Engine System Development: Change, Challenges, and Value

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Executive Summary

Introduction. The automotive industry continues to pursue cost-effective design and manufacturing solutions to meet the escalating demands of vehicle users. The gradual emergence and adoption of a modular or systems approach is but one of the many responses that the industry is exploring to satisfy these demands. This project details and analyzes the system strategies and the views of potential manufacturer customers as to engine top systems' value and worth, and how they fit with the manufacturers' other strategic initiatives.

For our purposes, systems are collections of components that are dependent on each other and that cannot operate independently, such as a braking or steering system. The engine top system, which incorporates all the fuel and air mixture subsystems, combined with the cylinder head, is an interesting choice because it is critical to fuel economy and emissions. This is also an area where even advanced powertrains of the future will continue to need support and innovation.

Understanding the manufacturer's view is essential to ensure that the system indeed offers the best value proposition, and that it can be presented in ways that make that value clear to the manufacturers. This study addresses this issue by interviewing eight key informants, vice presidents or directors in powertrain operations at Ford, General Motors, and DaimlerChrysler. These managers represent the three main functions of engineering, manufacturing, and purchasing, and are critical to understanding each of the manufacturer's thinking.

Industry Challenges and Drivers. Technology, fuel economy, and emissions constitute the most often reported challenge the manufacturers and their supply chain face over the next five years. Executives also report other challenges such as cost competition, customer satisfaction, and development of suppliers. Although all of these challenges are primarily driven by market factors, powertrain executives also see technology, competition, and company outsourcing models both as challenges and drivers.

System Adoption. Companies have differing criteria but similar methods for adopting systems, which includes the decision to develop systems internally or through one's suppliers. Five of the eight interviewees reported that systems are adopted on a case-by-case basis, while one interviewee noted a formal, company process based on strategic product assessment. Most respondents mentioned four criteria: cost/benefit aspects, particularly cost reductions; labor issues, including current union contracts for components; supplier issues, including supplier capability; and manufacturer sourcing/core competency strategy, including the potential loss of manufacturer control and knowledge to system integrators.

Executives report that the advantages of having suppliers develop systems include suppliers having a better knowledge of the product; manufacturers controlling their costs by not having to test and design systems, while suppliers reduce prices

because of scale; and suppliers having better control of processes, especially interfaces. Interviewees see the disadvantages primarily as a loss of control or knowledge within the manufacturers, labor strife over outsourcing, the loss of competitive advantage due to supplier part commonization, and the need to clearly allocate responsibility for warranty claims.

Engine Top Systems. When considering the value of engine top systems, executives focus on reducing costs, increasing revenue and profitability, improving functionality, and exceeding consumer expectations. One difference between functions surfaced: manufacturing and engineering executives value engine top systems more for improving reliability and durability than do purchasing executives.

Though executives consider the difficulties of developing engine top systems similar to developing other systems they see difficulties in the logistics of testing the cylinder head, top system, and base engine together, proving the reliability and functional performance of the system, and optimizing all the components of the subsystem.

At this point in engine top system development, the challenges in the value chain lie in the areas of engineering and purchasing, where system "prove out" and cost are still uncertain. In general, executives view U.S. companies as being in the early stages of system development, with clear advantages for the Japanese and European companies. Executives differ about who is primarily responsible for decisions made about these systems in their companies as well as when they will appear on vehicles in North America.

Interviewees see a wide range of roles for Covisint, consistent with the general uncertainty of how the industry will use the exchange. Responses range from seeing Covisint as basically a pricing/logistics exchange to seeing it as a comprehensive mechanism for forming alliances for development of highly engineered components and systems.

Conclusions. Although high-level manufacturer executives see the need to divest their companies of assets by outsourcing design, engineering, and manufacturing of major systems of the vehicle, implementing this initiative comes with some very important challenges. Powertrain executives, in particular, are concerned primarily about the capability of the supply base to actually design, engineer, and deliver these systems, and they worry that this strategy will eventually challenge their company's own ability to judge whether the systems that suppliers provide are optimized for their vehicles.

From a value standpoint, manufacturers risk missing some of the competitive advantage that systems can provide, emphasizing cost reduction rather than value-added processes. From a technical standpoint, executives have varying definitions of the system which may mean that solutions must be tailored to each

manufacturer, risking economies of scale. Manufacturers have an organizational challenge as they attempt to outsource more design, engineering, and manufacturing. There is uncertainty as to how to implement system adoption for the critical advantages it might confer. Some manufacturers are organized along component lines, leading them to say "systems" yet think "components."

Powertrain executives also note several serious supplier issues especially capability. They also see systems outsourcing possibly reducing their expertise and competitive advantage in engines, challenging their labor relations, and affecting their relationship with consumers through warranty issues.

Suppliers themselves also need to understand the challenges and risks involved in system development. Can they be profitable developing unique products for each customer? Can they develop sufficient economies of scale if they cannot commonize parts across manufacturers? Can they organize their company to benefit from knowledge gained from one manufacturer's system for subsequent systems for other customers without violating exclusivity agreements? Will these relationships lead system integrators to supply some rather than all manufacturers?

These powertrain executives raise serious issues about ceding system design to suppliers. This includes the loss of internal expertise, competitive advantage, and innovation; supplier capability; labor agreements; and warranty responsibility. However, manufacturers strive to cut costs while increasing functionality, and systems offer these savings.

Engine System Development: Change, Challenges, and Value

Introduction The automotive industry continues to pursue cost-effective design and manufacturing solutions to meet the escalating demands of vehicle users. The gradual emergence and adoption of a modular or systems approach is but one of the many responses that the industry is exploring to satisfy these demands.[1] However, there is surprisingly little systematic, reliable data and information on this process, and the manufacturers and suppliers that pursue such a strategy are left with little guidance beyond the industry's familiar—and often unreliable and inaccurate—conventional wisdom. In any case, such conventional wisdom offers little practical guidance as to how to develop modules, and little useful direction on how to accelerate their appropriate adoption in the industry.

The University of Michigan's Office for the Study of Automotive Transportation (OSAT) has undertaken a focused but important research investigation into system development with a case study of engine top systems. This project details and analyzes the system strategies and the views of potential manufacturer customers as to engine top systems' value and worth, and how they fit with the manufacturers' other strategic initiatives. Such case studies typically yield information of somewhat limited and constrained value to the general industry, however useful they may be to companies that actively compete in the product space of the target system. This situation reflects the difficulty of assessing the generality of case-study findings.

However, given the developing importance of system strategies, and the severe paucity of any information on their promise and problems, we believe this effort is significant and timely. The industry still lacks general, accurate, and reliable information on the situation and challenges associated with developing the engineering, purchasing, and manufacturing strategies appropriate to systems. Without this information, the industry is likely to incur the costs of pursuing sub-optimal approaches, ineffective efforts, and even blind alleys.

Industry Challenges OSAT research documents the automotive industry's rapid pace of change since the mid-1980s, identifying and describing major areas of

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[1] While some analysts have chosen to distinguish among sub-assemblies, modules, and systems, often along differing lines, we choose not to enter this conceptual debate now, but we do adopt a definition to anchor our respondents. Such distinctions are valuable to the extent that they are anchored in empirical referents with associated analytic and practical differences of importance. We view the paucity of research in this area as essentially rendering this debate speculative and of little practical or theoretical import at this time. This debate is rooted in the early development of modular strategies in the mid-1980s. See "Outsourcing Rediscovered", Michael S. Flynn, IEEE Spectrum, vol. 24, 10, October, 1987, pp. 47-49, and "Engineering Outsourcing," AIM Newsletter, 2, 1, November 1986, 5-7. Reprinted in AIM Newsletter, Special Edition, Winter 1987-1988, 11-13 pp.

change. This includes the escalating competition that forces continual improvement on industry key performance dimensions, such as cost and quality. At least four important challenges face all suppliers, but especially those large, technically sophisticated suppliers that are establishing themselves as system integrators. These challenges are the industry's globalization, the advent of e-commerce, the restructuring of the supplier industry, and changing supplier cost and profit models.

Vehicle assemblers increasingly insist that key suppliers follow them in the global marketplace, supplying parts and components wherever the manufacturer locates. This is a particularly daunting challenge, since the processes and economic situations of automotive suppliers often differ from their customers' and from one supplier to another. Suppliers' volume requirements and capital/labor mix vary widely. The combined human and capital resources required to support expansion efforts globally and to improve competitive performance in traditional markets are huge, and for most companies demand record investment levels.[2]

The accelerating deployment of information technology and the expansion of e-commerce is a second major challenge for the supplier community. The Internet today is "infomating" the industry's current practices and will eventually yield new business models. The resources required to meet this challenge are also enormous, and will stretch the capabilities of even large and successful suppliers.[3]

The industry's division of labor—and power relationships—is substantially shifting, as system integrators take on new roles and responsibilities, including management of technical, engineering, and supply chain functions. A more "tiered" supplier base is already developing, and new supplier-manufacturer relationships will shape transactions along this developing value chain.[4]

The cost and profit models for both manufacturers and suppliers are significantly changing. Because of the fierce competition, manufacturers can no longer pass cost increases on to consumers. They must control costs internally while also demanding cost reductions from their suppliers. This approach to cost control

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[2] *Cars, Capacity, and Competition in the 21st Century*, Michael S. Flynn, Sean P. McAlinden, Kim Hill, Kara Alkire, Morgan H. Edwards, 19 pp. August, 1999, UMTRI 99-43.

[3] *Beyond Y2K: Information Technology and the Automotive System Integrator.* Michael S. Flynn, Bruce M. Belzowski, Chris Booms, UMTRI 98-33, 22 pp. September 1998. Also, *Automotive System Integrators: Spiders or Flies in the e-Business Web?*. Michael Heidingsfelder, Antonio Benecchi, Michael Dergis, and Janet Rasche of Roland Berger, and Michael S. Flynn, Richard Senter, Jr., and Bruce M. Belzowski of OSAT, 55 pp. August, 2001, UMTRI 01-25.

[4] *Automotive Product Design and Development Delphi: A Forecast and Analyses of the North American Auto Industry Trends Through 2007*, Sridar Koda, Flynn, M.S., and Londel, G., paper delivered to International Body Engineering Conference and Exposition (IBEC, 99) 1BECA-2, September, 1999. Also, *Technical Responsibility, Change, and Partner Selection in the Automotive Value Chain.* Michael S. Flynn, Bruce M. Belzowski, Jack C. Cragen, Michael Ger. Presented at the Third International Workshop on Assembly Automation at Ca'Foscari University of Venice, Italy, 12 pp., October, 1995, UMTRI 88-915. Also, *Automotive System Integrators: Spiders or Flies in the e-Business Web?* Op.cit.

challenges suppliers in particular because many have taken on more engineering and design responsibility and, therefore, more cost. In addition, many have higher levels of debt as they merge and/or acquire other suppliers so that they can develop complete systems. These system integrators should earn more profit as their systems increase their value-share in the vehicle, yet manufacturers continue to ask for cost reductions. Indeed, reallocation of responsibility across each manufacturer's value chain severely tests the traditional business models of both manufacturers and suppliers.

These structural changes are gaining momentum as pressures to achieve truly system-wide effectiveness mount. Traditionally, suppliers succeeded by doing more of the same: adding customers and part numbers. Today, key suppliers must add higher-skill and higher-value work, such as engineering and design, in pursuit of improved business opportunities. One clear way for suppliers to do this is to develop modules or systems, built-up or aggregated units composed of parts and components that have traditionally been assembled in the manufacturers' operations.

System Strategies For our purposes we differentiate between modules and systems by defining modules as simple but convenient combinations of independent components, such as an instrument panel, and systems as collections of components that are dependent on each other and that cannot operate independently, such as a braking or steering system. System functionality depends on the integration of components that results in better performance, higher value, or lower costs over and above the simple combination of the components.

Thus, systems are much more than merely outsourced assembly operations, taking advantage of lower supplier wage rates. Rather, key suppliers also take on the engineering of these systems. This enables them to design and specify systems to fulfill not only the manufacturer's black-box requirements but to optimize jointly the efficiency of the integrator's own and the manufacturer's operations.[5]

All four of the challenges discussed above are important, and require suppliers to exercise considerable skill and care in making decisions about how to allocate their resources. After all, any one of these challenges could well absorb all of the available resources of even the biggest and most capable suppliers without in any sense guaranteeing survival, let alone competitive success. Each challenge demands rapid change and deep human, technical, and capital resources, and challenges may combine in ways that necessitate absolutely superb, coordinated strategic execution to achieve a world-class competitive position.

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[5] OEM Parts Purchasing: Shifting Strategies, Kara F. Alkire, Michael S. Flynn, David Graham, OSAT, January, 2001. UMTRI 00-48.

In particular, we believe that the broad-based development and control of well-conceived, engineered, and executed systems is a critical success factor for all companies that wish to remain major, key system integrators in the automotive industry. Successful implementation of a system strategy can empower suppliers, helping them to influence their own fate through developing value-added and customer selection approaches.

Developing any particular system, such as engine systems, will require three critical supplier efforts. First, the supplier must understand its customers' current views and thinking about the proposed system and the range or alternative approaches it permits. Second, suppliers must identify the value proposition the system offers the manufacturer, inevitably requiring an engineering/design strategy. Moreover, the supplier must articulate how the system fits into the overall strategic and change challenges facing their customers: Does this system approach bolster or weaken customer responses to challenges such as globalization and e-commerce, or, for that matter, do responses to these challenges constrain the system strategy? Third, the system, or lead, supplier must coordinate the activities and contributions of other suppliers cooperating in the system effort, whether they are internal to the lead's own organization, or external units of other suppliers.

Many system integrators are in the early to middle stages of their evolution. During the 1990s many supplier companies heeded the call of the manufacturers to take on system responsibility. To do this they often needed to merge with or acquire other suppliers to develop fully functioning systems. However, they frequently did not integrate these acquisitions into their companies, but used them to demonstrate system capability to the manufacturers. Many of these mergers and acquisitions were very costly, and over the past few years, system integrators are methodically evaluating all the plants and processes of their new acquisitions and selling or closing plants that are not integral to their business. Most of the merged and acquired companies originally functioned autonomously, developing components with the processes that were successful for them prior to the acquisition. However, as system integrators begin to truly assimilate their new plants into one company to develop systems, they face major integration challenges. The cost of this integration is significant and demands that the new company truly understand the manufacturers' view of the utility and value of the systems they create.

Suppliers simply cannot rely on their own engineering analyses and preferences to guide them, because the manufacturer has different criteria to optimize, and thus may well reach a different preferred solution. OSAT research has amply documented the problems the industry has encountered because manufacturers and suppliers pursued different strategies driven by different considerations without being aware of this situation, but rather thinking their efforts were

coordinated and complementary. In fact, in the mid-1990s we discovered just such a situation in how companies considered modules.[6]

There are a number of reasons to focus on engine systems, some practical and others theoretical. First, the engine is certainly a critical element in the vehicle's performance and functioning. Second, it is typically the most expensive system of the vehicle. Third, the engine also turns out to have properties that make it a particularly useful research target. Early and rapid developments offer researchers the opportunity to gather information ahead of the trend and provide them subsequent opportunities to test their initial ideas and findings. Engines would seem to qualify here, as another recent study identified engine modules as a "growth" area for modular strategies.[7]

The research presented here explores the value proposition of one engine system, the engine top system, which incorporates all the fuel and air mixture subsystems, combined with the cylinder head. This system is an interesting choice because it is critical to fuel economy and emissions, issues that consumers and the government tend to consider the domain and responsibility of the manufacturers. This is also an area where even advanced powertrains of the future will continue to need support and innovation.

Method Understanding the manufacturer's view is essential to ensure that the system indeed offers the best value proposition, and that it can be presented in ways that make that value clear to the manufacturers. This is critical information for system integrators because decisions made to develop particular "systems" have already led to the bankruptcy of a few suppliers. This study addresses this issue by interviewing eight key informants, vice presidents or directors in powertrain operations at Ford, General Motors, and DaimlerChrysler[8]. These managers represent the three main functions of engineering, manufacturing, and purchasing, critical to understanding each of the manufacturer's thinking.

Interviews are particularly useful when trying to gather early data on new products, approaches, or ill-defined futures. They are typically less useful than surveys in describing a population or amassing quantitative data for analysis. But interviews often provide richer and more useful data in initially suggesting and identifying the important parameters of an emerging situation or challenge. They also can provide a deeper understanding of the views of small, but critical groups of decision makers. The interview instrument is in Appendix A.

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[6] *The 21st Century Supply Chain, The Changing Roles, Responsibilities and Relationships in the Automotive Industry* by Michael S. Flynn, Bruce M. Belzowski, Bram Bluestein, Michael Ger, Manfred Tuerks, and John Waraniak,, 46 pp., 1996, UMTRI-96-15.

[7] *The Future of Modular Automotive Systems: Where are the Economic Efficiencies in the Modular Assembly Concept*, by Sean P. McAlinden, Brett C. Smith, and Bernard F. Swiecki, Michigan Automotive Partnership Research Memorandum, OSAT, No. 1, 30 pp. November, 1999.

[8] For this research we interviewed seven key informants and incorporated the responses of a purchasing executive in another study that addressed some of the general issues we discuss in this report.

For the most part, this small number of interviews does not support the development of data suitable for standard statistical analysis and interpretation. However, there are a few questions where differences between groups is so large that they are statistically reliable. For other questions, we are confident that the data they yield are reliable and useful in developing a general understanding of the views of the manufacturer community on engine systems. That is, the information is useful in sensitizing readers to the manufacturers' views, concerns, and values, although it does not provide a detailed statistical profile of them.

These interviews focus on powertrain executives' views of industry challenges and system adoption in general and engine top systems specifically. The results are presented in the same way with the first section presenting general questions of industry challenges and drivers, the second section examining questions of general system adoption, and the third section discussing the adoption of engine top systems.

Results

Industry Challenges and Drivers. We asked the manufacturer respondents what they considered the three major challenges their company and its supply chain face over the next five years. As Table 1 shows, technology, fuel economy, and emissions constitute the most often reported challenge, followed by cost competition, customer satisfaction, development of suppliers, the future role of their company in the supply chain, global competition and consolidation, and speed to market. Since the respondents come from the powertrain divisions of their companies, it is no surprise that technology/fuel economy/emissions are nominated first. For years, powertrain divisions have been charged with using new technology to increase fuel economy and reduce emissions, and these directives led manufacturers to experiment with electric, hybrid, and fuel cell powertrain technology. This list probably mirrors the concerns of powertrain executives throughout the industry as they compete to develop next generation powertrains.

Challenges	Number of Responses[9]	Percentage of Responses
Technology / Fuel Economy / Emissions	7	26%
Cost	5	19%
Customer Satisfaction	3	11%
Development of Suppliers	3	11%
Future Role of Company	3	11%
Global Competition / Consolidation	3	11%
Speed to Market	3	11%

Table 1. Manufacturer and Supplier Challenges Over the Next Five Years

These challenges reflect a number of issues that respondents raised throughout the interviews. The interviewees repeatedly noted cost pressures and the future role of the manufacturers in the value chain in terms of whether they can afford to maintain in-house engine system development. They also often highlight supplier development, especially the capability needed in the supply base to actually develop, test, and deliver systems. Throughout the interviews, they frequently questioned whether the supply base can deliver the breakthrough technology/fuel economy/emissions solutions that the government and consumers expect from the industry in the near future. Their concerns very clearly represent two major dilemmas of the manufacturers and especially powertrain executives. First, what systems can suppliers offer that the manufacturers themselves have not already developed? Second, how can an individual manufacturer outsource powertrain responsibilities to suppliers, yet maintain a competitive advantage over other manufacturers who themselves are also purchasing engine systems from the same suppliers?

Respondents see the drivers of these challenges, as shown in Table 2, to be primarily market factors such as changing market share, the inroads made by Asian and European makes into the U.S. market, the uncertainty of market requirements, and vehicle differentiation. They also see technology/fuel economy issues, competition, and company investment and sourcing decisions as drivers. One response combines a number of these drivers, again giving a powertrain perspective, "The drivers are intense competition and the uncertainty of what the market requirements will be. Will it be gasoline, diesel hybrids, all electrics, or whatever. None are cheap to get into. Layout of technology is important." Responses such as these show the commonality between the challenges manufacturers and suppliers face and the drivers of these same challenges. Although challenges are primarily driven by market factors, powertrain

[9] The interviewees could report up to three responses per question, so the number of responses exceeds the number of interviewees.

executives also see technology, competition, and company outsourcing models both as challenges and drivers.

Drivers	Number of Responses	Percentage of Responses
Market Factors	7	40%
Technology/Fuel Economy	3	20%
Competition	2	13%
Company Sourcing/Investment Decisions	2	13%
Other	2	13%

Table 2. Drivers of Manufacturer and Supplier Challenges Over the Next Five Years

The uncertainty respondents reveal in their responses is telling. Powertrain decisions affect numerous platforms and possibly millions of vehicles over a number of years, and the decisions these executives make have a significant impact on their company's financial future. Consequently, powertrain executives are reluctant to make quick decisions, yet at the same time they must respond to competitive pressures in a rapidly changing marketplace. Because of the pressures building from both the government and competitors, suppliers that can provide systems with improvements to the current internal combustion system or technology that initiates a powertrain paradigm shift will begin to play a larger role in each manufacturer's powertrain strategies.

System Adoption. Companies may have differing criteria, but they have similar methods for adopting systems, which includes the decision to develop systems internally or through one's suppliers. We asked respondents if their company has a formal strategy for adopting systems or if the decision is made on a case-by-case basis. Five of the eight interviewees reported that systems are adopted on a case-by-case basis, while one interviewee noted a formal, company process based on a strategic product assessment. Some respondents report having a system mentality for certain areas such as electronics, while for other product areas they have more of a component mentality. Finally, one interviewee reported that his company had no strategy for adopting systems, saying that they are still focused on optimizing at the component level. This view was echoed by another respondent who said, "People (here) base their thinking on building/designing beautiful components and not complete systems." These responses suggest that a system supplier might have more of an opportunity to have a sub-system adopted rather than a complete engine system.

We also asked what typical criteria are used to decide whether to adopt a system. About half of the respondents reported that these criteria were quite specific while the other half thought they were more general in nature. Respondents were first

asked to volunteer the criteria they consider typical, and then they were given a list of potential criteria to consider (Appendix B).

As displayed in Table 3, most respondents mentioned four criteria: cost/benefit aspects, particularly cost reductions; labor issues, including union contracts in place to build and assemble components; supplier issues, including supplier capability; and manufacturer sourcing/core competency strategy, including the potential loss of manufacturer control and knowledge to system integrators.

System Criteria	Number of Responses	Percentage of Responses
Cost/Benefit	8	25%
Labor Issues	6	19%
Manufacturer Sourcing/Core Competency Strategy	6	19%
Supplier Issues	6	19%
Functional Improvements	2	6%
Other	4	12%

Table 3. Typical Criteria for System Adoption

As noted earlier, cost is a major challenge for both manufacturers and suppliers, and it plays a dominant role in the decision to adopt a system. Cost reduction's dominance as a driver in the industry today is nicely illustrated here. Note that all of the respondents mentioned it as a criterion for system adoption, while only two mentioned improved functionality. Perhaps unfortunately, this is consistent with other recent OSAT research: the manufacturers emphasize cost reduction over value-add strategies.

This question also elicited two issues that recurred throughout our interviews: the challenge outsourcing system development presents to labor contracts and to manufacturer loss of control and knowledge. Certain engine systems produced by the manufacturers fall under current labor agreements, and only new agreements or new products that demand new processes will allow suppliers, especially non-union suppliers, to produce them. Receiving consent from unions to outsource these systems is a political issue that must be considered. One respondent summed up the control issue: "... if you outsource enough of the system development you lose the ability to be a good judge of what is going on. Do I drive the process? Does the supplier have a different agenda than I do? Will they (suppliers) drive an architecture that gives them a high piece cost?"

As noted in the introduction, these interviews focused on potentially outsourcing systems to system integrators rather than developing them in-house. We asked the interviewees what they saw as the advantages and disadvantages of placing responsibility for systems with the supply base. Respondents report that the advantages, as shown in Table 4A, include suppliers having a better knowledge of

the product because of their focus on only one area of the vehicle; manufacturers controlling their costs by not having to test and design systems, while suppliers reduce prices because of scale; and suppliers having better control of processes, especially interfaces within the system that are not done well when the system is simply a combination of components.

Advantages	Number of Responses	Percentage of Responses
Better Knowledge of Product	4	36%
Cost Control	4	36%
Better Knowledge of Process	3	27%

Table 4A. Advantages of Supplier System Responsibility

Interviewees see the disadvantages, displayed in Table 4B, of placing system responsibility with suppliers primarily as a loss of control or knowledge within the manufacturers, labor strife over outsourcing, the loss of competitive advantage due to supplier part commonization, and the need to clearly allocate responsibility for warranty claims. Interviewee responses to these questions offer some insight into the challenges powertrain executives face as they consider outsourcing system development to their suppliers. Executives understand that outsourcing offers cost advantages as well as potentially better products and process control, but they are also concerned about their labor commitments and their inability to control the process while they still are responsible for the product, especially in the eye of the consumer. Suppliers who establish relationships with manufacturers that help allay these concerns will probably come to play a larger role in engine development.

Disadvantages	Number of Responses	Percentage of Responses
Loss of Manufacturer Control / Knowledge	5	55%
Commonization/Warranty	2	22%
Labor Issues	2	22%

Table 4B. Disadvantages of Supplier System Responsibility

From this section on general systems development, four important questions arise from our interviewee responses that affect both manufacturers and suppliers. From the manufacturer's standpoint, first, how will outsourcing complete systems affect the manufacturer's ability to judge whether the systems that suppliers provide are optimized for their vehicles? And second, how do manufacturers manage the risk warranty claims present to their companies' reputations when suppliers are primarily responsible for the development of that system?

From the supplier's standpoint, first, how will suppliers be able to develop scale economies if each manufacturer requires specific, differential engine systems? And second, how will close collaborations between manufacturers and system integrators restrict system integrators from sharing process and product innovations developed with their different customers?[10] One respondent described the challenge of manufacturer-supplier partnerships very well, "As you integrate more complex systems critical to engine functionality, the ability to write engine performance requirements is more difficult and supplier participation as a partner and their willingness to take some risk with the manufacturer is important." This scenario makes each decision a balancing act for suppliers as they introduce new systems. Considering the large number of possible customers and the time investment needed to bring these systems into the manufacturer's environment, system integrators may actually need to choose which customers they partner with in system development.

Engine Top System Adoption. This section of the report looks specifically at how manufacturers view the value of engine top systems; the difficulties in developing and adopting these systems; the threats to further development; the major challenges in the value chain; the differences between how the U.S., European, and Japanese manufacturers approach engine top systems; the people who make the decision to adopt engine top systems; when they will appear on vehicles; the role Covisint may play; and the major reasons manufacturers should pursue an engine top system strategy and the major problems they will face if they do. At this point in the interview, a picture of a simulated model of an engine top system was shown to the interviewee as an aid to visualizing what a possible engine top system might look like.

What is the Value of Engine Top Systems?

To determine what areas carry more value to manufacturers in terms of engine top systems, we asked interviewees to rate the value of ten potential advantages of engine top systems on a one to five scale with one meaning low value, five meaning high value, and three meaning neither high nor low value. (This list is shown in Appendix C.) Figure 1 shows the ranking of engine top system advantages from high to low. All the mean scores are above the midpoint of the scale, showing that all the advantages represent some value to the manufacturers, but the highest scores focus on reducing costs, increasing revenue and profitability, improving functionality, and exceeding consumer expectations. These are high scores indeed for engine top systems, and clearly the reasons the manufacturers consider them important.

One interesting aspect of these ratings is the lower value interviewees assign to engine top systems in the areas of quality, reliability, and performance. These lower ratings may be due to the uncertainty executives have about how well engine top systems will perform, though they think these systems will improve

[10] This issue is one of the major findings from OSAT's recent report, *Working with Knowledge in the Automotive Supply Chain*, 2002, UMTRI 02-01

functionality. The dominance of the cost advantage of engine top systems mirrors the views of executives on the advantage of systems in general. Considering the cost savings and increased revenues and profits these powertrain executives think engine top systems offer, it may be extremely helpful for suppliers introducing engine top systems to "prove out" the quality, reliability, and performance aspects of these systems. Some supplier companies in similar situations develop demonstration projects that show the manufacturers the advantages their systems offer.

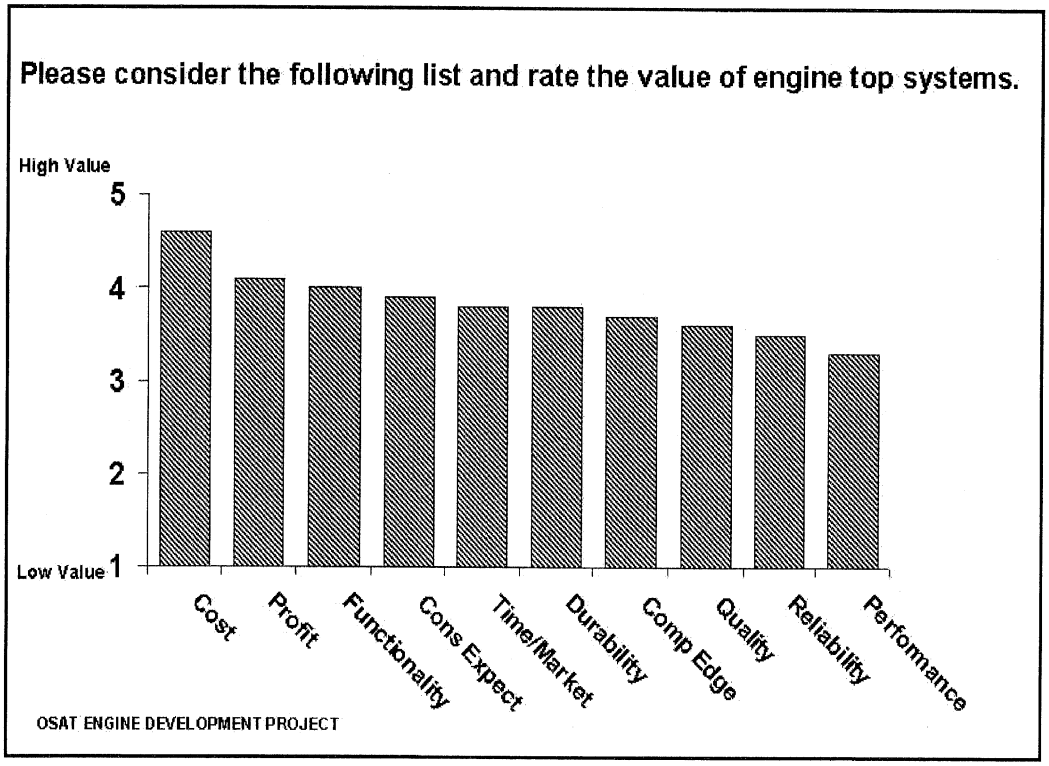

Figure 1. Engine Top Systems Value

Four differences occur when independently comparing the functions of the respondents. Figure 2 shows manufacturing and engineering respondents value engine top systems more for improving reliability and durability than do purchasing respondents. Considering that these systems are relatively new, it may be that the purchasing executives have less experience with them and their effects on reliability and durability. This understanding may account for the lower value values purchasing respondents give to these items. We also found that one company saw little value in engine top systems exceeding customer expectations and time to market, while the other two companies did. However, the general lack of differences among these three groups also shows a consensus about the value of engine top systems. Engine top system suppliers attempting to introduce these systems must consider the manufacturers' focus on cost savings and increased revenue and profit.

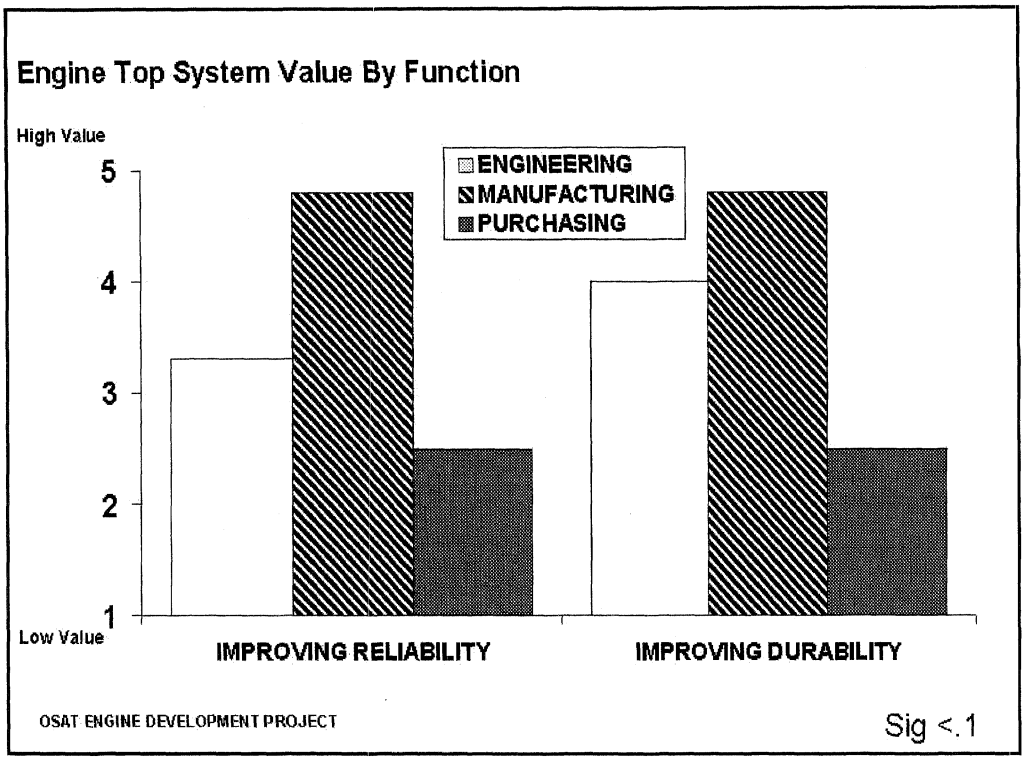

Figure 2. Engine Top Systems Value by Function

What Are the Difficulties in Developing and Adopting Engine Top Systems?
The major difficulties manufacturers will face as they try to develop and adopt engine top systems, as shown in Table 5, include almost all of the issues raised earlier about the general adoption of systems. This is not surprising since the respondents, when asked if they thought the primary factors for deciding to pursue or abandon engine top systems differ from systems in general, unanimously reported that the factors would not differ. The only new category deals with system issues, where manufacturers see difficulties in the logistics of testing the cylinder head, top system, and base engine together, proving the reliability and functional performance of the system, and optimizing all the components of the subsystem.

Difficulties	Number of Responses	Percentage of Responses
Supplier Challenges/Capability	6	37%
System Issues	4	25%
Labor Issues	3	19%
Technology Challenges/Limitations	2	13%
Feasibility and Cost Effectiveness	1	6%

Table 5. Difficulties in Developing and Adopting Engine Top Systems

What Are the Threats to Development of Engine Top Systems?

As shown in Table 6, the biggest threats to the further development of engine top systems– supplier capability, labor issues, and technology challenges–echo previously mentioned challenges and difficulties. The threat to further development of engine top systems is in the area of manufacturer differences. Respondents noted a possible difference between the functional performance objectives of the different manufacturers and the fact that all the manufacturers have different architectures and systems with very little commonization among them. These manufacturer differences also apply generally to any systems provided by suppliers, and the commonization issue again raises the issue of suppliers' ability to differentiate their products for each manufacturer while maintaining economies of scale. Commonization offers system integrators potential economies of scale, but the current lack of commonization may prevent it. This challenge also relates to the earlier point of close collaborations between system integrators and manufacturers and possibly limiting the number of manufacturers served. System integrators may need partner-like relationships with long-term contracts with manufacturers in order to justify expending the resources needed to develop individualized systems for each customer.

Threats	Number of Responses	Percentage of Responses
Supplier Capability	5	30%
Manufacturer Differences	4	25%
Labor Issues	3	19%
Technology Challenges	2	13%
Not Meeting Objectives	2	13%

Table 6. Threats to Further Development of Engine Top Systems

What Are the Major Challenges in the Value Chain?

Using the picture of the value chain in Figure 3, we asked interviewees where in the supply chain their major challenges in completing an engine top system are. Respondents identified more than one stage of the supply chain, and six selected engineering and design and six purchasing. They chose engineering because of the technology challenges and purchasing because of the labor issues in outsourcing as well as concerns about supplier capability. When we analyze only the first mentioned responses, three of the respondents chose engineering and four chose purchasing. These responses are consistent with earlier responses. These are complex issues with a variety of significant challenges facing both manufacturers and suppliers. At this point in engine top system development, the challenges in the value chain lie in the areas of engineering and purchasing, where system "prove out" and cost are still uncertain.

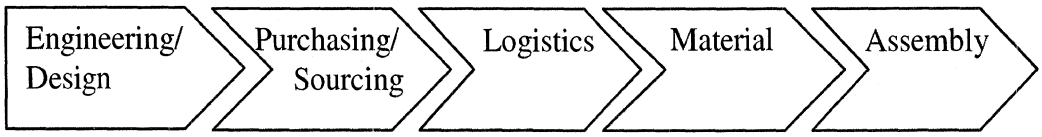

Figure 3. Current Automotive Supply Chain

What Are the Differences Between U.S., European, and Japanese Companies Concerning Engine Top Systems?

When considering the differences among U.S., European, and Japanese companies concerning engine top systems, respondents tended to generalize more to systems in the broadest sense. In general, respondents view U.S. companies as being in the early stages of system development, with clear advantages for the Japanese and European companies. Respondents do not think U.S. companies are as system oriented as Japanese and European companies. One respondent noted, "Americans are all over the map (concerning engine systems). We have a sort of lame excuse that we have bigger production runs."

Interviewees noted that the Japanese manufacturers are aggressive in the development of four and five valve technology. They think that there is more of a systems approach in Japan than in North America. They mentioned that Japanese engineers have a more systemic view of life and have always seen the vehicle as a system, willing to compromise a subsystem to optimize the system.[11] Respondents also mentioned the flexibility the Japanese manufacturers have with their unions, and the lower financial "hurdle rate" the Japanese have for long-term investment compared to North American manufacturers.

Interviewees also see the European manufacturers as more aggressive with four and five valve technology, with many engine top systems in vehicles, especially small engine designs. One respondent noted, "The Europeans are great systematizers. You lift up the hoods of the European cars and you see the consistency."

These responses suggest that Japanese and European companies may be better targets for suppliers in the short term for engine top systems, and that U.S. companies may need more time to accept these systems. Engine top system suppliers, in particular, may need to spend more time showing how their systems approach offers advantages to the manufacturers.

[11] This is supported in OSAT research on functional build and the fitting of doors to car bodies.

Who Makes the Decision to Adopt Engine Top Systems?
It is important to ask who is primarily responsible for decisions about such engine systems. Responses to this question vary by function and within the companies, but no particular pattern emerges. This suggests that these companies are indeed in the early stages of considering system adoption, which, of course, makes it difficult for suppliers to identify the effective path for pursuing systems.

When Will Engine Top Systems Appear on Vehicles?
Interviewees also vary as to when they think engine top systems will appear on vehicles. One respondent reports that they are already on vehicles in Europe, one thinks they will be on a vehicle in the 2002 model year, two respondents think they will be on vehicles in two to three years, two think it will take four or more years, and one thinks they will not be on any vehicles in the future. Obviously, these responses are based on the interviewees' knowledge of internal and external engine top system projects, but the wide range suggests that there is no industry consensus about where these system are in the product stream, nor what the current state of the competition is.

When asked if the appearance of engine top systems will vary by product line, the two respondents who answered said they would vary by product line, but they also noted that the introduction would be more tied to the engine family than the vehicle.

What Role Will Covisint Play in Engine Top System Development?
As mentioned in the industry challenges section of this report, e-business allows both manufacturers and suppliers to move many of their practices and processes from paper and phone to electronic communication. This includes not only e-procurement through auctions but also supply chain management through electronic communication of orders and collaborative e-product development. The creation of Covisint, a manufacturer-owned electronic exchange, offers the industry a common platform or space in which to conduct all the electronic processes between companies, either manufacturer-to-supplier or supplier-to-supplier. In early discussions about the role of Covisint in procurement, many analysts suggested that the exchange would only be used for parts or services that are not highly engineered. But recently, there have been reports that highly engineered components have been put through the electronic bidding process. We asked the respondents in this study how big a role purchasing exchanges like Covisint will play for highly engineered components like engine top systems.

Interviewees see a wide range of possibilities for Covisint, consistent with the general uncertainty of how the industry will use the exchange. Responses range from seeing Covisint as basically a pricing/logistics exchange with little effect to seeing it as a comprehensive mechanism for forming alliances for system development for highly engineered components and systems. Two respondents reported that an exchange works best with standardized components with common specifications, and that unique products are very hard to specify within

the exchange context. On the other hand, one respondent thinks all parts and services will be purchased through Covisint, including systems that will use the exchange to transfer all the data needed to bid and design them. One respondent reported that he was not sure the bidding process was yielding the best products, "We'll get in trouble trying to buy very sophisticated systems and treating them like commodities. It is only as good as the specifics you give suppliers who are bidding. Suppliers are signing up for low or no margins. We're not sure we're getting the best products."

Two possible outcomes from the creation of Covisint, as reported by interviewees, are that it may enable optimization of the lower tiers of the supply chain as information transparency and ease of communication flows through the tiers, or, as one respondent thought, it would lead to fewer suppliers or participants in the industry.

Why Should Companies Pursue Engine Top Systems? What Will Be the Biggest Challenge If They Do?

Finally, we asked respondents what they would tell their CEO if asked about the major reason their company should pursue engine top systems, and about the biggest problem they would face if they did. Concerning the major reason to pursue engine top systems, two respondents felt they should either not pursue these systems because they had more important issues to deal with or defer these systems to the firm's luxury division. Three respondents thought engine top systems would reduce costs, while others thought it would make their company more competitive, free up money for the company, improve quality, reduce manufacturing complexity, and improve technology, efficiency, and performance because of the capability of their supply base.

Although one respondent reported on the high level of capability of the supply base in arguing for pursuing engine top systems, four of the eight respondents reported that supplier capability will be the biggest problem they face if they pursue engine top systems. They see supply base challenges in dealing with warranty issues on almost a global basis, in trusting the supply base to deliver something this complicated without manufacturer support, and in supplier program management.[12] As one respondent commented:

> The biggest weakness of the supplier base is program management. Finding the person in the company is easy but finding the what and when is harder. The critical path is almost non-existent. The delivery schedule always slips by major chunks. The resources are poorly managed or just not there. The suppliers need to be spectacular not just in design but also in delivery. With the move towards systems and modules the supplier will no longer be tasked with just simple components but with trying to integrate the

[12] Other current OSAT research suggests that program management may indeed be weaker in the supply bloc than suppliers believe.

components into complex systems. Skilled program management is required to find out or to validate a design flaw. This will be a major hurdle in trying to develop complex systems.

Respondents also noted that they might lose their core competency in engines if they pursued engine top systems, and that their relations with labor unions would be taxed. They suggested the need to show the union how such systems benefit its members, not just that the company will be better off because of outsourcing. Finally, one respondent reported that outsourcing an engine top system introduces a level of inflexibility into the design collaboration between the manufacturers and suppliers. Both groups would have to have a good understanding of the system so they would not request costly and unnecessary changes. Parameters would have to be set about how much could be changed.

Conclusions. This study offers timely insight about the pace of industry restructuring and some of the major issues that both manufacturers and suppliers face in system development. These interviews, though small in number, generated some recurring themes that both manufacturers and suppliers need to consider as they pursue system strategies, including engine top systems. Although high-level manufacturer executives see the need to divest their companies of assets by outsourcing design, engineering, and manufacturing of major systems of the vehicle, implementing this initiative comes with some very important challenges. Powertrain executives, in particular, are concerned primarily about the capability of the supply base to actually design, engineer, and deliver these systems, and they worry that this strategy will eventually challenge their company's own ability to judge whether the systems that suppliers provide are optimized for their vehicles.

When considering the specific adoption of engine top systems, powertrain executives report significant potential value from these systems, especially in the areas of reducing costs, increasing revenue and profitability, improving functionality, and exceeding consumer expectations, but they also see technical, organizational, and supplier challenges that system integrators must address.

From a value standpoint, manufacturers risk missing the competitive advantage that systems may provide. The manufacturers may emphasize systems development based on cost reduction rather than as a value-added process. Cost reduction may drive the development of systems in a less fruitful direction by not focusing on what advantages systems bring to the consumer.

From a technical standpoint, some executives do not see the engine top system as a system. They see the complete engine from intake to exhaust as the system and the engine top system as a module in the larger system. Other executives have no trouble separating these systems. This varying definition of the system across respondents may mean that solutions must be tailored to each manufacturer, or a system integrator may need to "educate" manufacturers on the advantages of its

system. In these cases, suppliers of specific systems may need to use demonstration projects to focus manufacturer powertrain executives on the advantages of a particular system design.

Manufacturers have an organizational challenge as they attempt to outsource more design, engineering, and manufacturing. There seems to be uncertainty as to how to push internally for system adoption or the critical advantages it might confer. Some manufacturers are organized along component lines. This structure leads them to say "systems" yet think "components." Suppliers need to be aware of each manufacturer's organization and whether that pattern is changing. The manufacturer's organizational structure will affect its approach to certain systems. Indeed, one respondent could not clearly identify who makes a decision on systems in his organization.

Powertrain executives also note several serious supplier issues, some direct and some indirect, that will impact future system development. The direct issue focuses on their uncertainty about the true capabilities of their suppliers. While suppliers say they can design, engineer, program manage, and deliver a system, the executives are not yet convinced suppliers can actually do it.

The indirect supplier issues include the potential dwindling of manufacturer engine expertise, the manufacturer's potential loss of competitive advantage and innovation in engines, the long time it may take to alter existing labor agreements (perhaps only on completely new vehicles, engines or complete re-designs), and how warranty issues may affect brand value because the customer sees the vehicle as the manufacturer's rather than the system supplier's.

Suppliers themselves also need to understand the challenges and risks involved in system development. One manufacturer reported the need to have system integrators viewed as partners with all the associated risks. If system integrators must develop near partner-like relationships with each manufacturer, can they be profitable developing unique products for each manufacturer? Can they develop enough scale if they cannot commonize parts across manufacturers? Can they organize their company to benefit from knowledge gained from one manufacturer's system for subsequent systems for other customers without violating exclusivity agreements? Will these relationships lead system integrators to supply some rather than all manufacturers?

These powertrain executives raise some serious questions about what ceding system design to suppliers implies in relation to the loss of internal expertise, competitive advantage, innovation, supplier capability, labor agreements, and warranty responsibility. However, manufacturers continually strive to cut costs while increasing functionality. Systems offer these savings, and suppliers who can overcome these barriers have a better opportunity of gaining system business.

Appendix A

Engine Top Systems:
Change, Challenges, and Value

Interview Instrument

We are researching the general evolution of the relationship between large, technically capable suppliers and their manufacturer customers. For this project, our purposes are to gain a better understanding of how system strategies are developing, to identify the value or business proposition that systems must meet, and to understand the decision dynamics that lead to the adoption or rejection of particular systems. We also intend to explore the competitive contexts that may accelerate or retard the development and adoption of systems.

For our purposes we are defining a system as a collection of components that are dependent on each other and that cannot operate independently. System functionality depends on the integration of the components, resulting in better performance, higher value, or lower costs over and above the simple combination of the components which is how we would define a module.

We are targeting certain engine systems because of their value, the centrality of engines to vehicle performance and "personality," and their status as likely early developing systems. Our goal is to document and understand different choices manufacturers might make, not to make evaluations or negative comparisons across companies.

As is always the case with our research efforts, your individual interview responses will be treated confidentially, and no identifiable responses will be published without your consent. We hope that the respondent report we prepare, based on these interviews and our other analytic efforts, will assist you in evaluating and benchmarking your company's own decision processes and outcomes, and thus contribute to their improvement.

1. What do you think are the three major challenges facing your company and its supply base over the next five years? What are the key drivers of these changes, and how is your company responding to them?

2. Remembering that we're defining systems as the integration of components, resulting in better performance, higher value, or lower costs over and above the simple combination of the components as in a module. Does your company have a formal, general strategy for adopting systems, or do you make decisions more on a case-by-case basis? What are the typical criteria used for deciding to adopt or not to adopt a system?

3. Are decision criteria for adopting systems at your company specific and detailed, or more general and directional in nature?

4. When considering systems development, what do you see as the major advantages and/or disadvantages of placing responsibility for systems at suppliers, rather than within your company?

5. We are particularly interested in the role engine top systems might play in your company's future activity. We're defining an engine top system as a collection of parts integrated into the manifold and cylinder head that controls air and fuel to the engine with the purpose of optimizing engine performance while reducing costs. Considering the stages in the value chain for completing the top of the engine where do you currently find your major challenges? Are these challenges more time, cost, quality, or performance in nature? Where would you expect to find the major challenges if you developed an engine top system approach? Would you anticipate these would be more time, cost, quality, or performance challenges?

6. What do you see as the major difficulties, if any, you'll face as you try to develop and adopt engine top systems? What do you consider to be the three biggest threats to the further development of engine top systems?

7. When, if at all, do you see engine top systems appearing on vehicles? During what model year do think they will begin to appear?

8. Looking more closely at your company's consideration of engine top systems, where is primary responsibility for decisions about such engine systems located—what function and level controls it? Do you think the primary factors for deciding to pursue or abandon engine top systems differ from systems in general? How is that?

9. Do you see any general differences in the ways U.S., Japanese, and European manufacturers are approaching engine top systems?

10. How big a role will purchasing exchanges like Covisint play for highly-engineered components like engine top systems? Will they enable manufacturers to form and reform their supply base, avoiding dependence on system suppliers?

11. Is there anything about your company's approach to systems, especially engine top systems, that we haven't asked, but should understand?

12. Finally, if your CEO called you and asked "What's the major reason we should pursue engine top systems?", what would you answer? If he then asked "What's the biggest problem we'll face if we go that way?", what would you answer?

Appendix B

Criteria for Choosing Systems

Context issues
- Staff morale
- Union objections
- Loss of control of product
- Loss of control of process

Cost reduction
- Direct labor reduction
- Engineering labor reduction
- Inventory reduction
- Investment reduction
- Materials cost reduction

Process improvement
- Adaptability
- Flexibility
- Processing time reduction
- Processing waste/scrap reduction

Quality improvement
- Engineering improvement
- Field reliability
- First time quality
- Innovation ease
- Product durability and longevity

Appendix C

Engine Top System Value

SCALE →	1	2	3	4	5
	LOW VALUE	SOMEWHAT LOW VALUE	NEITHER HIGH NOR LOW VALUE	SOMEWHAT HIGH VALUE	HIGH VALUE

Reducing cost

Exceeding consumer expectations

Gaining a competitive edge

Improving quality

Enhancing revenue and profitability

Improving time to market

Improving functionality (with same or lower cost)

Improving performance

Improving reliability

Improving durability