PENNSTATE ARL

iMAST

Institute for Manufacturing and Sustainment Technologies

Powered by Naval Research

A U.S. Navy Manufacturing Technology Center of Excellence

QUARTERLY

2004 No.3

Dr. Tim Eden, acting director of ARL's Materials Processing department, describes a manufacturing process to BGen Thomas Waldhauser, Vice Chief of Naval Research.

Focus On Manufacturing Systems

Vice Chief of Naval Research Visits iMAST

Brigadier General Thomas D. Waldhauser, USMC, Vice Chief of Naval Research (VCNR), recently visited iMAST as part of a capabilities overview relative to on-going project efforts within the Navy ManTech Center of Excellence program located at ARL Penn State.

In his capacity as Vice Chief of Naval Research, Brigadier General Waldhauser provides expertise in Marine Corps matters to the Chief of Naval Research, RAdm Jay Cohen, USN. The Office of Naval Research (ONR) coordinates, executes, and promotes the science and technology programs of the United States Navy and Marine Corps through schools, universities, government laboratories, and non-profit and for-profit organizations. It provides technical advice to the Chief of Naval Operations, the Secretary of the Navy, and the Commandant of the Marine Corps. ONR works with industry to improve technology and manufacturing processes that enhance the capabilities of U.S. naval forces.

In addition to his duties as VCNR, General Waldhauser also serves as the Commanding General of the Marine Corps Warfighting Lab, located at Quantico, Virginia. In his capacity as Commanding General of the Warfighting Lab, General Waldhauser is tasked by the Commandant of the Marine Corps to improve naval expeditionary capabilities across the spectrum of conflict for current and future operating forces. The Marine Corps Warfighting Laboratory conducts concept-based experimentation to develop and evaluate tactics, techniques, procedures and technologies in order to enhance current and future warfighting capabilities. The charter of the Marine Corps Warfighting Laboratory is to:

- Provide the process for rapid military innovation while meeting current commitments
- Insert science and technology that enables the warfighter
- Focus on the efforts of the operating forces; and
- Within the framework of existing available technologies, initiate relevant employment of technology to support the warfighter

A native of South St. Paul, Minnesota, Brigadier General Waldhauser graduated from Bemidji State University in 1976. Upon graduation he was commissioned a second lieutenant in the United States Marine Corps. General Waldhauser also holds a masters degree in national security and strategies from the National War College. The general has attended U.S. Army Ranger School, Jumpmaster School, Expeditionary Warfare School, Marine Corps Command and Staff College, as well as the National War College in Washington, D.C..

An infantry officer, General Waldhauser has served throughout the Fleet Marine Force, Navy and in various joint commands. His company grade assignments ranged from Commanding Officer, Marine Detachment, USS *Long Beach* to

CONTINUED ON PAGE 7

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2004**	2. REPORT TYPE	3. DATES COVERED **00-00-2004 to 00-00-2004**

4. TITLE AND SUBTITLE **iMAST Quarterly, 2004 Number 3**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Penn State University,Applied Research Laboratory,Institute for Manufacturing and Sustainment Technologies,State College,PA,16804**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

PENNSTATE

iMAST

Applied Research Laboratory
Institute for Manufacturing and Sustainment Technologies

DIRECTOR
Robert B. Cook
(814) 863-3880 rbc5@psu.edu

MATERIALS PROCESSING TECHNOLOGIES
Timothy J. Eden, Ph.D. (acting)
(814) 865-5880 tje1@psu.edu

LASER PROCESSING TECHNOLOGIES
Richard P. Martukanitz, Ph.D.
(814) 863-7282 rxm44@psu.edu

ADVANCED COMPOSITES MATERIALS TECHNOLOGIES
Kevin L. Koudela, Ph.D.
(814) 863-4351 klk121@psu.edu

MANUFACTURING SYSTEMS TECHNOLOGIES
Mark T. Traband, Ph.D.
(814) 865-3608 mtt1@psu.edu

COMPLEX SYSTEMS MONITORING
Karl M. Reichard, Ph.D.
(814) 863-7681 kmr5@psu.edu

NAVY/MARINE CORPS REPAIR TECHNOLOGIES
Sean L. Krieger
(814) 863-0896 slk22@psu.edu

iMAST ADMINISTRATOR and EDITOR
Gregory J. Johnson
(814) 865-8207 gjj1@psu.edu

STAFF ASSISTANT
Lori L. Mowery
(814) 865-3264 llm1@psu.edu

WORLD WIDE WEB
www.arl.psu.edu/capabilities/mm_imast.html

NAVY PROGRAM MANAGER
John Carney
(703) 696-0352
carneyj@onr.navy.mil

IN THIS QUARTERLY

Feature Article 3
Institute Notes 7
Calendar of Events 8

DIRECTOR'S CORNER

New Fiscal Year Begins

The new fiscal year is in full swing. We are busy completing our FY-04 updates. As this newsletter goes to press we are also getting ready to attend the annual Defense Manufacturing Conference (DMC). Through a sharply focused series of presentations, forums, exhibitions, and informal networking sessions, DMC '04 will bring together leaders from government, industry, and academia to exchange perspectives and information about the DoD ManTech Programs, defense industrial base issues, and related DoD transformational initiatives. We will have government, industry, and congressional participation during our plenary sessions. This year's conference will once again highlight the technologies being developed through the DoD ManTech programs. The afternoon sessions will focus on a series of topics including the traditional metals, electronics, and composites processing, and lean manufacturing. In addition there will be sessions covering munitions, missile defense sponsored technologies, Title III, et. al. If you plan to attend this event, please be sure to stop by our exhibit booth.

Our featured article addresses a technology resident at the Applied Research Laboratory that provides a valuable visualization tool for doing concept trades. This tool enables personnel to study the impact on the system design of setting operational requirements. By addressing the options in the concept phase, and selecting the optimum, a better design should result with fewer changes downstream. While this is not a Manufacturing Technology issue, reduced manufacturing costs should result because fewer changes in the design will be necessary. At the same time, a system better fitted to the operating requirements will be produced.

The Navy established Centers of Excellence to provide places where technical expertise exists for the benefit of the sailor and marine. The Applied Research Laboratory at Penn State has extensive experience and knowledge in many areas. I encourage you to contact us if you are in need of knowledge, another opinion, or exploring options. We are here to help.

Bob Cook

Feature article note: Due to printing challenges, the color charts referenced in our feature article by Lorri Bennett do not appear in color. Please visit our web site's publications section ("iMAST Newsletters") to see the charts in full color. Thank you. <http://www.arl.psu.edu/capabilities/mm_imast.html>

PENNSTATE iMAST

MATERIALS PROCESSING TECHNOLOGIES — MECHANICAL DRIVE TRANSMISSION TECHNOLOGIES — LASER PROCESSING TECHNOLOGIES — COMPLEX SYSTEMS MONITORING TECHNOLOGIES

ADVANCED COMPOSITES MATERIALS TECHNOLOGIES — NAVY/MARINE CORPS REPAIR TECHNOLOGIES — MANUFACTURING SYSTEMS TECHNOLOGIES

Focus on Manufacturing Systems

A Concept Assessment Tool for the MAGTF Expeditionary Family of Fighting Vehicles

by Lorri A. Bennett

The Applied Research Lab has developed a conceptual design environment for armored vehicles which provides the ability to do concept assessment and technology tradeoffs for the U.S. Marine Corps Air-Ground Task Force (MAGTF) Expeditionary Marine Family of Fighting Vehicles (MEFFV). A vehicle system model has been developed that allows a user to select various mobility requirements and technology options for the vehicle. The system is then driven to a feasible and optimal design point by the use of an iterative solver. Hundreds of feasible designs can then be generated in an automated fashion by using an embedded Monte Carlo simulation tool. Using the Advanced Trade Space Visualizer (ATSV), a custom data visualization tool developed at ARL, we have demonstrated the capability to quickly visualize trends in vehicle parameters and visualize the impact subsystems choices have on the system.

Background

In the infancy stage of a fighting vehicle program, the sponsors develop a science and technology investment strategy that will mature promising new vehicle technologies for insertion into the program's design milestones. Although much attention and funding is provided to investigate new technology areas, very little funding is generally allocated at early program milestones to study the effect new technologies may have on the vehicle system as a whole. ARL Penn State has been funded by the Office of Naval Research (Code 353), NSWC Carderock, and the MEFFV program office to develop a conceptual design environment which will allow program managers to evaluate new technologies in the context of the system. It will further provide the capability to perform trade studies across a variety of vehicle requirements and technology options.

ARL Penn State's approach to developing concept assessment tools facilitates a design by shopping paradigm. In this paradigm, proposed by Balling[1], a decision maker forms a design preference and chooses an optimal solution after exploring a full set of feasible designs. The focus of our work is to develop a conceptual design environment that allows one to quickly generate a set of feasible vehicle designs, visualize the design trade space, see trends between design variables, and see the impact vehicle requirements and technologies have on critical system performance parameters.

Methodology

ARL Penn State's approach to building these models has three critical aspects: (1) capturing design rules for subsystem and system configuration, (2) developing a system model that iterates to a feasible design point, and (3) exploring the vehicle design space and analyzing trends between design variables using advanced data visualization techniques.

Design Rule Capture

Much of the effort in developing a concept assessment tool goes into capturing conceptual design rules. Design rules are written for each subsystem to calculate critical engineering parameters and configure components. Design rules establish relationships between system parameters in many different forms. They may be theoretical in nature, for example relating the muzzle energy of a weapon as a function of its projectiles mass and velocity.

$$\text{muzzleEnergy} = \frac{\text{mass vel}^2}{2}$$

Or rules may capture empirical knowledge, for example the cannon breech is approximately 3.2 times the size of the chamber diameter and the chamber area is 2% larger than the bullet area.

$$\text{breachWidth} = 3.2 \bullet \text{chamberDia}$$

$$\text{chamberArea} = 1.02 \bullet \frac{\pi \text{ calibre}^2}{4.0}$$

Mathematica by Wolfram Research is used to electronically capture the mathematical and empirical design rules related to armored vehicle configuration. One of the key features of Mathematica was the ability to write rules that were easy to read but also executable. Code can be written using engineering typeset, engineering notations, integration and derivative functions and imbedded text and code documentation. The code packages developed are both readable and executable. These software features along

PROFILE

Lorri A. Bennett is a research assistant in the manufacturing systems department at Penn State's Applied Research Laboratory. Ms. Bennett is a specialist in the development of advanced engineering environments, using generative technology and engineering automation tools for engineering design and research. Prior to joining ARL Penn State in 1997, Ms. Bennett was employed as a engineering software consultant with Knowledge Technology International (KTI). Specializing in the aerospace industry, Ms. Bennett supported accounts that included Boeing, Pratt and Whitney, and Lockheed Martin. Ms. Bennett holds a bachelors of science degree in mechanical engineering from The Pennsylvania State University. She can be reached by calling (814) 865-2902, or by e-mail at <lab27@psu.edu>.

with thorough code documentation allows us to distribute copies of the code for rule validation, which is critical when extracting design rules and relationships between multiple engineering organizations and program offices. A short example of Mathematica design rules is provided in Figure 1.

For the MEFFV program, design rules were categorized into drivetrain, survivability, weapons and turret configuration, and crew stations. For example, in the drivetrain group, an engine module was written that sized the engine based on vehicle power requirements and engine technology choices of gas turbine or diesel. When configuring the turret the user selects either a conventional cannon, a rail gun or a small calibre weapon and the weapons critical design parameters such as muzzle velocity or calibre. The full set of vehicle requirements and technology options that were embedded into the MEFFV armored vehicle model are listed in Table 1.

Mobility	
Technology Options	**Continuous Variables**
Conventional Drive Hybrid Electric Drive Drive Motor Configurations Battery Technologies Engine Technologies Wheels or Tracks Suspension Types	Power Distribution of Power Battery capacity Cruising Speed, Range Max Speed & Acceleration Silent mode capability
Lethality	
Technology Options	**Continuous Variables**
Rail Guns Conventional Guns Small Calibre Weapons Unmanned Turrets Autoloader Types Bustle Configurations	Muzzle Velocity Cannon Calibre Weapon system weight/vol Recoil Length/Force Ammunition Quantity
Survivability	
Technology Options	**Continuous Variables**
Threat types (AP, Ball, APDS) Threat size Armor Type (Ceramic, HHS, EM)	Vehicle level of protection Armor thickness Armor weight Threat range and speed

Table 1. Armored vehicle trade space

At the system level, design rules are captured that configure the critical vehicle components and create a hull and turret layout based on the user's preference for vehicle configuration. A critical dimensions module determines dimensions of the hull and turret and calculates center of gravity of the vehicle. This defines the vehicle area that has to be armored which has a substantial impact on vehicle weight. At the system level weight, volume and power

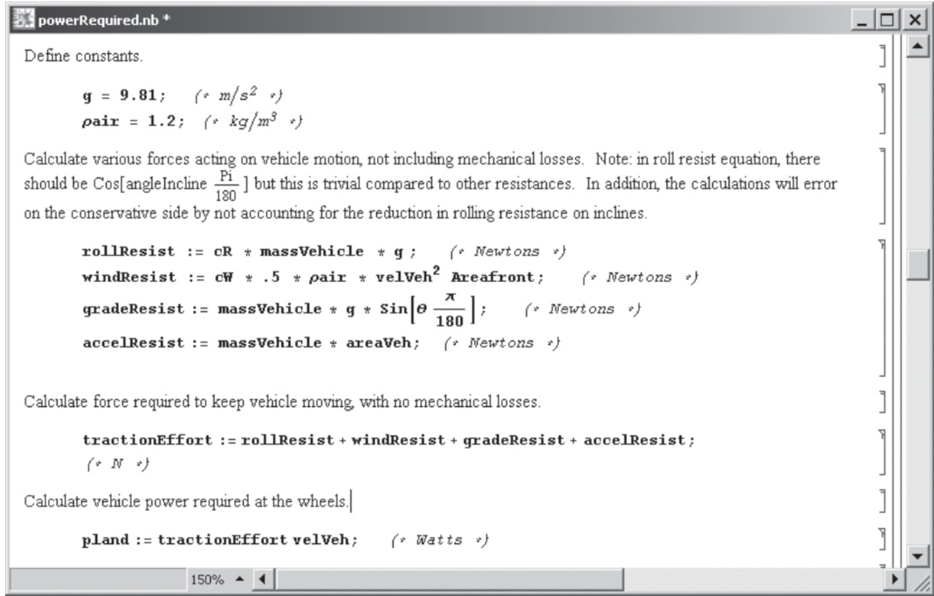


Figure 1. Example of Design Rule capture using Mathematica

requirements are calculated along with gross vehicle stability during weapon firing.

System Model Development

After the design rules are captured, a system model is created that establishes the interfaces between the subsystems and the system. This model is developed in Excel using the MathLink tool kit from Mathematica. This toolkit allows exported functions and design modules developed in Mathematica to be available from within the Excel interface. In any complex engineering system the dependency chain of the design parameters will not be straightforward.

There are typically circular dependencies between inputs and outputs of the component design rules. For example, to configure the wheels of an armored vehicle you need the total weight of the vehicle, but the total weight of the vehicle depends on the wheel configuration and weight, hence a circular dependency is formed. To handle the circular dependencies of the system an iterative solver is used to constraint design parameters and to converge to a feasible but optimal design.

Figure 2 shows an example of two design rule interfaces in Excel with the top parameters in each block representing inputs to a function and the

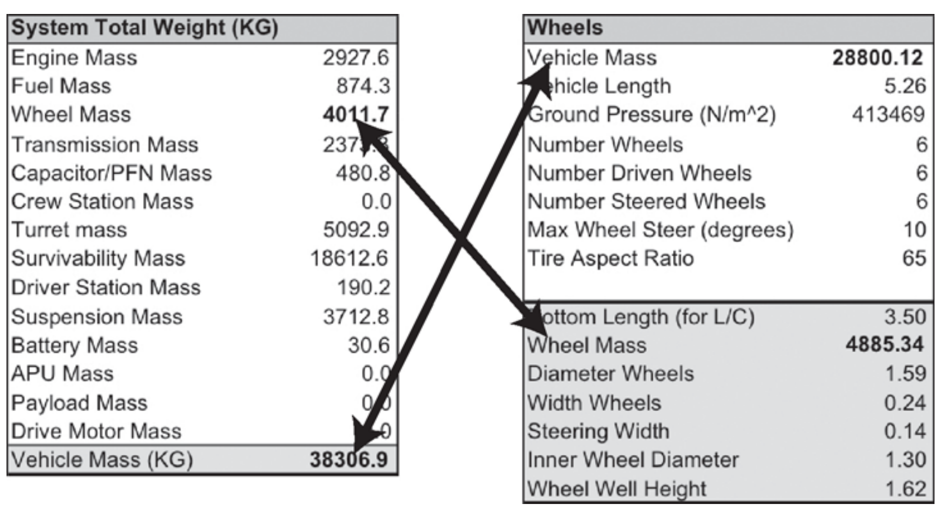


Figure 2. Interface to design rules in Excel

bottom parameters representing calculated values. Figure 2 also shows an example of one circular dependency in the armored vehicle model that is constrained by a solver when the model is executed.

Generating the Vehicle Design Space

A vehicle design space is defined as the set of dimensions and attributes that are used to define an armored vehicle. For example, if we have captured 100 design parameters that define the vehicle design then it is a 100 dimensional design space. This space is then populated with design points generated from the system model. Each design point has a set of critical design parameters associated with it and may have other related artifacts such as a conceptual geometric model.

The set of feasible designs is generated in an automated fashion from the system model using a Monte Carlo simulation method. The model's independent variables are randomly sampled within a range of interest, the vehicle system model is executed to produce a feasible design and the critical design parameters for that design are captured. This process is repeated automatically until enough designs are captured to be able to explore the design space and visualize trends between design variables.

In one trade study we compared vehicles with hybrid electric and conventional drivetrains; in addition mobility requirements were varied for both types of drivetrains. Furthermore, in this study, we varied the armor level, vehicle range and rail gun lethality so that we could explore the design options that were feasible for a specified vehicle weight class. We generated 5000 feasible design points to be able to fully explore the vehicle design space.

Exploring the Design Space

The Applied Research Laboratory has developed a powerful data visualization tool called the Advanced Trade Space Analyzer. This tool allows you to

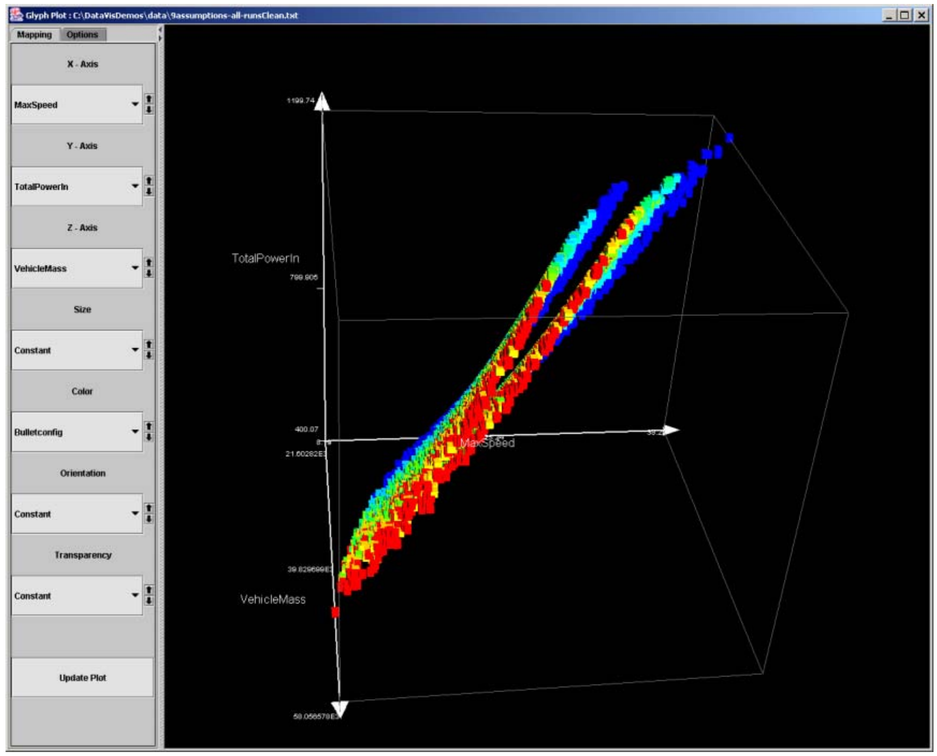


Figure 3. Design space exploration in ATSV

visualize multi-dimensional data sets in an interactive environment. The tool provides various methods to explore the design space including, pruning undesirable designs through brushing; highlighting preferred designs on the basis of critical parameter values; identifying Pareto points between selected variables; and calculating and displaying local derivatives in the design space.

Figure 3 shows an armored vehicle design space and a set of designs that were generated for one trade study on the MEFFV program. Each object or cube in the 3-D axis represents a design point from the data set. Its location in the axis represents 3 of its critical design parameters and its color and size represent another, with red designs being a higher value than blue. You will see the vertical Y axis represents the vehicle power; the X and Z axis represent vehicle speed and mass. The color of each object represents the Bullet protection level; this variable indicates how much armor protection is provided to the crew.

Notice how heavily armored designs (red objects) directly correlate to high vehicle mass in the space. Armor panel weight can be 20 to 40% of the weight of a fighting vehicle. Also notice in Figure 3 how two distinct surfaces exist, these surfaces correlate to designs that were configured with hybrid electric drive trains and those configured with conventional drive trains.

When exploring the design space, designs may be eliminated from the visual design set by brushing. This feature allows the decision maker to specify an upper and lower bound for each performance variable in the design space. For example, when exploring a set of vehicle designs, one can brush the vehicle weight class parameter to a maximum limit of 30 tons; this action would remove all vehicle designs above 30 tons from the design space. Brushing performance parameters is one of several ATSV features that assist the decision maker in forming a design preference. Figure 4 shows the same data set as shown in Figure 3, but with only HED designs being displayed and vehicle weight filtered to show designs between 34,000 and 38,000 kilograms. The curve in Figure 4 shows the power speed curve for a HED 41 ton armored vehicle. You will notice that there are very few designs in this weight class configured with high

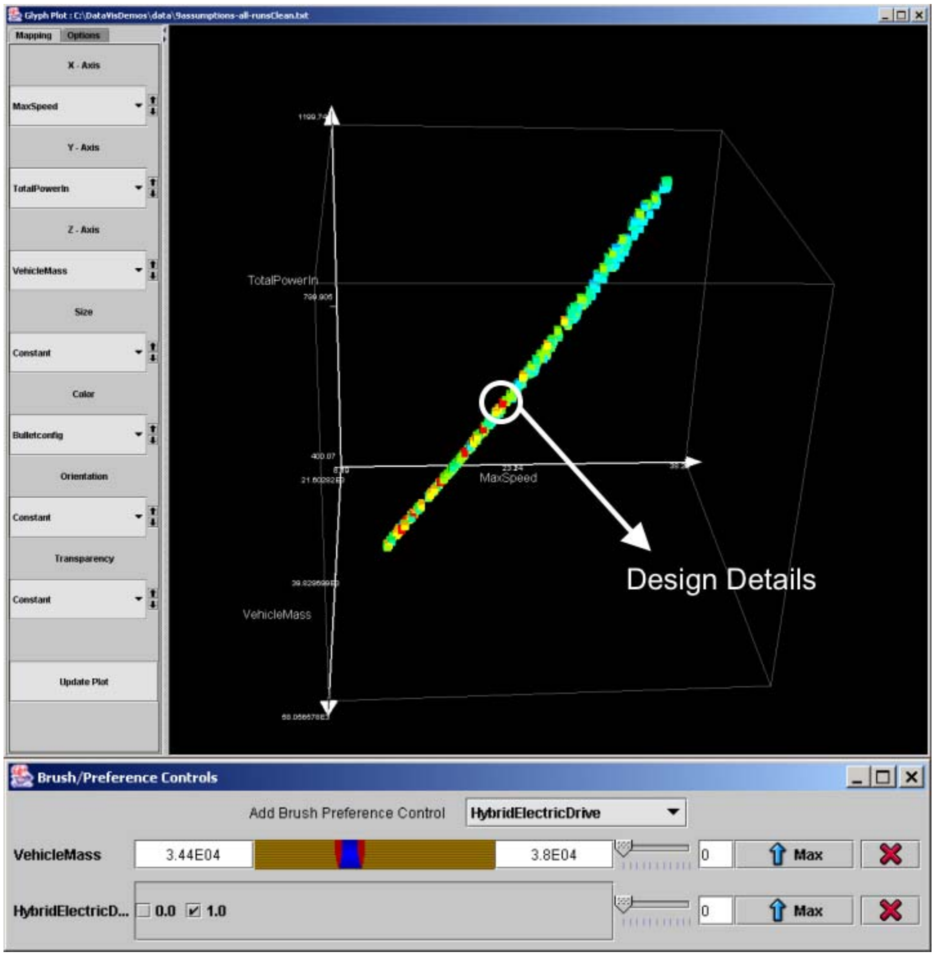


Figure 4. Filtering to weight class of interest in design space

levels of armor protection, or red design objects. In the visualization environment, shown in Figure 5, you can select any object in the design space and view its design parameters and design artifacts such as conceptual geometric models.

Summary

The Applied Research Laboratory at Penn State has successfully developed a concept assessment tool for armored vehicles, which allows rapid concept generation and provides a unique method for true design space exploration. We have captured configuration rules for multiple vehicle technologies and varying vehicle requirements, allowing our sponsor to evaluate design alternatives of key interest to the U.S. Marine Corps. We have developed a powerful data visualization tool that allows them to explore the design space, form a preference on design priorities, and spiral into a design area of focus.

Another growing area of interest for this tool is in the requirements definition and analysis phase of the vehicle program. This tool provides the interface between the requirements definition and the design synthesis phase of the acquisition process. It provides rapid feedback on how changing requirements impact the vehicle design.

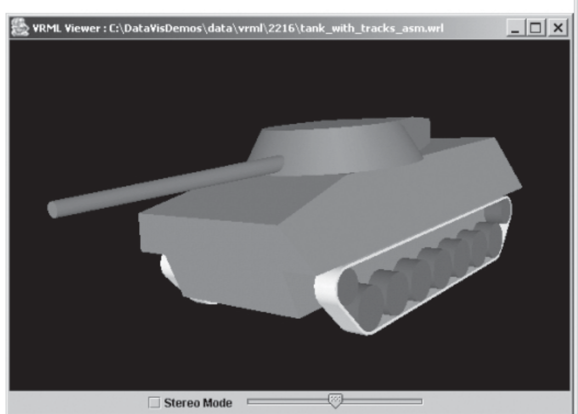
This modeling approach can be used across many engineering application areas. ARL Penn State has successfully developed and demonstrated concept assessment systems for underwater weapons, space systems, and communication networks.

Acknowledgement

The Applied Research Lab at Penn State would like to acknowledge the supoort of the Office of Naval Research, Code 353, NSWC Carderock, and the Marine Corps Systems Command. Any opinions, findings, conclusions and/or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the U.S. Navy or the Marine Corps.

References

1 Balling, R., 1999, "Design by Shopping: A New Paradigm," *Proceedings of the Third World Congress of Structural and Multidisciplinary Optimization (WCMSO-3)*, Buffalo NY, pp 295–297



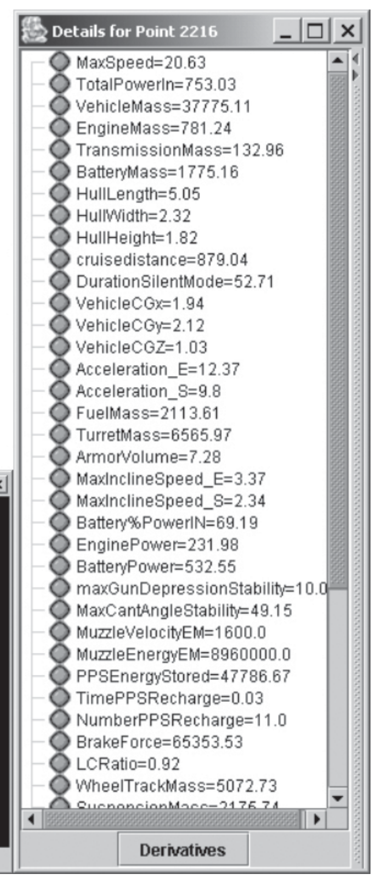


Figure 5. Exploring an individual design point

Navy SBIR/STTR Partnering Seminar Hosted by ARL

ARL recently hosted a Small Business Innovation Research/Small Business Technology Transfer seminar for regional manufacturing companies. Approximately 70 guests from central Pennsylvania attended the half-day session at Penn State to learn more about the program and how their companies can participate. Mr. John Williams, Navy SBIR Program Manager at the Office of Naval Research, provided an overview and guidance to participants. ARL and iMAST continue to support ONR manufacturing-related initiative as part of Navy ManTech's industrial outreach effort. For more information on the Navy program, contact John Williams at ONR at 703-696-0342, or by email at <williajr@onr.navy.mil>. ARL's point of contact is Thomas Hite, who can be reached at (814) 949-2665 or by email at <tmh9@psu.edu>.

ARL Hosts NSRP Welding Technology Panel Meeting

The laser processing department at ARL Penn State recently hosted a meeting of the National Shipbuilding Research Program's (NSRP) SP-7 Welding Technology Panel. The NSRP is a government/industry research program with the goal of developing more economical construction approaches to shipbuilding. The Welding Technology Panel (SP-7) provides a public forum for discussing methods and processes to improve the technology of welding, cutting, forming, and burning as it pertains to, and is applied to, the shipbuilding/repair industry and their customers. This panel attracts the leaders of the shipbuilding welding community—from the welding equipment suppliers, to the shipyard customers.

The meeting attracted more than 35 attendees from across the country, with representatives from both U.S. Navy and commercial shipyards, government and regulatory agencies, as well as a host of welding equipment suppliers. The meetings and presentations were followed by a tour of ARL Penn State's Laser Processing Laboratory. Demonstrations included a combined 4.5 kW Nd:YAG and GMAW welding unit to join 1/2 inch thick steel in a single pass. Laser free-forming (or cladding) of metal matrix composite materials was also demonstrated.

The hosting of this meeting (and others like it) supports a key element of Navy ManTech's role by developing and disseminating the latest research in various aspects of shipbuilding and repair to a broad and interested audience. It supports the goal of reducing overall ship acquisition and life-cycle costs by helping to transition technology developed in Navy ManTech-supported laboratories to shipbuilders and suppliers who can ultimately provide commercialized product and necessary follow-on support. For more information about ARL's laser processing department, contact Dr. Rich Martukanitz at (814) 863-7282, or by e-mail at <rxm44@psu.edu>.

iMAST research engineer, Ted Reutzel, discusses welding techniques during a demonstration.

COVER STORY CONTINUED FROM PAGE 1

Commanding Officer of the 2nd Remotely Piloted Vehicle Company.

In 1988, then Major Waldhauser was assigned as a faculty advisor and instructor at the Amphibious Warfare School, Quantico, Virginia. During this tour, he was a member of the Commander, U.S. Marine Central Command (Forward) staff aboard the USS *Blue Ridge* (LCC-19) during Operation Desert Shield/Desert Storm. In July 1992, Major Waldhauser joined the II Marine Expeditionary Force staff where he served in the G-3 Future Operations Branch.

During July of 2000, then Colonel Waldhauser assumed command of the 15th Marine Expeditionary Unit (MEU). During that tour the MEU participated in combat operations in Southern Afghanistan for Operation Enduring Freedom and also in Iraq during Operation Iraqi Freedom.

General Waldhauser's personal awards include the Defense Superior Service Medal, Legion of Merit with Combat "V", Bronze Star, Meritorious Service Medal with three gold stars and Navy and Marine Corps Achievement Medal with gold star.

CALENDAR OF EVENTS

17–18 Nov.	Materials and Manufacturing Advisory Board Meeting		State College, PA
29 Nov.–3 Dec.	DMC 2004	★★★★★★★ *visit the iMAST booth*	Las Vegas, NV
1–2 Dec.	Light Armored Vehicles Conference		Washington, D.C.
13–16 Dec.	International Soldier Systems Conference		Boston, MA
2005			
1–2 Feb.	NCEMT Ship and Ground Advanced Materials Conference		Orlando, FL
1–2 Mar.	ShipTech 2005	★★★★★★★ *visit the iMAST booth*	Biloxi, MS
22–24 Mar.	Navy League Sea-Air-Space Expo	★★★★★★★ *visit the iMAST booth*	Washington, D.C.
19–21 Apr.	NDIA Science and Engineering Technology Conference DoD Tech Exposition		Charleston, SC
1–3 Jun.	American Helicopter Society Forum 61	★★★★★★★ *visit the iMAST booth*	Grapevine, TX
2–3 Jun.	Johnstown Showcase for Commerce	★★★★★★★ *visit the iMAST booth*	Johnstown, PA
Aug. TBA	TechTrends 2005	★★★★★★★ *visit the ARL booth*	TBA
Aug. TBA	ONR Naval-Industry R&D Partnership Conference	★★★★★★★ *visit the iMAST booth*	Washington, D.C.
Aug. TBA	ARMTech 2005	★★★★★★★ *visit the iMAST booth*	Kittanning, PA
Sep. TBA	Combat Vehicle Conference		Ft. Knox, NY
13–15 Sep.	Marine Corps League Expo	★★★★★★★ *visit the iMAST booth*	Quantico, VA
Oct. TBA	Expeditionary Warfare Conference		Panama City, FL
Oct. TBA	DoD Maintenance Conference		TBA
Oct. TBA	AUSA Expo		Washington, D.C.
16–19 Oct.	AGMA Gear Expo 2005		Detroit, MI

Quotable

"Just because something doesn't do what you planned it to do doesn't mean it's useless."

—Thomas Edison

PENNSTATE

Applied Research Laboratory
P.O. Box 30
State College, PA 16804–0030

ADDRESS CORRECTION REQUESTED