in fall 2016 as part of her undergraduate program. The project she took on to complete her degree was to help organize and streamline CPULD's labs. Alina told us that she "became part of the Hokie family due to an internship where I performed a Lean manufacturing project, which was a requirement to graduate as an industrial engineer."

After interning for a semester with CPULD, Alina was hooked on being a Hokie. She said that her interest in packaging was sparked during her internship. "After being exposed to packaging science, I was interested in learning more about it due to the fact that it is the third largest industry in the world and it is a field that I had never been exposed to back in Costa Rica. The Virginia Tech graduate program focused on packaging efficiency, packaging distribution throughout the supply chain, and sustainable packaging — all of which captured my attention. By fall 2017, I had started my graduate program."

Alina expounded on her choice of CPULD. "I chose packaging science because as an industrial engineer my focus had been on what happens between the inputs and outputs of the manufacturing process. Packaging involves the processes that will allow the final product to reach the customer efficiently. Furthermore, packaging captured my attention due to the sustainability impact that reusable packages, packaging design, and pallet science can have on the world through all of the supply chains."

Image 2. Alina's graduate student picture.

Image 3. Alina with others at CPULD.

In addition to the normal stresses of graduate school, Alina had to deal with being an international student and leaving her support system in Costa Rica. “When I decided to start this journey, I knew it was going to be lonely, since I had to leave all my family and friends back home. Fortunately, I had the support of my now husband and along the way I had the luck to share classes and work with exceptional people who later became like family. Being from a different country, I was not totally certain about what my future would be after graduation. Therefore, during my school years, I selected the classes that exposed me to the topics I was the most passionate about, and, to me, this is the best feature the Department of Sustainable Biomaterials has for graduate students.”

“Studying in the packaging program at Virginia Tech opened many doors for me,” she continued. “I was able to work firsthand with professionals from diverse fields. I had the opportunity to go to conferences and on field trips where I experienced real-time operations. My Virginia Tech education helped to open my horizons; the job fairs exposed me to a great variety of companies looking for candidates from all fields. Some people might consider this as the norm, but for me, being able to select from such an upstanding list of companies was a luxury. My most interesting class was one taught by Dr. Laszlo Horvath in which I learned the importance of pallets and the different criteria you can apply in order to ensure high performance in different supply chains.”

Alina identified the three major lessons from her time with CPULD as proactivity, teamwork, and the Virginia Tech motto of *Ut Prosim* (That I May Serve). She describes “proactivity as always striving to do your best and be one step ahead — to not only identify the problem but what causes it and all possible solutions.”

She went on to explain how she learned about teamwork. “Being a laboratory manager allowed me to interact with a variety of people from different backgrounds and of different generations, genders, and levels of motivation. It was without a doubt one of the most enriching activities for me because, despite all the differences, I needed to guide my team to successfully complete specific activities in a timely manner. This allowed me to put into practice what I had read one day a long time ago: A leader is the person who knows how to optimize others’ performance by using each individuals’ skills.”

“*Ut Prosim* — That I May Serve,” Alina continued. “I apply this in every aspect of my life. It is too easy to expect things to get done by someone else, but the reality is that they might never get done if you leave it up to someone else. So grab it and do it. From helping your neighbor to inspiring young adults ... that I may serve.”

Image 4. Alina performing tests in the corrugated lab. Image 5. Alina and others after a team building exercise.

Alina wants future students to know that becoming a part of CPULD is a multi-field experience. She had the opportunity to take classes with the best professors as well as work and learn about the packaging industry in a hands-on environment. She also got to interact with real customers, working towards their specific requests and

timelines. And Alina managed up to 10 technicians, “which allowed me to collect managerial work experience while earning my master’s degree.”

“I would like to tell future students to keep your minds open, buckle up, and enjoy the ride,” she added. “Being part of CPULD will develop many different skills that you will end up using once you graduate. These skills and experiences truly upgrade your resume and open many different job opportunities. Additionally, there is a packaging alumni group that you can be part of after graduation.”

Alina is one of the many CPULD students who had a job lined up before graduation — in her case, with Alstom, a train manufacturing company. She is working at the French-owned corporation’s manufacturing facility in Hornell, New York, as a supplier product quality development engineer. “My general responsibility is to manage the suppliers that manufacture specific electrical parts according to the technical specifications. We are currently building the first high-speed train in the United States, and I am so grateful and proud to have been chosen to be part of it. My position allows me to work on a daily basis in conjunction with most of the departments in the company, such as engineering, sourcing, industrial, logistics, and supply chain, in addition to the supplier in order to achieve a good delivery. Our target is to have the parts ‘delivered right the first time, on time.’”

As with the rest of the world, COVID-19 has narrowed Alina’s social life. However, she said it has given her time to prepare her graduate research for publication as an article that will summarize her findings. She will soon add “published author” to her CV with “How Pallets Affect the Performance of Semi-Automatic and Fully Automatic Warehouses.”

Additionally, with the collaboration of her friends, Alina has been developing an Instagram page called “Ella Ingeniera” that will benefit woman in engineering. “We are creating this page to share our knowledge on how to strive and succeed in engineering school and how to adapt to different environments, especially for students looking to excel in a different country, and we will provide tips on how to transition from a student life to a professional one.” Ella Ingeniera will be released to the public in January 2021.

During her time here, Alina performed work as an industrial engineering intern, a global pallet researcher, and a laboratory manager in addition to being a full-time graduate student. She excelled at all positions and was a constantly friendly presence at CPULD. All of this contributed to her winning the Department of Sustainable Biomaterials 2020 H.E. Burkhart Outstanding Master’s Student Award.

Image 6. Alina with Drs. Horvath and White.


Image 7. Alina on graduation day.

Research Highlight – Investigation into the impacts and damages sustained by pallets during physical distribution

Image 1. Jorge Masís organizing pallets received from pallet recycling companies.

Master's student Jorge Masís is looking into the damages that pallets sustain during their trips through the distribution supply chain and how closely these damages match those created during our accelerated pallet durability testing called FasTrack. Jorge's research will be used to help update the FasTrack simulation to better represent the 21st century supply chain.

Image 2. Jorge Masis.

The end goal is for a pallet that has been run through the FasTrack durability tests in the lab to show the same damages as a pallet that has lived its useful life in a distribution supply chain. This will show that the FasTrack testing accurately predicts and mirrors what a pallet will actually experience.

The first step Jorge conducted was to collect and inspect the two different groups of pallets. The first was 306 used pallets that had been donated by three pallet recycling companies. The second was 265 pallets that had already been tested in CPULD's FasTrack durability simulation. Jorge inspected all of the pallets that had been collected and recorded the number and types of damages seen on each pallet. Broken pieces, missing wood,

twisted parts, and split boards are all expected as a result of the pallets' interactions with the material handling environment.

To quantify the common damage modes and damage frequency as well as damage severity, a data collection tool was created and a collection methodology was developed. The data collection tool was divided into three sections: company characterization (listing either the pallet recycling company's name or FasTrack), pallet characterization (including size, stringer/block, and other specifics), and damage characterization. This information was entered into the database for all 571 pallets.

Damages were identified according to both the Uniform Standard for Wooden Pallets developed by the National Wooden Pallet and Container Association and ISO 18613. Damages taken into consideration included splits, breaks, missing wood, and block twist.

Along with each damage type, a severity rating was issed. This severity scale takes into consideration the guidelines used to define damages for FasTrack. Medium-level damages, as defined for this study, take into account some damages that may not officially be considered "failures," but the presence of these damages suggest that a component is being hit consistently. High-severity damages are those that could threaten the integrity of the packages being carried or affect the physical properties of the pallet in such a way that it can no longer serve its purpose and/or could create a safety hazard if it continues to be used.

The output of damages per pallet was analyzed for each source with Minitab 19. Histograms and Box Plots were developed with this tool as well as descriptive statistics for each source, including mean, standard deviation, and coefficient of variation, among others. To identify the behavior of the data, normality tests were performed according to pallet class to compare the resemblance of the data to the normal distribution. To identify differences among groups, the Kruskal-Wallis test for difference in medians was utilized.

Per the data collected to date, the FasTrack durability tests tend to cause more splits but fewer breaks than pallets typically experience during their useful lifespan. For stringer pallets, the most common damage mode was splits (59.4%) followed by missing wood (32.4%) and broken components (8.2%). Block pallets presented a same damage mode distribution with splits (57.1%) and missing wood (39.1%) being the most prominent damage modes. 2.7% of block pallets also experienced block twist for the 48 in. middle blocks.

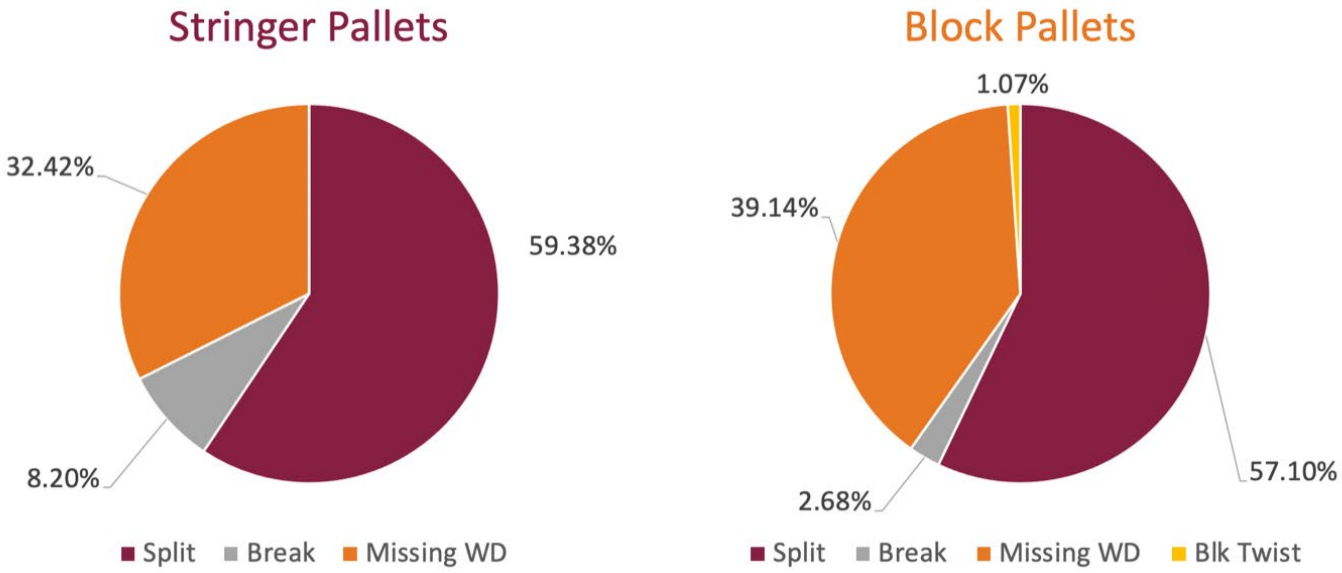

Image 3. Damage modes observed for stringer and block pallet cores.

For both stringer and block pallets, most damages were concentrated for the top lead deckboards with 53.5% and 46.6% frequency, respectively. The second most common damage location was the bottom lead deckboard and side stringers for

stringer pallets and bottom lead and bottom side board for block pallets. Damages to the bottom lead deckboards were most likely caused by forklifts because forklift drivers commonly lower the forks all the way to the ground when they try to pick up a pallet. The results of Virginia Tech's Fastrack simulation shows that adding chamfers to the bottom lead board can mitigate some of these damages. Block pallets experienced damages to their bottom side boards as well because block pallets have full four-way accessibility thus forktines can often hit the sides of the pallet during handling.

The study also investigated two different damage severity levels (medium and high). The results showed that the split between medium and high damages is about 50-50 for both pallet designs. In addition, most of the investigated components experienced the same number of medium and high damages. When the damage mode as a function of a pallet component was investigated, it was found that both block and stringer pallet top lead deckboards were mainly damaged due to splits and missing wood (which is most likely the consequence of splits too).

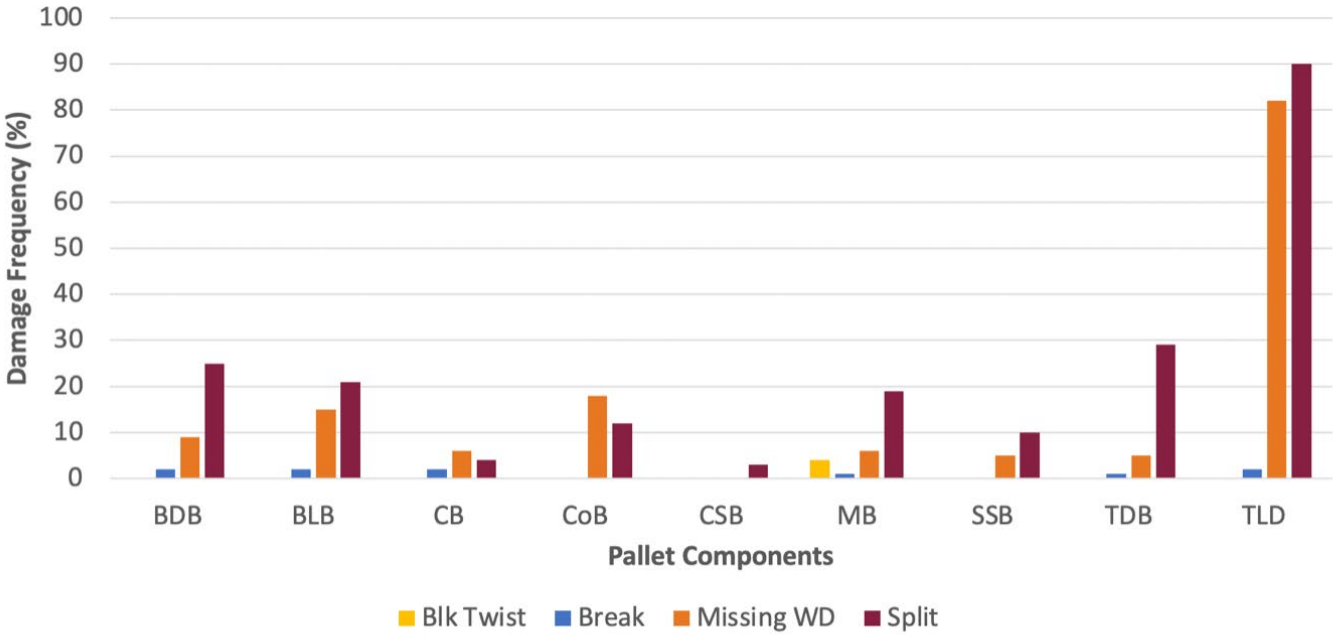

Image 4. Damage modes experienced by block pallets for the different pallet components.

Student Spotlight — Victoria Dashevsky

Image 1. Victoria Dashevsky's intern picture.

Victoria Dashevsky is currently working as a laboratory intern for the Center for Packaging and Unit Load Design. She applied for the Distribution Packaging Internship Program in spring 2020. After CPULD's labs were given essential status and allowed to re-open under strict COVID-19 guidelines in June 2020, all three Distribution Packaging Interns came back to campus to work in the pallet testing lab for the first part of their internship. Victoria has continued to work in the lab throughout this fall semester and quickly made herself a valuable team member.

Victoria is a senior from Alphretta, Georgia, and will graduate in spring 2021. She says went to a very typical high school that had an amazing choir program that she was very lucky to be a part of. She also told us that she chose to come to Virginia Tech "because I was looking for an out-of-state school and fell in love with the Hokie spirit when I came to visit." Victoria is a packaging systems and design major and added a minor in psychology because she has "always been amazed at how humans feel and wanted to take classes to learn more."

Victoria has always been close with her family and told us that she missed them a lot over her first few months at college. Victoria has one older sister who currently lives in Hawaii. When asked to share a funny story from her childhood, she told us about a visit to Sea World. She got bitten by a dolphin during a feeding experience. Although she was fine, it startled her mom so much that her mom dropped a bunch of sardines on her head, and she had to go through the rest of the day smelling like fish!

During the pandemic, Victoria has spent a lot of her free time trying out new recipes and honing her cooking skills — she especially loves pasta as "it's very versatile and, in my opinion, the best tasting of foods." She has also kept busy exploring nature and taking part in all the outdoor activities around Blacksburg, in particular, hiking the local mountains and enjoying the fall colors. In fact, she told us that "the best part of my time here at Tech has been my time on campus just spent enjoying the beauty of it, especially as the leaves change colors in the fall."

Victoria doesn't have a post-graduation job lined up yet but hopes to find something in the supply chain logistics and/or distribution fields. She's happy to have earned her ISTA Certified Packaging Laboratory Professional Technologist certificate during her time as an intern. Victoria has two favorite classes. The first is Dr. Laszlo Horvath's Global Distributions class because, she says, it really taught her all about how packages can get damaged in the shipping process. She also enjoyed Dr. Dan Hindman's Wood Mechanics class. "I have

never been the best at math, but this class helped me understand why the math was being used. I was able to better understand the math in this class because of the real-life examples the professor provided."

Victoria's advice to future packaging students is "do not be afraid to try and make new friends and join new clubs; that's how I have made some of my best friends."

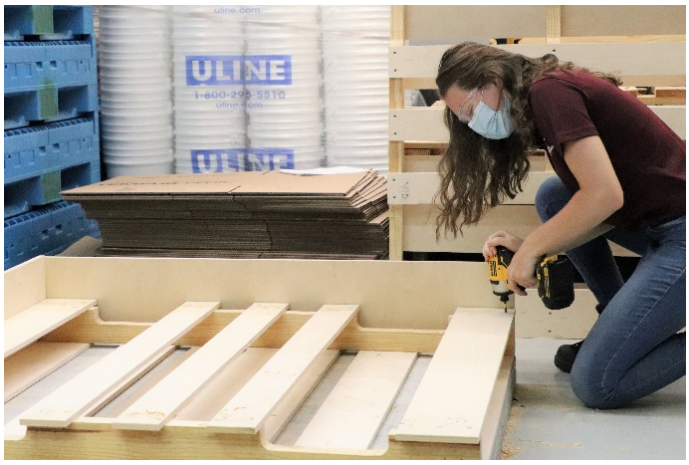

Image 2. Victoria helping construct pallets for testing.

Image 3. Victoria working the stretch wrapper.

Image 4. Victoria during a video shoot in the lab.

Image 5. Victoria helping build a unit load of pails

News — CPULD partnered with NWPCA to offer a webinar on fasteners and their use in pallet construction

Image 1. Example of product damage caused by fastener failure.

The Center for Packaging and Unit Load Design partnered again with the National Wooden Pallet and Container Association (NWPCA) on November 17 to offer a free webinar for members of either organization. The short course attracted over 50 attendees from multiple countries to the live webinar. The recording, including the question-and-answer portion, is being offered free to the public on YouTube (PDS Basics – Fasteners) through the end of this year. In 2021, it will be available only to members of NWPCA, so take the opportunity to watch this interesting lecture while it is available to everyone!

Brad Gething, director of science and technology integration at NWPCA, and Laszlo Horvath, director of CPULD, spoke about fasteners — their specifications and their use in pallet construction. Fasteners comprise only 5% of the cost of a pallet, but they can have a major impact on a pallet's durability, strength, and stiffness level. And when fasteners fail, products get damaged.

There are many different types and sizes of nails that can be used in pallet construction, but the most commonly used types are helically threaded and annularly threaded nails. Dr. Horvath spoke about many different aspects of fasteners and offered tips such as why to use annularly threaded nails in softwood components and helically threaded nails in the hardwood species. Using NWPCA's Pallet Design System (PDS) software can help decision-making during the pallet design process by filling in all the specs for the fasteners you've chosen, informing you how the selection will affect your pallet.

Pallet durability is the main issue for all design decisions. Since the 1970s, the formulas used to calculate pallet durability have included nine different factors; the first three of those factors directly relate to the fasteners used. Shank withdrawal, shearing, and head pull-through are the potential modes of failure, but they can be predicted and accounted for during the design process.

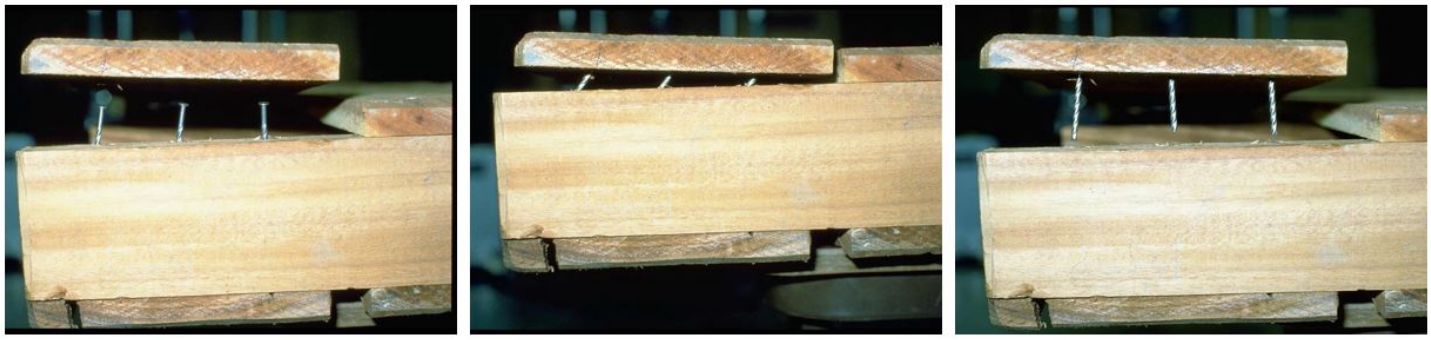

Image 2. Fastener failure modes.

The press-out of a fastener (the difference between the wire diameter and the thread-crest diameter) and its thread angle (calculated by the number of helixes and the thread length) are the main parameters that define the nail's withdrawal and pull-through resistance. Thread press-out has the most direct effect; increasing the press-out by just .015 in. can increase the fastener's withdrawal resistance by 55%. And decreasing the fastener's thread angle from 68 degrees to 60 degrees can increase withdrawal resistance by 34%. But a lot more factors than these go into the formulas for fastener testing. The species of wood and the thickness of the boards being used as well as the moisture content of the lumber all contribute to the fasteners' strength. Additionally, the number of fasteners per connection affects their individual strength.

Shearing is the result of fasteners that are too thin and/or aren't stiff enough. While fasteners' withdrawal and pull-through resistance can be calculated from their manufacturing specs, the shear resistance is something that must be physically tested to find. The number needed for figuring the shear resistance is called the fasteners' MIBANT angle, which is basically its resistance to dynamic impacts.

Image 3. MIBANT testing equipment.

The Uniform Standard for Wood Pallets (2014) includes requirements for how many and what types and sizes of fasteners to use as well as what their withdrawal, pull-through, and shear resistance numbers should be. This standard states other specifics as well, such as how deep a fastener must penetrate the stringer (at least 1 in.), the minimum head-to-shank ratio of the fasteners being used (2.00), and the number of fasteners per deckboard

connection (deckboards less than 5.25 in. wide require at least two fasteners while wider deckboards can require up to four).

At the end of the webinar, the presenters took questions from the attendees. Dr. Horvath spoke about the Virginia Tech research that backs up the MIBANT angles and press-out requirements and the most common fastener failures. He mentioned that fastener quality has decreased significantly over the years; 20 years ago, a fastener that would have been labeled “poor quality” is now considered “good” because average fastener quality has declined so much. But, as Dr. Gething points out, the PDS software can take a lot of the guesswork out of fastener choice because it will do all the calculations for you and let you know exactly what to use to get the durability ratings you want on a new pallet design.

The Center for Packaging and Unit Load Design offers a wide range of pallet fastener testing services and works with companies to eliminate the chances of nail failure in the distribution chain. For more information, visit https://www.unitload.vt.edu/facilities/fastener-testing-lab.html.

Watch the recording of this webinar to learn even more about fasteners and their effects on pallets!
https://www.youtube.com/watch?v=kQmtB34mUvI&feature=youtu.be

News — Dr. Laszlo Horvath was a guest speaker for the Tech on Tap lecture series and spoke about packaging during the age of COVID

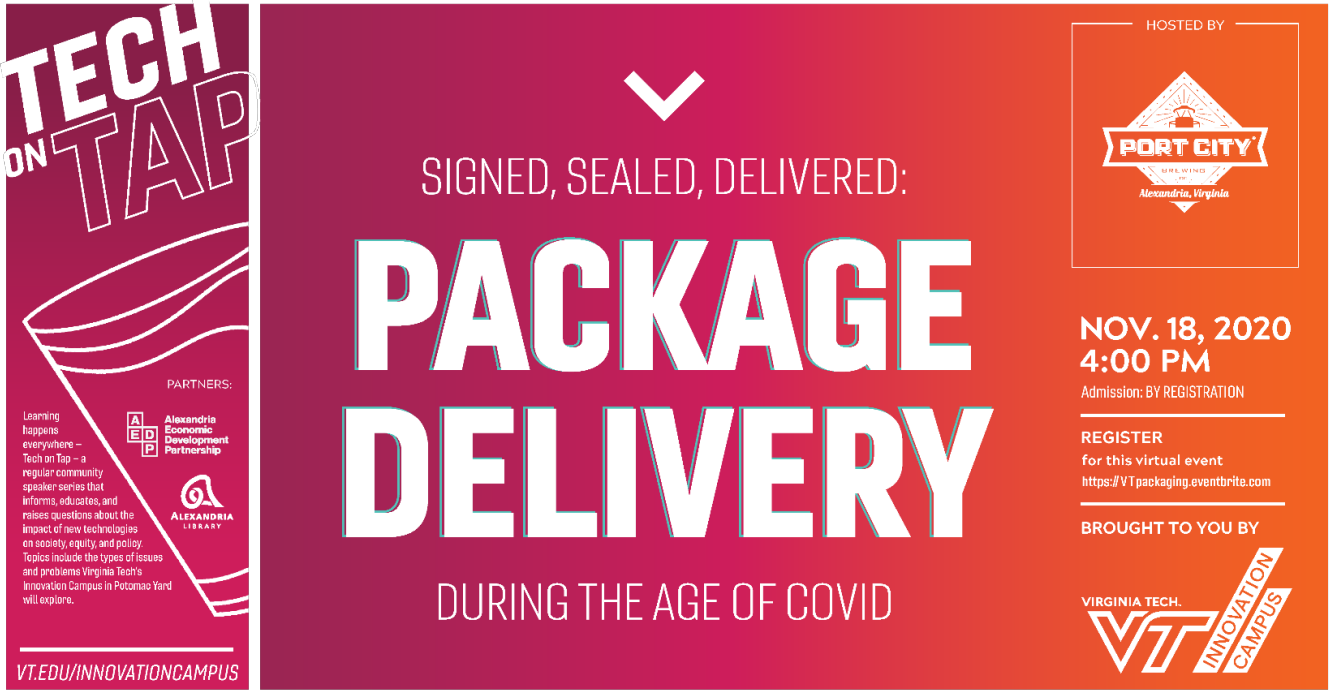

Image 1. Tech on Tap series advertisement about Dr. Horvath's lecture.

CPULD Director Laszlo Horvath was the featured speaker for the November 18 Tech on Tap virtual event. Based on the principle that learning can happen anywhere, Tech on Tap is a lecture series that informs, educates, and raises questions about the impact of new technologies on society, equity, and policy. Topics include the types of issues and problems that Virginia Tech and its new innovation campus in Potomac Yard look into and research. Past events addressed topics such as self-driving cars, the science behind beer, urban gardening, drones, and more.

Dr. Horvath's presentation about the future of the packaging industry was entitled, "Signed, Sealed, Delivered: Package Delivery During the Age of COVID." Package delivery is playing an important role in our lives now more than ever. From Amazon packaging rules to the growth of e-commerce, Virginia Tech is working with industry partners to optimize the future of package distribution.

During his lecture, Dr. Horvath covered the basics of packaging and its role in society. The global packaging industry is expected to exceed $1.3 trillion within three years, and 96% of Americans with internet access make purchases online. CPULD's vision is the be the hub of packaging innovation, where researchers, students, and industry professionals work together to improve the efficiency of the supply chain. He spoke about the package design process: first you must understand the distribution hazards a package will experience, then you design a package that should protect against those hazards, and finally your new package design must be tested in the laboratory to ensure that it does, in fact, protect your product from distribution hazards.

Image 2. The package design process.

In these days of COVID-19, with e-commerce soaring, the supply chain that packages travel on has changed dramatically. This new "omni channel" supply chain creates almost double the touch points for packages. In a traditional supply chain, a package is handled approximately 16 times, while the omni channel supply chain causes a package to be handled up to 30 times before it reaches the customer. The increase in handling means there are potentially more hazards for packages. That is in addition to needing more over-boxing, increased skus, and the need for packages to be designed to handle clamping, multiple orientations, and gaylord boxes (a large, pallet-sized box used for containment of smaller boxes or used in place of other containment methods such as shrink-wrap).

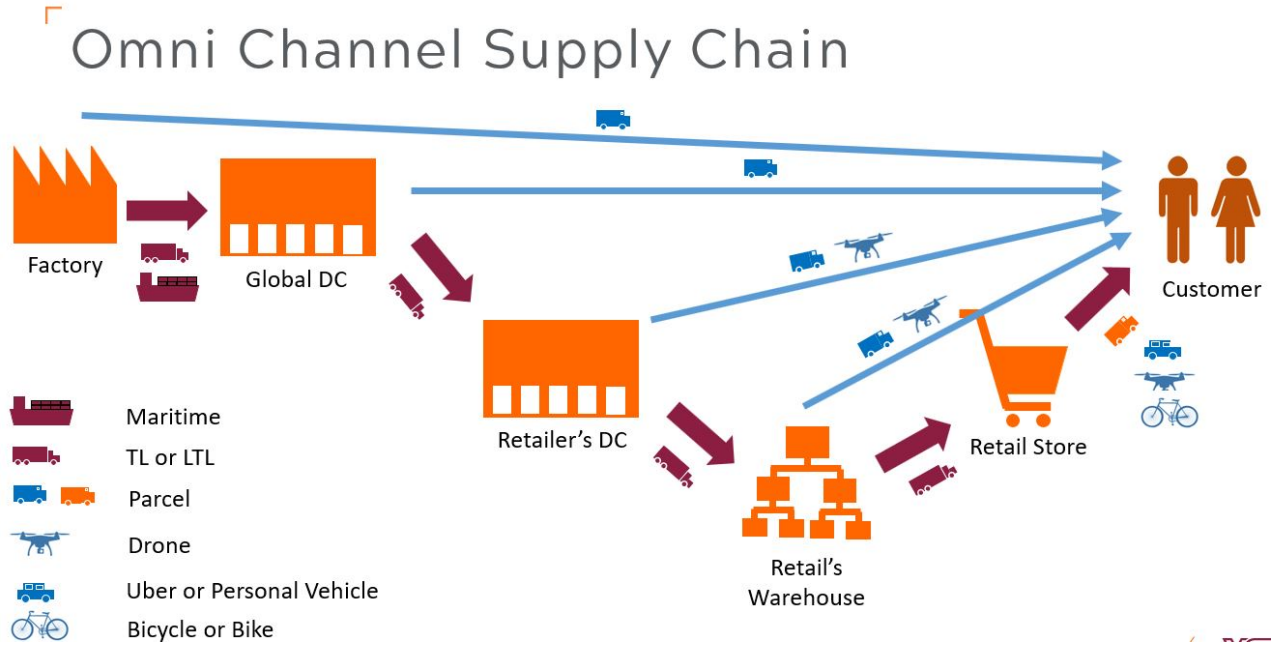

Image 3. Distribution in the omni channel supply chain.

Finally, Dr. Horvath talked about some of the recent IoT (Internet of Things) research being done in the CPULD labs that will help with these new package design issues. In particular, he explained about a recent project in which numerous packages were equipped with sensors to measure every vibration and shock the package experienced. The packages were shipped to Toronto, Canada, and Costa Mesa, California, and then returned to the lab, where the data from the sensors were downloaded and analyzed.

CPULD researchers found that the packages experienced more edge and corner drops than expected, with some drops from as high as 50 inches. However, current testing methods focus more on protecting packages against side impacts and only tests them with 18-inch drops. More research is needed, but it appears that the durability testing conducted on packages needs to be updated to match the realities of the modern distribution supply chain.

However, IoT research can also be helpful for more than just damage monitoring. It is becoming more popular in the distribution industry, as equipping pallets and unit loads with sensors can offer increased supply chain visibility and monitoring, help regulate temperature and humidity for fragile or sensitive products, reduce theft and loss numbers, and provide live feedback on road conditions. Dr. Horvath finished out his lecture by talking about the current framework for and challenges of integrating an IoT system into the palletized supply chain.

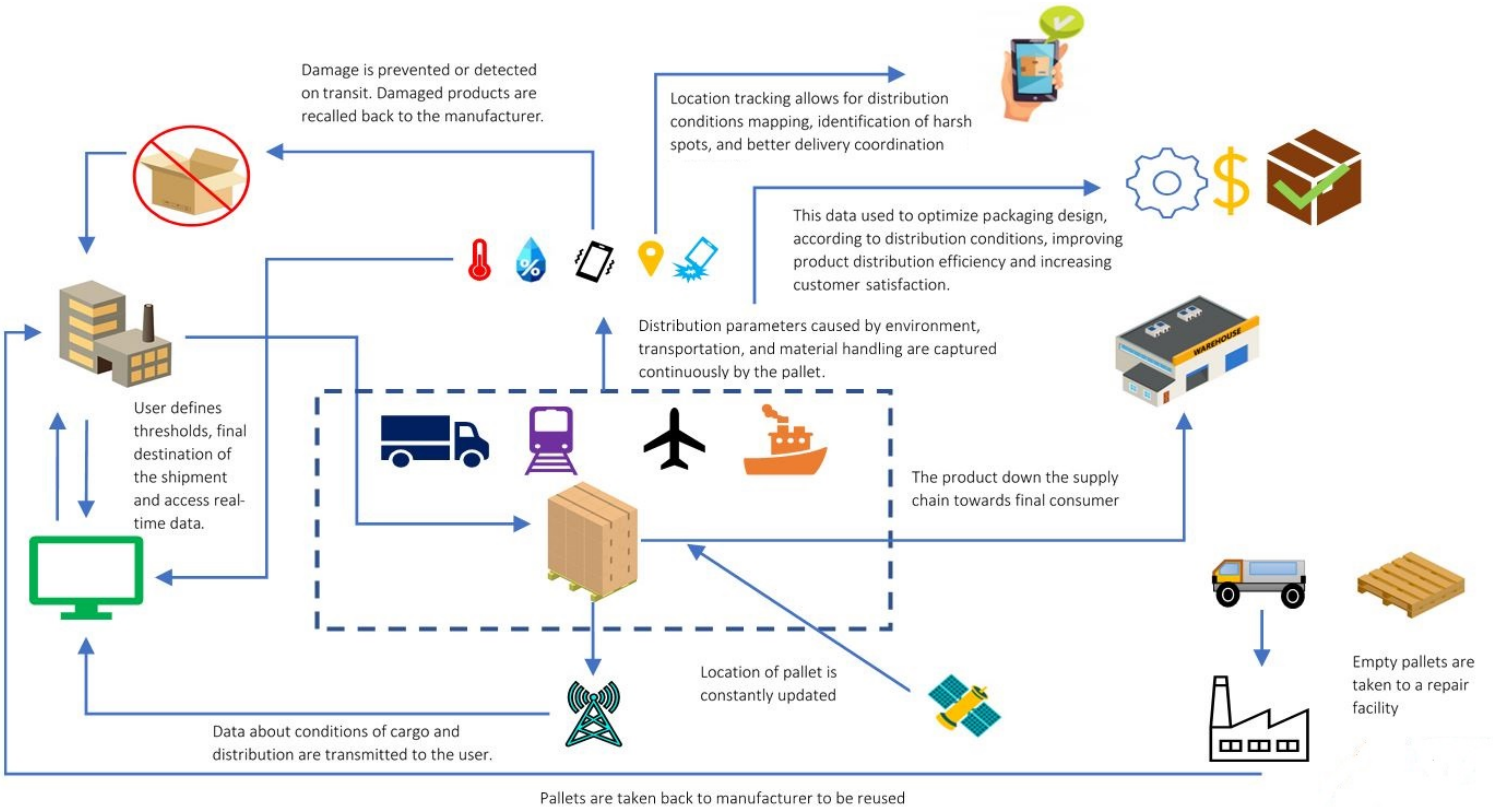

Image 4. IoT framework for a palletized supply chain.

Learn more about the Tech on Tap series and watch recordings of many of the webinars here: https://vt.edu/innovationcampus/events.html

News — CPULD partnered with ProLogis to offer their employees specialized training on pallets in automated warehousing supply chains

Image 1. Distribution supply chain warehouse.

In 2020, Virginia Tech partnered with ProLogis, Inc., a major real estate investment company in the U.S., to develop a custom training program for their maintenance technicians. ProLogis builds and/or rents out warehouse properties to its worldwide customers, including Amazon, FedEx, Home Depot, Walmart, Pepsi, BMW, and more. Especially during these days of COVID-19, more and more companies are expanding their delivery services directly to customers, creating the need for even more warehouses as opposed to retail spaces. In addition to simply renting buildings, ProLogis also offers streamlined help in setting up their customers' new automated warehouse systems as well as ongoing facility management/maintenance services.

Maintenance technicians are the boots on the ground workers for ProLogis. Because they work closely with the companies that rent the warehouses from ProLogis, they have firsthand knowledge of the major pain points for their customers. The training was designed to provide practical knowledge on a wide range of topics in order to enable attendees to identify potential improvement opportunities in the warehouses and offer solutions to their clients.

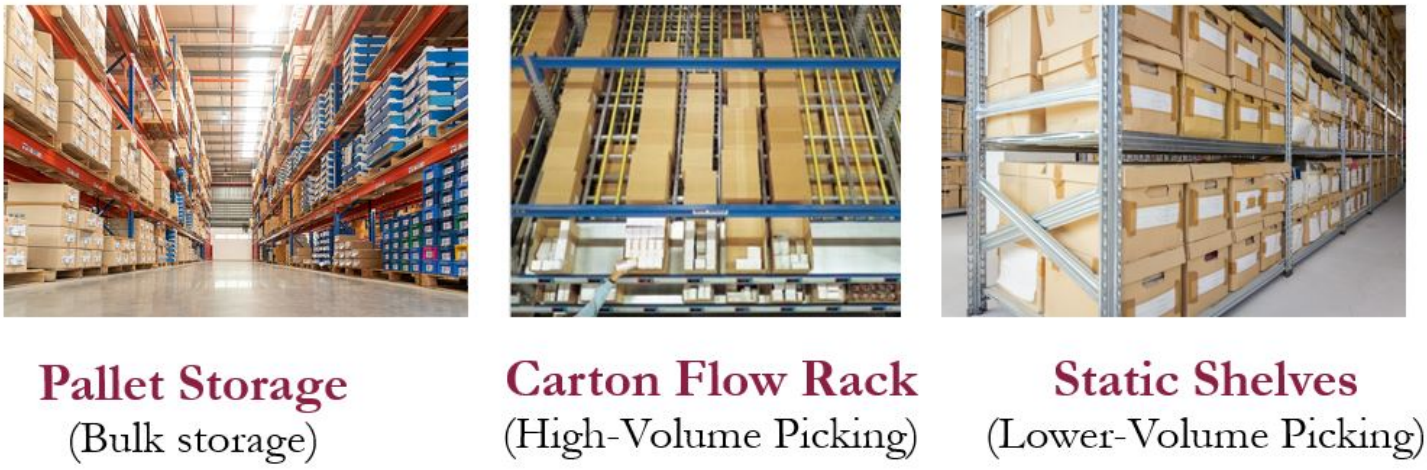

Image 2. Common forms of warehouse storage.

This new training course covered information focused on four major learning areas: supply chain management, material handling and storage systems, unit load stability, and warehouse optimization. The course was originally designed for in-person education, but due to the pandemic, the format was modified for online delivery but kept some of the hands-on aspects. Eduardo Molina, packaging instructor, and Dr. Laszlo Horvath, director of CPULD, each taught sections of this virtual training. The material was divided into six sessions. Between each lecture, the attendees received hands-on assignments that allowed them to translate the skills that they were learning into practice. To make learning easier, each module included on-demand, pre-recorded lectures that the attendees could watch on their own time and live lectures with facilitated discussions on the covered topics.

The attendees' final assignment challenged them to find an improvement opportunity in the warehouse that they are responsible for and present it to the leadership of ProLogis. The training was a huge success and will be repeated in March 2021 for a second cohort of employees.

Virginia Tech offers multiple short courses on a wide range of topics each year and works regularly with companies to build custom courses for them in the areas of packaging, pallets, and unit load design. See our current offerings at https://www.unitload.vt.edu/education/continuing-education.html.

News — The Unit Load Design and Performance short course was offered virtually in August 2020

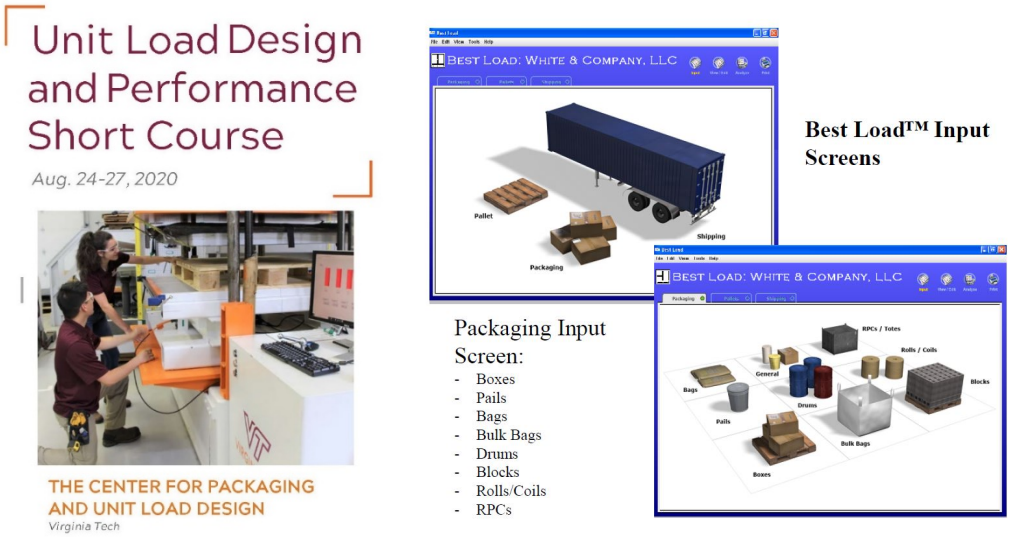

Image 1. Unit Load Design and Performance short course advertising materials and Best Load screenshots.

The Center for Packaging and Unit Load Design partnered with White and Company, creators of the Best Load and Best Pallet software packages, to offer its annual Unit Load Design and Performance Short Course entirely online this year. Due to the COVID-19 pandemic, this course, which is usually held in-person for two full days, was changed to multiple Zoom sessions over the last full week of August 2020. The course had 20 participants from seven U.S. states and two foreign countries (India and Mexico).

Over the course of four afternoons, participants listened to live lectures from both Laszlo Horvath, associate professor in the Department of Sustainable Biomaterials and director of CPULD, and Mark White, professor emeritus at Virginia Tech and president of White and Company, and participated in both group and individual exercises utilizing the design techniques about which they were learning.

This course focused on systems-based design of unit loads. Systems-based design means looking at the distribution supply chain as a whole, consisting of many interacting parts. In the past, corrugated board, packaging, pallets, unit loads, and material handling equipment were all designed separately to provide the best options possible as individual items. Recently, systems-based design has become more popular as it looks at the interactions between these individual items and how to make design decisions based on these interactions. The ultimate goal of design is to balance cost and performance. Over-designing is uneconomical; under-designing can be dangerous.

This short course covered the keys to implementing systems-based design methods, providing the participants with an overall summary of the current research into how packaging, pallet, and unit load handing equipment interact; educating them on systems-based design and how to look at the interactions instead of just the components; and providing them with tools that could model these interactions (namely, the Best Load and Best Pallet software).

Participants worked to perform an audit of an example warehouse and then analyzed their findings by inputting them into the Best Load software. Participants then were able to re-design individual components within the system in order to increase the effectiveness and reduce the cost of the overall system.

Learn more about CPULD short courses: https://www.unitload.vt.edu/education/continuing-education.html

News — COVID19 has brought new procedures to CPULD's classes and labs

Image 1. Lecture on over-the-road vibration of sensitive electronics

The COVID-19 pandemic has changed the way the packaging program at Virginia Tech educates students. Our packaging program is currently ranked No. 4 in the U.S. We focus on educating future packaging professionals using a hands-on and minds-on approach. Our program's coursework is heavily focused on hands-on laboratories and semester-long projects to ensure that each of the skills that the students are learning is translated into practical applications. Through the Center for Packaging and Unit Load Design, students also have the chance to work on real-life, company-sponsored packaging design and research projects. These projects allow students to work on relevant problems in the industry and to come up with solutions that could eliminate damage, increase effectiveness, and improve the sustainability of packaging.

The SBIO 4024 Packaging Design for Global Distributions course focuses on teaching students how to design protective packaging solutions that can survive the hazards of global physical distribution. The cornerstones of this course are the laboratory exercises and the semester-long redesign projects, both of which require the students to be physically present in the lab and use the equipment. In 2020, the maximum number of students in each course laboratory section decreased to six, and students had to keep 6 feet apart. All of this created new challenges for course delivery.

To overcome these challenges, Associate Professor Laszlo Horvath used digital technology to develop live laboratories that still allowed students to have high-quality, hand-on experiences with vibration and shock testing. During lab session, Dr. Horvath showed students how to simulate over-the-road transportation for highly sensitive electronics and how to identify critical elements such as memory units or graphic cards that could be damaged by the vibrations. To allow for social distancing, multiple webcams were used to stream the critical information to a 65-inch TV, which allowed students to see the vibration levels for different components from a distance.

Instrumented packages filled with shock sensors also allowed us to capture and present impact data during drop sequences simulating Amazon's distribution network. Students learned how to use the drop tester and to identify shock events from corner, edge, and face drops.

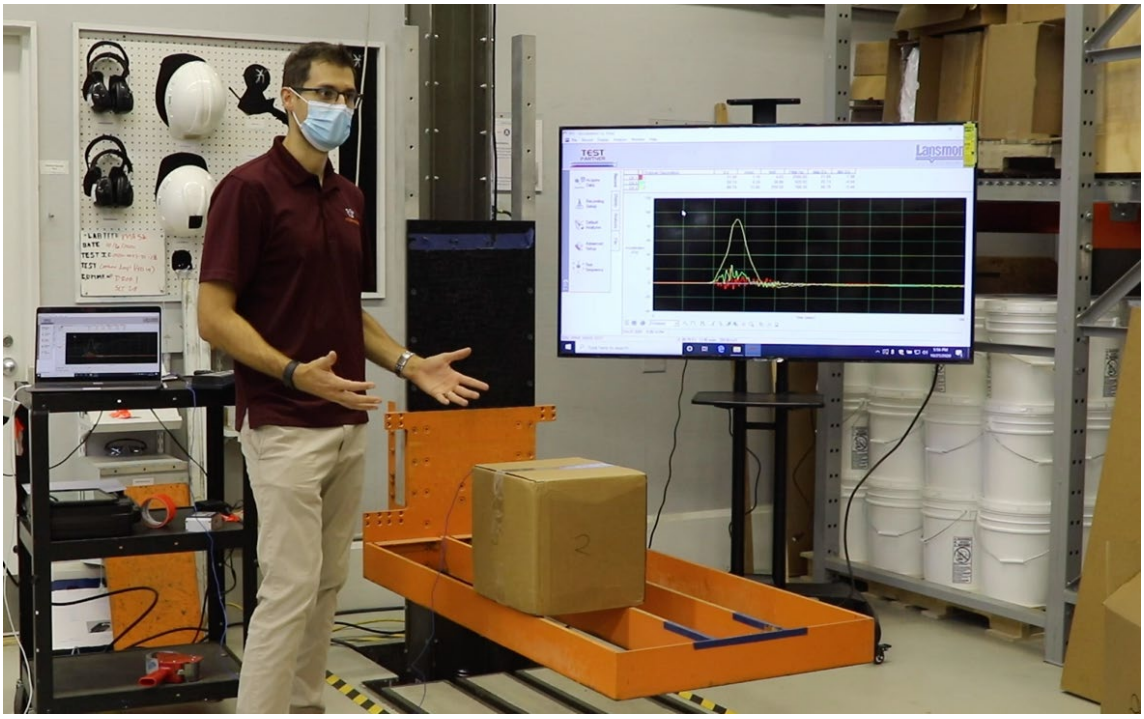

Image 2. Lecture using instrumented packages to measure impacts during the Amazon 6A drop sequence.

In order to teach students how to set up sensors in transportation devices and then collect and analyze the shock and vibration data from distribution, Dr. Horvath partnered with Lansmont Corporation. He used their state-of-the-art 3D15 and 9x30 remote data acquisition units to instrument a Penske truck and then collect data from their Blacksburg-Charlotte-Blacksburg and Blacksburg-Dublin-Blacksburg routes. The truck was instrumented with two different sensors to measure shock and vibration as well as two GoPro cameras in order to have video footage from the trips. After the data was collected, Erich Joneson, Lansmont's data analysis guru, joined the class remotely to teach students how to extract the needed information from the collected data.

Image 3. Shock data obtained from the recorded trip with a Penske truck.

News — CPULD's 2020 annual membership meeting was held virtually in August

Image 1. CPULD's Gold and Silver level member company logos.

During CPULD's annual Industrial Affiliate Membership meeting, which was held virtually August 12-13, 2020, our graduate students gave presentations regarding the research completed over the last year, the members gave their input on what directions they'd like research to go in the future, and everyone was updated on the state of CPULD due to COVID-19 and on the past year's renovations and budget.

Most of our students' research projects are done specifically at industry members' requests and are usually designed to satisfy questions or issues that have arisen in our industry partners' supply chains. These leading companies are working with us to be at the forefront of innovative pallet and package research. We are collaborating to develop new, innovative ways to design pallets and unit loads as well as to find ways to improve the sustainability of the packaging supply chain.

Over the past year, our graduate students have been researching the following topics:

- Evaluation of the maximum pallet deflection under forklift handling conditions (Yu Yang Huang).
- An operational concept of an IoT system for the palletized distribution supply chain (Nicolas Navarro).
- Life-cycle analysis for systems-based unit load design (Chandler Quesenberry).
- Finite element modeling of load bridging in unit loads (Eduardo Molina).
- Investigation of impacts and damages observed by pallets during physical distribution (Jorge Masís).
- Continuous improvement project — performance measurement at the CPULD (Yu Yang Huang).
- Continuous improvement project — the CPULD as a learning organization (Nicolas Navarro).

Each of the graduate students gave a presentation to the membership outlining the results of their research. The results have been made available to our members and the recordings of these presentations will be uploaded to the new Members Only section of CPULD's website once they are complete.

Our members also had the chance to offer suggestions for the focus of next year's research projects. Three long-range research initiatives were decided upon as well as three specific research questions:

- Look into the effects of load bridging on the load carrying capacity of pallets — i.e., determine the "real" load carrying capacity of pallets.
- Find what effect pallet stiffness has on the cost of packaging materials.
- Develop an industry standard for an accelerated pallet durability test.
- Evaluate maximum pallet deflection under forklift handling.
- What are the environmental benefits of increasing the stiffness of the pallet top deck for unit loads carrying corrugated boxes?
- Measure the hazards experienced by pallets during material handling.

Our industry affiliate membership is a three-level program offering industry promotion, discounts on CPULD's services, and access to a wealth of knowledge and world-renowned experts. In addition, we foster a close relationship between our member companies and their potential future employees — companies are regularly connected with our students during research projects, internship opportunities, and networking events.

CPULD is very excited about our 2020 research projects and the membership program's momentum. Join other worldwide companies in benefiting from an Industrial Affiliate Membership with the Center for Packaging and Unit Load Design at Virginia Tech.

Learn more about the Industrial Affiliate Membership program: https://www.unitload.vt.edu/membership.html

Outside News – Links to other articles and interviews about CPULD

Dr. Laszlo Horvath was interviewed by local media WSLS10 about the state of packaging during COVID19 and the holiday season:

https://www.wsls.com/news/local/2020/11/24/virginia-tech-researchers-examining-how-packages-are-treated-before-arriving-at-your-door/

Pallet Enterprise interviewed CPULD director Dr. Laszlo Horvath about the benefits of hiring CPULD graduates as employees:

https://palletenterprise.com/view_article/5538/Think-Differently-About-Your-Next-HireVirginia-Tech-Center-Offers-Opportunities-for-Independent-Pallet-Companies-to-Boost-Their-Staff-Expertise-

J. Kate Bridgeman, Administrative Assistant for CPULD, was featured in the Department of SBIO's interview series. Read more about One of Us: The Person Behind the Professional here:

https://sbio.vt.edu/about-us/one-of-us/kate-bridgeman.html

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2020 Webinars

CPULD is pleased with the response to our new webinar series. Director Laszlo Horvath gave four separate lectures in 2019, which were free to our members. Each webinar had around a dozen participants and received high satisfaction ratings from the survey sent out to attendees.

Throughout 2020, CPULD has partnered with NWPCA to offer four 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. These webinars have reached over 700 attendees in 18 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 future webinars are announced.

Wood Pallet Design and Performance Short Course, Fall 2021

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, Spring 2021

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/

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