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Commonality in Military Equipment

A Framework to Improve
Acquisition Decisions

Thomas Held, Bruce Newsome, Matthew W. Lewis

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1776 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138

1200 South Hayes Street, Arlington, VA 22202-5050

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Summary

Increasingly, the U.S. Army and the Department of Defense (DoD) as a whole are developing families of systems built around common components. For instance, the Army has procured a common model of tire (a component) across multiple vehicles (systems), which previously were procured with tires that were not alike. The Army has particularly pushed for common vehicle base models and infantry weapon systems. Historical examples of each of these cases are examined in this report.¹ Common items (including systems and components) are those that are the same, to all intents and purposes, across two or more higher-level items (e.g., systems are higher level than components). *Systems* are items that are designed for discrete use, although they may be used with other items. *Components* are designed as parts of systems. Theoretically, our recommendations are applicable for any item that can be part of another item, including nonmaterial items such as training systems, or any “system of systems,” a phrase that is used to describe collections of Army units and equipment or even the Army as a whole.²

Commonality is desirable because it can increase operational flexibility and reduce the procurement, logistical, and training burdens. It

¹ This document examines several historical examples of infantry weapons and military vehicles but does not examine projected items because much information on them remains imperfect. Therefore, we do not analyze those items under development as part of the program known as “Future Combat Systems,” even though they might be more topical.

² “Higher-level” items are composed of “lower-level” items. For instance, components can be described as combinations of subcomponents. A separate document, Newsome, Lewis, and Held (2007), explains these levels and the concepts and definitions in more detail.

can increase operational flexibility because shared components suggest improved readiness and shared operational capabilities, such as similar distances traveled before refueling. Modular and hybrid systems, in particular, offer broader (but not necessarily deeper) capabilities. Commonality can reduce the procurement burden by reducing the number of components that need to be developed or procured. It can reduce the logistical burden by reducing the number of components that need to be stocked and the number of maintenance procedures and personnel. It can reduce the training burden by reducing the number of items for which trainees need to be trained.

However, commonality can decrease design freedom and occasionally operational capability by making different host systems share a common component, even if the common component offers more inferior performance or fewer capabilities than does a unique component. For instance, the performance of a tank that normally carries a 1,500 horsepower engine would be seriously retarded by a 500 horsepower engine that might be common across several models of lighter armored vehicle. Commonality can also increase costs for certain systems that do not need the “excess functionality” offered by a common component over a cheaper, less capable component. For instance, lighter armored vehicles would be significantly more expensive if procured with a 1,500 horsepower engine instead of a 500 horsepower engine. (Although there may be operational advantages to a more powerful engine, it could impose increased stress on the vehicle’s other automotive components.) These factors suggest that commonality should be approached with caution.

To inform the Army’s decisionmaking process surrounding commonality, RAND Arroyo Center was asked to assess the advantages and disadvantages of commonality and how to best manage their trade-offs. To do so, this report uses historical analysis, literature analyses, and case studies of commercial and military efforts to exploit commonality. It presents analyses of the effects of commonality on costs, capabilities, and training. It offers a decisionmaking aid that designers, developers, and procurers, in particular, could use to inform their decisions about commonality. It concludes with relevant recommendations for the Army.

What Is Commonality?

We discovered early in our project that one impediment to the Army's clearer understanding of the potential costs and benefits of commonality is the lack of a shared lexicon for commonality-related discussions. Thus, at the beginning of this effort, the project team consulted different literatures and usages in order to define a set of concepts useful for discussion of commonality (Newsome, Lewis, and Held, 2007). Table S.1 summarizes our definitions. The Introduction provides more detail on our definitions.

Operational Outcomes

The operational advantages provided by a common system depend on the type of system used, whether hybrid (combining multiple capabilities in one system), modular (allowing functions to be exchanged

Table S.1
Summary of Recommended Commonality-Related Definitions

Term	Definition
Differentiated	Altered capabilities or items
Interoperable	Able to work together
Hybrid	Having combined capabilities or items that are normally separated
Family	A functionally differentiated set of variants of a platform/base model
Modular	Capable of changing functionality through the exchange or addition of modules
Module	Exchangeable or augmentable item used to change the higher-level item's functionality
Interchangeable	Capable of exchanging places without alteration
Standardized	Meeting a standard, such as a performance or material standard or a shared process or resource
Common	Similarity across more than one higher-level item

within one system), a family (in which many or major components are shared across systems, while others remain distinct), or a differentiated system (which is distinguished by its altered components or capabilities, usually in pursuit of specialization or enhanced capabilities).

There is no single “best” option that will apply in all cases. Therefore, in all cases, objective and informed analysis will be required to determine the best option.

Hybrids

Hybrids may underperform nonhybrids for their primary functions, but this trade-off may not be significant for the hybrid’s primary mission. Although hybrids are more flexible, they can introduce new operational risks. For instance, an infantry fighting vehicle (IFV) benefits from weapons that are not carried by a personnel carrier, but the IFV must expose itself to enemy fire whenever it utilizes those weapons. Since combined components or capabilities usually demand new operator skills, hybrid systems may impose increased training burdens if the operational benefits are to be realized.

Modular Systems

Like hybrids, modular systems can offer potential improvements in operational flexibility but can introduce new risks. For example, modularity may offer operators the option of leaving behind modules that are not needed for the current mission; however, the decision to leave some modules behind might leave operators without the modules they need, especially given that operational requirements can be difficult to predict. To reduce such operational risks, soldiers may elect to carry all their modules all the time, in which case the soldier might as well carry a more robust and efficient hybrid.

Families

Families of systems can increase operational compatibility between vehicles but may trade off on capabilities. For example, the main U.S. tank (the M4 Sherman) of the Second World War was a base model for a wide family of armored vehicles, but the tank itself was too small and underpowered to compete with heavier foreign tanks.

Differentiated Systems

Differentiated systems may excel at certain specialized capabilities demanding specific technologies, but they can prove inflexible. Differentiation is the preferred option if the priority is specialized capabilities or performance. However, as an item becomes more specialized, it becomes less flexible. Even if this lack of flexibility is considered acceptable when the item is first deployed, operational requirements can change over time.

Assessing the Costs of Commonality

To assess the value of commonality, the Army needs to know how the use of common items affects costs. Often greater commonality is automatically associated with lower costs. Our research shows a subtler picture. We looked at commonality's impact on the following life cycle elements:

- Component-related costs
 - Research and development (R&D) costs
 - Part costs including initial procurement
 - Inventory costs
 - Personnel costs in managing suppliers and ordering parts
- Training costs
- Maintenance personnel costs.

Component-Related Costs

Such factors as greater complexity leading to increased failure rate and excess functionality can tend to increase costs while economies of scale, greater factors of safety, purchasing power, and risk pooling can help lower costs. These factors may mean, for example, that R&D costs may be increased while inventory and repair parts costs are decreased. Further complicating the analysis is the timing of the expenses and uncertainty in future expenses. R&D costs are an up-front cost, whereas repair costs are a recurring cash stream that must be appropriately discounted through a net present value analysis and

that is highly related to a future operational tempo (OPTEMPO) that is unknown. Another important consideration for the cost analyst is whether a cost is a true savings, such as a reduction in repair parts costs due to economies of scale, or an opportunity cost, such as a reduction in procurement management effort that is realized only if the number of procurement personnel is reduced. These resources may then be used for other purposes.

R&D Costs. In terms of R&D, although increased commonality will decrease the number of components that need to be developed, the cost to develop a common component may be higher than to develop a single differentiated component if the component needs to be more flexible or offer additional capabilities. If the component can be made common with one that is already stocked, R&D costs can be reduced to zero.

Procurement Costs. Procurement costs may see a net increase depending on whether there is an increase in unit costs due to “excess functionality” (i.e., the component offers capabilities beyond requirements), a decrease in unit costs due to economies of scale, or, potentially, both, with one effect outweighing the other.

Parts Costs. Parts costs exhibit similar trade-offs: The benefit will be determined by the relative magnitude of “excess capability” compared with the economies of scale. Additionally, operations and maintenance parts costs will be affected by whether reliability has been improved or reduced by the common design, which will in turn affect the usage rate of the component.

Inventory Costs. An increase in the number of common components can be expected to decrease the number of units held in inventory, thus reducing costs. This reduction can be realized when increased risk pooling reduces the variability of demands. Net inventory costs, however, may either decrease or increase, depending on the unit price effect.

Personnel Costs in Managing Suppliers and Ordering Parts. The effort to perform these activities may be reduced and simplified through a smaller supply base. Without good activity-based cost data, these costs may be difficult to estimate. Further, a reduction in “costs”

is realized only if the number of personnel hours associated with supplier management is reduced.

Mechanic and Operator Training Burden

In addition to the above cost considerations, mechanic and crew training needs should also be considered when determining which components should be made common. Common components can reduce crew training and mechanic training if the uncommon components that they replace are significantly complex. For example, a common engine can significantly reduce mechanic training time, while common armaments can reduce crew or operator training time. In contrast, common nuts and bolts do not save training time, because nuts and bolts—simple components with a predictable form and function—are handled the same way even if they are uncommon.

Greater system commonality might allow some military occupational specialties (MOSs) in the Army to be consolidated. Systems that achieve greater commonality might require fewer mechanic types. The reduction in variability brought on by greater system commonality could also reduce the chances of spot shortages or excesses of MOSs.

Our review of commercial-sector firms identified several ways in which commonality led to savings in terms of training time and costs and operational gains. For example, some airlines have decided to use a single airframe or common cockpit controls and displays across planes in order to simplify the training of pilots, maintainers, and flight attendants. This decision also facilitated operations by eliminating the need to match crew qualifications to aircraft type. Significant savings can result when these benefits are multiplied across all high-value employees, such as airline pilots, in an organization.

The effects on training also depend on the trade-off between the reduction in training time per skill achieved by commonality and the need for increased cross training (i.e., the number of tasks to be trained). For example, to take advantage of the modular or hybrid benefits of a given system, it may be necessary to increase cross training if the roles performed by a particular system were previously taught only to specialist subpopulations. The number of personnel requiring training may affect the decision to hybridize or modularize.

Low-Hanging Fruit: The Best Opportunities for Reducing Costs Through Commonality

The cost elements discussed above point to four general categories of components for which it could be financially advantageous to pursue commonality.

Complex, expensive items appear to present the greatest cost opportunity by spreading the R&D cost over multiple items. For example, both commercial truck and military fleets try to reduce costs by specifying common engines. The key factor to consider is whether the cost of any excess functionality (in terms of procurement, operating, and inventory costs) outweighs the R&D and volume cost advantages.

Logistically burdensome items are another class of components that present a good opportunity for increased commonality. Large bulky items, such as tires, tracks, engines, and transmissions tend to dominate bulk storage, which can be problematic given the Army's significant storage constraints for mobile field warehouses. However, the advantages of commonality (such as reduced volume-related costs and logistical advantages) often must be traded off against the Army's desire for specialist or maximum capabilities (see the next section and Chapter Two).

High-demand items that have similar specifications are another potential common component category. Costs for high-demand items might be reduced through economies of scale, lower inventory levels, increased purchasing power, and lower order costs. Commercial research suggests these savings could be significant.

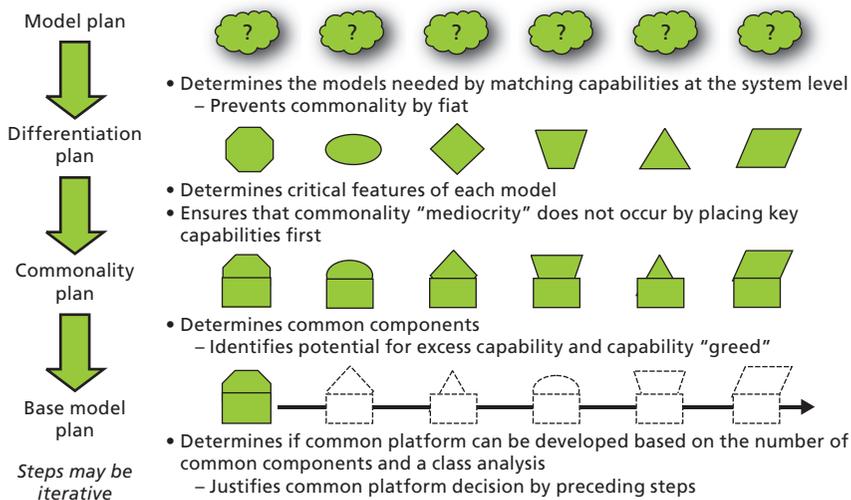
Items whose operation or maintenance are burdensome when training personnel, such as with complex software or user interfaces, should be made common in order to save on the training burden. In the text, we identify commercial companies that have insisted that user interfaces look the same across different systems so that users can be trained for just one interface.

Analytic Method to Guide Commonality Decisionmaking

As research has indicated, the process of trading off the advantages and disadvantages of commonality is subjective and imperfect. To guide designers, developers, and procurers, in particular, in their decision-making, we developed the decisionmaking aid shown in Figure S.1.³ The aid includes the development of four separate plans, each of which presents an important set of decisionmaking criteria.

This decisionmaking aid provides guidance for a structured process and so is best led by objective and informed experts. The procurer can use this aid to inform the requirements and the decision to pro-

Figure S.1
Capability-Based Commonality Decisionmaking Aid



NOTE: The shapes in the figure represent the transition through the application of the decision aid from requirements with unknown physical attributes (the cloud question marks), to known features (the varying geometric shapes), to common components potentially based on a common platform (the common rectangle with varying shapes on top of it).

RAND MG719-S.1

³ We based our decisionmaking aid on those in the commercial manufacturing literature, such as those by Meyer and Lehnerd (1997) and Robertson and Ulrich (1998).

cure. The designer can use this aid to choose among design strategies and balance the inevitable trade-offs during the design process. The developer can use the aid to audit the progress of development. And the logistician, trainer, and operator can use the aid to stay informed about relevant trade-offs and to determine whether designers and procurers remain cognizant of their primary concerns.

Model Plan

The designer first identifies the key capabilities needed to meet requirements and then decides which capabilities should be hybridized, modularized, or differentiated. A hybrid solution is indicated if, among other things, the key capabilities are operationally interdependent, the hybrid outperforms nonhybrids in their primary functions, the extra cost of the hybrid is less than the collective cost of nonhybrids, and the hybrid's new operational risks are acceptable. If personnel do not need all the capabilities all the time and the hybrid imposes additional costs, the system should be modularized rather than hybridized. If the hybridization or modularization would degrade critical capabilities, then differentiated models are indicated.

Differentiation Plan

The differentiation plan identifies attributes that are critical to the model's function and selects the lowest performance requirements needed to ensure the model's effectiveness.

Commonality Plan

This step identifies those components that can be made common without significantly retarding the system's capabilities. Here, decisionmaking should be guided by cost analysis, in particular. The remaining unique or "uncommon" items are then considered for interchangeability. Differentiation should be reconsidered at this stage, since cost analysis is likely to underrepresent operational impacts.

Base Model Plan

The base model plan determines whether the number or importance of common components is sufficient to warrant a base model. Although

the development of a base model may be seen as an economic decision, it also has operational impacts because a base model can allow for increased operational compatibility (since variants share similar operational performance) and reduced logistics burden (since many or significant components are shared). Even at this stage, the designer should reconsider differentiation if a base model is likely to retard critical capabilities.

Recommendations

This report makes a detailed analysis of the effects of commonality on key Army concerns, primarily costs, operations, and training. It also provides a decisionmaking aid, of particular value to the procurer, developer, and designer. In addition, we make the following four broad recommendations to the Army, concerning analysis, organizational changes, decisionmaking, and training.

The Army should determine *which* specific components should be made common through objective and informed analysis. Specifically, the Army should assess existing levels of component commonality and determine where efforts should be focused to reduce costs and the logistical footprint. The Army should develop preferred commonality metrics, similar to the metrics used in this document or those used by exemplary commercial companies, to examine the existing level of component commonality in the Army and its resultant cost and logistical burden.

The Army should determine what organizational changes need to be made so that better decisions about commonality are made. We have identified several historical examples of poor military decisionmaking related to commonality, for instance by prioritizing commonality while ignoring its disadvantages, or by ignoring opportunities to procure new systems with common components. Our decisionmaking aid can only help individual decisionmakers make better decisions and does not help implement decisions. The Army should study organizational changes that would help improve decisions about commonality during the acquisitions process.

The Army should adopt a capability-based commonality decisionmaking aid, of the type discussed in Chapter Five, in order to better guide decisions about development, design, and procurement.

To help accurately assess the effects of commonality on training, we recommend the use of a structured methodology, such as the Training Impact Estimation (described in Chapter Three). Training effects can be significant but are highly dependent on the specific type of commonality under consideration and on the specific components to be made common.