3. CANDIDATE CONCEPTS

3.1 SELECTION OF THE CANDIDATE CONCEPTS

Examination of the concept characteristics allowed the Concepts Team to reduce the eleven key concept characteristics to six. However, few of the alternatives within any characteristic could be definitively eliminated based on studying each characteristic alone, since the various characteristics are closely interrelated. The effectiveness of any characteristic alternative is very dependent on the other characteristics. Hence, it is necessary to compare complete concepts. While the team identified some alternatives that seemed less promising, they were not definitively eliminated, and were kept to evaluate for completeness. This leaves a total of 5 x 3 x 4 x 2 x 2 x 3 = 720 combinations of characteristics, i.e. candidate concepts. This is clearly more than can be reasonably evaluated, so the team developed a manageable set of candidate concepts. Recall that the team already had to limit themselves to a representative, not a complete, set of alternatives for the allocation of intelligence alone.

The team agreed that the set of concepts should consist of between 15 and 30 candidates in order to provide breadth, while being a small enough number to evaluate reasonably. This set of candidates needed to include representatives of the full range of feasible AHS solutions, and all of the most promising solutions.

The first step was to eliminate mismatched combinations. First of all, there is a strong correlation between the entry/exit strategy and the mixing of AHS and non-AHS vehicles, in particular the means to separate the two. Specifically, a transition lane is inconsistent with a continuous physical barrier, simply because the barrier prevents transition. Similarly, dedicated entry/exit only makes sense with a continuous physical barrier in order to maintain a consistent level of separation. It would not be reasonable to construct an expensive dedicated ramp, and then allow traffic from adjacent lanes to drift in through gaps. The team eliminated other combinations based on mismatches. For instance, both autonomous concepts have a free agent separation policy because vehicle-to-vehicle communications (by definition not a part of an autonomous concept) are by definition required for platoons. As another example, concepts with a slot separation policy by definition require heavy infrastructure involvement.

Next the team identified the most promising characteristic alternatives based on the analysis reported in Section 2. The following were judged to warrant examination in all or nearly all combinations.

Distribution of intelligence

- Cooperative
- Infrastructure Supported
- Infrastructure Managed

Separation Policy

- Free Agent
- Platooning

Mixing of AHS and Non-AHS

- Dedicated Lanes with Continuous Physical Barriers
- Dedicated Lanes with Some Gaps

Mixing of Vehicle Classes in a Lane

- Mixed

Entry/Exit

- Dedicated
- Transition

Obstacle

- Automated sensing and automatic avoidance maneuver if possible

Other characteristics were less promising, based on the analysis.

- Autonomous was addressed in two concepts, with and without automated obstacle avoidance, because the former represents a very minimal capability. It may not even be an AHS system, but

was maintained to allow a consideration of the extremes.

- Infrastructure controlled was kept in two concepts. The initial analysis indicated that lane keeping is far more efficiently managed by the vehicle, and completely centralized control risks single point failure, but this approach was kept as an extreme.
- Slotting was limited to a single concept, since the analysis indicated that it was extremely complex, and did not provide great capacity benefits.
- Dedicated lanes with virtual barriers were limited to two concepts, due to safety concerns.
- Full mixing of AHS and non-AHS vehicles appeared in only three concepts, due to concerns of safety, and loss of many AHS advantages.
- All but five of the concepts allow mixing of vehicle classes, since the stakeholders want access open to all classes, and the provision of dedicated lanes for each class may be prohibitively expensive.
- Only one alternative included manual obstacle avoidance, since a true AHS automates all driving tasks, but this was maintained as an extreme.
- Only three concepts have only the capability to automatic sensing, stop or manually avoid obstacles, since this too violates the spirit of AHS by forcing the driver to take over whenever the vehicle is confronted with a perceived obstacle.

Figure 3.1-1 summarizes the selected concepts. There were originally 23 concepts, but after some adjustments to correct inconsistencies concept 7 was seen to be redundant and eliminated. Subsequently, the evaluations rated concept 3 poor, due primarily to its reliance on an infrastructure controlled approach. Since this was the only slotting concept, a second infrastructure managed slotting concept was created, concept 3a, returning to 23 candidate concepts.

3.2 DESCRIPTIONS OF CONCEPTS

Figure 3.1-1 defines the skeleton of these 23 concepts, but more specifics were needed for estimates of performance, deployability and cost. The next step was to describe the concept in sufficient depth to allow evaluation. Specifically, each was fleshed out with details representative of the range of possibilities in order to provide an evaluatory design. That is not to say that the details are necessarily the only, or even the best, approach. The goal was representative designs to show the richness of the possibilities.

Each of the descriptions was assigned to a particular organization, as indicated in the matrix. Similar concepts were intentionally assigned to different organizations to get a range of viewpoints and approaches. The descriptions presented physical, functional and operational viewpoints. These documents were not only descriptive, but also provided insights into the applicability and limitations of various combinations of concept dimensions.

The following is the suggested outline for these descriptions. The authors were given this outline expanded with examples, and a great amount of latitude in selecting the scope and depth of information presented for an understanding and evaluation of the particular concept. This outline was provided as suggested content; no author was expected to provide all of the information included in it.

1.0 Overview

No more than 1/2 page. Why are we considering this concept? What is its distinguishing feature?

2.0 Selected alternative

From each dimension state the alternative chosen (e.g. autonomous, free agent, full mixing, etc.)

On each option, describe any local tailorability or cases in which the system is operating in different

Table 3.1-1. Twenty-Three Candidate Concepts

Candidate Concept Identifiers	1a	1b	2	3	3a	4	5	6	8a	8b	9	10	11	12a	12b	13	14	15	16	17	18	19	20
Distribution of Intelligence																							
Autonomous	X	X																					
Cooperative						X	X													X	X		
Infrastructure Supported								X	X	X	X						X		X				X
Infrastructure Managed					X							X	X	X	X	X		X				X	
Infrastructure Control			X	X																			
Separation Policy																							
Free Agent	X	X	X			X		X	X	X		X		X	X			X	X		X		X
Platooning							X				X		X			X	X			X		X	
Slot				X	X																		
Mixing AHS & Non-AHS Vehicles in Same Lane																							
Dedicated lanes with continuous physical barriers			X	X	X				X	X	X			X	X	X					X	X	X
Dedicated lanes with some gaps in the physical barriers						X	X	X				X	X				X						
Dedicated lanes with virtual barriers																			X	X			
Full Mixing	X	X																X					
Mixing Vehicle Classes in Same Lane																							
Mixed	X	X	X			X	X	X	X		X	X	X	X			X	X	X	X	X	X	
Not Mixed				X	X					X					X	X							X
Entry/Exit																							
Dedicated			X	X	X				X	X	X			X	X	X					X	X	X
Transition	X	X				X	X	X				X	X				X	X	X	X			
Obstacle																							
Manual sensing and avoidance of obstacles	X																						
Automatic sensing, stop or manually avoid																					X	X	X
Automatic sensing and automatic avoidance maneuver if possible		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			

alternatives at different locations or times. If some alternative does not quite seem to fit, describe what is special about that alternative in this concept.

3.0 Operational Concept

Describe how the system would operate. What happens when things are running regularly? What are the system operations, and how are they achieved? Discuss any special operating modes or behaviors.

4.0 System diagram

Show the vehicles and infrastructure and data flows among them, including sensing. Generally describe the content of each of the shown data flows. Roughly estimate the order of magnitude of the message size, update rate and range. Mention any other requirements or features.

5.0 Functional allocation

For at least the following functions, define its allocation to vehicle, infrastructure, human or combination, and describe the sequence of events for performing the function.

- Check-In
- Transition from manual to automatic control
- Automated driving including:
  - Sensing of roadway, vehicles, and obstructions
  - Lane and headway keeping
  - Detection of hazards
  - Maneuver planning (normal or emergency)
  - Maneuver execution
  - Transition from automatic to manual control
  - Check-Out
  - Flow control
  - Malfunction management
  - Handling of emergencies

6.0 Implementations

Describe at least one implementation of the concept, specifically what will be in the vehicle, the roadside and the AHS traffic operation center, above and beyond the standard and Intelligent Transportation System. Provide whatever level of detail you feel is necessary for a description of the concept, but be sure to address the following at a minimum:

- What are the options for different standard levels of AHS roads (rural or urban) in this concept?
- Describe the minimal deployable system. Describe what incentive there is to buy an AHS vehicle, given the minimal deployed system. Describe what incentive there is to extend the AHS roadway, or deploy additional AHS infrastructure, given the minimal deployed system.

7.0 General issues and considerations

Discuss any additional issues that should be considered in the evaluation of this architecture [a list of suggested questions was provided].

The descriptions of these 23 concepts are in Appendix H.

3.3 CONCEPTS SUMMARIES

The following tables summarize the 23 alternative concepts developed by the AHS Concept Team. The descriptions in Appendix H provide the basis for this summary. The descriptions are not full designs, and so have different emphases depending on the key characteristics of each concept. Thus, any lists that appear in this summary are not intended to be exhaustive, but merely to indicate the "flavor" of the concept. In particular, nothing should be inferred from blank cells in this summary.

3.3.1 Description of the Rows of the Table

3.3.1.1. Concept ID No.

Each of the 23 concepts was assigned a number. There were originally 20 concepts. Initial work on these suggested other variations, so you will see numbers such as 8a and 8b. Number 7 was eliminated as being redundant. 3a was added after the initial evaluation.

3.3.1.2. Key features

This is a brief summary of the characteristics that made this concept worth looking at and distinguishes it from the others.

3.3.1.3. Allocation of intelligence

Allocation of intelligence indicates whether the intelligence is primarily in the vehicle, in the infrastructure, or some combination (see 2.13).

3.3.1.4. Separation policy

The separation policy states whether platoons, free agency or slotting is used (see 2.13).

3.3.1.5. AHS/manual mix of vehicles

A "yes" indicates that automated vehicles would be able to share the road with manually operated vehicles as well as being able to operate in dedicated lanes. Any other answer indicates that the automated vehicles must have a dedicated roadway, which is distinguished by the type of barrier separating it from adjacent lanes. "Barriers" indicates a solid barrier that would be entered via dedicated ramps, "barriers with gaps" indicates a solid barrier with occasional openings through which vehicles may transition from the adjacent lane, and "virtual barriers" indicate a lack of any physical separation other than yellow lines.

3.3.1.6. Mixed vehicle classes in a lane

A "yes" indicates that various classes of vehicles (e.g., passenger cars and heavy trucks) use the same AHS lane at the same time (although they may not necessarily be in common platoons). A "no" indicates either that there are separate lanes for the various classes, or that only one class uses the AHS at a time (e.g. only passenger cars and small buses in rush hour, only heavy trucks other times).

3.3.1.7. Entry/exit

Entry and exit will occur either by an adjacent transition lane through manual traffic or a dedicated ramp that places vehicles directly on an automated lane.

3.3.1.8. Obstacle detection and avoidance

"Manual" indicates that the driver is fully responsible for seeing hazards and maneuvering around them. "Auto sense & avoid" indicates that the system will detect hazards and avoid them automatically. "Auto sense & stop" indicates that the system will automatically detect hazards and bring the vehicle to a stop, possibly allowing the driver to maneuver around the hazard manually.

3.3.1.9. Vehicle sensors

This indicates either what is being sensed by each vehicle or the actual types of sensors on the vehicle, depending on the approach taken in the write-up. The list depends on the level of detail in the full concept description and may not form an exhaustive list.

3.3.1.10. Infrastructure sensors

This lists the attributes of the traffic or other conditions that are detected by the roadway. Again, these lists are not exhaustive.

3.3.1.11. Vehicle-to-vehicle communications

This indicates the types of information that is passed between vehicles.

3.3.1.12. Vehicle-infrastructure communications

This indicates the types of information that is sent from the infrastructure (roadside or central) to the vehicles. It also may identify information sent from the vehicles to the roadside, or characteristics of the communications path.

3.3.1.13. Driver involvement

This identifies the activities that the driver must or can do while in the automated lanes.

3.3.1.14. Infrastructure modifications

These are the items that need to be added to a standard highway to implement this concept. In some cases there are options or alternatives listed.

3.3.1.15. Issues and solutions

In some cases, the concept author discussed some problems, issues or concerns that drove the concept design in a particular direction. Each issue and its corresponding solution are separated by a semi-colon -- Issue1; solution1. Issue2; solution2.

3.3.1.16. Reconcept ideas

One goal for the concept team was to identify alternative concepts or variations on these concepts that would perform better. These are described briefly here. In some cases these ideas were incorporated in the concept description, and in other cases they were merely comments on how to improve the concept.

3.3.1.17. Unusual approaches

In some cases, the approach to the development of the concept included a twist that was not the "standard" approach or that set it apart from the other concepts.

3.3.2 Abbreviations Used in the Table

@	at
accel	acceleration
addl	additional
AHS	Automated Highway System
auto	automated
b'cast	broadcast
comm	communications
coop	cooperative
deg	degree
det	detection or detecting
DGPS	differential GPS
dist	distance
FMCW	Frequency modulated continuous wave
GPS	Global Positioning System
incl	including
ind	individual
indiv	individual
inf	infrastructure
info	information
infr	infrastructure
infra	Infrastructure
IR	Infrared
ITS	Intelligent Transportation System
LOS	line-of-sight
mgmt	management
mod	modification
nav	navigation
opp	opposite
opt	optional
parms	parameters
pos	position
poss	possibly
prox	proximity
pt	point
recog	recognition
rel	relative
req's	requires
RF	radio frequency
rng	range
sec	second
sim	similar
std	standard
thru	through
TOC	traffic operation center
veh	vehicle
vel	velocity
w/o	without

Table 3.3.1-I. Summary Comparison of Concepts

Concept ID No.	1a	1b	2	3	3a	4
Key features	Automated cruise control and lane keeping	Automated cruise control, lane keeping, and lane changing	Infrastructure controlled	Slots	Slots	Cooperative flexible
Allocation of Intelligence	Autonomous	Autonomous	Infra controlled	Infra controlled (vehicle lateral control option)	Infra managed	Cooperative
Separation policy	Free agent	Free agent	Free agent	Slot	Slot	Free agent
AHS/manual mix of vehicles	Yes	Yes	Barriers	Barriers	Barriers	Barriers with gaps
Mixed vehicle classes in a lane	Yes	Yes	Yes	No	No	Yes
Entry/exit	Transition	Transition	Dedicated	Dedicated	Dedicated	Transition
Obstacle detection and avoidance	Manual	Auto sense & avoid	Auto sense & avoid	Auto sense & avoid	Auto sense & avoid	Auto sense & avoid (maneuver into transition)
Vehicle sensors	Variation 1: Forward-looking FMCW radar. Variation 2: Fusion of forward-looking FMCW radar and vision sensor.	Forward, backward Doppler radar, GPS, side proximity, IR, vision	Lane & obstacle sensors	Supplemental obstacle (optional); lateral control reference (opt.)	Supplemental obstacle (optional); lateral control reference (opt.)	Lane, headway, adjacent vehicles, roadway, obstacles (forward & side)
Infrastructure sensors	None	None	Sense position & velocity of all vehicles	Vehicle position; hazards	Congestion, environment, hazard info; vehicle position (opt.)	Obstacles
Vehicle-vehicle communications	None	Detection of signals	None	None	None	Signals entry/exit; platoon parameters; coordination among platoons
Vehicle-infrastructure communications	None	GPS	Control signals, 20/sec for each vehicle	One way inf to veh control signals	Vehicle sends position; infra sends position changes	Veh requests permission to enter; infra sends target speed; veh sends exit notice

Table 3.3.1-I. Summary Comparison of Concepts (Continued)

Concept ID No.	1a	1b	2	3	3a	4
Driver involvement	Obstacle sensor; override at any time; lane change	Command transition out of automated mode			lert AHS of hazards and malfunctions	Takes/ surrenders control in transition lane
Infrastructure mods	Variation 1: Magnetic nails. Variation 2: DGPS ref stations, radar-reflective roadway markings.		Comm, computation, remote servo controller for each section of roadway	Lane markings (optional)	Lane markings (opt.); obstacle detection (opt.); vehicle position (opt.)	
Issues and solutions	Variation 1: Obstacle recognition on curved road; curvature coded in roadway. Variation 2: Obstacle recognition on curved road; curvature through DGPS and map.		Detecting driver intentions; automated brake & signal detectors. Aggressive manual vehicles; sophisticated algorithms	Remote servo control; high bandwidth, high reliability, handoff across sections	Capacity depends on position sensing accuracy; advanced or closely spaced sensors. High update rate; high level of real-time processing.	Capacity depends on ability of vehicle to maintain position in slot. High update rate; high level of real-time processing.
Reconcept ideas	Alarms, manual steering required to keep driver alert	Locally directed vehicle-vehicle comm	Vehicles determine own steering, braking, throttle		This is an infra managed version of Concept 3	Infrastructure approves check-in, tracks routing; pseudo-platoons with front-end comm
Unusual approaches	Auto detection of manual vehicle intentions					Time synchronous vehicle management

Table 3.3.1-I. Summary Comparison of Concepts (Continued)

Concept ID No.	5	6	8a	8b	9	10
Key features	Cooperative platoons	Free agent with moderate non-AHS exposure	Infra supported free agent, DGPS	Infrastructure supported free agent without mixed classes	Infrastructure supported platooning	Infra managed, no veh-veh comm
Intelligence	Cooperative	Infra supported	Infra supported	Infrastructure supported	Infra support, some infra managed	Infrastructure managed
Separation	Platoon	Free agent	Free agent	Free agent	Platoon	Free agent
AHS/.manual mix of vehicles	Barriers with gaps	Barriers with gaps	Barriers	Barriers	Barriers	Barrier with gaps
Mixed vehicle classes in a lane	Yes, unmixed platoons	Mixed	Mixed	No	Yes (local option)	Yes (local option)
Entry/exit	Transition (with check-in)	Transition	Dedicated	Dedicated	Dedicated	Transition
Obstacle detection	Auto sense & avoid	Auto sense & avoid	Auto sense & avoid (veh & opt. infra)	Auto sense & avoid	Auto sense & avoid	Auto sense & avoid
Vehcile sensors	Lane edge, road curvature, junctions, abs position, rel speed & dist, adjacent hazards	Lateral control, distance (radar), obstacles	Distance, passive markers	Adjacent vehicles, lane markings	Sophisticated obstacle sensors, lane, distance & rel vel, adjacent veh's	Longitudinal position & obstacle, lane keeping, right side large object. All ranging
Infrastructure sensors	Traffic flow	Congestion, surface, weather	Std. ITS	Traffic flow	Occupancy, speed upstream from entry; flow; obstacles; ind. veh movements	None
Vehicle-vehicle communications	Within platoon with lead, adjacent lanes, directed or broadcast	Share speed & accel data with adjacent, position & intended maneuver	Substantial data & coordination, including b'cast hazards		Lane position, velocity, coordination, advisory & nav (daisy-chain)	None

Table 3.3.1-I. Summary Comparison of Concepts (Continued)

Concept ID No.	5	6	8a	8b	9	10
Vehicle-insfrastructure communications	Emergency, advisories, static info	Infra to veh only.	DGPS, beacon @ check-in; broadcast beacons elsewhere; use veh-veh comm (opt.)	Advice to vehicles	Infra local b'cast to veh's: lane, speed, exits, hazards, etc. Vehs send hazards	Short range 2 way, complete coverage
Driver involvement		Entry, exit requests; receives status	Command auto, desired exit, take-over in system failure	Exit preference, take over in system failure	Initiate transition	Transfer control at entry, resume control in transition lane (incl. failure)
Infrastructure mods	Magnetic markers, barriers	Sensors for traffic flow, zone controllers, TOC, poss. lane markers	GPS, optional beacons, roadway markers	Lane marking	Section controller, entry controller, road reference, short-rng transmitters	Encoded roadway markers, cameras @ entry
Issues and solutions	Variations in barriers; several alternatives. Selfish maneuvers; cooperative protocols	Access to receive bandwidth in maneuver; addressing	Detection of vehicles & traffic cones, recognition of obstacles; passive markers (obstacles don't have them). Emergency; response protocol	Prevent mishaps; strict check-in & -out (2 gates)	Pure infra support is limited; infra-indiv. veh. comm for entry/exit, dynamic routing, emergency. Two cars changing into same lane from opp sides; query 2 lanes over.	Passing in single lane; use transition lane. Inadequate obstacle detection; driver spotter
Reconcept ideas	More global comm, infra support				Infra-individual veh control on entry, infra req's detected movement of ind. veh's	Driver spotter

Table 3.3.1-I. Summary Comparison of Concepts (Continued)

Concept ID No.	11	12a	12b	13	14	15
Key features	Infra managed platoons	Infra managed mixed free agents	Infrastructure managed unmixed free agents	Maximum achievable throughput	Infra supported platooning with transition lane	Infra managed, full mixing
Intelligence	Infra managed	Infra managed	Infra managed	Infra managed	Infra support, some infra managed	Infra managed
Separation	Platoons	Free agent	Free agent	Platoon	Platoon	Free agent
AHS/manual mix of vehicles	Barriers with gaps	Barriers	Barriers	Barriers	Barriers with gaps	Yes
Mixed vehicle classes in a lane	Yes	Yes	No	No	Yes (local option)	Yes
Entry/exit	Transition with entry check	Dedicated	Dedicated, separate class ramps	Dedicated, separate class ramps	Transition (with check, poss. stop)	Transition (shared with manual)
Obstacle detection	Auto sense & avoid	Auto sense & avoid	Auto sense & avoid	Auto sense & avoid	Auto sense & avoid	Auto sense & avoid
Vehicle sensors	Forward looking radar, prox sensors for gaps, camera for stripes	lateral prox & lane pos, 2 rng, rng rate longitudinal, platooning controller	lateral prox & lane pos, 2 rng, rng rate longitudinal	lateral prox & lane pos, 2 rng, rng rate longitudinal	Sophisticated obstacle sensors, lane, distance & rel vel, adjacent veh's	Distance to any adjacent vehicles
Infrastructure sensors	Vehicle speed, weather	Traffic flow speed & density; weather	Traffic flow speed & density; weather	Traffic flow speed & density; weather	Occupancy, speed upstream from entry; flow; obstacles; ind. veh movements	All vehicles' locations, obstacles
Vehicle-vehicle communications	None directly	Vel, accel, braking, coordination	Vel, accel, braking, coordination	Vel, accel, braking, coordination	Lane position, velocity, coordination, advisory & nav (daisy-chain)	None

Table 3.3.1-I. Summary Comparison of Concepts (Continued)

Concept ID No.	11	12a	12b	13	14	15
Vehicle-infrastructure communications	2 way, voice & data short range. Veh receive satellite. Infra tracks vehs thru comm	Broadcast & 2-way individual address	Broadcast & 2-way individual address	Broadcast & 2-way individual address	Infra local b'cast to veh's: lane, speed, exits, hazards, etc. Vehs send hazards	Two-way local
Driver involvement	Initiates lane changes, calls in obstructions, takes over in failure	Optional obstacle spotting. Takes over in emergency. Requests destination, change of exit	Optional obstacle spotting. Takes over in emergency. Requests destination, change of exit	Optional obstacle spotting. Takes over in emergency. Requests destination, change of exit	Initiate transition	Some will drive always
Infrastructure mods		Lane markers	Lane markers, dedicated separate ramps	Lane markers, dedicated separate ramps	Section controller, entry/exit controller facilities, road reference, short-range transmitters	Local controllers, TOC
Issues and solutions	Optimizing inter-veh spacing; spacing is sum of fixed veh parameters & dynamic system parms. In-vehicle computer failure; redundancy					Pure infra support is limited; infra-indiv. veh. comm for entry/exit, dynamic routing, emergency. Two cars changing into same lane from opp sides; query 2 lanes over.
Reconcept ideas		Minimal infra-structure manage-ment (vehicle plans normal maneuvers, platooning)	Minimal infrastructure management (vehicle plans normal maneuvers)	Minimal infrastructure management (vehicle plans normal maneuvers)	Infra-individual veh control on entry, req's det movement of ind. veh's. Dedicated ramp.	May need some mgmt of non-AHS vehicles

Table 3.3.1-I.Summary Comparison of Concepts (Continued)

Concept ID No.	16	17	18	19	20
Key features	Free agent virtual barriers	Coop platoon, vitural barriers	Cooperative, auto obstacle sense & stop	Platooning, atuo obstacle sense & manuall avoid	Low risks
Intelligence	Infra supported	Cooperative	Cooperative	Infra managed	Infra supported
Separation	Free agent	Platoon	Free agent	Platoon	Free agent
AHS/manual mix of vehicles	Virtual barrier	Virtual barriers	Barriers	Barriers	Barriers
Mixed vehicle classes in a lane	Yes	Yes	Yes	Yes (mixed platoons)	No
Entry/exit	Transition	Transition (vehicle self test)	Dedicated (veh only check-in)	Dedicated	Dedicated (with stop & at obstacle)
Obstacle detection	Auto sense (veh) & avoid	Auto sense (veh) & avoid	Auto sense & stop	Auto sense & stop, manually avoid	Auto sense & stop, manual avoid
Vehicle sensors		Forward, side, lane marker. Velocity and range of adjacent vehs	360 deg Doppler radar for obstacles, vision system, IR	Distance to vehicle ahead. Roadway, vehicles, obstacles (platoon lead only)	Forward range, range rate; passive marker sensor; side prox
Ingrastructure sensors			None	Obstacles	
Vehicle-vehicle communications	Broadcast RF with global addressing, packet.	Short range, 2-way	Beacon. Performance parameters, emergency vehicle notice	None	Short range LOS
Vehicle-infrastructure communications	1 way infra to veh. broadcast RF	Roadside receivers & processors, continuous coverage	None	Roadside beacons.	

Table 3.3.1-I.Summary Comparison of Concepts (Continued)

Concept ID No.	16	17	18	19	20
Driver involvement	Entry, exit requests, opt. detect hazards & malfunctions	Can request no platoon. Alert button. Request lane change	Tell vehicle to ignore obstacle or manually avoid obstacle	Request entry/exit	Drive around obstacles
Infrastructure mods	Broadcast RF	Reflective lane markers	None	TOC, beacons, controllers	Passive lane markers
Issues and solutions	Sensor blind spot; vehs broadcast speed & position. Obstacle detection; add'l sensors or driver spotter. Obstacle recog; vehs b'cast positions			Rural can't afford continuous comm; have platoon leads carry data to next comm pt.	Obstacles are major disruption; breakdown lanes for breakdowns & driving around obstacles
Reconcept ideas	Physical barriers. Few entry/exit, long trips only	Local processor (sim to infra supported)	Manual obstacle avoid technically insupportable. Use vehicle maneuver capability		Infrastructure check at check-in
Unusual approaches	Veh check-in before entering freeway. Highly vehicle centered	2-way comm veh-roadside, transition lane for passing, platoons formed by destination	Completely vehicle centered	Extremely infrastructure centered, platooning w/o veh-veh comm	