Appendix J:
WAVE/DSRC Standards

TABLE OF CONTENTS

TABLE OF FIGURES

1 Background

The purpose of this appendix is to summarize the findings of standards-related tasks - Task 5 and Task 13 - of the Vehicle Safety Communications (VSC) project. The VSC project goals related to DSRC standards were to:

- Work with standards development organizations to ensure that proposed DSRC communications protocols meet the needs of vehicle safety applications;
- Investigate specific technical issues that may affect the ability of DSRC (as defined by the standards) to support deployment of vehicle safety applications; and
- Assess the ability of proposed DSRC communications protocols to meet the needs of safety applications.

The VSCC has been participating in the development of the DSRC standards currently underway through organizations such as the American Society for Testing and Materials (ASTM), the Institute of Electrical and Electronic Engineers (IEEE), and the Society of Automotive Engineers (SAE). The VSCC participation was focused upon ensuring that vehicle safety applications requirements were addressed. Results from Tasks 4 and 6 of the VSC project were provided as input to DSRC standards development. The VSCC established liaisons with other related projects, such as those undertaken by Virginia Tech and the DSRC Industry Consortium (DIC).

Early in the VSC project, it was recognized that there were many DSRC-related standards either under development or that needed to be developed before vehicle safety applications could be successfully deployed. There were many different groups, some with conflicting interests, who were involved in the standards development process. Some of these vested interests were known to be in direct opposition to the anticipated communications needs of possible future vehicle safety applications. The direct participation of the VSCC in the DSRC Standards Writing Group appears to have been a highly efficient way to understand, analyze, and influence the development of the majority of DSRC standards over the course of the VSC project. Active participation in standards development organizations (SDOs) included the development of the vehicle-to-vehicle safety message set standard in SAE.

The basic premise for the operation of the 5.9 GHz DSRC band is for shared usage between public and private users, and between safety and commercial uses of this spectrum; the theory being that commercial applications are likely to help subsidize roll-out of infrastructure and vehicle transceivers that will also support safety applications. It is expected that the safety applications will have the highest priority in terms of access to the spectrum, but commercial applications will also share the 75 MHz bandwidth. The commercial applications will use this bandwidth, as long as they comply with the prioritization scheme.

The DSRC standards group devised a channel switching scheme that includes a control channel in order to support a site licensing system for roadside transponders, a general priority system for applications, and still use the full spectrum of the DSRC band. The 75

MHz of spectrum was divided into seven channels, one control channel and six service channels. The basic concept is that the control channel will support very short announcements or messages only, and any extensive data exchange will be conducted on service channels.

The FCC released its 5.9 GHz DSRC Report & Order in February 2004. This DSRC rulemaking contained a number of features that were of benefit to the potential deployment of vehicle safety communications using 5.9 GHz DSRC. The FCC rulemaking mandated the ASTM E2213-03 standard as required for operation at layers one and two on the 5.9 GHz DSRC spectrum. However, this does not include, for example, the limitation of channels to particular usage (such as the high-availability, low-latency channel), the operation of the control channel, the channel-switching scheme, or the priorities of the applications.

The high-availability, low-latency channel was not specified in the FCC Report and Order. At the present time, upper layer protocol standards, rather than FCC regulation, were expected to specify the necessary channel utilization. However, these upper layer standards need to be specified and enforced for use in the 5.9 GHz spectrum.

The FCC rulemaking specified licensing of On-Board Units (OBUs) on a license-by-rule basis, as recommended by the VSCC. As well, the licensing rules specified for Roadside Units (RSUs) are expected to allow rapid deployment of RSUs to support vehicle safety communications. The RSU licensing rules also appear to allow for the rapid deployment of commercial services, as lower priority users of the spectrum. The commercial services may help to subsidize the infrastructure costs, and contribute to a more rapid deployment of RSUs to support vehicle safety and public safety application.

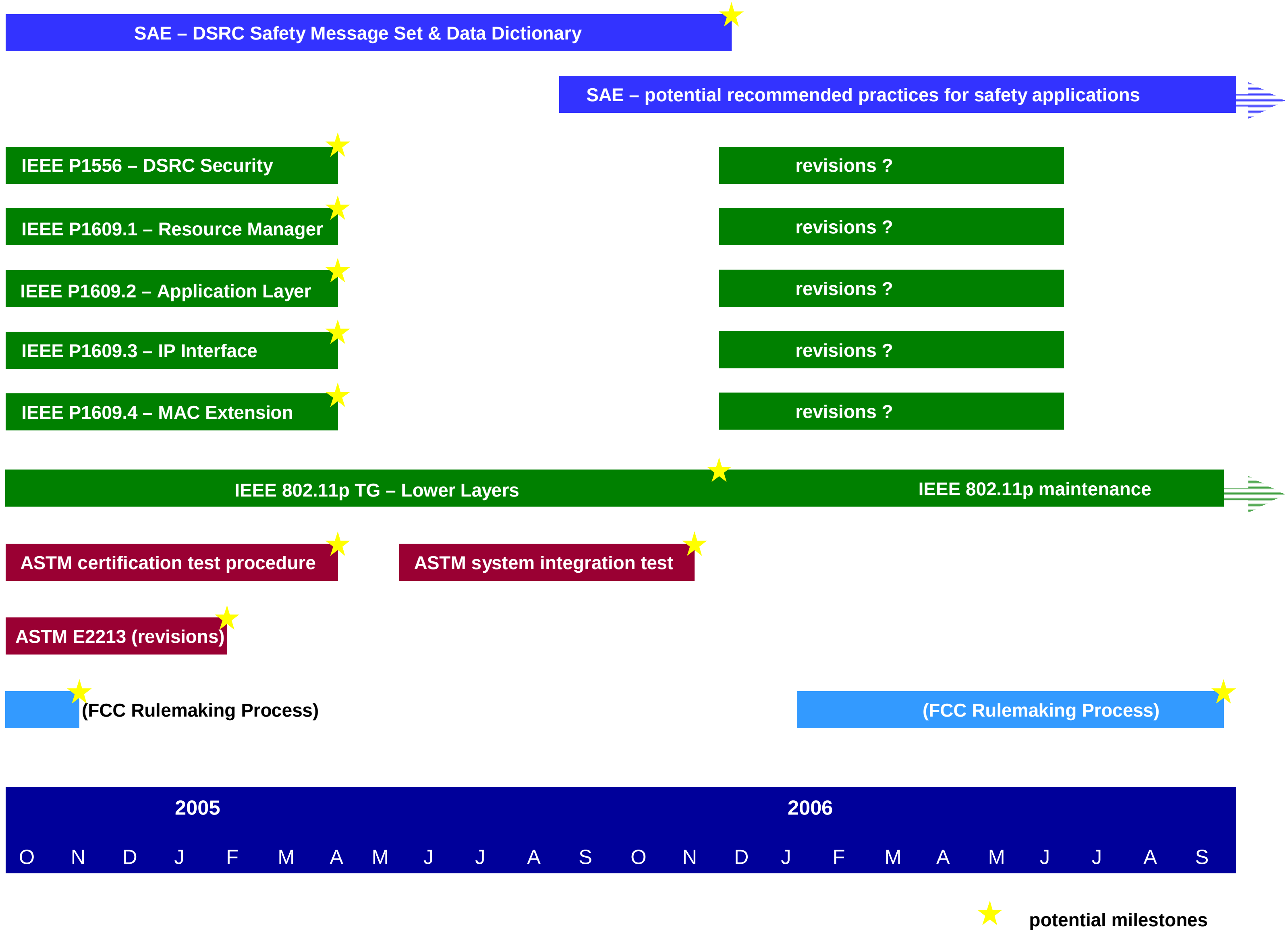
2 DSRC Standards Progress

2.1 DSRC Standards Roadmap

The DSRC standards roadmap illustrates the expected future development of the many DSRC-related standards within various Standards Development Organizations (SDOs) as of September 2004. The time line shown in the roadmap illustration (Figure 1) extends until the third quarter of 2006.

Testing and validation of the DSRC standards is expected to begin as soon as software that implements the DSRC standard protocols on generic host computers, and/or standards-compliant prototype equipment, becomes available. Revisions to the standards are likely to be required as a result of this testing and validation by various stakeholders. If such revisions are required, fully validated DSRC standards may be available by the middle of 2006.

Figure 1. DSRC Standards Roadmap – September 2004

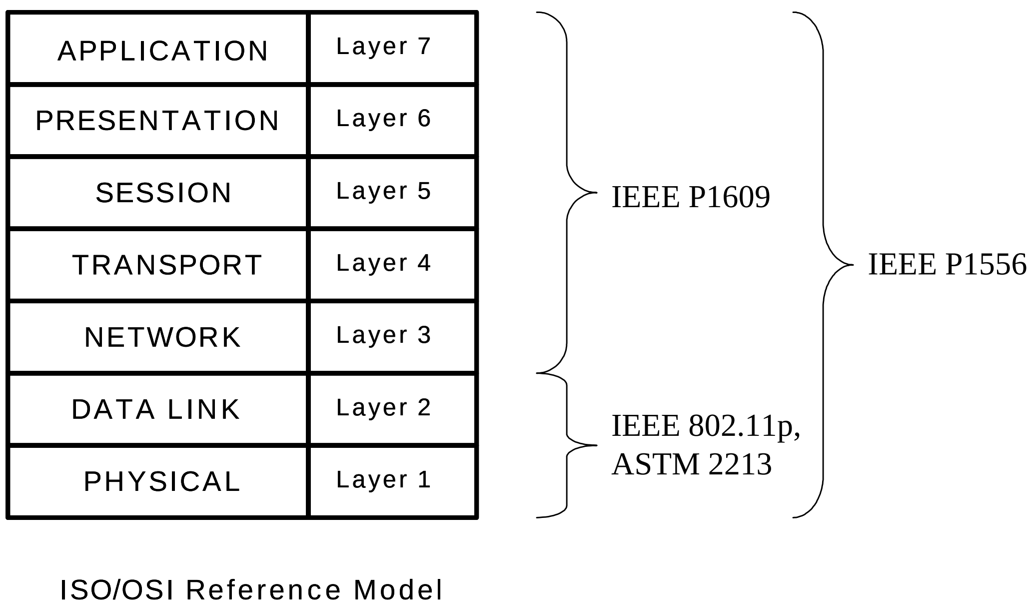


NOTE: This figure is best viewed in color, and may not reproduce well in black and white format.

2.2 ISO/OSI Reference Model

Much of the organization for DSRC standards development is based upon a layer approach toward protocol development. The most widely used model is the seven-layer ISO/OSI reference model. This model is shown in Figure 2, along with the protocol layer relationships of various DSRC standards.

Figure 2. ISO/OSI Reference Model



In this model, each layer provides services to support those layers above it. The protocol implementations for many common systems do not completely follow this model. The Internet protocol, for example, has layers that do not exactly match the ISO/OSI model. The main benefit of the model is that it provides a logical, structured approach toward understanding and developing protocol stacks.

Layers 1 and 2 are often called the “lower layers”. This reference model therefore forms the basis for the “lower layer” designation of the ASTM standard, for example. In general, the IEEE 802.11 working group only prepares standards that apply to layers 1 and 2. The existence of standard lower layer protocols allows various upper layer systems to use the same lower layers. For example, the same IEEE 802.11 Medium Access Control (MAC) is used “on top of” various modulations on different frequencies (e.g., 2.4 and 5.8 GHz) to provide common services for upper layer protocol stacks over 802.11b, 802.11g and 802.11a.

2.3 FCC Rulemaking

This section outlines the current FCC Rulemaking and expected follow-on process. The current expected timeline is shown in Figure 3. However, at this time, it is not possible to accurately forecast the timing or completion of these processes. For example, comments for reconsideration have been submitted, requesting the commission to keep the current docket open until the revised ASTM lower layer standard is completed, in order to change the FCC mandate to the newer version of this standard.

Figure 3. FCC Rulemaking Timeline

This diagram shows a milestone in November 2004. This milestone marks the anticipated finalization of the FCC Report & Order that was published in February 2004. This document can be found at:

http://www.itsa.org/ITSNEWS.NSF/4e0650bef6193b3e852562350056a3a7/7904e45fa730413885256e36006bf0fc?OpenDocument.

This Report and Order contains the details of the rulemaking for the use of the 5.9 GHz DSRC spectrum. The DSRC rulemaking provides a number of features that are of benefit to the deployment of vehicle safety communications using 5.9 GHz DSRC.

The rulemaking specifies vehicle safety and public safety as high-priority users of this spectrum. This effectively addresses the expressed concern that vehicle-to-vehicle safety applications cannot fit within the established definitions of public safety, and these definitions cannot be changed without an act of Congress. The current text of the FCC rulemaking provides a solution that appears to support the needs of vehicle safety communications in this regard.

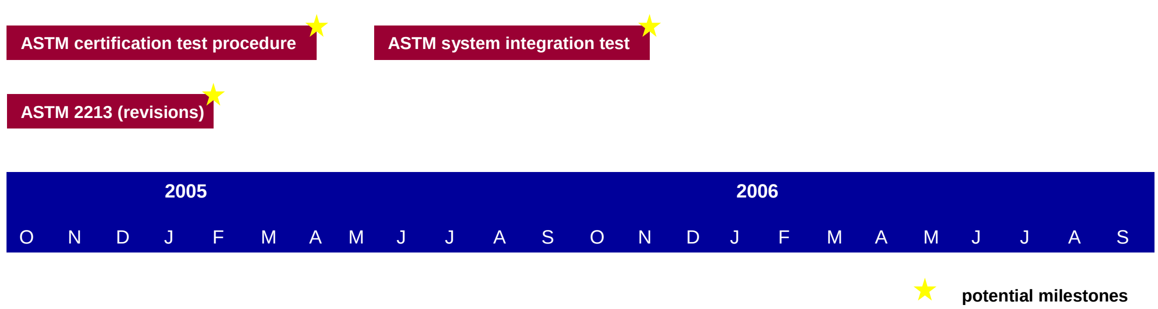
The FCC Report and Order mandates the use of the ASTM E2213-03 lower layer standard for all operations on the 5.9 GHz DSRC spectrum. This is an optimistic development for vehicle safety communications, since the VSCC has been actively involved in the development of the ASTM E2213-03 standard in order to ensure that it can support the anticipated communications requirements of vehicle safety applications. The mandating of this single standard provides the level of interoperability at the lower layers that is essential for vehicle safety applications. The FCC Report and Order also specifies licensing of On-Board Units (OBUs) on a license-by-rule basis. This approach for OBU licensing was recommended by the VSCC for technical reasons, in order to ensure interoperability among vehicles produced by different manufacturers, as well as between various vehicles and roadside units (RSUs).

The FCC Report and Order did not meet the needs of vehicle safety communications in one critical area: the high-availability, low-latency channel (proposed for channel 172). The FCC was reluctant to designate any channel for a particular usage. At the present time, upper layer protocol standards, rather than FCC regulation, are expected to specify the necessary channel utilization. However, if low-priority RSUs, such as commercial users, are licensed and deployed using channel 172, this may limit the capability of DSRC to support some of the critical vehicle safety applications in the future.

2.4 ASTM E2213 Lower Layer DSRC Standard

The expected timelines for potential revisions of the ASTM E2213 lower layer standard, the ASTM certification test procedure standard, and the actual DSRC system testing are shown in Figure 4.

Figure 4. ASTM Timeline



Some modifications have been proposed for the lower layer standard, as a result of technological considerations in the development of the upper layer standards. These modifications are expected to bring the lower layer standard more closely in line with the basic IEEE 802.11a standard. As of September 2004, the proposed modifications were being made to the ASTM lower layer standard, and the revised standard is expected to proceed through the formal voting process for approval within the ASTM organization.

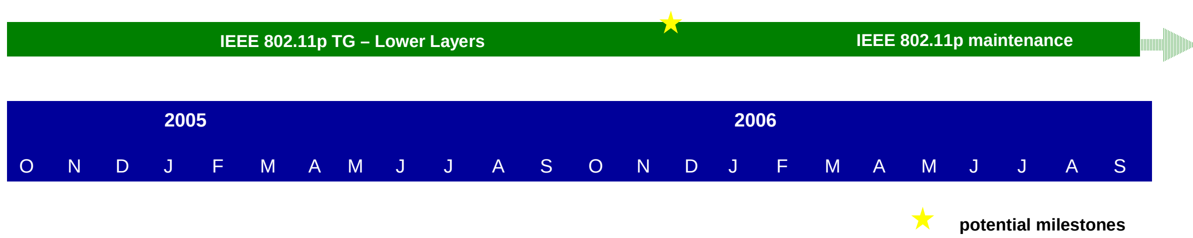
The ASTM certification test procedure standard has been under development for some time. This test procedure document has not yet been completed, however, since the modifications to the lower layer standard must be finalized before the certification test procedure document can be finished.

The system integration testing requires standards-compliant, prototype DSRC units to be available. As shown in Figure 4, this testing is expected to be completed by the fourth quarter of 2005. If this testing, or parallel testing performed by the VSCC and other potential users of the technology, identifies problems that require revisions to the standards, then retesting may be required after the completion of the required revisions to the standards. This retesting is not shown in the diagram.

2.5 IEEE 802.11p Lower Layer WAVE Standard

As of September 2004, IEEE 802.11p was formally approved by the IEEE as a task group to prepare a WAVE standard. Figure 5 illustrates the expected timeline for the IEEE 802.11p WAVE standards development. The completion of IEEE 802.11p by the end of 2005 is a rough estimate at this time, since uncertainty remains regarding the technical consensus process within this task group. After approval of the IEEE 802.11p WAVE standard, continuous maintenance activities will be required in order to keep the IEEE 802.11p standard consistent with ongoing developments within other IEEE 802.11 task groups.

Figure 5. IEEE 802.11p Timeline



One of the main reasons cited for moving the lower layer DSRC standard development into IEEE 802.11 was to ensure that a stable standard would be available over the longer term and would be supported by appropriate experts in wireless technology. A long-term, stable standard would be required in order to deploy the necessary vehicle and infrastructure systems to support enhanced vehicle safety and ensure interoperability between vehicles made by different manufacturers, and with roadside infrastructure in different geographic locations. The IEEE 802.11a standard offers an excellent technology base for these operations. The ASTM DSRC standard was based upon IEEE 801.11a for this reason. An IEEE 802.11p WAVE standard is expected to provide a credible standard that can be maintained in concert with other ongoing developments in IEEE 802.11, as well as a stable standard that can support long-term deployment plans for vehicle safety. The synergy with IEEE 802.11a chipset designs is expected to help ensure the necessary production economies of scale that will allow a quicker, more cost effective deployment of vehicle safety applications.

The IEEE 802.11 working group has a very large member base and the plenary meetings are often attended by more than 800 members. This is also a very successful, high-profile standards group, since the group's 802.11b standard forms the technological basis for the "WiFi" networks that are rapidly becoming ubiquitous in airports, hotels, offices, and homes.

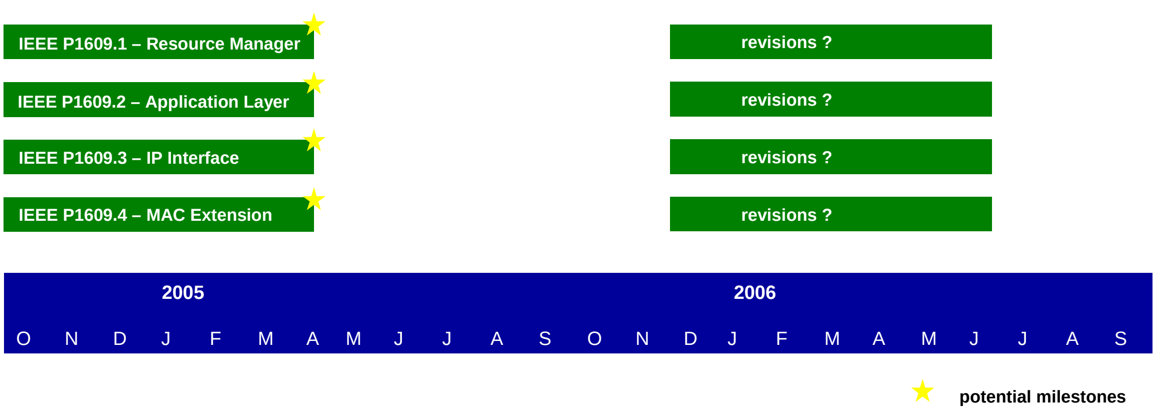
The size and success of this group provides substantial inertia that must be overcome in order to proceed with the development of a new standard like the proposed IEEE 802.11p. As well, since the IEEE 802.11 working group is such a large working group, it has adopted a dense and complex aggregation of rules, administrative procedures and policies. These bureaucratic structures may represent formidable obstacles toward gaining approval of any new standards that are developed.

2.6 IEEE P1609 Upper Layer WAVE Standards

The estimated timeline for the completion of the upper layer WAVE standards is shown in Figure 6. This timeline estimate takes into consideration the drafting activities being undertaken by the DSRC Industry Consortium (DIC) as of September 2004. The milestones shown on the chart represent stated plans for the completion of these standards, as well as estimates for the development of consensus and completion of balloting procedures within the IEEE.

Besides the formal testing and validation planned for these standards, the VSCC may be able to evaluate these standards in detail in future projects in terms of support for vehicle safety communications. These evaluations may uncover areas of the standards that will need to be revised. The possible revision segments shown (December 2005 – June 2006) provide recognition that such revisions may be required after evaluations during most of 2005.

Figure 6. IEEE P1609 Timeline



The implementation of the standards into operational production units will likely be the final validation testing for the standards. If the previous pre-production evaluation, validation and testing have been completed thoroughly enough, problems should have been identified and resolved before operational production units are being produced.

2.7 IEEE P1556 Security Standard

Figure 7 shows the estimated timeline for the completion of the IEEE P1556 DSRC security standard. There are some significant uncertainties in this estimate, since very diverse security needs must be integrated into the final standard. The security experts that the VSCC employed as consultants have generated a potential security architecture that may be able to support vehicle safety communications. It is hoped that his potential solution can become a fundamental part of the overall security solution that will be specified in the IEEE P1556 standard. However, the integration effort has not yet been completed. As well, this initial security solution proposed by the VSCC has not yet been tested.

Figure 7. IEEE P1556 Security Standard Timeline

For widespread deployment of DSRC vehicle safety applications, effective security must be provided. An effective mechanism for key management and administration must be established before full-scale DSRC deployment can begin. Beyond the technical considerations of security solutions, there are policy issues that must be resolved. Some of these policy issues related to the P1556 standards concern key management for roadside and public safety DSRC units.

2.8 SAE DSRC Technical Committee Developments

The SAE initiated a DSRC technical committee with the initial focus of developing a standard message set and data dictionary for vehicle safety communications using DSRC. Vehicle safety communications in this context includes both vehicle-to-vehicle and vehicle-to/from-infrastructure communications. The anticipated timeline for the completion of these standards is shown in Figure 8. The milestone shown (December 2005) represents the expected completion of standard message sets for the high-priority vehicle safety applications, as well as a related data dictionary.

Figure 8. SAE DSRC Technical Committee Timeline

Within the SAE DSRC technical committee, there are three subcommittees, as of September 2004:

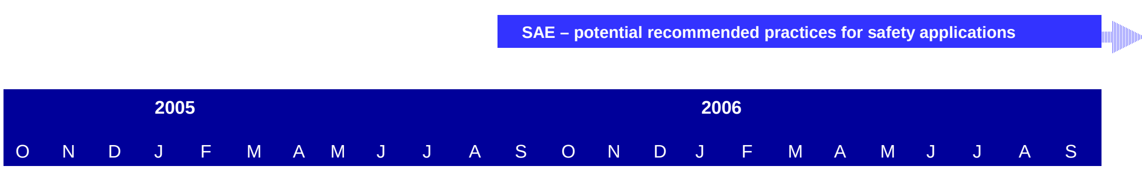
- Vehicle Safety Messages
- Vehicle Non-Safety Messages
- Message Framework

Many of the VSCC technical members have been actively participating in this technical committee, and several members have been elected to leadership positions. This automotive focus in the leadership of the committee and subcommittees is expected to result in a standard that is useful for vehicle manufacturers.

2.9 Potential SAE Recommended Practices for DSRC Vehicle Safety Applications

The potential activity to develop recommended practices for vehicle safety applications is anticipated, but not yet planned. As more complex vehicle safety applications that use DSRC communications are developed, the development of recommended practices for vehicle safety applications may be the best way to support interoperability between safety applications installed on vehicles produced by different manufacturers, as well as between vehicles and infrastructure systems installed by various road authorities.

Figure 9. Potential SAE Recommended Practices Timeline



The development of recommended practices could provide an agreed framework for the particular vehicle safety applications, without totally constraining the application design or precluding technological improvements and enhancements.

The SAE has developed recommended practices for vehicle safety applications in the past, and appears to be well-positioned to undertake such developments for DSRC vehicle safety applications if, as expected, this is deemed to be desirable. For this reason, it seems that the SAE would be the most likely standards development organization to prepare any of these potential recommended practices that relate directly to vehicles.

At the present time (September 2004), recommended practices development activities are expected to be required within the next two years. The timeline illustrated in Figure 9 represents an estimated starting time in the third quarter of 2005. However, it is not clear exactly when these activities may be initiated. The development activities can be expected to continue for some time into the future, as indicated by the arrow in the figure.

3 Incorporation of VSCC Positions into DSRC/WAVE Standards

As part of the Task 5 and Task 11 activities, the VSCC actively participated in meetings of the DSRC Standards Writing Group, and associated ASTM E2213, IEEE P1609, IEEE P1556 meetings. As well, the VSCC actively participated in IEEE 802.11 Working Group meetings, beginning when the DSRC lower layer standards development was moved to the IEEE 802.11 Working Group from the ASTM E17.51 DSRC group. In addition, the VSCC has assumed leadership positions in the newly formed SAE DSRC Technical Committee, and actively participated in the meetings of this committee.

As a result of the consistent, active participation at DSRC standards meetings, the VSCC was able to present and interpret the communications requirements of vehicle safety applications into the DSRC standards development process. This allowed the standards to be modified and further developed in a number of areas in order to support, or better support, the communications requirements of vehicle safety applications. These areas are described in the following subsections.

Sporadic participation in DSRC standards development activities in the various SDOs would be much less effective in promoting support for the communications requirements of vehicle safety applications. One reason for the lower effectiveness of the sporadic attendance approach is that the voting rights in the SDOs typically require ongoing attendance, with very little allowance for missed meetings. Most SDOs operate on an individual representation basis, rather than organizational membership, precluding the sending of substitute attendees to maintain voting status. Another consideration is that there is a technical learning curve associated with each aspect of the standards development, and the basis for many standardization decisions is a dynamic, evolving knowledge base that is shared among the regular, active standards development participants.

The approach that was mainly used for the necessary active participation in DSRC standards development during the VSC project was for a single representative from the VSCC automobile manufacturer members to input and interpret vehicle safety communications requirements to the standards development groups. The representative would also report DSRC standards developments and issues back to the VSCC members and the USDOT. This approach was fairly effective during the VSC project time frame, but standards developments may not be currently optimized for vehicle safety. A more direct approach may be required in the future if automobile manufacturers and the USDOT desire to optimize the DSRC standards to most effectively support vehicle safety applications.

3.1 Broadcast-Type Messages

Broadcast-type messages were identified by the VSCC as the most likely transmission mechanism to support the initially identified range of vehicle safety applications. One of the main reasons for this assessment was that a vehicle would be unlikely to have *a priori* knowledge of the network address of another vehicle of interest in the dynamic, mobile environment of public roadways. As well, the dynamics of vehicle interactions at roadway speeds appeared to require update rates roughly equivalent to those of vehicle sensors for active safety systems. These considerations defined the preliminary communications requirements for vehicle safety applications that were input into the DSRC standards development process. Through active participation in the DSRC standards developments in ASTM, IEEE and SAE, the VSCC secured effective support for broadcast-type messages to support vehicle safety applications in the completed and planned DSRC standards. It should be noted that this broadcast approach has been regularly questioned within DSRC standards development organizations. The role of VSCC participation has been instrumental in conveying the communications requirements of safety systems to the standards development community. This type of safety system requirements interpretation, however, appears to be required on an ongoing basis, since new participants continue to join the various standards development groups. These new participants must be informed of the communications requirements of vehicle safety so that these requirements are not forgotten or ignored in the ongoing development of the standards.

3.2 Random MAC Addresses

Early in the VSC project, privacy was identified as a fundamental requirement for vehicle safety applications enabled or enhanced by DSRC. The concept of Random Medium Access Control (MAC) addresses for On-Board Units (OBUs) was introduced and promoted by the VSCC. This technique was accepted by the DSRC Standards Writing Group and became embedded in the DSRC standards. It appears that the use of this technique, as written into the DSRC standards, will allow privacy to be protected, since no one should be able to explicitly identify a particular vehicle by its DSRC transmissions.

3.3 Short Header for Vehicle Safety Messages

Full IPv6 (Internet Protocol version 6) adoption throughout the DSRC protocol stack, including the over-the-air message format, was strongly proposed by a number of DSRC standards development participants. In order to allow the maximum number of vehicles to simultaneously use the control channel, the VSCC insisted that full IPv6 headers not be required for vehicle safety broadcast transmissions. The full IPv6 packet headers contained more bytes than the entire expected vehicle safety message payload, and the mandatory use of these headers would have greatly reduced the number of vehicles that could use the control channel at the same time. Instead, several approaches were identified to allow efficient vehicle safety transmissions. One of these approaches was planned to be embedded into the DSRC standards.

3.4 Antenna Characteristics

Since the development of the DSRC standards had been underway for several years before the VSC project became involved, there were a number of aspects of the proposed standards that were designed in a way that did not support the safety communications requirements of automobile manufacturers. These vehicle safety communications requirements were introduced to the DSRC standards development process through the active participation of the VSC project. In particular, two aspects related to vehicle antennas had been proposed in ways that would not support the communications requirements of vehicle safety applications. If these initially-proposed standards had not been able to be modified through the VSC project participation in the standards development, DSRC would not have been able to effectively support vehicle safety applications.

3.4.1 Omni-Directional Antenna Coverage

The initial drafts of the ASTM E2213 lower layer standard specified horizontal and vertical antenna directionalities that would have been very favorable for the design of electronic toll collection systems. The VSCC successfully made the case in the ASTM standards meetings that the majority of anticipated vehicle safety applications required omni-directional antenna coverage. This portion of the standard was subsequently revised to support the omni-directional antenna coverage necessary to support vehicle safety applications.

3.4.2 Vertical Antenna Polarization

Polarization was another antenna issue in which the initially-proposed standards were optimized for toll collection applications. The initial balloted and approved version of the ASTM lower layer standard for 5.9 GHz DSRC specified that "all DSRC antennas shall use right-hand, circular polarization". This designation would have made it difficult and expensive to implement omni-directional antennas. This also appeared to introduce a great deal of cost and complexity into vehicle antenna design. The VSCC insisted that vertical polarization also be allowed for DSRC antennas. The VSCC, therefore, secured agreement for a revised version of the ASTM standard to allow vertical polarization as well as right-hand circular polarization. This accommodation was written into a revision that was integrated into the current version (ASTM E2213-03) of the lower layer standard, which was mandated by the FCC DSRC Report and Order.

3.5 Vehicle Safety Messages on Control Channel

In the band plan that was initially proposed to the FCC, channel 172 was specified as the "vehicle-to-vehicle" channel, at the prior suggestion of the DSRC Standards Writing Group. When the VSCC analyzed the communications requirements of the identified potential vehicle safety applications, it became apparent that both vehicle-to-vehicle and vehicle-to/from-infrastructure vehicle safety communications must operate on the same channel. The VSCC made this argument effectively in the DSRC Standards Writing Group, and convinced the group that vehicle-to-vehicle safety communications should be allowed to operate on the control channel along with vehicle-to/from-infrastructure safety communications.

There were serious concerns expressed within the DSRC Standards Writing Group regarding the loading of the control channel that may result from the repetitive transmission of vehicle safety messages by all vehicles in a dense traffic environment. Simulation results of DSRC communications in dense traffic environments were presented at meetings of the DSRC Standards Writing Group. These results indicated that full-powered transmissions of rapidly repeating vehicle safety messages from all vehicles in such environments may result in overloading of the control channel. An overloaded control channel would prevent the effective operation of vehicle safety applications, as well as other applications. The main issue for vehicle safety communications in this environment continues to be how to intelligently control the power and/or repetition rates in order to allow the effective operation of vehicle safety applications. This issue is discussed further in Section 3.10.

3.6 High-Availability, Low-Latency Channel

From the standpoint of vehicle safety, one of the major benefits of 5.9 GHz DSRC is the potential for high-availability, low-latency communications. Portions of the 5.9 GHz DSRC spectrum can be designated for high-availability, low-latency access, and used, for example, for two vehicles on an imminent collision course to exchange vital information during the last 500 milliseconds before impact. This vital information exchange could potentially allow the vehicles to better prepare to protect the occupants from the impact.

An immediate, massive deployment of vehicle-to-vehicle and vehicle-to/from-infrastructure safety applications on the control channel (channel 178) is not expected, due to the existing base of non-DSRC equipped vehicles, and required infrastructure deployment time frame. In the future, though, a significant penetration of these applications, in conjunction with other uses of the control channel, may significantly impact the control channel capacity. To plan for that time, some portion of the 5.9 GHz DSRC band must be dedicated so that high-priority safety applications can have low-latency access for urgent emergency communications, even if all the other channels are fully loaded with more routine communications.

It is imperative for automobile manufacturers to have assurance that this communications capability will be available in the longer-term, in order for a commitment to be made by the manufacturers to deploy 5.9 GHz DSRC-based vehicle safety applications. Channel 172 should therefore be re-dedicated as the High-Availability, Low-Latency DSRC channel to effectively support vehicle safety and other high-priority applications. This channel should be limited to only transmissions related to vehicle safety and other high-priority applications, in order to prevent low-priority transmissions from limiting the availability of the channel, or increasing the latency of communications on the channel.

The DSRC community reached a consensus to support this dedicated use of channel 172, as proposed by the VSCC. The necessity of this channel was illustrated by the pre-crash application scenario: when two vehicles determine that a crash is imminent, they need to immediately switch to a channel that is uncluttered with routine communications and effectively exchange information in the final few hundred milliseconds before the crash that can be used to help mitigate the effects of the crash on the occupants of the vehicles.

3.7 Priority for Vehicle Safety Applications

The DSRC standards group devised a channel switching scheme that includes a control channel to use the full spectrum of the DSRC band, and a general priority system to allow some applications to have preferred access to the spectrum. The 75 MHz of spectrum was consequently divided into seven channels: one control channel and six service channels. The basic concept is that the control channel will support very short announcements or messages only, and any extensive data exchange will be conducted on the service channels.

The basic premise for the operation of the 5.9 GHz DSRC band is for shared usage between public and private users, and between safety and commercial uses of this spectrum. The theory is that the commercial applications are likely to help subsidize the roll-out of infrastructure and vehicle transceivers that will also support safety applications. It is expected that the safety applications will have the highest priority in terms of access to the spectrum, but commercial applications will also share the 75 MHz bandwidth. The commercial applications will use this bandwidth, as long as they comply with the prioritization scheme.

The legal definitions for “public safety” services did not apply for the types of vehicle-to-vehicle safety applications considered by the VSCC. Changing the definitions for public safety would have required an Act of Congress. This issue was raised within the DSRC Standards Writing Group, and was subsequently conveyed to the FCC. In deference to this intervention, the FCC Report and Order specifically described “vehicle safety” and “public safety” services as the high priority users of the 5.9 GHz DSRC spectrum.

3.8 Message Set Standardization

There were divergent views within the DSRC Standards Writing Group concerning how to ensure interoperability at the applications level in DSRC systems. One view was that DSRC applications should be standardized. The alternate view was that message sets and usage contexts could be standardized, and this would lead to sufficient interoperability. The problem with standardizing applications is that a standards development process must be undertaken for each individual application, and also for any subsequent technological improvements to the application. The alternate view – message set standardization – seems to be more commonly held within the DSRC group. The standardization of message sets and usage contexts seems to allow for different versions of similar applications to be interoperable, without forcing a particular application implementation to be adopted by everyone. This approach was supported by VSCC members, since this would allow applications to be custom-designed to address the particular customer profiles of different brands and models.

As a result of further discussion within the DSRC Standards Writing Group, the decision was taken to establish a standardization activity for DSRC message sets and data dictionary. The message set development was initially planned for IEEE P1609. The SAE was identified as the most likely SDO to undertake this work, and was approached to take on this assignment. The SAE consequently worked to develop a two-year project plan, and successfully submitted the plan for funding. A DSRC message set and data dictionary technical committee was established by the SAE, and initial development efforts were focused on the common vehicle-to-vehicle safety message set. This rearrangement of responsibilities allowed IEEE upper layer work to be adjusted to include the required MAC extension.

3.9 DSRC / WAVE Security

The vehicle safety applications appeared to require enough security to be reasonably certain that any transmission received came from a legitimate DSRC unit, and that the contents of the message had not been altered. The main issue related to this type of security revolved around the one-way broadcast nature of the expected communications of many of the vehicle safety applications. Providing adequate security for one-way broadcast communications presented potential problems, since most security schemes for data communications were developed for local area and wide area networks, where two-way communications sessions represented the main operational mode, and node relationships were relatively long-term compared to the mobile environment. As well, the private, commercial services that are anticipated for DSRC appeared to require mainly security for two-way financial transactions. This presents a dichotomy in security requirements for DSRC standards. Most existing security technologies had been designed to operate on networks where two-way, point-to-point communications sessions were used. Consequently, the available security techniques were generally not appropriate for one-way, broadcast communications.

In Task 6B of the VSC project, research was conducted to determine from which threats vehicle safety applications needed to be secured, and whether or not these needs could be met by known security approaches. Further work continues to be required (as of September 2004) to integrate the security schemes appropriate for vehicle safety applications with the security schemes appropriate for financial transactions, and incorporate such an integrated approach into the DSRC security standard.

As a result of this research, the VSCC defined the security threat model for identified vehicle safety applications, and identified the associated constraints to develop a security solution that could meet the requirements of the vehicle safety communications. Based upon this security threat model, the VSCC employed expert security consultants to generate a potential security architecture that may be able to support vehicle safety communications, both for RSU and OBU installations.

In conjunction with Task 6B, the VSCC provided significant input into the IEEE P1556 DSRC security standard development. However, further work continues to be required (as of September 2004) to integrate the security schemes appropriate for vehicle safety applications with the security schemes appropriate for the needs of other stakeholders, and incorporate such an integrated approach into the DSRC security standard.

4 Evaluation of Proposed DSRC / WAVE Standards

The evaluations in this chapter focus on the adequacy of the proposed DSRC / WAVE standards to support the preliminary communications requirements of the vehicle safety application scenarios identified in Task 3 of the VSC project. Section 4.3 describes standardization issues that have been identified and remain unresolved as of September 2004.

4.1 Lower Layer Standards

There were a number of aspects to proposed lower layer standards. In a liberal interpretation of the physical layer, the FCC channel rules were also included in this section.

4.1.1 ASTM E2213-03

The ASTM E2213-03 lower layer standard was mandated by the FCC in the DSRC Report and Order. This standard formed the basis for much of the testing conducted during the VSC project.

The VSC field testing results demonstrated a range of communication capability well beyond the maximum required range of 300 meters for the vehicle safety application scenarios identified in Task 3. Field testing at highway speeds confirmed that the underlying lower layer technologies operating effectively in this highly mobile environment. Even in dense traffic conditions field test results exceeded initial expectations in terms of the percentage of packets received. Transmissions with up to three sender units appeared to be robust enough to support a variety of vehicle-to-vehicle and vehicle-to/from-infrastructure applications.

The final portions of field testing in Task 10 were conducted with new test kits which more closely approximated the implementation of the ASTM 2213-03 standard. These field tests confirmed the positive assessment of the performance of the lower layer DSRC / WAVE technology to potentially support vehicle safety applications.

4.1.2 ASTM E2213-x

Updates to the ASTM E2213 standard have been proposed in the DSRC Standards Writing Group. These revisions reflected developments in the upper layer standards that indicated lower layer approaches that appeared to better support the overall DSRC protocol requirements.

At the time this report was written (September 2004), the proposed changes appeared to be favorable for the support of vehicle safety applications, as well as bringing the DSRC lower layer more closely in line with the IEEE 802.11a standard.

Final assessment of the proposed revisions will require completion of the revisions to the standard, development of equipment to implement the revised standard and field testing to validate the effective operation of the revised DSRC technology.

4.1.3 IEEE 802.11p

The initial ASTM lower layer standard was heavily based upon IEEE 802.11a, so IEEE 802.11p developments, based upon the ASTM lower layer standard, can be expected to remain generally consistent. Since many of the emerging standards of potential relevance to the DSRC standards were being developed within 802.11, it should be desirable to have the DSRC lower layer standard also in the 802.11 family. This should help to ensure ongoing consistency with other developments in wireless local area networks. As previously mentioned, there is a remaining risk that the different stakeholder groups represented in IEEE 802.11 may be motivated to change some portions of the existing ASTM lower layer standard in ways that will not be conducive to vehicle safety applications.

As with the evaluation of the proposed revised ASTM lower layer standard, final assessment of the IEEE 802.11p standard will require completion of the standard, development of equipment to implement the standard and field testing to validate the effective operation of the IEEE 802.11p technology.

4.1.4 FCC Channel Rules

The FCC Report and Order was viewed as generally supportive to the communications requirements of vehicle safety applications. In the case of the channel plan included in the Report and Order, however, one important change would be necessary to adequately support the needs of vehicle safety applications. Channel 172 should be dedicated as the high-availability, low-latency DSRC channel to effectively support vehicle safety applications. This issue is discussed in Section 4.3.1.

4.2 Upper Layer Standards

4.2.1 IEEE P1609 Upper Layer Standards

The IEEE P1609 series of upper layer standards were being drafted by the DSRC Industry Consortium (DIC) as of September 2004. This drafting arrangement was designed to expedite the completion of these standards, and ensure that they were consistent with the prototype equipment developed by the DIC. These standards were to be based upon the requirements established in the IEEE standards development process. The draft standards were to be presented to the IEEE upper layer standards group for consideration for standardization.

Any effective evaluation of these upper layer standards will require future field testing to determine how well vehicle safety applications would be supported. This field testing would require the implementation of the standards in software or equipment. There appears to be a significant potential for revisions based upon these field testing and validation results.

4.2.2 IEEE P1556 Security Standard

The IEEE P1556 security standard was also being drafted by the DIC as of September 2004, for the same reasons as described for P1609 standards. The P1556 security standard, once completed, will require a strategic “practicality” review from a systems level perspective.

The IEEE P1556 security standard will also require technical testing and validation for determination of support for vehicle safety applications. As with the P1609 standards, there will be a strong potential for revisions based upon testing results.

4.3 Identified Issues

During the course of the VSC project, a number of issues have been identified, particularly in areas relating to standards development. The issues described in the following subsections present various elements of unresolved risk toward the effective deployment of vehicle safety applications.

4.3.1 High-Availability, Low-Latency DSRC Channel

As described in Section 3.6, there is a strong requirement for channel 172 to be dedicated as the high-availability, low-latency DSRC channel to effectively support vehicle safety and other high-priority applications. However, in the DSRC Report and Order, the FCC did not designate specific uses for channels, other than the control channel. The FCC indicated that it was premature to assign specific channels, since in their opinion an open channel structure could best provide flexibility in DSRC system design. The FCC maintains the initial basic concept that both public safety and non-public safety licensees should be authorized to share access to the full band. This has raised a serious issue for the potential implementation of vehicle safety applications.

The FCC announced that DSRC licenses would be issued beginning in October 2004. This raised the prospect that even if future field and simulation testing demonstrates the necessity of the high-availability, low-latency dedicated channel to the FCC, there may be incumbent licensees on this channel using low-priority applications. It may be very difficult to vacate the channel at that time, and classes of vehicle safety applications, like pre-crash scenarios, requiring high-availability and low-latency may not be able to be supported using DSRC technology.

This situation would raise the prospect of requiring the designation of separate spectrum, potentially in a different frequency band, to support the communications requirements of these vehicle safety applications. If that were the case, other vehicle safety applications would likely use this different spectrum, in order to integrate vehicle safety applications onto one transceiver. If this happens, then the synergies between commercial applications and safety applications will not be able to be realized. This would also invalidate, to a large extent, the original safety rationale for the allocation of the 5.9 GHz DSRC spectrum.

4.3.2 Potential Control Channel Congestion

The loading of the control channel that may result from the repetitive transmission of vehicle safety messages at high power levels by all vehicles in a dense traffic environment is considered to be a major issue. Since an overloaded control channel would prevent the effective operation of vehicle safety applications, devising effective approaches to provide the necessary congestion mitigation would be clearly in the best interests of the VSCC. However, further research would be required to design and test potentially effective technological congestion mitigation approaches, like intelligent power control or situationally variable transmission repetition intervals.

4.3.3 Potential Priority Conflicts in RSU Zones

A potential conflict between application priority levels accessible to OBUs and RSUs exists within RSU communication zones. A command and control model guides the proposed communications between RSUs and OBUs within an RSU communication zone. Recent standards proposals included the concept of RSUs providing synchronized timing through beacons. Close scrutiny of evolving upper layer standards proposals will likely be required in order to preserve the OBU's capability of initiating high-priority communications for vehicle safety applications within RSU zones. As well, RSUs may be given the capability of sending OBUs to a service channel in order to complete lengthy lower priority applications. Preserving the capability for vehicle safety applications to have low-latency access to adjacent vehicles, while in a RSU communications zone, will also likely require ongoing interaction with the upper layer standards development process.

Finally, there appears to be a belief on the part of a number of DSRC standards development stakeholders that RSUs should inherently have access to a higher level of priority than OBUs. This issue is related to the larger issue of priority assignment and enforcement (see Section 3.10.6), but also may extend into the design of the protocol mechanisms being designed into the standards to support priority discrimination.

4.3.4 IEEE 802.11p Lower Layer Standards Developments

While there were major potential benefits associated with the movement of the lower layer DSRC standards to the IEEE 802.11 Working Group, there were significant risks as well. The IEEE 802.11 Working Group has high credibility with regard to its technical capabilities in the area of wireless networks. As well, many of the emerging standards of potential relevance to the DSRC standards were being developed within 802.11. Having the DSRC lower layer standard also in the 802.11 family will help to ensure ongoing consistency with other developments in wireless local area networks. However, there is a remaining risk that the different stakeholder groups represented in IEEE 802.11 may be motivated to change some portions of the existing ASTM lower layer standard in ways that will not be conducive to vehicle safety applications.

At the time this report was written, the expectation was that there would not be much reason for such changes, since the ASTM standard drew so heavily upon the 802.11a standard. Additionally, the FCC has already mandated the ASTM lower layer standard for DSRC, and this may provide a major incentive for 802.11 not to change any of the DSRC technology. One further concern with this change in venue for the lower layer standard was that the completion of the lower layer standard within IEEE 802.11 may be delayed for some time, mainly due to the formal processes in the IEEE 802.11 Working Group.

4.3.5 Upper Layer Interoperability

The FCC DSRC Report and Order mandated the ASTM lower layer standard for use on 5.9 GHz DSRC spectrum. However, this mandate did not include any of the upper layer protocols. For interoperability, rules for the use of the 5.9 GHz DSRC spectrum need to specify the use of the upper layer standards, in addition to the lower layer standards.

The mandated ASTM lower layer standard specifies the required operations at layers one and two. However, this does not include, for example, the specific operation of the control channel, the channel-switching scheme, or the priorities of the applications. These types of DSRC operations are being specified in the upper layer DSRC standards, and need to be mandated for interoperability up to the application layer.

It remains unclear how such rules will be made and enforced. The DSRC Standards Writing Group proposed that the USDOT initiate a rule-making process that would apply to vehicles. There was also discussion of a USDOT rule-making that might apply to federal highways and other roadways with federal funding. The USDOT appeared to be in the best position to determine the optimal approach toward rule-making, or another approach, that would ensure DSRC interoperability at the upper layers. The chosen approach would need to operate in a complementary manner with the FCC Report and Order for the use of the 5.9 GHz DSRC spectrum.

4.3.6 Application and Message Priorities

There have been general discussions in the DSRC Standards Writing Group to the effect that safety applications will be assigned a higher priority than private applications. This group even drafted preliminary suggested priorities for identified applications. However, there was not yet any defined process to establish a priority framework, let alone evaluate applications and assign priorities to them. As well, no process or responsible authority had been established to set and maintain the priority levels for various applications.

The FCC Report and Order also described general rules for the assignment of priorities for applications. However, specific aspects were not defined, nor were methods of assignment or enforcement.

The process that is put into place to determine and assign priorities for applications is likely to require public/private cooperation, as well as authority to enforce the priorities of applications.

4.3.7 DSRC / WAVE Security Considerations

At the time this report was written (September 2004), there was a remaining risk within the VSCC security developments that the solutions that have been proposed to provide adequate security may be too costly, or too bandwidth inefficient, to be deployed. There were also significant remaining risks involved with coordinating such a solution with the security solutions of other stakeholder groups.

As additional major considerations for the IEEE P1556 security standard, a number of policy and implementation issues will need to be resolved before deployment can proceed.

4.3.8 Potential Interference from Other Services

An interference assessment of adjacent band Fixed Satellite Service (FSS) earth station uplinks was conducted in association with the DSRC Standards Writing Group. The analysis suggested a minimum impact of 40 dBm for DSRC channels 172-180, and approximately 50 dBm at channel 184 in the direct vicinity of these earth stations. An estimated 4 km distance would be required to avoid interference on channels 172-180, while 22 km would be required for channel 184. Mitigation of this potential interference was seen as an issue to be resolved for the effective deployment of DSRC.

United States military radars were viewed as potentially a larger threat to DSRC. However, military radars within 75 km of DSRC stations must be coordinated in new FCC rules. Apparently, there were only a few of the potentially interfering military radars deployed. Shipboard radars may also interfere with DSRC, but these radars were expected to be disabled during the time that the ships were in port.

Under a practical assessment of the interference issue, there were not too many places where this interference would be expected to be realized in actuality. The antenna directionalities, narrow antenna beam widths and distance of sites from roadways were all viewed as potentially mitigating factors. In the final analysis, DSRC units will need to be designed to accept this interference, and be protected from damage from these high-level signals.

4.3.9 Privacy Concerns

Privacy was a significant constraint for security considerations. However, privacy was a core requirement for automobile end users, and therefore for automobile manufacturers. The level of privacy provided in the proposed DSRC standards depended upon the use of a temporary random MAC address to provide only a relative identification of the vehicle. This approach was not able to solve all privacy concerns, however, since information resident in other vehicles, or the infrastructure, may be able to be linked to a particular vehicle in conjunction with other sensors (e.g., video detection) or events (e.g., crashes).

The level of anonymity provided by random MAC addresses must be maintained in practice as user-specific applications are implemented on DSRC systems. This may become a significant issue in conjunction with the use of Internet-connected devices within the vehicle. These devices may have fixed IP addresses that could be used to identify the vehicle. In addition, applications that need positive identification of the user, like those that entail financial payments, might contain aspects that compromise the privacy of the end user.