SYSTEMS ENGINEERING RESEARCH CENTER

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY®

Design Evaluation, Automation and Optimization Dashboard for Armament and Ammunition Packaging

Kishore Pochiraju, Souran Manoochehri, & Chan Yu
Mechanical Engineering, Stevens institute of Technology

Sponsor: Lisa Aversa & Jason B. Runell, DEVCOM Armaments Center, Picatinny Arsenal, NJ

WASHINGTON DC VIRTUAL
NOV. 2-4 2021
ANNUAL SPONSOR RESEARCH REVIEW

Our Sponsor/Customer/Collaborator

Logistics Research and

Engineering Directorate (LRED)

Background and Project Objectives

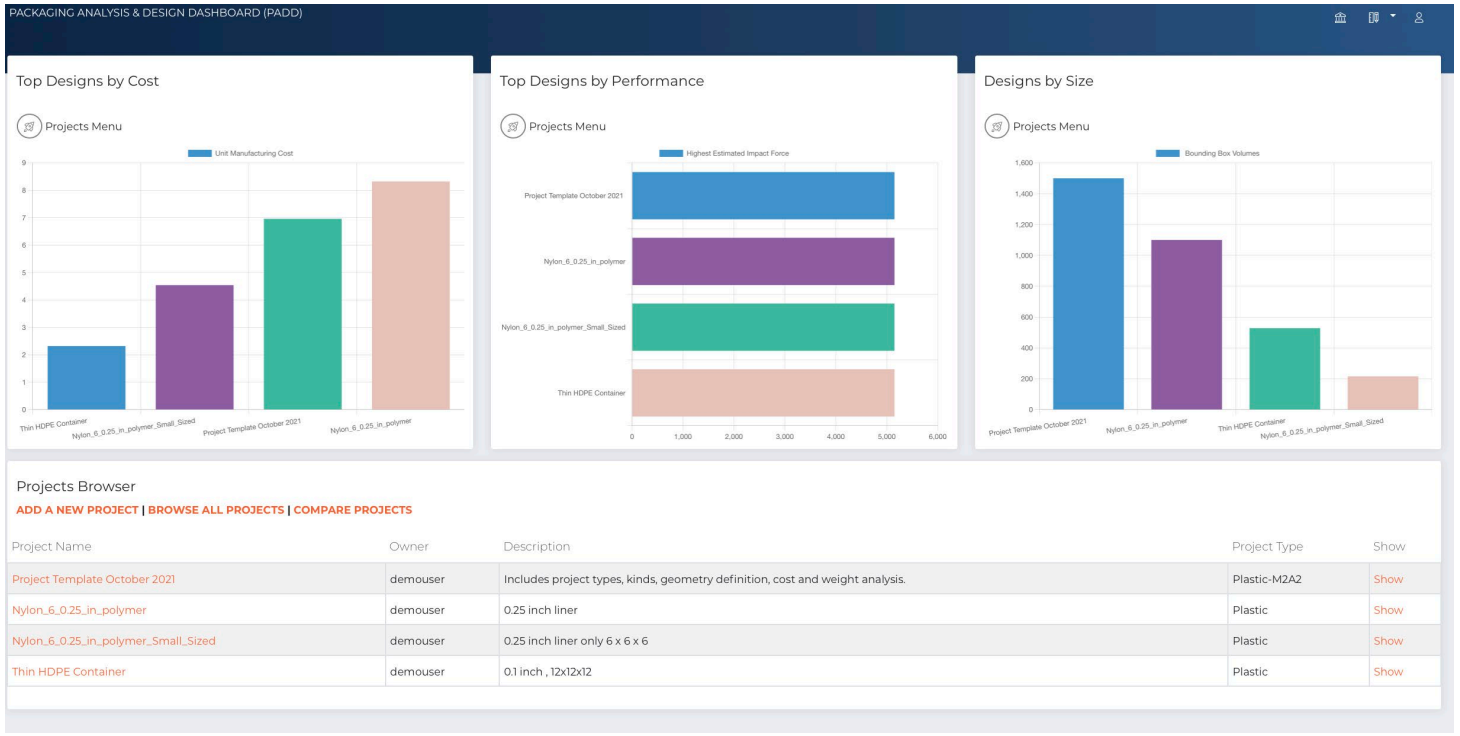
- Create a visual and data-driven view (Dashboard) of selected design performance metrics (cost, performance, durability, etc.) relevant to the package system
- Select methodologies for evaluating Design for X (DFX) metrics for the packaging systems.
- Evaluate DFX analysis processes for opportunities to reduce designer-analyst-designer round trip cycle times
- Enable tracking for the rationale behind design changes and decisions.
- Enable Trade-off Analysis and Optimization of designs for cost, performance or with multiple objectives

PADD: Packaging Analysis and Design Dashboard

Computational Engine
Impact Response. Cost. Geometry. Process Model

User Interface

Database
Project Data . Materials Data

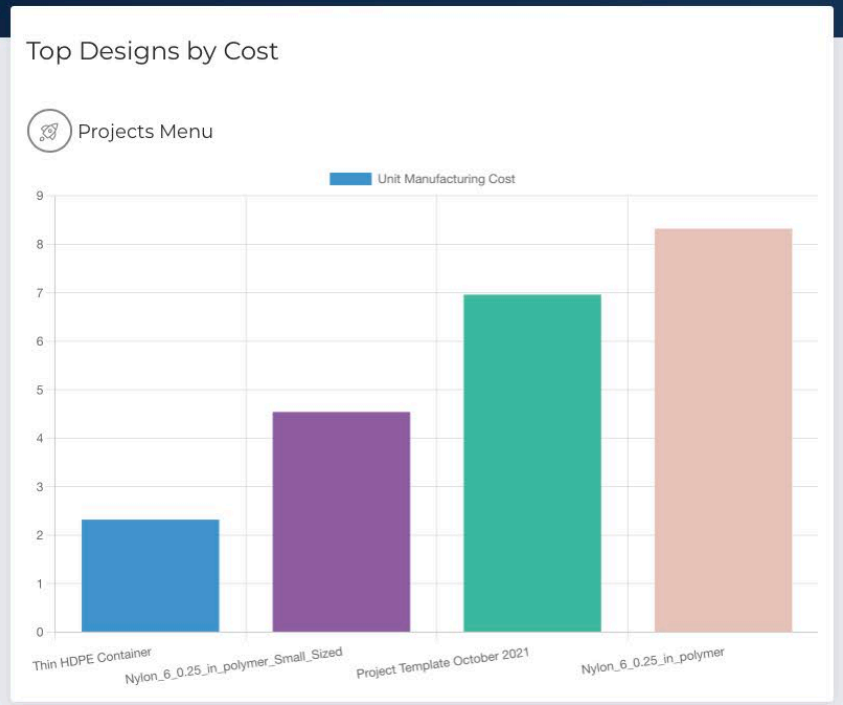


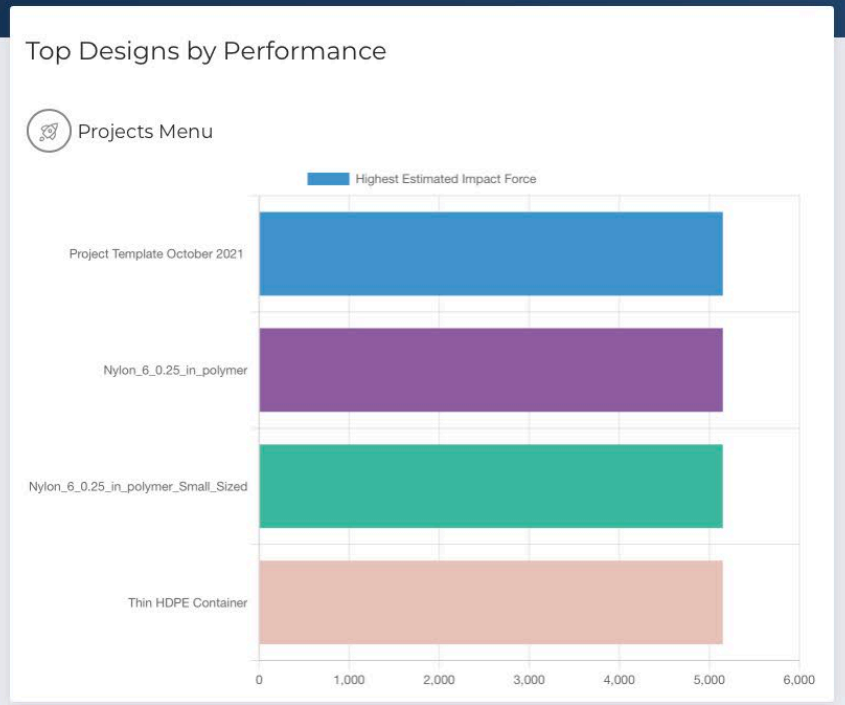
Computational Engine: Python evaluation engine with dependency graphs; Customized models for molded ammunition packages

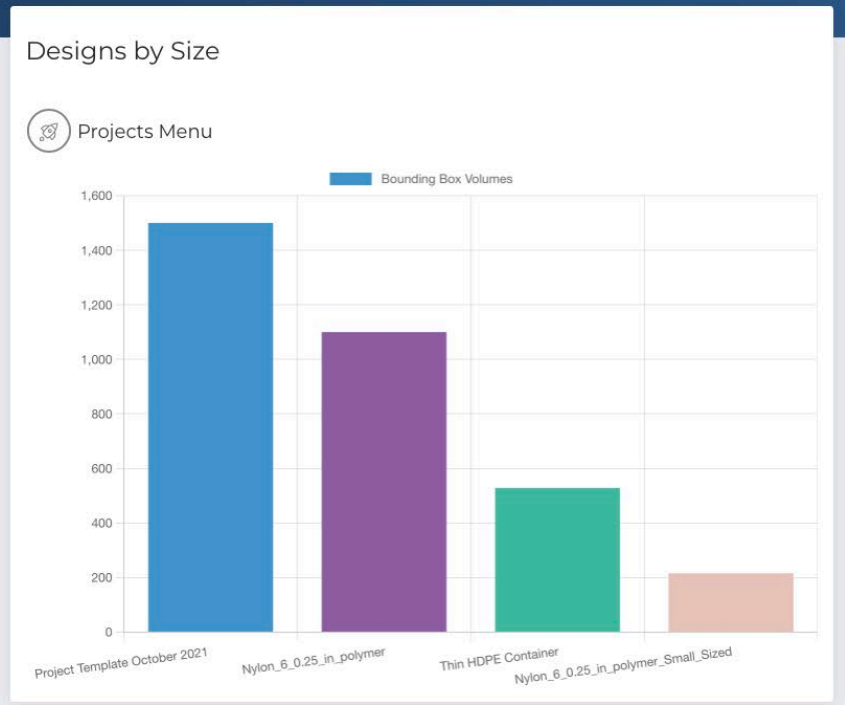
Database: SQLite-3

User Interface: HTML/CSS.

Main Dashboard Shows Top Designs

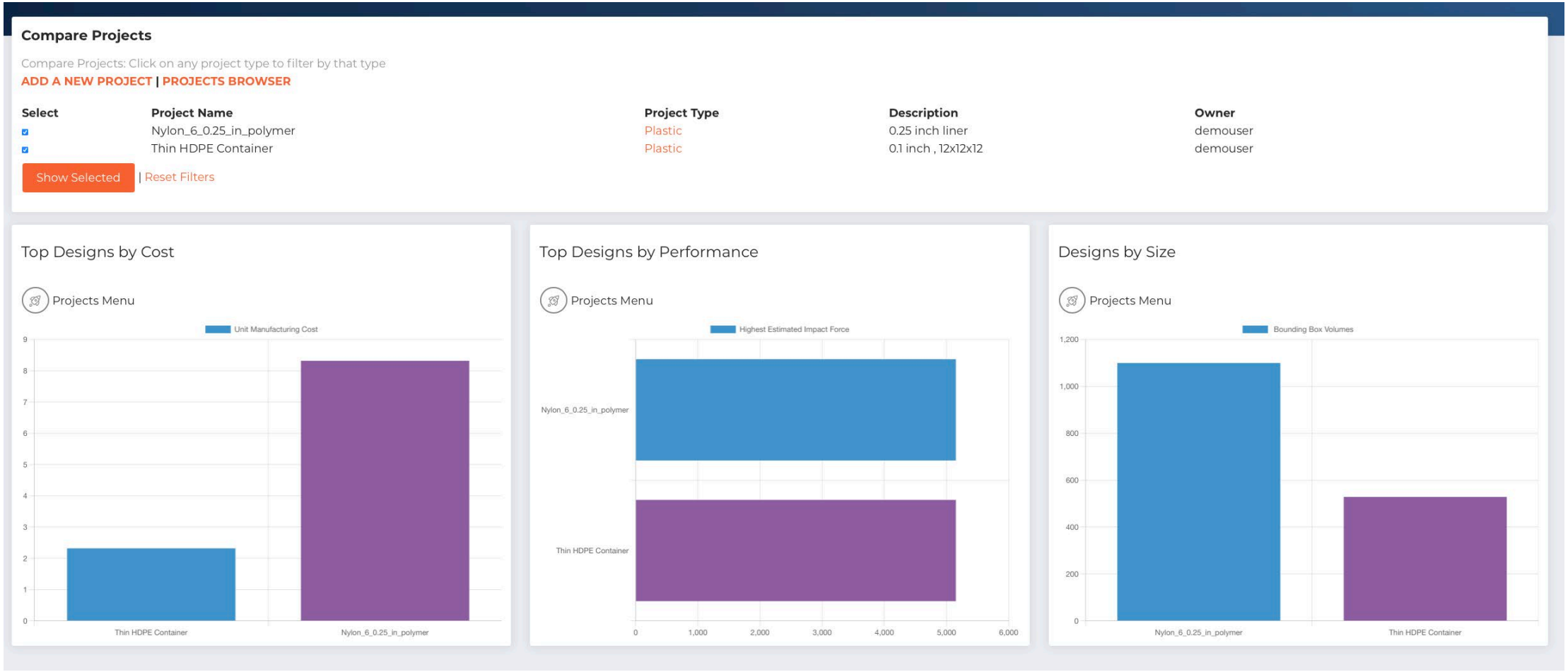






Designers can search and compare existing designs

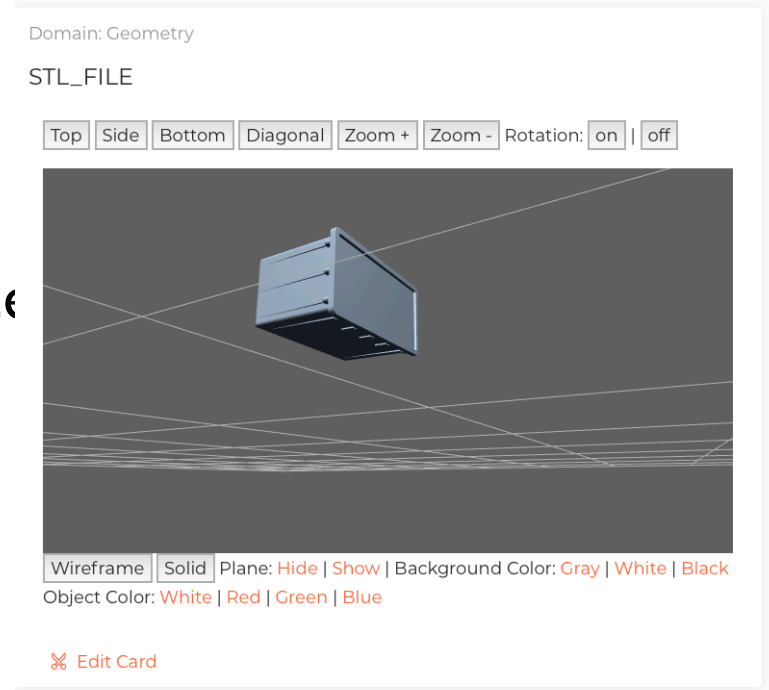
Two Selected Plastics Containers



PADD Geometry Engine

Geometry Representations:

- CAD File Processing: Dimensions, surface area and volume determined with CAD File processing
- User Entry: Enter length, width, height and thickness for quick what-if calculations
- Or Switch between the two.



Upload STL FILE

Required geometric Parameters are Inferred from the STL

Inputs/Propagates

Edit	Description	Value	Unit
Length_From_STL	Length as Deciphered from STL	11.979176	in
Width_from_STL	Wiidth from STL	7.2499995	NA
Height_from_STL	Height from STL	6.087176	in
Effective Thickness Estimate for STL	This is an estimate of the thickness - Automatically obtained from STL	0.2466940419365467	NA

Sizing What If Analysis

- Quick interface to resize to check weight, cost and process cycle time

Inputs/Propagates

Edit	Description	Value	Unit
Specify_Material	Copy/Paste one of these names into values: Prime N100STL Nylon 6 Unfilled, HDPE DMDA-8007, HDPE HD7960.3, HDPE 2909, Polyamide 66 41 NT	HDPE 2909	NA
Change_Height	Enter New Height	15	in
Change_Width	Enter New Width	10	in
Change_Length	Enter New Length	10	in
Change_Thickness	Enter New Thickness	0.2	in
Add_Lid	Enter Yes if lid needs to be included	Yes	NA
Specify_Production_Volume	Enter the target production volume	10000	NA
UseSTLforGeometryAnalysis	Enter 1 if STL needs to be used instead of the entered dimensions	No	NA

Track impact on design metrics

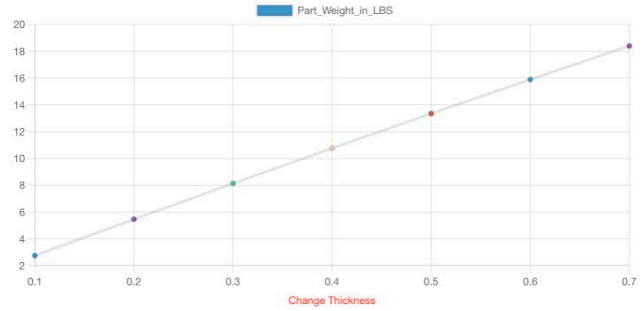
Formula/Equates/DB References

Edit	Description	Value	Unit
Part_Weight_in_LBS	Estimated weight in lbs is shown here	5.47	lbf
Single_Cavity_Mold_Cost	Estimated cost for a single cavity mold	27858.77	NA
Part_Cycle_Time	The cycle time estimate for one part (Injection+cooling)	190.31	seconds
TotalCost	Estimated unit manufacturing cost in USD	6.96	USD
EstimatedImpactForce	ReservedItems for Dashboard	5149.115	
PackageDimensions	ReservedItems for Dashboard	[10,10,15]	in

Look for more attractive solutions in nearby design space

Domain: _Dashboard_

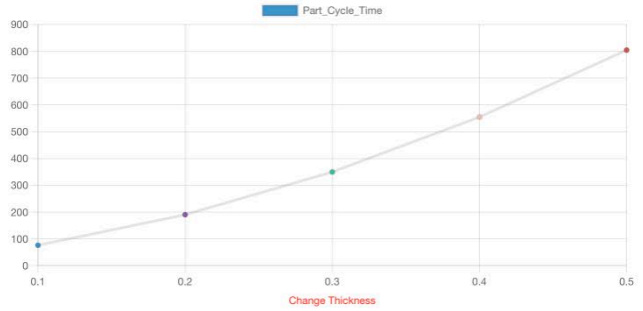
Thickness Effects on Weight



Edit Card

Domain: _Dashboard_

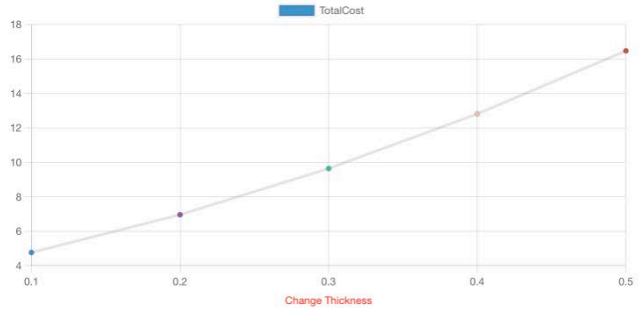
Cycle Time Vs. Thickness Effects



Edit Card

Domain: _Dashboard_

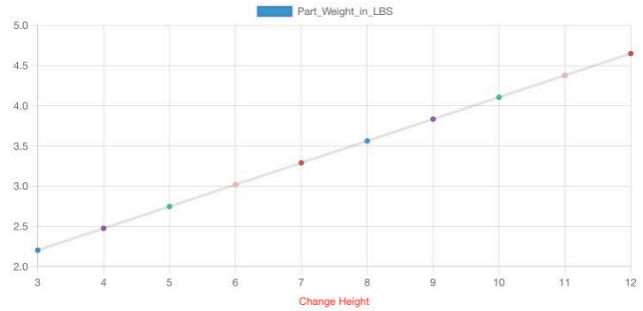
Total Cost Vs. Thickness



Edit Card

Domain: _Dashboard_

Depth vs. Weight



Edit Card

Unit Manufacturing Costs

Cost are built from components:

Batch Cost:

Material costs : Weight of (Material Used + Scrap) * Cost / Kg

Process costs: (Processing time estimate) * Process Cost/hr

Tool fabrication cost: F(tool complexity, estimated hours)

Unit Cost: Batch Costs/Batch Size (or production volume)

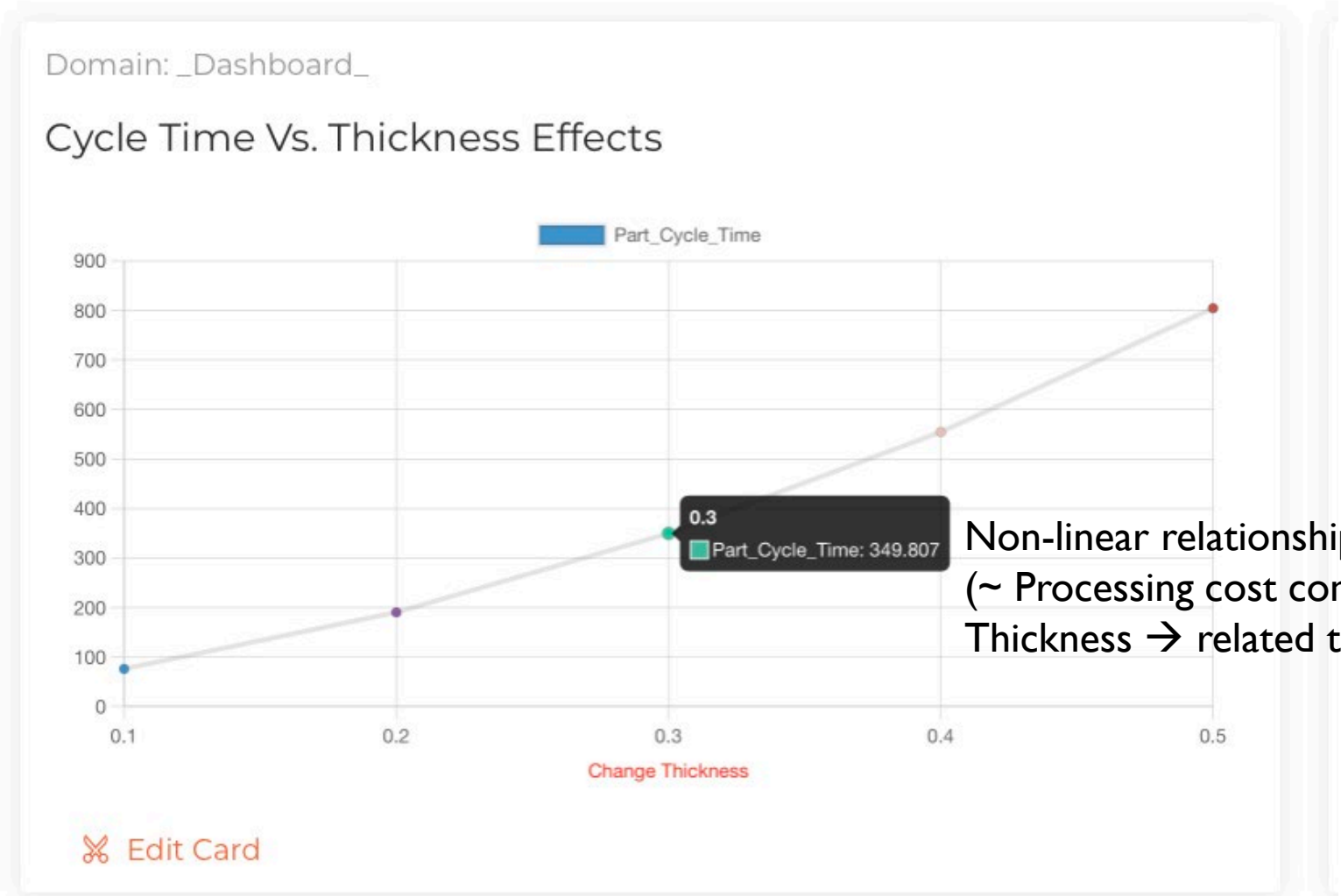
Processing time estimates are physics-based ;Tool fabrication cost is empirical but a well known model

Cost Breakdowns per Part

Formula/Equates/DB References

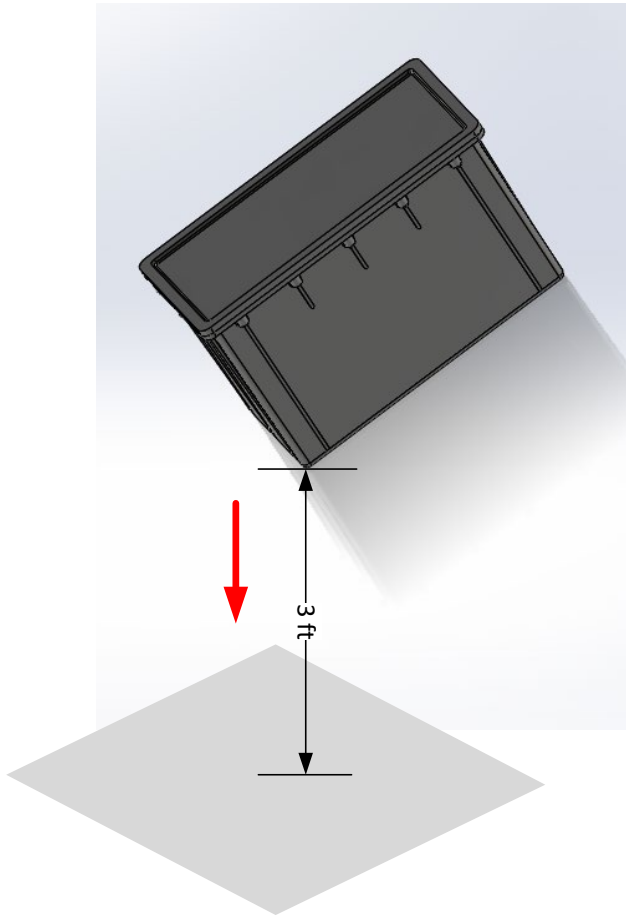
Edit	Description	Value	Unit
Processing_Cost	Total processing cost per cycle	2.11	$
Mold_base_cost	Cost of mold base plate	1951.93	$
Single_cavity_and_core_fabrication_cost	Single cavity and core fabrication cost	27858.77	$
Multicavity_mold_fabrication_cost	Multicavity mold fabrication cost	27858.77	$
Tooling_Cost	Tooling Cost	2.98	$
Material_Cost	Material Cost	1.86	$
Unit_Manufacturing_Cost	Unit Manufacturing Cost	6.96	$

Cost vs. Any Cost Driver Visualized

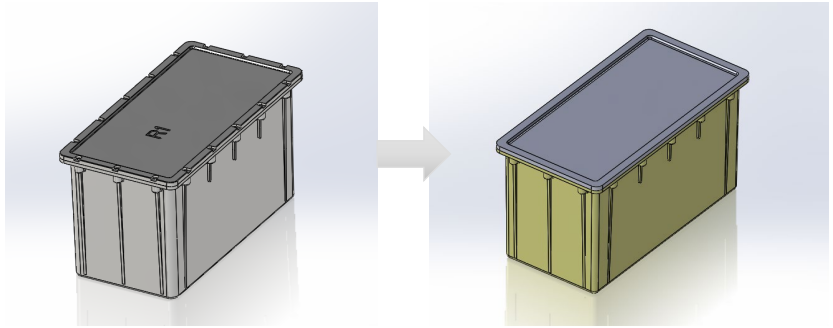


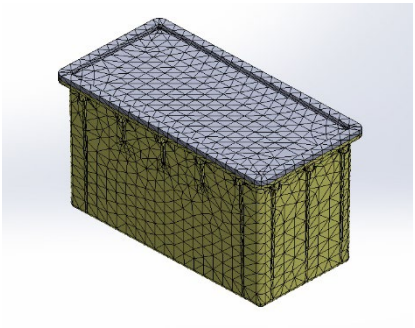
Non-linear relationship between cycle time (~ Processing cost component) and part Thickness → related through physics of cooling

Impact Performance Via Drop Test Simulations

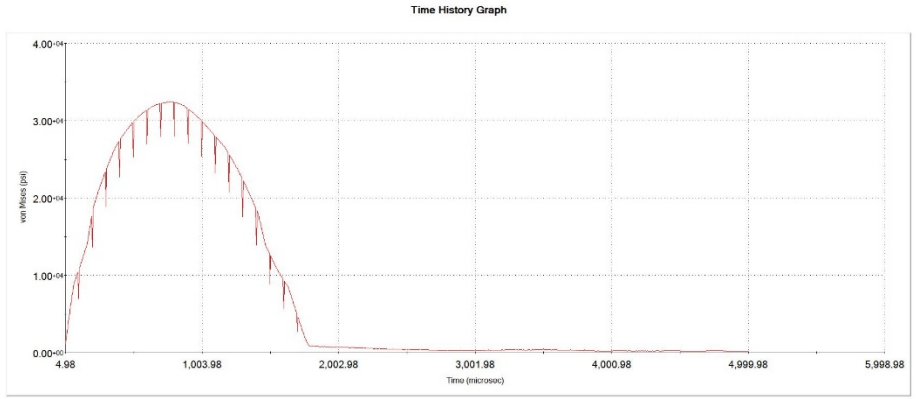


- Material used:
  - PA66
  - HDPE
- Drop height: 3 ft
- Including ammunition load: XX lbs

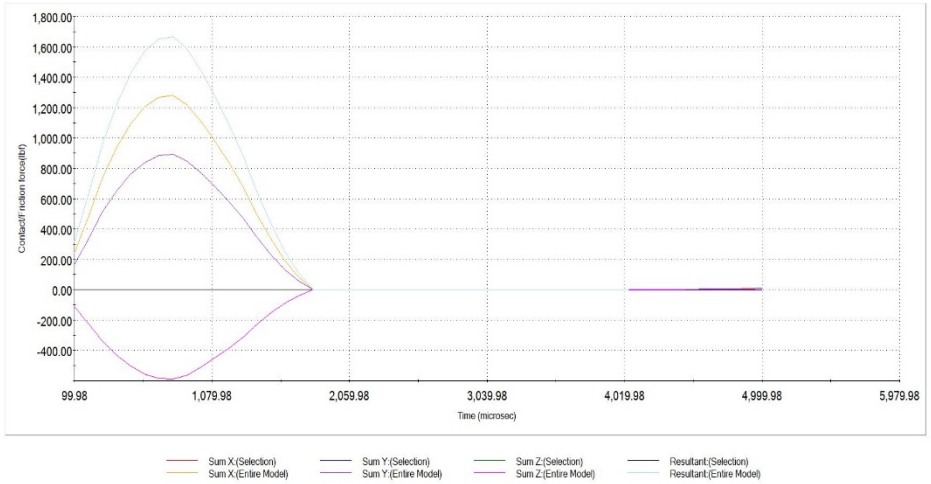




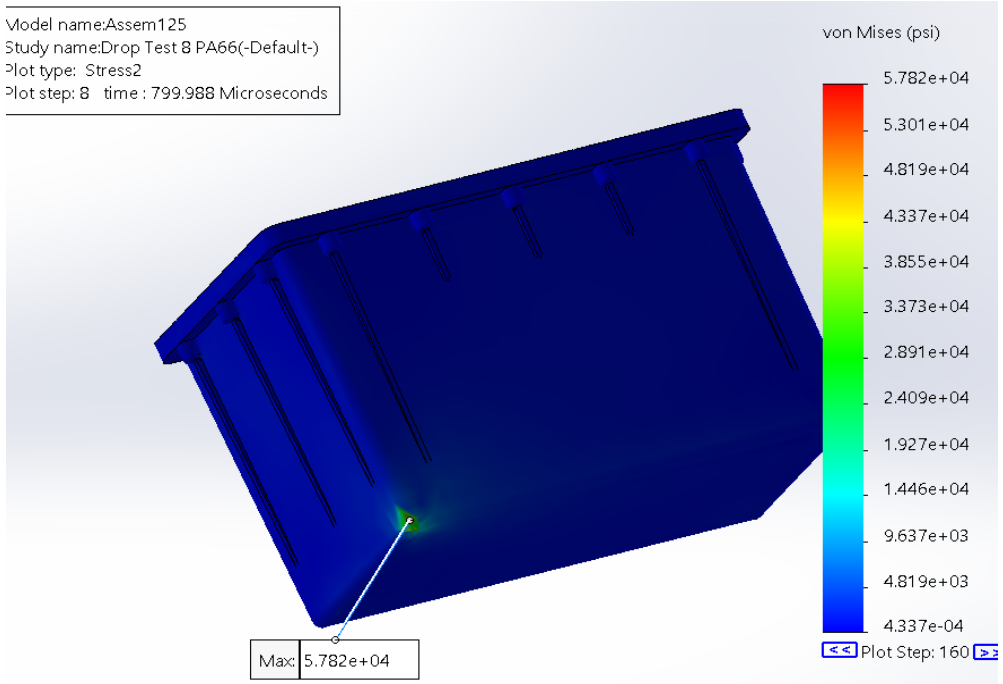
Impact Force and Impact Time (high-res simulations) – 0.125 in thick



Time History Graph of von Mises Stress at the Impact Point

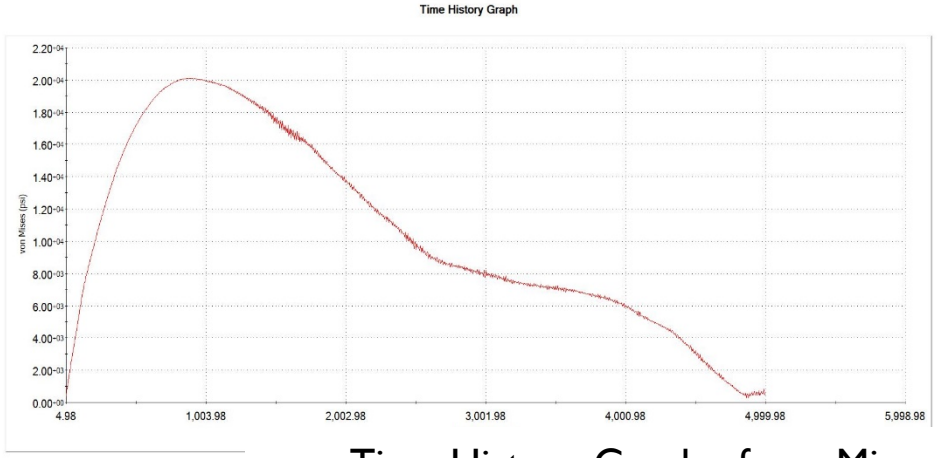


Time History Graph of Contact Force at the Impact Point

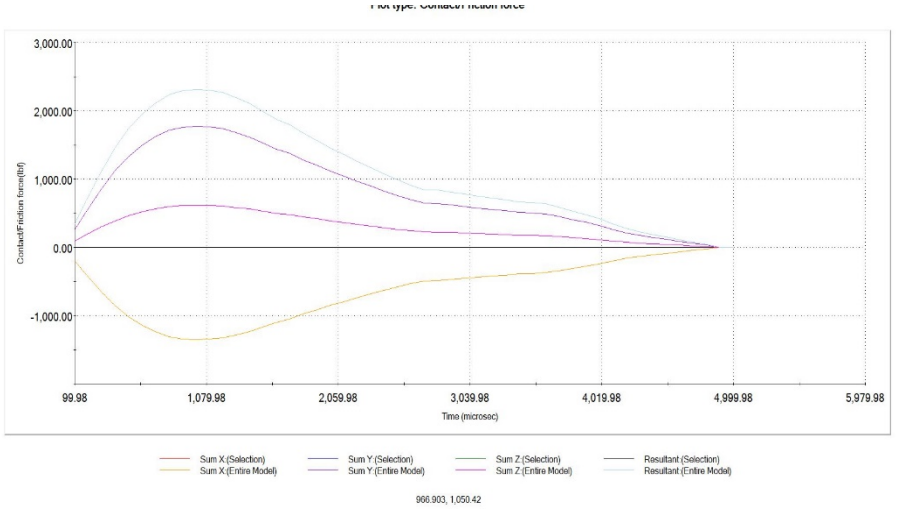


von Mises Stress at the Time of Peak Contact Force

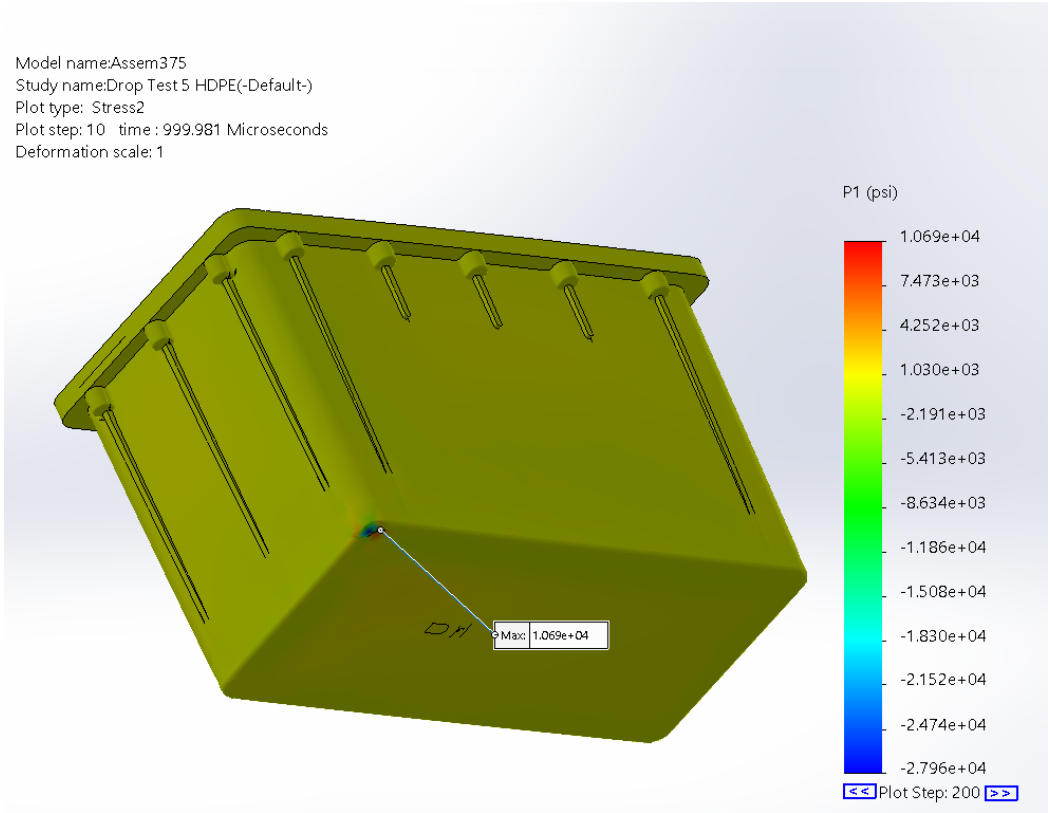
Larger Thickness Container



Time History Graph of von Mises Stress at the Impact Point

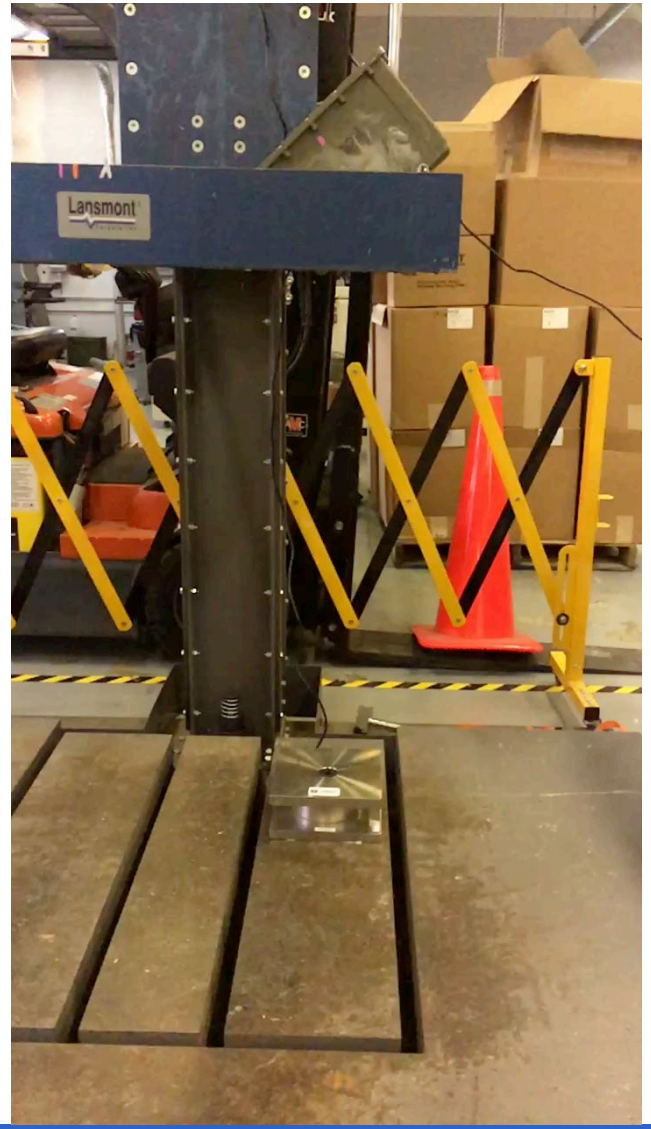


Time History Graph of Contact Force at the Impact Point

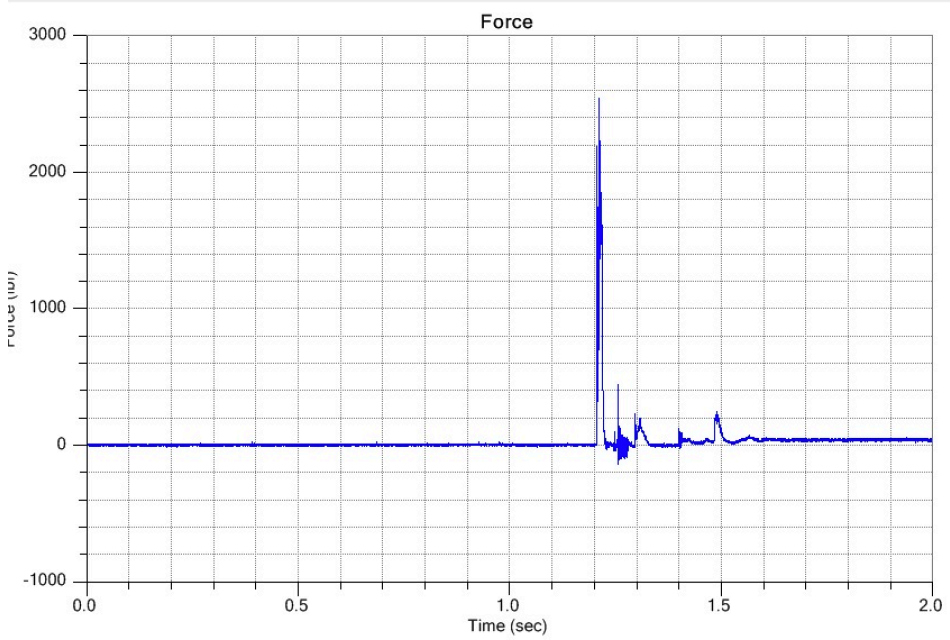


1st Principal Stress at the Time of Peak Contact Force

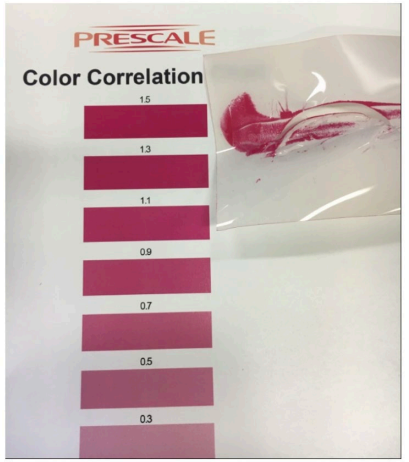
DEVCOM Armament Center Drop Tests



FORCE PLATE



IMPACT PRESSURE FILM (CHANGES COLOR)



PADD Impact Performance Experiment Record

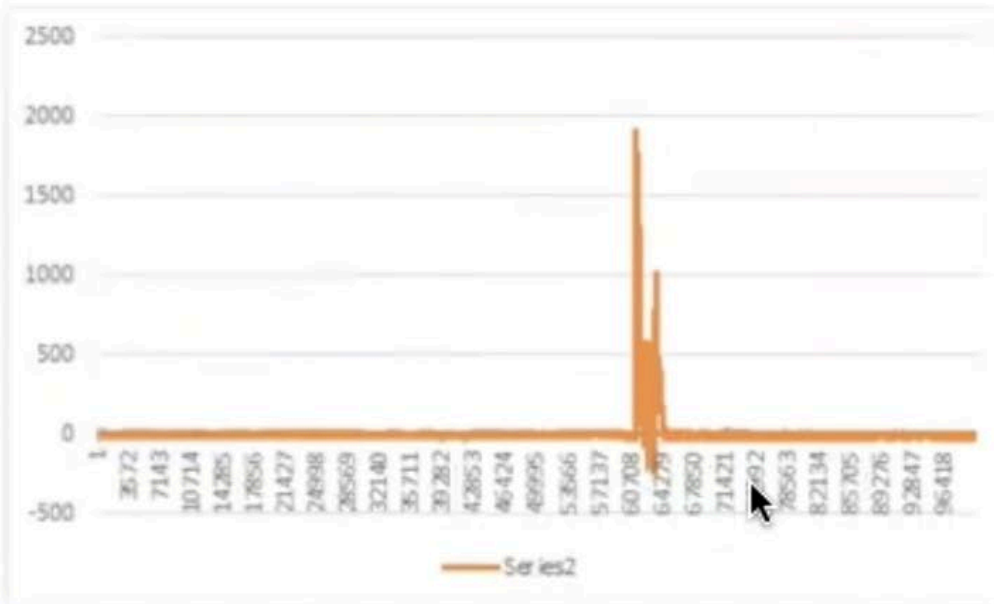
Inputs/Propagates

Edit	Description	Value	Unit
DropMode	Drop Mode - Drop height and orientation	3FeetCorner_45	N/A
Test_Configuration	Test configuration	bare container	N/A
Capture_Time	Total time for data capture	2	seconds
Sampling_Rate	Data sampling frequncy - samples/sec	20000	Hz
Peak_Force	Low impact force after 3 foot drop	5149.115	lbf
Time_Peak	The time at the peak force observed	0.4137	second
Low_Force	Peak impact force after 3 foot drop	1002.838	lbf
Num_Peak	Number of peak (bounces) observed	6	N/A
Test_Temperature	Temperature set for the test environment	160	degree F
Damage_Observed	Damage observed	No damage	N/A

PADD allows impact data and video storage

Domain: Drop Test -1 Edge Impact

Drop Test Impact Force Trace



Edit Card

Domain: Drop Test -1 Edge Impact

Drop Test Real Time Video

Edit Card

Impact Force Model (simplified)

Inputs/Propagates

Edit	Description	Value	Unit
Test_Configuration	Test configuration	bare container	N/A
Capture_Time	Total time for data capture	2	seconds
Sampling_Rate	Data sampling frequncy - samples/sec	20000	Hz
Experimental_Peak_Force	Low impact force after 3 foot drop	5149.115	lbf
Time_Peak	The time at the peak force observed	0.4137	second
Low_Force	Peak impact force after 3 foot drop	1002.838	lbf
Num_Peak	Number of peak (bounces) observed	6	N/A
Test_Temperature	Temperature set for the test environment	160	degree F
Damage_Observed	Damage observed	No damage	N/A
Drop_Height	Drop Height	3	ft
Loaded_Weight	Loaded weight	36	lb
Impact_Duration	Impact duration	0.003	NA

Formula/Equates/DB References

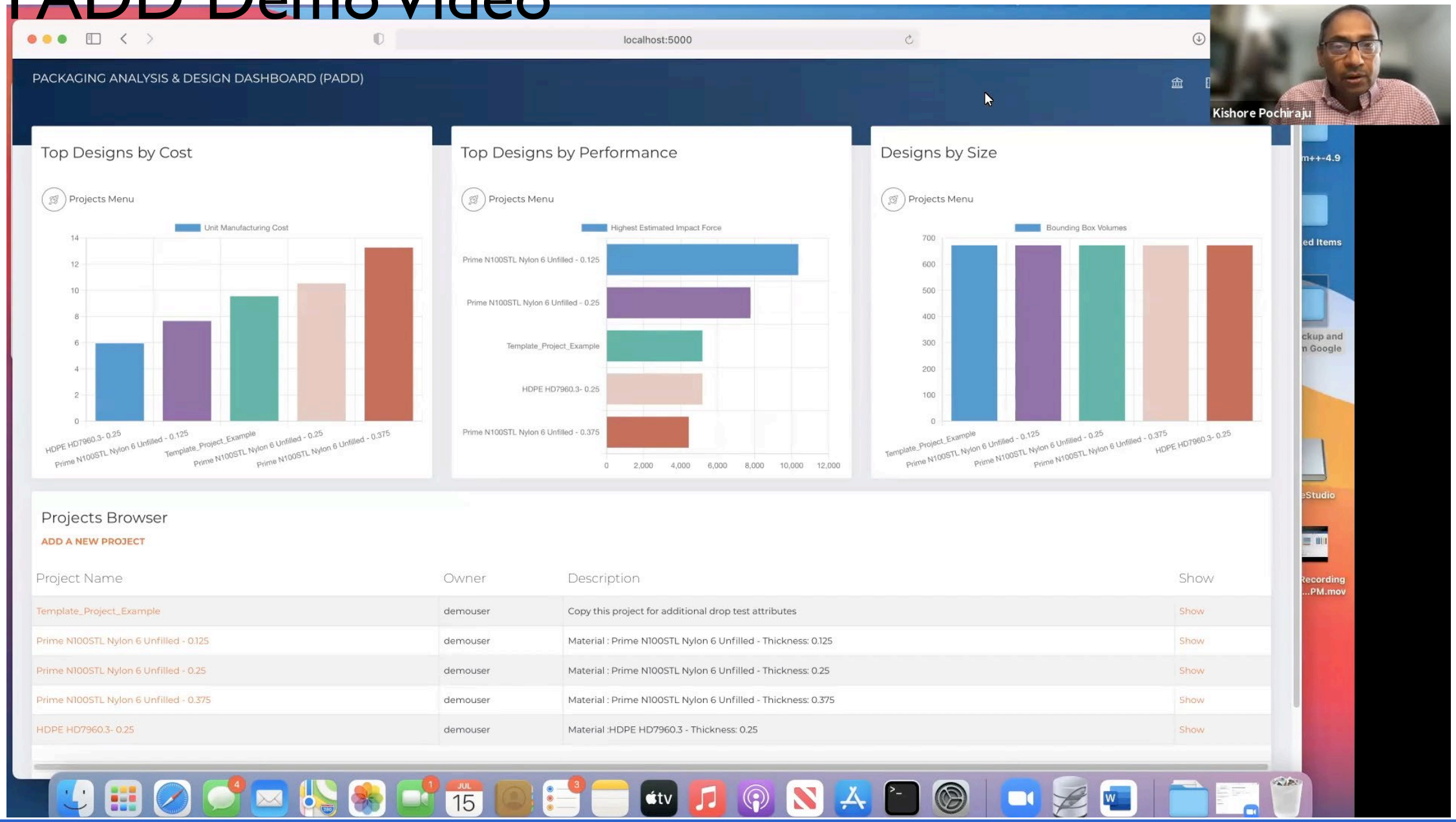
Edit	Description	Value	Unit
Impact_Velocity	Velocity at impact	13.89	ft/sec
Impact_Deceleration	Deceleration	4631.35	other
Estimated_Impact_Force	Impact force estimated	5182.08	lbf

Impact force will be estimated

Opportunity to learn from the data

Provide an approximate impact duration

PADD Demo Video



Concluding Remarks

- PADD: A dashboard for evaluating, analyzing and performing trade-offs for ammunition containers was designed and developed.
- The system has an extensible computational engine, general purpose database, and a customizable user interface.
- Three DFX modules were provided:
  - Cost Analysis
  - Process Cycle Time Analysis
  - Impact Performance Analysis.
- PADD has been hosted at Stevens Institute and access was provided to DEVCOM armament center personnel for prototype testing.