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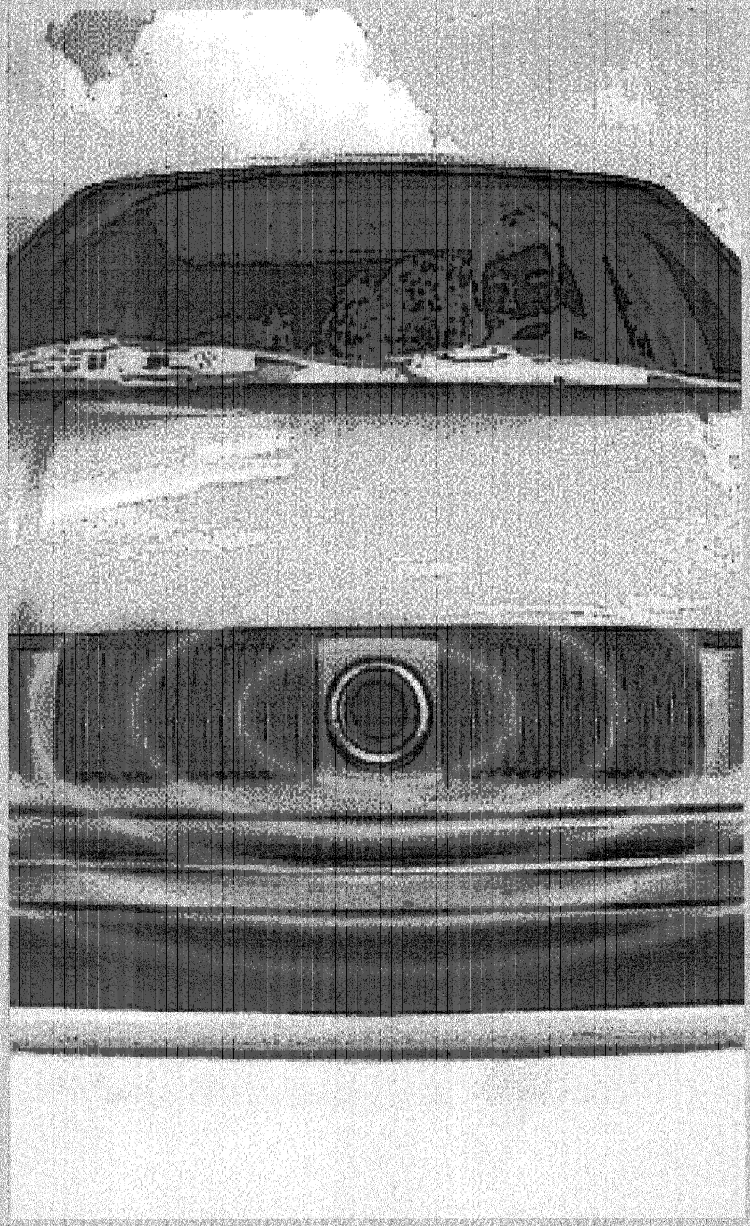
ADAPTIVE CRUISE CONTROL

An Industry Outlook on Product Features & Marketing



Archives

Adaptive Cruise Control

An Industry Outlook on Product Features and Marketing

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16. Abstract

An interview method was employed to determine the auto industry outlook on adaptive cruise control (ACC), with special emphasis on the likely profile of the U.S. market. Both supplier and OEM companies were questioned on their expectations for product feature requirements, preferred technologies, institutional issues, management strategy, and marketing. The report presents the "data" received through interviews together with evaluation of results based upon marketing analogues and the University of Michigan's own experience in ACC research. Results show a substantial industry consensus exists on a number of product features, and yet divergent views prevail on other items. It is clear that ACC will be marketed on luxury cars first, that most products will employ radar as the range sensor, that the driver will have a means to adjust headway time, and that common entry prices will be on the order of $1000, although different feature sets may cause the price to vary considerably. The major source of technical uncertainty is in the ranging sensor, although uncertainties also exist in terms of functional features that will minimize liability risk and yet give suitable utility for the customer. Noting significant apprehension in the industry over the "safety" versus "convenience" perceptions of this product, it seems fair to say that ACC will radically extend the locus of automotive design concerns beyond those that are traditional to this industry.

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We also wish to acknowledge Mr. Paul S. Fancher from UMTRI who participated in many of the interview sessions and who provided supplemental notes and observations, based upon his background in leading the University of Michigan's engineering research program in ACC. Finally, the gracious assistance of Ms. Annise Johnson is recognized for the production of the report document.

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This document contains (95) pages.

Executive Summary

This study has sought to assess the industrial outlook on adaptive cruise control (ACC), with special emphasis upon the issues pertinent to the domestic U.S. market. The ACC function, which is an enhancement to conventional cruise control, automatically manages both the speed of the equipped vehicle and its headway or clearance to a vehicle in the same lane ahead. This sophisticated electronic feature is seen as having special significance since it will be the first large-volume automotive product that senses the presence of other vehicles by an on-board technology. The ACC function is also perceived to change the relationship between the driver and the vehicle in subtle new ways. Since other related safety and convenience functions may later evolve if the ACC market is successful, many of the automotive electronic suppliers and virtually every automaker in the world sees some strategic significance in this item and is currently involved in either developing products, planning for product launch, or test marketing a trial ACC product.

This study has undertaken live interviews both with suppliers that were known to be prospective vendors of ACC components or subsystems and with selected Original Equipment Manufacturers (OEMs) of new automobiles. Both U.S.-owned and foreign-owned companies were interviewed. The interviews were organized around a written outline of questions that covered product feature requirements, preferred technologies, institutional issues, management strategy, and marketing. The report presents the "data" received through interviews together with analyses based upon marketing analogues and upon the University of Michigan's own experience in ACC research and operational testing since 1992.

The results show the following:

- The group of six OEMs and four supplier companies is divided on certain requirements needed for the first-entry ACC product, as follows:
  - on whether ACC should act in response to vehicles that are stopped ahead,
  - on the range of weather conditions over which ACC must operate,
  - on whether the ACC system must engage the service brakes,
  - on whether an intervention prompt or audible alert is necessary.

- Conversely, there was a virtual consensus on the following requirements:
  - on the need to track vehicles through freeway-radius curves (although no company anticipates that any first-entry ACC product will continuously track vehicles through tangent-to-curve transitions),
  - on the need to provide for driver adjustment of headway time,
  - on the display of both the SET speed value and the "target-acquired" state,
  - on the minimum engagement speed of ACC (most expect the same value as with conventional cruise control).
- There is a broad expectation that radar will become the sensing technology of choice in most ACC products for the U.S. market. Infrared sensing is likely to be bypassed because of constraints on its operability in winter weather and fog conditions, even though it is less costly at present.
- Various approaches are planned for extrapolating the host vehicle's path, including the use of yaw rate sensors, wheel spin signals from the antilock brakes/traction control (ABS/ATC) subsystems, steering wheel angle, and video image processing from a forward-looking camera.
- There is small but manageable concern that ACC poses problems for compatible integration with the rest of motor vehicle design.
- The major source of technical uncertainty at present is in the performance and manufacturability of the ranging sensor.
- Although ACC is seen as an entry point into later markets for crash warning and avoidance products, most companies wish to differentiate ACC as a convenience feature as opposed to the manifest safety intent of the other concepts.
- Companies have ambivalent views on the role of the National Highway Traffic Safety Administration (NHTSA) in the ACC issue: government specification (but preferably not via Federal Motor Vehicle Safety Standards, FMVSS) of basic safety-related features might help mitigate the liability, but the dynamics of the specification process might impede the path to market.
- Tort liability is a central concern in the minds of all companies interested in ACC. Further, the expected launch of ACC14 in luxury-end vehicles requires higher functionality to please the customer and thus a larger liability exposure than may later accompany scaled-down systems.
- All companies acknowledge the more benign liability environments of Europe and Japan and the value of gaining early market experience in those regions. Nevertheless, most apparent plans for ACC market entry simply target each company's home market rather than proceeding on a strategy of "easiest markets first".

- The ACC market is expected to grow slowly; perhaps, somewhat like that of conventional cruise control which took twenty years to reach 50% penetration.
- The target price of ACC is in the $100 to $400 dollar range for volume sales, although initial entries will be closer to $1000, or above.
- Initial launch of ACC products will be in luxury sedans, followed subsequently by high-end, sport-utility vehicles, pickups and vans.

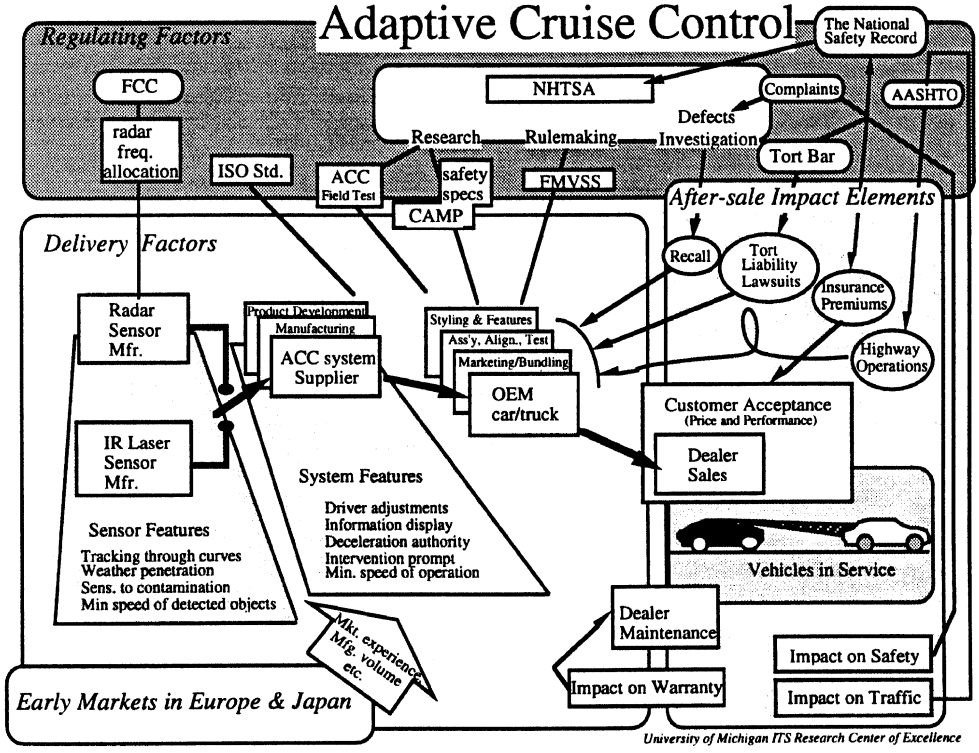
This report presents a summary of responses to each interview question followed by discussion of associated issues that were discovered more informally outside of the interview process. The report also presents and discusses historical market data from other automotive products that have been recommended by our respondents as analogues for estimating ACC market growth, namely those of antilock brakes, which have been sold as a safety feature, and conventional cruise control and power steering, both of which were marketed as convenience features. A final part of the analysis develops the view that ACC will radically extend the locus of automotive design concerns beyond those that are traditional to this industry.

1.0 Introduction

This document serves to report an assessment of the industrial outlook, as it existed in late 1996 and early 1997, on a pending automotive innovation called adaptive cruise control (ACC), also known as intelligent cruise control. The ACC function is an enhancement to conventional cruise control, automatically managing both the speed of the equipped vehicle and its headway or clearance to a preceding vehicle just ahead, for the sake of relieving the stress of highway driving. There is also reason to believe that ACC may significantly alter the likelihood of rear-end collisions.

This study is one of three undertaken concurrently under the auspices of the Intelligent Transportation Systems (ITS) Research Center of Excellence at the University of Michigan. The goal of the center's "industry studies" has been to facilitate the growth of ITS-related business opportunities by clarifying the impediments to ITS productization and by identifying areas of research need. Each of these projects singled out an emerging ITS product type for study. Since the ACC function has been an object of research within the university since 1992, it was seen as an attractive product area for examination.

Figure 1



Virtually the entire worldwide auto industry is currently engaged in developing (and in some cases already test-marketing) an ACC product. The purpose of the ACC study was to sample from this industry—both its vehicle manufacturing and its supplier

companies—in order to characterize the industrial plans and expectations for this product. The scope of inquiry spanned a broad context as depicted in Figure 1.

The figure implies that the context for delivery of ACC to the consumer market includes regulating and after-sale impact (risk) factors that lie well outside of the control of the manufacturing industry. These factors are more or less recognized by the industry, but many have either not been substantively assessed by the auto companies or the factors are still taking shape through the action of other players. For this and other reasons, various uncertainties exist that appear to have slowed the dates of expected product introduction, especially wherever the technical requirements for ACC are perceived to influence the risk outcomes.

It was the intent of this study to expose these factors and to determine the state of ACC product definition, in light of such concerns. The study also embraced, with mixed success, the broader questions of corporate strategy, market expectations, and nominal approach to product launch.

The study methodology involved live interviews with both automotive electronic supplier companies that were known to be prospective ACC vendors and with selected Original Equipment Manufacturers (OEMs) of new automobiles. The interviews were organized around a written outline of questions. A few companies were unable to arrange face-to-face or conference-call interviews and, instead, submitted written comments in response to the outline. This report is intended, primarily, to present the "data" received from the sampled companies, per the interview outline. The authors also offer some interpretation or elaboration on the respective issues based upon other published sources or from the university's direct experience in the analysis and testing of ACC prototypes, including the first U.S. field operational test of ACC that employs a fleet of ten equipped vehicles in normal service by lay persons.

In Section 2.0, the data collection technique is described and the sampled companies are identified. Section 3.0 presents a summary of the comments received in response to each of the interview questions, plus observations by the authors on the apparent implications of these responses. The complement to Section 3 is Appendix A in which all of the responses from participating companies are compiled by interview question. Section 4 presents interpretative aspects of the study, particularly relating to analogies for projecting the size and possible pace of growth of the market. Section 5 is argumentative, presenting the authors' view that ACC will radically extend the locus of automotive design concerns beyond those that are traditional to this industry.

2.0 Data Gathering Technique

A six-part interview was developed, comprising a total of 36 questions. The six portions of the outline covered the topics of:

1) Requirements of the ACC system

2) Technologies to be employed in the product

3) Technical challenges posed by ACC as a subsystem of the motor vehicle

4) Impediments to an ACC market

5) Issues of corporate management posed by ACC

6) ACC marketing issues

The complete questionnaire is presented, with all responses, in Appendix A.

The interview method

It was proposed to each company that the researchers would facilitate a more or less informal discussion, prompted by the questions listed in the interview outline. In each case, the company was asked to provide both technical and business persons to participate in the interview. Although most of interactions did involve such a mix, the overall tilt of expertise among the corporate participants was toward the technical aspects of the product. During the interview, two and sometimes three researchers took notes documenting the comments of the company representatives. Later, the various notes were reconciled and the comments edited as faithfully as possible in the form of complete sentences that captured the expressed views.

Attribution

Companies were advised that all of the information gathered during the study would be made public through the report, but that no comments would be attributed to any named company in reporting the results. In the compilation of interview results in Appendix A, comments by the respective OEM and supplier company are arbitrarily numbered OEM-1, 2, 3, etc. and Supplier 1, 2, etc. so that individual attribution cannot be inferred, but company type can be. It was believed that readers would wish to distinguish OEM comments from those of suppliers since ultimately it is the OEM that specifies the requirements for automotive products (albeit in close consultation with supplying vendors.) Further, the strategy for marketing to the final customer is overwhelmingly in the hands of the OEM. Correspondingly, response to "marketing" questions by the supplier company tends to reveal their own prognostications on what the OEMs would eventually stipulate for this product. Where suppliers took the view that OEM

requirements are overly ambitious or demanding, given supplier readiness to deliver a component or subsystem, further delay in the introduction of ACC products seems to be a reasonable inference.

Participating Companies

The following companies participated in the study by responding directly to the interview questions:

OEMs

Chrysler

Ford

General Motors*

Mitsubishi

Nissan

Toyota

* (Since GM was the first company interviewed, certain interview questions were still in a preliminary form at the time. Follow-up contact was made to ensure that GM's responses covered the same range of issues as all others.)

Suppliers

Automotive Distance Controls (ADC)

Eaton/VORAD

Lucas Varity (with input from Thomson CSF)

TRW

In addition, publicly available materials were received and individual technical conversations were held with persons representing the OEMs: BMW, Honda, and Mercedes-Benz and the suppliers: Delco Electronics, ITT Automotive, and Siemens. However, none of these additional companies participated in responding to the full set of structured interview questions and none of their inputs are presented as "results" either in Section 3, or in Appendix A. Nevertheless, insights gained through these interactions have certainly influenced the authors' outlook which is represented in comments throughout the report.

3.0 Summary of Interview Results

In this section the collected responses of all of the interviewed organizations are presented and discussed in a summarized form. The material follows the interview outline which also appears in Appendix A. For each question whose responses are summarized below, the central issue is shown in a gray header bar, together with the number of interviewed OEM and supplier organizations that actually addressed the question. Prominent or common forms of the response are cited directly under the gray header, showing the number of OEM and supplier organizations who subscribed to the view that is presented, when more than one gave an equivalent response. Other selected views are listed next. Finally, the authors present comments seeking to expand these views by means of any other information that has been gained through the university's own involvement in ACC research.

Part A

Comment on expected requirements for the following ACC attributes:

Minimum forward speed of preceding vehicles warranting ACC response

10 responses (6 OEMs, 4 suppliers)

2 Suppliers, 2 OEMs say ACC must respond down to 0 mph preceding vehicle speed.

4 OEMs cite a minimum in the range of 0 mph < V min < 10 mph.

Selected Views

- Stopped vehicle detection and response is seen by all to be an eventual requirement for all ACC products, as the market matures.
- 1 Supplier, 1 OEM: The ability to detect stopped vehicles is a characteristic of collision warning systems and is inappropriate for ACC.

- Most systems can readily track a once-moving, acquired target all the way to zero velocity; the problem is to detect and path-discriminate a vehicle that is already stopped.
- Different geographic markets determine this requirement differently.
- If collision warning (CW) is integrated with ACC, 0 mph is definitely required.

Authors' Comment:

The requirement for system response to zero-speed vehicles ahead impacts upon both sensing and system-level capabilities, recognizing the need for both reliable detection and the confident projection of one's own path into an intersection with the vehicle that has been detected ahead. Thus, although this appears to be an issue of the performance of the range sensor, itself, it also embraces other aspects of system performance. When braking is implemented within the ACC control function, the penalty for false determination of a stopped vehicle ahead can be substantial. Thus, a companion ACC requirement for automatic brake actuation constitutes a primary factor discouraging some manufacturers from also requiring "zero-speed detection/response." An associated concern is that of the stopped, non vehicular object. No vehicle manufacturer is known to currently specify that the ACC sensor must detect (and the system must act upon) non vehicular objects, although at least one OEM acknowledges that the occasional detection of (and response to) some trivial non vehicular objects will be the inevitable price to pay for insistence on detection of and response to stopped vehicles. Although the stopped-vehicle requirement may appear as only one of a great host of detailed requirements appearing in an OEM's sensor/system specification, it is currently regarded as one of the single most difficult for vendors to satisfy.

Ability to track through curves and curve transitions

9 responses (5 OEMs, 4 Suppliers)

Some extent of curve tracking capability is universally required.

A common specification is derived from the range of curve radii that appear in national distributions of highway curve data.

Selected Views

- 5 OEMs, 4 Suppliers: Curve tracking is necessary in all beginning ACC products
- 3 OEMs, 1 Supplier: Emphasis is on tracking through freeway-type curves (cited specifications for minimum radius coverage ranged from 760 feet to 1640 feet)

- Some cite the inability of the sensor to track through a curve as a failure that will yield a negative perception of the system by the customer.
- 1 Supplier: There is still a possible market for fixed monobeam sensors having no curve tracking ability as a second-wave product for cheaper cars in Europe.

Authors' Comment:

It is clear that the loss of targets in curves or their late acquisition upon entering a curve constitutes a functional shortcoming that is seen as unacceptable in early ACC products—virtually every OEM is planning to deal with it. On the other hand, no company has indicated to us that their early ACC systems must anticipate the *transition* from a tangent section to a curve—apparently recognizing that transitional dropouts in target detection occur only when the range-to-target is somewhat longer, are rather short-lived, and do not typically pose a sustained control disturbance that would strongly reduce customer satisfaction. Curve-related and other detection dropouts are sometimes dealt with, at the system level, by configuring a "softer" control loop that minimizes disturbance to the driver during the dropout incident.

Weather penetration capability of range sensor

10 responses (6 OEMs, 4 Suppliers)

2 Suppliers, 2 OEMs say all-weather performance is necessary.

1 Supplier, 3 OEMs want "broad range" of weather performance covering "normal" states of precipitation.

Selected Views

- 1 OEM, 1 Supplier: Assuming that all-weather performance will not be provided, there is a need to inform driver when the sensor is not able to operate reliably due to weather (perhaps leaving driver with the choice of disengagement).
- 2 OEMs, 1 Supplier: There is concern over weather-robust systems that enable unwise operation under conditions of poor visibility, such as in fog.
- 1 Supplier: ACC should be available for use whenever CCC was—therefore, all weather.
- 1 Supplier: There is a need for a standard defining the weather-operability requirement.
- Weather penetration is seen as the prime differentiator between radar and infrared technologies.

Authors' Comment:

Although the sentiment for nearly all-weather capability is broadly held, the degree of conviction over prudent driver utilization of such capability seems quite soft. For example, there appears to be almost no experience across the industry with the decisions that lay drivers will, in fact, make when facing foggy or other marginal-visibility conditions with a radar-based ACC system available. Although the driver's sensation of deceleration initiated by the ACC system may provide the driver with a good cue when approaching a vehicle in the fog ahead, one must travel at a speed sufficiently high to engage ACC in order to access this desirable cue—but this speed value may be higher than good judgment would otherwise support, under the conditions. Further, driving requires attentiveness to many other potential contingencies than simply that of the presence of a vehicle in one's own lane, although ACC only deals with this core contingency. Moreover, weather poses a crucial context in which the implications of ACC as a convenience device become heavily blurred with those of ACC as a safety device.

Means for driver adjustment of headway time

10 responses (6 OEMs, 4 Suppliers)

3 Suppliers, 5 OEMs mention driver adjustment of headway as necessary.

Where adjustment is seen as a requirement, controversy exists over setting the limits of adjustability.

Selected Views

- 1 Supplier: Truck/car markets may differ in their need for driver adjustment, with the truck product more likely requiring a fixed headway time.
- Headway time adjustment is viewed as a discretionary enhancement, one that might not be offered on some low-priced cars in Europe.
- 1 Supplier: No numerical values of headway time should be communicated to the driver, just unscaled adjustment.
- 1 OEM: A standard is needed that specifies the minimum headway value.
- Most respondents commented on the liability implications of the minimum headway adjustment value—a jury could perceive that the driver was allowed to follow "too closely."

Authors' Comment:

ACC field test data collected by the University of Michigan Transportation Research Institute (UMTRI) shows a remarkable degree of separation in the preferred headway time adjustments of drivers as a function of age. With 20-30 year olds preferring a headway time of 1.0 seconds, 60-70 year olds preferring 2.0 seconds, and middle-aged drivers landing tidily in between, it seems unlikely that a broad population of customers would be pleased with any system that did not allow headway time adjustment. Substantial controversy exists, however, on the matter of the minimum setting allowed. In any case, no manufacturer appears to be considering a minimum setting value that approximates the very short headways (say, less than 0.6 seconds) that typify conventional commuter-driving behavior on U.S. freeways. Also, there is broad recognition that the deceleration authority of the ACC controller will impact strongly on the headway time values that may be desired or accepted by drivers.

Deceleration authority of the system

10 responses (6 OEMs, 4 Suppliers)

1 Supplier, 3 OEMs see braking added on only at a later stage of the ACC market.

2 Suppliers, 3 OEMs plan for braking control in the first ACC implementation.

Selected Views

- When brakes are to be used for ACC control, deceleration authority will maximize at approximately 0.18 g to 0.30 g.
- Systems implemented without braking will control by throttle modulation and a single downshift of an automatic transmission.
- 1 OEM, 2 Suppliers: The braking issue is evolutionary. More deceleration authority will come over time with acceptance and maturity of the technology.
- 1 OEM: Only a moderate level of deceleration authority is appropriate in order to ensure customer realization of their need to control the vehicle.
- 1 Supplier: Braking will be simply inevitable as ACC evolves to include collision avoidance.
- 1 OEM does not see ACC including actuation of the service brakes due to the liability burdens thereof.
- The pending position of the Japanese Ministry of Transport will affect the Japanese domestic products regarding the inclusion of braking.

Authors' Comment:

The question on "decel authority" addressed only the issue of whether the service brakes are needed or not. The European view seems to be universal that ACC without braking-level decels is not attractive because of the large speed differentials that are typical on the motorway/autobahn network. Traffic on the U.S. road system, however, is such that a good deal of serviceability would derive from an ACC system that does not engage braking. On the other hand, ACC operation in most cases of rush-hour commuting on U.S. freeways will indeed require braking capability. The insistence upon braking capability by most OEMs also stems from their market strategy of offering ACC first on luxury vehicles (see the marketing responses under Part G of this section). Most OEM's take the view that the luxury-car buyer in the US will expect the higher functionality, (such as the ability to use ACC while commuting) given the high introductory-level price that is expected for the feature.

An alert which prompts the driver to intervene on ACC operation

9 responses (6 OEMs, 3 Suppliers)

1 Supplier, 4 OEMs definitely see the need for an alert.

1 OEM will not provide such an alert.

2 Suppliers, 1 OEM are undecided on the addition of such a warning, but it is seen as potentially necessary.

Selected Views

- An alert is to be used when the ACC is near the limit of its performance capability.
- An alert will imply to the driver that the present situation is potentially dangerous.
- The alert information is used to remind/support the driver to maintain ultimate control of vehicle.
- 1 OEM does not want to "bother" the driver with such information. Sees information as potentially "annoying" to the intelligent driver.
- 1 OEM: The driver is still ultimately responsible while in ACC mode. They will use the alert information to help the driver adjust to the deceleration limits of the vehicle.
- 1 Supplier: Intervention information could potentially mislead customer into thinking ACC is a collision warning system.

Authors' Comment:

There is a general recognition that as the deceleration authority of an ACC system rises, the need for an intervention alert also rises. An audible and/or visible means of alerting is, however, imagined to be a fairly crude backup mechanism for the intuitive grasp that the driver would ideally derive when a serious conflict is pending, calling for intervention. Thus, it would appear that the more sophisticated system will strive to condition an accurate perception of the system limitations simply by means of its control behavior, with or without an explicit (say, audible) intervention prompt. The controller design may progress toward this goal both by moderating the decel level actually delivered and by smoothing and, perhaps, somewhat delaying the onset of deceleration when responding to the much more frequent, lower-level conflicts through which the driver's mental model of the system is presumably being built up. Then when a substantially greater conflict develops, the driver's visual appraisal of the situation may more readily yield the decision to intervene. One industry conviction often heard in this regard is that people are very smart when it comes to appraising their immediate headway conflicts, as long as they are attentive to watch for them. It's like Yogi Berra said, "You can observe a lot by just watching."

Minimum information displayed to the driver

9 responses (6 OEMs, 3 Suppliers)

2 Suppliers, 5 OEMs require the display of the current set speed value.

1 Supplier, 5 OEMs require display of the target-acquired or follow-mode state.

Selected Views

- There is a rough consensus that some form of display is needed for the driver to note that ACC is in its engaged mode.
- 1 OEM: Driver notification is secondary to the driver achieving a level of comfort with the "handling" of the system.
- 1 OEM, 1 Supplier: Target range information may also be provided, especially to the Japanese customer.
- 1 Supplier: Set-speed display is not recommended.
- 1 Supplier: Note that a perfect sensor needs no "target acquired" indicator.

Authors' Comment:

Most OEMs indicate great reluctance to provide any display item that is not truly essential. Set-speed display is commonly seen as essential because of the concern that the driver be aware of pending system responses when traveling for some time behind another vehicle at a speed value below that of the set speed. That is, the system is "poised" to accelerate automatically, in such a situation, as soon as the lead vehicle constraint moves away. Some features of the display seem to be expected only for the early-generation ACC products, when all customers are neophytes in ACC usage and will thus benefit from display-related aids while learning to use this function. As the product history evolves, many or perhaps all of the displays that are unique to ACC may become unnecessary.

Minimum speed needed before ACC will engage

8 responses (5 OEMs, 3 Suppliers)

2 suppliers, 4 OEMs mention that this speed should be the same as for CCC: approximately 25-35 mph.

Selected Views

- There is general agreement that the initial offering of ACC should mimic the speed envelope of CCC.
- 1 OEM: ACC is only for highway usage. The minimum set speed should actually be higher than that used now for CCC.
- 2 OEMs, 1 Supplier: The minimum set speed will get lower as technology matures, since there are distinct benefits to the ACC function in stop-and-go driving.
- 1 Supplier: Lower (than CCC) speed allowance should only come about if braking system authority is included.
- 1 Supplier: An ACC set speed minimum of around 11mph is needed for European operation.
- 1 Supplier: Regardless of the minimum value for ACC engagement, some systems with braking will continue to decelerate in following a preceding vehicle down to zero speed (if the braking transient began while the ACC vehicle was still above its minimum for engagement).

Authors' Comment:

It appears to be an assumption across the industry (and in the draft ISO standard) that early ACC products are intended for "free-flowing" traffic which can include substantial degrees of congestion, but not the flow instabilities that yield stop and go operations. Nevertheless, the long term desire will be to gradually extend the range of utility of the system into the traffic condition faced by the daily commuter—for example, that of dense freeway traffic which fluctuates broadly across the speed range. The challenges of stop and go functionality arise from the likely desire of drivers to engage such an ACC system while off of the freeway environment whereby the presence of pedestrians, signalized intersections, tight turning and parking movements, and other complexities make the sensing/decision making process much more difficult. An "in-between" case involves the ACC feature by which braking is continued even below the minimum engaged-speed value while following a lead vehicle at close range that began a sustained braking transient from higher speed. This constitutes a special case that is being considered for early ACC systems even though it does result in active system control even down to virtually zero speed of ACC operation. Presumably, the justification is that the operating environment is assured to be relatively simple if the "brake-to-zero" function is only undertaken from an initially ACC-worthy operating condition. Prototype implementations of this feature that are known to UMTRI discontinue all further control if the lead vehicle's braking transient pauses even briefly while the host vehicle is below its minimum engagement speed. Also, these sample systems will not re-accelerate under any conditions when they are below their minimum engaged-speed value.

Other attributes

6 responses (4 OEMs, 2 Suppliers)

1 Supplier, 1 OEM: Some occurrence of false alarms is acceptable; false alarm rate must be low, however.

1 Supplier, 1 OEM: Cost determines the initial level of functionality of ACC. Too much functionality too soon for too much money will result in the failure of the product.

Selected Views

- 1 OEM: The purpose of ACC is simply to relieve the driver's stress.
- 1 OEM: We will define our own specific ACC, not necessarily follow the common ideas.
- 1 Supplier: The initial ACC offering must be simple and direct. Additional convenience will come at a later date, with more legal, market heritage for the product.
- 1 Supplier: They started with collision avoidance under PROMETHEUS, then went to forward collision warning (CW). Eventually, liability concerns caused them to back up even further to the comfort item, ACC. ("It's like ABS, but this time we start from the human factors rather than the other way around.")

Authors' Comment:

The false alarm issue (or more broadly, detection errors of various kinds) is of concern across the industry. The detection performance of sensors will continue to improve, but market pressures seem to be causing movement into product decisions while a substantial degree of unreliable detections is still occurring. The common automaker's question is, "how much will the customer be bothered by occasional glitches that are probably felt as accel or decel pulses?" Concern over this issue will probably tend to encourage softer control loops and thus less crisp system response in the initial product offerings, thereby muting the drivers sensation of errors in detection and tracking.

Part B

Comment on the technology that will be used for ACC to achieve:

Range and range-rate sensing

10 responses (6 OEMs, 4 Suppliers)

Radar or infrared (IR) ranging sensors are the two most common technologies for ACC implementation.

General consensus exists on the existence of trade-off between IR and radar technologies in terms of cost versus performance, with a broad preference for radar.

Selected Views

- 2 OEM, 1 Supplier: Millimeter wave radar is the best option for ACC.
- There is a view that IR is good enough for initial systems, but radar is necessary for higher performance ACC systems and for later implementations of ancillary CW/CA functions
- 1 OEM, 1 Supplier: An additional consideration exists with radar in terms of manufacturability: process variation may require manual tuning of sensor, at a higher cost.
- 1 OEM: IR systems are more feasible in the European market, where windshields do not block IR as heavily.

Authors' Comment:

IR sensors have been vigorously developed in Japan and have been selected for both ACC and forward collision warning products that have already reached the domestic Japanese market. Widespread use of IR sensors in ACC prototypes during the PROMETHEUS program has not been followed by broad adoption of IR technology in the current product development phase in Europe. The trend toward a more universal selection of radar sensors in ACC products in most market regions seems to be driven by A) continuing progress by radar sensor developers toward attainment of both cost and performance targets, B) growing insistence by OEMs that the early ACC offerings in luxury cars must offer high functionality (i.e., virtually all-weather availability) in order to justify the high introductory price and C) sober awareness that placement of IR sensors behind windshields, at least for the U.S. domestic market, is simply not going to happen due to more or less irreversible investments in glass production plants that embed IR shielding within the windshield glass, itself. On the last item, the windshield situation is a powerful barrier since it appears to be quite difficult to ensure that an outside-placed IR sensor performs suitably well under many conditions of winter precipitation and wintertime salt coatings in the northerly tier of states.

The university's experience with IR sensors in its current fleet of ACC field test cars indicates that if there were no wintertime issues, IR sensors can support ACC operations over virtually the entire range of precipitation conditions in which the level of visibility is still sufficient to support vigilant driving.

Tracking of targets on curves and curve transitions

9 responses (5 OEMs, 4 Suppliers)

All 9 interviewees note the necessity of some form of vehicle state information to successfully track targets through curves.

Differences exist on the conception of technology required to achieve curve-tracking ability.

Tracking across curve transitions calls for technology solutions that are not generally available at present

Selected Views

- 2 OEMs, 2 Suppliers: Use vehicle yaw rate in projecting the host-vehicle's path.
- 2 OEMs, 2 Suppliers: Develop a video image approach for analyzing the driving situation and determining curves and curve transitions.
- 1 OEM, 1 Supplier: Explore an on-board navigation system approach to detect curves and transitions. This would require the use of global positioning system (GPS) in the navigation system and a matching micro-geometry map database.
- 1 OEM, 1 Supplier: Use differential wheel velocity to deduce current curve radius—an existing element of information already commonly available on ABS equipped vehicles.

Authors' Comment:

The tracking of targets through steady-state turns seems rather straightforward at this point, using yaw rate and/or wheel speed and/or steering wheel angle information. The step up to a supplemental imaging system offers not only to handle curve transitions better, but also to more tightly contain the selection of the proper vehicular target ahead as the object for ACC headway control. Presumably, addition of a vision system has the eventual benefit of transitioning the ACC function toward collision warning (CW) and collision avoidance (CA) enhancements. While a number of parties have shown good vision imaging performance under conditions of favorable illumination, weather, and roadway reflectance, the robustness of such technology covering all driving conditions still has a long way to go.

Actuation of the service brakes

9 responses (5 OEMs, 4 Suppliers)

4 OEMs, 2 Suppliers want braking employed in ACC operation, using some form of command from ACC algorithm to the braking system.

1 OEM does not want to use braking system authority in ACC algorithm, due to liability issues.

Selected Views

- 2 OEMs, 1 Supplier: They intend to implement braking system via commands to the traction control system of the vehicle—this will maintain stability of vehicle during speed adjustment.
- 2 OEMs, 1 Supplier: They envision the use of an electronic, or "smart" vacuum brake booster to provide braking assistance to ACC (this adds cost over that of conventional platforms).
- 1 OEM: The need exists to limit systems that decelerate the vehicle. They do not want the system to be able to bring the vehicle to a complete stop.

Authors' Comment:

The implementation of brake control seems to be only a cost issue and not an issue of the state of technology. Very sophisticated forms of electronic control of braking already exist in most luxury models. Since braking via the traction control feature on 2-wheel drive vehicles presents the possible handicap of excessive friction utilization on lower-friction surfaces, it might be expected that the installation of traction-control braking modulators would be simply extended to cover all four wheels. Individual wheel-level braking control of this type already exists in support of dynamic stability enhancement features already available in various vehicles.

Part C

Comment on the challenge for ACC in relation to its:

Compatibility with other features of the motor vehicle

8 responses (5 OEMs, 3 Suppliers)

There is general consensus that ACC is compatible with other vehicle systems.

The concern is more related to the success of integrating ACC into existent vehicle electronic architectures.

Selected Views

- 3 Suppliers, 1 OEM: Vehicle styling is a significant concern. This deals with placement, materials, and space requirements of sensor antennas (or optical modules).
- 2 OEMs: ACC must be compatible with CCC elements of the engine controller and the man-machine interface (MMI).
- 2 Suppliers: Ability to share the sensor output data is needed to allow the implementation of other driver-assistance features.
- 1 OEM: There is mild concern with electromagnetic radiation from the ACC sensor and perhaps from exhaust emissions associated with ACC throttle modulation

Author's Comment:

The styling integration of ACC sensors is clearly a major issue that governs the product potential of any given concept. Some OEMs have advised us that interior mounting of IR sensors is simply unacceptable to their stylists because of its intrusive profile, whether the IR-blocking windshield problem can be solved or not. All OEMs indicate that integration of radar antennas into the grille or bumper areas must be done more or less transparently from the stylists' point of view (unless at some time in the future the mere presence of such antennas may emerge as a status feature, whereupon the antenna will be made apparent in some subtle way.) Clearly, the movement into the 77 GHz range of radar frequencies was driven strongly by concerns for the smaller antenna sizes that could be more readily integrated into the styling.

Integration of the ACC system from the viewpoint of automotive electronics seems to be a non issue. The modern motor vehicle has become so sophisticated and reliable in

terms of supporting serial communications, computing, self-diagnostics, and so on, that ACC appears to be simply another set of modules on the network.

Complexity as a vehicle subsystem

8 responses (4 OEMs, 4 Suppliers)

Complexity of system is not a major issue.

2 OEMs: ACC system should be as similar to CCC as possible in order to avoid the risk of introducing too much complexity into initial system.

Sensor reliability and liability of false detection presents the biggest complexity issue.

Selected Views

- 1 OEM: Sensor maintenance/repair will be too complex for dealer service—unit must be sent to factory!
- 1 Supplier: Level of complexity of ACC for suppliers is determined by their level of participation in the total system. If the total system is supplied, then there is more of an issue with complexity than simply supplying a sensor to perform a specific task.

Authors' Comment:

The respondents dealt with this question as it pertains to the complexity of the modules that will be installed as a subsystem on the vehicle. In this regard, the general impression is that ACC is not altogether more complex than say the various drivetrain and chassis control subsystems (perhaps with special recognition that the front-end processing of radar and IR signal returns and optical images constitute remarkable achievements in their own right). Another slant on the complexity issue could pertain to the issues of human interaction with ACC and many questions of driver adaptability, risk modification, readiness to intervene properly, and so on. Although the interviews did not dwell on driver-use complexities at any length, the authors have the impression that the interviewed parties varied widely in their familiarity with and confidence on such matters.

Technical uncertainty, as seen in 1996

8 responses (5 OEMs, 3 Suppliers)

The major source of technical uncertainty is in the ACC sensor. This is the most complex and least mature part of an ACC system.

The majority of responses fall into two categories: the uncertainty in reliably detecting and acting on vehicle targets, and the manufacturability of the sensor module to meet all performance and cost targets.

Selected Views

- 2 OEMs, 1 Supplier: Sensor robustness and target detection accuracy are the most uncertain aspects of ACC operation.
- 1 OEM, 2 Suppliers: the manufacturability of the ACC sensor is technically uncertain, in terms of ability to manufacture the sensor at a reasonable cost while maintaining performance and in terms of manufacturing the sensor to operate reliably over the life cycle of the vehicle.
- 2 OEMs: The perception of the customer in terms of the aforementioned technical uncertainty in the system operation is important. This relates to the knowledge the user has of the performance limitations of the ACC feature.

Authors' Comment:

Delays in the development of product-ready sensors are most often cited as the reason for postponed introduction of the ACC feature as an automotive option. In fairness to the sensor developers, however, it appears that the sensing requirements have been a moving target over much of the last decade of automotive interest in this feature. The movement of these targets has been propelled by the steadily broadening understanding of the OEMs on what the ACC functionality actually demands over the tremendous distribution of driving conditions that will be encountered. As with many product innovations, a certain basic functionality might not be too hard to achieve, but the devil lies in application requirements arising from phenomena that manifest themselves rarely, but insistently. The radical nature of the ACC function has also carried with it the need to structure a corporate philosophy toward this product. Evolution of the philosophy has in turn contributed its own twists and turns to the product's requirements and thus to the uncertainty over when ACC will be ready for production.

Introduction vis-à-vis crash warning/avoidance products

9 responses (5 OEMs, 4 Suppliers)

The relationship of ACC to CA/CW systems differs depending on the market in question (i.e., U.S. vs. Japan *and* Europe, in general).

There are two contrasting views on the relationship between ACC and CA/CW:

- 2 OEMs, 2 Suppliers: ACC is an entry point into the introduction of CA/CW technologies, since ACC includes the sensing technology which characterizes the extravehicular environment within which crash-threatening conflicts arise.
- 3 OEMs, 1 Supplier: ACC is primarily a comfort/convenience feature, and CA/CW systems will need separate introductions since these are primarily safety devices.

Selected Views

- 2 OEMs: The need exists for government intervention/action to introduce CA/CW technology. This need arises from the lack of customer awareness with CA/CW, as opposed to the familiarity of users with conventional cruise control.
- 1 Supplier: ACC and CA/CW are symbiotic in the mind of the OEM. Eventual CA/CW compatibility will be necessary in implementing an ACC system.

Authors' Comment:

There is, firstly, a highly-charged semantics problem raised by the terms "convenience" and "safety". In one sense, the semantics distinctions are simply silly. A jury of lay people may well make its own observations on the functionality of ACC, regardless of the terms that were written to describe the system in the owner's manual. Nevertheless, the selected terms seem to have profound significance within the auto companies themselves as they anticipate how their respective products will be perceived and judged. Our interview question was intended to expose the marketing strategies that would distinguish a function whose engagement was *manually* switched (that is, ACC which is engaged by means of its ON button and its subsequent SET or RESUME buttons) from one or more CW or CA functions that stand ready to engage *automatically* on a full-time basis. Analagous full-time systems would obviously include the air bag and the ABS or ATC packages.

Taking sides on the semantics issue, the authors suggest that an ACC system that is actively controlling throttle and brakes to manage the headway to a preceding vehicle is manifestly managing a crash threat, albeit in a driving mode which the driver has consciously elected to engage. Thus, the introduction of additional layers of crash-threat management by means of CW and/or CA functions of any other kind will simply constitute changes in the *degree* of equipping the vehicle with technology for active safety. ACC will, by itself, usher the company markedly into the era of active safety technology (if ABS and automatic stability control, ASC, products have only marginally done so) by presenting a product which directly manages an intervehicular crash threat to its owner. Note that ABS and ASC do not manage crash (i.e., collision) threats, but rather manage threats to loss of control.

Part D

What is the importance as impediments/accelerants to an ACC market of:

NHTSA regulation/specification/defects authority

9 responses (6 OEMs, 3 Suppliers)

2 OEMs, 2 Suppliers mention NHTSA participation as useful to mitigate liability for the operation of an ACC system.

NHTSA involvement in writing system specifications is generally regarded as intrusive to the market development of the technology.

Selected Views

- 2 OEM, 1 Supplier: The Collision Avoidance Metrics Program (CAMP) is beneficial for Ford, GM and NHTSA for jointly advancing the means to evaluate systems like ACC while avoiding FMVSS action.
- 1 OEM: NHTSA involvement in collision avoidance regulation or development is a beneficial means of increasing public awareness of such technology, but may also confuse ACC with CW or CA.
- 1 OEM: NHTSA should play the role of technology observer, not technology director.

Authors' Comment:

The respondents felt that, in the currently exploratory stage of ACC technology development, any NHTSA initiative would curb the development of ACC's full potential.

While government/industry collaborations are viewed as being positive for R&D, federal involvement at this time is seen as having a restricting influence. However, there is general acknowledgment that there would be some liability mitigation if ACC is developed according to a federally mandated specification.

These views seem mutually contradictory, in practical terms, as if the industry would like to have its cake and eat it too. The only federally mandated specification of which NHTSA is capable is a federal motor vehicle safety standard. Such standards will, by nature, be restrictive to product design. NHTSA can, on the other hand, simply participate with industry in defining a specification which might be accepted by industrial standards bodies such as the International Standards Organization (ISO) or the Society of Automotive Engineers (SAE), (although such standards often tilt toward allowing for many variations in the application—perhaps failing to offer the degree of restriction that could unburden automakers from some of the liability for ACC design.) The authors observe that NHTSA has a statutory mandate to concern itself with the safety implications of ACC or any other potential feature of the OEM motor vehicle. Thus, some degree of exploration of ACC by this agency is inevitable. As long as the USDOT is being pressed by Congress to show public value for its participation in the ITS program, NHTSA will feel internal pressure to pursue ACC or any of the CA and CW functionalities that may promise a payoff in reduced traffic accidents.

International standards (especially via ISO TC204)

10 responses (6 OEMs, 4 Suppliers)

A standard on ACC technology can be limiting or beneficial. The main concern is to what extent the standard dictates the technology to be incorporated into an ACC system.

5 OEMs, 2 Suppliers view standards as beneficial to help harmonize the technology across global markets and to promote the ACC product.

Selected Views

- 3 OEMs: The differences between the requirements of US and foreign markets is impeding the development of a global standard on ACC technology.
- 1 Supplier: The development of a standard in automotive markets is destructive to the competitive advantage of individual companies.
- 1 Supplier: The development of standards is less important than regulatory actions taken by governments.

Authors' Comment:

The development of a standard is not seen as imperative by all of the respondents. This situation accounts for much of the lack of consensus in the ISO TC 204, WG-14 committee that is striving to create a standard on ACC. Firms acknowledge that a standard would help further ACC along the product development cycle from R&D to commercialization, but conflicts in requirements and system definitions arise from the fact that ACC has been developing along different functional trajectories in Japan, Europe, and the U.S. Clearly, the differing legal environments tend to strongly differentiate the parties that must collaborate to create a global standard for ACC.

Tort liabilities posed by ACC

8 responses (5 OEMs, 3 Suppliers)

Tort liability is viewed generally as a very important issue, since all manufacturers have aspirations for an ACC market in the US.

Overcoming liability is not viewed as impossible, however the liability of ACC is seen as widely dependent on the market into which it is introduced.

Selected Views

- 2 OEMs: Some government regulation/standardization is viewed as helpful in defining the limits of liability for the manufacturers.
- 2 OEMs: This is the biggest issue in the development of ACC systems.

Authors' Comment:

Inter country differences are felt most keenly in the area of tort liabilities. In comparing the U.S., Japan, and Europe, it is clear that the U.S. has the most litigious environment and Japan has the least. Consequently, in a market where liability is a small concern, manufacturers feel the freedom to innovate actively without constant fear of legal reprisal. The consumer's expectation of the product takes into consideration the fact that the product is new and may be imperfect in its functionality. This environment is conducive to the commercialization of a new product such as ACC whose eventual success may depend significantly upon experimentation with many technical alternatives and on feedback from experience with the initial product offerings. Nevertheless, it is interesting to note that German automakers that are known to be eagerly moving ahead toward the launch of ACC products are also keenly sensitive to performance issues that might be perceived as compromising safety. One should observe, then, that most modern auto manufacturers are very attentive to the safety of their customers since safety, and the

perceptions thereof, are central to the enduring relationship between a manufacturer and his customer, regardless of anybody's threat of lawsuit.

Gross traffic flow impacts of ACC at high penetration levels

7 responses (5 OEMs, 2 Suppliers)

3 OEMs do not see any great importance in this issue.

Other respondents have not given the issue serious thought.

Selected Views

- 1 OEM: The proliferation of ACC products and their use will be beneficial to the transient response of traffic flows.
- 1 OEM: The trade-off between traffic efficiency and safe following distance is important. This will impact traffic flows, but this impact is secondary.
- 1 Supplier: This issue is entirely within the domain of the OEM.

Authors' Comment:

Concern for traffic flow is traditionally the province of the traffic engineer, an employee of the public sector using professional techniques and tools generally unknown by the automotive professional. Thus, it is probably not apparent to automotive developers of ACC that the traffic engineer has virtually no basis for projecting the impact of ACC on traffic flow. None of his tools and techniques are very useful in anticipating the net effect of the new traffic dynamic arising from high-volume penetration of ACC into the vehicle population. Nevertheless, while the automakers may not be, themselves, in a position to anticipate the impact of ACC on traffic, it does seem that they have every reason to want its impact to be positive, or neutral, at worst. A research collaboration between, say, the Federal Highway Administration, and the parties developing automotive ACC products would seem warranted to address this important long term issue. If certain ACC features are later seen to cause gross reductions in freeway traffic capacity, a public uproar could ensue that might jeopardize the further opportunity for this product.

Insurance incentivization

5 responses (4 OEMs, 1 Supplier)

Four of 5 respondents do not see any potential insurance incentivization from ACC.

No respondents felt the issue to be of great importance.

Selected Views

- 2 OEMs: The reason for no insurance benefit is that ACC is not viewed as a safety product; rather, it is a convenience item.

Authors' Comment:

Recent bad experience by auto insurers with their incentivization of ABS seems to have soured the insurance industry to some degree along these lines. The view seems to be that some compelling evidence of safety benefit from ACC would have to be shown from actual crash experience before an insurance incentivization could even be considered.

Findings from field operational testing (FOT) of ACC

6 responses (5 OEMs, 1 Supplier)

FOT results are beneficial to determine specific customer wishes and product acceptance.

FOT results can provide information about specific aspects of ACC development.

Selected Views

- 1 Supplier: Useful information should include customer willingness to pay for ACC and ACC options.
- 1 OEM: findings of field operational testing could be used to reduce the tort liability of ACC

Authors' Comment:

UMTRI will complete its Field Operational Test of ACC in late 1997. This field test employs ten 1996 Chrysler Concorde sedans equipped with an infrared sensor whose outputs are used to control throttle and transmission downshift in managing speed and headway. The results of this work will shed a good deal of light on issues of customer acceptance, safety implications, ACC utilization, mechanisms of ACC interaction with driving style, willingness to pay, and so on. Subsequent field trials will be necessary to gain comparable insights on ACC systems having the higher decel authority levels provided by brake actuation.

Part E

Please comment on your own situation as an ACC-interested firm:

What is your organizational structure for ACC development?

5 responses (5 OEMs, 0 Suppliers)

The majority of respondents cited a joint development activity as on going.

ACC is developing within advanced research and development entities of the companies.

Selected Views

- 1 OEM: There is no structured organization, but a single investigative entity involved in ACC analysis.

Authors' Comment:

The organizational structure to facilitate ACC development is not consistent across the respondents. While none perceive ACC to be simply an R&D activity at this stage, some companies have joined their research groups with vehicle platform developers, and others have placed the work squarely within the product platform teams, alone. In most cases, organization for ACC development follows a path that has been historically followed by each company in developing other electronics-heavy innovations to the product line. Those firms with a history of outsourcing or of rather independent internal development by platforms appear to be following the same route for ACC. Those firms with a strong history of technological leadership and R&D are attempting to maintain their image of

technological superiority through ACC development even though they might eventually transfer the technology and manufacturing expertise to an outside supplier.

How would you describe the involvement of management in ACC development?

4 responses (3 OEMs, 1 Supplier)

Three of 4 respondents mention positive and active support from management.

Selected Views

- 1 OEM: The exhibition of the technology through the PROMETHEUS program pushed ACC development forward a great deal.
- 1 OEM: The market potential in Europe is a catalyst for fueling management interest in ACC development.

Authors' Comment:

The active participation and encouragement of management is evident where ACC development is taking an aggressive pace. The strategic posture of the firm and the extent to which the management feels that ACC could be a source of competitive advantage is signaled by the formalization of the ACC development process and the resources devoted to the program. Some respondents feel that the ACC is inevitable and is a great opportunity waiting to happen. Accordingly, the top management has made adjustments to foster the creative development process. Where the top management team is ambivalent toward the commercial feasibility of ACC in the near future, the subject is being carried only as a peripheral research activity.

With whom have you partnered for ACC development?

7 responses (5 OEMs, 2 Suppliers)

4 OEMs, 2 Suppliers have partnered with outside vendors to create a system design.

Selected Views

- 2 OEMs: System design competency exists in-house. They are looking for capable component suppliers.
- 1 OEM: In-house capability is not being developed; rather, they seek a complete system to be provided by a supplier.

Authors' Comment:

Those OEMs who have a history of working in sensor or system development and have developed the technological capability to explore new opportunities in sensor applications appear to be devoting significant resources to ACC research within their own organization. However, these capabilities do not seem to be precluding their interest in other sensor vendors who may be able to resolve the technical problems of the ACC application. Other OEMs appear to be content to simply rely on external sources to develop ACC to their specifications. It is obvious that since ACC must be deployed within the context of a highly integrated automotive platform, suppliers must work closely with OEMs throughout the ACC development phase in order to have a chance at getting the business. Further, it is not surprising that nonautomotive organizations specializing in radar, infrared, and video sensing technologies have been bought by, or are otherwise partnering with, companies that are already established as core suppliers to the OEMs.

What are your specific technical/product competencies for ACC?

7 responses (5 OEMs, 2 Suppliers)

OEMs possess the system integration capability to develop ACC, and most of the suppliers are more competent in specific component design.

Selected Views

- 2 OEMs, 1 Supplier : System integration capability is a core competency.
- 1 OEM: They have first-hand experience with developing their own distance control system.

Authors' Comment:

The specific competencies that seem to be valued for ACC development are in the development and manufacturing of sensors and in systems integration. The supplier industry, as indicated earlier, is still heavily engaged in advancing the sensor technology for ACC, although generally without having competencies in both IR and radar technologies, at the same time, inside of a single organization. OEMs appear to be quite open to many alternatives that might add to the systems' solution, although some started on this path over ten years ago such that a substantial "hardening" of their selection options has already occurred. Suppliers, on the strength of their respective proprietary technologies, have each been constrained to advance only a few among the many conceivable approaches toward a winning sensor technology. The radar suppliers, in particular, have sorted themselves out along lines of favored schemes for modulating and,

processing their signal transmissions. Their research tends to have less variety but more focus since it is almost imperative that the supplier prove the superiority of their specific technology in reaching the low-cost, high-performance targets. Suppliers with strong systems-integration capability have figured strongly in the joint development efforts with most OEMs, even through the OEM may intend to purchase only a rather isolated module such as a sensor. Interestingly, some suppliers undertook to build their own ACC demonstrators on the strength of their own integration engineering efforts, simply to have a "talking piece" from which to introduce their sensing capability to the OEM. The resulting savvy over integration issues presumably positions such suppliers better to work with the OEM, having gained a broad systems perspective due to the creation of full working prototypes.

Why did you choose to develop ACC?

7 responses (5 OEMs, 2 Suppliers)

OEMs entered into ACC development on the expectation that ACC will find an active market as an enhanced comfort feature. Some also feel that ACC will serve as the crucial "stepping stone" to more advanced active safety technologies.

Tier 1 suppliers to the OEMs entered into ACC development to maintain advanced technology capability and their Tier 1 status in the face of potential competition from others. Isolated developers of sensor technology sought to find a market for their products, even if necessarily joining with an OEM-sanctioned automotive supplier to gain the opportunity.

Selected Views

- 1 OEM: There seems to be a unilateral opinion that ACC is beneficial to the customer.
- 1 OEM, 1 Supplier: ACC is an initial technology leading to advanced CW technology, and the reason they are developing ACC is due to this perceived progression of the technology into CW.

Authors' Comment:

There is virtually no controversy that customers will be attracted by the functionality of ACC, according the respondents. Also, ACC seems to be a natural "next generation" enhancement of the existing systems. Cruise control and the limited introduction of distance warning systems were mentioned as related precursor products, but one could also consider the host of other electronically controlled functions of the drivetrain and chassis subsystems as helping to set the scene for ACC. Further, ACC is purported to be on the technology trajectory of active safety device concepts, (and that is largely their

status, at present) many of which depend upon remote sensing of objects in near proximity to the host vehicle. The development of ACC, according to both OEMs and suppliers, is seen simply as a competitive necessity. Noting that OEM products across the world are very similar in most respects, ACC constitutes a bold, differentiating feature that is especially well suited to those automakers who have established their corporate identities as pioneers in safety and convenience.

What other similar initiatives have you undertaken?

8 responses (5 OEMs, 3 Suppliers)

3 OEMs have participated in or initiated automated highway system research activity.

2 OEMs have also mention advanced safety vehicle project participation.

Selected Views

- Blind spot detection, ABS development, and vehicle navigation technology are other activities mentioned.

Authors' Comment:

Similar initiatives aid the organization to manage new technology development effectively. Prior experience in advanced technology development has been an asset to the firms interviewed. A number of the respondents have been focusing on extending the use of sensors, per se, for automotive applications. Initiatives through government / industry collaborations such as advanced cruise assist research in Japan, PROMETHEUS in Europe, and the automated highway system and NHTSA cooperative agreements in the U.S. have provided a supplemental impetus to direct research energy onto ACC. The possibilities that open up due to new technology cannot be anticipated. As one respondent suggested, it was only after ABS was incorporated into the vehicle that a whole string of new functionality followed from the on-board availability of wheel spin-rate data including ATC, ASC, low-tire pressure warning, and miscellaneous enhancements to the drivetrain. Some expect that the availability of near-field data from remote sensors will have a similar cascading effect on feature innovation.

Part F

Please address your expectations on market issues.

Do you expect that prior ACC product experience in europe or Japan will be crucial for the early entrants into the U.S. market?

9 responses (5 OEMs, 4 Suppliers)

1 OEM, 3 Suppliers: Prior experience in other markets is beneficial to varying degrees.

4 OEM, 1 Supplier: Prior experience is not crucial. The question implies a tradeoff between introduction across the markets or in a sequential manner.

Selected Views

- 1 OEM, 1 Supplier: ACC launch experience will come from the luxury segment first and then will expand into other market segments.

Authors' Comment:

The general sentiment appears to be that the U.S., Japanese, and European markets are sufficiently different that experience in one region is not going to significantly influence the introduction in another. However, any experience is better than no experience, especially when the technology is new and the initial product is marginally experimental. Experience with actual customers in real driving situations provides feedback about how ACC works as a system and about any operational conflicts that ACC may introduce due to its interfaces with other vehicle elements. The information relating to the technological dimensions of ACC will be useful regardless of whether the feedback is from Europe, Japan, or the U.S. although differences in system configuration needed by the various markets may tend to blunt the level of such usefulness.

Are you planning to introduce ACC in Japan, Europe; U.S.? When and in what order?

8 responses (5 OEMs, 3 Suppliers)

There exists an apparent lack of uniformity in where ACC will be launched first, but almost all launches are planned for year 2000 and beyond.

The choice of initial market into which ACC will be launched is tied closely to the home market of the manufacturer.

Selected Views

- 2 OEMs plan for a launch in Japan as their first entry.
- 3 OEM and 1 Supplier plan for U.S. as their initial launch.
- 2 Suppliers plan for an European launch first.

Authors' Comment:

The home market of the respondent is the typical, but not exclusive, choice for launching ACC products. An early launch, regardless of the location, is likely to be especially valuable analytically, but differences in the social, institutional, and traffic environments of Europe, Japan, and the U.S. are sufficiently different from one another that market experience in one sector doesn't simply predetermine experience in another. Therefore, to be a global competitor, adjustments have to be made to accommodate the differences in respective markets. The suppliers seem to have greater flexibility in terms of where they can introduce the product since many are working with a variety of OEMs concurrently. Although a few OEMs have either already launched, or have announced an ACC product introduction date, the general sentiment is that broad marketing of ACC across more than, say, 3 or 4 vehicle platforms will not occur in any market until after the 2000 model year.

What dealer-based activities are anticipated to support ACC introduction in the U.S.?

7 responses (5 OEMs, 2 Suppliers)

4 OEM, 1 Supplier: Some form of dealer training activity is anticipated to launch ACC. This training is meant for either the sales staff or the individual buyer.

Selected Views

- 2 OEMs: Demo ride or video of such is important to educate customers.
- 1 OEM: Dealers should be educated in the new maintenance issues posed by an ACC option.

Authors' Comment:

The dealer is likely to be a significant factor for the eventual success of ACC. Since ACC significantly alters the driver's role in vehicle control, it seems that a distinct communications challenge will exist to ensure the safety and product satisfaction of new ACC customers. The experience with ABS and the driver confusion stemming from pedal feel phenomena during ABS actuation is an exemplary case in point. Only after a great deal of negative feedback from the field did an ABS supplier consortium emerge to undertake a driver orientation/education initiative on behalf of increased product satisfaction. Since driver understanding of ACC will be very superficial until at least a brief episode of ACC driving has been experienced, the clumsy question of taking a meaningful test drive also arises. But many dealers are situated in an area which is rather far removed from a road segment that suitably supports ACC driving, such that a demo drive may be implausible. Moreover, the authors' impression is that ACC developers and product planners have not generally given much substantive thought to the issue of dealer role, aside from the classical considerations that the product must be maintained through dealer repair facilities.

What steps may be taken to make ACC more observable to potential customers?

8 responses (5 OEMs, 3 Suppliers)

Responses concentrated either on exterior/ interior markings to highlight the ACC-equipped vehicle or on methods by which product functionality awareness can be achieved.

Selected Views

- 2 OEM, 1 Supplier: Logo badge or similar marking on vehicle may be desirable to identify vehicle as ACC-equipped.
- 3 OEM, 1 Supplier: Active promotion of product functionality is desired.

Authors' Comment:

In general, ACC has not progressed to the stage of product development where the firms are concerned actively with its marketing aspects. Many new technologies have been diffused and become widely accepted through creative marketing. For example, new technologies have been introduced in the automobile market through specialized logos or acronyms emblazoned on back or side panels. Many cars, for example, have sported vanity designations such as Electronic Fuel Injection (EFI), ABS, 24-Valve Engine, and so on to increase the awareness among the driving public that such options exist and are desirable. While the respondents were concerned predominantly with ACC's technology and functionality, some felt, after the question was posed and elaborated upon, that ACC, too, would need active promotion. The idea that the ACC sensor itself could be a marketing tool is interesting and thought provoking. The need to educate the customer about the use and limitations of ACC is also acknowledged.

Authors' Comment:

The general thought is that ACC is likely to grow slowly, partially or wholly replacing the present CCC product in the long run. ACC is seen as a viable option in Europe where CCC has not enjoyed much of a market to date due to its low utility on a road system that is very heavily trafficked and has relatively short stretches of open rural mileage. From the point of view of one supplier company, the size of the market for an individual ACC product is initially likely to depend on the extent to which the corresponding OEM is risk averse. That is, the greater the risk the OEM is willing to take by offering a high level of ACC utility (perhaps expressed by a high level of decel authority), the larger the initial market for the system may be, assuming that cost is not out of line. Generalizing most simply, growth in the ACC market will be defined by the classical customer judgment of value received for the price that was paid.

Part G

Please comment upon:

The likely size and pace of growth of an ACC market in the U.S.

8 responses (5 OEMs, 3 Suppliers)

The market will grow slowly. Respondents feel ACC will replace some specific percentage of the existing CCC market in the U.S.

Selected Views

- 1 OEM: Some equilibrium between CCC and ACC will evolve, ACC achieving a different percentage of the segment based on vehicle platform.
- 1 OEM: Eventually ACC will replace CCC altogether.
- 1 Supplier: ACC is more likely to penetrate markets with less significant CCC heritage.

Worthy analogues for estimating this market

8 responses (5 OEMs, 3 Suppliers)

Two most frequently mentioned analogues:

ABS (1 OEM, 2 Suppliers)

CCC (3 OEMs)

Selected Views

- The rate of market penetration that ACC is likely to follow will depend on whether the market perceives it as a convenience or safety feature. CCC is likely to be the analogue for a minimum rate of ACC market growth.
- 1 Supplier: ACC will likely follow the same path and time frame of market penetration as remote keyless entry systems.

Authors' Comment:

The issue of market estimation through the use of analogues is typical for a new product whose technology is new to the producer and whose functionality is new to the consumer. The CCC analogue is logical since it is expected that consumers may perceive ACC as an enhancement of CCC. However, the researchers, engineers, and developers who are familiar with the technology are aware of ACC's safety implications such that the ABS analogue seems to provide a framework for analysis on that basis. Section 4 deals with forecasts and volume estimation in greater detail.

The cost to the car buyer of the ACC product

8 responses (5 OEMs, 3 Suppliers)

Range of cost estimates of ACC system: $100-$400 for a simple system with basic functionality to $1000 for a standard ACC package.

3 OEMs, 1 Supplier: The initial cost will be significantly greater on a per unit basis.

Selected Views

- 2 OEMs: ACC target cost is the current cost of CCC.
- 2 OEMs: ACC should be marketed as part of an option package, not as a stand-alone option.

Authors' Comment:

The initial cost of the system to the car buyer will certainly be high due to the high development costs of the sensor. As the uncertainty surrounding the technical configuration resolves, the opportunity for volume manufacture arises, lowering the cost. It is realistic to expect that the OEMs and suppliers will not be able to fully recover the cost of developing the product through their initial offerings in luxury cars. Nevertheless, initial losses will be offset by valuable information gained through manufacturing and maintenance experience, through customer feedback, and through the opportunity to influence other potential buyers. The price estimates offered by the respondents range from 1% to 4% of the luxury car price. In order to achieve wide acceptability of ACC products, although perhaps at some reduced level of functionality relative to the luxury offerings, price points of the order of 2% to 3% of the total price for a mid-size car are expected to be needed to attract approximately 85% of the automotive market. Such vehicles account for about 15% of the total car/truck market. We note that the current prices of the ACC option in Japan are at $610 on the Toyota Celsior and at $3,180 on the Mitsubishi Diamante. European sale of ACC on the Mercedes S-Class sedan in MY 1998 is expected to appear at a price of approximately $1700.

Where in the auto product line will ACC be introduced?

9 responses (6 OEMs, 3 Suppliers)

All 9 respondents cite luxury vehicles as the point of initial introduction of ACC systems.

Selected Views

- 1 OEM, 2 Suppliers: Sports Utility Vehicles (SUVs) will also receive the ACC option at an early stage.
- 2 Suppliers: Manufacturers are looking at the possibility of introducing CW and ACC on lower-end vehicles.

Authors' Comment:

The obvious expectation is that ACC will follow the tradition of first introduction on the luxury car platforms. This classical marketing approach is driven by the high initial cost of the system, the predisposition of luxury car buyers to value comfort and convenience features, and the limited exposure to risk that the lower-volume platform poses for this new initiative. By way of example historical precedents, cruise control, power steering, ABS, and air conditioning all had their introduction and, indeed, nearly 100% penetration in the luxury segments before the option was offered on a more

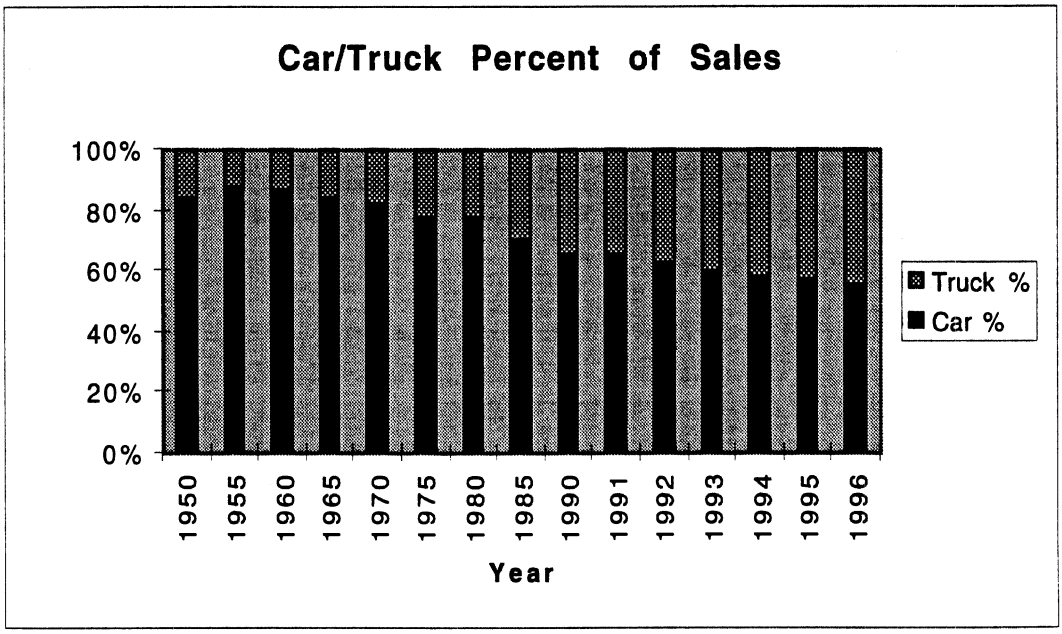
widespread basis. The recent popularity of high-end SUVs and minivans could also serve to support early market offerings of ACC. ACC is unlikely to be offered in vehicles below, say, the $30,000 price threshold until good experience with the initial luxury-car products and price reductions based upon volume make the business case acceptable. The prospect for CW products in mid-scale passenger vehicles is interesting but seems to depend upon the successful market and litigation experience with ACC products before it will be considered as a serious possibility for the U.S. market.

4.0 Implications for ACC Strategy and Marketing

The technological refinement of ACC is proceeding steadily while firms acknowledge that some challenges still exist before ACC can be successfully commercialized in the U.S.. This section looks at the competitive landscape and addresses certain strategic implications given the current technological and legal environment for this product. The size of the targeted segments of the light vehicle market are considered, followed by estimates of potential market penetration under different conditions, using analogues suggested by the respondents and using other relevant archival data (Thomas 1993).

ACC Forecasts - Market Opportunity

The forecast discussion begins with an examination of the population of vehicles whose market segments are to be targeted for ACC introduction. Our respondents consistently indicated that ACC will be introduced in the luxury platforms first, but light trucks (i.e., pickups, SUVs, and vans) may also be included among the platforms targeted for early ACC marketing. Inclusion of the upscale end of the light truck market is certainly understandable given the rapid growth of this segment and the expansion of feature content in these product lines over the last several years.

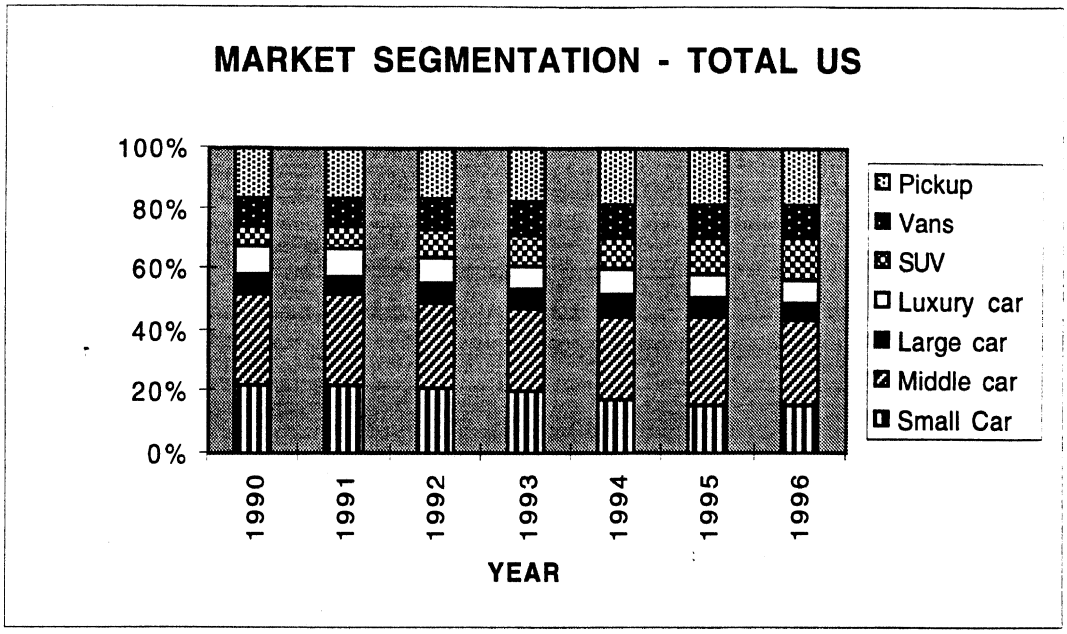


Source : Ward's Automotive Yearbook

Figure 2

The growing size of the light truck market as noted in Figure 2, for example, is the proportion of cars and light trucks sold in the U.S.. We see that light trucks

accounted for less than 20% of the U.S. market in 1975 but have grown from 34% to 45% of the total light duty vehicle market since only 1990.



Source : Ward's Automotive Yearbook

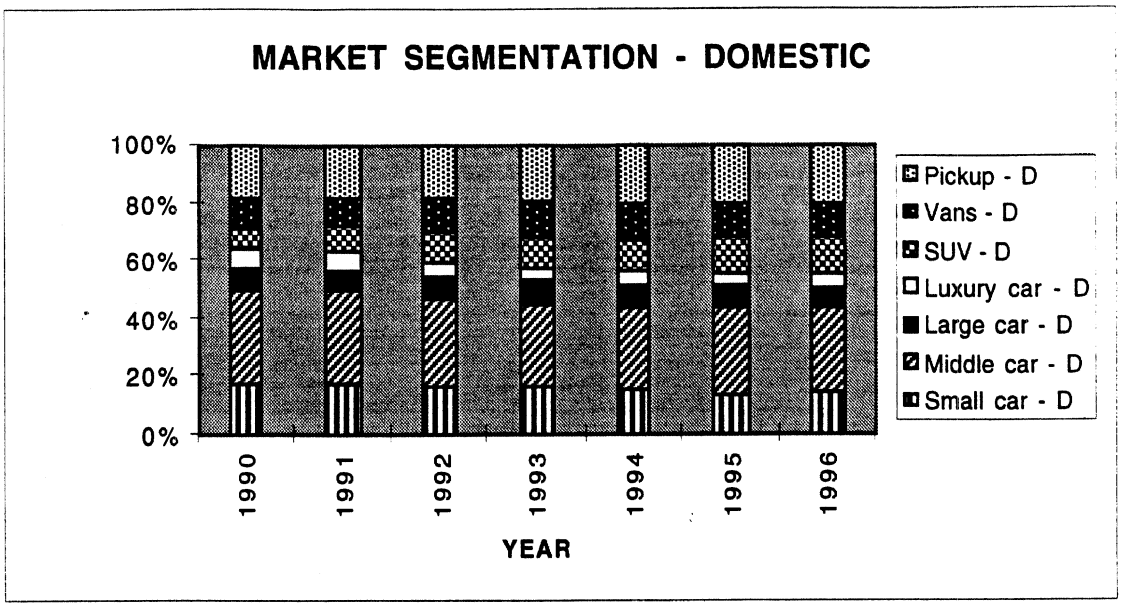
Figure 3

A breakdown of the domestic U.S. market provides some further insight into the market opportunity for ACC. The focus of the discussion is on the decade of the 1990s which has been especially prosperous over the last five years and which enjoys a rather optimistic forecast based upon economic indicators such as the expected corporate cost of capital and the federal budget deficit. Therefore, it seems reasonable to use the period from 1990 - 1996 as a foundation for our analysis of the ACC market opportunity.

Figure 3 shows the segmentation of light duty vehicle market from 1990 to 1996. Losses in the car market that have accompanied the growth in trucks have come largely from the small car segment which has dropped from 22% in 1990 to 15% in 1996. The luxury car segment shows a small drop from 9% to 8% of the market and the midsize car has shown a similar dip from 30% in 1990 to 28% in 1996. The large car segment has been consistently capturing about 6% of the market. Clearly, the largest gains have been made in the SUV segment which had 7% of the market in 1990, but doubled its share to 14% in 1996. The van market has remained between 9% and 11% throughout this period.

The growth of SUVs and the relative stability of the van, large, and luxury car markets seems to bode well for the ACC market opportunity since they project a larger targetable market cross section for the rather expensive ACC feature, accounting collectively for nearly 40% of the total light vehicle market. While the total size of the light duty vehicle market is likely to remain relatively stable for the

next few years, the introduction of ACC is targeted for the segments that are growing. The four segments included in the market opportunity, large and luxury cars, vans, and SUVs, are all typically priced at or over $25,000.



Source : Ward's Automotive Yearbook

Figure 4

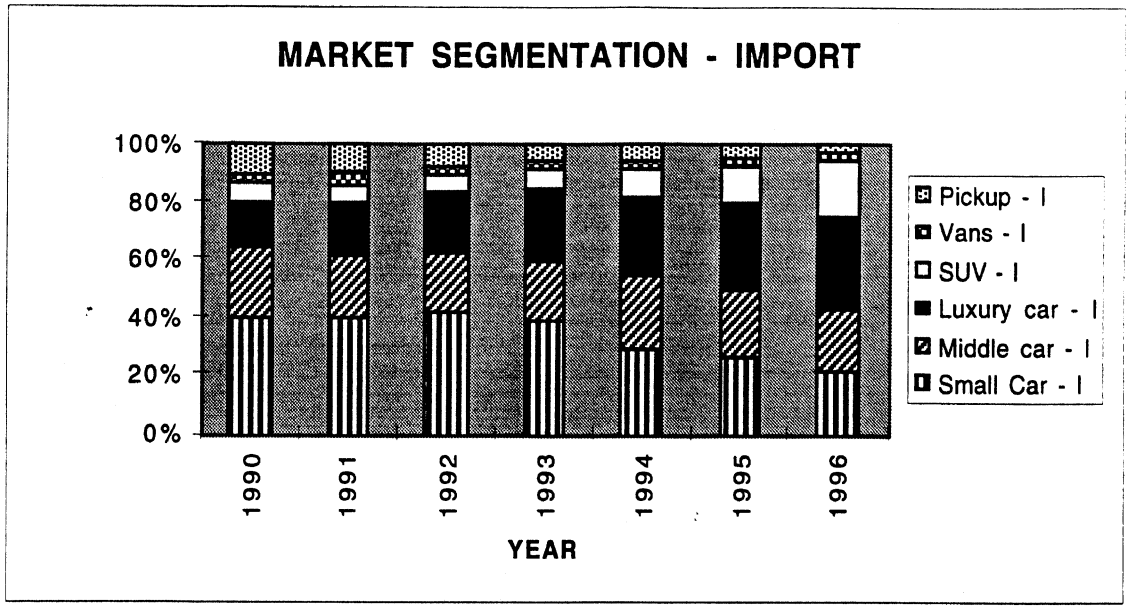
Figures 4 and 5 show the respective market segmentation of vehicles made domestically and those imported. Important trends in these graphs that are relevant to the initial ACC deployment include the following:

• The large car is manufactured entirely by domestic OEMs. The stable market share held by this segment and the continued economic prosperity indicate that this segment has good potential for early ACC deployment.

• While the luxury car market is equally populated by domestics and imports at about 4% of the total, each, the fraction of these sales taken by imports has grown throughout the nineties. Expecting that ACC will indeed be marketed first in this vehicle segment, one might speculate that domestic manufacturers would not wish to see importers get a jump on them by an early launch of ACC if this feature seemed to constitute another means for losing more market share. In any case, it is clear that the comparable luxury car volumes, imported and domestic, offer the prime ACC opportunity to a broad range of OEM players.

• The SUV market has approximately doubled for both the domestic and import manufacturers although it is overwhelmingly dominated by domestic brands. Domestically manufactured SUVs have increased from 5% to 12% of the total market and from 7% to 13% of the domestically manufactured market. The same trend is true for the imports with their SUV share growing from 1% to 2% of the total market and from 6% to 19% of all import sales. With strong presence in the SUV market by all

of the technology leaders in the industry, this segment seems to also pose a major opportunity within which a broad array of ACC products should appear in the years ahead.



Source : Ward's Automotive Yearbook

Figure 5

• The van market has shown modest growth among the domestics while the import of vans has diminished steadily to half of the 1990 levels. High-end vans may constitute something of a niche market for ACC, particularly for certain OEMs that may wish to use the feature as a help in maintaining their dominance in that segment.

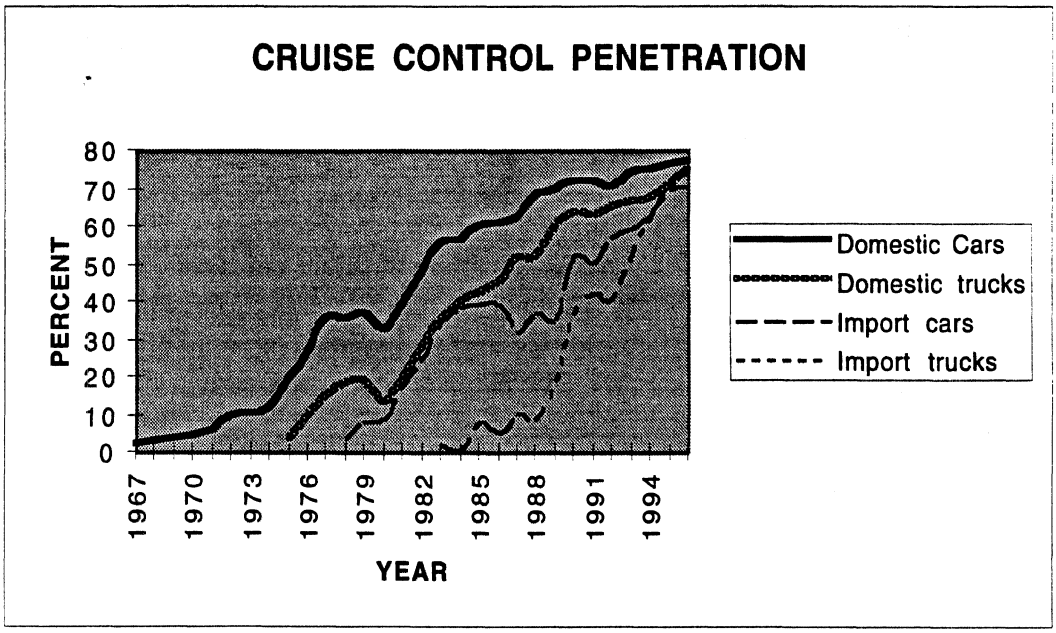
In summary, the luxury car market seems to provide the greatest market opportunity for OEMs who import light vehicles. The domestic manufacturers have their largest opportunity in the SUV market, although luxury platform introduction may still provide the best business case. Van and large car markets are not to be dismissed, but they are less contested between domestic and import manufacturers such that competition pressured by ACC as a differentiating feature is not likely to come from the imports.

ACC Forecasts - Potential Market Penetration

In order to forecast the market potential for ACC it is useful to focus on likely consumer perceptions of ACC and to employ as marketing analogues other automotive options that seem to have succeeded on the strength of similar perceptions. The two themes that emerge repeatedly as the assumed consumer

perceptions of ACC are those of convenience and safety. While automakers all reveal at least some tension between the convenience and safety perceptions of ACC, they clearly wish to offer the feature as a convenience option without explicitly stating whatever safety advantages may also prevail. In order to approximate the path of penetration that ACC is likely to follow, we present cruise control and power steering as analogues for "convenience" devices and ABS as an analogue for a "safety device."

The Case of Conventional Cruise Control



Source : Ward's Automotive Yearbook

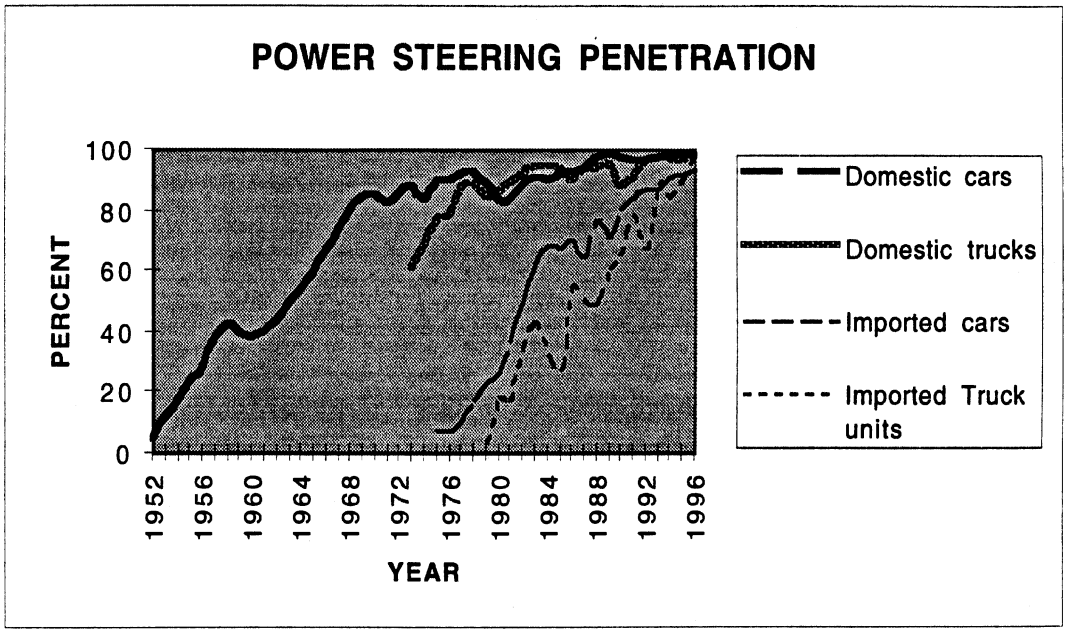
Figure 6

Data on the market growth of conventional cruise control represent one analogue case that can be used to project the possible rate of ACC penetration (assuming, that all other factors of perceived price and value are equal). Of course, ACC will have the benefit of entering the market as the enhancement of a known commodity—that of conventional cruise control—while CCC was offered as a function that had no corresponding precedent of any kind, when it was first introduced. On the other hand, ACC sales may be retarded upon introduction if the feature bears the unusually high introductory price level that many manufacturers have expected. Historically, we see in Figure 6 that conventional cruise control followed the typical S-shaped adoption path of many innovations. It achieved less than 10% penetration within the first five years but grew slowly to reach an apparent saturation level at about 77% in domestic cars. Domestic trucks and import cars took a longer time to achieve significant penetration levels. Now, thirty years since its introduction, conventional

cruise control has reached comparable levels of penetration across all segments of the light duty market and is offered as standard equipment on many platforms.

The Case of Power Steering

The analogy of power steering, while not suggested by our respondents, seems to constitute a plausible case by way of a convenience item that came in originally with a rather high price tag. As shown in the market data summary in Figure 7, we see that import vehicles offered the power steering option nearly twenty years after the feature was first offered by domestic manufacturers in the U.S. (Note: data regarding adoption of power steering for domestic trucks is unavailable for early years). The adoption rates of power steering, rising to approximately 50% of domestic-car sales within 10 years, provides a classic illustration that American consumers are willing to pay for convenience features that are perceived to give value in everyday driving. Along these lines, ACC offers the prospect that the cruise control function—often limited in utility except when driving on open rural freeways—will now have utility over most freeway driving conditions and, with future enhancements, may actually offer a stress-reducing mechanism in the surface-street environment as well. Surely the grossly optimistic scenario for the eventual volume of an ACC market would be represented by the case of power steering which now approximates 100% penetration in all light duty vehicles.



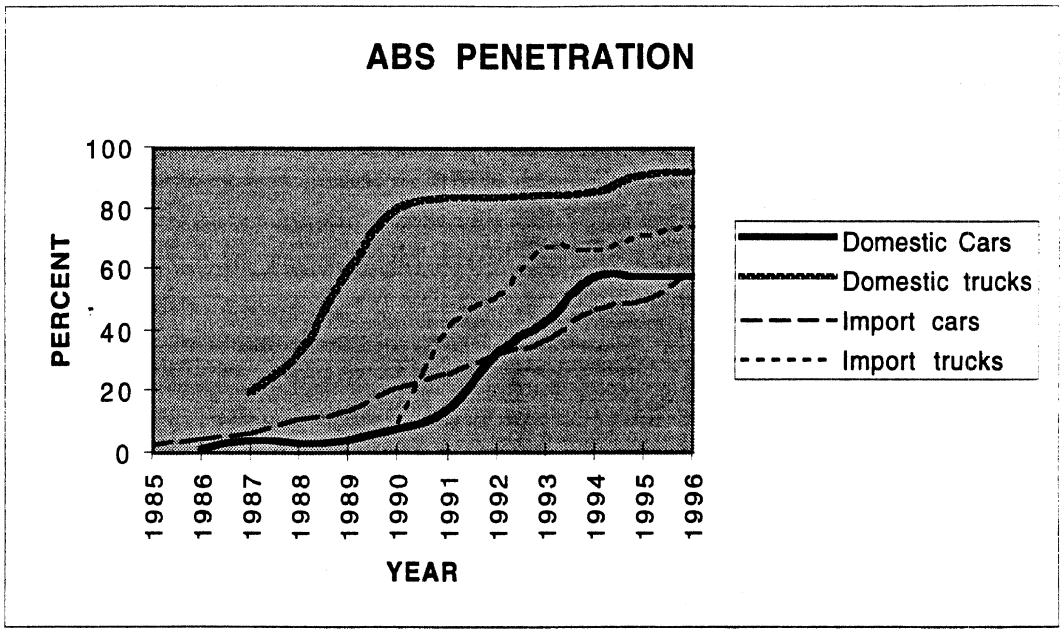
Source : Ward's Automotive Yearbook

Figure 7

The Case of ABS

The suggestion of ABS as a market analogue by many of our respondents implies that they expect the public to perceive ACC as a safety enhancement even though the

vehicle manufacturer will have studiously avoided such a message. Assuming that there is some credence to this suggestion, Figure 8 provides a basis for quantifying the proposition.



Source : Ward's Automotive Yearbook

Figure 8

While there were very limited introductions of ABS in a few domestic car models around 1970, no significant penetration of ABS in the light vehicle market occurred until import products appeared around 1985. A look at the detailed market history indicates that modern ABS products first reached substantial penetration rates in the U.S. on German-made luxury cars with some of them achieving nearly a 100% penetration before other OEMs had offered ABS as an option. The second wave of sales came when ABS was made standard equipment as rear-wheel systems on domestic light duty trucks. (Domestic trucks currently have over 90% ABS adoption, including both rear-only and 4-wheel systems, while import trucks follow close behind with nearly 75%.) The rapid growth in ABS sales has led industry observers to conclude that something of a sea change in consumer sentiment toward "safety items" occurred in the late eighties. If one was willing to extrapolate that sentiment into the '00 to '05 time frame in which many ACC products are expected to appear in the U.S. and if the consumer does indeed embrace ACC as a safety enhancement, we might consider the ABS market history as an optimistic scenario for projecting the rate of growth in ACC sales.

In summary, cruise control, power steering, and ABS provide some insight as analogies to the probable market growth of ACC. The authors' view, however, is that the fundamentally radical nature of ACC technology—with its first-ever sensing and automated response to the obstacle environment around the vehicle—makes the case simply unique. Any bad publicity on ACC experience during the early years of

productization could make for a highly unpredictable market, especially in the wake of the mixed publicity that car buyers have encountered with ABS and airbags in the recent past. On the other hand, a swelling consumer group seems bent on living to spend their retirement investment and may well have a keen interest in the long-term trend toward active safety products.

Strategic considerations

ACC provides unique challenges to the involved businesses. Firms trying to develop and commercialize ACC have several strategic considerations. First, as is true of any emerging industry, there is a high degree of uncertainty with few guidelines to direct strategic thought. Second, the absence of standards adds to the environment of uncertainty and inhibits the rapid development of ACC as a product. Third, the issues relating to liability dominate the deployment and commercialization processes and pose a significant barrier to early implementation. Finally, ACC, being a leading edge technology and the first of perhaps a stream of remote-sensing-based automotive products, has the potential to impact the strategic competence of a manufacturer and its resulting global competitiveness in the long run. Each of these strategic considerations are discussed briefly below.

Businesses are seeking to commercialize ACC under conditions of significant uncertainty. First, there is uncertainty as to the underlying sensor technology: its design, manufacturability, cost, and performance characteristics. Second, as is true of any new product, the ACC market is largely uncertain although car clinics seem to have universally revealed that ACC has a high level of consumer appeal. Difficult judgments are posed, however, by the need to select a set of attributes for the early ACC product that results in affordable cost while ensuring the valued level of functionality. This is especially challenging when the initially targeted market involves a buyer whose expectations on product functionality call for setting the bar higher than it may later need to be; in particular, an ACC product that does not engage braking would seem to constitute a much less risky package for the U.S. market but is perceived as having insufficient utility for the luxury buyer. Third, the competitive arena is undefined. ACC is a complex system that must interact with many components to do the job. Manufacturers of the ranging sensor and the respective Engine Control Units (ECU) for the brake, engine, and perhaps the automatic transmission, as well as other components supporting the ACC control computations and the instrument panel displays each may face differing opportunities for engagement in an ACC market. Supplier firms are struggling to define how ACC system architectures may be partitioned by each OEM so as to define a truly winning strategy for delivering ACC components to many platforms. This overall situation makes strategic decision making on ACC quite a challenge. Surely, vigorous attention is being paid to reducing uncertainty in the technological, market and competitive dimensions so that ACC turns out to be simply one of a string of commercial successes in the arena of driver assistance products.

The issue of standards relates in some ways to that of technological uncertainty but goes beyond technology to the issue of the eventual "reach" of a supplier's product design, across many platforms. It is clear that ACC is still in the emerging phase of the technology life cycle. During the emerging stage, firms compete on the technological dimensions of the product with the motivation that their design will allow them to dominate the industry. The firm with the dominant design has advantages accruing from patents and licensing and, additionally, has the advantage on the learning curve of ACC manufacturing. These considerable advantages tend to inhibit the inter company cooperation needed for standards setting. While the development of and agreement upon standards for ACC will accelerate the progress of the industry as a whole, the establishment of standards (excluding defacto standards emerging from the market, itself) reduces the rents of innovation which stimulate new product development (Nagarajan 1996).

It is clear that the most significant attribute of the U.S. market inhibiting ACC commercialization is the legal environment. Clearly, the auto industry finds itself in an era of frequent claims, both frivolous and substantive, resulting in lengthy and expensive court battles leading to or resulting in either settlements or judgments that, over time, have caused a strongly conservative tilt when it comes to product innovation. Not surprisingly, manufacturers have become so wary of the consumer and the tort bar that they try hard to anticipate both the litigate-ability of a product design as well as its safety quality, per se. While this predisposition impedes new product development even when the function is patently benign relative to any safety connection, the ACC product seems to make an unprecedented change in the relationship between the driver (who is the only truly "intelligent" controller) and the vehicle. This change seems inescapably to call for lots of field experience if the risk environment is to be truly understood. While we recognize that experience of this type is already being gained through the early introduction of ACC products in Japan and will soon be accruing through products offered in Europe, OEMs are distinctly anxious about bringing this automotive product onto the American market when its safety suitability has not been exhaustively demonstrated, beforehand. Accordingly, it seems highly significant that Japanese and European markets are much more conducive to the early entry ACC product manufacturers, especially since this innovation undertakes such a curious modification in the driving task.

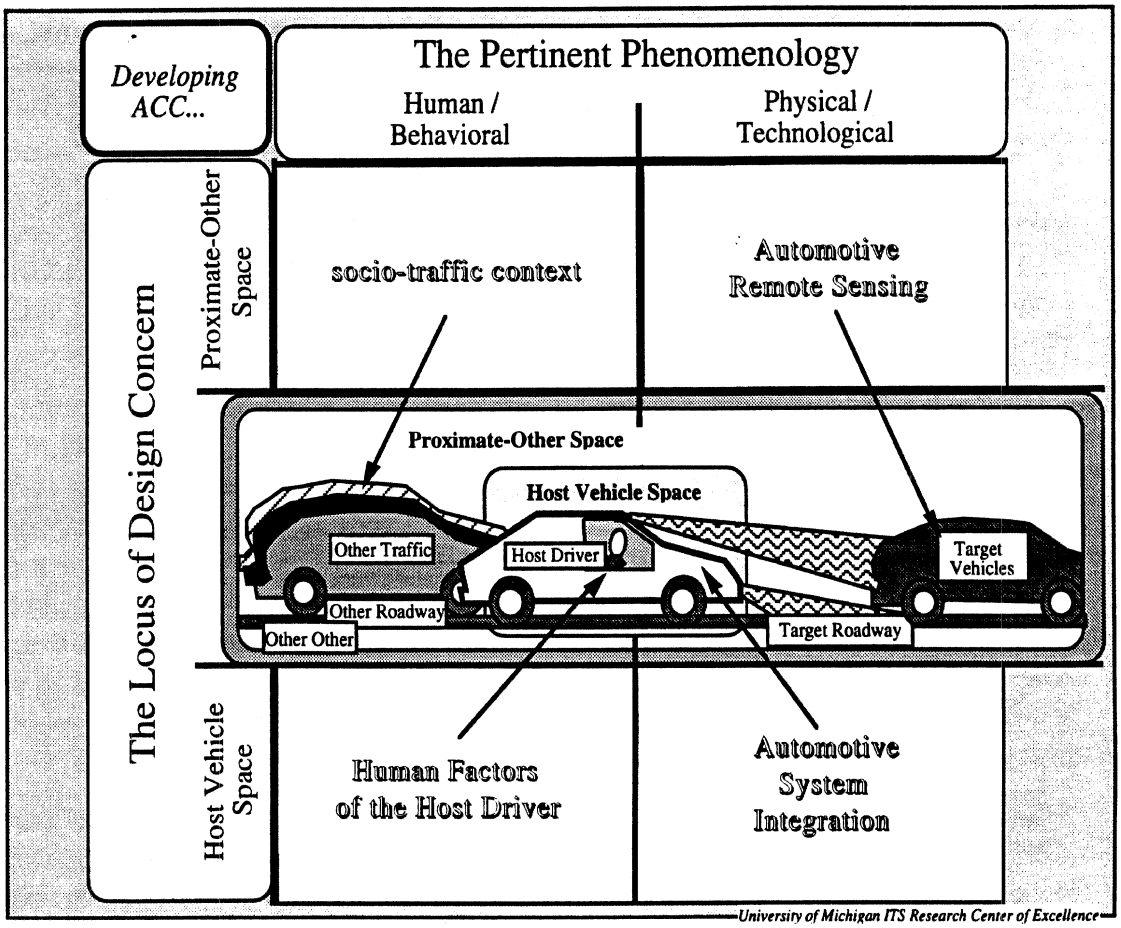
Simply in terms of market demand, there is reason to believe that ACC may become a modestly popular option in Japan and Europe, even though CCC has not been historically popular in either region due to the predominance of short, congested trips. In any case, however, there seems to be an expectation that the U.S. market will afford the primary venue for business opportunity from ACC, perhaps outpacing the total non-U.S. market. Thus, the early market experience and growth in production volume gained through entry into non-U.S. markets may afford a strategic competitive advantage to companies posturing themselves for large-scale ACC productization beginning a few years later in the U.S.. The preference for one's "home market" in launching ACC products seems, in turn, to foretell a handicap by

the U.S. domestic players if, indeed, they choose not to participate in the pending overseas markets (primarily in Europe).

In summary, the commercialization of ACC is posing many challenges to OEMs and suppliers. The inherent uncertainty of an emerging industry, the standards-setting process, the legal environment, and national differences among competing global firms increase the difficulty of bringing the ACC product to the U.S. market. Governments and associations can contribute to alleviating some of the issues raised here but, eventually, it is the marketplace that will decide which companies take dominance in delivering a convenient and safe ACC product to the consumer.

5.0 Recognition that ACC Radically Extends the Locus of Automotive Design Concern

The figure below provides an abstraction on the tasks that underlie ACC development so as to expose the fundamental nature of what's really new here. A two-by-two matrix is used to divide the total knowledge domain into four cells. Competence in each cell will be needed for the efficient development of ACC products and their derivatives. The pictorial in the center serves to label the driving environment which ACC must deal with.



The horizontal rows in the matrix represent the two "spaces" comprising the respective loci of design concern posed by ACC. The spaces in question are either inside the host vehicle or outside of it. The outside is termed the "proximate-other" space because within it operates every other motorist as well as the plethora of confounding elements associated with the road surface, the weather, roadside appurtenances, pedestrians, animals, road junk and so on. (Ervin 1994).

The vertical rows differentiate the two classes of phenomena that are of central issue here, namely, the human/behavioral issues arising from the ACC user and all other drivers nearby and the technological issues arising from the physical setting for ACC's speed and headway control function. Consideration of the four quadrants of this matrix serves to suggest that ACC and the associated driver assistance functions that may follow

it—all based upon remote sensing—represent a very significant change from the tradition of automotive products.

At the lower right, we have the traditional centroid of automotive engineering knowledge. The physical and technological features of the motor vehicle have been addressable by considering the physical attributes of everything on the vehicle, itself, and all physical effects which actually touch the vehicle over its service life. The fact that ACC is a complex physical system requiring, for example, electronic integration with various other elements on board the vehicle calls for a focused engineering effort within this quadrant.

At the lower left, we have the locus of human factors considerations addressing the driver of the host vehicle. Those aspects of the driver's behavior, perception, and cognition that should impact upon ACC design will be addressed here. In general, the challenges for human-friendly ACC are seen to be extensive. As evidence of this, system developers from every company that we interviewed revealed various personal concerns over the thin base of knowledge on human performance that underlies the ACC innovation. Nevertheless, concern over satisfying the driver of the host vehicle is very much within the tradition of motor vehicle development—i.e., automotive human factors is not new as a discipline, although its application from one company to the next has not been altogether uniform.

One remarkable human factors concern, expressed by an ACC developer in Europe, involved the observation of his own inability to maintain normal attentiveness to the traffic lights when driving ACC on arterial streets, even after thousands of miles of field experience with the system. This insightful individual noticed, in himself, the disturbing tendency to delay in detecting red lights apparently due to excessive attention to the headway-keeping aspect of the ACC function. This troubling experience may relate to a phenomenon in cognitive psychology that has been explained as "implicit versus explicit focus" within the perceptual cycle (Sanford and Garrod 1981). In any case, the very limited scientific community associated with ACC research holds the view that we have much to learn about the human factors of these functional interactions.

In the upper tier of the figure, it is obvious that the basic idea of ACC deals directly with the proximate-other space and that this distinction is more or less unprecedented in the history of automotive products. That is, there is virtually no tradition in motor vehicle engineering and development that addresses either the "other drivers" or the "other stuff" that is not itself part of or hitched to the host vehicle. Some exceptions should be noted, for the sake of completeness. It is true, for example, that some current vehicles do measure outside air temperature to display it to the driver. Other modern products sense the ambient light level as a means of switching from daytime running lamps to nighttime lighting. There have also been vehicles that automatically dimmed their own headlamps upon detecting illumination from approaching vehicles at night. However, before the very recent appearance of radar, infrared, and video sensing items in test-market production, *no automotive product feature in the history of the industry has tried to automatically determine the physical layout or the kinematic contents of the proximate space surrounding the vehicle*, as it goes down the road. Clearly, control of one's vehicle within the "proximate space" has been only the purview of the human

operator, based principally upon the capabilities of the individual to observe the scene, visually, and to respond with good judgment.

In the upper-left quadrant, a successful ACC technology must accommodate the fact that other drivers are nearby and that driving, itself, has a sociological dimension (Ervin 1994). In a nutshell, the sociological aspect of driving comes from the fact that we watch each other operate, day after day, and we learn how traffic works. After gaining experience, all drivers have developed a complex web of expectancies concerning the behavior of others which, if violated, may result in accidents or at least unsettling incidents (Evans 1991). If ACC control causes the host vehicle to act in a way that is "abnormal" in a "sociotraffic" sense, there is some chance that it will provoke unfavorable responses on the part of others. Concern exists, for example, that anomalous braking by an ACC-equipped sedan, perhaps up to .25 G in response to a false target detection, would threaten collision from behind by a pickup or SUV whose driver, situated to peer over the sedan and seeing only an open road ahead, was tailgating with the expectancy that no braking by the lead vehicle would occur (e.g. Herman 1973). Other aspects of ACC system behavior may fail to provide certain graceful accommodations that other drivers have normally come to expect. The tendency of ACC to "pinch-off" the merging vehicle at an entrance ramp is a simple case in point (Fancher 1994).

Clearly, sociotraffic phenomena of this type lie entirely outside of that realm of reality which has been considered in developing automotive products since the beginning. Further, there is virtually no science here to build upon. (Note that the civil engineering community has, over many years, developed a collection of observations on traffic behavior to support the practice of traffic engineering but this body of knowledge appears to give precious little insight into the intervehicular choreography that determines the safe operation of individual vehicles from moment to moment.)

At the upper-right quadrant, we have the domain of remote sensing. Although this is brand new as an automotive discipline, much of the extensive knowledge gained from military sensing applications carries over. The carry-over is largely in the solid understanding of electromagnetic sensory phenomenology, given the respective media of active infrared and radar and passive optical imaging devices. Automotive remote sensing faces special challenges of its own, however, because of the remarkable variation of objects and sensing conditions that prevail on public roads. The stochastic properties of these objects and sensing conditions are also more or less undocumented. The authors observe that the neophyte in ACC development has typically started off assuming a simple schema for the road and its contents and has gradually become sobered with recognition of the very large number of conditions that must be handled.

The complexities mostly have to do with the fact that the real world is rather cruddy. It rains; it snows; dust floats around; bugs pile up; dirt changes the reflectance properties of vehicles; vehicles tow all sorts of odd, even home made, trailers having strange sensory cross sections; adjacent vehicles reradiate radar energy in peculiar ways; odd reflective elements appear at the roadside and on overpasses; vertical and horizontal curvatures of the road itself cover wide ranges of values, and on and on. Of course, conventionally, human vision—even through a somewhat obscured windshield—

provides an exceedingly effective filtering of that which is important for vehicle control from that which is trivial in the "proximate space." The big stretch will be for remote sensing technologies supporting ACC to accomplish much of the same. One can be sure that as long as the remote sensor is only able to deal with the middle segment of the bell curve of operating conditions, such as those examples litanized above, none of the associated automotive products will come to market. The hard judgments set in when it's clear that no technology will cover the entire conceivable distribution of conditions. So, how much is enough?

Moreover, the two-by-two matrix of pertinent domains for ACC product development reveals that much is fundamentally new here, from an automaker's perspective. This is both a curse and an opportunity. Companies developing deep competence in this arena will be few because it will be hard. With the ability to convert competence into a product business, however, a few organizations may emerge to dominate not only the ACC market but also the other associated driver assistance products that may follow.

6.0 Concluding Remarks

We conclude that the diverse responses of the interviewees tend to confirm that the "ACC industry," if one can use such a term, is still in an early stage of its development, notwithstanding the appearance of some products and many near-product plans. In particular there is still a wide distribution of opinion on various product issues and there also appears to be a wide range of competencies in dealing with them. Perhaps understandably, the OEMs seem to have a distinct concern for resolving the subtle risks that may attend ACC products in the hands of their customers. Indeed, apprehension properly summaries the outlook of some. It also appears that some of the industry's real experts who have worked on the ACC application for 8 to 10 years have concern that market pressures may stimulate some higher-risk features in the entry products than such experts would like, perhaps with only limited time to gain field experience on the implications. A central case in point concerns all the implications of higher deceleration authority levels in early systems.

In the years of ACC market exploration that are just ahead, the crucial drama will unfold. Will ACC products in fact deliver an almost sure reduction in the stress of driving without also either actually or perceptually posing a safety risk? Taking the positive tilt, will we find that ACC *both* reduces the stress of driving *and* affects a net benefit as a collision avoidance aid? A large group of interested parties looks eagerly forward to the outcome.

7.0 References

Evans, L. *Traffic Safety and the Driver*, New York: Van Nostrand Reinhold, 1991.

Ervin, R. D. Evaluating Active Safety Technology for the Motor Vehicle, *Collision Avoidance Systems: Issues and Opportunity, Workshop Proceedings*, Washington, D.C., ITS America, 1995.

Fancher, P.S., Ervin, R.D., Bareket, Z., Johnson, G.E., Trefalt, M., Tiedecke, J., Hagleitner, W. Intelligent Cruise Control: Performance Studies Based Upon and Operating Prototype, *Proceedings of the IVHS AMERICA 1994 Annual Meeting*, Volume 1, Washington, D.C., IVHS AMERICA, 1994.

Herman, R., Lam, T., Rothery, R. An Experiment on Car Size Effects in Traffic, *Traffic Engineering and Control*, 15: 90-93, 99, June, 1973.

Nagarajan, A. Acquisition Of Technology In An Emerging Industry - *A Study of The Intelligent Vehicle Highway System Industry.* Ph.D. dissertation, University Of Michigan, August, 1996.

Sanford, A.J., Garrod, S.C. *Understanding Written Language*, New York: Wiley & Sons, 1981.

Thomas, R.J. New Product Development: *Managing and Forecasting for Strategic Success*, New York: Wiley & Sons, 1993.

Appendix A

Interview Responses

This appendix presents both the interview outline and a compilation of the responses of the participants to each point or question raised in the outline. The interview outline is below:

A) Comment on expected requirements for the following ACC attributes:

1. Minimum forward speed of preceding vehicles at which they are detected
2. Ability of the range sensor to track through curves and curve transitions
3. Weather penetration capability of the range sensor
4. Means for driver adjustment of headway time
5. Deceleration authority of the system
6. An alert which prompts the driver to intervene on ACC operation
7. Minimum information displayed to the driver
8. Minimum speed needed before ACC will engage
9. Other attributes

B) Comment on the technology that will be used for ACC to achieve:

1. Range & range-rate sensing
2. Tracking of targets on curves and curve transitions
3. Actuation of the service brakes

C) Comment on the challenge for ACC in relation to its:

1. Compatibility with other features of the motor vehicle
2. Complexity as a vehicle subsystem
3. Technical uncertainty, as seen in 1996
4. Introduction vis-à-vis crash warning/avoidance products

D) What is the importance as impediments/accelerants to an ACC market of:

1. NHTSA regulation/specification/defects authority
2. International standards (especially via ISO TC204)
3. Tort liabilities posed by ACC
4. Gross traffic flow impacts of ACC at high penetration levels
5. Insurance incentivization
6. Findings from field operational testing of ACC

E) Please comment on your own situation as an ACC-interested firm.

1. What is your organizational structure for ACC development?
2. How would you describe the involvement of management in ACC development?
3. With whom have you partnered for ACC development?
4. What are your specific technical/product competencies for ACC?
5. Why did you choose to develop ACC?
6. What other similar initiatives have you undertaken?

F) Please address your expectations on market issues.

1. Do you expect that prior ACC product experience in Europe or Japan will be crucial for the early entrants into the U.S. market?

2. Are you planning to introduce ACC in Japan; Europe; U.S.? When and in what order?
3. What dealer-based activities are anticipated to support ACC introduction in the U.S.?
4. What steps may be taken to make ACC more observable to potential customers?

G) Please comment upon:

1. The likely size and pace of growth of an ACC market in the U.S.
2. Worthy analogues for estimating this market
3. The cost to the car buyer for the ACC product
4. Where in the auto product line will ACC be introduced?

Comments made throughout each interview were captured and later edited in order that the free-flowing dialogue could be made more or less readable. The results of this process are presented below, taking one question and sub item at a time. Each section begins with a restatement of the item and the number of respective OEM or supplier companies that chose to respond. Each company was assigned a randomly selected designation such as OEM1, OEM2 etc. or Supplier1, Supplier2, and so on as a means of uniformly tracking the comments made by each organization. These designations appear after each comment or set of statements made by each organization during the interview on each item. When the company chose not to respond, it is also noted using the designation code. Coding was used in this way both for the sake of simply differentiating OEM and Supplier comments, as respective categories, and to allow an especially avid reader to later recompile the results by specific designation codes so as to discern a pattern in individual company perspectives. Although this outlook is a bit far-fetched, perhaps, it is nonetheless made possible by the coding.

Compiled Interview Results

A) Comment on expected requirements for the following ACC attributes:

1. Minimum forward speed of preceding vehicles at which they are detected. (10 responses: 6 OEMs, 4 Suppliers)

It is not the intent of ACC that it would detect stopped vehicles . It is to pace you with a vehicle in front on you, maintaining a distance (determined by the driver), maintaining speed. It is anticipated that the driver will be in control of the vehicle at all times. Detection of zero-speed vehicles implies collision avoidance. (OEM1)

Marketing, near term, will be as a comfort and convenience device. Thus, if they can achieve target detection of stopped vehicles, they will, but they are not even going to ask suppliers to do this. In any case, they must ensure that the customer is clear about what the ACC technology can do. (OEM2)

Stopped object protection is seen as required, but Europe does not feel this way, and this requirement is clearly a big technological burden. (OEM3)

Their system detects targets down to Vt = 0 when host Vh > 15 km / hr. (OEM4)

Now they are planning 10 mph minimum forward speed. Eventually, they want stopped vehicles detection also. In the U.S. stopped vehicles are on the shoulder of the

road. In Japan there is no shoulder. Therefore, if ACC is used only on the highway in Japan, then there is no requirement for stopped vehicle detection. (OEM5)

The ACC processor generally ignores stable objects including stopped cars. The company is still considering, however, what should be the minimum nonzero value of target speed above which detection and tracking occurs. (OEM6)

The issue of detecting previously stopped vehicles is driven by product liability concerns. It has different meanings for different OEMs. The problem, primarily, has to do with whether the stopped object is in the driver's lane or beside the driver. They will not offer such a function. It is not the purpose of the system. Rather, that is what CA will attempt to deal with. They do not expect an ACC standard that will require detection of stopped vehicles. They are aware that at least one European OEM (in Southern Germany) will require stopped vehicle detection in their ACC sensor. (Supplier1)

There is no need to detect stopped vehicles—5 mph minimum is OK. In the truck market, if they are buying ACC as a supplement, stopped vehicle detection is an important part of collision warning. (Supplier2)

Yes, they expect OEMs to require detection of stopped objects. But, they hope to persuade OEMs to accept a sensor capability that simply tracks a vehicle to a stop after it had previously detected it and forego (at least in initial ACC products) the requirement to detect a previously stopped vehicle upon first approaching it from long range. (Supplier3)

You need to be able to discern whether there are stopped vehicles and other objects in your line of travel. Among the objects, for example, a cardboard box must be differentiated from something hazardous. (Supplier4)

2. Ability of the range sensor to track through curves and curve transitions. (9 responses: 5 OEMs, 4 Suppliers)

This requirement has to be maintained. The system must track other vehicles through curves. Tracking through curve transitions is one of the more difficult features of the system to accomplish. They will only deal with it to some degree. (OEM1)

They seek continuous tracking through curves. To do so, moderate ranges of sensing are needed. They wish to avoid ever letting the drivers feel that they do not have control (as in target loss in a curve). (OEM2)

No Response (OEM3)

The range sensor must handle all the curves on all interstates and state highways. Their scan (azimuth) angle is equal to 12 degrees. There are 800 resolutions in one scan. The scanning sensor is supported by CCD image processing but the CCD is not so reliable especially in bad weather. (OEM4)

Their specification is to sustain detection on curves at a radius larger than 300 m / 985 ft radius. This may imply a scanning feature. This specification is only for Japan. In the U.S. there are larger curves. (OEM5)

On curved roads, the sensor needs to detect and track the target also. Regarding the sensor's range, it depends on the road geometry and the maximum speed. Generally speaking, the radius of the highway will mostly be greater than 500 m such that the range needs to be about 100 m at a maximum speed of 120 km / h. (OEM6)

As for continuous tracking around curves, that is, even through the transitions, there is no consensus. On the other hand, everyone in Europe requires the tracking of vehicles within a steady turn, down to some minimum radius. Later as the market for ACC broadens to include cheaper vehicles, it is possible that we will see fixed beam sensors in Europe (but not in the U.S., as per their expectations). (Supplier1)

It is pretty important to cover all curve situations. If the driver does not perceive that the vehicle is following a car in his lane, it is a failure. (Supplier2)

Yes, it is an expected requirement. They are examining video lane detection, but otherwise they have fine resolution of azimuth by means of millimeter wave (MMW) radar. (Supplier3)

Seven and one-half degrees covers 99.5% of roads based on U.S. highway statistics. Therefore, a 14 degree field of view (giving left-and right-turn coverage) seems needed. Also, ACC should engage at 35 mph. (Supplier4)

3. Weather penetration capability of the range sensor. (10 responses: 6 OEMs, 4 Suppliers)

System should be capable of penetrating certain weather conditions. Laser/infrared is dependent on excellent weather. The sensor should be capable of penetrating fog, weather, rain conditions. Nevertheless, the driver should not depend on it as a CA or CW device; it is a comfort device. Because dirt / snow will obscure an IR lens, the sensor needs to be behind the windshield to be acceptable. Because the windshield glass is formulated to resist infrared penetration, we cannot mount an IR sensor inside the car in the U.S. (OEM1)

It is very important that the sensor be perceived to be robust by the customer. Market research says that "radar " per se is perceived as a quality technology. Whatever the technology, the manufacturer needs to have careful understanding of where, from a weather point of view, the sensor does or does not work.

Again, since ACC is a comfort and convenience feature, it is not necessary that it work in the fog. There is a need to spell out for the customer that the system cannot work under certain circumstances. Since the driver is the best system and has other inputs, we should not undertake unilaterally to turn off the ACC in bad weather without driver participation. (OEM2)

There are 2 schools of thought within the company:

- too much help if a radar sensor leads a driver to continue operation through a fog, and

- not enough value if sensor fails to operate in bad weather. (OEM3)

It is expected that eventually all ACC systems should perform under normal rainy and foggy conditions. Early products, when operating in fog and spray, may alert the driver if an automatic ACC shut off occurs, but some degree of warning function continues. (OEM4)

This is not decided yet. (OEM5)

Considering laser radar, it is obvious that capability limitations exist due to the weather, but laser radar ACC can still deliver customer satisfaction to some extent. Perfect capability is not necessary now if the customer accepts the function. (OEM6)

Weather penetration is an open issue— everyone talks about but nobody defines "all-weather" capability. Their view is that the "all weather" outlook is a collision warning requirement, not an ACC requirement. (Supplier1)

Any sensor technology that they put on the market in North America needs to be as capable as technology will allow. If a driver is going to be able to use CCC, the driver should be able to use ACC. This performance is available if the technology is radar. The technology must cover virtually all weather conditions. (Supplier2)

Yes, they assume an all weather requirement. (Supplier3)

The company is convinced that ACC must function well over a broad range of precipitation conditions—even continuing to perform when the driver's vision is obscured. The sensor does not need all weather penetration but must inform the driver whenever low signal-to-noise ratios in bad weather cause the system to disengage. A standard would be valuable here. (Supplier4)

4. Means for driver adjustment of headway time. (10 responses: 6 OEMs, 4 Suppliers)

Yes, the system needs to provide for adjustment of headway time. The safety concern is that if we give the driver an ability to select a rather short value of headway adjustment then he might imagine a liability claim if there is an accident. The system will default to a rather long value of headway time when first turned on. The minimum headway setting would be approximately 1.2 sec. (OEM1)

They do expect to provide a means of driver adjustment. (OEM2)

Yes, this is needed, but they would prefer a standard on minimum value of headway time. (OEM3)

This is a recommended feature. (OEM4)

They have not decided yet whether or not to allow adjustment in passenger car systems. In heavy duty trucks, they did provide for headway adjustment—long, medium, near, because:

(1) heavy duty trucks allow the adjustment device to be mounted in many places and

(2) the heavy duty truck driver is a professional and can understand the limitations of the system (this feature particularly applied to CW in heavy trucks).

They are anxious about the liability issue relative to the function of headway adjustment. Sensor availability and the algorithms are the focus now. However, maybe for the convenience of the driver, some headway adjustment is necessary. (OEM5)

To meet various customers' driving habits / feelings as well as the traffic situation, headway time adjustment is very desirable. Adjustment is not a must, but, in case of fixed headway time, it needs to be set near a maximum value such as more than 2 sec. (OEM6)

An adjustable range setting is very important in U.S. products, but there is no consensus on the details of this requirement. Since the adjustment is only a comfort feature, they expect to see only one headway setting for cheap cars in Germany. (Supplier1)

This should be simply adjustable by the driver over a reasonable range. They must allow the driver to adjust as conveniently as possible without reference to quantitative values.

Question - Would the driver like to see numerical indicator?

This may not be necessary for cars. Truck drivers may need to know headway time for safety considerations. A fleet may want the driver to maintain a preset distance. (Supplier2)

An adjustment does need to be required although they did much of their work at 1.4 sec headway time. They expect to need higher than linear headway times at higher speeds. (Supplier3)

Initially, there should be no adjustment of headway time by the driver. Headway time might be fixed at 2 seconds. In any case, one needs to consider:

(1) liability - how far do you want the system to work

(2) utility - how far do you want the user to be able to use it. (Supplier4)

5. Deceleration authority of the system. (10 responses: 6 OEMs, 4 Suppliers)

Initially, they would implement a system that controls only throttle plus a single down shift of transmission. The system would be sold only with vehicles having an automatic transmission since otherwise there is insufficient deceleration authority. Eventually, they could incorporate brakes, but not in the U.S. initially because of liability. A further shift from 3rd to 2nd gear is not something they want to do. (OEM1)

They expect to provide, with the aid of service brakes, a moderate range of deceleration authority, avoiding the higher levels so as to keep the driver from feeling he is along for the ride. Involvement with PROMETHEUS has been an asset in developing the company's awareness and experience with tuning the system's performance. (OEM2)

They believe that braking is necessary but not over .25 g. (OEM3)

The system should control the throttle, transmission downshift, and perhaps the service brake, also. The company started deliberately with a low level of decel authority. They tend to be apprehensive of using the brakes but it is the next step. (OEM4)

It should be controlled by throttle and downshift. They have many active braking systems and their implementation is not difficult. They could certainly produce braking-assisted ACC now, but the Japanese Ministry regulations currently prevent it. If the

regulation is changed, then they are interested in introducing braking as soon as possible. All Japanese companies make automatic braking systems for the ASV project but the braking vehicle could be hit from behind in a rear end collision. (OEM5)

No brake control will be required in the company's initial product offering since throttle and downshift will serve for controlling the vehicle under regular highway traffic flow. This will help the customer to understand his responsibility of controlling the vehicle. When the market penetration of ACC rises due to customer demand and the reliability of the sensor becomes confirmed by field experience, then the company will add the brake control function to achieve decelerations in the range of .2 to .3 g. (OEM6)

In low speed driving, a .3 g to .4 g level of decel authority would not be a problem. For highway driving, .2 g levels are expected. European manufacturers do not want standardization of the decel authority level in ACC systems. They feel that different strategies are needed depending on the driving situation and the system application. (Supplier1)

For cars, depending on the OEM, when it settles out, light use of service braking will be required, perhaps like European cars. For trucks, ACC would control downshift and engine brake but not the service brakes. For most of the travel on the highway, vehicles go on one gear so downshift is not a problem. They are able to downshift and use the Jake brake on heavy trucks. Some truck transmissions provide automatic shifting between top 2 gears. (Supplier2)

Braking in the range of .2 or .3 g of deceleration authority is needed for ACC. The customer has been gradually prepared for this significant step by the proliferation of ABS products. The company feels that braking is needed to handle higher velocity differentials. They expect .25 g capability but perceive that GM may accept less. (Supplier3)

The deceleration level of control will be determined through modulation of throttle, downshift, and braking, but the specific strategy will be applied by differing manufacturers in an evolutionary way. This supplier expects that control of both throttle and braking will be needed for collision avoidance products and that ACC must embrace much of the functionality of such products, as it evolves. (Supplier4)

6. An alert which prompts the driver to intervene on ACC operation. (9 responses: 6 OEMs, 3 Suppliers)

There should be some alert. At least a light that might turn red. An audible prompt might be better but some research shows users do not like it. The ACC function extends cruise control utility into an intermediate category of driving situations. Suburban driving is OK unless traffic is heavy. ACC is not meant to take more control of the vehicle. (OEM1)

Customers do not want to be told anything that is bothersome, such as via an intervention alert. No headway warning is planned for ACC but it is necessary for collision warning. You could annoy a good driver with information that the driver does

not really need. They have considered a headway indicator as a gauge but even that can be distracting. (OEM2)

Yes, this is probably required if deceleration authority is near .25 g but there is no agreement on this. (OEM3)

The company deems this to be necessary. They choose to provide an audible prompt. (OEM4)

This is not decided yet. This might be necessary but they have no idea of what would be best. (OEM5)

A closing alert is not technically necessary, because ACC is depending on the drivers' responsibility to operate the car. To support the driver's judgment, an alert function is desirable because it may help the driver realize the system's deceleration limitations rate. (OEM6)

Here, too, there is no consensus. Most of the systems will have an alert feature whose intent is to help the driver from becoming too comfortable with the system. (Supplier1)

For trucks, this appears to be a desirable feature, building on the CW function as a base system. For cars, this feature is more controversial since the company needs to avoid the perception that ACC is a collision warning device. Some alert may be important for the safety of the driver when the system has recognized a potentially dangerous situation. OEMs are concerned over the implied liability of "not alerting" as well as the converse risk if they do. They do not wish to set false expectations as a CW device. (Supplier2)

No Response (Supplier3)

A warning prompt is being considered. It should also warn the driver of poor driving conditions for ACC usage. (Supplier4)

7. Minimum information displayed to the driver. (9 responses: 6 OEMs, 3 Suppliers)

Displays and special controls would include:

- digital set speed

- light indicating ACC is engaged

- light indicating vehicle is tracking another vehicle

- yellow/red - alert driver to intervene

- switch with near and far (continuous)

(No display of distance/time to the vehicle ahead would be included). (OEM1)

In any matter relating to information to the driver, there is a lot of opportunity for collaboration among the auto companies. You have to show the driver the set speed. A lamp indicating that you are in a follow mode is also important. The company's general

point of view is that getting a consistent and intuitive "handling" performance from the system is more important than the ACC information display. (OEM2)

Assume set-speed display but the cost is an issue with this feature. (OEM3)

Display should include the set speed, a sign for locking onto the preceding vehicle, and an indication of system failure. They also indicated that an additional visual display of headway is targeted for the Japanese buyer. (OEM4)

This is not decided yet. Malfunction warning and an ACC-mode indicator may be necessary. (OEM5)

Several levels of indicators are being considered, as follows:

necessary: SET SPEED and SYSTEM STATUS (on/off)

desirable: TARGET DETECTING or TARGET ENGAGED

maybe or maybe not: TARGET RANGE LEVEL. (OEM6)

Set speed should be displayed. Indication of the status of target tracking is not a necessary feature. This issue is a function of sensor performance. Note that a perfect sensor does not need to have any display of the "target tracking" condition. The minimum display requirements are for system on/off as expressed through a combined display of the set speed. (Supplier1)

For cars and trucks, it is important to show set speed (absolute minimum). The driver needs to glance down and know the set speed. The distance from host is not important. (Supplier2)

No Response (Supplier3)

The only information that is necessary is a visible/audible disengagement cue. Display of set speed is not necessary. The company does not recommend this. (Supplier4)

8. Minimum speed needed before ACC will engage. (8 responses: 5 OEMs, 3 Suppliers)

The minimum speed before ACC will engage will not be lower than that of conventional CC. In as many aspects as possible, ACC should be simply an enhancement of traditional CCC (i.e., the current system sets at 30 mph and resume at 25 mph. There is an upper limit on set speed at 80 mph in the U.S.. (OEM1)

Initially they expect the minimum speed to be the same as conventional cruise control but a lot of benefit is to be gained from lowering the minimum speed. (OEM2)

No Response (OEM3)

The minimum for ACC is 40 km/hr. The corresponding minimum value of host vehicle speed for CW is 15 km/hr. (OEM4)

The first step would be similar to cruise control—about 25 - 30 mph. (OEM5)

As the system should only be used on the highway, minimum set speed should be the same or greater than that of normal CC. (OEM6)

There is agreement that the minimum speed for ACC engagement is 5 m/sec (11 mph). When slowing down in the ACC engaged state, however, the system may remain engaged (lacking application of the brake pedal) all the way down to zero speed. (Supplier1)

Similar to CC. The driver should understand that it is simply an improved cruise control. Lower speeds may be possible only with automatic braking. (Supplier2)

No Response (Supplier3)

Initial products will not engage below a speed of 30 or 35 mph. The market will tend toward stop and go functionality over time but this feature is much harder and requires a wider sensor field of view. The market will not see stop and go before the year 2005. (Supplier4)

9. Other attributes. (6 responses: 4 OEMs, 2 Suppliers)

Stop and go functionality is a big step ahead (i.e., It is not expected that this functionality will be offered anytime soon because of the liabilities). Also, range measurement and tracking out to 300 ft is required. (OEM1)

They have had 70 drivers and 100,000 miles of field experience with ACC prototypes. They cited driver expectations to intervene to assist CCC in maintaining uphill speed as an example that the customer does not expect omni-functionality or perfection from ACC. Note that if the product is too costly due to excessive functionality, the lack of customer availability would eliminate the competitive advantage. It is very important for OEMs to emulate functionality of speed control for which the legal environment has been great. Regarding fidelity of sensing (in curves or generally), there can be some anomalies and false detection. They will not be zero but it is not going to occur every half to one hour of operation. Nevertheless, the rate of false detection or interrupts must not foil the driver's sense of stress relief that should be experienced from operating ACC. The company expects to make its own conservative judgment on details of ACC functionality as it did on its Mayday system offering. The point is that in these innovative product areas, the OEMs do not simply duplicate one another's product features and functionalities. (OEM2)

No Response (OEM3)

No Response (OEM4)

No Response (OEM5)

No Response (OEM6)

For an ACC-convenience system, it does not matter whether the sensor is radar or infrared. The sensor does matter, however, to CA or CW products. Their ACC project started in the PROMETHEUS program with collision avoidance. Then they came to

collision warning. Eventually, liability concerns led to focus on a comfort item ACC. ACC is similar to ABS as an automotive innovation except that this time we start by considering human factors. (Supplier1)

Angle of view for the range sensor for handling transitions and curves—the wider the angle of view, the fewer times you are going to lose the car you are following.

Fidelity of sensor detection—regarding CW—as long as false alarms are minimal, the experience is tolerable. The product does not have to be perfect. It is for warning not avoidance. In our limited testing of ACC, unexplained control disturbances have not been a problem. When the driver is using our product now, and there is a sound or light display, he has to be alert to what is going on. Car drivers are less tolerant about false alarms than professional truck drivers. Ambiguous target identification problem is an issue for ACC development in cars. Many things vie for a truck driver's attention right now. Therefore, the safety implication of the ACC implementation is a priority issue. (Supplier2)

Human machine interaction poses a challenge to ACC development. One European OEM has the expectation of selling a cheaper basic ACC where the sensor has neither cut-in nor stopped-object detection capability. (Supplier3)

There is a need to imagine what attributes will be needed in the future and evaluate these in terms of initial deployment versus eventual deployment. Consideration must also be given to which attributes will be necessary for business reasons, which attributes are required because the market demands them, and which attributes are essential for liability reasons. (Supplier4)

B) Comment on the technology that will be used for ACC to achieve:

1. Range & range-rate sensing. (10 responses: 6 OEMs, 4 Suppliers)

They are leaning toward a segmented beam radar at this point, although IR is cheaper. They will not allow a wiper on the sensor in order to enable an externally mounted IR device. They note that IR may get more usage in Europe due to the practice of using clear windshields. (OEM1)

At this point, radar seems to be it. Nevertheless, IR has good packaging and cost considerations, so it will be under consideration also. The company can not be just told to "drive" the IR sensors to determine whether the treatment of the weather constraints by IR sensors is OK. The company needs to be shown the science by which they can get a generalizable basis of understanding. Note the implausibility of getting "representative" driving experience pertaining to the issue of weather. (OEM2)

Radar system performance is higher here but the issues of technology selection also relate to radar manufacturability for the motor vehicle installation. Both IR and radar are feasible for detection of stopped vehicles. IR is sluggish, over filtered so that you feel like you are floating. IR behind the glass would have been accepted but the glass is inherently IR blocking. (OEM3)

The technology will be either scanning laser radar or multibeam/scanning/steering MMW radar. IR and MMW will compete over the next few years but they expect MMW to emerge as winner (Mitsubishi Electric and Denso are known to be developing MMW radar). (OEM4)

Both laser radar and MMW radar are under consideration. MMW is not necessary all around. LIDAR takes a long time to give an accurate reading of the relative speed to the preceding vehicle. MMW is continuous frequency-modulated continuous wave (FMCW). It also handles many conditions better but it is expensive. For ACC, laser radar is possibly enough but for CW, they need MMW radar. (OEM5)

More than 100 m range and more than 100 km/h performance is at least required. These numbers are depending on the range of set speed. If the operation is allowed over 200 km/h, the range should be greater than 150 m. Sensor technology can be laser radar, MMW radar, image processing at this time. 100% capable in any weather condition is preferred but currently cost and performance pose trade-offs between laser infrared and MMW radar. Note that even the cellular phone cannot be used outside the coverage area or under a cell busy situation, but the customer accepts the inconvenience and still chooses to purchase and employ the service. Additional comments are that salt spray is an issue with laser radar but the fog problem is overrated. The company recognizes that LIDAR got a bad reputation on some products but the bottomline view is that LIDAR is probably OK for early product applications. (OEM6)

Nobody knows whether IR or radar sensors will win in the ACC competition. The company does see combined sensor technologies in the future being fused for achieving high functionality. The biggest problem for radar is related to volume manufacturing so that the performance specs are met in an automated manufacturing process without requiring manual adjustment. This requires new technology for its achievement. Mitsubishi uses a camera in its ACC system. Nobody else will do it. It is too expensive. (Supplier1)

The Japanese are offering optical CW systems in Japan; it is not offered here due to liability in bad weather. In Japan, laser sensors have come out in CW for trucks. It could come out in the U.S.. If a customer demands it, it will be here. However, in the U.S., it will be radar because of performance advantages particularly in adverse weather. "The US customer wants it whenever he wants it." In Japan, there was a driver who was surprised that he had an accident using system in fog. It was a shrug of the shoulders there, according to the culture; here, it would be in court. (Supplier2)

There is no one clear technology that surpasses others across the range of requirements. They are partnering to employ monopulse radar having FSK modulation. Beginning with integrated approach one must understand radar—signal processing—target identification—antenna design. They see limitations of fixed 3° beams as unable to handle cut ins. (Supplier3)

MMW technology is the most robust, offering longer range through all weather, and high S/N. IR sensors may be possible for the early low-deceleration market. (Supplier4)

2. Tracking of targets on curves and curve transitions. (9 responses: 5 OEMs, 4 Suppliers)

They are looking at using differential wheel spin. Steering wheel angle is not attractive due to influence of side wind and road crown. The true winning approach is not known at this time. (OEM1)

A yaw rate sensor is needed at a minimum. Note that a different yaw rate sensor is needed for ACC as opposed to automatic stability control. (OEM2)

No Response. (OEM3)

Lane mark detection with a camera is the expected technology. Line painting is poorer in the U.S. and lanes are wider in Japan. (OEM4)

They are considering the use of laser radar (3 beams) to detect the movement of a stationary object or they could estimate the curve radius using the yaw rate or the use of an image from a video sensor. The video sensor is one solution but a video is not necessary. It all depends on cost/performance. The laser transmitter is a very important component and expensive. Also, the images are difficult in the night/bad weather. In some cases, they can tie in with the navigation systems to recognize curves coming up. 30% to 40% navigation systems are already installed by the OEMs. There is a big after-market too. Honda says it is possible. However, while it is difficult, the navigation system being there makes tracking the curves through this method a cheaper way. (OEM5)

Curve tracking by some means will be necessary. Regarding laser radar, beam scanning can be done easier than MMW radar. At longer range, roadside objects/walls may obstruct the sensor's sight. The minimum road radius limits the use of the system. In the U.S., recommended use will be limited to interstate highways and some other limited access highways. (OEM6)

For the next 5 years, they will stay with a yaw rate sensor only. Eventually, steering wheel angle and differential wheel spin rate may be used as well. (Supplier1)

There is technology to track through curves. Sensors are capable of giving two dimensions of information (angular +distance), and they have knowledge from the vehicle about its own path. They can use mono pulse radar coupled with information from vehicle. Steering/yaw rate sensor, acceleration, etc. can alternatively give you feedback about the current vehicle response. Nevertheless, technology to track through curve transitions is a ways away. One can do interesting things about determining the probable upcoming path. They have two dimensional information coming back from the sensor in front. Like a school of fish, all moving (turning), they can make the assumption that there is a point in space where you can suspect you are going to change. This could be dangerous though because the number of vehicles is limited to a few and can act independently by changing lanes. It would be better to have technology to "see" the road ahead. Cameras and vision systems are highly accurate. GPS is another alternative when they need to know where you are going. Reflective strips in infrastructure may become important. Tracking though transition is important. A system that has adequate angle of view can do an acceptable transition. They know the current radius of curvature. The driver might experience a bit of hesitation or slowing but the consequences of handling

transitions is not bad. However, the company needs to wait for technology that tells us where lanes are going. (Supplier2)

Use of video also being examined to enhance the tracking of vehicles on curves. (Supplier3)

High reliability tracking in curves is a requirement. There will be sophisticated algorithms operating on sensory data to finely section the azimuth. The ACC must distinguish between sustaining the track of a once acquired target by means of a tracking algorithm and finding a new target in our lane on a curved path. Radar sensor can do both, eventually even detecting curving lanes ahead by itself and providing the means for consistent, sustained functions. Radar sensor may be able to support lane keeping/lane sensing, perhaps complemented by a video image processing module. (Supplier4)

3. Actuation of the service brakes. (9 responses: 5 OEMs, 4 Suppliers)

They are not inclined to implement brake assisted ACC at this time. If they did, it would entail maybe 10-25% (maximum) braking effort. The implementation would be by means of the ABS system as is used for traction control. A smartbooster is not desirable because it increases cost. (OEM1)

Braking will be obtained though electronic commands to the powertrain and the braking systems. In later systems requiring full authority, centralized control of 4 wheel braking will be employed. (OEM2)

No Response. (OEM3)

The means for braking include the electrohydraulic brake unit for the traction control system, 4 wheel independent brake system that also controls the vehicle yaw stability control, or the so-called smart booster form of control. (OEM4)

They would like to use a hydraulic booster eventually. However, they would not want to engage the brakes so as to bring the vehicle to a complete stop. In Japan, pedestrians can become a liability if they use an "inching system". It is the driver's responsibility to stop the vehicle. (OEM5)

Technology for actuating brakes is available now and is used for ABS, TRC, VDC (Vehicle Dynamic Control) or VSC (Vehicle Stability Control). Introduction timing is mentioned in response to question A - 5. (OEM6)

Brake assistance will be commonly attained through a smart vacuum booster. It will depend on what is cheaper and what is available on the vehicle platform. (Supplier1)

Use of traction control may be a possibility. Service brakes need to be applied in a very controlled way. OEMs best protection is to begin this product with the safest system implementation technologies available and then take it from there in terms of liability. (Supplier2)

No comment, but expressed concern that dynamic yaw stabilizer enhancement may be required for ACC, with braking engaged. (Supplier3)

They would prefer to have vehicle manufacturers comment on this. (Supplier4)

C) Comment on the challenge for ACC in relation to its:

1. Compatibility with other features of the motor vehicle. (8 responses: 5 OEMs, 3 Suppliers)

Styling is a big problem. Since it will function with CC, the biggest challenge is making ACC compatible to CC. ACC will be an add on to CCC with a switch to move from one to the other. Then, all the other aspects of both systems must become compatible. (OEM1)

Engine emission is an issue due to modulation of the throttle and the ACC duty cycle. Electromagnetic interference issues to other vehicles are also a concern. Biohazard issues (real or perceived) are a concern. (OEM2)

No Response (OEM3)

This is not a problem. (OEM4)

No other feature seems to have compatibility problems with ACC. (OEM5)

Almost the same operation as CCC will be desired. If a headway adjustment function is included, the operation of the distance setting and the speed setting while a target is engaged will be a new or different action from that of conventional CC. Use of the same switch (ACCEL/COAST) as CCC is one idea for setting the distance selection. Use of an additional Switch is another idea. (OEM6)

There are no major compatibility issues. Styling is often mentioned as an issue but the antenna may eventually become a stylized promotional feature. ACC may be a bit of a problem for increased fuel consumption in certain applications but on the whole fuel is saved, especially when compared to base line manual driving. (Supplier1)

There are vehicle limitations; it needs to have CCC and an electronic engine. The electronic engine software has to be compatible with ACC. There are older trucks where the technology cannot be applied. Therefore, the company thinks of the ACC market as the new truck market. Antenna size and styling is a big deal with OEM stylists. The sensor needs to have the view of the road ahead, and therefore it cannot be behind a metal bumper or at the back of the car. Radar can be mounted behind a plastic fascia, however. Also, ACC communication needs are being accommodated by the common communication bus. Any audible alert might need to be coupled to a radio volume drop. (Supplier2)

No Response (Supplier3)

Styling is a big issue; there is sustained pressure for small antenna size, with aerodynamics also remaining an issue. Evolution over the long term will be toward an omnidirectional raydome that performs many communications and sensing functions. A broad set of information can be exchanged with one technology and multiple functions

can be accomplished (using the antenna for receiving multiple frequencies/signals supporting many ITS functions). (Supplier4)

2. Complexity as a vehicle subsystem. (8 responses: 4 OEMs, 4 Suppliers)

Not a whole lot different from how they began with CCC which is already integrated into the engine controller. Suppliers have to be challenged to provide the control option for modulating both engine and transmission, although this company considers its own engine controller as a highly proprietary component. (OEM1)

No Response (OEM2)

No Response (OEM3)

ACC is highly complex but realizable. (OEM4)

Complexity is not a major issue. The human interface has been designed so that it is easy for the driver. There are some dealer/service issues. The vehicle has to be sent to the factory for maintenance because not many dealers can handle malfunction or correct misalignment. The complexity is higher than with ABS. (OEM5)

ACC should be compatible with CCC. As multiplex wiring systems become popular, the system is not so complex. The main difference from CCC is in the addition of the front sensor. (OEM6)

This is not a problem. It can be compared to the normal complexity of integrating ABS. (Supplier1)

They cited a 9 month project, working full time with a truck manufacturer, of ACC integration onto a class 8 truck. As future OEMs integrate ACC into their chassis it should be easier and faster.

For the car, it is easier than ABS, harder than others. Engineers at car OEMs will want to know more about the system and what the sensor is delivering. Buying this kind of technology is as complex as anything they have done. It is, therefore, important for the company to minimize complexity. Capabilities and limitations are minimal knowledge for OEMs. There are two situations. If an OEM looks for only a smart sensor, then coping with the complexity is in the OEMs court. However, if the company supplies the full system, then they will handle it entirely. (Supplier2)

There is a concern about possible product backlash because early systems are risky and uncertain. (Supplier3)

The complexity in ACC as with other modern features is pervasive. (Supplier4)

3. Technical uncertainty, as seen in 1996. (8 responses: 5 OEMs, 3 Suppliers)

ACC is something that is going to come inevitably, probably by 2001 in the U.S. and by 1999 in Europe. Now systems are cumbersome and at an early stage of development; that is, they are not ready for production. This company anticipates seeing launch of ACC on more than one U.S. vehicle in the 2003 - 2005 time frame. Some strides are being

made especially in sensor technology to reduce its space requirement to within a 3" x 5" cross section if it is to be mounted external to the vehicle. Styling would like the dimensions of 2" x 9". (OEM1)

The biggest challenge is manufacturability of the sensor. It is difficult to achieve cost objectives with aerospace performance standards that have steered the development of these technologies. At the system level, there are some challenges but these can be dealt with. One system issue, alignment of the sensors on the finished vehicle, is very challenging. (OEM2)

No response (OEM3)

The company is afraid of the driver's perception and risk taking. Sensor robustness is the largest source of uncertainty.(OEM4)

The greatest uncertainty is in the reliability of the target detection systems in the market place. How to deal with vehicle posture, static axis alignment, dynamic variation in alignment, insufficient maintenance, misdetection or false detection, misrecognition of targets due to environmental conditions are all issues. How does one explain to the customer when the weather is good? For example, it may not be raining but because of rain in the recent past, one cannot use ACC because of splash and spray. (OEM5)

As for uncertainty, generally, the company thought 5 years ago that brake by wire might never happen but now we have dynamic stabilization enhancement. (OEM6)

Integration is not a problem. There is no significant degree of uncertainty for basic ACC for example ruling out the tracking of stopped vehicles. For example, there is no significant uncertainty in introducing the system in the Mercedes E class vehicles. They expect to see the ACC option available in Mercedes C class products within 5 years. (Supplier1)

No Response (Supplier2)

Some recently developed radars have turned out to be unmanufacturable. A fully integrated circuit is needed for the automotive market. The gun diode has been especially problematic with manufacturing. A gun diode often goes off tune. 3 - D assembly within specification has been almost impossible. (Supplier3)

There is some concern regarding the false error rate, both misses and false detects. The company is more confident of radar technology but less confident of the decision algorithms. Uncertainty in the overall sensing technology is very low; the real problem is reaching a market acceptable cost. Manufacturability, maintainability and performance for a 10-year service life, within the cost constraint, are the biggest issues. (Supplier4)

4. Introduction vis-à-vis crash warning/avoidance products. (9 responses: 5 OEMs, 4 Suppliers)

It depends on government action. ACC would come first as a customer comfort device, then after drivers get acclimated to it, maybe they would step up to CW, etc. Not just reading stationary objects but acting on them is the challenge of CA. (OEM1)

ACC offers a functionality whose perceived value by the customer is very high. Further, since ACC is essentially a conversion of conventional cruise control, the customer has a means of understanding the function and its stated benefits. As for collision avoidance/warning, customers do not readily understand the value and won't pay (why pay for a problem I don't have?). In Europe, ACC is an entry point product since there is virtually no conventional cruise control there. In the future, the U.S. driving conditions are going to become as challenging as those in Europe.

Consider that in the case of airbags, it took a government mandate for people to understand their potential value.

The company sees CAMP as a means for helping to carry forward the conceptual development of requirements for Collision Avoidance Systems and CW products. (OEM2)

No Response (OEM3)

Introduction as a fully autonomous system is probably not feasible. Lane departure warning will be the earliest system that is linked to steering activity. It will be on the market this year in Japan as a "driver alertness" warning in heavy duty trucks. (OEM4)

ACC is a convenience/comfort-oriented feature. This is quite different from safety and accident prevention products such as collision warning and collision avoidance. In Japan, ACC is an improvement of CCC. In the U.S., CA and CW seem to be tied with ACC. In Japan, they insist that the systems are different.

CC -> ACC -> CW -> CA in the U.S..

CW -> CA -> AHS and CCC -> ACC in Japan. (OEM5)

A crash warning product is seen as different from ACC at this time. Technologically, these two are using similar technology, so in the future these convenience and safety features will be combined into one system. (OEM6)

The progression from ACC to CW to CA started with PROMETHEUS for the European companies. Some OEMs feel that CW capability will be required in order to get the opportunity to implement an ACC product. (Supplier1)

Regarding the expectation of offering a bundle of CW and ACC, they consider that CW has a cost saving potential and ACC is a primarily driver convenience. The pay back from a CW device is more since it works all the time. It will be difficult to market ACC without CW for trucks. CW poses special economic benefits to trucking fleets. A recent J.D. Powers study shows that 74% of the people polled wanted CA for trucks but only 34% of the automotive customers wanted the CA product. The truck driver's and car driver's perspective of accident probability is different. (Supplier2)

Ultimately, they would be interested in lateral and longitudinal control and the careful integration thereof. The ACC class of product comes under their goal of integrated driver support. (Supplier3)

ACC will be the first product feature of this kind in U.S. passenger cars. In Europe and Japan, there will be early opportunities for CW also. Europe and Japan are technology leader markets and offer lower liability. The company is looking for portability of its radar technology from one application to the next. (Supplier4)

D) What is the importance as impediments/accelerants to an ACC market of:

A lot of current activity is focused on ACC as a "comfort system". This is taken to mean that safety is not a concern. However, the company feels that safety is the first thing that one needs to worry about. (Supplier3)

Order of importance among the questions in section D: 3> 1> 2> 6> 5> 4. (OEM4)

1. NHTSA regulation/specification/defects authority. (9 responses: 6 OEMs, 3 Suppliers)

The big 3 are concerned that NHTSA may regulate ACC. What is NHTSA really after in the ACC-FOT, for example? OEMs don't expect NHTSA to foster a regulation that would simply be helpful in limiting the liability of ACC. (OEM1)

On the one hand, the company wishes to enter into as many cooperative arrangements as they can. But NHTSA's red tape makes cooperative efforts really unattractive. As for NHTSA safety standards, the CAMP initiative is partially seen as a means of avoiding FMVSS action, but mostly in the CW and CA context. The company does not expect any FMVSS rule making on ACC. There is also concern with global disharmony in radar emission constraints (with our FCC, for example, requiring differing power levels, standing still versus moving). NHTSA should let technology be deployed and monitor it. (OEM2)

CAMP is cofunded by NHTSA. They see this as a response to the concern on the NHTSA specification process. (OEM3)

This may be important. The company is not sure about the expected contents. (OEM4)

If NHTSA takes a long time and regulation is stringent, it will be an impediment, but some action from NHTSA can avoid some law suits and product liability. In Japan, 5 ministries are involved in ITS—Ministry of International Trade and Industry (MITI), police, construction, transport, post and telecommunications. (OEM5)

NHTSA's notice or regulation will help make collision avoidance more observable to the public but this will mislead the public to confuse between ACC and CA. Also the liability issue will still remain an industry concern (notwithstanding NHTSA actions). The passenger air bag is a good example. The industry is very concerned. (OEM6)

A NHTSA regulation would help to deal with the liability concerns in the U.S.. Otherwise, there may be no product opportunity; it is still not clear. Development of forward collision warning requirements through the CAMP partnership is proceeding. (Supplier1)

A study is about to be launched by NHTSA in terms of ACC in a large fleet. This is a valuable service for NHTSA to provide. Also valuable is the analysis of why accidents happen. This would be helpful in CW sales. NHTSA should not be in the business of writing specs. It should be in the business of protecting customers from faulty products. NHTSA is involved in studying technology and performance. This could be a potential problem for any manufacturer. If NHTSA writes specs, it does not allow free market to work. De facto industry standards come from free market competition. It could be good only if companies felt that, by complying with minimum requirements of NHTSA there is a reduction in liability. Otherwise each competitor wants to be the winner. NHTSA has been very helpful in analyzing accident data but should not be involved in writing specifications. This could be injurious to the business world. (Supplier2)

No Response (Supplier3)

The company is concerned over NHTSA's role. NHTSA wants OEM and suppliers to help define requirements The company does not look for an FMVSS standard on ACC; it presents too many mines. Unless properly managed, NHTSA could deflect deployment rather than encouraging it. Also, the company is concerned with FCC certification of radar products and Occupational Safety and Health Administration (OSHA) certification for radiation exposure in the automotive assembly workplace. The UAW has expressed concern about work hazard with microwave transmitters. Overall, U.S. regulatory agencies appear to be eager to get involved. Unilateral government intervention in such an area is never warranted. (Supplier4)

2. International Standards (especially via ISO TC204). (10 responses: 6 OEMs, 4 Suppliers)

A standard for radar sensing seems possible since everybody has the same frequency. A global standard for ACC would be nice. The design would be easier on the overall system. (OEM1)

Standards developed through ISO TC 204 are not empowered by the U.S. government and thus are less important here, but global harmonization is of strategic importance. One approach to harmonization is to engage with one government in the lead market and then have other governments follow from there. SAE standards groups have strong relationships to ISO and serve as an especially good forum for getting all of our domestic OEMs lined up. (OEM2)

Standards not seen as simply necessary but could be very helpful. (OEM3)

International standards are important. The company is concerned that all cars would need a standard. (OEM4)

Although international standards are desirable, it is not clear whether the U.S. will work with Japan. Regions have specific conditions. For example, there are many stopped (parked) vehicles on the streets in Japan. However, international standards will lower cost and be an accelerant. (OEM5)

Standards will help promote these products, but it is felt that Europe is rushing to overstandardize and specify ACC. ISO doesn't weigh for much in the U.S. CAMP is striving to determine what the driver needs to see if certain features can be made uniform across the industry. (OEM6)

Standards are only needed here to cover liability. In Europe nobody likes to have a standard, but there is interest in seeing some specification appear through ISO. (Supplier1)

This is useful information. It helps the company see what they had not thought of. They see these as guidelines not specifications.

In the auto side, there is no interest in having a common spec. In Europe (PROMETHEUS) there was an ACC group trying to develop a common spec. They were able to get only so far. The partners were not able to complete that. OEMs in the U.S. seem to be following the same track—still vying for competitive advantage. An ISO standard is useful but this company dislikes a dictating standard. The standard should only protect the minimum public interest. (Supplier2)

ISO standards development has a focus on human factors issues via WGs 13 and 14. The ISO standard for ACC as drafted by WG 14 is seen as very diluted. Certain European companies are trying to push the standard which is watered down to their present technical capability. The ISO technology standard should be challenging not limiting. (Supplier3)

Suppliers are now getting involved in ISO activities. There is concern about electromagnetic radiation that saturates receivers in other nominal frequency bands. For example, there is concern that the third harmonic of side-looking 24 GHz radar will blind oncoming ACC equipped with 77 GHz. .Standards should allow a neutral playing field for late entrants. Regulatory aspects are much more of concern to the company than ISO standards. (Supplier4)

3. Tort liabilities posed by ACC. (8 responses: 5 OEMs, 3 Suppliers)

If the regulatory situation will limit the liability it would be an aid to development. The government might put some specification which will provide some immunity. In the end, the company has two dominant concerns: 1) cost 2) liability. (OEM1)

The company will take the steps so that the tort liability concerns are suitably addressed; the issues are not insurmountable. At the same time, they will be very cautious. Moreover, the company will market wherever the customer has the need and wants the system. Their ACC product will be essentially identical across continents (i.e., U.S. and Europe as they are not seriously considering Japan now). (OEM2)

No Response (OEM3)

The company felt that this is an important concern. (OEM4)

This is a big concern for the auto OEMs. Ultimate responsibility rests with drivers. (OEM5)

This is the biggest issue. Technology must conquer this to the maximum extent first, but a standard will provide some protection by defining a basis for comparison that will better establish the burden of proof on the plaintiff. If the system complies with an industry-accepted standard, then it is far easier to define system faults, and subsequent liability is more controlled. The CAMP effort of GM and Ford seems to be oriented along these lines. (OEM6)

They have no experience yet. (Supplier1)

Tort liability will become clear as the market develops. (Supplier2)

Liability issues are inhibiting participation and development in the U.S. market. (Supplier3)

No comment. (Supplier4)

4. Gross traffic flow impacts of ACC at high penetration levels. (7 responses: 5 OEMs, 2 Suppliers)

This has not been looked at yet. (OEM1)

They think it will be fine. People tend to not have as quick a reaction time as does the ACC system. They expect very positive impact of ACC on traffic, with no rubber banding of transient flow. (OEM2)

No Response (OEM3)

This is not so important. (OEM4)

This is not an impediment or an accelerant. No tangible impact is expected because ACC will not increase traffic flow. The penetration rate will be the determining factor. (OEM5)

Traffic efficiency and safe distance poses a trade off. ACC will be part of a convenience system and any traffic impact is secondary. (OEM6)

Here, also, there is no real experience. There is a need for research. There is certainly no consensus within the industry; the question isn't raised. (Supplier1)

No Response (Supplier2)

No Response (Supplier3)

This is the concern of the vehicle manufacturer, not the supplier. (Supplier4)

5. Insurance incentivization. (5 responses: 4 OEMs, 1 Supplier)

The company is not sure that the insurance industry would offer any incentives here. If they understood it well, they should, but they will not. (OEM1)

No Response (OEM2)

No Response (OEM3)

This is not so important. (OEM4)

It is unlikely that insurance companies will provide insurance incentives since ACC does not directly contribute to safety. (OEM5)

This is a very good means of promotion but it implies that ACC is seen as a safety product. Thus, there is no big hope. After the experience with ABS, insurance companies demand proof of improved safety prior to providing any incentives. Hopefully, if ACC-equipped cars are proved to be safer than nonequipped cars, the insurance industry may offer a discount for ACC. (OEM6)

No Comment (Supplier1)

No Response (Supplier2)

No Response (Supplier3)

The company does not expect this. (Supplier4)

6. Findings from field operational testing of ACC. (6 responses: 5 OEMs, 1 Supplier)

The FOT results could be very valuable if the test is set up properly. (OEM1)

No Response (OEM2)

The company has conducted its own field trials, for examples, in electric vehicles and methanol, but not in ACC. The company assesses safety benefits up to finding neutral or positive effect beyond which they do not normally seek to quantify the likely benefits of a product. They value the FOT as well as PROMETHEUS and other European programs of testing, etc., with the view, "the more the merrier." Eventually, they must adopt a "rule of reasonableness" and proceed with decisions that yield a specific product. UMTRI's calibration on the necessary level of system capability seems to argue for lower functionality than this company's results show. (OEM3)

The company felt that the findings of the FOT would be important. (OEM4)

The findings should be used to eliminate tort liabilities. The joint evaluation of ACC through UMTRI's FOT is also a good step to make ACC more observable to customers. (OEM5)

The focus of an FOT should be: (1) to determine whether there are negative impacts on traffic, and (2) to delineate the usable/unusable situation. (OEM6)

No Comment (Supplier1)

No Response (Supplier2)

No Response (Supplier3)

These should be beneficial. They are particularly interested in an indication of what the market will pay. (Supplier4)

E) Please comment on your own situation as an ACC-interested firm.

The company has laid low since 1994 because it was re-evaluating alternatives; now the company is in a position to act because of the market's active picture. They expect rapid development of the market in the years ahead. (Supplier3)

There are a tremendous number of interdependencies in ACC. Individual companies cannot develop/market ACC alone. OEMs observe that too few suppliers have expertise in all the components. Further, the OEM would risk becoming hostage to a single supplier that offered to fully integrate ACC by also supplying ABS, engine ECU, transmission controller, etc. Thus, an OEM is generally seen as best suited for integration of ACC onto the vehicle platform. This company is likely to provide the range and range-rate sensor and its first entry will be as a sensor supplier, only, not a system integrator. (Supplier4)

1. What is your organizational structure for ACC development? (5 responses: 5 OEMs, 0 Suppliers)

The organizational structure is nonexistent. Just one person is involved. The company is at the stage of a very low-key feasibility study right now. The minivan group is more interested in blind spot detection (using these types of sensors). Because of cost, there is a low key interest in the SUV platform. (OEM1)

An advanced development group supports the vehicle centers. They have been involved in ACC development at the product level for 2 years domestically, following 6 - 7 years of related involvement in PROMETHEUS. They have engaged a global team and have benchmarked the sensor suppliers. (OEM2)

No Response (OEM3)

The Electronics Engineering Departments of the Office of Passenger Car Development and Engineering and the Office of Truck and Bus Development and Engineering are involved in the development of ACC. (OEM4)

The ACC was a joint development effort of their R&D department, research center, and technical center. The basic sensor technology is developed and then the suppliers get the transferred technology. Designers from the technical center have to decide where to put the sensor. The designers are the ultimate authority for styling/cost issues. (OEM5)

There is no ACC project manager, but rather a disperse set of people in various units—no single skunk works. (OEM6)

No Response (Supplier1)

No Response (Supplier2)

No Response (Supplier3)

No Response (Supplier4)

2. How would you describe the involvement of management in ACC development? (4 responses: 3 OEMs, 1 Supplier)

There is very little interest at present, but it would be interesting to see what happens if ACC takes off in Europe. (OEM1)

Top management is supportive of these developments. Nevertheless, the leap from aerospace to automotive technology takes substantial investment. Radar and other remote sensors will become a core technology that will allow many new applications. PROMETHEUS put on a great show and it helped move this field forward. (OEM2)

No Response (OEM3)

They are actively promoting ACC development. (OEM4)

No Response (OEM5)

No Response (OEM6)

No Response (Supplier1)

No Response (Supplier2)

No Response (Supplier3)

The involvement of management is throughout and deep. (Supplier4)

3. With whom have you partnered for ACC development? (7 responses: 5 OEMs, 2 Suppliers)

They have not partnered with anyone. They are simply receiving prototyping help. They expect to specify a system and then competitively select a vendor. They might dual source for a while, for competitive reasons also. They do not want to buy a sensor and then develop a control strategy. They want the whole control system. They cannot talk to radar experts like Raytheon because they do not know the automotive system. Other suppliers, such as Supplier4, know about system interfacing for the vehicle application. (OEM1)

The company is very concerned with core engineering systems. They want a common architecture for all their ACC and related systems. Thus, this OEM will work together with its sensor supplier to integrate ACC. Note that they have many brake system suppliers across various platforms and, thus, need an ACC architecture that is common at the level above the brake system. (OEM2)

No Response (OEM3)

They have partnered mainly with sensor suppliers and control unit suppliers. (OEM4)

They have partnered with capable affiliate suppliers. Design is within the OEM organization and manufacturing is done by the suppliers. (OEM5)

The company is working with several suppliers. (OEM6)

No Response (Supplier1)

No Response (Supplier2)

They have employed 2 professors from a leading university for working on the fine tuning of algorithms.

They courted almost every player in Europe, now converging on a specific radar supplier to support the company's specialty in system integration via the brakes. The partner finally chosen is one who is most ready to get to the automotive market using monopulse with frequency shift-key (FSK) modulation giving better target definition. They are also the most advanced monolithic microwave integrated circuit (MMIC) production company. (Supplier3)

They have partnered with those who are strategic complements to them. (Supplier4)

4. What are your specific technical/product competencies for ACC? (7 responses: 5 OEMs, 2 Suppliers)

There are no sensing technology experts within the company. They look for these competencies outside. (OEM1)

They have been working on radar for a number of years. Basic competency is in automotive system integration and customer needs awareness. (OEM2)

No Response (OEM3)

They have experience with a preview distance control product which has been put into the Japanese market since January 1995. (OEM4)

They are an automotive manufacturer. (OEM5)

System integration, software development, and signal processing are the specific competencies the company has for ACC development. (OEM6)

No Response (Supplier1)

No Response (Supplier2)

The company is a tier 1 system supplier of brake systems and they see the brake system as their channel to the ACC market. They see a logical progression to becoming a car dynamic control system supplier since they already have the system capability. (Supplier3)

They are an across-the-board supplier. They simply choose to limit themselves to initiatives having special promise to them. (Supplier4)

5. Why did you choose to develop ACC? (7 responses: 5 OEMs, 2 Suppliers)

They chose to develop ACC because it enhances technology in the system and makes it more useful as a customer convenience. As a leader in the industry, they have to be aware of what is going on. There is no controversy over whether ACC is going to benefit the customer. (OEM1)

Their European subsidiary brings ACC knowledge. The sensing technology itself, is still largely new to the company. PROMETHEUS was the prompt, and it serves as a lesson that U.S. companies need to empower their engineers. (OEM2)

No Response (OEM3)

It contributes to realizing safer and easier driving as an advanced system derived from cruise control and a distance warning system. (OEM4)

ACC is an improved cruise control. Also, ACC requires basic technology that leads to AHS. (OEM5)

It is one of the next generation of promising systems that please the customer and tend toward a safety system technology. (OEM6)

No Response (Supplier1)

No Response (Supplier2)

The firm sees a need to move to ACC, CW and CA in order to simply maintain their tier 1 position as brake supplier. (Supplier3)

They chose to develop ACC for business reasons, particularly to enter the technical competition for the next generation of safety products. ACC, by itself, is a convenience feature, but the sensors are stepping stones to safety systems like collision warning and collision avoidance devices. There will be a domino sequence across OEMs with Mercedes in the lead. (Supplier4)

6. What other similar initiatives have you undertaken? (8 responses: 5 OEMs, 3 Suppliers)

Blind spot detection as relates to backing and lane change hazards are similar initiatives undertaken by them. (OEM1)

The experience in ACC seems similar to that which has been experienced in the vehicle dynamics area. Namely, although they began only with ABS, they discovered a lot more functionality that could be obtained using with sensors on wheels. Limited production pilots are very important for gaining experience in such new areas. (OEM2)

No Response (OEM3)

Other similar initiatives include the development of an infrastructure-oriented automated highway system, participating in the Advanced Cruise Assist Highway System Research Association (AHSRA) with an R&D budget from Japan's Ministry of

Construction, and the development of an advanced safety vehicle (ASV) under the ASV Project advocated by Japan's Ministry of Transport. (OEM4)

AHS and cruise assist are some projects that are similar. Nissan Diesel, Heno, Mitsubishi and Izuzu, all heavy truck manufacturers, have provided headway distance control since 1991 using IR sensors. (OEM5)

The company has initiatives in AHS, advanced safety vehicle, and navigation. (OEM6)

This is not an adventure, they have been here before. (Supplier1)

No Response (Supplier2)

Participation in PROMETHEUS marked the serious entry of this and many other companies into this field. Reasons for our own and Europe's extensive development of ACC lie in oura history of aerospace and defense and the subsequent technology diversification. Governments are actively pushing PROMETHEUS which has led to many products almost ready for commercial application. The Big 3 are not technology leaders; they need proof from somewhere else that things work. PROMETHEUS really did provide the initial stimulus to the auto industry in Europe to lead in these areas. (Supplier3)

We have taken many other similar initiatives. The market will be moving toward active support packages. (Supplier4)

F) Please address your expectations on market issues.

ACC buttons should be close to CCC so as to identify it as an extension of CCC. (OEM1)

The firm needs to identify a "smart buyer" OEM. The next step would be to form a partnership with the OEM and to ensure that the ACC product that is offered adds value to the customer. Once the customer acceptance is gained, volume manufacture is anticipated, and this will bring down the cost of manufacturing ACC. (Supplier3)

1. Do you expect that prior ACC product experience in Europe or Japan will be crucial for the early entrants into the U.S. market ? (9 responses: 5 OEMs, 4 Suppliers)

Possibly, but it is probably not what the Big 3 will do because the vehicles they sell in Europe are not the luxury type. For the Big 3 manufacturers, ACC will probably be first introduced in the U.S.. (OEM1)

They want an interchangeable design that can be marketed both in Europe and the U.S. (maybe with small tweaks and software changes as needed in the respective markets). (OEM2)

No Response (OEM3)

This is not crucial, but such experiences are always useful. They expect Toyota to be second in Japan with ACC. (OEM4)

They do not expect prior ACC experience to be crucial. Market needs are different in each region and strategy should vary. (OEM5)

U.S. traffic offers the best situation for the use of ACC. Nevertheless, markets in Japan and Europe will serve to mature the technology, especially for gaining experience with the sensor. (OEM6)

Mercedes will bring their product onto both European and the U.S. markets at the same time. (Supplier1)

It would be beneficial from anywhere. It is not a requisite. (Supplier2)

Yes, ACC product experience will be crucial for early entrants. One must have a global approach in order to succeed in driver-assist systems. The first products will be coming in Europe. Mercedes and BMW will be first followed by Audi who needs to compete in same class. Differentiation among OEMs is expected as is the early appearance of ACC on Volvo, which has a safety image. Mercedes will sell the automatic "brake assist" for applying the brake when the pedal is rapidly applied. This kind of feature has some synergy with ACC. (Supplier3)

Of course. Prior ACC product experience is particularly important because it is high technology. The company expects to see the major product push to start with luxury vehicles in Europe and to then go to the U.S. and then Japan. All suppliers need to enter these markets as they emerge globally in order to increase production and to go up the learning curve. (Supplier4)

2. Are you planning to introduce ACC in Japan; Europe; U.S.? When and in what order? (8 responses: 5 OEMs, 3 Suppliers)

They chose not to answer. (OEM1)

They intend to enter both Europe and the U.S. markets, but they are not planning for Japan immediately. They will pilot the product in small fleets in the U.S. before offering it to a bigger market. (OEM2)

We are expecting ACC introduction in the U.S. by 2002 at the earliest. (OEM3)

Introduction has already occurred in Japan in January 1995. Introduction in either Europe or the U.S. has not been decided. (OEM4)

They will introduce ACC in Japan first, but they are not sure about when. They will introduce ACC in a strategy that is similar to the process for the navigation product. (OEM5)

In 1996, it is still too early to introduce ACC in the US because social acknowledgment of the function has not matured. The company expects to introduce

ACC first in model year 1998 or model year 1999. Forward collision warning might be introduced in model year 2003. (OEM6)

No Response (Supplier1)

They would like to follow the pattern of launching to a customer base where the product is designed and manufactured. Some automotive OEMs are looking for only the sensor. Others look for entire system capability. The company will launch ACC in the U.S., one year from now through the truck manufacturers. The availability depends on truck manufacturers. In Japan, they have a partner company for entering the truck ACC market, but they will be entering that market no earlier than the US. They are expecting 77 GHz to be allowed in Japan.

They anticipate entering the passenger car ACC market in the U.S. by the year 2000 or shortly thereafter. Within a year or so after introduction in the US they will introduce the product in Japan and, after that, in Europe. There they are working with a European manufacturer for CW but have not discussed ACC because they have not introduced it here yet. Usually, they introduce products here in the U.S. first because they have more control. Because of a close working relationship with the Japanese partner, Japan is likely to be before Europe. (Supplier2)

Introduction is being planned in Europe for middle scale cars (lower cost, higher volume) in 5 - 10 years. This approach is suited to our radar supply partner as well. However, one must get into the U.S. market in order to have a significant business opportunity in the long run. (Supplier3)

They are planning to enter the ACC market in Europe, first, in theU.S., second and in Japan, third. (Supplier4)

3. What dealer-based activities are anticipated to support ACC introduction in the U.S.? (7 responses: 5 OEMs, 2 Suppliers)

A demo drive could probably be essential but a video type demo might also suffice as is done currently on other new features. (OEM1)

Serviceability is important. It is hard to offer an instructive demo ride via dealers. Car buff magazines may speak of ACC. (OEM2)

No Response (OEM3)

They had no idea. (OEM4)

This has not been discussed. They expect that maintenance of ACC to be a dealer activity. (OEM5)

The usefulness of ACC may be enhanced through instructions communicated by individual dealers. ACC will serve to raise the technology image of the company by showing its advanced (ITS) technology. (OEM6)

No Response (Supplier1)

None for cars. They expect dealer training around the U.S. for the CW product for trucks. After-market installation centers are being opened. There, they train fleet operators and drivers for CW. ACC is less complex but is an adaptation of CW so they will have similar treatment. (Supplier2)

No Response (Supplier3)

This is an OEM issue. (Supplier4)

4. What steps may be taken to make ACC more observable to potential customers? (8 responses: 5 OEMs, 3 Suppliers)

The ACC product may be sold within a package of other options such that the customer would not need to specifically choose it. ACC would probably appear in a logo on the outside of the vehicle. This would simplify marketing because initially the user will not understand ACC well enough to want to buy it. (OEM1)

Maybe some luxury vehicles will sport a logo for ACC. (OEM2)

No Response (OEM3)

They may wish to make a presentation about the effectiveness of the system. (OEM4)

There has been a mistake in marketing airbags as "supplemental," giving the impression that there is no need to fasten the seatbelt. They have to make sure that this misunderstanding does not occur in ACC. For example, in the case of ABS, they need to emphasize that ABS improves braking stability and does not improve braking distance. (OEM5)

The company will promote the product in many occasions like Delco does with its FOREWARN series. (OEM6)

The ACC sensor could be made to be a part of the styling like the ABS sticker. The sensors need not be covered, similar to the aluminum wheels the buyer purchases, to let others observe the feature. Also, inside features are important. It is important for the driver and the passenger to be able to evaluate the new system's operation. Therefore, a display inside should be observable, especially for luxury cars so as to enhance ACC sales to other buyers. (Supplier1)

In the truck market, 5000 buyers buy 90% of new vehicles. Suppliers have to make 30,000 calls on 1700 truck dealers and actively train and support the customers. They are an active marketing, sales, and service organization. They can communicate ACC and new concepts using current methods. For example, in the use of CW, they have market awareness of about 1/3 of the market (according to a company survey). It is more efficient to reach the truck market, unlike the customers for private autos. Since trucks are specified by customers, the availability of ACC would be encountered in the normal process of ordering a new vehicle. Truck manufacturers do not want to encourage decals for each part such as an external logo for ACC.

On the inside of a car, there may be value in labeling ACC for the novice driver or for someone who did not buy the car and, thus, does not expect the presence of ACC on the vehicle. (Supplier2)

No Response (Supplier3)

This is an OEM issue. (Supplier4)

G) Please comment upon:

1. The likely size and pace of growth of an ACC market in the U.S. (8 responses: 5 OEMs, 3 Suppliers)

They expect slow growth beginning with 20,000 to 50,000 in the first year, out of a total volume of 300,000 units per year in their LH product line. ACC might saturate somewhere near 50% of all cruise control sales, currently. (OEM1)

OEMs will expect to deploy ACC slowly. It probably will not take off like remote entry. If people begin to understand the benefits of ACC real quickly, then it will spread across all vehicle lines over a fairly short period. Methodical growth seems more likely, however. Eventually, cruise control alone will go away as a vehicle option; it will be replaced by ACC. (OEM2)

No Response (OEM3)

It is impossible to predict at present. (OEM4)

They have no idea. (OEM5)

Small and slow growth at the first step.

The maximum conceivable market for ACC is the entire CCC market. ACC will never exceed the CCC market in the U.S., however, because ACC will not change the usable situation significantly. Ward's Automotive yearbook is believed to show that CCC selection versus the selling price of cars is as follows: 95% penetration in cars > $ 18K and 30% penetration in cars < $ 18K. The target vehicle population is 30 % - 40 % of the industrial world build. As a side observation on its competitors, the Mercedes S - class ACC product is seen as a "jewel box" having little significance as a practicable benchmark for the industry. (OEM6)

The U.S. market will not significantly appear before 2000. Their target is North Europe where they expect that the ACC market could be substantial. In countries where cruise control has not been popular, ACC is likely to permeate. (Supplier1)

Although CW is their first approach in the truck market, a market survey shows that there is a high level of interest in ACC. The ACC market would be a subset of the CW market. It is expected to be about as successful as ABS or satellite communication systems in the truck market which would imply 30% penetration in year 6 (assuming a free non-regulated market).

Regarding marketing to owner operators who have 10 % - 15 % of the truck market, they feel that an owner operator would like the idea of a CW system because it promotes a feeling of safety. The comparative appeal of ACC would be less because it is not going to save his life, but will only make his driving less stressful.

For the passenger car market it is hard to estimate from the point of view of a supplier because it is a very lumpy sort of decision when you are selling to an OEM. OEMs risk aversion can inhibit the market. (Supplier2)

No Response (Supplier3)

The market will grow first in high-end luxury and SUV products. They are not expecting a market in lower end vehicles but some aspects/similar products (e.g., CW) may appear in lower-end vehicles. They do not expect ACC to be offered as standard equipment. (Supplier4)

2. Worthy analogues for estimating this market (8 responses: 5 OEMs, 3 Suppliers)

CCC is a useful analogue; it started around 5% to 10% and reached 30% only after about 10 years. Now it is standard on luxury and SUV products. (OEM1)

The analogy is ABS. It was around for a while before it took off. (OEM2)

No Response (OEM3)

They had no idea. (OEM4)

Cruise control would be a good analogy. A 70% penetration can be expected in the U.S. and 30% in Japan. They can also use other systems in the same price range. (OEM5)

In the U.S., CCC will be a good analogue. Note : ABS and airbags are like buying insurance, not like buying a convenience feature. (OEM6)

High-functionality ABS is definitely a good analogue. (Supplier1)

ABS and satellite communications are worthy analogues for estimating the ACC market for trucks. Since ACC is a significantly enhanced version of CCC, it should be higher than CCC for trucks. CCC is the minimum.

For cars, they do not expect ACC to be considered a safety enhancement product. Rather, it is a convenience feature that does have safety implications. If the market defines ACC as having a safety benefit and this is proven, then its market growth is likely to follow ABS curve. (Supplier2)

No Response (Supplier3)

Remote keyless entry took 10 years to reach 35% penetration of new sales. (Supplier4)

3. The cost to the car buyer for the ACC product (8 responses: 5 OEMs, 3 Suppliers)

The nonluxury customer will not buy it at just any price; perhaps a useful ceiling price is $600. Probably $100-$400 would be the range for a simple system that would not be able to track curves. This is, at present the likely manufacturing cost. That is why inclusion in a package is likely. (OEM1)

The cost will be much less than $1000 initially, and the eventual target is the approximate current cost of CCC. (OEM2)

No Response (OEM3)

The target price is $300 including sensors, actuators, and the controller, although an introductory product offering both ACC and CW is selling at $3,600. Its sales volume is 10 vehicles a month. Most of the vehicles are believed to have been bought by researchers and competitors. (OEM4)

An in-house study of value for the money of ACC must be conducted in every market. They expect that with a cost of $400 - $600 they can obtain about 20% user acceptance in Japan and probably less in the U.S.. This can be compared with the navigation system, where a customer is willing to buy the device at $2000 in Japan but the price has to be $1000 in the U.S. for customer acceptance. In Japan, they probably could tie ACC with the navigation system or with aluminum wheels or some other feature. A customer for ACC by itself is going to be very rare. (OEM5)

Less than 3 times the amount of CCC will be a temporal (midrange) target. First introduction is a different story. The company expects $500 - $1000 as the initial introduction price of the ACC option, but they acknowledge that it will be a hard sell at $1000. (OEM6)

You should ask the OEMs on the matter of price of the ACC option. Considering only the sensor as a system component, nominal costs of $200 and $500, respectively, will differentiate IR versus radar ACC sensors for some time to come. The price of the ACC option is likely to be less than 2% of the car. (Supplier1)

The company expects the cost in the early days to be in the $1000 range, maybe more in luxury cars. Over time the cost is likely to come down to about $500 - $700 for midsized cars. These are the most likely ranges from now until 2005.

Truck CW is $2500. This will come down. ACC will be a modest increase over that. In the next 5-10 years CW and ACC can be expected to cost under $1000 to the truck fleet. (Supplier2)

No Response (Supplier3)

It will be determined by competition. A possible cost benchmark is the CD player whose volume is 1.5 million units. The ACC product may have to be priced at this level and may also have to be perceived as giving comparable value. (Supplier4)

4. Where in the auto product line ACC will be introduced? (9 responses: 6 OEMs, 3 Suppliers)

It would be targeted for sequential introduction in luxury cars, then SUVs , then minivans. (OEM1)

Top-end cars will be the entry point but, after that, they will go to the platform programs where the customer wants ACC. (OEM2)

We will introduce ACC in stages as a conservative approach. We will probably begin with the luxury platform with a low-volume introduction at a high-feature price. The customers will expect high functionality due to the high price. This puts requirement on high g authority that puts stress on excellent sensing and presents risk that false braking events will burden the system. This conundrum is delaying the market introduction of ACC. (OEM3)

ACC introduction will be in the luxury and small luxury vehicles. (OEM4)

Introduction should be in the vehicles used most often for long distance driving. Consider the Mitsubishi advertisement for ACC. It shows that the CCC is used on and off 300 times on a trip from Tokyo to Osaka. With ACC, the driver intervenes only about 50 - 100 times. It could be introduced in the luxury platform because these cars already come with the navigation system. Also, buses and trucks, like Greyhound and Freightliner, are good choices for ACC. (OEM5)

The top range of the luxury line is always the preferred entry point for new technology, introduction especially a convenient system. (OEM6)

First introductions will be in luxury cars. Nevertheless, three car manufacturers are fighting to introduce a simple system for their low-end cars. There will be no after market sales of ACC because of the stringent requirements of system integration and product liability. (Supplier1)

The company will not be surprised if ACC is a hidden cost in a luxury line since it is hard to ask people to pay for evaluating something they have not experienced. It will probably be introduced in luxury cars and SUVs, and then midsize cars. It may be a long time before small cars have ACC. This pattern is the same as any new technology. You cannot bring down the cost until you get volume. (Supplier2)

No Response (Supplier3)

ACC will be introduced on luxury platforms and high-end SUVs. CW product at the low-end may be on small cars. They are concerned about insufficient value of ACC in its initial levels of functionality. They are looking for more value when it has more functionality. (Supplier4)

Miscellaneous:

An introductory product received inspection from the national DOT, but although they studied it hard, they understood nothing. (OEM4)