DEFINING ACQUISITION TRADE SPACE THROUGH "DERIVE"

Prashant R. Patel, David Gillingham, and David Sparrow

The Problem

A lack of analytical rigor and poor communication between the program developers and the acquisition oversight community often lead to "false-starts" and "do-overs" during program initiation.

IDA's trade space framework—Deducing Economically Realistic Implications Via Engineering (DERIVE)—links engineering and physics analysis, operational constraints, and semi-parametric cost estimates.

IDA's trade space framework—Deducing Economically Realistic Implications Via Engineering (DERIVE)—links engineering and physics analysis, operational constraints, and semi-parametric cost estimates. The goal is to increase the efficiency of the acquisition process by reducing friction between the program office, the Services, the Joint Staff, and the Office of the Secretary of Defense (OSD), especially at program initiation and during the early stages of development.

IDA designed the DERIVE framework to link important technical inputs to programmatic and operational outputs in a straightforward, traceable, and transparent manner. The framework provides an analytic structure that could be used to build understanding and communicate intent. It could be especially helpful for programs whose complex interactions between requirements, operational restrictions, and technology—rather than any individual issue—drive acquisition outcomes.

Trade Space

The use of trade studies in engineering is not new. It has a long history in the technical community and has now been formally adopted into the DoD acquisition decision-making process. Recent experiences suggest that the Services' trade-space tools are being used to inform their internal deliberations. However, several recent new-start proposals have been the subject of follow-on trade studies and amended Analysis of Alternatives efforts, suggesting room for improvement.

Schedule delays associated with follow-on analyses can be avoided if the trade study processes and analytical outputs are structured to support both user and oversight objectives. The outputs of IDA's DERIVE framework are constructed to achieve this goal by enhancing traceability and transparency of inputs, outputs, and decision making.

Traceability

Traceability is used by systems engineers to manage technically complex endeavors by flowing down program objectives into discrete technical goals. Alternatively, students employ traceability to demonstrate to professors that they have a firm grasp of the nature of problems even if small errors are present in the analysis. Traceability can also be leveraged by the Services and program offices to demonstrate that they have rigorously analyzed the operational environment and have a firm understanding of the technical issues and programmatic consequences for a new program.

DoD asked IDA to develop and demonstrate DERIVE on a generic infantry fighting vehicle (IFV). The results of that effort will be used below to illustrate how DERIVE's outputs are designed to foster traceability.

Creating traceability requires exposing objectives of the program, how they relate to technical assumptions, and how the various elements interact to drive results. An output of the DERIVE process traces the desired capabilities to the commensurate technical inputs. Table 1 shows how key performance and programmatic attributes can be mapped to specific technical requirements for an IFV.

Cross-referencing the technical assumptions and desired capabilities in a single, compact form provides two benefits. First, it allows the program developers to clearly articulate the user's goals and the technical requirements necessary to achieve those goals. Second, it allows the oversight community to understand the potential loss of capability if there are technical shortfalls during development.

Similarly, Table 2 shows how cost traceability can be achieved. Various cost categories are mapped to the data sources and assumptions used in generating the cost estimate. This trace-

Table 1. Performance and Technical Traceability Matrix

Capability Area		Specifications (Desires)	Analytical Implication
Force Protection	**Ballistic**	Trade space	Integral ballistic armor must be able to passively defeat ballistic threats.
	Explosive	Survive an **X** class of IED and a **Y** RPG	Supports 45 pounds/square foot (psf) of integral underbody armor and 95 psf or add-on EFP armor.
Passenger Capacity		Trade space	Interior volume scales based on human factors and number of passengers (32 cubic ft/person and 450lbs/person).
Full Spectrum	**Weight**	Desire system to reliable	Structure, engine, transmission, etc. must be sized to support add-on EFP armor.
	Power	Increased exportable power	Has a 50-horsepower generator for electrical power.
Timing		Field System Quickly	Uses currently producible armor materials, engines, etc.
Transportability		Transportable by C-17	IDA-defined combat weight limited to 130,000 lbs and must fit inside compartment E of C-17.
Mobility		Speed of **X** up a grade of **Y**	Uses an Abrams-like track and has 20 horsepower/ton of engine power.
Lethality		Lethal to similar class of vehicles	Has a manned turret. Reserved 2.1 tons for non-armored turret weight and 120 cubic feet of volume. Also, 2.5 tons for ammunition and fuel.
Electronics and Sensors			Has sensors/electronics similar to Abrams and Bradley.
General			Includes other fixed vehicle components (e.g., wiring, bolts, weld material). Weight allocated to these types of items is 2.5 tons.

ability matrix allows oversight organizations to qualitatively assess the riskiness and fidelity of the estimate.

Table 2. Cost Elements and Costing Assumptions and Data Sources

Cost Element	Description/Sources/Methodology
Hull/Frame	Cost estimating relationship depends on material type and weight. Assumed a buy-to-fly of 1.
Suspension, Engine, Transmission, Auxiliary Automotive, Integration, Assembly, Tests, and Evaluation	Army Ground Vehicle Systems Bluebook (2006)
Add-on EFP armor	Estimated as cost per ton from budget data and publicly reported contract values.
Electronics/sensors	Estimated from President's Budget submissions for ground vehicle upgrade programs. Focused on sensors and electronic upgrades
Contractor non-prime mission product cost elements	Estimated using historical contractor cost data reports. Applied as a multiplication factor on the prime mission product.
Support	Estimated using Selected Acquisition Reports. Applied as a factor on contractor costs.
Deflation/inflation rates and conversions	Joint Inflation Calculator (http://www.asafm.army.mil/offices/office.aspx?officecode=1400).

Finally, the logic used to estimate the costs and performance of the IFV trade space is described in Figure 1.

- **Determine size of the box (volume under armor)**
  - Number of dismounts and crew; soldier space claim
  - Interior mission equipment and auxiliary automotive space claim
- **Determine weight of the box**
  - Front, side, rear, ballistic force protection; underbody and EFP protection
  - Areal density of protection technologies
  - Other - radios, seats, steering, soldiers, etc.
- **Determine weight and size of subsystems that move the box**
  - Drivetrain, suspension, support structure
  - Engine track/tires based on mobility requirements – hp/ton, ground pressure, etc.
- **Cost the system based on identified materials and components**
  - Scale contractor and program costs
- **Prune infeasible solutions**
  - Impose constraints such as transportability weight restrictions

Figure 1. Outline of Process Used in Creating Infantry Fighting Vehicle Trade Space

In sum, the DERIVE framework helps program developers and the acquisition oversight community build a common understanding of the key technical, operational, and cost drivers of new capabilities being sought by the Department.

Transparency

The DERIVE framework improves the transparency of the analyses supporting acquisition decisions. Figure 2 shows an output of the DERIVE framework for the IFV example. It enhances transparency by illustrating the entire trade space rather than a few point designs. Showcasing the full trade space demonstrates the thoroughness of the investigation and reduces the possibility of having to include additional cases. Also, instead of using a value function, the analysis simply highlights the desired point solutions and lists the rationale for the decision and the relevant trade-offs that were considered and accepted as part of the decision-making process. Showing trade space data, the rationale, and the resulting decision together serves to enhance trust, convey thoroughness, and reduce institutional friction.

Conclusion

DERIVE and similar approaches provide a framework that can be used to engage and improve acquisition outcomes. DERIVE fuses a variety of information sources (capabilities,

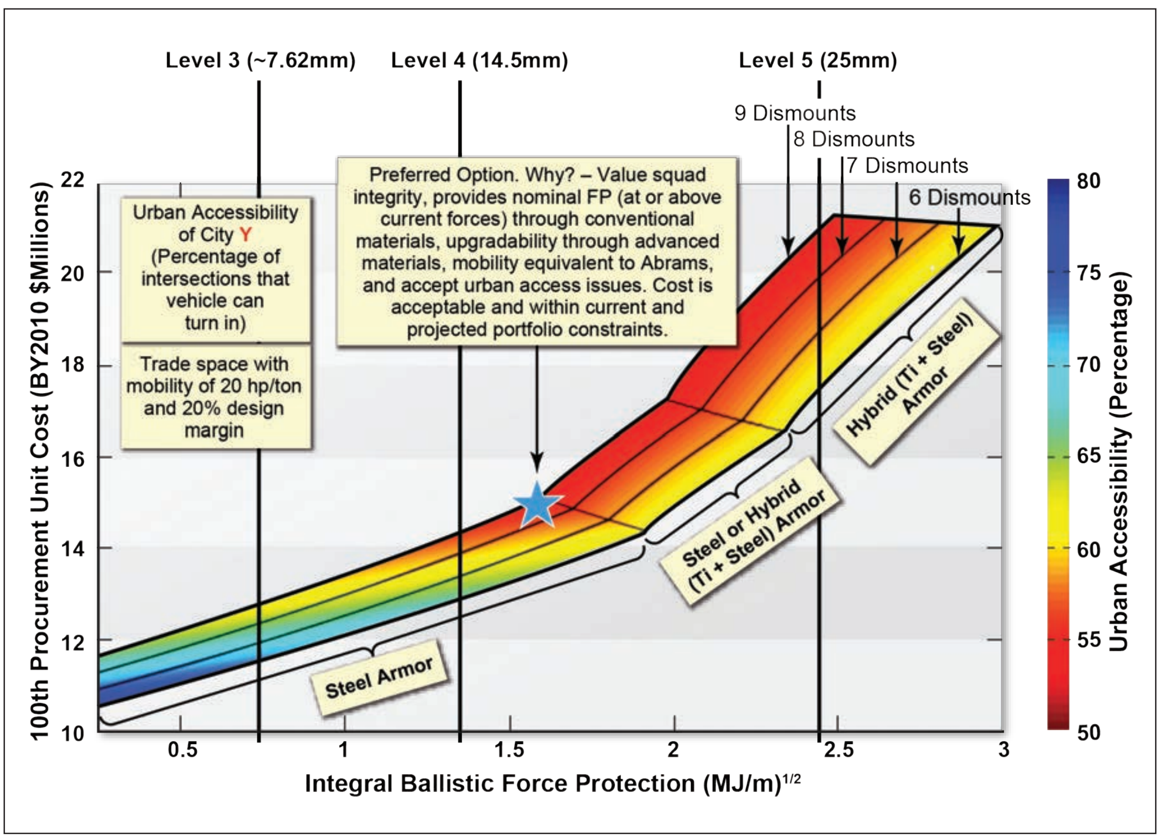

Figure 2. Infantry Fighting Vehicle Trade Space with Logic for Decision

operational, technical, and cost) to enable more thorough analyses in support of decision making and to reduce friction between program developers and the acquisition oversight community.

Dr. Patel is a Research Staff Member in IDA's Cost Analysis and Research Division. He holds a doctorate in aerospace engineering from the University of Michigan.

Dr. Gillingham is a Research Staff Member in IDA's Science and Technology Division. He holds a doctorate in physics from the University of Maryland, College Park.

Dr. Sparrow, a Research Staff Member in IDA's Science and Technology Division, received a doctorate in physics from the Massachusetts Institute of Technology.