Team #30

Digital Thread Blaster

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Customer Background

Los Alamos National Laboratory's (LANL) mission is to solve national security challenges through simultaneous excellence. The Department of Energy funds the facility but LANL is managed by Triad National LLC. This company is made up of the nonprofit Battelle Memorial Institute, the Texas A&M University System and the University of California University System. Even though they primarily research nuclear weapons, other fields housed in the facility as well. This research facilities house a nanotechnology center, electron microscopy lab, explosives center, high magnetic field laboratory, and a unique proton radiography center. They are trailblazers in science, technology and engineering for the entire nation.

Problem Statement/Scope of Work

Currently, document-based systems engineering (DBSE) product life cycles at LANL are corrupted by three scenarios; product definition change, missed change impact, and copy-paste propagation. The three scenarios are based on data that is changed in one step of the product process but not changed in the others. These errors can be avoided by utilizing a digital thread that links all steps of the product life cycle together. These steps can be defined as dimensions in the CAD data, physical analysis in Matlab, and manufacturing information. Transforming LANL from a DBSE to a model-based systems engineering (MBSE) will improve transparency by not only introducing and encouraging a constant feedback loop, but also reduce error likelihood thus increasing efficiency and reducing development costs. Like how JavaScript is a programming language, MBSE uses a modeling language called SysML to enable engineers to create and maintain blocks that encompass software, hardware, data, process and concepts. A system is defined by four components described as the four pillars of SysML. They are Requirements, Structure, Behavior, and Parameters. This project explores MBSE by designing a simple system like a blaster through the lens of MBSE and the SysML pillars. A digital thread is utilized in order to avoid the three previously stated complications. There are two deliverables at the end; the physical, 3D printed system and the Cameo model that fits within the digital thread.

Requirements Matrix

Table 1: Requirement Matrix

Rep. #	Requirement	Description	Test to Verify
1	Product weight should not exceed 4.6kg	Since this product is typically used by children, the overall design of the product must be light and ergonomic.	A triple beam balance will be used to validate the final weight
	Rational and Reference: In the meeting on 10/14, the client Denver Smith set these requirements with the capstone team in the project introduction.		
2	Product handle diameter must be between 0.75 and 1.5 inches	As this is a handheld product, it must be relatively compact and ergonomic	A dial caliper will be used to measure the handle diameter
	Rational and Reference: In the meeting on 10/14, the client Denver Smith set these requirements with the capstone team in the project introduction.		
3	Product length must not exceed 15 inches	As this is a handheld product, it must be compact and small enough to hold with one hand.	A dial caliper will be used to measure the product length
	Rational and Reference: In the meeting on 10/14, the client Denver Smith set these requirements with the capstone team in the project introduction.		
4	Product width must not exceed 3 inches	As this is a handheld product, it must be compact and small enough to hold with one hand.	A dial caliper will be used to measure the product width
	Rational and Reference: In the meeting on 10/14, the client Denver Smith set these requirements with the capstone team in the project introduction.		
5	Product height must not exceed 9 inches	As this is a handheld product, it must be compact and small enough to hold with one hand.	A dial caliper will be used to measure the product height
	Rational and Reference: In the meeting on 10/14, the client Denver Smith set these requirements with the capstone team in the project introduction.		
6	Projectile distance must not exceed 30 meters	This product is based off a children's toy and is also handheld and thus we do not want the projectile distance to not exceed 30 meters	A measuring tape and sandbox will be used to identify the distance the projectile travels
	Rational and Reference: In the meeting on 10/14, the client Denver Smith set these requirements with the capstone team in the project introduction.		
7	Projectile velocity must not exceed 100 meters per second	This product is primarily handheld and not intended to injure people. Thus, the velocity must not exceed 100 meters per second	A ballistic chronograph will be used to measure the velocity of the projectile immediately after leaving the chamber
	Rational and Reference: In the meeting on 10/14, the client Denver Smith set these requirements with the capstone team in the project introduction.		
8	Projectile force immediately out of the barrel must not exceed 8 Newtons	The product is not intended to cause bodily harm and thus will not exceed a force of more than 8 Newtons	A force plate will be used to measure the force exerted by the projectile when exiting the barrel
	Rational and Reference: In the meeting on 10/14, the client Denver Smith set these requirements with the capstone team in the project introduction.		
9	Projectile material must be steel	As steel ball bearings are simple to acquire and have uniform construction and hardness, they are the best choice for projectile material	The vendor provides material certificates that prove the authenticity of the material, along with a traceable lot number
	Rational and Reference: In the meeting on 10/14, the client Denver Smith set these requirements with the capstone team in the project introduction.		
10	Projectile shape must be circular and uniform	A circular projectile will have uniform air resistance and will also have balanced weight thus allowing for accurate theoretical calculations	We will use a Bal-Tec ball plug gage to validate the uniformity of the ball bearing
	Rational and Reference: In the meeting on 10/14, the client Denver Smith set these requirements with the capstone team in the project introduction.		
11	Product material type must be PLA Plastic and also REACH and RoHS compliant	PLA plastic is both durable and easy to use when 3D printing through additive manufacturing. This is both light and strong enough to withstand the force of the projectile	The vendor provides standard PLA Plastic and is also compliant with REACH and RoHS 3 regulations (non-toxic substances)
	Rational and Reference: In the meeting on 10/14, the client Denver Smith set these requirements with the capstone team in the project introduction.		

Experimentation/ Concepts Exploration

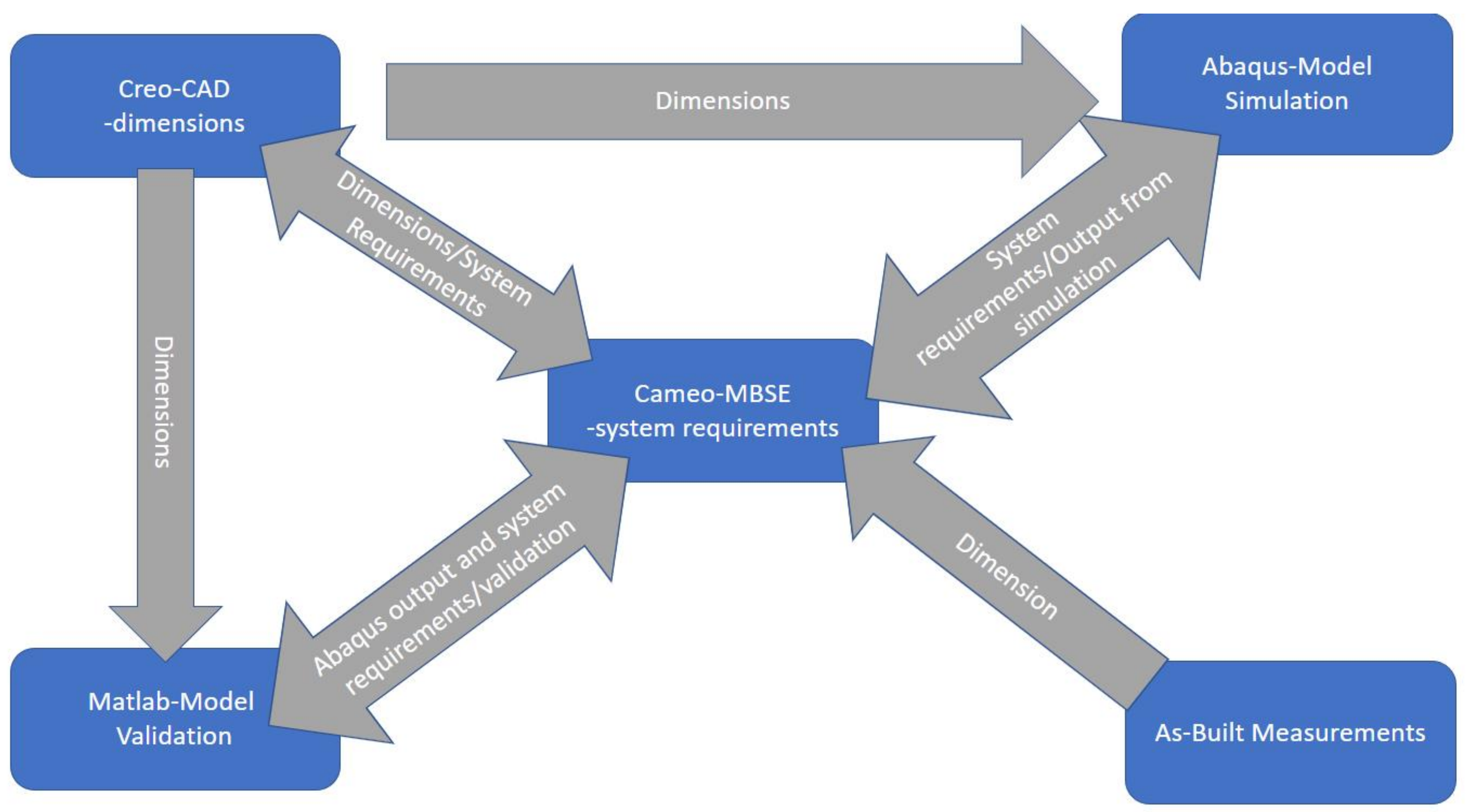

Figure 1: Draft Connections between Software

Final Design

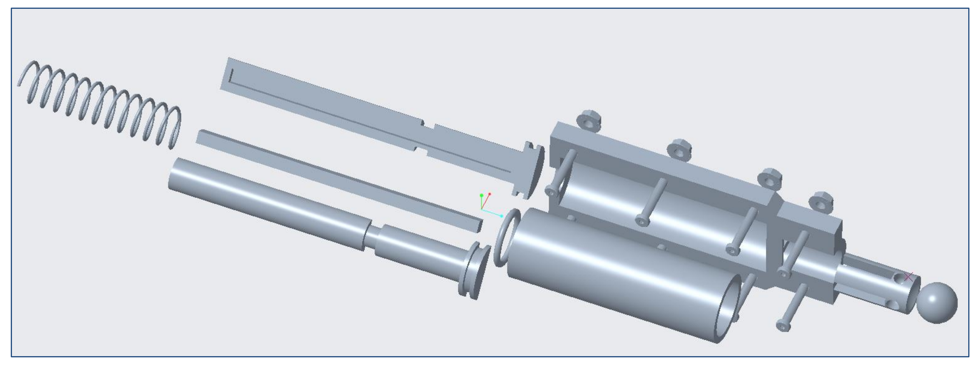

Figure 2: Exploded View of Final Blaster Design

The blaster design underwent many changes using both traditional engineering techniques and implementing the digital thread process. The original intent was to use a pneumatic design to propel the ball. When this was found to be inadequate, a hybrid pneumatic/kinetic revision was made. After performance was tested, the digital thread process was used to make changes to the blaster.

As stated in Figure 1, the Cameo software package is a critical part of the final design of the capstone project. Cameo fulfills the four pillars of SysML (Structure, Behavior, Requirements, Parameters) which is critical to the purpose of the project. Figure 3 showcases the Behavior pillar with the title connections between part blocks. The purpose of Figure 3 is to communicate and visual the relationships between parts. The other two boxes within the figure are State Machine diagrams which also show the behavior of individual parts. These are all very important elements of Cameo, but Cameo is not the entire digital thread. The digital thread consists of information flowing from Creo into Cameo, then from Cameo into Matlab and Abaqus and then the validation results finally being released. Without Cameo and the model, the data would be housed in multiple place and lead to errors depending on where the user looked.

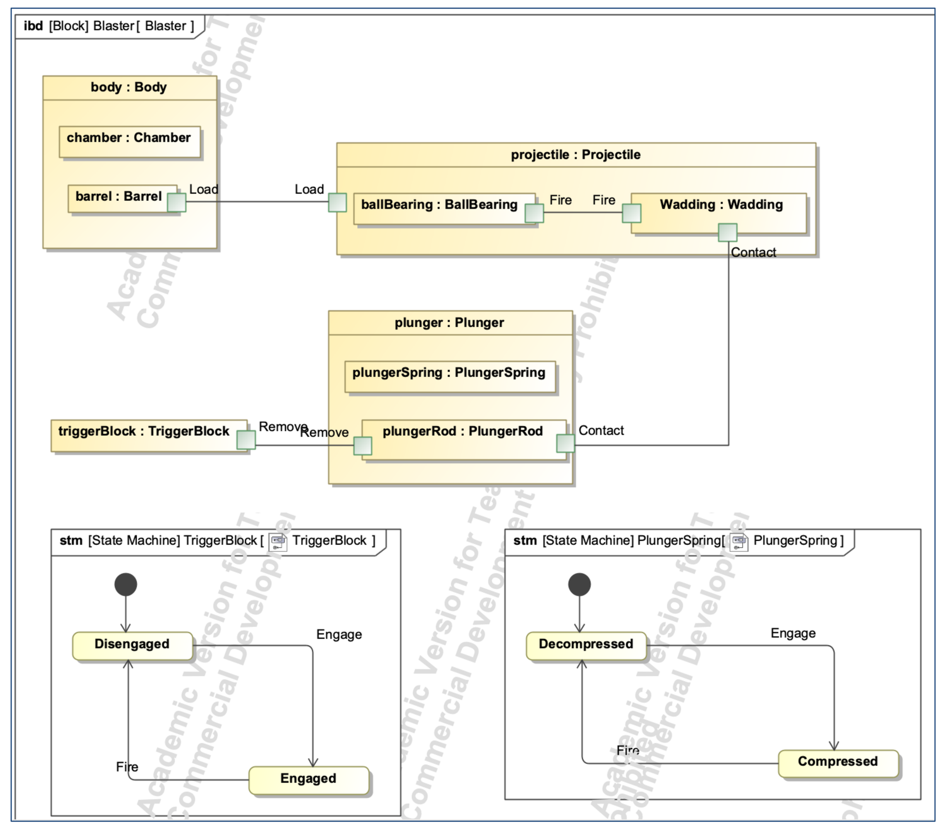

Figure 3: Internal Block Diagram for Blaster

Failure Mode and Effect Analysis

Table 2: FMEA

FMEA - Faliure Modes and Effective Analysis									
Key Process Step	Potential Faliure Mode	Potential Faliure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Taken
Movement of Plunger									
Plunger Moves Back	Plunger wont move	Spring tension cannot be obtained	8	Spring is jammed; trigger release is jammed; chamber is too tight	7	Tolerance of joined parts	8	448	Shave printed pieces so no excess
Plunger Moves Back	Plunger doesn't stay cocked	Spring tension cannot be obtained	8	Trigger release is broken off; trigger release is not engaged	7	Enlargen trigger release; ensure pieces must touch in CAD	8	448	Enlargen trigger
Plunger Moves Forward	Plunger is jammed	Ball is not hit	8	Spring is jammed; trigger release won't relase; chamber is too tight	7	Tolerance of joined parts	8	448	Shave printed pieces so no excess
Plunger Moves Forward	Plunger moves too fast	Projectile has too much velocity	3	Spring is too compressed	3	Set specific travel distance for spring with location of spring release	8	72	Replace spring with less one with less K constant
Plunger Moves Forward	Plunger stops midway	Ball is not hit	8	Cyclinder is too constricted ; spring tension is weak; obstruction in chamber	2	Tolerance of joined parts; spring K constant is strong; file inside of chamber	8	128	Shave printed pieces so no excess
General									
Trigger System	Trigger is jammed closed	Spring tension cannot be released	8	Trigger is jammed; trigger relase is jammed; housing is too tight	6	tolerance of trigger housing	8	384	Shave printed pieces so no excess
Ball bearing is Shot	Plunger does not hit	Projectile is not launched	8	Plunger spring is too loose	1	Spring K constant is calculated and given an level of error correctly	8	64	Larger sptring inserted

Testing

To measure the distance that the ball travelled, along with the exit velocity of the pneumatic gun, we implemented the following test set up as seen in Figure 6. We Tested each iteration of the gun 30 times and marked off where it was landing on the carbon paper as well as recording the exit velocity for each shot.

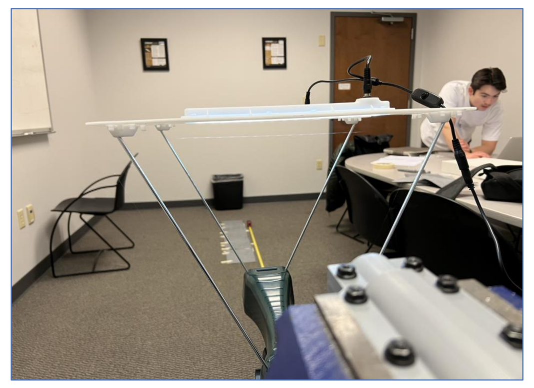

Figure 6: Overall Distance Testing Setup

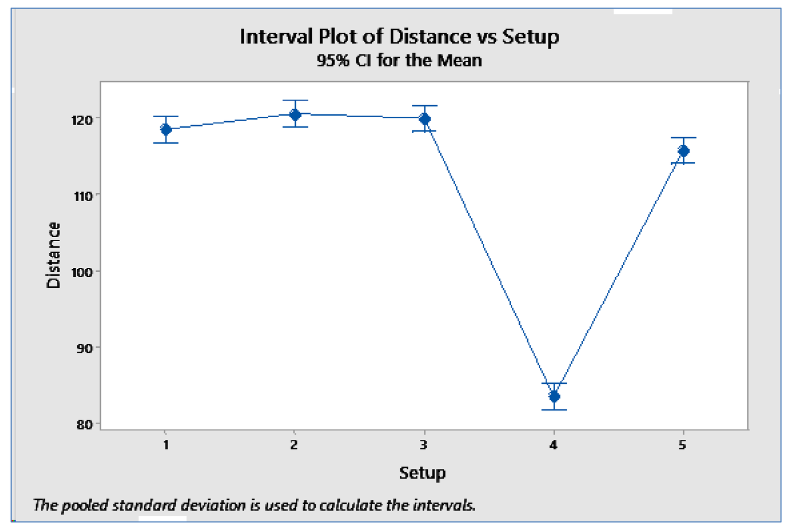

Figure 4: Comparison of Different Setups on Mean Distance

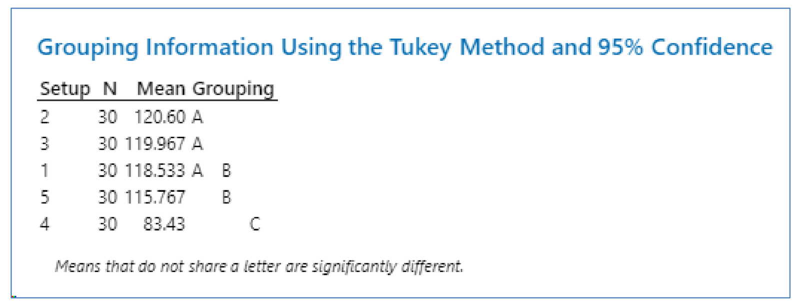

Figure 5: Tukey Comparison of Different Setups on Mean Distance

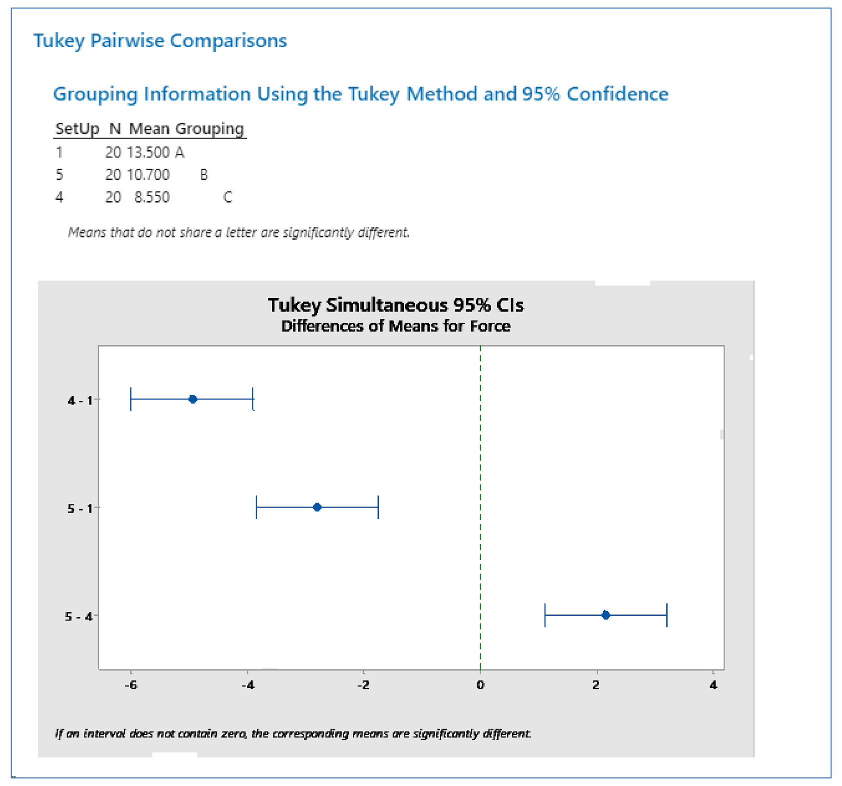

Figure 6: Tukey Comparison of Different Plungers on Force

To measure the force exerted by the slug directly out of the barrel a test, which can be seen in Figure 7, was set up using a force plate. Through this test, the exerted force was calculated by taking the absolute value of the difference between the initial and final output in newtons. The 1.5-inch, 1.75-inch, and 2-inch slugs were each tested thirty times.

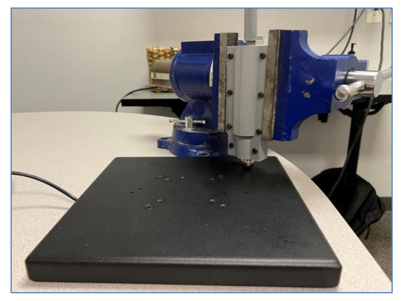

Figure 7: Force Plate Testing Setup