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:

- Measurement of Hazards Experienced by Pallets During Material Handling
- Evaluation of packaging designs for portable AC units to be shipped thru ecommerce distribution channels
- Evaluation of temperature control units' supply chain distribution routes and the damages experienced
- Initial prototype of a simplified method to evaluate fastener properties for pallet joints
- Exploration of insulated shipping containers for cold chain distribution
- Other graduate and undergraduate research project info
- Alumni spotlight: Tyler Matusevich
- Graduate student spotlight: Sean Hobbs
- Summaries and updates on CPULD events and conferences
- Congratulations to Joseph Keller and Clark Sabattus on passing their Master's defenses!

Research Highlight - Measurement of hazards experienced by pallets during material handling

Image 1. Clark Sabattus equips a forklift with a sensor to measure the shock events experienced in warehouse facilities.

Recently graduated CPULD alumni, Clark Sabattus (Master's Degree, Arlington, TX), researched the "Measurement of hazards experienced by pallets during material handling" for his Master's project (Image 1). The objective of this research project was to investigate the intensity of the vibration and horizontal shock impacts that forklifts exert on pallets during material handling. Although often overlooked, pallets can become costly for a company if not designed correctly for their specific supply chain. Forklifts are the dominant mode of material handling for palletized products, and they are responsible for the majority of damages experienced by pallets.

Despite the prominence of forklifts in the supply chain and their importance to pallet design, there is a lack of research focusing on the interactions between forklifts and pallets. It is important to be able to replicate what a pallet might experience in the field, so when testing in a laboratory setting, a company will be able to accurately gauge their pallet's functional capabilities. The creation of a simulated material handling environment in 1993, named FasTrack, has aided in researching a pallet's useful life. FasTrack simulates a pallet going through a series of trips, utilizing material handling equipment such as forklifts and pallet jacks. It was designed to replicate the environments that a unit load of products may travel through in the field in order to observe the common damage modes that may occur to a pallet.

The first study that investigated forklift handling in a laboratory setting was conducted in 2021 by Yu Yang Huang[1], another CPULD alumni. His project investigated gas, reach, and electric forklifts. Each forklift went through a series of handling scenarios to determine the effect of different variables such as unit load weight, speed, road conditions, and sensor location. A follow up study by Borocz[2] was conducted, also in 2021, which expanded the number of investigated forklifts and proposed a PSD profile that could be used during laboratory simulation of forklift handling.

These two research projects provided a basic understanding of the vibration levels seen during forklift handling and how different variables affect that vibration; however, there was still a lack of research investigating the vibration and shock environments during material handling in a field environment. Thus, the objective of this research project was to characterize the vibration environments and the horizontal shocks experienced by pallets during forklift handling in different types of facilities.

Forklifts in multiple facilities were instrumented with data loggers (Lansmont SAVER 3X90 and 3D15) to measure the acceleration peaks, g's of shock impacts, duration of impacts, random vibration intensity, and RMS(g) values during forklift handling in the field. This field data was collected from three different types of facilities: a distribution center, a manufacturing facility, and a pallet manufacturer. The mean peak acceleration values in the field were relatively similar between facilities. The values were the lowest for the pallet manufacturer (0.264g) and highest for the distribution center (0.353g). The acceleration values at 98% also revealed that peak accelerations experienced by the forklift can be as high as 1.65g.

The mean acceleration values found during this project are lower than what was recorded by Huang et al. in the laboratory environment (Huang et al., 2021). An explanation for the differences between the field and the laboratory measurements could be the presence of "dead head travel" where forklifts travel without carrying any load. This type of movement can produce higher frequency vibrations that, when averaged into the data, can alter the observed vibration profile.

The intensity of impacts during forklift handling were also assessed in the same facilities. The Saver 3x90 dataloggers were attached to the forklifts behind the carriages holding the fork tines. The summary of these acceleration/shock duration values for the investigated facilities are presented in Table 1. Over the four-week investigation, only 25 shock events occurred at the distribution facility, while 245 shock events were of interest at both the LTL and manufacturing facilities. The results of these measurements showed that LTL facilities recorded the highest average shock impacts of all the facilities investigated with an average acceleration value of 4.74 g's and an average shock duration of 7.42 msec. When the harshness of handling in the field was compared to the handling intensity found during FasTrack simulations, it was determined that the simulated intensity in Fastrack is only slightly harsher than what was observed in the field. The results indicate that the FasTrack simulation is a good representation of the handling processes used in the field.

Percentile	**LTL**		**FasTrack**	
	Acceleration (peak, g)	**Duration (msec)**	**Acceleration (peak, g)**	**Duration (msec)**
60th	4.83	7.2	3.70	6.00
80th	6.60	10.56	4.76	6.00
90th	7.80	13.58	5.46	8.00
95th	9.22	15.54	6.53	8.00
Mean	4.74	7.42	3.50	5.44
Maximum	21.4	32.2	8.38	14.00

Table 1. Acceleration and duration values for the investigated facilities versus the FasTrack simulation.

References:

1. Huang, Y. Y., Horvath, L., & Böröcz, P. (2021). Measurement and Analysis of Industrial Forklifts Vibration Levels for Unit Load Testing Purposes. *Applied Sciences*, *11*(7), Article 7. https://doi.org/10.3390/app11072901

2. Böröcz, P., & Singh, S. P. (2018). Measurement and analysis of delivery van vibration levels to simulate package testing for parcel delivery in Hungary. *Packaging Technology and Science*, *31*(5), 342–352. https://doi.org/10.1002/pts.2327

Alumni Spotlight – Tyler Matusevich

Image 1. Tyler Matusevich, Sustainability Director, Brook + Whittle, 2023.

Tyler Matusevich, a local southwest Virginian, came to Blacksburg from just a few miles away in Radford, VA. "Having grown up in the New River Valley, going to many Virginia Tech athletics games in my youth, I knew I wanted to officially be a Hokie. Additionally, it's a great school known for innovation with a well-established College of Natural Resources and Environment. I was accepted into CNRE as an undecided major in 2009, but after talking to my advisor and taking the Intro to Packaging course that first semester, I declared my major." Tyler graduated in May 2013 with a B.S. in the degree that is now named Packaging Systems & Design. He continued his studies at VT by joining the graduate school in 2015 and got his Master's degree in Natural Resources.

At first Tyler thought he'd want to go into nature conservation, but in order to help his future career path, he decided to switch to the packaging major. He told us that "I actually went into the college of NR&E because growing up, I would watch The Discovery Channel and Animal Planet and wanted to do something with conservation of our natural resources to benefit biodiversity. However, once I took the Intro to Packaging course and talked to my advisor about the careers in packaging, the opportunities, the pay, the retention, etc., I quickly decided to declare and knew I could take up conservation efforts for packaging. That is how I found my niche in sustainable packaging which has grown incredibly fast over the past decade with constant innovation and regulatory development for many years to come."

When asked which classes were his favorite and which he's found to be useful in his life after college, Tyler told us that "A friend of mine's dad once told me that college is for you to learn how to learn. I do agree with that in general and Virginia Tech enables that. However, packaging science, similar to all studies, is of course beneficial to learn the finer details of areas that you will advance throughout your career. For me, in my current career, the most beneficial courses were related to material science, namely plastics and paper. However, the most important skills I learned were project management through labs, work at the CPULD, and internships/co-ops.

This is a major aspect of my career in sustainable packaging, working with our suppliers, partners, and customers to develop innovative solutions. I also happened to find o-chem and my graduate statistics courses interesting, although I had to go to nearly every teacher assistance workshop."

In addition to the classes, Tyler let us know that the relationships forged and the lessons learned during his time at VT were particularly memorable. "The memories and connections I made during my time at the CPULD and in general at Virginia Tech have helped develop my career and personal life. The systems thinking approach that is taught at VT PKG is critical to understanding the proverbial "real world." You must understand the principle of causation. Every decision, change to a packaging component, design element, material, etc., all have subsequent impacts throughout the value chain from price, availability, performance, or end-of-life to name a few. Understanding cause and effect is something I use daily whether that's in working with our operations team, sourcing, R&D, marketing, sales, or customers."

Tyler has focused his career on turning the packaging industry more sustainable. He currently works for Brook + Whittle as their Sustainability Director. Brook + Whittle is "a leading manufacturer of pressure-sensitive labels, shrink sleeves, flexible packaging, and heat transfer labels with a focus on sustainability. We are headquartered in Guilford, Connecticut, with a total of 16 manufacturing locations across the US; however, I live and work out of Richmond, Virginia."

"As the Sustainability Director at Brook + Whittle, I drive the label printing and flexible packaging industry towards a more sustainable future through product innovation, environmental programs, and strategy, implementing sustainability partnerships throughout the value chain. Essentially making sustainability a part of everyone's job. My day-to-day changes as one day it's looking at scope 1, 2, and 3 emissions, the next is pushing us towards zero waste to landfill, working with suppliers and industry groups on product development and certification, creating marketing content, working with our sales and customers to find the best solution, or developing our ESG framework."

A large part of life is balance, and according to Tyler, "My home life consists of my wife, Katie, and our two dogs, Evie and Fitz who are both border collie mixes. When I'm not working, my hobbies mainly include both watching and playing sports, exercising, and socializing with friends (usually at a brewery). Some of my favorite things to do are watch my favorite teams (Green Bay Packers, Milwaukee Bucks, Arsenal, and of course Virginia Tech), go to the gym, and outdoor activities including walking, hiking, skiing, swimming and paddle boarding (usually with the pups)."

Throughout his school and career, Tyler has received numerous awards and certificates, including:

- AF&PA scholarship
- Conducted ASTM and ISO testing
- Graduate Certificate of Global Sustainability
- Graduate Certificate of Natural Resources
- Certified lead auditor for ISO 14001
- Certificate from Business Training Experts for The Leadership Journey

Research Summary – Evaluation of six packaging designs for portable AC units to be shipped thru ecommerce distribution channels

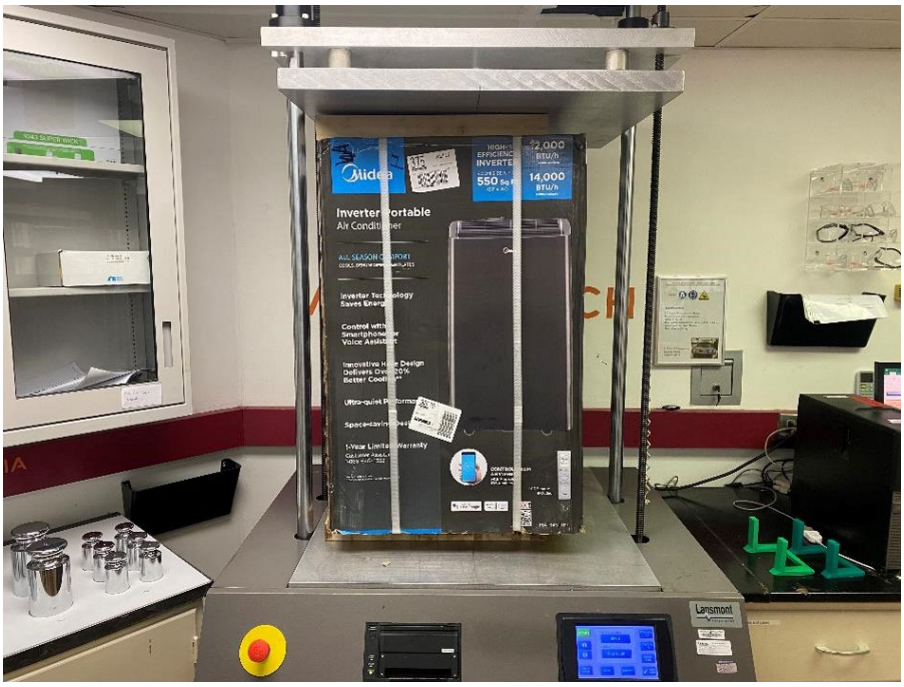


Image 1. Portable AC unit being compression tested during this undergraduate research project.

One of the world's largest manufacturers of major home appliances sponsored an undergraduate research project for the students in our department for the fall semester 2022. Undergraduate student Matt Simonson (Junior, Franklin Lakes, NJ) and Mehr Ghotra (Senior) were selected to evaluate various packaging systems used to transport portable AC units thru e-commerce distribution channels. A final report was presented to the sponsor summarizing the findings and giving theoretical analysis of the packaging systems' performances and recommended improvements to the packaging.

E-commerce is the market where goods and products are sold via the internet. Nearly anything can be bought through ecommerce today and that market is highly competitive. Ecommerce packaging is driving packaging engineers to develop new, sustainable solutions and more convenient ways of shipping products throughout the world. It also affects material use; packages that are shipped between multiple places need to withstand more hazards and be more protected while in transit. The responsibility of protective packaging has increased with the growth of ecommerce. Each characteristic is important to make sure products can be shipped worldwide while being protected to withstand risks. Engineers have had to increase the usage of protective packaging, like foam or corrugated materials, and even implement flexible packaging options just to comply and compete in a complex market and supply chain that is not as easy as typical retail.

For this investigation, the students evaluated six different models of portable air conditioners from six major brands. Each unit went through a performance test and analysis using the ISTA Amazon 6 Series testing sequence, which is a full testing protocol with general simulations used to test a package's protection abilities. There are many different tests that all evaluate different aspects of a package's strengths and protection

capabilities. Examples include drop testing, compression testing, and vibration testing - all to simulate real-world situations that these packages could experience during distribution.

First, the AC units were broken down and parts-lists were created to detail the packaging specifications of each model (Table 1 and Image 2 & 4). When creating these Bills of Materials (BOM), our packaging students put the knowledge that they learned about the different packaging materials to the test. A quantitative assessment of the different types of materials used for the packaging solution is not just important in ensuring that the proper packaging is used, but it is also essential in determining the environmental performance of the packaging solution.

Table 1 – Descriptions of the tested portable AC units and corrugated materials used.

Design	Total Weight (lbs.)	Brand	Outside Dimensions (inches)	Burst and Strength (lbs.)	Box Type	Flute	Manuf's Joint	Top Sealing Method	Bottom Sealing Method	Straps	Hand Holds
1	73.4	Toshiba	34 ½ x 19 3/8 x 16	275	HSC	BE	(2) Double Stapled	Tape	Tray	Yes	Yes
2	64.8	Hisense	34 ¼ x 18 ¾ x 14 15/16	N/A	HSC	BE	(2) Double Stapled	Tape	Tray	Yes	Yes
3	65	LG	34 ¼ x 19 x 14 3/8	200	HSC	BE	(2) Double Stapled	Tape	Foam Insert	Yes	Yes
4	70	DeLonghi	35 x 18 ½ x 15	N/A	HSC	BE	(1) Double Staples	Tape	Tray	Yes	Yes
5	89.8	Midea	34 ½ x 22 9/16 x 18	N/A	HSC	BE	(2) Double Staples	Tape	Foam Insert	Yes	Yes
6	63.8	G&E	26 1/8 x 18 x 18 1/2	200	HSC	BE	(2) Single Staple	Tape	Foam Insert w supports	Yes	Yes

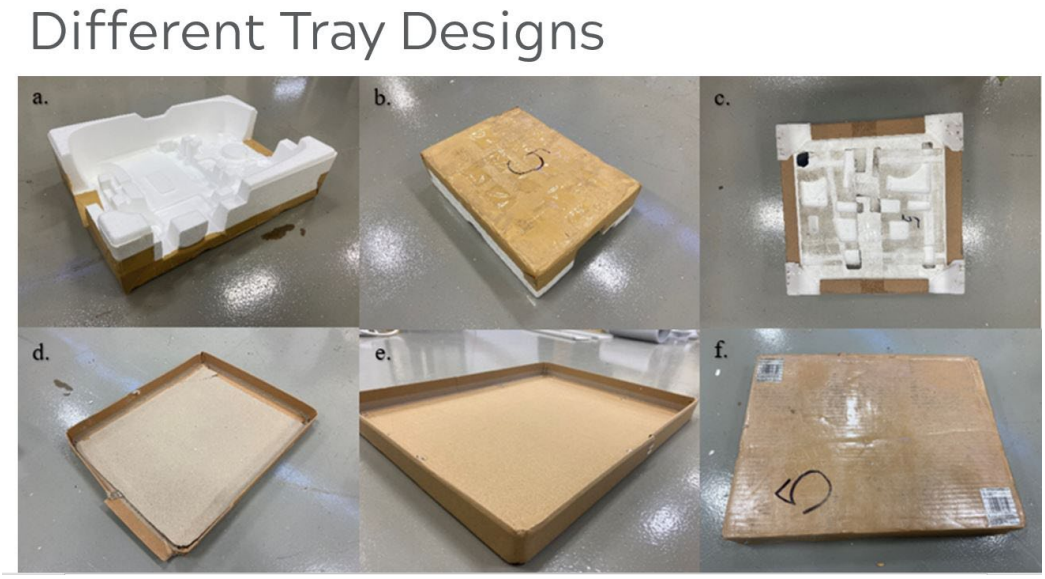


Image 2. Pictures of the bottom trays of the investigated designs

The ISTA Amazon testing processes gave the students substantial information about the portable AC units. They ran all six brands through the same test sequences, so they were able to compare and identify which units had stronger protection properties than others. They were able to see which units performed better in certain areas, and they came up with theoretical conclusions to determine which of the units had the best strength and protection abilities.

All of the packages were put thru a series of drop tests on each face and edge, vertical compression tests, and stacking compression tests. Then each package was subjected to four different vibration profile tests before again being drop-tested on its various faces/edges (Image 3). Once the units completed the ISTA 6B testing sequence, they were each broken down to inspect and assess any damage that could have occurred to the packaging materials and the unit itself through testing.

To assess the sustainability of the packaging solutions, the packaging materials used for each of the different designs were sorted and calculated to determine the percentage of curbside recyclable materials, percent of fiber-based materials, and also the package-to-product weight ratio as a percentage. Knowing all of this showed the researchers which designs were more sustainable and what could be improved as possible redesigns of any or all of the current packaging systems.

Image 3. ISTA Amazon 6B drop tests being conducted on portable AC units.

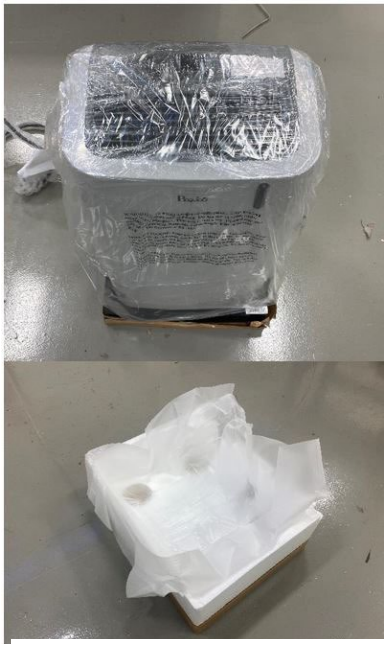


Image 4. Examples of bags and sheets used to protect the AC unit within the corrugated packaging.

The project was a great opportunity for our students to practice package testing and creating packaging specifications. In addition, the project sponsor will be able to take this information and improve or alter their current packaging designs in order to compete with companies that might have stronger components in their portable AC packages.

Research Summary – Evaluation of temperature control units' supply chain distribution routes and the damages experienced

Image 1. Heat pump unit being vibration tested during this undergrad research project.

One of the world's largest manufacturers of major home appliances sponsored an undergraduate research project for students in our department for the fall semester 2022. Undergraduate students Shak Kataev (Senior) and Collin Kennedy (Junior, Chesterfield, VA) were selected to evaluate various packaging systems used to ship heat pumps and air handlers. A final report was presented to the sponsor summarizing their findings and giving analysis of the packaging systems' performances.

Six units were provided for testing purposes. The units included two types of products (air conditioning units and heat pumps) from three different brands: Midea, Mitsubishi, and Trane. All units were shipped in corrugated packaging sleeves. Both Mitsubishi units and the Trane air conditioning units were transported on pallets. All units arrived with some level of plastic strapping for additional containment strength. However, the bottom of the Midea AC unit arrived disintegrated. This unit was deemed untestable as containment of the unit was already compromised, so only five units ended up being used for this project (Table 1).

Table 1. Properties of heat pumps and air conditioners researched during this project.

Unit ID	D1-1	D1-2	D2-1	D2-2	D3-1	D3-2
Brand	Midea	Midea	Trane	Trane	Mitsubishi	Mitsubishi
Type	Air Conditioner	Heat Pump	Air Conditioner	Heat Pump	Heat Pump	Air Conditioner
Serial Number	--	0822V32601	22295UFW4F	22035M33V	13U001377H1L94	23G0072032P816

Place of Origin	China	China	Columbia, South Carolina	Columbia, South Carolina	Japan	Japan
Length (in)	25.31	39.25	33.25	25.19	41.63	28.44
Width (in)	20.81	15.75	30.25	20.25	17.75	18
Height (in)	41.63	28.75	33.75	54.38	41.38	46.5
Gross Weight (lb)	116	107.8	170.6	115.5	211	116
Individual Palletization	None	None	Yes	None	Yes	Yes
Notes	Did not test due to defective packaging					

The specific procedures used to test the Midea, Mitsubishi, and Trane heat pumps and air conditioning units followed the ISTA 3E standard. This standard serves to mimic movements and stresses surrounding loading, full truckload shipping, and unloading individual packages. In real life, each step carries risks of drops and falls. The ISTA 3E standard is the perfect testing process to replicate the mechanical stresses, vibrations, and potential damage experienced by a package during shipment to and from distribution centers. Packaging systems that pass these tests can then be certified as such and utilized for global distribution.

The units tested were large products (all more than 100 lbs.) shipped in large boxes. Each product was unitized by itself; it was its own unit load and not made part of a larger load. Due to the packages' large sizes, individual manual and mechanical handling was the most optimal. Inclined impact tests were conducted to simulate drops or shocks that could be experienced while being handled by a forklift or by hand. The manual handling of the units needed to be simulated with particular emphasis on the failures that can occur; to simulate a failure in manual handling, shock testing was conducted to simulate the dropping the unit (Image 2).

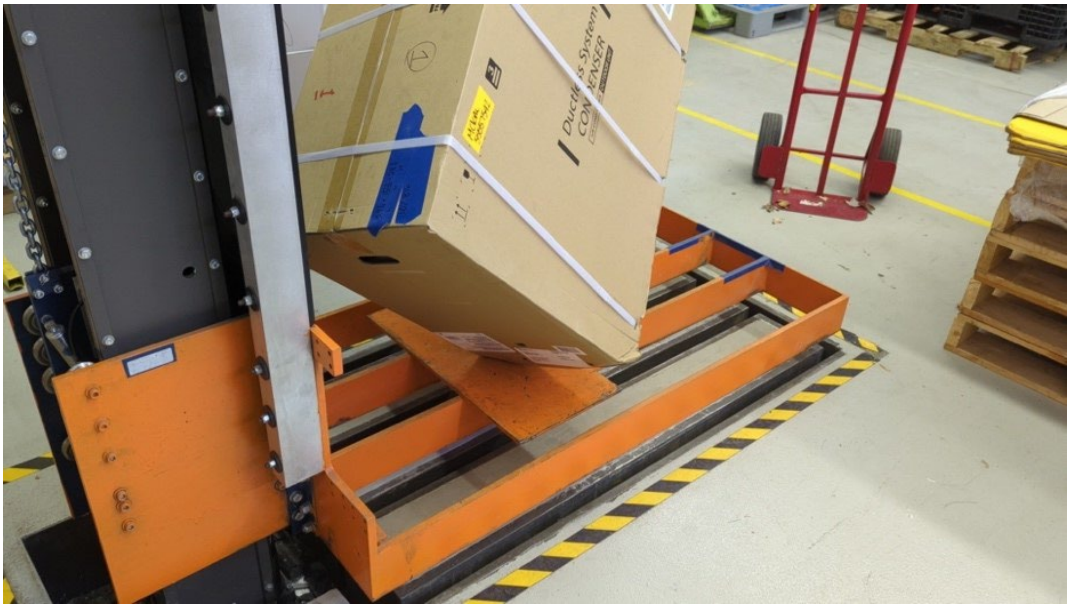


Image 2. Drop testing a heat pump.

Custom testing sequences were developed for each product using the ISTA testing standard to best mimic the transport sequence of the product being shipped in its package. No test sequence followed the same order, but each unit was tested in a way that the standard outlined. The units were measured, weighed, and properly inspected before any testing procedure began. Then, in general, stability tests, mechanical handling by forklift, drop tests, impact tests, and more drop tests were conducted. The packages were then vibrated under various profiles, and subjected to stacking conditions as they would experience in a warehouse. Finally, more vibration tests and drop tests were conducted before each package was taken apart for inspection.

Each of the units and their packaging systems were visually inspected for damage, discrepancies, and anything of note that may have occurred during the testing phases. Corrugated packaging was measured in length, width, and caliper. Polymer foams and polymer straps were weighed and measured for caliper. Curbside-recyclable components were fully assessed and weighed as a percentage of the total packaging. Pallets, under the palletized units, were similarly inspected; their stringers and deck boards were measured and examined for damage. Some units came with polymer bags containing components important to the units' operation. And, some units came packaged in large polymer bags just under the corrugated sleeves which were large enough to cover all of those boxes' various items.

All units sustained some damage to their corrugated packaging. Tears and punctures were common among all tested units. For the remaining Midea product, this packaging damage was all that was incurred. However, the Trane units had shifted on the pallets, which resulted in lots of damage to all corners and straps. Also, once the packaging was removed, there were dents and scratches in both of the Trane products (Image 4). The Mitsubishi units also sustained damages to their packaging, pallets, and the products themselves. As these units were designed to be installed in homes by professionals, it was not able to be determined if the units would still function; however, none of the observed damages seemed severe enough to be the cause of product malfunction.

Image 3. Example of a dent to a Trane product which was incurred during testing.

The students also created a breakdown of the packaging materials by recyclability and what proportion of the overall packaging was recyclable. Packaging made from forest/wood products, such as corrugated fiberboard,

laminate, wood, and other derivatives was deemed curb-side recyclable. Fiber-based packaging was separated into its own category. Packaging components made from recyclable plastic polymers was also deemed curb-side recyclable. Polystyrene (PS), metal, unlabeled plastic components, instructions, installation and operations manuals, and accessories were not deemed recyclable. All recyclable materials were calculated as a percentage of the total packaging and then as a percentage of each unit's total weight (Table 2).

Table 2. Recyclability of packaging materials.

Unit	Gross weight (lbs.)	Packaging weight (lbs.)	% of unit weight in packaging	Fiber-based packaging weight (lbs.)	Weight of polymer-based recyclable packaging (lbs.)	% of packaging weight that is recyclable	% of unit weight that's recyclable
D1-2	107.8	6.36	5.90	4.91	0.135	79.32	4.68
D2-1	170.6	18.3085	10.73	17.577	0	96.00	10.30
D2-2	115.5	8.9465	7.75	8.7635	0	97.95	7.59
D3-1	211	23.2165	11.00	21.724	0.71	96.93	10.67
D3-2	116	19.123	16.49	18.543	0	96.97	15.99

Research Summary - Initial prototype of a simplified method to evaluate fastener properties for pallet joints

Image 1. Alonda Johnson

To determine the strength of fasteners in joints on a pallet, it is generally necessary to conduct an incline impact test, which involves a pallet colliding into simulated forklift tines. While this method accurately predicts pallet performance, it is time-consuming and expensive. Individual fastener strength can be estimated by conducting a Fastener Quality Analysis (FQA), which includes a Morgan Impact Bend Angle Nail Test (MIBANT), and then using that data to mathematically predict the fastener's performance. However, there is no existing testing methodology that can be used to evaluate the dynamic performance of individual pallet joints. The purpose of this study was to ideate a testing apparatus that could simplify testing the strength of the fasteners in pallet joints.

CPULD undergraduate student, Alonda Johnson (Senior, Newport News, VA), was selected to conduct this sponsored research project (Image 1). During this project, Johnson designed and manufactured a prototype of a small-scale tester to be used in measuring dynamic pallet joint strength. She then compared the data collected from her new testing equipment to the currently-used incline impact tester and outlined recommendations for future research.

Failure in pallets happens most commonly at the joints. Several factors contribute to what type of failure occurs and how soon it occurs. The type and number of fasteners used in the joint are definitely factors, as well as the strength and placement of said fasteners. Factors such as the diameter of the fastener head, the depth of penetration into the pallet joint, the distance the fastener is from the edge of a board, and the distance between fasteners also affect the strength of a pallet joint. In comparison to 2.5-inch nails, 2-inch nails can increase pallet

rigidity by 36%, strength by 17%, and decrease end-splitting of deckboards by 50% if the number of nails per pallet is increased by approximately 50%.

Fastener performance can be estimated by calculating three values: fastener withdrawal index (FWI), fastener shear index (FSI), and head pull-through resistance (HPT). FWI is characterized by the amount of resistance that a fastener experiences when being withdrawn from a material. FSI is the fastener's resistance to lateral deformation from shear forces. FSI is calculated using the wire diameter and its resistance to impact. The resistance to impact is derived from the fastener's bend angle, determined using the Morgan Impact Bend Angle Nail Test (MIBANT). Finally, HPT is the tendency of the fastener to embed deeper into the material than originally placed.

The test samples created closely mimicked the section of a pallet that consists of a top deck board and two stringers. The sample was constructed by using pieces of wood that were similar to the dimensions and wood types used in a standard 4-stringer pallet. The incline impact test determines a pallet's resistance to lateral impact forces such as interactions with material handling equipment like forklifts and pallet jacks. That test can simulate impacts from any part of a forklift on any part of a pallet. This first prototype testing equipment that was designed was a vertical impact tester (Image 2).

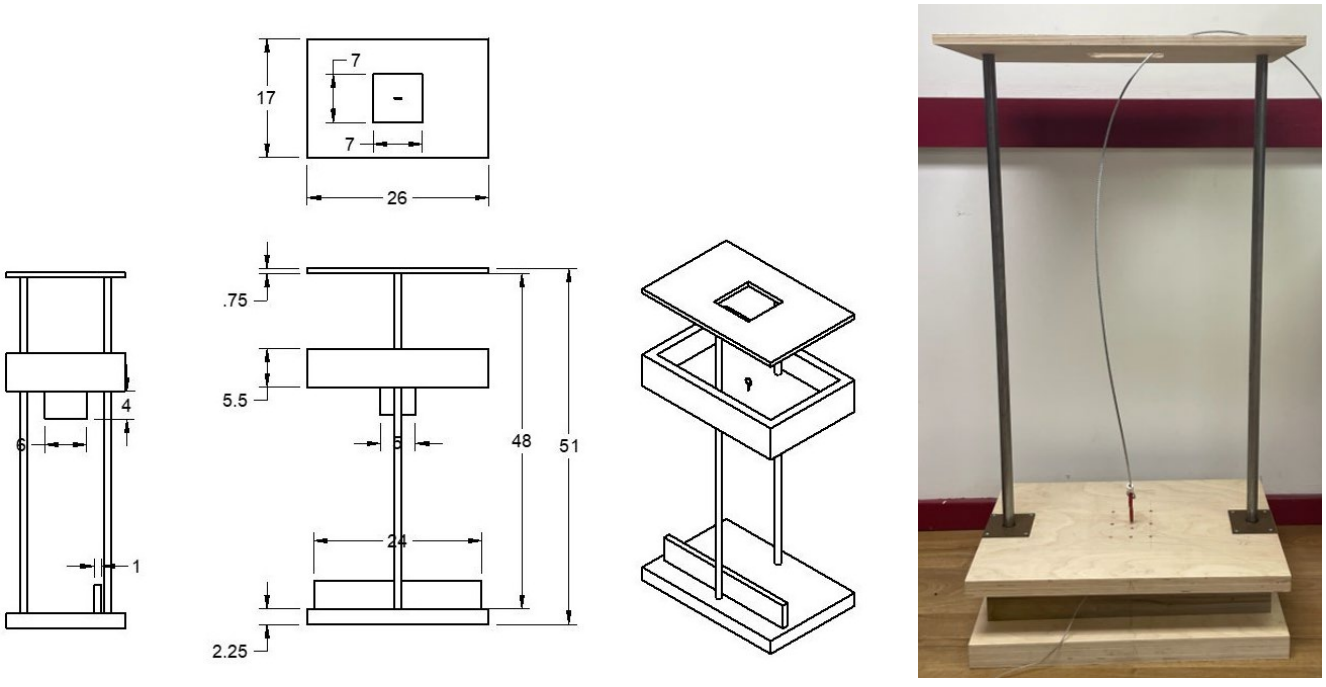


Image 2. Vertical impact tester developed for this research project.

This prototype tester was designed to isolate the vertical component of the incline impact test. This is done by mathematically correlating the kinetic energy at various speeds of the incline impact test to the vertical impact test. The testing hazard on the sliding platform was to simulate the front of the shank of the forklift tines impacting the pallet during handling. To perform the vertical impact test, an accelerometer was attached to the sample. The calculated weight was applied to the sliding platform of the testing equipment. The platform was

then lifted until there were 24 in. between the sample and the testing hazard. The sliding platform was then released and impacted the sample.

For future research, a new iteration of the prototype must be designed. Better vertical trajectory must be ensured, as well as better control of the height of the moving platen. A rubber stopper should be added to each of the rods to aid in switching the samples by allowing the sliding platform to stay elevated.

This project concluded with the recommendations for future iterations of the testing equipment design and conducting more comprehensive validation and verification testing. Future studies should be designed to compare quantitative data, such as cumulative kinetic energy, to the incline impact tester results. This would allow for analysis not only of how precise the data is but also of its accuracy. CPULD is currently in the process of designing and manufacturing the next iteration of this testing equipment.

Research Summary – Exploration of insulated shipping containers for cold chain distribution

Image 1. The various locations and needs of a cold chain.

This study aimed to identify trends in cold chain packaging as well as to discover the materials and technologies used to successfully transport products at various temperatures. This project analyzed current trends and future innovations in cold chain processes and researched how they've contributed to developments in the industry. Undergraduate students in the Department of Sustainable Biomaterials, Alonda Johnson (Senior, Newport News, VA), Konnor Rafferty (Junior, Virginia Beach, VA), and Gracie Dixon (Senior, Richmond, VA) were chosen to conduct this research project.

The researchers looked into various technological advancements and how they have been used to improve tracking temperatures and shipments. The goal was to create a methodology that could be used to research cold chain insulated-container performance. The main objective of this study was to identify market-available, insulated-container systems that could maintain a temperature within 2°C and 8°C for at least 48 hours. This was done by conducting a market search/discovery, subsequent testing of the samples by closely replicating the ISTA 7E standard, and finally, analyzing all data points between the different materials and brands.

Given the complex nature of cold chain distribution, it can be difficult to regulate temperatures for long periods of time. Thermally insulated packaging protects products that need to stay within a certain temperature range to be considered stable and safe to use once they arrive at their destination. The temperature needs to be regulated, not only during transit, but also during the packaging process and storage. If the temperature is not kept within a certain range, sensitive products (such as food or pharmaceutical items) can spoil, and the customer will not be able to use them. Temperature trackers are necessary to confirm that the product was kept within the allowable temperature ranges throughout the packaging and shipping process.

The sponsor of this research project currently utilizes corrugated boxes lined with six panels of Expanded Polystyrene (EPS) foam in four different sizes: small, medium, large, and extra-large. The other samples that were evaluated were chosen based on criteria such as size, availability, qualifications, and materials (Table 1). As shown, a variety of shipping containers were gathered to explore their insulation abilities during this research. The 2-piece EPS, insulated liners, thermal panels, and recycled thermal panels did not come with corrugated boxes. To control for this, a C-flute Regular Slotted Container with an Edge Crush Resistance (ECT) of 40 lbs./in. was constructed using a Kongsberg Edge X24 computerized cutting table to fit each investigated container.

Table 1. Non-sponsor cold chain packages investigated during this research project.

Product ID	**Materials**	**Internal Dimensions (mm)**	**Empty Weight (gram)**	**Packed-Out Weight (gram)**
Small Veritiv	Corrugated and 2- piece EPS	307x262x260	1,360.78	5,715.26
Small EFP	2-piece EPS	210x160x220	816.47	4,263.77
Medium EFP	2-piece EPS	315x315x292	1,632.93	7,529.63
Small Uline	Corrugated and 2- piece EPS	270x215x235	816.47	4,263.77
Medium Uline	Corrugated and 2- piece EPS	390x319x300	1,179.34	7,711.07
Large Uline	Corrugated and 2- piece EPS	660x420x300	2,358.68	15,966.45
Small Uline Liner	Deluxe Box Liner	130x130x140	181.44	1,905.09
Medium Uline Liner	Deluxe Box Liner	230x210x210	544.31	4,717.36
Large Uline Liner	Deluxe Box Liner	280x270x290	816.47	8,346.10
Extra Large Uline Liner	Deluxe Box Liner	385x410x410	1,360.78	12,609.87
Small Uline Panel	Thermal Panels	160x160x160	453.60	2,177.24
Medium Uline Panel	Thermal Panels	210x190x210	725.75	4,717.36
Large Uline Panel	Thermal Panels	300x300x300	725.75	8,799.69
Medium Uline R-Panel	Recycled Thermal Panels	180x200x180	635.03	2,902.99
Large Uline R-Panel	Recycled Thermal Panels	280x280x250	1,088.62	8,436.82

Image 2. 2-piece EPS insulated shipper with C-flute Regular Slotted Container built around it.

EPS is a polymer that is lightweight, ridged, and moisture-resistant (Image 2). These properties allow for several advantages during shipping. The lightweight property translates to lower shipping costs and a lower environmental footprint during transportation. Since it is so lightweight, EPS can transport more volume of product by weight than most other insulating materials. Its rigidity allows the container to have a high compression strength value, and this added strength is especially important for products that are fragile and cannot be used if damaged. EPS's moisture resistance properties help protect the corrugated box by creating a barrier between the box and any condensation created by the cooling mechanisms used during shipment.

The liner inserts are 1-piece systems made from two parts, an exterior liner and an interior foam. The exterior, a metalized LDPE, creates a moisture barrier and has high oxygen permeability. These properties protect the corrugated box from moisture but also ensures circulation throughout the packaging. The interior, a polyurethane foam, has high insulating and cushioning properties. Its insulating property allows the package to keep its temperature for an extended time. This foam layer is able to absorb shock forces and potentially mitigate harm to the product. Overall, this solution is very lightweight and flexible (Image 3A).

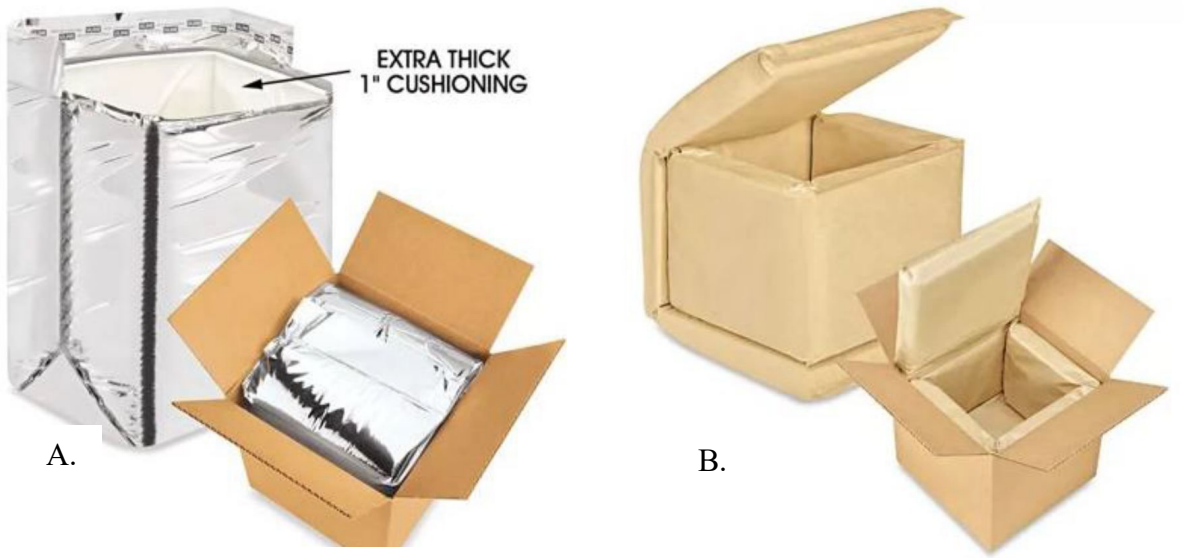


Image 3. A) Uline box liner insert system and B) Uline recyclable panel insert system for temperature-controlled shipping.

The Recyclable Panel insert (Image 3B) is comprised of two different parts: liner and filler. The exterior is made from kraft paper. In the US, kraft is made from 50% recycled fibers and 50% virgin fibers. The filler is made from a blend of renewable plant-based components and starch. This mixture creates a moisture-resistant element to the container. This option is also curbside recyclable, thus making it the most sustainable container that was tested.

Bluetooth temperature probes, by the brand Onset, were placed throughout the shipping containers to track the changes in temperature throughout the container. The inside probe was used to primarily determine if the products were staying in the desired temperature range and the outside probe was used to determine if the container itself was staying in the desired range. The disposable sensors turned red if the temperature surpassed 8 degrees Celsius.

Throughout the testing of these cold chain containers, many variables were discovered that could alter the results of the tests. Some presented themselves immediately, such as the starting temperature of the chamber and which products were used for insulation. However, other variables arose including the temperature of the cold packs themselves, the starting temperature of the products, the amount of void fill, the amount of time spent packing boxes, and sensor variations/malfunctions/etc... Furthermore, in a testing environment, it is not possible to simulate the exact handling that packaged products will endure once in shipment due to supply chain variability. Taking these points into consideration, the results of this study are meant to act as comparative data among the various packaging systems and not as validation results to count on during shipment in a cold chain.

After conducting the study, the four insulated containers that performed the best included: EFP EPS, Uline Recyclable Panel, Uline Panel, and Uline Liner (Table 2). However, the Uline Recyclable Panel was ruled out because of the condensation that was produced and leaked through to the corrugated board, damaging the quality of the box. The Uline Panel Small showed potential to do well for 24-hour shipping, but all other sizes of the Uline Panel failed under normal conditions. The Uline Liner performed well for almost all sizes, and it has the widest range of sizes. It could possibly be a good candidate for frozen shipments rather than refrigerated ones as it was able to drop the temperature quickly and did not heat up quickly.

Table 2. The average time that each container lasted between 2 degrees C and 8 degrees C.

	Small	**Medium**	**Large**	**Extra Large**
Veritiv 2- Piece	48.3 hours			
EFP 2-Piece	43.5 hours	57.5 hours*		
Uline 2-Piece	30.1 hours	27.7 hours	56.8 hours Δ	
Uline Liner	3.1 hours	60.6 hours Δ	85.4 hours Δ	47.7 hours
Uline Panel	28.3 hours	48 hours Δ	70.9 hours Δ	
Uline R-Panel		48.5 hours*	70.8 hours Δ	

Note. The "*" indicates the temperature went below 2 °C before it reached above 8°C for 3 hours or less and was a less than a 1°C drop under 2 °C. The "Δ" indicates the temperature went below 2°C for longer than 3 hours or dropped more than 1 °C under 2 °C.

But, the top recommendation from this study is the EFP 2-piece EPS. This container performed best with an alternative pack out that used less materials. This lighter anticipated weight translated to a lower impact on the environment and shipping costs. The main material used was EPS, which is lightweight, durable, and affordable. The durability adds extra strength to the container, which can be especially helpful during shipping.

In total, 64 test trials were conducted for a total of 3,025 hours and on four different materials across three brands. Many of the containers tested, even if they failed the 48-hour tests that were conducted, have the potential to be utilized in other ways, such as in shorter shipping timeframes, or in a frozen shipping system. Stemming from the results of this study, there are several other topics that should be investigated. Possible future studies could focus on the pack-out process itself, look into the effect of the type of corrugated board that is used to ship these temperature-controlled packaging systems, and explore more sustainable alternatives.

Research Summary – Investigation of last-mile grocery delivery in a suburban environment

Image 1. Kyle Main and Zachary Weston of this research group.

The objective of this investigation was to map and fully characterize the process that packaged-goods experience from the moment they are picked up from a shelf in a grocery store to when they arrive at a consumer's doorstep. An additional goal was the identification and evaluation of the potential hazards that may occur during this process. Graduate student Joe Keller (M.S., Charlottesville, VA) was selected to lead the group of undergraduate students, Zachary Weston (Senior, Ferndale, VA), Morgan Bright (Senior, Littleton, NC), Kyle Main (Senior, Virginia Beach, VA), and Jiyu Niu (Senior, Qingdao, China) through this research project (Image 1).

Last-mile delivery for groceries has shown increased popularity in recent years. A 2019 study of U.S. residents taken during the Covid-19 pandemic showed 31% of respondents engaged in online grocery shopping, and 21% of them responded that they purchase groceries through delivery by local retailers at least once a week. An estimated 33% of the U.S. national grocery market now utilizes online delivery services, so this investigation into last-mile delivery reflects the probable outcome for a large share of grocery-type consumer packages.

The increased handling that is introduced by delivery services presents a variety of additional, potential hazards that need to be considered. In extreme cases, these hazards may yield damaged, spoilt, or otherwise compromised items. Most grocery delivery services are carried out by consumer vehicles which are built to provide a smoother, steadier ride compared to delivery trucks. Due to this, for purposes of this investigation, vibration was deemed inconsequential. Shock hazards were the primary focus of the experimental data collection. This shock data will aid in simulating the potential high-risk situations, as well as any drop scenarios, that could compromise the packaged goods. In addition, this study investigated the effects of delivery size, grocery stacking, and overtime delivery. Proper accounting of these factors during research helped to evaluate whether current packaging standards are sufficient to guarantee acceptable conditions for last-mile delivery.

In the interest of creating a general map of the delivery process, data was gathered from multiple services to account for differing approaches. To better understand the delivery handling process, four drivers and two store representatives from four different companies were interviewed on the procedures they follow from the moment the product leaves the shelf at the retailer to when it is placed at its destination by the delivery service. After gathering sufficient information regarding the handling process, we were able create an outline of the general procedure for a delivery (Image 2).

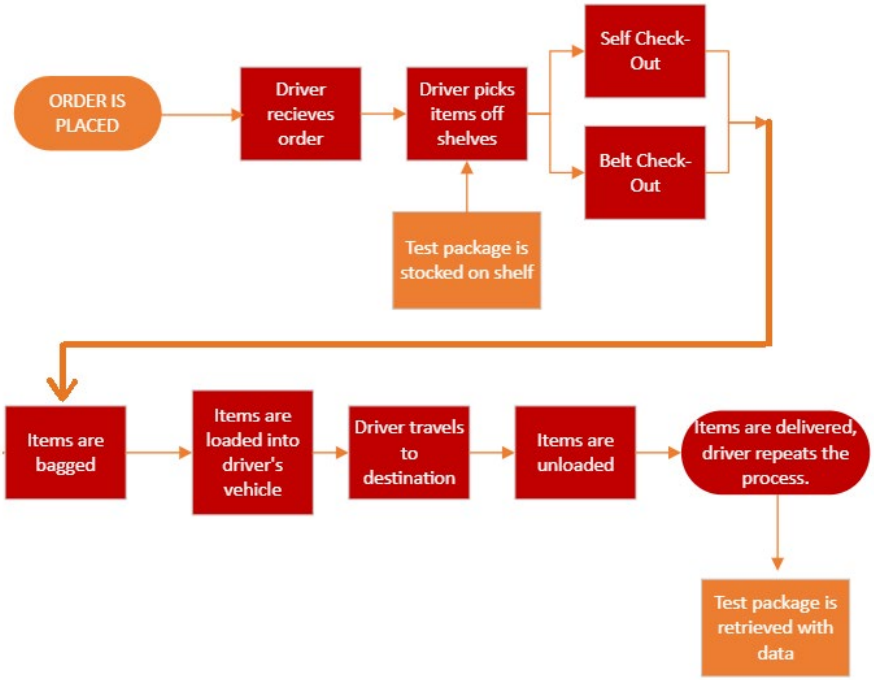
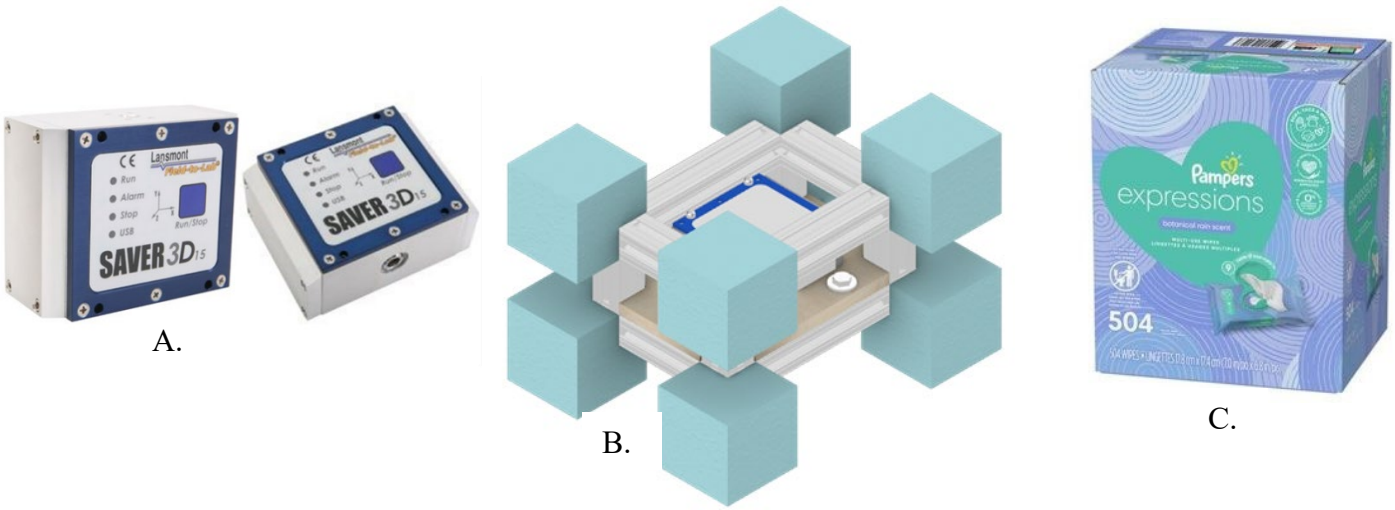


Image 2. Procedures for last-mile data collection.

The shock data for this experiment was collected using Lansmont Saver 3D15 sensors (Image 3a) which were housed in custom, decoy corrugated containers. To account for differences in grocery item size and ensure accuracy for the sensor, two box sizes were used: one small box friction fit with foam, and one bigger metal framed box equipped with a steel frame and foam corners (Image 3b). Using these decoy boxes (Image 3c) with 3D15 sensors, eight trials, in two sets of four, were conducted at a suburban chain grocery store following the delivery process map that was outlined through the interviews.



A. B. C.

Image 3. a) Lansmont 3D15 sensor in b) a stabilizing frame with urethane corners and c) the box utilized as decoy for the sensors.

The trials each had the same delivery route and destination 2.7 miles away. The trials began when the decoy package with the activated sensor was placed in the shopping cart. During the first set of four trials, all drivers placed the groceries in the backseat of their vehicles, while the second set placed all groceries in their trunks. Alternating drivers and shoppers were used and some trials used the belt-checkout lines, while the others were placed through self-checkout. Events while driving and shopping were manually recorded with a timestamp to later compare to sensor data collected events. The trials ended when the test package was received at the doorstep and the sensor was deactivated.

To determine where products undergo the most shock events, seven orders were placed through a third-party delivery service to the same suburban grocery store chain and timed to find the average times spent in each area of the process. Event data was collected from the simulated grocery delivery trips and compiled. Notably, most of the drops that occur throughout the entire delivery route are below two inches. Significant drop heights (of greater than 3") correspond in order of intensity and frequency with: leaving the box at the door, putting the product in the car, and putting the product in the cart. The maximum number of events that occurred in a single trip was seven and the minimum number of events were two. Common across all the trips were two events; once as the package was being placed in the cart and again when it was being placed at the customer's door (Image 4).

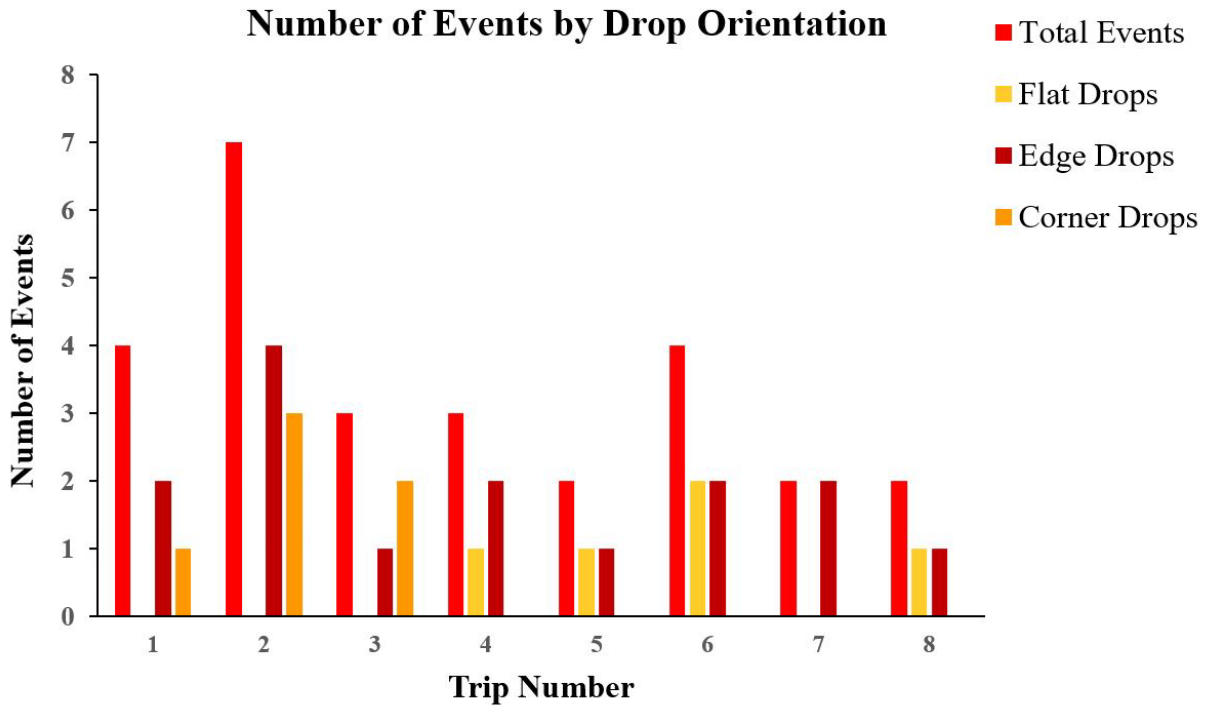


Image 4. Number of shock events by drop orientation for all drop heights >.5 inches.

The study improved our understanding of the processes involved with last mile grocery delivery that were not in focus from historical evaluations. Based on the collected shock data, it appears that last mile grocery delivery does not pose any significant hazards to packaging.

This research project has been highlighted by VT as a Daily Video!

Research Highlight - Predicting the joint stiffness of wooden pallets assembled with lag screws and carriage bolts

Image 1. Joe Keller setting up a fastener test in the MTS machine

In order to design pallets that can be used safely, the load capacity of the pallet needs to be measured or calculated. Although the load capacity of a pallet depends on a multitude of factors, the stiffness of the joints between pallet components has a major influence on overall pallet load capacity. Heavy-duty pallets are often assembled with alternative fasteners such as bolts and lag screws. Currently, the effect of these alternative fasteners on joint stiffness is not understood; this limits the use of these fasteners by the industry. Therefore, the objective of this research was to investigate the stiffness of pallet joints constructed using alternative fasteners such as bolts and lag screws. Master's student, Joe Keller (2023 alumni, Charlottesville, VA), was selected to work on this research project which was sponsored by The Pallet Foundation / National Wooden Pallet and Container Association.

In order to predict joint stiffness, head embedment stiffness, shank withdrawal stiffness, and rotational stiffness were measured for each joint type. The objective of this project was to determine the head pull-through, shank withdrawal, and edge crushing stiffness of pallet joints made from carriage bolts and lag screws using two different species of wood. Southern yellow pine and red oak were used for this study. Half of the pine samples were tested in a green condition, while the other half were tested at a 19% moisture level. The oak samples were only tested in the green condition.

A model had been developed by previous researchers to predict the rotational stiffness of pallet joints in which nails were used. The model consists of three stiffness values that must be calculated including: head embedment stiffness, shank withdrawal stiffness, and moment rotation stiffness. This project's researchers followed the original model.

For the head embedment test, specimens were assembled by inserting the investigated alternative fastener into a pre-drilled hole in the wooden board. The board with the alternative fastener was placed upside down on I-beams and clamped to prevent bending. A sensor was placed under the head of the alternative fastener to measure the amount head embedment. The MTS equipment was used to pull the shank of the alternative fastener and cause the head to embed into the wooden board (Image 2).

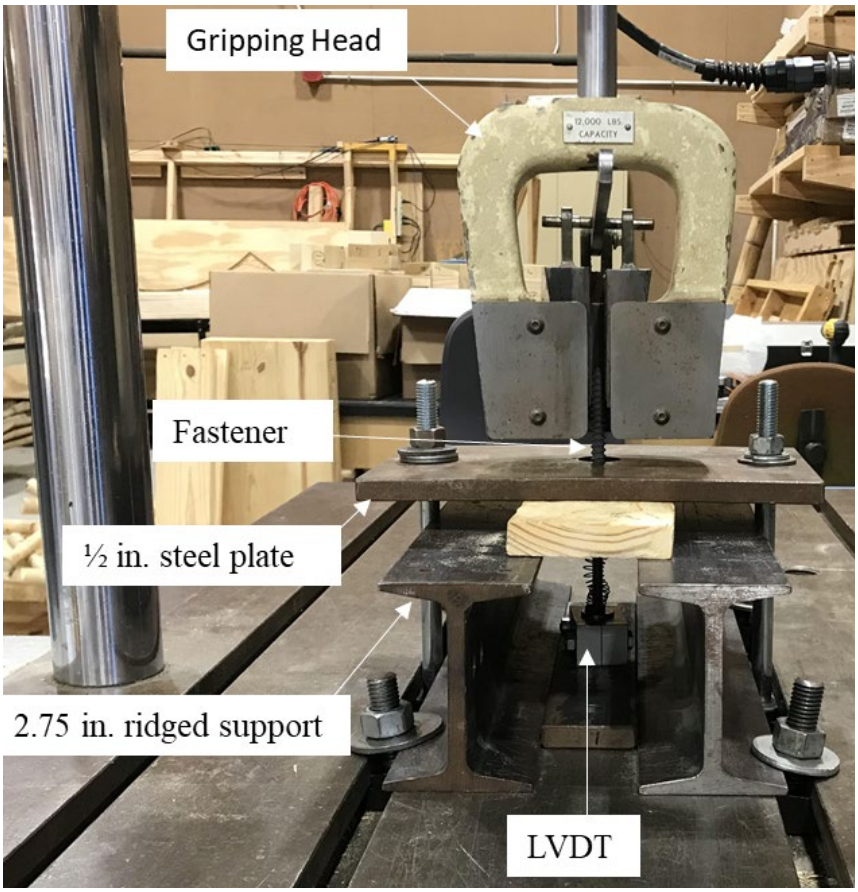


Image 2: Picture of experimental setup used for the determination of the Head Embedment Stiffness.

The next test performed was the shank withdrawal test. The setup involved screwing alternative fasteners into properly conditioned wooden blocks. The blocks were supported on each side and a sensor was placed against the head of the alternative fastener in order to accurately measure nail movement relative to the block. A steel bar was pushed by a wooden yoke which was attached to the MTS equipment, and a load was applied.

The final test that was performed was a moment rotation test to find the third stiffness measurement needed to complete the model. These tests gave the researchers the edge crushing stiffness – basically the crushing that the pallet joint will experience. Different species of wood will experience different amounts of crushing because of their cellular structures. So, different species needed to be tested in order to give accurate estimates. Deckboard samples had alternative fasteners screwed into predrilled holes which were used to attach the deckboards to the side grain of the blocks. The samples were then rigidly clamped to the base of the MTS machine, and a sensor was placed to measure the deflection of the deckboard joint during testing (Image 3).

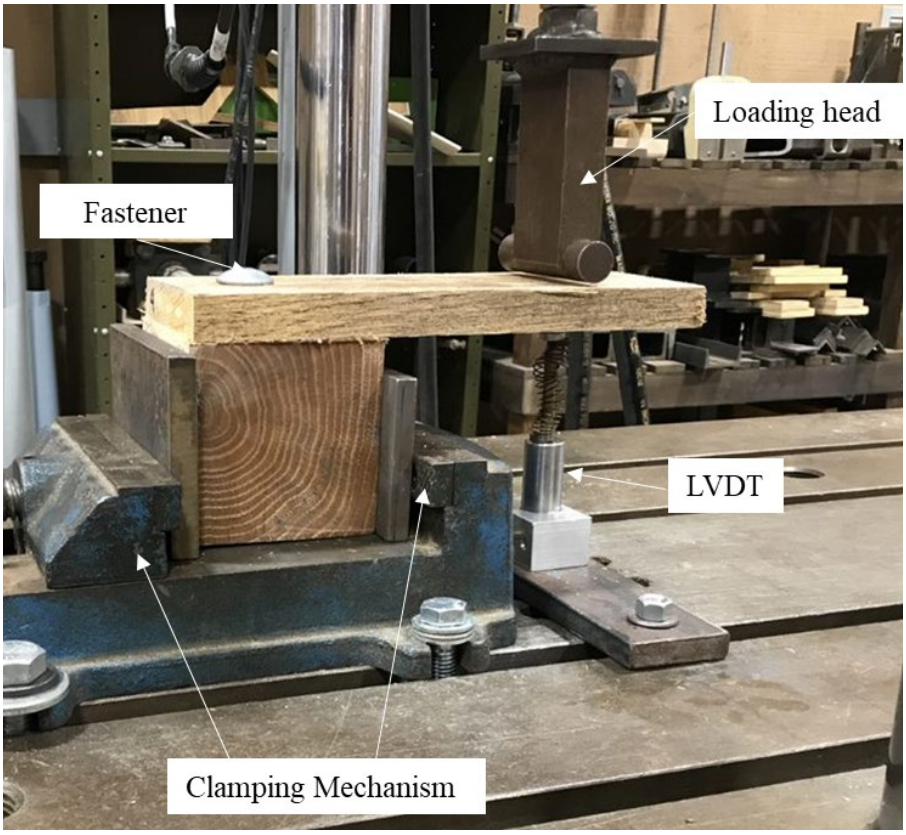


Image 3. Picture of experimental setup used for the measurements of the Moment Rotation testing.

Overall, this study suggested that using carriage bolts and lag screws will provide greater stiffness than using nails in pallet joints manufactured from green oak, green pine, and KD-19 pine. The size of the fastener used in a pallet joint had a direct effect on the stiffness of each pallet joint. The larger the size of the fastener, the larger the head embedment and shank withdrawal stiffness. This study found that if green oak is used in pallet construction with lag screws or carriage bolts, it will provide stiffer connections than green pine or KD-19 pine with the same fastener types. KD-19 pine provides a slightly greater stiffness then green pine, but this was not seen as statistically significant. The head embedment stiffnesses investigated for the two fastener types (lag screws and carriage bolts) were similar enough to not be seen as statistically significantly different during analysis.

The results of this study will be included in the Pallet Design System (PDS) software in order to allow pallet designers to design pallets using bolts and lag screws.

Grad Student Spotlight – Sean Hobbs

Image 1. Sean Hobbs

Sean Hobbs came to Virginia Tech from East Rockaway, NY. He graduated with his Bachelor's degree in Packaging Systems and Design and moved directly into working on his Master's degree in Forest Products, which he will finish in the fall of 2023. Sean has one older brother and prior to coming to VT, in high school, he played baseball and ran track. Here in Blacksburg, his favorite hobbies are practicing his guitar, fishing the local waterways, and playing pick-up basketball games with his friends.

When asked what made him choose CPULD, Sean responded: "What lead me to this program is that it is like applied engineering. I love to work with my hands and packaging goes into almost everything, so it is truly important. I choose my research topic because pallets due truly help move the world so helping the industry gain knowledge could make a huge impact. My education will help me reach my goals by giving me knowledge that not many people around the world would have. It will make me look more attractive to companies and also give me a leg up on my competition."

Sean is now studying under Dr. Laszlo Horvath. His research project involves surveying the wood pallet industry to get information on the current state of the industry including common pallet sizes, pallet styles, material usage, pallet recycling, pallet end of life, and effect of the COID-19 pandemic on the industry. Sean described his research project this way: "I will be able to see trends in the market and how they compare to previous years. This will help the industry by allowing them to make better decisions based off the trends of the entire industry." His project is financially supported by the Pallet Foundation and the National Wooden Pallet and Container Association.

Part of his graduate work includes working in the labs here at CPULD. When we asked him, what has been helpful about working here and about his plans were for the future, Sean informed us that: "The most helpful thing I would tell future students is to perfect time management. The hands-on experiences that I have gotten from working in the lab are also valuable to me. Since we work on many different projects, I feel I will be a well-

rounded employee, having a wide range of knowledge. I do not have a job lined yet, but as for company I'd want to work for, it would mostly need to have a good work culture for it to be my dream job. I am more concerned about being in a good environment where I can succeed rather than a specific job type.

"But, the absolute best part of my time here has to be working closely with the other graduate students. It is nice to know I am always part of a team that has my back. We learn from each other and are constantly there for each other."

Sean hopes to eventually find employment back home on Long Island. Because, as he told us, "it has everything I enjoy. It provides city and country style living mixed together and all in one place." Sean also shared with us that he would love to be a sea otter as "they seem so happy and carefree all the time. They always seem relaxed." And, finally, he also mentioned that his favorite food is pizza: "I could eat pizza from back home every day. I mean, who doesn't love a good slice!"

News – Dr. Laszlo Horvath will give a presentation for CPULD at the national ISTA conference

Image 1. ISTA TransPack conference.

CPULD is proud to announce that our director, Dr. Laszlo Horvath, has been accepted to present his graduate student, Clark Sabattus', research findings at the ISTA TransPack global industry conference and forum in May 2023 (Image 1). 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.

Dr. Horvath will share the findings of the 2022 research project titled "Measurement of Hazards Experienced by Pallets During Material Handling." This project focused on understanding the impacts that pallets experience in the field. Although often overlooked, pallets can become costly for a company if not designed correctly for their specific supply chain.

The creation of a simulated material handling environment in 1993, named FasTrack, has aided in researching a pallet's useful life. FasTrack simulates a pallet going through a series of trips utilizing material handling equipment, such as forklifts and pallet jacks. It was designed to replicate the environments that a unit load of products may travel through in the field in order to observe the common damage modes that may occur to a pallet.

Forklifts in multiple facilities were instrumented with data loggers (Image 2) to measure the acceleration peak, g of shock impacts, duration of impacts, random vibration intensity and RMS(g) values during forklift handling in the field. This field data was collected from three different types of facilities: a distribution center, a manufacturing facility, and a pallet manufacturer.

Image 2. Clark Sabattus equipping a forklift with a sensor to measure the shock events experienced in various warehouse facilities

The intensity of shock events measured during the Fastrack procedure were slightly greater than what was observed at the investigated facilities. This indicates that the Fastrack simulation is slightly harsher than the field handling of pallets. Based on the results of these measurements, new intensity levels were recommended for FasTracks's incline impact tests in order to better represent the real levels of harshness of handling seen in the field.

The results of this study will be used to revise durability testing procedures used in pallet testing standards in order to better represent the current material handling processes found in modern supply chains.

News – CPULD's in-person short course in the fall of 2022 was a great success!

Image 1. Short course classroom

In November 2022, the Center for Packaging and Unit Load Design (CPULD) offered a hybrid in-person/virtual short course. The Advanced Wood Pallet Design short course was hosted in conjunction with the National Wooden Pallet and Container Association (NWPCA) and was an intensive 2.5-days of classes that taught techniques to help save money when designing pallets by considering the interactions between all of the components of the material handling system.

The instructors (Dr. Laszlo Horvath, CPULD Director; Dr. Brad Gething, VP NWPCA; and Kristen DeLack, professional engineer, NWPCA) informed attendees about the advanced principles of wooden pallet design, how to conduct material handling audits, and the basics of packaging and pallet design as well as material handling systems. They learned about the interactions between material handling equipment, packaging, and pallets, as well as how to diagnose and solve their material handling problems. The course used the 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.

This course had 35 people registered for it. Attendees were from all over the USA, including CA, GA, MD, NH, NY, OH, SC, TN as well as VA. We also had attendees join us from Canada and Mexico. Everyone had great discussions about pallets! While this course was designed to be delivered in-person, CPULD also offered a virtual option with live participation. Webcams and virtual meeting softwares were used to include approximately 30% of attendees in the assignments and discussions.

The Advanced Wood Pallet Design short course always receives high grades on the satisfaction surveys conducted. Of respondents, 94% felt that the course provided all the knowledge they had come to learn, and said that they would be recommending the course to others in their company and the industry.

We have been told "This course, for me, was one of the best that I have attended as it pertains directly to my job. The PDS application is very user friendly and well designed. They have very knowledgeable staff and it is obvious that they enjoy their jobs and the industry." And another happy participant told us that "The course covered (and

covered it well) more than I expected and would definitely attend more similar courses. Dr Laszlo was particularly educational, well spoken, easy to relate to and had real life examples for any questions that arose."

Pallet design is an integral part of the material handling system. Wood pallet suppliers, designers, and sales professionals, professionals responsible for pallet purchasing, packaging engineers and pallet specifiers, as well as corrugated box designers all benefited from gaining an understanding of how to design pallets that last longer and perform better.

If you are interested in attending this course in 2023, or learning more about the other short courses that CPULD offers, please visit our continuing education page: https://www.unitload.vt.edu/education/continuing-education.html

Sign up for CPULD's mailing list: http://eepurl.com/db45eD

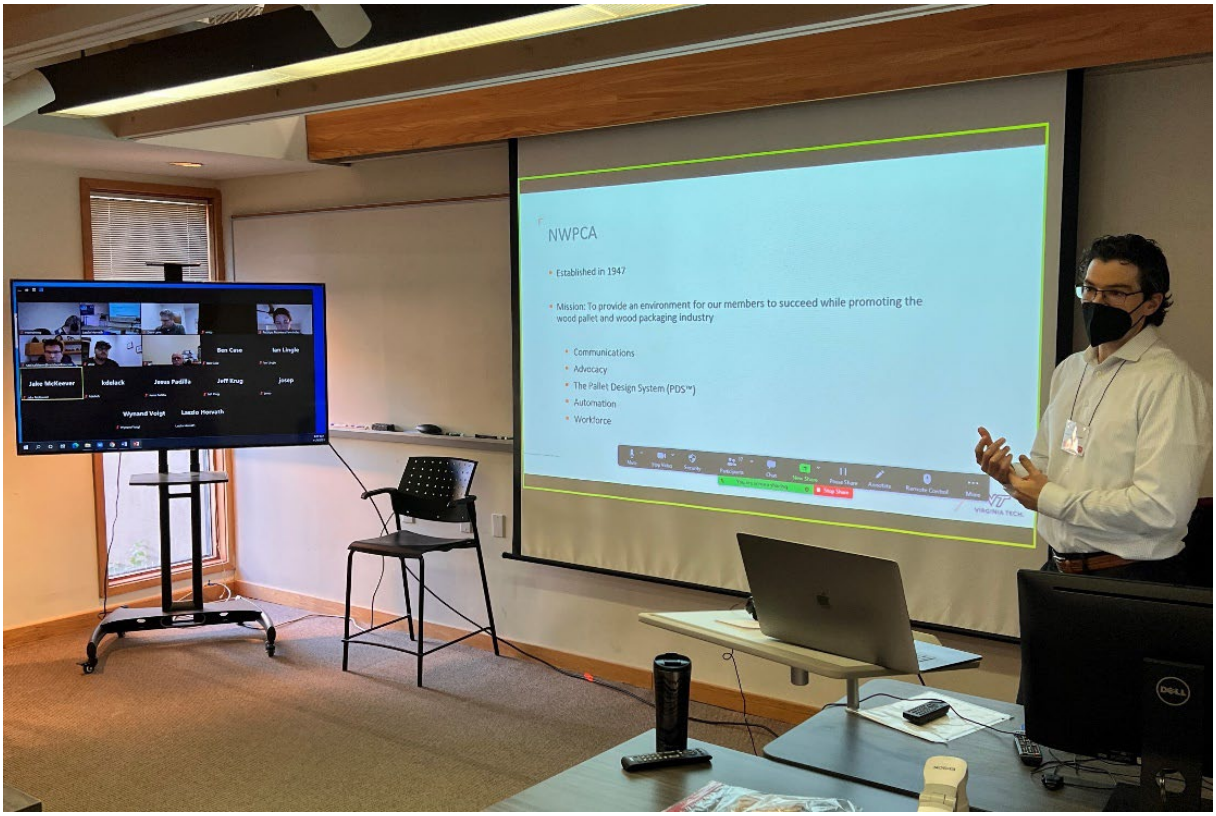


Image 2. Brad Gething speaking about NWPCA

News – Joe Keller and Clark Sabattus have recently graduated with their Master's Degrees

Image 1. a.) (right) Joe Keller with (left) Dr. Laszlo Horvath and b.) (right to left) Clark Sabattus with Nicolas Navarro and Dr. Laszlo Horvath

The Center for Packaging and Unit Load Design congratulates Joseph Keller and Clark Sabattus for passing their Master's defenses! Clark graduated in December 2022, and Joe will officially graduate in May 2023.

Clark's research had focused on the "Measurement of Hazards Experienced by Pallets During Material Handling." His work is featured in a CPULD News article. Based on the results of his research, new intensity levels were recommended for some tests conducted during CPULD's FasTrack procedure in order to better represent the real levels of harshness of handling seen in the field. The results of this study will be used to revise durability testing procedures used in pallet testing standards in order to better represent the current material handling processes found in modern supply chains.

After graduating, Clark moved back closer to his family in Texas and currently lives in Austin, TX where he's working in Logistics Account Executive for the Total Quality Logistics company.

Joe's research was titled "Predicting the Joint Stiffness of Wooden Pallets Assembled with Lag Screws and Carriage Bolts." His research has also been featured in a CPULD News article. Joe's study concluded that the model that had been developed for common pallet nails could also be used to predict the performance of pallet joints made with alternative fasteners. The results of his study will be included in the Pallet Design System (PDS) software in order to allow pallet designers to design pallets using bolts and lag screws.

After successfully defending his thesis in February, Joe currently interviewing with companies.

"I had a privilege to work with these exceptional students," said Laszlo Horvath, CPULD director and an advisor to both students, "and I am looking forward to see the difference that they will make in the packaging industry."

News – Packaging students attended the PackExpo conference in Chicago

Image 1. VT group at the Chicago PackExpo

Thirty packaging major students from the Department of Sustainable Biomaterials and the Center for Packaging and Unit Load Design (CPULD) were among the 40,000 attendees of the last PackEXPO International which was held in Chicago, IL. PackEXPO is the nation's largest trade show for the packaging industry and provided our students with the opportunity to connect with packaging companies from around the world. The trip was organized by members of the PS&D Club, which aims to provide packaging students with career opportunities while fostering connections and hosting events.

Virginia Tech's booth was extra-large this year due to the work of Drs. Laszlo Horvath, Eduardo Molina, and Jennifer Russell who submitted the proposal which was accepted by the conference organizers. Virginia Tech was one of two universities approved to present the future of sustainability in the packaging industry. The Hokie booth gave examples of how to use sustainable materials to solve specific packaging problems and also discussed the wider perspective of how to use environment-minded strategies in a trillion-dollar industry.

Many who attended PackEXPO participated in competitions that helped them gain hands-on experience with the industry. One competition in particular was the Amazing Packaging Race during which student groups visited various booths and solved problems, completed tasks, and took quizzes. Tasks included such things as programming a robot, listening to a company's info speech, or simply taking a picture with a specific package. This year was the first time that high school student groups were also invited to compete.

According to the PackEXPO website, they "offer activities aimed at getting students excited about careers in packaging and processing and connecting them with professional mentors in the industry. In addition to exciting networking events and student programs, PackEXPO International is the best place to see never-before-seen solutions from 2,000+ leading suppliers on the show floor, bringing more than 40 vertical industries together to generate a cross-pollination of ideas and crossover solutions."

News – Sean Hobbs and Yash Mansharamani gave presentations for CPULD at the NWPCA conference

Image 1. Sean Hobbs and Yash Mansharamani at the NWPCA conference.

CPULD graduate students, Sean Hobbs and Yash Mansharamani, both gave presentations about their ongoing research projects at the National Wooden Pallet and Container Association (NWPCA) Annual Leadership Conference in Fort Worth, TX this spring. The NWPCA holds multiple events a year with the goal of facilitating connections between research institutions and the packaging/pallet industry. In conjunction with the NWPCA, The Pallet Foundation sponsors research projects like those of both CPULD graduate student presenters.

Sean Hobbs is researching the current status of new wooden pallet manufacturing and pallet recycling in the U.S. A comprehensive survey is being used to gain important insights to the pallet market. 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. Data collection for this project started in September 2022 with the survey being deployed to collect detailed trends for the calendar year 2021. In particular, his study is investigating new pallet production estimates as well as collecting info about recovered pallets and what is done with them. Hobb's is studying 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 by previous Pallet Foundation / NWPCA grants.

Yash Mansharamani is researching the total amount of woody material and the number of wood pallets and crates that are received, recycled, and landfilled at MSW and C&D landfills as well as the tipping fee structure of landfills and the types of recovery operations that they have on site. A survey is being used to gain important insights into pallets' various end of life scenarios throughout 2021. The Pallet Foundation has historically funded survey projects like this about landfilled pallets every 5-10 years. Mansharamani has developed an updated survey based on the previous projects. Data collection started in 2022 with the survey being deployed to collect detailed trends for the calendar year 2021. Mansharamani will analyze long-term trends by comparing his 2021 results to the results of previous market studies - especially the research conducted by previous Pallet Foundation / NWPCA grants.

Research Update – New grant from the Pallet Foundation for Yash Mansharamani's landfill survey project

Image 1. Yash Mansharamani

Each year, 804 million wooden pallets are manufactured and recycled across the United States. Although the vast majority of the pallets are repaired or recycled into secondary products such as mulch or boiler fuel, a portion of all pallets end up in landfills at the end of their useful life cycle. The purpose of this research is to investigate the total number of pallets and crates reaching landfills in the United States as well as to gain a better understanding of the overall waste stream.

Our director, Dr. Laszlo Horvath, has received a new grant from The Pallet Foundation to investigate the total amount of woody material and the number of wood pallets and crates that are received, recycled, and landfilled at MSW and C&D landfills as well as the tipping fee structure of landfills and the types of recovery operations that they have on site. A comprehensive survey will be used to gain important insights into pallets' various end of life scenarios throughout 2021. The Pallet Foundation has historically funded survey projects like this about landfilled pallets every 5-10 years with the last survey being conducted for 2016.

Yash Mansharamani (Image 1), a graduate of NC State's undergrad program, was selected to work on this graduate level research project for his Master's degree. Mansharamani has worked to develop an updated survey based on the previous projects. The study will use electronic and paper surveying of all licensed Municipal Solid Waste (MSW) and Construction and Demolition (C&D) landfills in the continental United States. Data collection started in 2022 with the survey being deployed to collect detailed trends for the calendar year 2021. Mansharamani will analyze long-term trends by comparing his 2021 results to the results of previous market studies - especially the research conducted in 1995, 1998, and 2016 by previous Pallet Foundation / NWPCA grants.

Research Update – New funding from a private international company to research Korean e-commerce last mile measurements

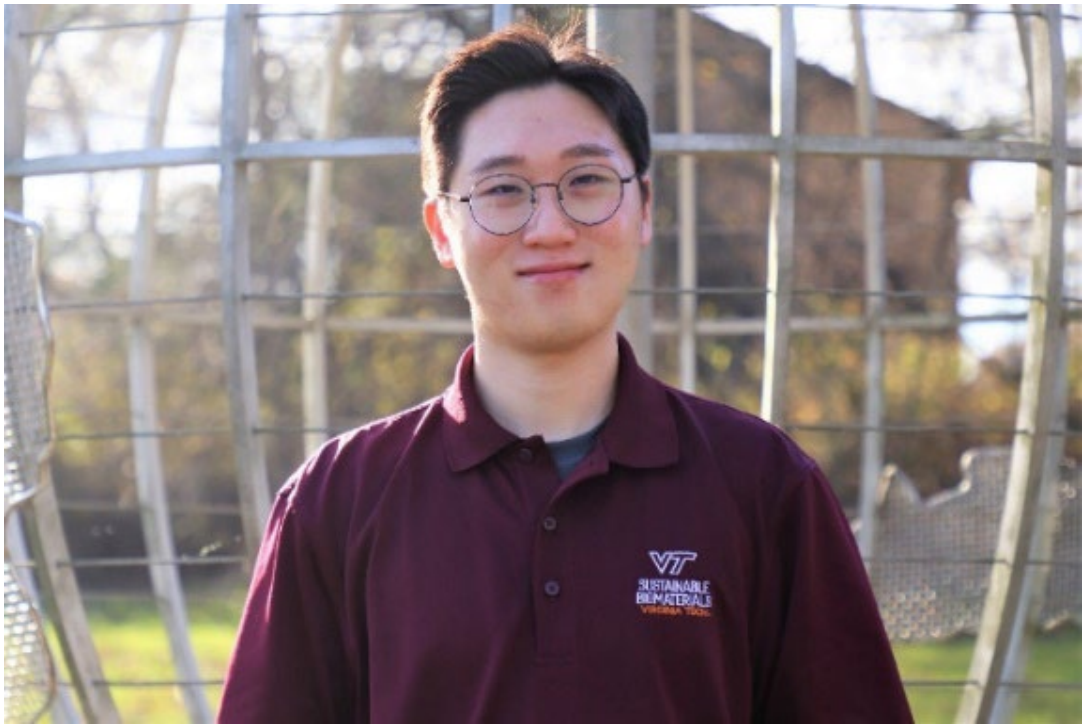


Image 1. Saewhan Kim

This research project will collect information about the level of shocks and vibration experienced by packages transported throughout the South Korean parcel delivery system, particularly during the last-mile delivery portion of distribution. The collected data will allow the research team to recommend drop tests and vibration profiles that simulate the hazards actually experienced during South Korean parcel delivery. This data will be compared to internationally used packaging testing standards in order to help develop a proposed testing plan for Korean e-commerce package testing.

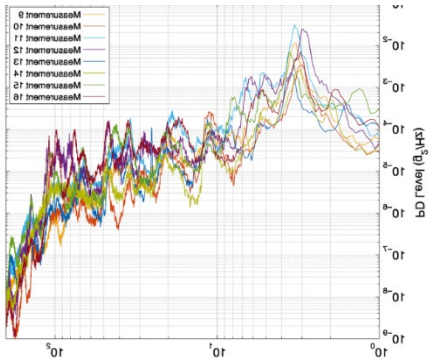
Our director, Dr. Laszlo Horvath, received funding from a private international company to investigate the parcel delivery system in South Korea in order to be able to develop recommended testing protocols for packages that will be distributed through their system. Graduate student, Saewhan Kim, PhD candidate (Image 1), was assigned to this research project. Kim determined that three regions that would be investigated including the major metropolis of Seoul and two small, rural towns. Additionally, five distribution facilities in these regions were chosen to be audited by Kim, where he collected data regarding how the packages are handled.

Before flying to South Korea, Kim built decoy packages to be used to test their parcel delivery systems (Image 2a & 2b). Dozens of one-way trips between the distribution facilities are planned for these decoy packages. This is in order to collect the most data possible about the shocks that packages experience. The shock data will be analyzed and the equivalent drop heights will be calculated based on the measured delta velocities. Additionally, to collect the last-mile vibration environment, multiple parcel delivery vehicles will be instrumented with Lansmont Saver 3x90 data loggers and GPS units. The vibration profiles of each transportation mode will be recorded to be used in laboratory simulations. All results will be used to develop a proposed testing sequence for Korean e-commerce package testing.

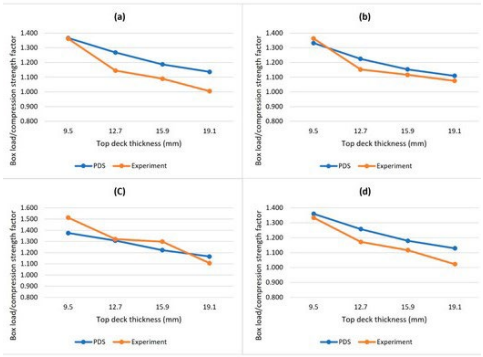
Image 2. A) Kim building frames for sensors and B) building decoy packages.

News – Articles published in peer-reviewed journals by CPULD faculty & graduate students, 2022-2023

1. CPULD Ph.D. student, Mary Paz Alvarez, successfully published another paper in Packaging Technology and Science. The article can be accessed: https://onlinelibrary.wiley.com/doi/10.1002/pts.2672

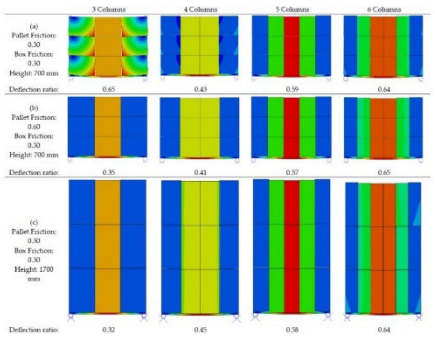


2. The results of a great collaborative research project between Dr. Laszlo Horvath and Peter Borocz was recently published in ASTM Journal of Testing and Evaluations. The paper presented a potential testing profile that can be used to simulate the vibration environment when unit loads are transported with industrial forklifts. The paper can be accessed here: https://www.astm.org/jte20210293.html

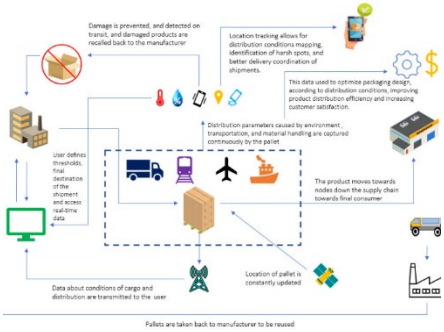


3. Saewhan Kim, successfully published his thesis results in Applied Sciences. His research focused on a novel design methodology that allows packaging engineers to reduce the overall cost of the unit load by increasing the stiffness of the pallet top deck. The article can be freely downloaded at https://www.mdpi.com/1996-1944/14/21/6613

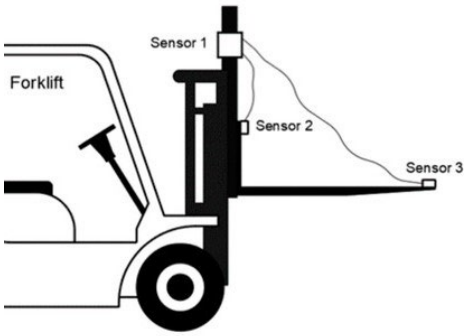
4. Jorge Masis' research article from his thesis was published in Applied Sciences. The research project focused on investigating the variables that affect the level of horizontal shock impacts that forklifts exert on pallets. The results will help us improve the durability simulations in different pallet testing standards. The study is freely accessible at: https://www.mdpi.com/2076-3417/12/14/7035



5. Dr. Eduardo Molina published a peer-reviewed article that provides a detailed analysis of the interactions between packages and pallets during rack storage, and how they impact pallet performance. Read "Development of a Gaussian Process Model as a Surrogate to Study Load Bridging Performance in Racked Pallets" here: https://www.mdpi.com/2076-3417/11/24/11865

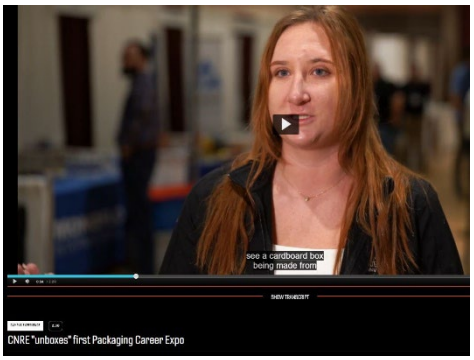


6. Nicolas Navarro, successfully published his M.S. research in Systems as a peer-reviewed article. The research investigated the potential design to implement IoT devices for palletized unit loads. His article can be freely downloaded from https://www.mdpi.com/2079-8954/10/1/4

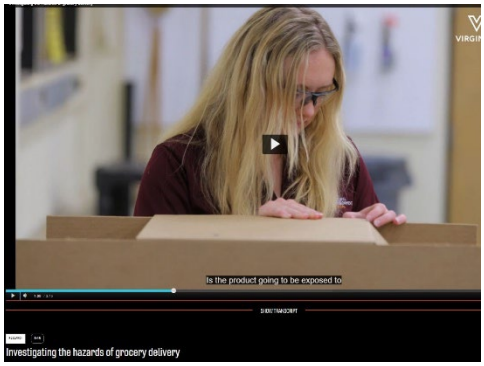


7. A novel research paper was published by CPULD alumni, Yu Yang Huang, in Applied Sciences. The study was a first of its kind to characterize the vibration environment produced by an industrial forklift. The results will be used to develop a new dynamic pallet testing simulation. The paper can be freely viewed: https://www.mdpi.com/2076-3417/11/7/2901

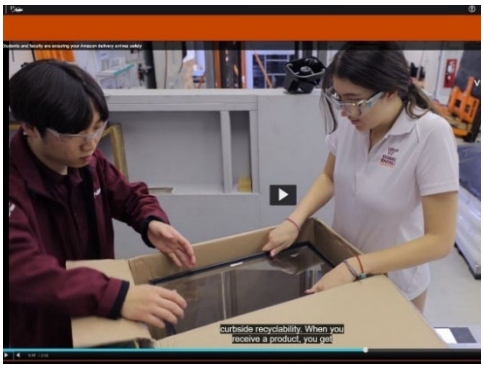
News – Outside news articles about CPULD faculty and students



1. First ever packaging career fair held at VT in Feb. 2023. Watch the VT video about this here: https://vtx.vt.edu/videos/k/2023/02/1_3seslkan.html



2. Collegiate Assistant Professor Eduardo Molina and a group of his undergraduate students investigated the hazards that grocery packages experience during last-mile delivery to customers, by designing and assembling instrumented packages and sending them through the supply chain. Watch the VT video about this project: https://vtx.vt.edu/videos/k/2022/10/1_gvfungxh.html



3. Students and faculty at CPULD work to certify packages for use in the Amazon distribution network. The certification ensures that products will survive the harshness of physical distribution. "Due to COVID, we saw a huge increase in people that want that certification," said graduate student Mary Paz Alvarez Valverde, noting that manufacturers that once relied on brick and mortar have switched over to e-commerce since the pandemic. Watch the VT Daily video here:

   https://vtx.vt.edu/videos/k/2022/11/1_p3n6pfzb.html?utm_source=cmpgn_news&utm_medium=email&utm_campaign=vtUnirelNewsDailyCMP_112322-fs-1

4. Packaging Systems and Design student Rosa Williams the focus of a VT article about internships available to our students. Read this article here: https://vtx.vt.edu/articles/2022/08/cnre-summer-internships.html

5. Our director, Laszlo Horvath was elected to be one of the Board of Directors of the International Association of Packaging Research Institutes. It is a great honor to be recognized by the global packaging community. He will serve a 3-year term and will focus on to promoting and expanding organization. Learn more about IAPRI here: https://iapri.org/

6. CPULD is proud of our PS&D students' attendance at Pack Expo! VT Daily has featured our students and booth in an article. Read the full VT Daily article here: https://vtx.vt.edu/articles/2023/01/cnre-pack-expo.html?utm_source=cmpgn_news&utm_medium=email&utm_campaign=vtUnirelNewsDailyCMP_012423-fs

7. VT is proud of the group of students representing our university at Pack Expo. Packaging and processing companies scouting for the next generation of professionals needed to look no further than the floor of Pack Expo International. Dozens of students were among the 40,000 attendees at this year's expo in Chicago. Read the full article:

https://www.packworld.com/news/workforce/article/22578366/students-explore-packaging-and-processing-at-pack-expo-international

8. Packaging Systems and Design student Joy Mendoza was featured on the SBIO website! Read more about Joy: https://sbio.vt.edu/about-us/student-showcase/joy-mendoza.html

9. Packaging Systems and Design student Gabby Brophy was featured on the SBIO website! Read her interview here: https://sbio.vt.edu/about-us/news-publications/news/brophy.html

10. CPULD is happy to that our department's booth at the Kid's Tech University program was a great success! Thanks go out to the students and faculty who interacted with the visiting children and taught them about packaging and building pallets. Visit this link to learn more about the KTU program: https://ktu.fralinlifesci.vt.edu/

11. CPULD is part of the SBIO Department and the College of Natural Resources, and our Dean, Dr. Paul Winistorfer, recently was interviewed for a VT Daily article about upcoming improvements to our buildings and labs: https://vtx.vt.edu/articles/2023/03/cnre-winistorfer-bov-facilities.html

~ Continuing Education Opportunities ~

2023 Webinars

CPULD is pleased with the response to our webinars. Over the last few years, Director Laszlo Horvath has given multiple separate lectures, which were free to our members. CPULD has partnered with NWPCA to offer 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. So far, 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 2023 webinars are announced!

Wood Pallet Design and Performance Short Course, TBD Fall, 2023

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 2.5-day short course (being offered both in-person and virtually) 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!

Advanced Packaging Dynamics, October 3rd-5th, 2023

Advanced Packaging Dynamics: Measurements and Simulations teaches an approach that can significantly reduce the cost of distributing products to consumers by understanding how packaging protects products and designing packaging using the latest research data.

This intensive, 2.5 day, in-person (only) course and will inform attendees about the principles of shock, free, forced and random vibration, field data collection practices, sensor selection, laboratory simulations of field data and how to use the obtained information to optimize the packaging and eliminate damage. By the end of the course, the attendees will be able to collect field data, analyze the collected data, and setup laboratory simulations. Attendees will also be taken on a tour of working, state-of-the-art, packaging and pallet testing laboratories!

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

COLLEGE OF NATURAL RESOURCES AND ENVIRONMENT
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Spring 2023

Center for Packaging and Unit Load Design
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Ph: 540-231-7107 | www.unitload.vt.edu

Contact Our Team:

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

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Scheduling meetings with Dr. Horvath, short course information, other center events, website and marketing

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Immediate needs, delivery info, invoicing questions, AP / AR

Angela Riegel
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Corrugated materials testing, IKEA testing, scheduling corrugated deliveries

Dr. Eduardo Molina
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Primary packaging design and testing questions, primary packaging research

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