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A First Example Specification Of An Automated Freeway

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TABLE OF CONTENTS

Glossary of terms	iii
Introduction	1
Control System Overview	2
Physical layout	3
Roadside Communication Systems	7
Some Definitions	9
System Architecture	10
Vehicle Controllers	13
Message Structure	16
System Modes	17
Vehicle Modes	19
The Roadside Controllers	
A. Regulatory Level	21
B. Platoon Level	35
System Operation	
A. Operation on TL before entry to AL	37
B. Entry to AL and Operation on it	42
C. Continued travel on AL and Exit from it	47
D. Operation while leaving the TL	50
Acknowledgments	53
References	54

TABLE OF CONTENTS (continued)

Appendixes - Introduction	A. 1
How to Use the Module Definitions	A. 1
General	A. 3
VPD Controls:	
on TL (fig 3)	A. 8
on AL (fig 4)	A. 14
at on-gates (fig 5)	A. 15
at off-gates (fig 6)	A. 17
Iterators:	
Loniter (fig 7)	A. 19
Prepiter (fig 8)	A. 22
Aliter (fig 9)	A. 25
Lofiter (fig 10)	A. 29
Postiter (fig 11)	A. 31
Vehicle modes:	
U (unconcerned) mode (fig 16)	A. 34
PC (provisional controlled) mode (fig 17)	A. 37
C (controlled) mode (fig 18)	A. 43
PP (provisional preplatoon) mode (fig 19)	A. 47
P (preplatoon) mode (fig 20)	A. 54
E (entry) mode (fig 21)	A. 59
A (AL) mode (fig 22)	A. 62
X (exit) mode (fig 23)	A. 71
EX (emergency exit) mode (fig 24)	A. 73
PX (platoon exit) mode (fig 25)	A. 75
XA (exitrans) mode (fig 26)	A. 77
XP (postplatoon) mode (fig 27)	A. 83

GLOSSARY OF TERMS

In this paper, a number of specially-defined terms of art, and a number of abbreviations are used. The following table refers the reader to the definitions of the terms and spells out the abbreviations.

Term	*Page*
A -AL mode	20
AL - automated lane	3
aliter	30
AL license	**8,14**
AR - **asychronous** register	6
block	2
block transfer controller	3
C - Controlled mode	20
chicane	8
counter	4
Crashstop Mode	18
degraded mode	19
E - entry mode	20
EX - emergency exit mode	21
full platoon braking	9
gate AR	22
hazard (see Hitchcock 1991)	1
Highway Patrol	8
identifier	8
iterator	**2,12**
lateral guidance reference	6
lofiter	29
LOFR - logical off-ramp	4
loniter	29
LONR - logical on-ramp	4
manual spacing	10
maxspeed	12
Natural Mode	17
Normal Mode	**2,17**

off-gate 4
Offok 22
on-gate 4
Onok 22
P - preplatoon mode 20
PC - provisional controlled mode 20
platoon (see Hitchcock 1991) 1
platoon spacing 9
postiter 34
postplatoon 21
PP - provisional preplatoon mode 20
prepiter 29
preplatoon 40
PX - platoon exit mode 21
Resume Mode **2,18**
RSV - roadside state vector 6
sensor range 9
sensor range speed 9
SRC Mode - sensor-range-continue 17
SRX Mode - sensor-range- exit 17
Stop Mode **2,18**
System supervisor 9
target speed 12
TL - transition lane 4
turning-point marker 6
U - unconcerned mode 20
vehicle mode 19
VPD - vehicle presence detector 2
VSV - vehicle-borne state vector **6,14**
X - Exit mode 21
XA - Exitrans mode 21
XP - Exit Platoon Mode 21

A First Example Specification of an Automated Freeway

INTRODUCTION

This paper is complete in itself. However, the background to it is discussed in "Methods for Analysis of XVHS Safety: Final Report of PATH MOU 19" (Hitchcock, 1992a). Readers not familiar with the area are strongly advised to read the other report first. Yet shorter accounts of the background can be found in Hitchcock 1991 and Hitchcock 1992b.

This paper sets out a specification for an automated freeway in a fully formal manner. A series of safety analyses have been carried out on the specification. The objective of the programme of work of which this is part is to derive a technique of safety analysis for such systems. The system reported here is the first example on which a trial analysis has been demonstrated. The analysis depends on the precise nature of the system specified. It is therefore necessary that this be recorded unambiguously. This requires great detail. In any case the method of analysis recommended by Hitchcock, 1992a does require formal documentation. This paper is consequently intended as an exemplar of such documentation. This applies especially to the appendices. Here a formalized language has been proposed, which is analogous to some computer languages.

The freeway specified here operates with vehicles in ***platoons.*** This is the basis on which other work in PATH has been carried out. There was no good reason to do other here. The safety argument in favour of platoons is reviewed in Hitchcock, 1992a.

The method of demonstrating safety used in the larger programme starts by defining certain ***hazards.*** A safety criterion is selected. The criterion used here is that two or more simultaneous faults must occur independently before the hazards can arise. The process, and the hazards, are described in Hitchcock 1991.

In the same paper it is pointed out that any automated freeway is part of a larger, hierarchical system of IVHS architecture (IVHS = Intelligent Vehicle/Highway Systems). This extends the work of Varaiya and Shladover, 1991. The highest level in the hierarchy is law. Law controls all the freeways in different areas. What the law permits or requires determines what can be designed. The legal provisions relevant to the system considered here are set out in Hitchcock 1991.

This paper does not detail the special procedures which are required when the system is under manual supervision. Manual supervision is necessary in fault conditions. The so-called **Stop Mode** is used when special action is needed to remove debris, move injured, clear blocked vehicles, etc. **Resume Mode** is used after such processes are complete, in order to revert to **Normal Mode.**

CONTROL SYSTEM OVERVIEW

The automated freeway system is divided into ***blocks,*** each containing one entry and one exit. The blocks are typically about a mile long on average. Each vehicle contains a control system, communicating with one the roadside ***iterators.*** "Iterator" is the name given to the asynchronous controllers which communicate with each vehicle under their control in turn. There are five roadside iterators in this design, because it is convenient to regard those controlling vehicles in different situations (entering, exitting, in platoon, solo . ..) as distinct.

A sixth iterator examines the ***vehiclepresence detectors (VPDs).*** The **VPDs** cover much of the track. This iterator provides data which enables the system to keep account of vehicle movements and identities.

Three other asychronous roadside controllers control the movements and manoeuvres of platoons. A fourth is called the ***block transfer controller.*** The block transfer controller passes control from block to block.

All these controllers are in communication. They are described here as separate asynchronous computers. In practice it may be convenient to combine one or more of the ones in one block. However, whether the computers are combined or not the roadside state vectors, (to be discussed later, page 5) need to have asychronous access. The block transfer controllers need to communicate with one another, block to block. Some form of hard-wired connection is envisaged.

In operation, a vehicle enters the system under its driver's control. The driver resumes control as the vehicle leaves. In between, there are a total of eleven possible vehicle modes. System commands are appropriate to a particular mode - a vehicle will not process signals which refer to other modes. Some of the modes are for emergency use only. Others represent alternative paths through the system.

In parallel, seven different operating modes of the roadside system are distinguished. Besides normal operation there is a succession of degraded modes for use in fault conditions. Normal, Stop and Resume modes have already been mentioned.

PHYSICAL LAYOUT

The system contains one automated lane, called the AL .Other traffic also has access to the freeway. In Hitchcock 1991 arguments are presented indicating that the physical layout of such a system is restricted to a very small number of possibilities, and subsequent work has shown that at most one of these can conform to the safety criterion used in this work. The same is probably true if a different initial requirement specification is chosen. This might be a multi-lane reserved facility. The present layout is shown in Figure 1.

The AL is the leftmost lane on the freeway. It is separated from the others by a fence in which there are some off-gates and ***on-gates.*** The length is divided into blocks, as already mentioned. In each block there is:

a. a length of AL. There is an AL controller, which controls vehicles on this length.

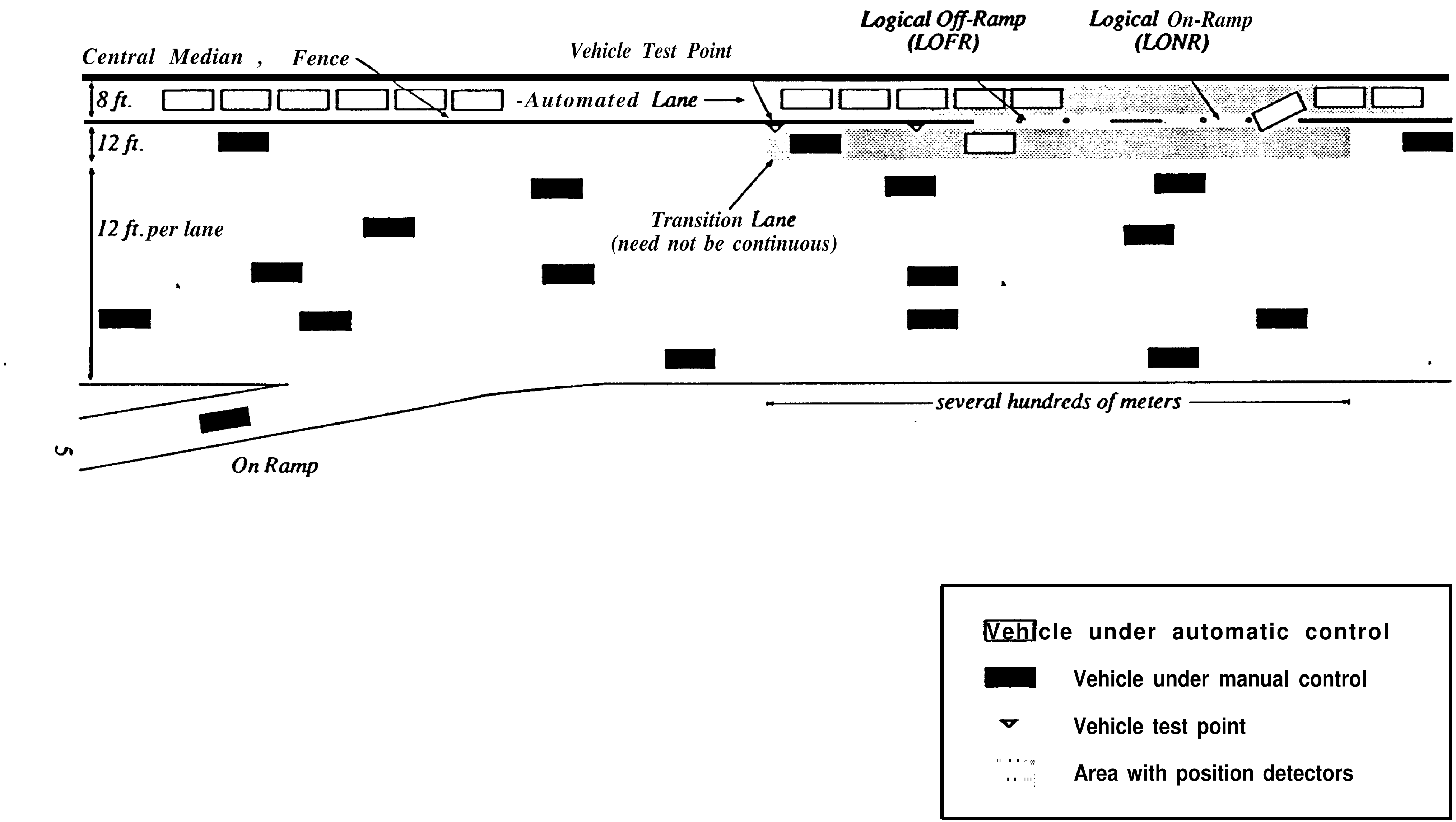
b. a set of off-gates, and an associated roadside controller, which controls vehicles as they leave the system. The gates are called collectively the ***logical off-ramp*** or ***LOFR.*** The roadside controllers is also called the **LOFR.**

c. a set of ***on-gates,*** and a roadside controller which controls vehicles entering the system. ***These are*** called the ***logical on-ramp*** or ***LONR .***

d. a vehicle ***counter*** on the AL, controlled by the block transfer controller.

Each block is controlled by a separate set of roadside controllers.

From some distance upstream of the upstream (first) off-gate to a few metres downstream of the downstream (last) on-gate (ie to the end of the block and the counter) the AL is covered with vehicle presence detectors **(VPDs).** A VPD enables the presence or absence of a vehicle or other object on a short length of lane to be signalled to the controllers. The length of a VPD is short - say 10 - 30 cm. At the gates, the **VPDs** are split into left and right halves. Part of the lane adjacent to the AL is also covered by **VPDs.** These **VPDs** stretch from a longer distance (say 500 m) upstream of the first off-gate to a 100 metres or so below the last on-gate. Again these **VPDs** are split by the gates. This part of the adjacent lane is called the ***transition lane*** or ***TL.*** The TL is thus not necessarily continuous. The AL, in contrast, proceeds from block to block without any physical break.



Layout of One-Automated-Lane Freeway

Along the center lines of both the AL and the TL runs a lateral guidance ***reference.*** Close to, and upstream of, each off-gate there is on the ***AL*** a ***turning-point marker*** and there are similar markers on the TL upstream of each on-gate.

All these features are, as shown in Hitchcock 1991, necessary for a system which meets the safety criterion. The following physical features are also included in the system considered. Here the designer has made choices. These features may not be necessary.

When the **VPDs** detect a vehicle on the TL a ***roadside state vector (RSV)*** is assigned to the vehicle by the detector-controller. The RSV is a computer store which can hold a record describing the vehicle. This particular store is special, however. The RSV is an asynchronous access device shared between all the roadside controllers in one block. We call this ***an asynchronous register (AR).*** There is a similar device (the ***vehicle state vector (VSV)*** on each vehicle. Much of the data in VSV and RSV is common. There are differences, however.The RSV records the data set out below. Many of the fields below have not yet been defined. These quantities will be clarified later.

a. *Vehicle mode

b. *Vehicle (temporary) identity

c. *Position on AL or TL (special signal indicates “on AL outside VPD area”)

d. Maxspeed, target speed (for communication to VSV).

e. Lateral control variable (from VSV).

f. Distance of vehicle ahead (NULL if none detected) and other variables transmitted from VSV.

g. Control variables required for vehicle control (usually speed and acceleration of platoon leader) - for transmission to VSV.

h. Various "message" fields, set by different roadside controllers, which confirm that some check has been made, and the result.

If a vehicle is under manual control, it is said to be in U (unconcerned) mode. For a vehicle in U mode only the fields labelled * are not null. Identity is assigned arbitrarily by the VPD controller when the vehicle is first detected, and the RSV is deactivated if the vehicle quits the VPD area of the TL. The position variable is updated cyclically by the VPD controller, at intervals short enough for the identity of the vehicle corresponding to a moving trace to be known unambiguously.

On changing modes a vehicle changes its identity. In this paper the RSV is referred to as if it retained some kind of identity throughout such changes. It does not matter if this is physically true or not - it is a minor detail of software
organization. Other material - like the identity of the following or preceding vehicle may also be recorded on the RSV. Once again this is a matter of software design, and not relevant here.

Roadside Communication Systems

Along both AL and TL runs a line transmitter and receiver. The receiver can pick up a suitably coded message from any vehicle in the appropriate lane. The transmitter can transmit a message to any vehicle in the lane. These messages are sent/received wherever the vehicle is in the block. Consequently the vehicle's position cannot be known from the mere fact of transmission. As will be seen later, page 17, almost every message identifies a particular vehicle. Most of the others identify a block. Vehicles change name as they pass a block transfer controller or as they cross between AL and TL. Thus messages from other areas may create noise. A message will not be acted on, however, if it are received by a vehicle other than the one(s) addressed.

At suitable points on the TL there are two short-range, directional communication devices which address only vehicles on certain **VPDs** near by. One or more ***identifiers*** are present on **each** T'L, including one at its extreme upstream end. The position of the identifiers is displayed to drivers by signs on the fence. Identifiers receive the message **Takeme** (for description of messages see later, page **17),** and admit vehicles to the system. When the driver instructs the vehicle to request entry, **Takeme** is sent. After that a system identity is assigned to the vehicle. The vehicle is taken under automatic control and the particular trace of its movement as revealed by the RSV is associated with that identity. This means that the system "knows" where each vehicle is, and which vehicle is which.

Also on the TL there are a number of chicanes. Here again (two-way) communication is short range and directional. At chicanes, special sensors can observe the motions of a vehicle with some accuracy. Here a number of commands are given to a vehicle in motion - accelerate, decelerate, swing left or right. The effects observed. Appropriate responses ensure that there are functioning control devices in the vehicle. At the same time the exterior dimensions of the vehicle are measured and compared with the ones on its AL ***license*** in the VSV (see later, page 14). This comparison ensures that the vehicle is not towing a non-equipped trailer or carrying an external load. Both of these practices are illegal (see Hitchcock 1991). They are dangerous. A load or trailer may fall off.

Under various conditions, the system must communicate with human controllers, This advice will reflect a limited number of standard conditions. Physically therefore advice can be text on a VDU, teletext or automatic voice-mail as requested. In this paper the people receiving are referred to ***as Highway Patrol*** when the function is concerned with recording a violation or license endorsement. It is the Highway Patrol, too, which is advised of abnormal traffic conditions (i.e. degraded modes).

Under some fault conditions maximum speeds will be reduced or traffic stopped. It may be necessary to clear accident debris or move injured people. This may well require a number of unusual manoeuvres, and will need to be followed by a controlled reversion to normal. In this system all these activities are carried out within a special system mode called Stop Mode under direct human control. This and similar situations are advised by a call to the Highway Patrol and/or the ***System Supervisor.***

In addition, there are lights mounted on the fence on either side of the off-gates. When a vehicle is programmed to leave the AL through the gate the lights flash. If, in fact, a vehicle in U mode (see page 21) does attempt to join the TL at this point the vehicle on the AL will not exit. This is inconvenient for its driver. That is why the request to keep clear is made.

SOME DEFINITIONS

Each vehicle will have a maximum deceleration when brakes are applied, which will vary between vehicles. Under some circumstances it will be necessary to decelerate as quickly as possible, short of generating within-platoon collisions. The appropriate deceleration is called ***full platoon braking*** It is clearly a function of the road surface, and is therefore set by each block as vehicles enter.

Platoon spacing is that spacing within which a vehicle decelerating at full platoon braking can avoid colliding with one ahead decelerating at some standard rate (one might choose 0.8 g - a practical maximum). The following platoon is supposed to be warned within some standard interval.

Sensor-range speed is the speed from which a vehicle can come to rest at full platoon braking within the distance - ***sensor range*** - where the vehicles' forwards-looking sensors are guaranteed to function.

Manual spacing is the spacing at which drivers normally drive without being alarmed. It is a function of vehicle speed and road surface condition. A parameter to describe the latter is passed by the block controllers on entry.

SYSTEM ARCHITECTURE

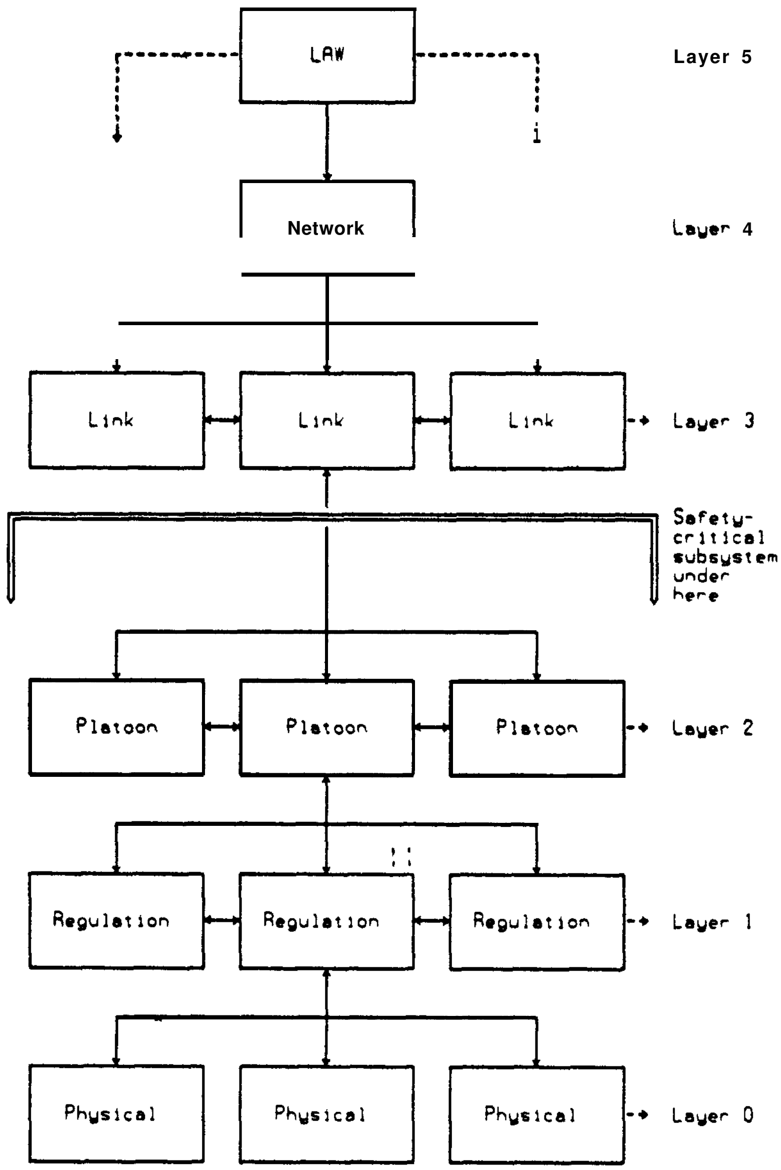
The system architecture is that described by Varaiya and Shladover 1991. More precisely, when this paper was published,it was recognized that the terms used by these authors expressed what had already been designed here very clearly. Varaiya and Shladover had a group of designs in mind which were very different to the one discussed here. However, the hierarchical architecture they do describe is more general than is claimed in their paper, perhaps more general than they recognized. To complete their architecture we addition a sixth layer - law. Law controls many distinct networks - as explained earlier. Figure 2 shows the Varaiya and Shladover scheme. This figure is in fact the only aspect of their work taken in here, but it contains very powerful concepts.

According to this architecture there is a succession of layers, each with an accompanying behaviour model. For our purposes only the link, platoon and regulatory layers are important. The physical layer details the way a vehicle responds to movementsof the steering axle, throttle and brakes, which is not significant for our purposes while the network and law layers define functions that are also not discussed here. It is seen that each layer is composed of ***modules.***

In the design considered here a single link module operates over one or more complete blocks. The platoon layer consists of a number of inter-linked, asynchronous controllers. Each controller contains several modules. There is one set of controllers per block. The controllers communicate with each other, the VPDs and vehicles on AL and TL. These entities are asychronous, which is why the RSVs and VSVs are part of the communication process.

Figure 2. IVHS Control Architecture

After Varaiya and Shladover (1991)



Some of these controllers are ***iterators,*** which communicate successively, (going upstream) with the controlled vehicles assigned to them, receiving and passing control variables to and from the regulatory layer.

Part of the regulatory layer is vehicle-mounted. The vehicles each contain a ***lateral-control system,*** a ***longitudinal-control system,*** a ***communication system*** and a ***self-monitor.*** These are not specified in detail in this paper - the specification is of the whole system. The regulatory system operates on the physical system by its control of throttle, brakes and steering. On the roadside, the VPD controllers' interaction with **VPDs** is a regulatory function.

The platoon, regulatory and physical layers make up the safety-critical subsystem **(S-**CS). The link layer lies outside the S-CS. Link control communicates information about the desired speed and configuration of vehicles and platoons only to the platoon layer.

Since link control is not in the SC-S, this information must be capable of being overridden by platoon level in the interests of safety. So far as speeds are concerned this is done as follows. The speed of a vehicle is controlled by three separate indicators. One is the maximum speed **(*maxspeed*),** which is set by the platoon level. Platoon level will change this if the safety position as revealed, e.g. by the **VPDs,** requires it. A second speed indication is the ***target speed,*** set by link control, The third is the speed required by the longitudinal control system for a vehicle within a platoon. **Maxspeed** will never be exceeded, whatever the other readings. Similar checks are made before a link control suggestion of a lane change or a platoon formation is obeyed. We say that link control advice is ***mediated*** in the light of the safety of a proposed manoeuvre before being obeyed by the vehicle controllers.

Maxspeed is clearly of great importance in vehicle safety. Its transmission to the vehicle and its storage on-vehicle are therefore duplicated. The regulatory level at the roadside transmits it, RSV to VSV. Separately, platoon level sends it direct to another on-vehicle AR, using a different communication link. Therefore, we do not need to concern ourselves here with failure of a vehicle to accept a maxspeed.

The link layer has functions of great economic importance. It manages the whole strategy of forming vehicles into platoons, admitting them into the AL, and exitting at the chosen place. These effects are achieved by controlling the speeds of vehicles and platoons. Vehicles arrive at on-gates and off-gates in the right relative positions. The efficiency of the algorithms in link control determines system capacity.

VEHICLE CONTROLLERS
(regulatory layer)

The longitudinal controller consists of:

a. sensors which detect the distance from the vehicle ahead and the rate of change of this distance. These sensors are effective and accurately reproducible at distances of 10 cm. to about 10 m. There is a minimum distance, called the sensor range, at which the sensor can be relied on to operate and give a tolerably accurate relative speed reading.

b. throttle and brake controls which will adjust the settings of the throttle and the brakes.

c. a control device which, when activated by an appropriate mode setting on the VSV (see below), will maintain the vehicle, by the use of throttle and brake controls, at a fixed short distance (approx 1 m.) from the vehicle in front. In doing so it must not exceed its maxspeed, as set on the VSV (and duplicated in the other AR). Under other conditions, the controller will maintain the vehicle at the target speed, also recorded on the VSV. There are other control variables (speed and acceleration of the lead vehicle of platoon) which are used by the controller.

d. A ***vehicle state vector (VSV)*** is an AR, which holds the following fields. * indicates permanent data, only changeable by licensed operatives of the "highway patrol". These records are referred to later as the ***AL license. (The*** AL license is, of course, a license relevant to use of the automated lanes. The usual vehicle and driving licenses are different.) Otherwise, when appropriately stimulated, the VSV will receive data from or pass data to the controllers, the communicator or the self-monitor. The data are stored as fields of its record. Existing data is overwritten as appropriate.

* a. unique identity, linked to license plate number.

* b. date of last inspection.

* c. validation bit (can be reset by the system).

* d. exterior dimensions of vehicle.

* e. monitor bit - normally set, reset by monitor if system fails tests, can then only be reset by system supervisor

f. Vehicle mode and temporary identity. Initially, mode = U (unconcerned) and temporary ID = unique ID. Set externally.

g. Maxspeed, target speed. Set externally.

h. Lateral control variable. Set by lateral controller.

i. Distance to vehicle in front (NULL if no vehicle detected) and other variables set by longitudinal controller.

j. Externally set longitudinal control variables.

k. Monitor bit, set by self monitor.

1. Turn left, right bits, set externally.

m. Destination code. (NULL if driver has not yet set it.)

* n. Special bit indicating that a "vehicle" is a trailer. Rules for trailers are not discussed here.

o. Block variables - name or number of block, and variables, like sensor-range speed, which are set by the block because they are dependent on local conditions.

The lateral controller contains sensors which detect the position of the vehicle relative to the lateral guidance reference. A control system operates on the steering axle. In general, the control system maintains the vehicle centered on the reference, and so delivering a near-zero lateral control variable, which it records on the VSV.

This is modified when one of the turn bits is set in the VSV. Then the controller causes the vehicle to run, with a displacement to left or right of the reference. When the turning point in the road is reached the controller steers further to the relevant side, until a new reference is picked up, which then becomes a central line reference. The bit is then reset. (That is, the vehicle changes lanes.)

The communicator receives messages from the roadside. If the identity field in the message record matches the (temporary) one in the VSV, then action is taken appropriately. Usually the required action is to modify fields in the VSV, and/or respond with a message containing the vehicle's temporary ID and one or more fields in the VSV. One of several messages, oral or visual, may also be passed to the driver.

The self-monitor, as its name suggests, monitors the action of the rest of the controller and sets or resets the relevant bit in the record accordingly.

In following sections the action of the vehicle-borne controllers will not be described even in as much detail as is implied here. The statements will be like "Set **maxspeed** to . . ..", "Reduce speed to cause vehicle to drop back . .." and so on. There are a strictly limited number of such actions, though some are quite complicated. Here we have provided only a limited initial requirement specification for the controllers.

MESSAGE STRUCTURE

Many of the operations of the controllers are accomplished by sending a message to one of the other controllers. Others are started by receiving message from a controller. Messages to and from the iterators are always accomplished by changing a record in the relevant RSV or VSV.

Some messages are transmitted between vehicle and roadside, others are transmitted between different roadside controllers. Each commences with a message-identity field. If a controller receives a message whose identity is such that it is not relevant, the message will be discarded. The appropriate controller, however, on receipt of a message will activate the corresponding control module. The module will carry out the appropriate actions. These will often involve sending further messages, or restimulating the calling controller.) The receiving controller will then await the next message. All this implies queuing arrangements for messages. The queuing logic is not discussed here. We assume that capacity is sufficient for every message to be acted on with insignificant delay.

There are three types of messages:

a. vehicle referents are the vast majority. The second field is a vehicle identity, and the module called by the message will act on that particular vehicle, or its RSV, only.

b. general referents refer to all vehicles, or, at least to all that are in a particular mode, position, etc. These messages normally reflect an emergency. Here the second element will be a block referent, and the message refers to vehicles in that block alone. The message may, however, be communicated to controllers in adjacent blocks and induce general or system mode messages there.

c. system mode messages may be induced by the self-monitor of the roadside controllers following some inconsistency in roadside actions. An example is “cease to scan this (faulty) VPD”. Another source is the controllers themselves. An example is “vehicle XXX has hit an unknown object: go to **Stop Mode.** The system controllers may send messages like ‘Ire-open gate YYY”.

In this paper, not all roadside sensor or controller failures are identified **-** it is merely noted that a mode degradation may occur at any time.

SYSTEM MODES

Each block will be operating in one of seven modes. These form a sequence. The system is permitted to downgrade any block, in response to detection of faults. To upgrade, however requires intervention by the system controllers. They do this by using **Resume Mode,** where the speeds of individual platoons and vehicles can be manipulated so as to approach a **Normal Mode** condition.

The modes are listed below.

1. **Natural Mode:** the controllers are all switched off, and, subject to signs erected by the Highway Patrol, those vehicles able to enter are not constrained.

2. **Normal Mode:** is appropriate to normal operation.

3. **Sensor-range/continue (SRC) Mode:** vehicles on the AL are reduced to sensor-range speed. All gates remain open, and upon entering the next block there may be reversion to **Normal Mode.**

4. **Sensor-range/exit (SRX) Mode:** the same as SRC **Mode,** but at the end of the block all vehicles must exit. On-gates are closed.

5. **Crashstop Mode:** all vehicles on AL brake to rest at full platoon braking, and stay stopped, except for one platoon, identified in the message calling the mode, in which each vehicle goes to maximum deceleration. This is used when there is known to be a stationary object on the AL. In such a case, the vehicle damage associated with unlimited braking is accepted. The high-speed **colision** may be avoided. Otherwise its severity is reduced. System controllers will normally proceed to **Stop Mode** and inspect damage.

6. **Stop Mode:** same **as Crashstop Mode** in initiation, except no vehicle decelerates at more than full platoon braking. However, under Highway Patrol supervision, a number of unusual manoeuvres are permitted in this mode to allow emergency vehicles to enter. These manoeuvres also allow unaffected vehicles to proceed. These manoeuvres include backing on the AL and entry by the downstream off-gate.

7. **Resume Mode** can be called for by the system controllers at any time when the block is not in **Normal Mode.** It is used to revert to **Normal Mode** from one of the degraded modes. **Resume Mode** contains a number of special commands. The commands enable named vehicles and platoons on the AL to be speeded up successively. The process begins at the front. In other modes only a command reducing **maxspeed** on the AL in a whole block can be sent. That command is sent to all vehicles and platoons on the AL in that block. In this way vehicles are prevented from closing on each other on that part of the AL where there are no detectors.

The intended use of these system modes is almost self-explanatory. Each block's mode is, in principle, independent of that in other blocks. There are some logical necessities however. If one block is in **Stop** or **Crashstop Mode,** the block upstream must be in SRX or a more degraded mode.

Natural Mode is used, eg during construction or during maintenance, when the controllers are, for some reason, not working, but it is desired to allow access to the AL and TL for uncontrolled traffic.

Normal mode is the desired operating condition at all other times.

A vehicle or a roadside component can be detected as faulty. In some fault conditions, operation at reduced speed will satisfy the safety criterion. This happens under conditions where safety can be assured by the operation of the vehicle-borne equipment only. **SRC** and SRX **Modes** are intended to provide such ***degraded*** operational conditions. Speed is reduced, but if sensor-range is adequate the capacity of the AL and TL is unaffected. According to standard platoon theory, capacity shows a maximum as a function of speed. **Normal Mode** operates in the region where capacity decreases with increase of speed. The degraded modes may be able to operate at the same capacity on the rising part of the capacity/speed curve. This is possible if the sensor range is large enough.

Stop and **Crashstop Modes** represent the final stage of degradation. Vehicles on the AL in one block are at rest and gates are closed. On the TL, vehicles under control are invited to resume manual control. This is the same process as that which occurs when a vehicle quits the AL at the end the trip.

VEHICLE MODES

In passing through the system vehicles enter a succession of ***vehicle modes.*** Often, control will pass from one roadside controller or iterator to another when the vehicle changes mode. The temporary identity by which it is addressed in messages also changes. A vehicle in a platoon will be referred to as vehicle j, mode y, in platoon **XXX.** A solo vehicle will be vehicle (unique ID) in mode x. Mode, and ID for sending and receiving messages are written into the VSV. Unique ID is held permanently in the VSV.

The modes are:

a. ***Unconcerned (U)*** refers to vehicles on the TL under manual control. Tracked by the **VPDs,** but not under system control. Referred to in system by name assigned by VPD controller.

b. ***Provisional Controlled (PC)*** refers to a non-platoon vehicle, not yet tested at chicane, seeking entry to AL It is addressed by unique ID.

c. ***Controlled (C)*** refers to a non-platoon vehicle, successfully tested at chicane, seeking entry to AL. It is addressed by unique ID.

d. ***Provisional preplatoon (PP)*** refers to a platooned vehicle, not yet tested at chicane, seeking entry to AL. It is addressed by platoon designation and position. These may change if the platoon merges with another.

e. ***Preplatoon (P)*** refers to a platooned vehicle, successfully tested at chicane, seeking entry to AL. It is addressed by platoon designation and position. Again, these may change if the platoon merges with another.

f. ***Entry (E)*** refers to a platooned or non-platooned vehicle at point of entry to AL. The vehicle is addressed its former ID. A new ID as a member of platoon (perhaps of one vehicle) on AL is assigned as the vehicle leaves E mode. Once a vehicle enters E mode, it cannot be recalled from entry.

g. AL ***(A)*** refers to a platooned vehicle on AL. It is addressed by AL platoon ID, which is changed by block transfer controller on change from one block to another.

h. *Emergency* ***Exit (EX)*** refers to a platooned vehicle on AL. Addressed by AL platoon ID, which is changed by block transfer controller on change from one block to another. A vehicle in EX will be forced to quit AL, as single vehicle, as soon as possible.

i. *Platoon* ***Exit (PX)*** refers to platooned vehicle on AL. It is addressed by AL platoon ID, which is changed by block transfer controller on change from one block to another. Such a vehicle will be forced to quit AL, in platoon, as soon as possible. As it does will receive new ID.

j. ***Exit*** (X) refers to a platooned or non-platooned vehicle on AL at point of exit from it. Vehicle is addressed by AL ID. As the vehicle leaves X mode, it is given a new ID (unique) as a vehicle on TL. Once a vehicle enters X mode it cannot be recalled from exit.

k. ***Exitrans (XA)*** refers to a non-platooned vehicle on TL ready to resume manual control. It is addressed by unique ID.

l. *Exit Platoon* ***(XP)*** refers to a platooned vehicles on TL, ready to resume manual control as soon as the platoon has dispersed. Such a platoon on the TL is called a *postplatoon* It is addressed by platoon designation and position.

THE ROADSIDE CONTROLLERS

(A. Regulatory level.)

There are ten separate asynchronous roadside controllers per block. They communicate through **ARs** and by sending messages to each other. The form of the links will almost certainly be hard-wiring. Four of the controllers work at the platoon level and six at the regulatory level. These six are iterators, as defined on page 2. All six can send and receive messages from vehicle controllers. There is also a further link controller, outside the safety-critical system, which communicates with the platoon-level controllers only, and a **self-monitor**, to which all apparent vehicle failures are reported. This last examines the patterns of reported fault events. It advises the system controllers. It may also degrade the -block, if a pattern of faults emerges which suggests failure of a roadside controller, communicator or sensor.

Al. Control of **VPDs.**

One of the iterators is concerned to use the data from the **VPDs** to update the **RSVs** with positions and speeds and with such data as vehicle separations that can be deduced. This VPD controller sends messages, via the message bits in the RSV, to the platoon-level controller. Such messages normally reflect incipient emergencies. An example might be that a vehicle is too close to the vehicle in front. The VPD controller has four elements. One element cycles through the set of **VPDs** on the **TL,** moving upstream. Fig 3 shows a flow chart of this. Another element is shown in Fig 4. This does the same thing through the part of the AL which is occupied by **VPDs.** It also marks an RSV with the appropriate mark as it moves off the part of the AL which has detectors present into the next block. The third and fourth elements of the VPD controller set and reset the *Gate* ***ARs, Onok*** and ***Offok.*** There is one gate AR for each on-gate and one for each off-gate. These **ARs** bear a single bit. If the bit is set, the **VPDs** indicate that the gate is clear for passage. For an on-gate this would mean that:

a. no vehicle is approaching too rapidly on AL from upstream, and

b. **either** a vehicle has just passed **or** gap ahead exceeds platoon spacing).

There is a similar condition for off-gates.

When there is a vehicle present in the neighbourhood of a gate, the VPD controller also iterates, more rapidly than happens at other times, through the VPDs in this area. (See Figs 5 and 6 for flow-charts). The process of transfer between AL and TL (or failure to transfer) is monitored by the VPD controller. If transfer is completed a message will be sent to platoon level. If it becomes apparent that no transfer will be made another message will be sent. In both cases the message will vary, depending whether or not a transfer has been called for. (The third possibility, that a vehicle partially transfers and so hits the gate post, is also covered.)

A2. Vehicle Control Iterators.

The five vehicle-control iterators differ only in the location and configuration of the vehicles controlled. The modules they contain are illustrated in Figs 7-11. Each iterates through the RSVs of the vehicles it controls moving upstream. A message "....con" is sent to each vehicle in turn. Strictly, the message is sent to all vehicles on the AL or TL, as the case may be, but because it identifies one vehicle, all others disregard it. The iterative character of the controller and the short range of its signals, ensures that noise levels are low, and that messages are not garbled or overlain. The message 'I-..........con" contains control information required by the vehicle controller. This data is stored, on-vehicle, in the VSV. In response, the vehicle communicator sends a message ". . ..res", which identifies the vehicle. The message "...res" contains information about the vehicle's behaviour. The data passed includes speed, target speed, maxspeed, lateral position and whether or not it is faulty. If the vehicle is a member of a platoon, the distance to the vehicle ahead is also passed.

Should no intelligible response be received from a vehicle the iterator will alert the platoon-level controller with the message ". ..nores". It is recognized that single failures to respond may occur for a variety of innocent reasons, or reflect a roadside failure. If, however, failure to respond is repeated it will be deduced that the vehicle is faulty. Action will then be taken to remove the vehicle from the system as expeditiously as is safe. The

Fig. 4. Control of Vehicle Presence Detectors on AL

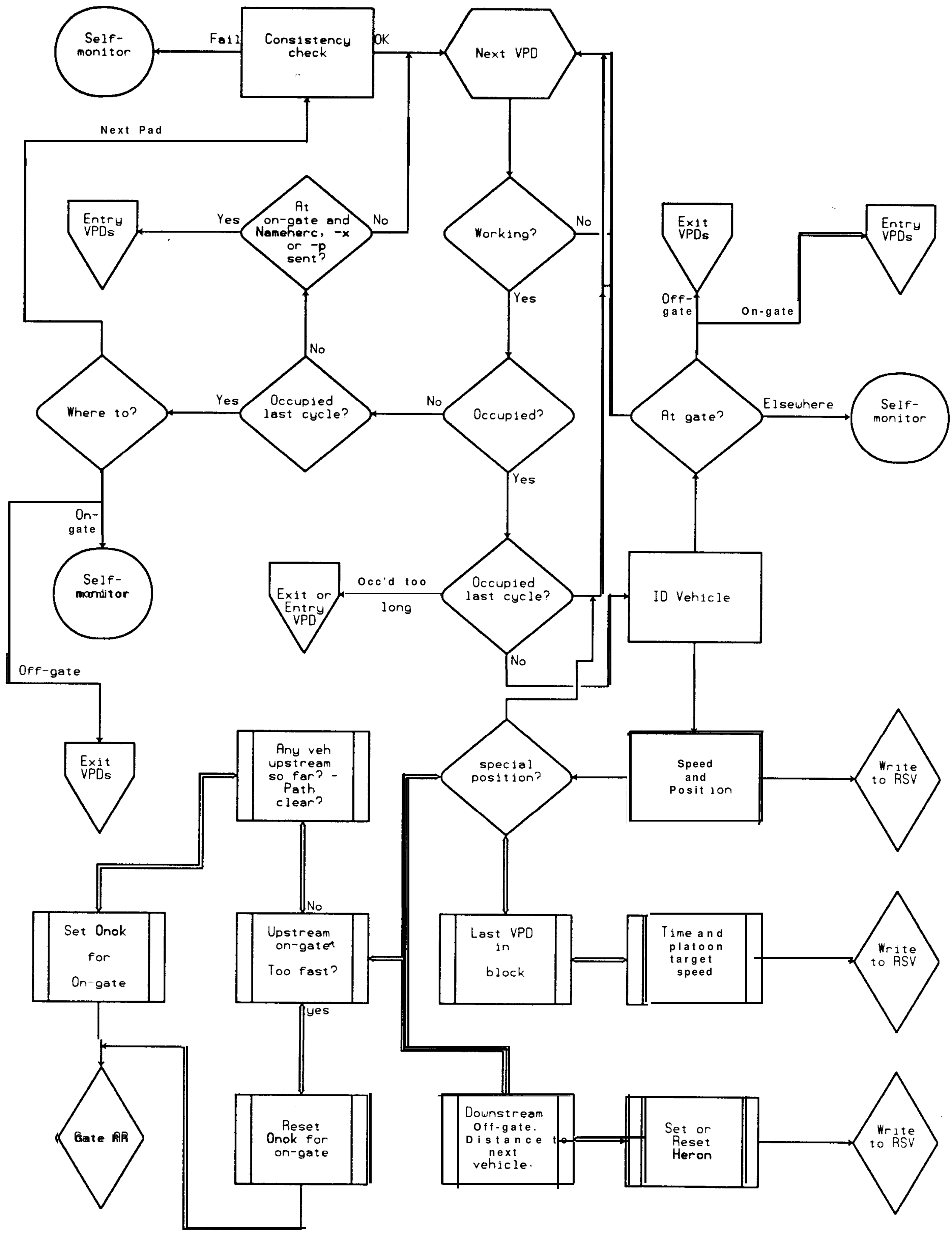


Fig. 5. Control of Vehicle Presence Detectors at On-gate

When these sequences are stimulated,
frequency is several times VPD freqency

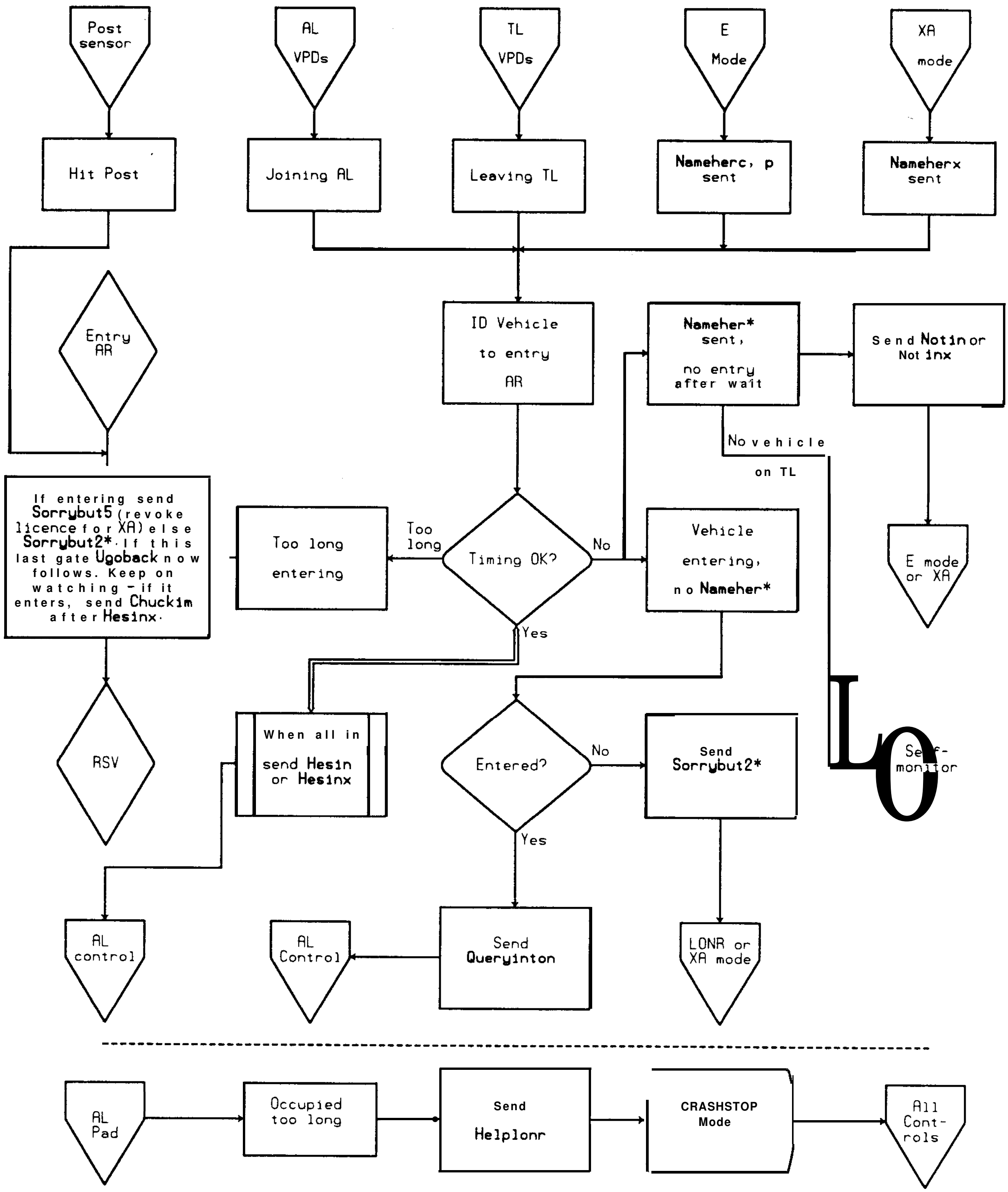


Fig. 6. Control of Vehicle Presence Detectors at Off-gate

When these sequences are stimnlated
frequency is several times VPD frequency

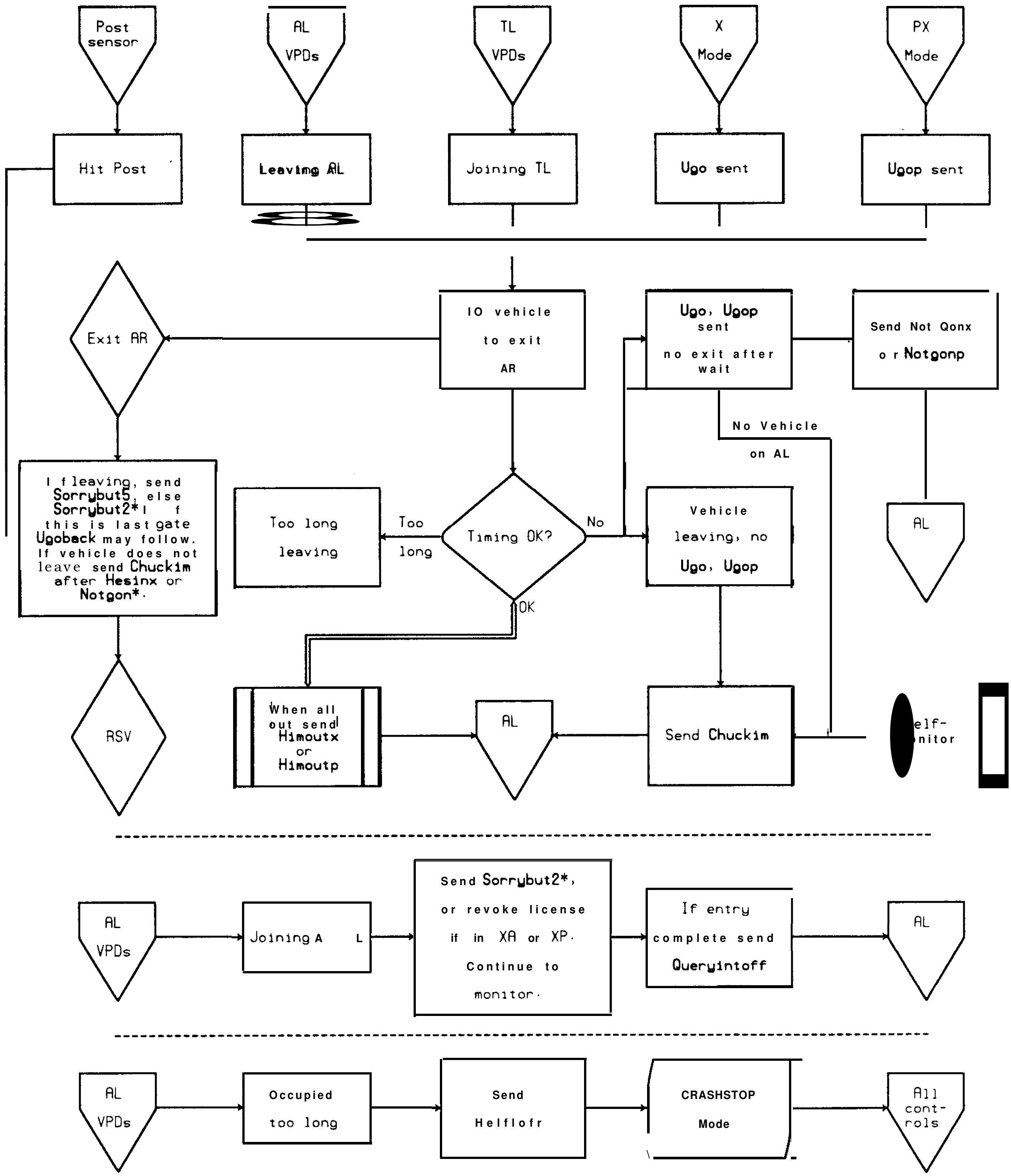


Fig. 7. Modules in Loniter

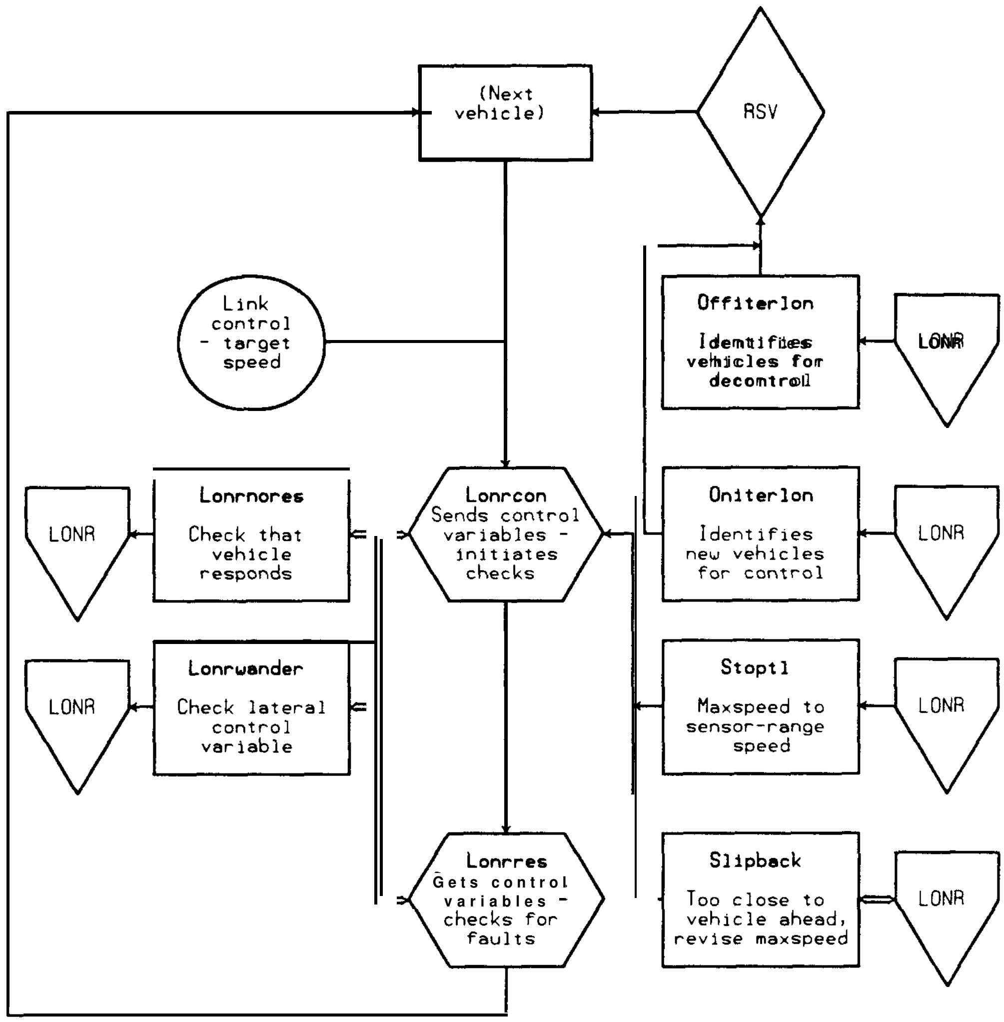


Fig 8. Modules in Prepiter

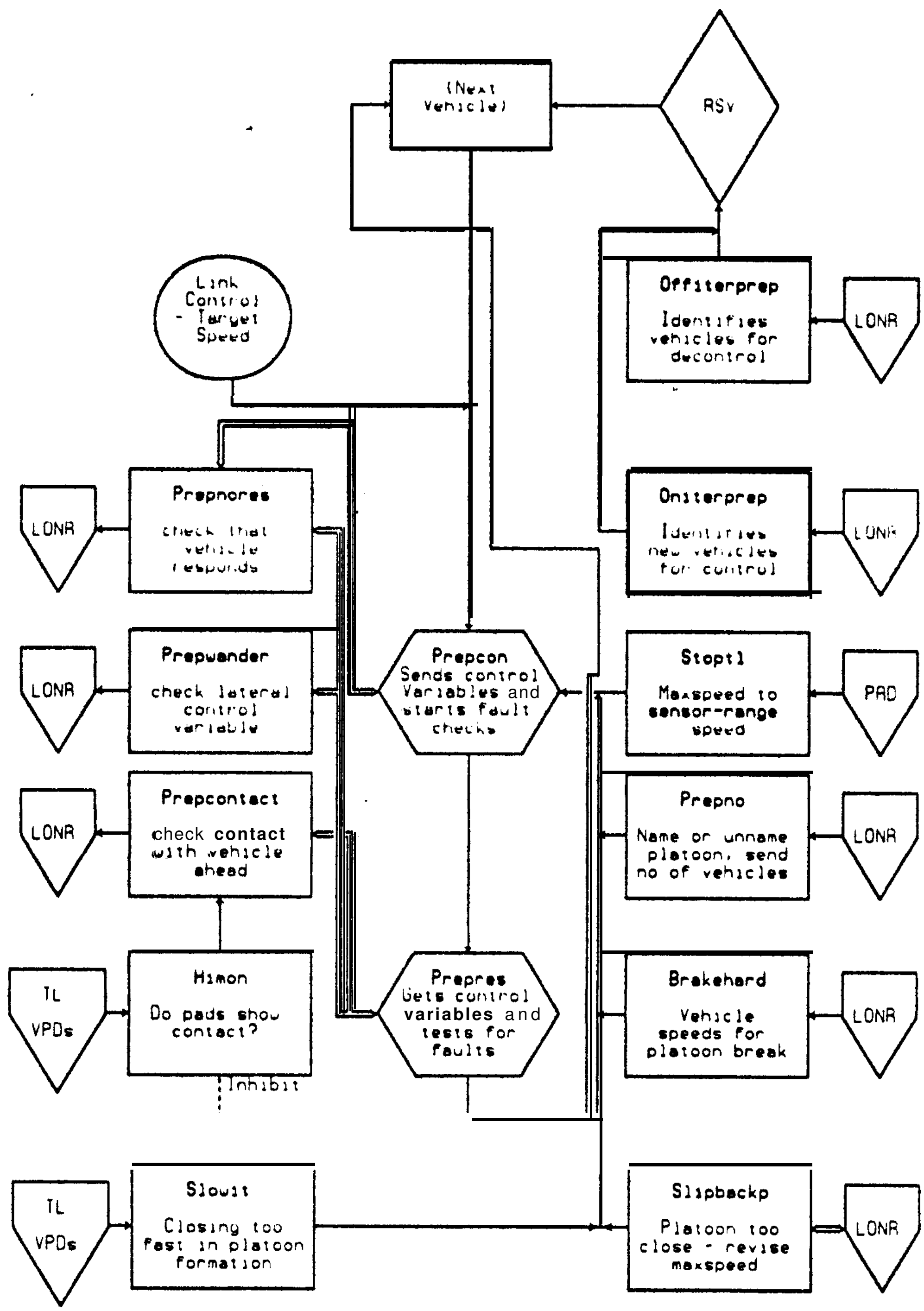


Fig 9. Modules in Aliter

AL- is AL control upstream block -via upstream counter
AL+ is AL control downstream block -via counter.

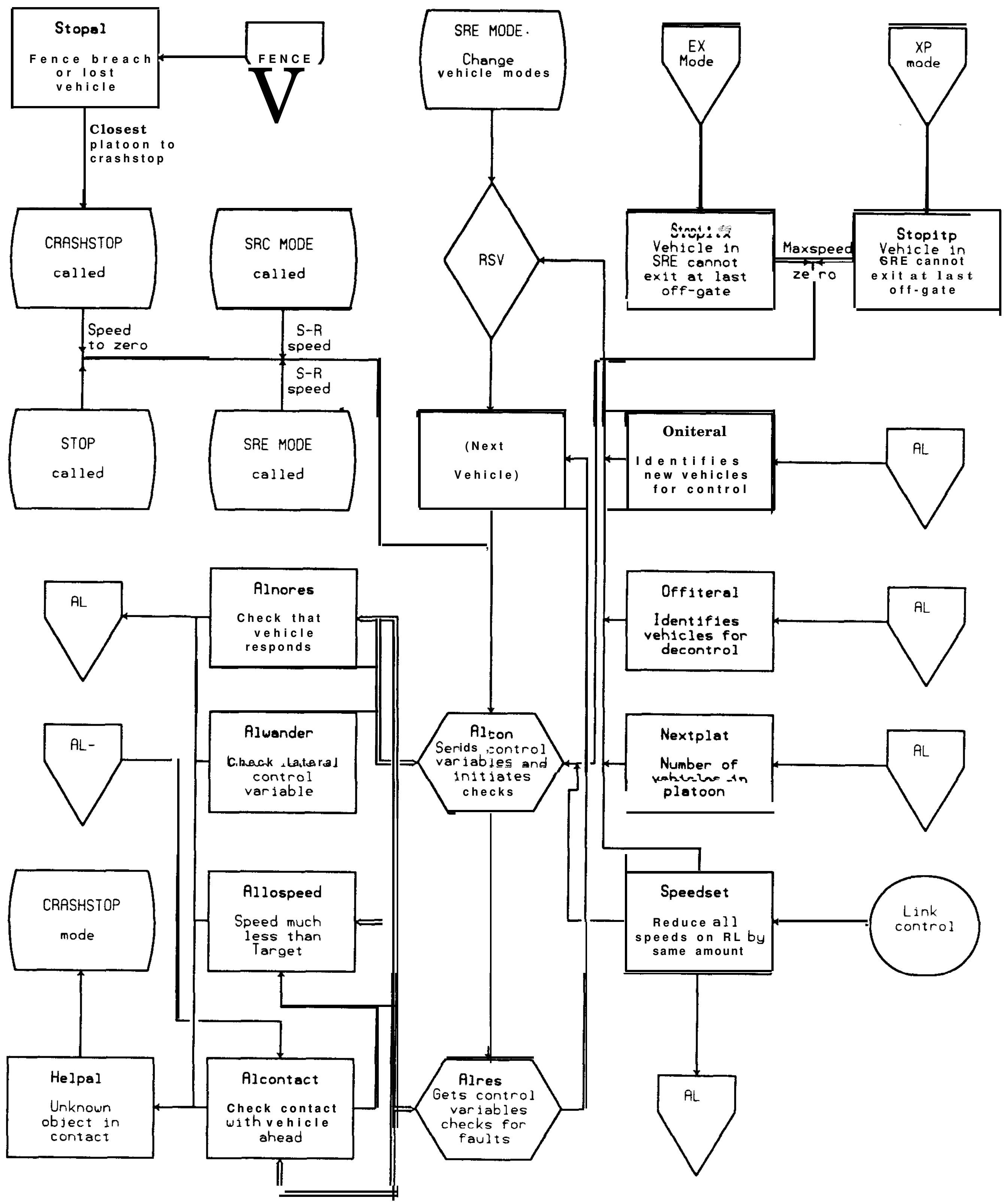


Fig. 10. Modules in Lofiter

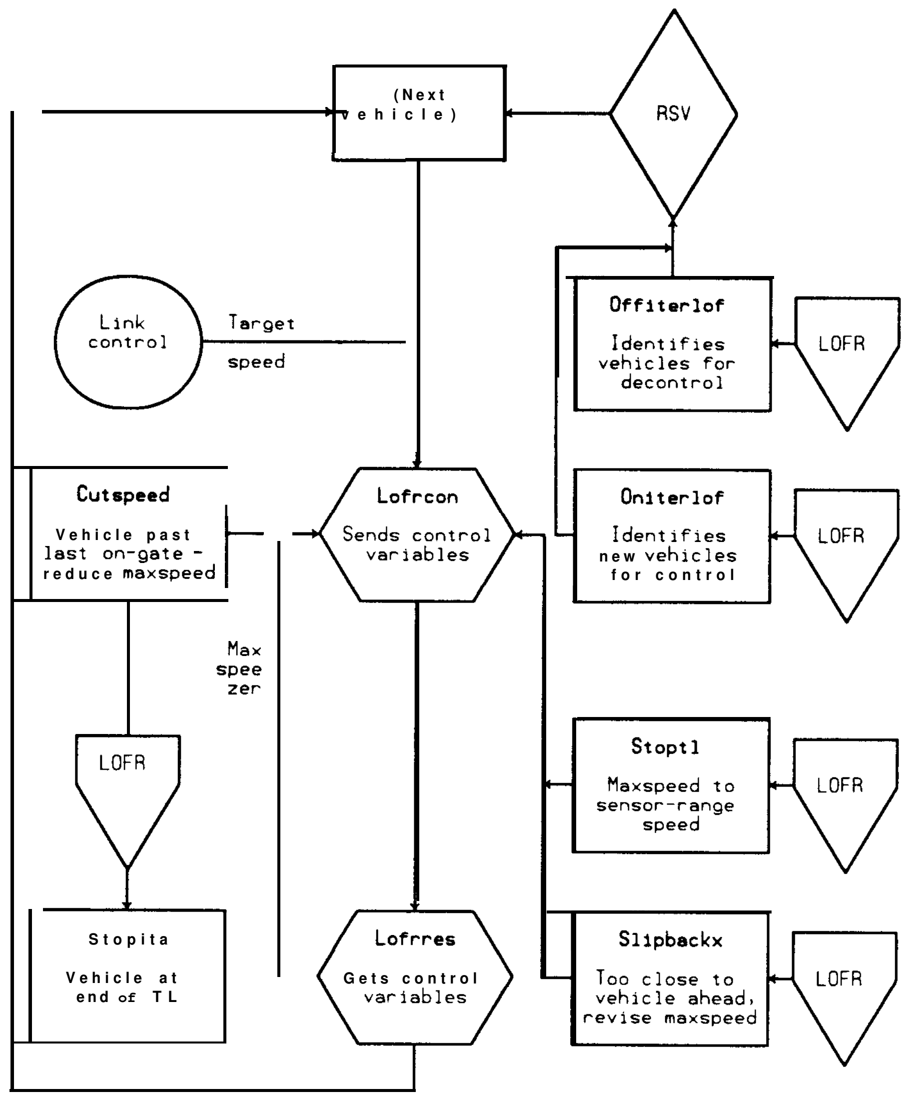
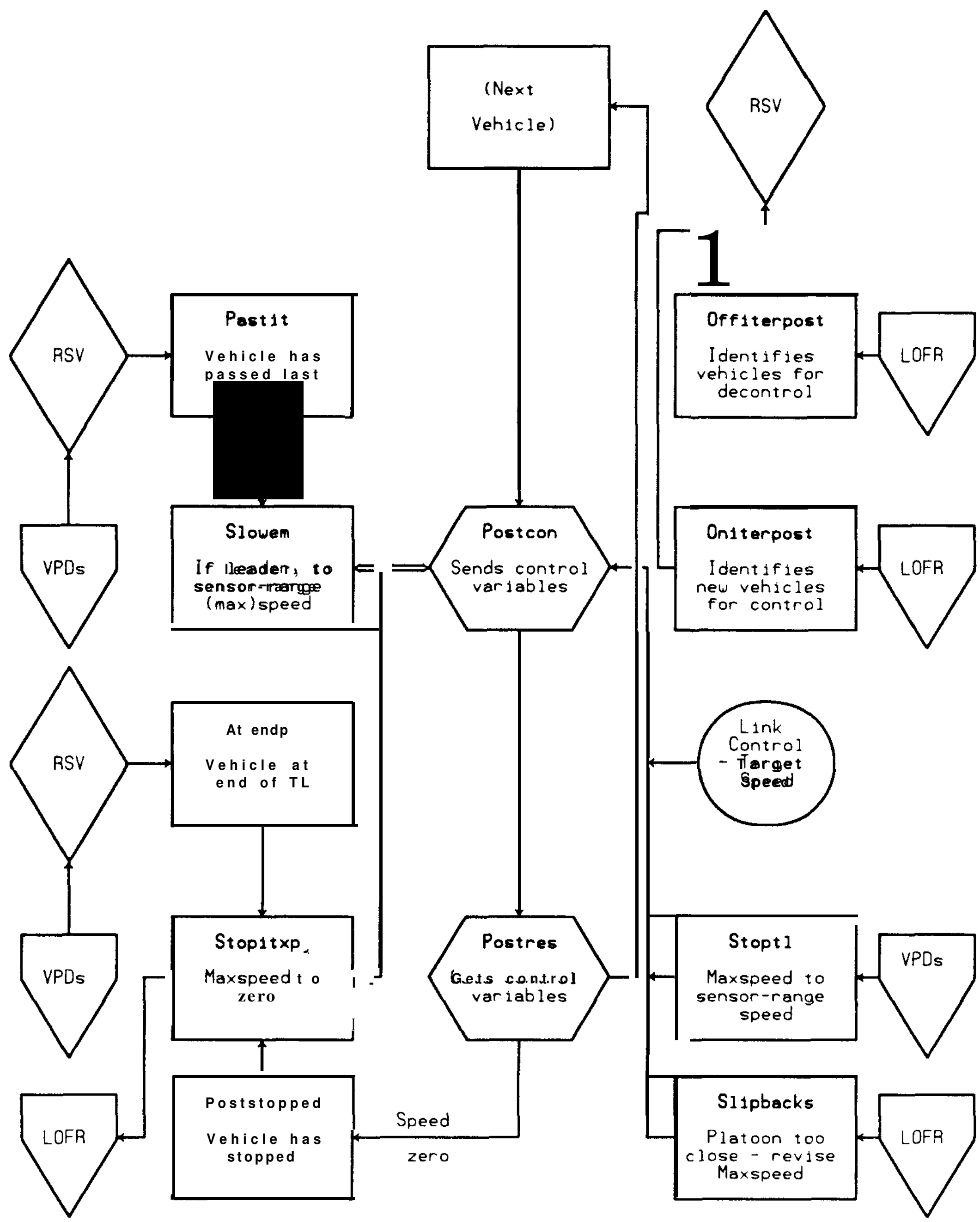


Fig. 11. Modules in Postiter



system will also invalidate the AL license. The vehicle then cannot rejoin the AL before inspection by the system controllers.

Similar action is taken ·**if** the vehicle reports itself faulty or its lateral position indicates imperfect lateral control. A "wrong" answer to the question "are you in touch with the vehicle ahead in the platoon?" will produce a variety of emergency responses, depending on the situation and history.

Four iterators control vehicles on the TL. Which one is responsible depends on whether the vehicle is or is not in a platoon, and whether it is entering or leaving the system. It is probably desirable that the corresponding iterators are interleaved so that only one vehicle on the TL is addressed at once. It may also be desirable that vehicle entering or leaving at the gates are communicated with rather more frequently than others.

The vehicle control iterators are:

a. The ***loniter*** (solo vehicles controlled by LONR). Vehicles not in platoons, seeking admission to AL. It controls vehicles in vehicle modes PC, C. (See page 20 for a discussion of vehicle modes.)

b. The *prepiter* - vehicles in platoons on TL seeking admission to AL - ie ***prep*****latoons.** Vehicle modes PP, P.

c. The ***lofiter*** (solo vehicles controlled by LOFR). Vehicles not in platoons, seeking exit from system. Vehicle modes XA.

d. *The postiter* - vehicles in platoons on TL seeking exit from the system - ie postplatoons. Vehicle modes XP.

e. The ***aliter*** **-** vehicles on **AL,** entering or leaving it, whether in platoons or not. Vehicle modes A, E, EX, PX, X.

A sixth iterator is the VPD controller.

ROADSIDE CONTROLLERS

(B. Platoon Level)

There are four platoon-level controllers per block. They are responsible for:

a. receiving proposals for system control from the link level, to cause vehicles to form into platoons, or to join or quit the AL.

b. for control of the process by which vehicles are admitted to the system, tested and ultimately discharged from it.

The four controllers communicate with each other, with link control and with the iterators and vehicle controllers by transmitting messages. These messages may read from or write to selected fields in both the **RSVs** and **VSVs.**

No flow charts are shown which describe the separate actions of the platoon-level controllers. It is more convenient to show actions based on the vehicle mode (see below). The modules shown in Figures 16-27 all come from one or another of the platoon-level controllers.

The platoon-level controllers control vehicles at different points in their passage through the system. They probably could be combined into a single computer. However the designer found it easier to think of them as separate. The four are:

a. The LONR, which controls vehicles from entry to the system until they enter the AL (or are rejected). Vehicle modes PC,C,PP and P.

b. The LOFR, which controls vehicles from their exit from the AL (or from refusal of admission to it) until they resume manual control. Vehicle modes XA and XP.

c. AL control, which controls vehicles on the AL in the block. Vehicle modes A, E, EX, PX and X.

d. The block transfer controller, which passes data about vehicles on the AL which are to enter the next block to **RSVs** on the next block.

The controllers do not, of course affect vehicles in mode U (not under system control). The presence of vehicles in mode U on the TL is noted by the VPD controller. **RSVs** are assigned to mode U vehicles.

No provision is necessary for passing information about vehicles on the TL to the next block, because the TL is not continuous. This does mean that vehicles nearing the end of the TL not yet under manual control present a problem. It would be dangerous to restore manual control without a signal of readiness from the driver. Where possible such vehicles are taken back onto the AL. They then exit again at the next LOFR. If this cannot be done they are brought to rest at the end of the TL. Warnings are sent to other vehicles). Thus, if a vehicle, or its driver, does not regain manual control and signal that it has done so, it will be taken down the AL, way past its declared destination. In the end such a vehicle is admitted to a “dormitory” lane. Here it is brought to rest. Here, too, it is accessible to the Highway Patrol.

SYSTEM OPERATION

Figures 12 through 15 show the steps through which a vehicle passes as it:

a. enters the system
b. is marshalled into a platoon
c. enters the AL
d. proceeds to its off-gate on the AL
e. quits the system.

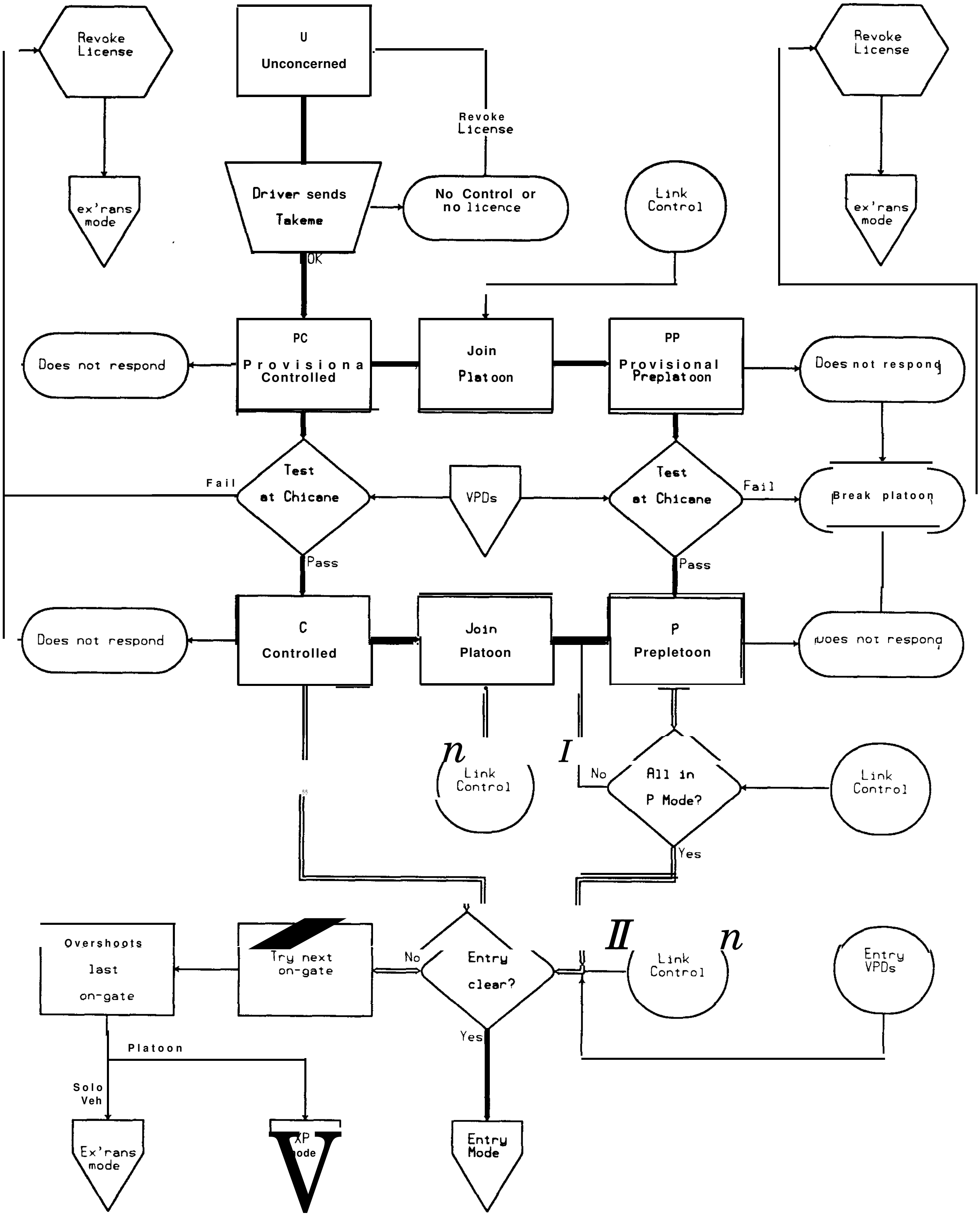
The figures also show most, but not all, of the reactions to fault conditions. The figures show the vehicle modes through which the vehicle passes as it enters and proceeds through. In Figures 12-15 the bold type and heavy lines show the "normal" progression.

A. Operation on TL before entry to AL.
(Fig. 12)

A vehicle starts in Unconcerned (U) mode. There is no reason why it should not remain there, under manual control on the TL. If it remains on the ULs - uncontrolled lanes - it will not affect the system. A vehicle in U on the TL will be tracked, via the VPDs. An RSV is assigned to a vehicle in U. Controlled vehicles will have to move in such a way that the presence of the U vehicle causes no danger. If, however, the vehicle is equipped with a control system and has a valid AL license, its driver may choose to request entry. The driver sends the appropriate message (Takeme) at an identifier. The identifier has only a very short-range communication ability. There is therefore no doubt which RSV corresponds to the requesting vehicle.

If the VSV bears a valid self-monitor bit, and a valid, in-date AL license, it will be admitted on a provisional basis. It enters Provisional Controlled (PC) mode. The driver is

Fig. 12. Enter System and Join TL



so advised. Control is now passed to the vehicle's auto-control system as informed by the loniter via the VSV.

The loniter also monitors vehicle behaviour. Potentially dangerous deviations are reported to the **LONR.** If these are repeated, vehicle controller failure is indicated. The LONR willtransfer the vehicle to Exitrans (XA) mode. A message to the driver says why. The AL license is invalidated. XA mode is normally assumed by a vehicle after it has quitted the AL. The driver is invited to resume manual control. As soon as he/she signals his readiness to do so (see Fig 15) manual control resumes. The vehicle re-enters U mode.

In PC mode the vehicle is addressed by the loniter and **LONR** only. Its ID in messages is its unique license-plate identity.

From this point there are two normal paths. If the vehicle next encounters a chicane, the latter will challenge it. The chicane communicator emits appropriate control signals. The vehicle should respond with the correct series of manoeuvres. (It will be recollected the chicane has only short range communication.) Nevertheless, the vehicle also responds by indicating its identity as well as giving physical responses. There are instruments at the chicane which can determine if the responses are appropriate. The instruments also check that the external dimensions of the vehicle are those on the AL license. This ensures that a vehicle is excluded if it is carrying an external load. An external load may drop off and present a danger to following platoons.

A vehicle which "fails" the test at the chicane transfers to XA mode. Its AL license is invalidated. Thus, it cannot seek re-entry to the system again until its repair has been certified. A vehicle which "passes" the test at the chicane transfers to Controlled (C) mode. A vehicle in C mode may enter Entry (E) mode if so advised by link level. It then joins the AL. A vehicle in PC cannot do this. Otherwise, however a vehicle in C moves in the same way as one in PC. In particular, a vehicle in C may still be transferred to XA mode if it does not respond to control signals.

Alternatively, a vehicle in PC mode may be invited to join a platoon. It will either by move up to the rear of another vehicle or platoon or being approached by a platoon from the rear. This will happen on receipt of appropriate advice from link control by the **LONR**. The LONR checks that there are no intervening vehicles before passing on link's request. Such a platoon on the TL formed in anticipation of entry to the AL is called a ***preplatoon***. As soon as such an order is accepted by the LONR the vehicle will transfer to Provisional Preplatoon (PP) mode. The vehicle is given receive a preplatoon ID. It will now receive control from the prepiter.

When the vehicle in PP reaches a chicane, it is tested in the same way as one in PC. If it passes the test, it transfers to Preplatoon (P) mode. Members of a preplatoon, all of whose members are in P mode, bears a special bit in their **RSVs,** and may be admitted to E mode. If the vehicle tested fails the test at the chicane, the command Brakehard causes the vehicles behind the one in question to separate out from it by reducing speed. Then the offender too falls back from its predecessors. The faulty vehicle transfers to XA mode, and has its AL license invalidated. The same thing happens if the vehicle's responses to the prepiter indicate a faulty controller. This will occur in P mode as well as in PP.

A vehicle in C mode can be invited to join a platoon. It then enters P mode directly.

Throughout the passage of vehicles on the **TL,** the **VPDs** are testing for overclose approach of a vehicle to its predecessor (in the sense defined by the hazards). If this is observed, a marker is set (or is reset if such approach is not observed) and a relevant message sent to the LONR. The LONR itself will cause this message to be repeated after an interval. There are the following possibilities:

a. Vehicle ahead is one with which the vehicle in question could form a platoon on request from link control, but:

    no such request received and no "wait" marker set;

set "wait" marker, and recall routine on next cycle.

b. Vehicle ahead is one with the vehicle in question could form a platoon on request from link control; but:

no such request received;

"wait" marker set;

if wait not exhausted, recall routine.

if wait exhausted, send appropriate message Slipback, which will cause **maxspeed** to be reduced for a specified period. Set period marker for Slipback.

c. Vehicle is part of platoon in formation and vehicle ahead is also part of this platoon. Safety condition is now different:

if vehicle reports sensor contact with vehicle ahead,

end sequence.

otherwise if closure is too fast,

send **Slowit. Slowit** will reduce maxspeed.

d. Vehicle has received Slipback.

If period not exhausted, recall routine. If period exhausted, end sequence.

(If vehicle is still too close VPD controller will repeat.)

e. Vehicle ahead is one with which vehicle in question cannot form platoon (ie in U, XA or XP).

Send Slipback, as in b. above.

On each passage through the iterator the lateral control variable is examined. The precise criterion for exclusion has yet to be determined. Clearly there are a great number of minor faults in road or vehicle which can lead to an occasional excessive value of this variable. Once established, an excessive value may persist for several iterations. Allowing for this, if the values suggest excessive wandering, the vehicle will be rejected to XA mode as already described. A precisely similar logic is used to deal with occasional non-receipt of a response to interrogation by the iterator. A similar routine is followed if the vehicle self-monitor reports a fault..

In platoon, reports of contact with the vehicle ahead are compared with the marker Himon. Himon is set by the VPD controller inn the RSV. It indicates that the spacing between two vehicles is reduced to sensor-range spacing. If non-contact is repeatedly reported, malfunction of a sensor is assumed, and again the vehicle is rejected.

Faults of these kinds are reported to the block self-monitor. Should a pattern emerge of repeated failures of one kind at a particular point, a sensor fault will be assumed, and the logic of the fault detection will be changed. Sensors - particularly the VPDs, are duplicated. If there is a difference, the faulty one can be isolated by reference to the rest of the evidence. A sensor fault of this kind will therefore be rare unless there are maintenance delays.

In addition to these fault conditions, a driver is permitted to press the panic button and request exit from the system before the vehicle has joined the AL. The procedure, once the message is received, is the same as when a fault is found, except that the AL license is not invalidated.

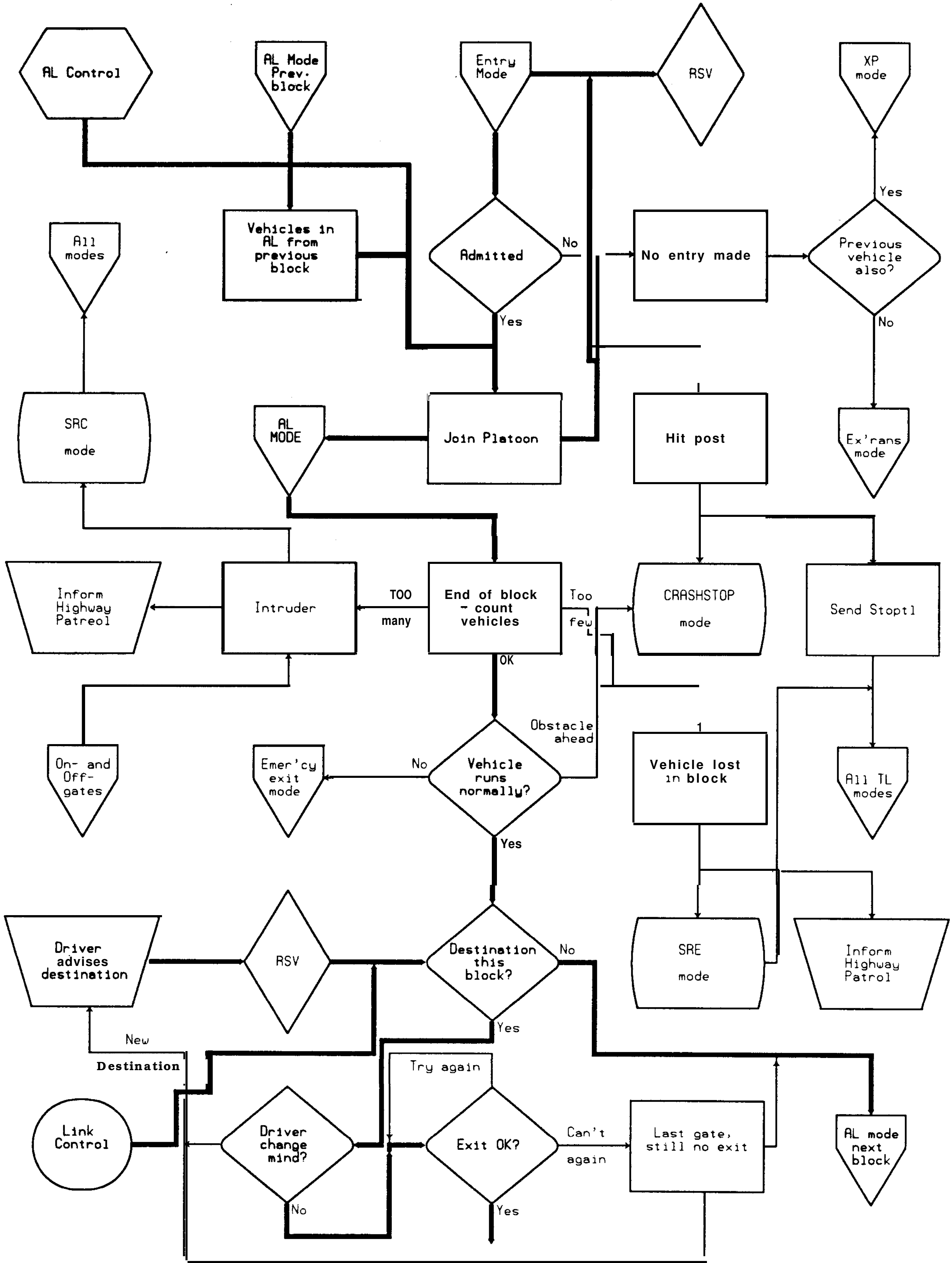
This concludes the description of the parts of the system covered by Figure 12. Finer detail, showing all the modules employed are shown in figs 16 - 20. Specifications of the modules are found in the appendix.

B. Entry to AL and operation on it.

(Figure 13)

When a vehicle is called by link control to enter the system, either individually or as a platoon member, the LONR verifies that:

Fig. 13. After Entry to AL



a. all members of the platoon are in P mode (or C mode, for a single vehicle).

b. the gate is open, and the system mode permits entry.

c. the AR **Onok** is set at the relevant gate. This indicates that upstream of the gate there is no vehicle too close. It also indicates that downstream there is either a very close platoon, or a gap of length exceeding platoon spacing.

As each vehicle in a platoon approaches these tests are repeated, and as each is passed successfully the vehicle enters Entry mode. The vehicle is now committed to enter. The option of withdrawal is no longer open to the driver. As the vehicle reaches the turning point, the vehicle control system steers to the left. Then the control system will picks up the lateral guidance reference on the AL. A message to the RSV and thence to the **VSV** records its new ID as a member of a platoon on the AL.

Usually the whole of a preplatoon will enter the AL. It is possible, however that for some reason the following platoon will arrive before link control had calculated it would. Alternatively the entering platoon may be later than had been calculated.In either case, platoon level control ensures that the platoon will be broken when further entries would violate the hazards.

Entry is checked by the detectors at the on-gate. Vehicles entering are counted. If a vehicle enters successfully it has to join a platoon. It makes contact with a vehicle ahead and closes up the gap. This manoeuvre is monitored by the detector controller, in the same way as platoon formation is monitored on the TL. The vehicles which have entered now transfer to AL mode.

If the vehicle fails to enter, it is transferred to XA mode. The subsequent manoeuvres are similar to those following failure to respond to control on the TL. If the vehicle strikes the gatepost, a message induces Crashstop Mode. The messages also reduces traffic on the

TL to sensor-range speed. **Crashstop Mode** is also induced if entry of an unexpected body which remains in the gate is observed. Such a body would probably be accident debris from an accident between unconcerned vehicles on the **ULs.** If an object enters unauthorized and then seems to drive on, like a vehicle, the presence of an intruder is tentatively deduced. A message is sent to the Highway Patrol. The Highway can verify the presence of an intruder visually. Then they can use the AL controls to take such action as they think fit.

If the AR **Onok** is not set, the vehicle cannot enter. If **Onok** is not set because the block has been placed into **SRX, Stop** or **Crashstop Mode,** solo vehicles are transferred to **Exitrans** (XA) mode at once. Platoons are transferred Exit Platoon (XP) mode (see later). Otherwise further attempts may be made to enter at later gates. However, if the last on-gate has been passed, transfer to the exit modes follows.

When a platoon has passed all the gates it will arrive at the vehicle counter. The counter marks the boundary of two blocks.

The counter is controlled by the (platoon-level) block transfer controller. The block transfer controller has received messages from the block transfer controller controller upstream advising it of the numbers of vehicles which entered in a given platoon. Messages from the other platoon-level controllers advise it of the numbers of vehicles entering and leaving. This count includes intruders. As each vehicle enters the new block it is given a new ID. This ID records its current position in the renamed platoon. Thus, renaming keeps count of each vehicle's position in platoons. The renaming also ensures that messages from one block do not influence vehicles in another. When a platoon has all entered, the number of vehicles has been found in two ways. The direct count is compared with the total obtained from the previous history of the platoon:

a. If there is a vehicle missing, the Highway Patrol is informed. The block is put into SRX **Mode.** It is up to the HP to find the missing vehicle, if it exists. When it is found, or the HP decide that it does not exist, the HP will do what is necessary. Then they will advise that the block revert to **Normal Mode.**

b. If there is an intruder, the block goes into **SRC Mode.** There is now no need to clear the block. Again the Highway Patrol will be advised. **Normal Mode** may be resumed after the HP has evaluated the situation and acted appropriately.

Downstream of the counter on the AL, there are no detectors. As each vehicle enters the new block it is given control parameters by the block transfer controller. The block transfer controller calculates, for each platoon leader, that speed which means that the leader will be exactly one platoon spacing behind the rear of the preceding platoon when the latter reaches the next counter. Alternatively an overall maximum speed is chosen. This speed is now set to both **maxspeed** and target speed of the platoon leader.

Link control cannot affect the speed of individual platoons or vehicles on the AL. In response to link control advice the **aliter** will reduce (only) speed by a given decrement for all platoons on the AL. If this is correctly carried out, two platoons will never become closer than platoon spacing. Resume **Mode** is an exception here.

If a vehicle on the AL develops a fault it cannot be rejected at once. Faults here comprise vehicles which:

a. wander excessively

b. do not respond to messages from the **aliter**

c. lose speed (perhaps because the vehicle has run out of gas)

d. lose contact with the vehicle ahead

e. report themselves faulty.

All these conditions are tested for by the **aliter.** With a faulty vehicle present it is desirable to reduce speed of following platoons to sensor-range speed. Then if the faulty vehicle slows or stops there will be no hazard. (Following vehicles in the same platoon will slow if the faulty one does.) Vehicles on the AL which have been diagnosed as faulty are transferred to Emergency Exit (EX) mode. The driver is so advised. The vehicle will now be caused to quit the AL as soon as convenient, irrespective of its announced destination. Its AL license will be invalidated.

This concludes the description of the parts of the system shown on Fig 13. Further detail, including all the separate modules involved are shown in Figs 16-25. The modules are specified in the appropriate appendixes.

C. Continued Travel on AL and Exit from it.

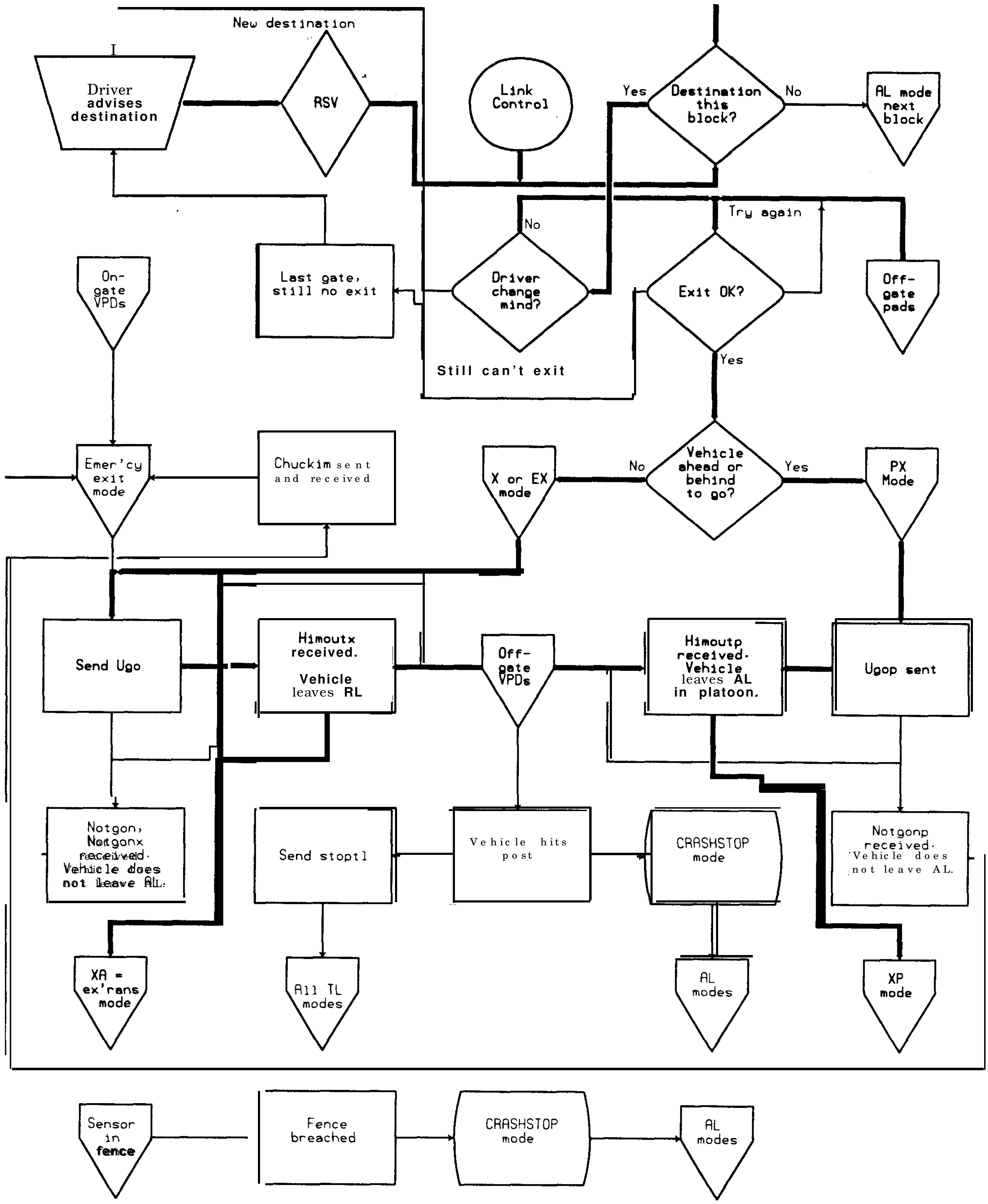
(Figure 14)

As travel continues on the AL, link control is consulting its list of vehicle destinations. A vehicle may call in its destination at any time on AL, or on TL before entry. The choice can be varied at any time. The driver will be advised if the choice is unavailable. This could be because it means going the wrong way. Another possibility is that the gates are closed). If there are closures between here and there, the driver will be advised to seek general information about the state of the system. All this activity is outside the **safety-**critical subsystem. If the vehicle is in EX (Emergency Exit) mode, its destination is the block in which it is, no matter what the driver has declared. If the block is in **SRX** Mode, all vehicles are in EX mode.

When the car enters the block containing its destination, link control will attempt to schedule it for one or more of the off-gates. A message is sent to the driver, asking for confirmation of destination. Unless the choice is changed, link control will advise AL control

Fig 14. Leaving AL

Upper part is repeated from figure 13
"After entry to AL"



of an appropriate off-gate. AL control will check that the exit is clear. AL control will also check if the vehicle(s) behind or following are also to exit. Link control will normally avoid this. However if two or more vehicles are to exit at the same gate, they enter exit platoon (XP) mode. Other vehicles in A mode enter X mode, while those in EX remain there.

The, vehicle's lateral control system now causes it to swing to the right at an appropriate point. If the starting point is correctly chosen the following manoeuvre will be one smooth motion. When the control system detects the turning point marker, the vehicle swings further; the control system relinquishes contact with the marker on the AL and the vehicle moves right until contact with the references on the TL is made.

The VPD controller sends a message if exit is complete, and the vehicle now transfers to exitrans mode (XA) if solo. The vehicles transfer to postplatoon (XP) mode if in a platoon.

Should the vehicle fail to leave when ordered, a different message is sent by the detector pads. A solo vehicle is put into EX mode, and the Highway Patrol is advised. Should the same vehicle fail repeatedly to leave the AL, the Highway Patrol may choose to take extraordinary action. One possibility would be to enter Stop mode and physically enter the car to replace a sick driver. Such situations cannot be diagnosed by the system alone.

It may prove to be impossible for a vehicle to leave by its planned gate or at any other in the same block. This could be because a vehicle enters the TL from the other side. A driver could ignore the warning lights. If a vehicle cannot exit, therefore, a message is sent to the driver of a vehicle in A mode. The message explains the situation. Selection of another exit is invited. The vehicle now enters the next block. If a driver in A mode does not give another destination (or omits to do so in the first place) the vehicle will eventually be carried into a dormitory at the end of the AL. The dormitory may be that at the end of the AL or one at some intermediate point.

If the block is in **SRX** mode, it is not possible to proceed to the next block. If this is the last off-gate, the vehicle is brought to rest. This will cause the remainder of the platoon to come to rest also. The vehicle retains X, EX or XP mode. When a gap appears at the gate, the vehicle will exit. A-message is sent to the Highway Patrol. Under conditions of high flow the HP may choose to put the upstream block into **SRX** Mode also. A major traffic jam is likely to ensue. A great deal of capacity has been lost.

This concludes the description of the parts of the system shown in Figure 14. A full account of each individual module can be found in Figures 21-25, and in the accounts in the appendix of modules for vehicles in A, E, EX, X and XP modes.

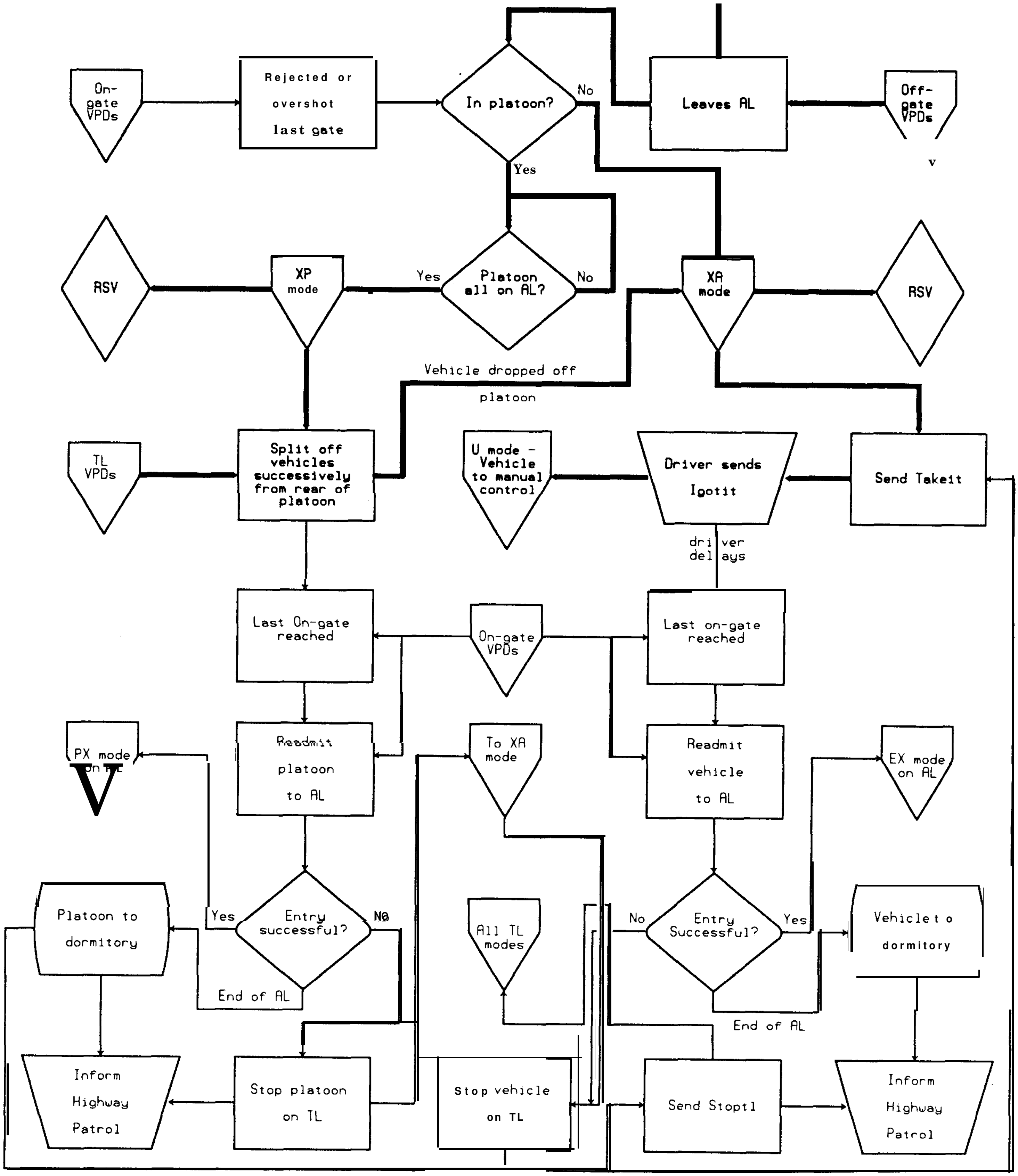
D. Operation while leaving the TL.
(Figure 15)

A vehicle can only revert to manual control if it is in XA mode. As soon as a vehicle enters **XA** mode, it receives a message inviting the driver to resume manual control. The driver must send a positive indication of readiness before automatic control is relinquished. This applies to vehicles entering XA mode because they have completed their journey on the AL. It applies equally to those entering XA mode following driver's change of mind, system failure or rejection as unfit by the system.

When vehicles leave in a postplatoon, the system waits until the whole platoon has exitted. Then the rear vehicle is braked until it is at manual spacing behind the rest of the platoon. The vehicle is then transferred to XA mode. A message is sent to cause the new rearmost vehicle in the platoon to brake. The same happens when a postplatoon is formed in some other way. This might be because entry had to be denied to a preplatoon.

If the invitation to resume manual control is accepted, the vehicle is no longer under system control and re-enters U mode. The detectors continue to track it until it leaves the TL.

Fig. 15. Leaving TL



There is a design fault here. No vehicle enters **XA** mode at an unsafe distance from its predecessor. But, as the system is designed it might be going much faster than its predecessor. Moreover, no attempt is made to check that a vehicle's speed is still safe at the time of release to manual control. This fault that was detected by fault tree analysis. The system was designed in order to demonstrate the fault tree technique. Therefore the fault has not been corrected. Correction would be quite simple.

A vehicle may fail to resume manual control. As a vehicle in XA approaches the last on-gate, an attempt will be made to admit it to the AL. If this succeeds the vehicle is put into EX mode. The Highway Patrol is informed. The AL license is invalidated. If a postplatoon has not had time to break up, it too will be admitted (in PX mode) if this is possible. AL licenses will not be automatically invalidated in this case. In either case, however, the vehicles will perforce exit as soon as safety permits.

It is thus possible, if a driver or vehicle is unable or unwilling to resume manual control, that the vehicle will be repeatedly switched out of the AL and in again until it finishes in a dormitory. It is this possibility that caused the name to be given.

If admission at the last on-gate is denied, platoons are immediately slowed down to a low speed. This may enable successive releases of vehicles to XA to occur before the end of the TL is reached. Manual control can now be resumed, though the drivers who were in the middle of a postplatoon may still experience some difficulty in joining the lanes to their right because of their low speed, while the way ahead may remain blocked for many seconds.

If a vehicle or a platoon reaches the end of the TL while still under system control it is brought to rest. This means that a safe spacing has certainly been achieved and all vehicles can enter XA mode, and leave the system as best they can.

This concludes the description of the parts of the system shown in Figure 15. Again, a full specification of each module is given in the appendixes. Figures 23-27 gives detail also.

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The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. The report does not constitute a standard, specification or regulation.

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APPENDIXES - INTRODUCTION

The, appendixes contain formal statements of the form and effect of each module. The form selected is loosely based on the statements required in a number of formal computer languages. There is however no computer language known which can accept these statements. Since many of the terms used are not axiomatized, a great deal more would be needed before these formal statements could be so used.

However, this form has been found to be adequate for manual verification of the statements made in the course of a fault tree analysis, and this is the application intended.

The general section of these appendixes contains the modules which refer to more than one vehicle or platoon, and others which appear repeatedly in the operation. The other modules are arranged in alphabetical order in groups determined by the vehicle mode to which they refer, with separate sections for the iterators and the **VPDs.** Figures 3-6, 7-11 and 16-27 are organized on the same basis. In those figures, modules at the junction of two modes are repeated, and the same is done in the appendixes, though the full statement is not repeated. A cross-reference is given.

The following abbreviations are used for system modes:
N - Normal, Q - Natural, SRC, SRX, C - Crashstop, S - Stop,
R - Resume.
Cy, Sy mean that all the on-gates in the block are also closed. Sn, Cn mean that some, at least are open.

The reader may wish to be reminded of the glossary of terms on pages ii - iii.

HOW TO USE THE MODULE DEFINITIONS

If it is wished to determine exactly how the system, or some part of it works, it is necessary to consult the written module definitions. The figures provided here do act as a guide to the flow of control through the modules. However, they are not a full flow-chart. Where a module is at a branch, for example, the figures do show two successors. They do not say what the branching criterion is. That is done in the written module definitions. Similarly, a the branching criterion may require external input. This input often comes from the RSV. The relevant module in the VPD controller is shown in the figure as giving an input to the module. But the figure does not say just what information is garnered.

An example may be in order. What happens if a vehicle on the AL runs out of gas? This should not happen, of course. If gas gets low, the vehicle should declare itself faulty and be escorted off the system. However, let us look. If the vehicle is on the AL it is controlled by the aliter. Turn to figure 9. There is a module "Allospeed", with the annotation "Speed much less than target". This looks right. Strictly, the use of the figure is unnecessary. We could have read every module specification in pp A. 62-70.

Look at the specification of Allospeed. Allospeed has an internal variable called Ic. Look at the figure. Predecessors are Alres and Alcontact. Alres says nothing about Ic. Look at the specification of Alcontact. Ic is set and reset by Alcontact. Ic is set if the vehicle is in contact with something ahead (SCV set), and has been since it left the VPD area (Ae set). Otherwise Ic is reset. Look again at the specification of Allospeed. It may be called from Alcontact. From the Alcontact specification we see that Allospeed is called if the vehicle was in contact with a vehicle ahead, but is no longer - i.e. it cannot keep up. In this case Ic is reset.

Allospeed can also be called from Ah-es. Alres is the module which receives a message from the vehicle, and places data from the VSV in the RSV. It also looks at this data. Here Alres may find that speed is much below the expected value. If so Allospeed is called. Ic has just been set by Alcontact.

What now does Allospeed do, if it is called? Look at the specification. It examines Ic. If Ic is set (which happens if there is a vehicle ahead of it in contact) no action is taken - the vehicle is going slowly because its predecessor is slow. But if there is no contact ahead, whether there used to be or not, the module Chuckim is called.

Turn to figure 22 and page A. 49. Chuckim calls for SRC mode. Following platoons slow down to sensor-range speed. Now, should they catch up with a slow vehicle, they have time to slow, or stop, also. Chuckim also puts the vehicle into EX mode. If it does manage to limp to an exit, it will be pushed from there on to the TL.

Name: Crashstopcall
To: General
Admitted in: N SRC SRX R
ID: Vehicle upstream of incident or **none**
Requires: Several possible faults
If Branch: No
Effect: Block to Crashstop;
Fig: -
From: Many possible
Inhib in: C S Q
Other Input: Nil
Condition: -

Name: Gopx
Specification in: AL
Fig: 22,25

Name: Helpal
To: AL and vehs on it
Admitted in: N SRC SRX R
ID: AL
Requires: Alcontact
If Branch: No
Fig: 9, 22
From: Aliter
Inhib in: Q S C
Other Input: Nil
Condition: Mode Normal?
Effect: If Normal or Resume mode, station to Crashstop Mode, (identifying vehicle detecting obstacle);

Name: Helplofr
To: AL and vehicles on it
Admitted in: N SRC SRX R
ID: AL
Fig: 9, 23
From: VPD control
Inhib in: S C Q
Other Input: Nil
Requires: Stationary object detected inside off-gate (includes vehicle hit gatepost)
If Branch: Yes.
Condition: Mode Normal?
Effect: 1. If mode = N or R, block to Crashstop Mode (identifying leading vehicle of platoon approaching gate if within platoon spacing);
2. Else no action; **endif**

Name: Helplonr
Fig: 9, 21
To: AL and vehicles on it
From: VPD control
Admitted in: N SRC Sn Cn R
Inhib in: SRX, Sy, Cy, Q
ID: AL
Other Input: Nil
Requires: Stationary object detected inside on-gate (includes vehicle hit gate)
If Branch: Yes
Condition: Mode Normal?
Effect: 1. Call **Onclose;**
2. If Mode = N or R, block to Crashstop Mode (identifying leading vehicle of platoon approaching gate if within platoon spacing);
3. Else No action; **endif**

Name: Offclose
Fig: -
To: General
From: Many possible
Admitted in: N SRC SRX S C R
Inhib in: Q
ID: None
Other Input: Off-gate no.
Requires: Several fault conditions
If Branch: No
Condition: -
Effect: Named off-gate is closed;

Name: Offopen
Fig: -
To: General
From: HP
Admitted in: R
Inhib in: N SRE SRX C S Q
ID: None
Other Input: Gate number
Requires: Action by HP
If Branch: No
Condition: -
Effect: Named off-gate is re-opened;

Name: Offspot
Fig: 9
To: Link control
From: Any Veh
Admitted in: N SRC R
Inhib in: SRX S C Q
ID: AL, Prep or unique
Other Input: Desired destination
Requires: Nil
If Branch: Yes
Condition: Dest accessible?
Effect: Link control advised of desired destination of vehicle - recorded on VSV, RSV; If destination is accessible in this direction and not closed, calls Offspotok; else calls Offspotout; **endif;**

Name: Offspotok
Fig: 9
To: Any Vehicle
From: AL or LONR
Admitted in: N SRC R
Inhib in: SRX S C Q
ID: AL, unique or prep
Other Input: Destination
Requires: Offspot
If Branch: No
Condition: -
Effect Confirmatory message - destination entered;

Name: Offspotout
To: Any Vehicle
Admitted in: N SRC R
ID: **AL,** prep or unique
Requires: Offspot
If Branch: No
Fig: 9
From: AL or LONR
Inhib in: SRX S C Q
Other Input: Nil
Condition: -
Effect: Negative response - destination not accessible by veh in this direction, or in closed section; If **Offspot** sent previously, old dest holds, else no destination recorded;

Name: Onclose
To: General
Admitted in: N SRC SRX S C R
ID: None
Requires: Several fault conditions
If Branch: No
Fig: - .
From: Many possible
Inhib in: Q
Other Input: On-gate no.
Condition: -
Effect: Named on-gate is closed;

Name: Onopen
To: General
Admitted in: R
ID: None
Requires: Action by HP
If Branch: No
Fig: -
From: HP
Inhib in: N SRE SRX C S Q
Other Input: Gate number
Condition: -
Effect: Named on-gate is re-opened;

Name: Queryintoff
To: AL and down-AL
Admitted in N: SRC SRX S C R
ID: Al (of **prec** veh)
Requires: Moving object enters by off-gate
If Branch: No
Fig: 6, 22
From: VPD control
Inhib in: Q
Other Input: Nil
Condition: -
Effect: Call Srccall; Call to **Countem*;** HP advise.

Name: Queryinton
To: AL and down-AL
Admitted in: N SRC SRX C S R
ID: AL (of **prec** veh).
Fig: 5, 22
From: VPD control
Inhib in: Q
Other Input: Nil
Requires: Moving object detected entering at on-gate without Comeinc(21) or Comeinp(21).
If Branch: No
Condition: -
Effect: **Maxspeed** in Newspeed* (9) set to sensor-range; HP advise; Call to **Countem*** (9); Call Srccall;

Name: Queryoff **Fig: 22**
To: Vehicle in A **From: AL**
Admitted in: N SRC R **Inhib in:** SRX S C Q
ID: AL **Other Input:** Destination
Requires: Veh has entered block with announced exit
If Branch: No **Condition: -**
Effect: Message sent : "Still want to leave at .... ?". If no reply received before time to quit, calls Nogo; endif;

Name: Srccall **Fig: -**
To: General **From:** many possible
Admitted in: N R **Inhib in:** SRC SRX S C Q
ID: None **Other Input: Nil**
Requires: Several possible faults
If Branch: No **Condition: -**
Effect: Block to SRC mode; return;

Name: Srxcall **Fig: -**
To: General **From:** many possible
Admitted in: N SRC R **Inhib in:** SRX S C Q
ID: None **Other Input:** Nil
Requires: Several possible faults
If Branch: No **Condition: -**
Effect: Block to SRX mode; return

Name: Stopal **Fig: 9, 22**
To: AL **From:** Fence or AL
Admitted in: N R **Inhib in:** SRC SRX S C Q
ID: None **Other Input:** Position
Requires: Breach in fence or lost vehicle in Countem
If Branch: No **Condition: -**
Effect: Works out which is next platoon upstream of position. Full Braking to this; Full platoon braking to others - sends Crashstopcall; If position is opposite TL, call Stoptl; return;

Name: Stoptl **Fig: 3,7,8,10,11,21,23,26**
To: General to TL **From:** VPD control, LOFR, LONR
Admitted in: N SRC SRX C S R **Inhib in: Q**
ID: None **Other Input:** Position
Requires: Stationary object on TL
If Branch: No **Condition: -**
Effect: All vehs upstream of location stated reduce maxspeed to sensor-range speed; For on-gates in block upstream, call Onclose; return;

Name: Stopcall
To: General
Admitted in: N SRC **SRX** C R
ID: None
Requires: Fault condition or HP decision
If Branch: No
Effect: Block to Stop mode;

Fig: -
From: Several possible or HP
Inhib in: S Q
Other Input: Nil

Condition: -

Modules in VPD Control
(On TL - fig. 3)

Name: Atenda
To: LOFR
Admitted in: **N** SRC SRX C S R
ID: Unique
Requires: Veh in XA detected about to quit **SA.**
If Branch: No
Effect: Induces Stopita (26);
Fig: 3, 26
From: VPD control
Inhib in: Q
Other Input: Nil
Condition:

Name: Atendp
To: LOFR
Admitted in: **N** SRC SRX C S R
ID: Postplatoon
Requires: Veh in XP detected about to quit **SA.**
If Branch: No
Effect: Marks RSV: induces Stopitp (27);
Fig: 3, 27
From: VPD control
Inhib in: Q
Other Input: Nil
Condition:

Name: Chicc
To: Lonr
Admitted in: **N** SRC Sn Cn R
ID: Unique
Requires: Veh in PC reaches chicane
If Branch: No
Effect: Calls Testuc, starts test process;
Fig: 3, 17
From: VPD control
Inhib in: SRX Sy Cy Q
Other Input: Nil
Condition: -

Name: Chicp
To: Lonr
Admitted in: **N** SRC Sn Cn R
ID: Preplatoon
Requires: Veh in PP reaches chicane
If Branch: No
Effect: Calls **Testup,** starts test process;
Fig: 3, 19
From: VPD control
Inhib in: SRX Sy Cy Q
Other Input: Nil
Condition: -

Name: Dropbackc **Fig: 3, 17, 18**
To: LONR **From:** VPD control
Admitted in: N SRC SRX C S R **Inhib in: Q**
ID: Unique **Other Input:** Speed, separation
Requires: Veh in PC, C less than manual spacing from Veh **in** U, XA or XP or moving up to it so that it will be in less than say 2 sec.
If Branch: Yes, determined by labels, il, i2 initially zero **Condition: See** below;
Effect:
a. Calculate intl = least of 2 **sec** and time to **3/4** manual spacing;
b. if il = 0, set il=l;
c.else intl = least of intl and its previous value decremented by passage of time;
d. **endif;** if preplatc received for vehicle ahead or intl > 0.0, ;
e. else if **i2** = 0, calculate actions required to reestablish manual spacing; calculate int2 = time required to execute these;
f. set **i2** = 1; pass parameters to Slipbackc; break;
g. else if int2 decremented from its previous value by passage of time > 0.0, ;
h. else set il = 1, i2 = 0;
i. repeat from beginning; **endif; endif; endif;**

Name: Dropbackp **Fig:** 1, 19, 20
To: LONR **From:** VPD control
Admitted in N SRC SRX C S R **Inhib in: Q**
ID: Prep **Other Input:** Speed, separation
Requires: Veh in PP, P less than manual spacing from Veh in U XA or XP or moving up to it so that it will be in less than say 2 sec.
If Branch: Yes, determined by labels, il, i2. initially zero. **Condition: See** below;
Effect:
a. Calculate intl = least of 2 **sec** and time to **3/4** manual spacing;
b. if il = 0, set il=l;
c. else intl = least of intl and its previous value decremented by passage of time; **endif;**
d. if preplatp received for vehicle ahead or intl > 0.0,;
e. else if **i2** = 0, calculate actions required to reestablish manual spacing; calculate **int2** = time required to execute these; set i2 = 1; pass parameters to Slipbackp; on return from Slipbackp, break;
f. else if int2 decremented from its previous value by passage of time > 0.0,;
g. else set il = 1; i2 = 0; repeat from beginning; **endif; endif; endif;**

Name: Dropbacks
Fig: 3, 27
To: LOFR
From: VPD control
Admitted in: N SRC SRX C S R
I.nhib in: Q
ID: XP
Other Input: Speed, separation
Requires: Veh in XP less than manual spacing from another veh or moving up to it so that it will be in less than (say) 2 sec.
If Branch: Yes, determined by labels, il, i2 set to zero on **first** call for this vehicle
Condition: See below;
Effect:
a Calculate intl = least of 2 **sec** and time to **3/4** manual spacing;
b. if il = 0, set **i1=1;**
c. else intl = least of intl and its previous value decremented by passage of time; **endif;**
d. if intl **>** 0.0,;
e. else if i2 = 0, calculate actions required to reestablish manual spacing; calculate int2 = time required to execute these; set **i2** = 1; and pass parameters to Slipbacks; on return from Slipbacks, break;
f. else if **int2** decremented from its previous value by passage of time **>** 0.0, ;
g. else set **i1** = 1, **i2** = 0; repeat from beginning; **endif; endif; endif;**

Name: Dropbackx
Fig: 3, 26
To: LOFR
From: VPD control
Admitted: in N SRC SRX C S R
Inhib in: Q
ID: XP
Other Input: Speed, separation
Requires: Veh in XA less than manual spacing from another vehicle or moving up to it so that it will be in less than (say) 2 **sec**
If Branch: Yes, determined by labels, il, i2, initially zero.
Condition: See below;
Effect:
a.Calculate intl = least of 2 **sec** and time to **3/4** manual spacing;
b. if il = 0, set il=l;
c. else intl = least of intl and its previous value decremented by passage of time; **endif;**
d. if intl **>** 0.0, ;
e. else if i2 = 0, calculate actions required to reestablish manual spacing; calculate int2 = time required to execute these; set i2 = 1; pass parameters to Slipbackx; on return from Slipbackx, break;
f. else if **int2** decremented from its previous value by passage of time **>** 0.0, ;
g.else set il = 1; i2 = 0; repeat from beginning; **endif; endif; endif;**

Name: Droptoff **Fig: 3, 27**
To: Lofr **From:** VPD control
Admitted in: N SRC SRX S C R **Inhib in: Q**
ID: Postplat **Other Input: -**
Requires: Dropoff (27); Veh manual spacing behind one ahead.
If Branch: No **Condition: -**
Effect: Induces **Postoff** (27) and calls **Dropoff** (27) for veh ahead;

Name: Himon **Fig: 3, 8, 19, 20**
To: Prepiter **From:** VPD control
Admitted in: N SRC Cn Sn R **Inhib in: Q** SRX Sy Cy
ID: Preplatoon **Other Input:** Nil
Requires: Veh detected within sure sensor range of one ahead
If Branch: No **Condition: -**
Effect: Sets presence bit in Prepcontact; Inhibits **Slowit;**

Name: Jordc **Fig: 3, 17, 18**
To: LONR **From:** VPD control
Admitted in: N SRC Cn Sn R **Inhib in: Q** SRX Cy Sy
ID: Unique **Other Input:** Speed Separation
Requires: Veh in PC, C less than platoon spacing behind veh in C, PC, P, PP.
If Branch: Yes, determined by labels, il, i2 initially zero **Condition: See** below;
Effect:

a. Calculate intl = least of 2 **sec** and time to platoon spacing less (say) **10m;**
b. if il = 0, set il= 1;
c. else intl = least of intl and its previous value decremented by passage of time; **endif;**
d. if preplatc received for vehicle ahead or intl **>0.0,** ;
e. else if i2 = 0, calculate actions required to reestablish manual spacing; calculate int2 = time required to execute these; set i2 = 1; pass parameters to Slipbackc; on return from Slipbackc, break;
f. else if int2 decremented from its previous value by passage of time > 0.0, ;
g. else set il = 1; i2 = 0; repeat from beginning; **endif; endif; endif;**

Name: Jordp
Fig: 3, 19, 20
To: LONR
From: VPD control
Admitted in: N SRC Cn Sn R
Inhib in: Q SRX Cy Sy
ID: Preplat
Other Input: Speed Separation
Requires: Veh in P,PP less than platoon spacing behind veh in C, PC, P, PP.
If Branch: Yes, determined by labels, il, i2 initially zero
Condition: See below;
Effect:

a. Calculate intl = least of 2 **sec** and time to platoon spacing less say **10m;**
b. if il = 0, set il=l;
c. else intl = least of intl and its previous value decremented by passage of time; **endif;**
d. if **preplatp** received for vehicle ahead or **int1 >** 0.0,;
e. else if i2 = 0, calculate actions required to reestablish manual spacing; calculate int2 = time required to execute these; set i2 = 1; pass parameters to Slipbackp; on return from Slipbackp, break;
f. else if **int2** decremented from its previous value by passage of time **>** 0.0, ;
g. else set il = 1; i2 = 0; repeat from beginning; **endif; endif; endif;**

Name: Outok
Fig: 3, 22, 24, 25
To: AL
From: VPD control
Admitted in: N SRC SRX R
Inhib in: Q S C
ID: None
Other Input: Nil
Requires: Spaces on TL around off gate clear enough to permit exit.
If Branch: No
Condition: -
Effect: Setting in gate AR: enables Ugo (22); inhibits **Nogo** (22);

Name: Oshotc
Fig: 3, 17, 18
To: RSV
From: VPD control
Admitted in: N SRC SRX S C R
Inhib in: Q
ID: Unique
Other Input: Nil
Requires: Vehicle in PC, C past last on-gate
If Branch: No
Condition: -
Effect: Calls **Overshootc;**

Name: Oshotp
Fig: 3, 19, 20
To: RSV
From: VPD control
Admitted in: N SRC SRX S C R
Inhib in: Q
ID: Preplat
Other Input: Nil
Requires: Vehicle in PP, P past last on-gate
If Branch: No
Condition: -
Effect: Calls Overshootp;

Name: Pastit
To: LOFR
Admitted in: N SRC SRX S C R
ID: Postplatoon
Requires: Leading veh in postplatoon past last gate.
If Branch: No
Effect: On test by Postcon(11), calls Slowem (11);

Fig: 3, 11, 27
From: VPD control
Inhib in: Q
Other Input: -
Condition: -

Name: Slowit
To: LONR
Admitted in: N SRC Sn Cn R
ID: Preplat
Requires: Veh in P or PP closing on one ahead too fast and no marker from Himon
If Branch: No
Effect: Maximum speed reduced by amount calulated; params to Slipbackp (9);

Fig: 3, 19, 20
From: VPD control
Inhib in: Q SRX Sy Cy
Other Input: Speed, separation
Condition: -

Name: Stoptl
Specification in: Gen
Fig: 3, 7, 8, 10, 11, 17, 18, 19, 20, 23, 27

Name: Ugo
Specification in: AL
Fig: 3, 6, 22, 23, 24, 26

Name: Ugop
Specification in: AL
Fig: 3, 22, 24, 25, 27

Modules in VPD Control
(VPDs on **AL:** fig. 4)

Name: Heron
Fig: 4, 22
To: Aliter, Al
From: VPD control
Admitted in: N SRC SRX R
Inhib in: C S Q
ID: AL
Other Input: Nil
Requires: Veh detected within sure sensor range of one ahead.
If Branch: No
Condition: -
Effect: Sets enabling bit in Alcontact; Inhibits call to Queryinton from Alcontact;

Name: Nameherc
Fig: 4, 5, 21
Specification in: E

Name:Nameherp
Fig: 4,.5, 21
Specification in: E

Name: Nameherx
Fig: 4, 5, 26
To: AL
From: LOFR
Admitted in: N SRC R Sn Cn
Inhib in: SRX Sy Cy Q
ID: Unique
Other Input: Nil
Requires: Ugoback (26) and permitted mode and **Onok**
If Branch: No
Condition: -
Effect: Vehicle transfers to EX mode; Receives new ID, appropriate to AL, Enables Hesinx or Notinx;

Name: Onok
Fig: 4, 18, 20, 21, 26
To: RSV
From: VPD control
Admitted in: N SRC Sn Cn R
Inhib in: SRX Sy Cy Q
ID: None
Other Input: Nil
Requires: Long gap on Al, or rear of platoon just passed
If Branch: No
Condition: -
Effect: Sets gate AR; enables Comeinc **(18),** Comeinp **(20),** Ugoback (26);

Modules in VPD Control
(VPDs in on-gate. Fig. 5)

Name: Chuckim **Fig: 5, 6, 22, 24**
Specification in: AL

Name: Helplonr **Fig: 5, 21**
Specification in: Gen

Name: Hesin **Fig: 5, 21, 22**
To: AL **From:** VPD control
Admitted in: N SRC Sn Cn R **Inhib in: Q** SRX Sy Cy
ID: AL **Other Input:** Nil
Requires: Namherc (21) or Nameherp (21) and detector shows entry.
If Branch: No **Condition: -**
Effect: + 1 to **Countem*** (22); Calls Oniteral (7);

Name: Hesinx **Fig: 5, 22, 23, 26**
To: AL **From:** VPD control
Admitted in: N SRC Sn Cn R **Inhib in: Q** DX Sy Cy
ID: AL **Other Input:** Nil
Requires: Ugoback (26) and entry confirmed by VPD control
If Branch: No **Condition: -**
Effect: + 1 to **Countem*;** Calls Offiterlof and Oniteral.

Name: Nameherc **Fig: 4, 5, 21**
Specification in: E

Name:Nameherp **Fig: 4, 5, 21**
Specification in: E

Name: Nameherx **Fig: 4, 5, 26**
Specification in: VPD control

Name: Notin **Fig: 5, 21**
To: LONR **From: VPD** control
Admitted in: N SRC Sn Cn R **Inhib in: Q** SRX Sy Cy
ID: AL **Other Input:** Nil
Requires: Nameherc (21) or Nameherp (21) and detection of non-entry.
If Branch: No **Condition: -**
Effect: Induces Ugoacla (17, 18, 19, 20, 21, 26). Report to HP, License invalidated.

Name: Notinx **Fig: 5, 26**
To: LOFR **From:** VPD control
Admitted in: N SRC Sn Cn R **Inhib in:** SRX Sy **Cy** Q
ID: AL **Other Input:** Nil
Requires: Ugoback (26) and (detection of non-entry or **Onclose)**
If Branch: No **Condition: -**
Effect: Maxspeed to sensor range speed; Calls Hooua (26).

Name: Queryinton **Fig: 5, 22**
Specification in: Gen

Name: Sorrybut2c **Fig: 17, 18**
Specification in: PC mode

Name: Sorrybut2p **Fig:** 19, 20
Specification in: PP Mode

Name: Sorrybut5 **Fig: 5, 6, 21, 23**
To: Veh in E or X **From:** VPD control
Admitted in: N SRC SRX R **Inhib in: S C Q**
ID: AL **Other Input:** Nil
Requires: Vehicle hits (on- or off-) gate-post
If Branch: No **Condition: -**
Effect: HP informed; **Licence** invalidated; Calls Ugoacla and Stoptl;

Modules in VPD Control
(VPDs in Off-gate: Fig 6)

Name: Chuckim **Fig: 5, 6, 22, 24**
Specification in: AL

Name: Helplofr **Fig: 6, 23**
Specification in: Gen

Name: Himoutp **Fig: 6, 22, 25, 27**
To: LOFR **From:** VPD control
Admitted in: N SRC SRX R **Inhib in: Q S C**
ID: AL **Other Input:** Nil
Requires: Ugop (25) and vehicle exit detected
If Branch: No **Condition: -**
Effect: Subtracts 1 from **Countem** * (22); calls Callposta (27) and Offiteral (9);

Name: Himoutx **Fig: 6, 22, 23, 26**
To: LOFR **From:** VPD control
Admitted in: N SRC SRX R **Inhib in: Q S C**
ID: AL **Other Input:** Nil
Requires: Ugo (22) and vehicle exit detected
If Branch: No **Condition: -**
Effect: Subtracts 1 from Countem*; Calls Hooua (26) and Offiteral (9).

Name: Notgonp **Fig: 6, 25**
To: AL **From:** VPD control
Admitted in: N SRC SRX R **Inhib in: C S** R
ID: AL **Other Input:** Nil
Requires: Ugop **(25),and** VPD indicates no departure
If Branch: No **Condition: -**
Effect: Calls Goonp(13);

Name: Notgonx **Fig: 6, 23, 24**
To: AL **From:** VPD control
Admitted in: N SRC SRX R **Inhib in: C S** R
ID: AL **Other Input:** Nil
Requires: Ugo **(22)**, and VPD indicates no departure
If Branch: Yes **Condition:** Last gate and SRX?
Effect:
a. Veh transfers to EX; HP advised; licence invalidated;
b. If (last gate and SRX), Maxspeed = 0; endif;

Name: Queryintoff **Fig: 6, 22**
Specification in: Gen

Name: Sorrybut2c **Fig: 17, 18**
Specification in: PC mode

Name: Sorrybut2p **Fig: 19, 20**
Specification in: PP Mode

Name: Sorrybut5 **Fig: 5, 6, 21, 23**
Specification in: VPD control

Name: Ugo **Fig: 3, 6, 22, 23, 24, 26**
Specification in: AL

Name: Ugop **Fig: 3, 6, 22, 24, 25, 27**
Specification in: AL

Modules in Loniter (**Fig.** 7)

Name: Lonrcon
Fig: 7
To: Vehicle
From: Loniter
Admitted in: N SRC Sn Cn R
Inhib in: Q SRX Sn Cn
ID: Unique
Other Input: Target speed (from link control); other control variables.
Requires: Oniterlon: repeated every cycle stimulated by clock.
If Branch: No (but see below)
Condition: -
Effect:
a. Passes control vars to VSV;
b. Passes current time to, and calls Lonmores;
c. On return, signals for Lonrres from same veh;

Name: Lonrnores
Fig: 7, 17, 18
To: Lonr
From: Loniter
Admitted in: N SRC Sn Cn R
Inhib in: Q SRX Sy Cy
ID: Unique
Other Input: Nil
Requires: a. Lonrres. b. Lonrcon.
If Branch: Yes
Condition: Intl var restime
Effect:
a. Sets restime to current time; return;
b. If (current time - restime) too large, call Lonctnores; sets restime to present; **endif;** return;

Name: Lonmores
Fig: 7, 17, 18
To: Lonr
From: Loniter
Admitted in: N SRC Sn Cn R
Inhib in: Q SRX Sy Cy
ID: Unique
Other Input: Nil
Requires: a. Lonrres. b. Lonrcon.
If Branch: Yes
Condition: Intl var restime
Effect:
a. Sets restime to current time; return;
b. If (current time - restime) too large, call Lonctnores; sets restime to present: **endif;** return;

Name: Lonrres **Fig: 7**
To: Loniter **From:** Vehicle
Admitted in: N SRC Sn Cn R **Inhib in: Q** SRX Sy Cy
ID: Unique **Other Input:** Lateral control variable (LCV).
Requires: Lonrcon
If Branch: Yes **Condition:** Message rec'd?
Effect: 1. If message received,
a. Updates control vars in RSV;
b. Passes current time to Lomnores;
c. Passes current time to Lomwander and calls Lomwander; **endif;**
2. On return to iterator for Lonrcon for next vehicle.

Name: Lomwander **Fig: 7, 17, 18**
To: Lonr **From:** Loniter
Admitted in: N SRC Sn Cn R **Inhib in: Q** SRX Sy Cy
ID: Unique **Other Input:** LCV, time
Requires: Lonrres
If Branch: Yes **Condition:** LCV excessive? or veh fault?
Effect: 1. If LCV in bounds or no veh fault, updates (time of LCV in bounds);
2. Else if (current time - time of LCV in bounds) too large, call Lonctwander; time of (LCV in bounds) to present; **endif;** return;

Name: Offiterlon **Fig: 7,16,17,18,19,20,21,26**
To: Loniter **From: Lonr**
Admitted in: N SRC SRX S C R 6 **Inhib in: Q**
ID: Unique **Other Input: -**
Requires: Preplatc or Ugoaclc
If Branch: No **Condition: -**
Effect: Loniter ceases to send to this vehicle;

Name: Oniterlon **Fig: 7, 16, 17**
To: Loniter **From: Lonr**
Admitted in: N SRC Sn Cn R **Inhib in: Q** SRX Sy Cy
ID: Unique **Other Input:** Nil
Requires: Okbut
If Branch: No **Condition: -**
Effect: Initiates sequence of commands Lonrcon, etc from loniter;

Name: Slipbackc **Fig: 7, 17, 18**
Specification in: PC.

Name: Stoptl **Fig: 3,7,8,10,11,21,23,26**
Specification in: Gen

Modules in Prepiter (Fig. 8)

Name: Brakehard **Fig: 8,** '19, 20
Specification in: PP

Name: Himon **Fig: 5, 8,** 19, 20
Specification in: VPD control

Name: Offiterprep **Fig: 8, 19, 20, 21, 26, 27**
To: Prepiter **From: Lonr**
Admitted in: N SRC SRX S C R **Inhib in: Q**
ID: Preplatoon **Other Input:** Nil
Requires: Comeinp or Ugoaclp or Ugoaclf
If Branch: No **Condition: -**
Effect: Prepiter ceases to send to this vehicle;

Name: Oniterprep **Fig: 8, 17, 18,** 19, 20
To: Prepiter **From: Lonr**
Admitted in: N SRC Sn Cn R **Inhib in: Q** SRX Sy Cy
ID: preplatoon **Other Input:** Nil
Requires: Preplatc
If Branch: No **Condition: -**
Effect: Initiates sequence of commands **Prepcon,** etc from prepiter;

Name: Prepcon **Fig: 8**
To: Vehicle **From:** Prepiter
Admitted in: N SRC Sn Cn R **Inhib in: Q** SRX Sy Cy
ID: Preplatoon **Other Input:** Target speed
(from link control); other control variables.
Requires: Oniterprep: repeated each cycle stimulated by clock.
If Branch: No (but see below) **Condition: -**
Effect:
1. Passes control vars to VSV;
2. Passes current time to, and calls Prepnores;
3. On return, signals for Prepres from same veh;

Name: Prepcontact
Fig: 8
To: Lonr
From: Prepiter
Admitted in: N SRC **Cn Sn** R
Inhib in: Q SRX Sy Cy
ID: Preplatoon
Other Input: Sensr contact (SCV)
Requires: Prepres (Var Hn set by **Himon** when closeness detected)
If Branch: Yes
Condition: Intl vars Hn **&** He
Effect:
1. If Hn set, set He;
2. else if Hn reset and He set, call **Sorrybut2p;**
3. else if **Hn** set and SCV reset **-** call Prepctnocont;
4. **endif; endif; endif;** return;

Name: Prepno
Fig: 8, 17, 18, 19, 20
To: Prepiter
From: Lonr
Admitted in: N SRC Sn **Cn** R
Inhib in: Q SRX Sy Cy
ID: Preplatoon
Other Input: Names platoon(s)
Requires: Preplatc or Preplatp or Brakehard
If Branch: No
Condition: -
Effect: Updates record in prepiter of no of vehicles in platoon; sets var X (platoon entry marker in beacon of leader) to sum of values in platoons, or increments it if joining or joined veh is in PC; provides name of new platoon; if platoon identity merged into another, calls **Offiterprep;**

Name: Prepnores
Fig: 8, 19, 20
To: Lonr
From: Prepiter
Admitted in: S N SRC Sn Cn R
Inhib in: Q SRX Sy **Cy**
ID: Preplatoon
Other Input: Nil
Requires: a. Prepres b. **Prepcon**
If Branch: Yes
Condition: Intl var restime
Effect:
a. Sets restime to current time: return;
b. If (current time **-** restime) too large, call Prepctnores; sets restime to present; **endif;** return;

Name: Prepres
To: Prepiter
Admitted in: N SRC Sn Cn R
ID: Preplatoon
Fig: 8
From: Vehicle
Inhib in: Q SRX Sy **Cy**
Other Input: Lateral control Variable (LCV), sensor contact variable (SCV)
Requires: Prepcon
If Branch: Yes
Condition: Message Rec'd?
Effect:
1. If message received,
   a. Updates veh control vars in RSV;
   b. Passes current time to Prepnores;
   c. passes current time to Prepwander; calls Prepwander;
   d. calls Prepcontact; **endif;**
2. Call **Prepcon** for next vehicle;

Name: Prepwander
To: Lonr
Admitted in: N SRC Sn Cn R
ID: Preplatoon
Fig: 8, 19, 20
From: Prepiter
Inhib in: Q DX Sy **Cy**
Other Input: LCV, time
Requires: Prepres
If Branch: Yes
Condition: LCV excessive? or veh fault?
Effect:
1. If **LCV** in bounds and no fault, updates (time of LCV in bounds);
2. Else if (current time **-** time of LCV in bounds) too large, call Prepctwander, time of LCV in bounds set to present: return;

Name: Slipbackp
Fig: 8, 19, 20
Specification in: PP.

Name: Slowit
Fig: 3, 8, 19, 20
Specification in: VPD control

Name: Stoptl
Fig: 3,7,8,10,11,21,23,26
Specification in: Gen

Modules in **Aliter** (Fig. 9)

Name: Alcon | **Fig: 9**
To: Vehicle on AL | **From: Aliter**
Admitted in: N SRC SRX R | **Inhib in: S C Q**
ID: AL , | **Other Input:** Maxspeed, n, del-speed (n), Control variables, Veh Mode
Requires: Oniteral plus clock pulse **-** repeats each iter cycle
If Branch: No | **Condition: -**
Effect:
1. Passes control vars to VSV;
2. Passes current time to and calls Alnores;
3. passes to **Alres** from same veh;
(n, delspeed (n) are set from Speedset)

Name: Alcontact | **Fig: 9, 22**
To: AL | **From: AL**
Admitted in: N SRC SRX R | **Inhib in: S C Q**
ID: AL | **Other Input:** Sensr contact (SCV)
Requires: Alres (Var An set/reset by Heron as closeness detected)
If Branch: Yes | **Condition:** Intl vars An, Ae
Effect:
1. If An set, set Ae; **endif;**
2. If An reset and Ae set, reset Ic in Allospeed; call Allospeed; **endif;**
3. If Ae set and SCV reset **-** call Alctnocont; **endif**
4. If Ae reset and SCV set **-** Call **Helpal; endif**
5. If Ae set and SCV set, set var Ic in Allospeed; else reset Ic; **endif;**
6. return;

Name: Allospeed | **Fig: 9, 22**
To: AL | **From: Aliter**
Admitted in: N SRC SRX R | **Inhib in: Q** SRC SRX S C
ID: AL | **Other Input:** Nil
Requires: a. Alres, speed **<<** maxspeed; b. Alcontact
If Branch: Yes | **Condition:** Intl var Ic set:
Effect:
1.If Ic reset, call Chuckim (22);
2. **Endif;** return;

Name: Alnores
To: AL
Admitted in: N SRC SRX R
ID: AL
Requires: a. Alres b. **Alcon**
If Branch: Yes
Fig: 9, 22
From: Aliter
Inhib in: S C Q
Other Input: Nil

Condition: Int var restime

Effect:
1. Sets restime to current time;
2. If (present **-restime)** too large, call Alctnores; sets restime to present: **endif;** return;

Name: Alres
To: Aliter
Admitted: in N SRC SRX R
ID: AL
Fig: 9
From: Vehicle on AL (A or PX)
Inhib in: S C Q
Other Input: Veh speed, contact variable Lateral Control Variable (LCV) Veh mode

Requires: Alcon
If Branch: Yes
Condition: Message Rec'd? (b) speed **<<** maxspeed?

Effect:
1. If message received,
2. Contains internal variable n. If **n** in **Alcon** differs, **intl** var is updated and target speed in VSV reduced by **delspeed(n)** from **Alcon;** Other control variables from **Alcon** also updated in VSV;
3. Passes current time to Alnores;
4. passes current time to **Alwander** and calls Alwander;
5. On return calls Alcontact;
6. On return if speed **<<** maxspeed, calls Allospeed;
7. On return to **aliter** for **Alcon** for next veh, returning relevant control vars.

Name: Alwander
To: Al
Admitted: in N SRC SRX R
ID: AL
Requires: Alres
If Branch: Yes
Fig: 9, 22
From: Aliter
Inhib in: Q S C
Other Input: LCV, time

Condition: LCV excessive? or veh fault?

Effect:
1: If LCV in bounds and no fault, update (time of LCV in bounds);
2: Else if (current time - time of LCV in bounds) too large, call **Alctwander;** set (time of LCV in bounds) to present; **endif;** return;

Name: Helpal
Specification in: Gen
Fig: 9, 22

Name: Nextplat
Fig: 9, 22
To: Aliter
From: AL
Admitted in: N SRC SRX R
Inhib in: S C Q
ID: AL (Plat name)
Other Input: No of vehicles,
Requires: Countem (22)
If Branch: No
Condition: -
Effect: Passes name and no of members of platoon to **Alcon,** when all have entered; calls **Countem*** (9); calls Rename (9); return;

Name: Offiteral
Fig: 9, 22, 23, 25, 27
To: Aliter
From: AL* or LOFR
Admitted in: N SRC SRX R
Inhib in: S C Q
ID: AL
Other Input: Nil
Requires: Rename **(21), Himout (23,26),** Himoutx **(24), Himoutp(25,27)**
If Branch: No
Condition: -
Effect: Alcon no longer sent on clock pulse to vehicle, receipt of Alres disabled;

Name: Oniteral
Fig: 9, 21,22,26
To: Aliter
From: AL' or LONR
Admitted: in N SRC SRX R
Inhib in: Q S C
ID: AL
Other Input: Nil
Requires: Rename'(22) or **Hesin** (28)
If Branch: No
Condition: -
Effect: Alcon sent on clock pulse to vehicle; Receipt of **Alres** enabled;

Name: Speedset
Fig: 9, 22
To: Aliter
From: Link control
Admitted in: N SRC SRX R
Inhib in: Q S C
ID: AL
Other Input: label n, delspeed(n)
Requires: a. Decision of linkcontrol or b. Srccall or Srxcall
If Branch: No
Condition: -
Effect:
1. Updates n and delspeed n in **Alcon,** and passes these to **Newspeed** (22)
2. Updates n in **Alcon -** sets delspeed(n) to (maxspeed - contact speed)

Name: Stopal
Fig: 9, 22
Specification in: Gen

Name: Stopitp
Fig: 9, 25
To: Aliter
From: AL
Admitted in: SRX
Inhib in: N SRC S C R Q
ID: AL
Other Input: Nil
Requires: Veh at last **offgate** does not receive **Outok**
If Branch: No
Condition: -
Effect: Calls Alcon - maxspeed set to zero; (Vehicle is still at off-gate in mode PX, consequently on next iteration calls Ugop again, till vehicle exits)

Name: Stopitx
Fig: 9, 24
To: Aliter
From: AL
Admitted in: SRX
Inhib in: N SRC S C R Q
ID: AL
Other Input: Nil
Requires: Veh at last **offgate** does not receive **Outok**
If Branch: No
Condition: -
Effect: Calls **Alcon - maxspeed** set to zero; (Vehicle is still at off-gate in mode EX, consequently on next iteration calls Ugo again, till vehicle exits.)

Modules in Lofiter (Fig. 10)

Name: Cutspeed
Fig: 10, 26
To: Lofiter
From: LOFR
Admitted in: N DC DX S C R
Inhib in: Q
ID: Unique
Other Input: Speed reduction
Requires: Notinx or (Ugoback and **Onok** reset)
If Branch: No
Condition: -
Effect: Maxspeed reduced;

Name: Lofrcon
Fig: 10
To: Vehicle
From: Lofiter
Admitted in: N SRC SRX S C R
Inhib in: Q
ID: Unique
Other Input: Target speed (from link control); other control variables.
Requires: Oniterlof: repeated every cycle stimulated by clock.
If Branch: No
Condition: -
Effect: Passes control variables to VSV, signals for Lofrres from same veh;

Name: Lofrres
Fig: 10
To: Lofiter
From: Vehicle
Admitted in: N SRC SRX S C R
Inhib in: Q
ID: Unique
Other Input: Nil
Requires: Lofrcon
If Branch: No
Condition: -
Effect:
1. Updates control vars in RSV.
2. On return, to iterator for Lofrcon for next veh.

Name: Offiterlof
Fig: 10, 26
To: Lofiter
From: Lofr
Admitted in: N SRC SRX S C R
Inhib in: Q
ID: Unique
Other Input: -
Requires: Igotit or Hesinx
If Branch: No
Condition: -
Effect: Lofiter ceases to send to this vehicle;

Name: Oniterlof
Fig: 10, 26
To: Lofiter
From: LOFR
Admitted in: N SRC SRX R
Inhib in: Q S C
ID: Unique
Other Input: Nil
Requires: Takeit
If Branch: No
Condition: -
Effect: Initiates sequence of commands Lofrcon etc from **lofiter;**

Name: Slipbackx
Fig: 10, 26
Specification in: XA.

Name: Stopita
Fig: 10, 26
To: Lofiter
From: Lofr
Admitted in: N SRC SRX R S C
Inhib in: Q
ID: Unique
Other Input: Nil
Requires: Atenda (VPD control)
If Branch: No
Condition: -
Effect: **Maxspeed** = 0; Message to driver "Please resume Manual control at once - you have committed an **offence** already"; Calls Stoptl; (Igotit remains enabled)

Name: Stoptl
Fig: 3,7,8,10,11,21,23,26
Specification in: Gen

Modules in Postiter **(Fig:. 11)**

Name: Atendp **Fig: 3,** 11, 27
Specification in: VPD control

Name: Offiterpost **Fig:** 11, 27
To: Postiter **From:** Lofr
Admitted in: N SRC SRX S C R **Inhib in: Q**
ID: Postplatoon **Other Input:** Nil
Requires: Droptoff (27) or Stopitxp (27)
If Branch: No **Condition: -**
Effect: Postiter ceases to send to this vehicle;

Name: Oniterpost **Fig:** 11, 27
To: Postiter **From:** Lofr
Admitted in: N SRC SRX S C R **Inhib in: Q**
ID: Postplatoon **Other Input:** Nil
Requires: Callpost
If Branch: No **Condition: -**
Effect: Initiates sequence of commands Postcon, from postiter;

Name: Pastit Fig: 3, 11, 27
Specification in: VPD control

Name: Postcon **Fig:** 11
To: Vehicle **From:** Postiter
Admitted in: N SRC SRX S C R **Inhib in: Q**
ID: Postplatoon **Other Input:** Target speed (from link control); other control variables.
Requires: Oniterpost - repeated every cycle stimulated by clock.
If Branch: Yes **Condition:** Leading veh?
Effect:
1. Passes control variables to VSV;
2. If leader and Pastit shows past last gate, call Slowem;
3. In any case signals for Postres from same veh;

Name: Postres
Fig: 11
To: Postiter
From: Vehicle
Admitted in: N SRC SRX S C R
Inhib in: Q
ID: Postplatoon
Other Input: Nil
Requires: Postcon
If Branch: Yes
Condition: Veh speed zero?
Effect:
1. If veh speed zero, call Poststopped; return to Postcon for next veh;
2. else update control vars in RSV; then returns to iterator for Postcon for next veh, returning relevant control vars;

Name: Poststopped
Fig: 11, 27
To: Lofr
From: Postiter
Admitted in: N SRC SRX R S C
Inhib in: Q
ID: Postplatoon
Other Input: Nil
Requires: Postres
If Branch: No
Condition: -
Effect: Calls Stopitxp (27)

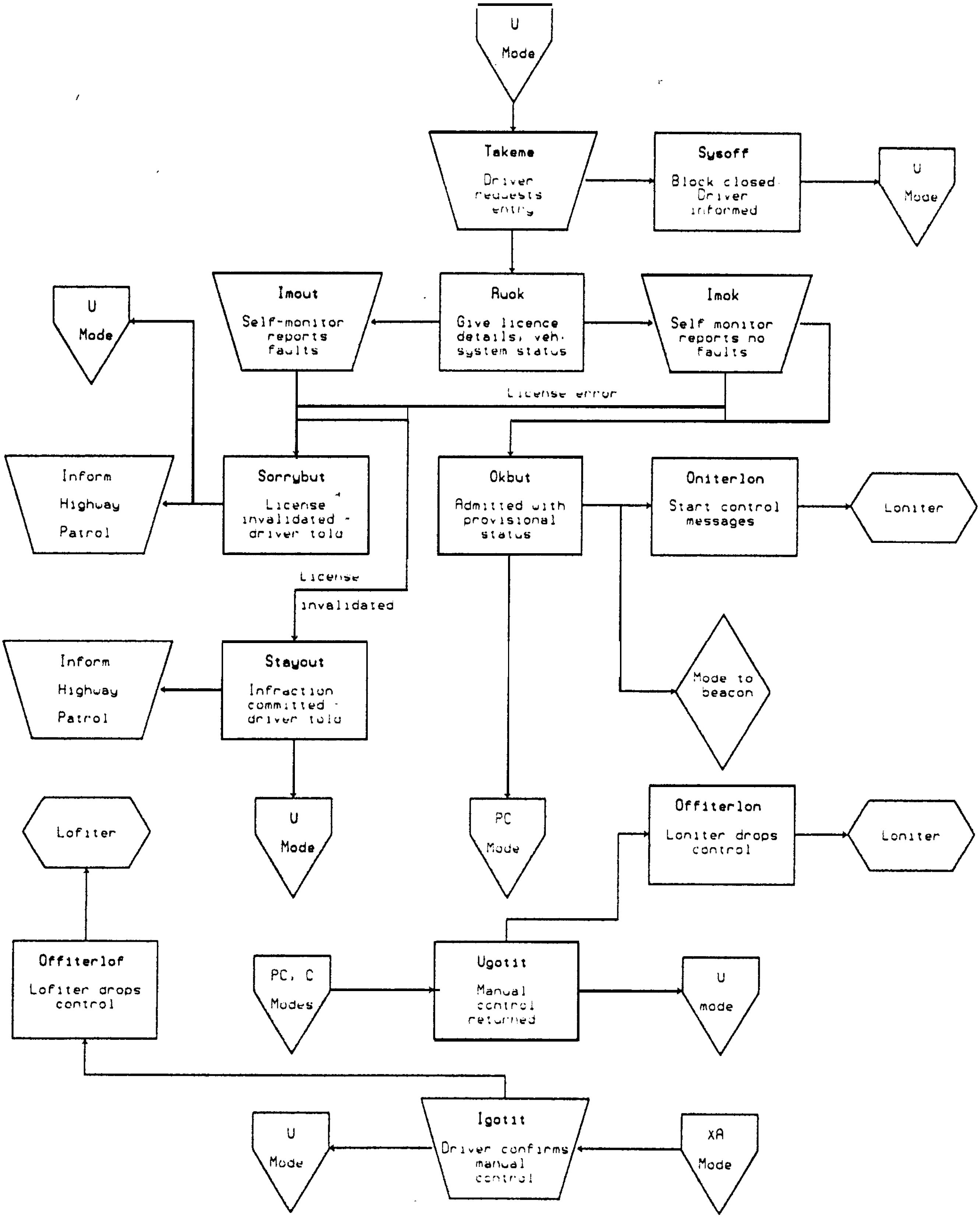
Name: Slipbacks
Fig: 11,27
Specification in: XP.

Name: Slowem
Fig: 11,27
To: Postiter
From: Lofr
Admitted in: N SRC SRX S C R
Inhib in: Q
ID: Postplatoon
Other Input: Nil
Requires: Postcon
If Branch: No
Condition: AR Pastit set?
Effect: Sets maxspeed for all members of Postplatoon to sensor-range speed; return;

Name: Stopitxp
Fig: 11, 26, 27
To: Postiter
From: Lofr
Admitted in: N SRC SRX R S C
Inhib in: Q
ID: Postplatoon
Other Input: Nil
Requires: Atendp (VPD control) or Poststopped
If Branch: No
Condition: -
Effect: Maxspeed = 0; Call Offiterpost; call Hooux (11); call Stoptl; return;

Name: Stoptl
Fig: 3,7,8,10,11,21,23,26
Specification in: Gen

Fig 16. Modules for vehicles in U



Modules for Vehicles in U (Fig. 16)

Name: Igotit
Specification in: XA
Fig: 16, 26

Name: Imok
To: Lonr
Admitted in: N SRC Sn Cn R
ID: Unique
Fig: 16
From: Veh in U
Inhib in: SRX Sy Cy Q
Other Input: Licence details
Requires: Ruok and internal monitor says controls valid
If Branch: Yes.
Condition: Licence valid?
Effect:
1. If licence valid, then if in date, send Okbut;
2. Else send Sorrybut; endif;
3. Else send Stayout; endif; return;

Name: Irnout
To: Lonr
Admitted in: N SRC Sn Cn R
ID: Unique
Fig: 16
From: Veh in U
Inhib in: SRX Sy Cy Q
Other Input: Licence details
Requires: Ruok and veh internal monitor reports controls invalid
If Branch: Yes
Condition: Licence valid?
Effect:
1,If licence valid, send Sorrybut;
2. Else send Stayout; endif; return;

Name: Offiterlof
Specification in: Iter/lof
Fig: 11, 26

Name: Offiterlon
Specification in: Iter/lon
Fig: 7,8,16,17,18,19,20,21,26

Name: Okbut
To: Veh in U
Admitted in: N SRC Sn Cn R
ID: Unique
Fig: 16, 17
From: Lonr
Inhib in: DX Sy Cy Q
Other Input: Maxspeed
Requires: Imok and valid licence
If Branch: No
Condition: -
Effect: Vehicle transferred to PC - entry in RSVs. Message to driver, warning of need for mechanical test - admittance provisional; calls Oniterlon;

Name: Oniterlon
Specification in: Iter/lon
Fig: 7, 16, 17

Name: Ruok
Fig: 16
To: Veh in U
From: Lonr
Admitted in: N SRC Sn Cn R
Inhib in: SRX Sy Cy Q
ID: Unique
Other Input: Nil
Requires: Takeme
If Branch: No
Condition: -
Effect: Calls for response from veh - Imok or Imout, indicating monitor state, also licence details;

Name: Sorrybut
Fig: 16
To: Veh in U
From: Lonr
Admitted in: N SRC Sn Cn R
Inhib in: SRX Sy Cy Q
ID: Unique
Other Input: Nil
Requires: (Imout and valid licence) or (Imok and outdated licence)
If Branch: No
Condition: -
Effect: Licence invalidated; Message to HP; Message to driver, "admission refused,licence invalidated", and why;

Name: S tayout
Fig: 16
To: Veh in U
From: Lonr
Admitted in: N SRC Sn Cn R
Inhib in: SRX Sy Cy Q
ID: Unique
Other Input: Nil
Requires: (Imout or Imok) and invalid licence
If Branch: No
Condition: -
Effect: Message to HP; Message to driver - licence invalidated for previous infraction, highway patrol informed;

Name: Sysoff
Fig: 16
To: Veh
From: Lonr
Admitted in: SRX Sy Cy Q
Inhib in: N DC Sn Cn R
ID: Unique
Other Input: Nil
Requires: Takeme
If Branch: No
Condition: -
Effect: Message to driver "this block [or more detail?] closed";

Name: Takeme
Fig: 16
To: Lonr
From: Veh in U
Admitted in: N SRC SRX S C R Q
Inhib in: Nil
ID: Unique
Other Input: Nil
Requires: Nil!
If Branch: Yes
Condition: DX, Sy, Cy or Q?
Effect:
1.If in modes stated calls Sysoff - entry closed here;
2. Else Calls Ruok (3) - Requests entry to system; endif;

Name: Ugotit

Specification in: PC

Fig: 16, 17, 18

Modules for Vehicles in PC (fig 17)

Name: Chicc **Fig: 3, 17**
Specification in: VPD control

Name: Dropbackc **Fig: 3, 17, 18**
Specification in: VPD control.

Name: Itakeit **Fig: 17, 18**
To: LONR **From:** Veh
Admitted in: N SRC SRX S C R **Inhib in: Q**
ID: Unique **Other Input:** Nil
Requires: Okbut or Okokc
If Branch: No **Condition: -**
Effect: Driver wishes to resume manual control - calls Ugotitc;

Name: Jordc Fig: 3, 17, 18
Specification in: VPD control.

Name: Lonrctnores Fig: 17, 18
To: Lonr From: Lonr
Admitted in: N SRC Sn Cn R **Inhib in:** SRX Sy Cy Q
ID: Unique **Other Input:** Nil
Requires: Lonnores
If Branch: Yes **Condition:** Intl var N too large
Effect:
1. Intl var N initially 0. Incremented each time Lonrctnores called;
2. If N is too big, calls Sorrybut 2c; endif; return;

Name: Lonrctwander Fig: 17, 18
To: Lonr **From:** Lonr
Admitted in: N SRC Sn Cn R **Inhib in:** SRX Sy Cy Q
ID: Unique **Other Input:** Nil
Requires: Lomwander
If Branch: Yes **Condition:** Intl var N too large
Effect:
1. Intl var N initially 0. Incremented each time Lonrctwander called;
2. if N is too big calls Sorrybut2c; endif; return;

Name: Lonrnores **Fig: 7, 17, 18**
Specification in: Iter/Lon

Name: Lomwander Fig: 7, 17, 18
Specification in: Iter/lon

Fig. 17. Modules for Vehicles in PC

(see also Fig 17a)

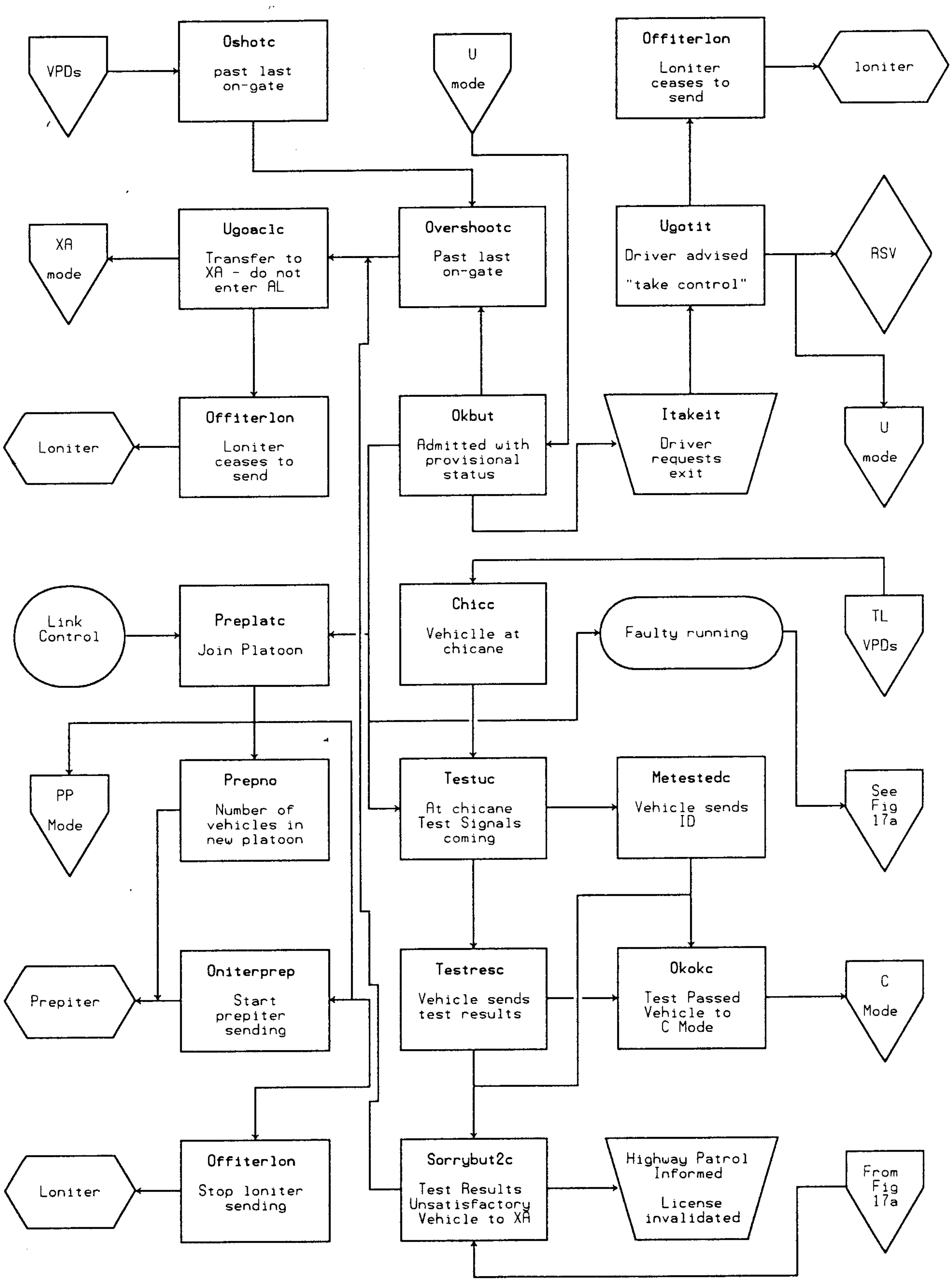
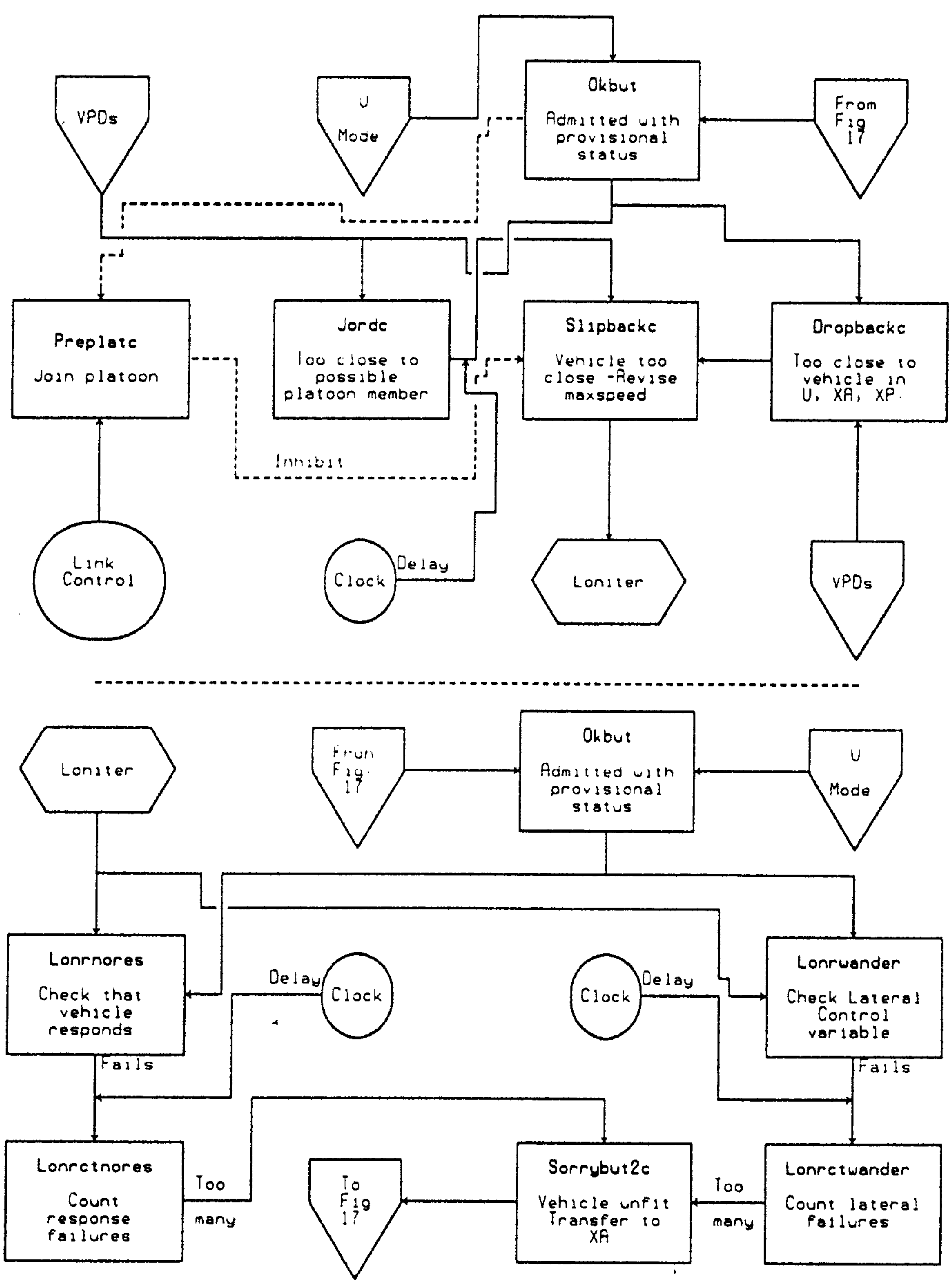


Fig 17a. Modules for Vehicles In PC (continued)

(see also Fig 17)



Name: Metestedc
To: Lonr
Admitted in: **N** SRC Sn Cn R
ID: See below
Requires: Testuc
If Branch: No
Effect: This message is responded to by any vehicle receiving both it and a test signal for its control (and therefore at the chicane) whether the ID refers to it or no: Reply gives both ID received and actual ID, as well as actual mode. If the ID's do not tally, RSV is corrected. In this case and/or if veh responding is not in PC mode, monitor is advised: Test ceases if vehicle is not in PC.

Fig: 17, 18, 26
From: Veh at chicane
Inhib in: SRX Sy Cy Q
Other Input: ID sent, mode
Condition: -

Name: Offiterlon
Specification in: Iter/lon
Fig: 7,16,17,18,19,20,21,26

Name: Okbut
Specification in: U
Fig: 16, 17

Name: Okokc
To: LONR
Admitted in: **N** SRC Sn Cn R
ID: Unique
Requires: Tesresc
If Branch: No
Effect: Veh transfers to C;

Fig: 17, 18
From: LONR
Inhib in: SRX Sy Cy Q
Other Input: Nil
Condition: **-**

Name: Oniterprep
Specification in: Iter/prep
Fig: 8, 17, 18, 19, 20

Name: Oshotc
Specification in: VPD control
Fig: 3, 17, 18

Name: Overshootc
Specification in: C
Fig: 17, 18, 21

Name: Preplatc
Fig: 17, 18, 19, 20
To: Lonr
From: Link Control
Admitted in: **N** SRC Sn Cn R
Inhib in: SRX Sy Cy Q
ID: Unique
Other Input: Targt Speed New ID
Requires: Okbut (PC) or Okokc (C) and Link Control
If Branch: No
Condition: -
Effect:
1. LONR checks that other vehicle or platoon is also to receive Preplatc and that they are adjacent on TL; If so,
2. Vehicle transfers to PP (from PC) or P (from C);
3. Vehicle receives new ID, as 1st or last in named platoon;
4. Passes notice of call to Jordc (VPD control) via RSV;
5. Calls Prepno and Offiterlon and Oniterprep;
6. Endif; return;

Name: Prepno
Fig: 8, 17, 18, 19, 20
Specification in: Iter/prep

Name: Slipbackc
Fig: 8, 17, 18
To: Veh in PC, C
From: LONR
Admitted in: N, SRC, Sn, Cn, R
Inhib in: Q, SRX, Sy, Cy
ID: Unique
Other Input: (On 1st call only) Params describing temp slowing
Requires: Dropbackc, jordc, or call from loniter.
If Branch: Yes.
Condition: 1st call? or manoeuvre incomplete?
Effect:
1. Repeated calls cause vehicle to drop back from one it follows too closely.
2. On 1st call sets params. Then always sets max speed, sets param in loniter to cause Slipbackc called again, unless manoeuvre complete, in which case resets this param and RSV markers for jordc and dropbackc.

Name: Sorrybut2c
Fig: 17, 18
To: Veh in PC, C
From: Lonr
Admitted in: **N** SRC Sn Cn R
Inhib in: SrX **Sy Cy Q**
ID: Unique
Other Input: Nil
Requires: Tesresc or Lonrctwander or Lonrctnores
If Branch: No
Condition: -
Effect: Message to driver - “vehicle unfit”; calls Ugoaclc; report to HP; Licence invalidated; return;

Name: Testresc
Fig: 17, 18, 26
To: Lonr
From: Lonr
Admitted in: **N** SRC Sn Cn R
Inhib in: SRX Sy Cy Q
ID: Unique
Other Input: Receives Metestedc output

Requires: Testuc
If Branch: Yes **Condition:** Test res and Metestedc output
Effect:
1. If Metested returns mode XA or U, inform self-monitor;
2. If Metestedc returns mode C, inform self-monitor; endif;
3. If test results not ok, or if no response Metestedc call Sorrybut2c (4);
4. Else if IDs from Metested and Testuc do not agree, modify RSV, and inform selfmonitor; endif;
5. Call Okokc; endif; endif;

Name: Testuc **Fig: 17, 18, 26**
To: Veh in PC **From:** Lonr (chicane t'mitter)
Admitted in: N SRC Sn Cn R **Inhib in:** SRX Sy Cy Q
ID: Unique **Other Input:** Nil
Requires: Chicc
If Branch: No **Condition: -**
Effect: Chicane transmitter will emit test signals. Calls for Metested from vehicle in chicane; Calls Tesresc;

Name: Ugoaclc **Fig: 17, 18, 26**
To: Lofr **From:** Lonr
Admitted in: N SRC SRX S C R **Inhib in: Q**
ID: Unique **Other Input:** Nil
Requires: Sorrybut2c: or Sorrybut5c or Onclose (Gen)
If Branch: No **Condition: -**
Effect: Vehicle transferred to XA; calls Offiterlon and Takeit;

Name: Ugotit **Fig: 16, 17, 18**
To: Veh in PC, C **From:** Lonr
Admitted in: N SRC SRX S C R **Inhib in: Q**
ID: Unique **Other Input:** Nil
Requires: Itakeit
If Branch: No **Condition: -**
Effect: Calls Offiterlon; Vehicle reverts to U; RSV marked;

Modules for Vehicles in C (Fig. 18)

Name: Comeinc
Fig: 18, 21
To: Lonr
From: Link Control
Admitted in: N SRC Cn Sn R
Inhib in: SRX Cy Sy Q
ID: Unique
Other Input: Nil
Requires: Okokc, and message from Link control
If Branch: Yes
Condition: Onok True?
Effect:
1. If **Onok** is True, Veh swings to left and prepares to switch to AL at marker point on lateral reference;
2. calls Offiterlon and attempts to enter; Enters E mode, Calls Nameherc (8);
3. Else if last gate call **Overshootc; endif; endif;** return;

Name: Dropbackc
Fig: 3, 17, 18
Specification in: VPD control.

Name: Itakeit
Fig: 17, 18
Specification in: PC

Name: Jordc
Fig: 3, 17, 18
Specification in: VPD control.

Name: Lonrctnores
Fig: 17, 18
Specification in: PC

Name: Lonrctwander
Fig: 17, 18
Specification in: PC

Name: Lonrnores
Fig: 7, 17, 18
Specification in: Iter/Lon

Name: Lomwander
Fig: 7, 17, 18
Specification in: Iter/lon

Name: Offiterlon
Fig: 7,16,17,18,19,20,21,26
Specification in: Iter/lon

Name: Okokc
Fig: 17, 18
Specification in: PC

Name: Oniterprep
Fig: 8, 17, 18, 19, 20
Specification in: Iter/prep

Fig. 18. Modules for Vehicles in C

(see also Fig 18a)

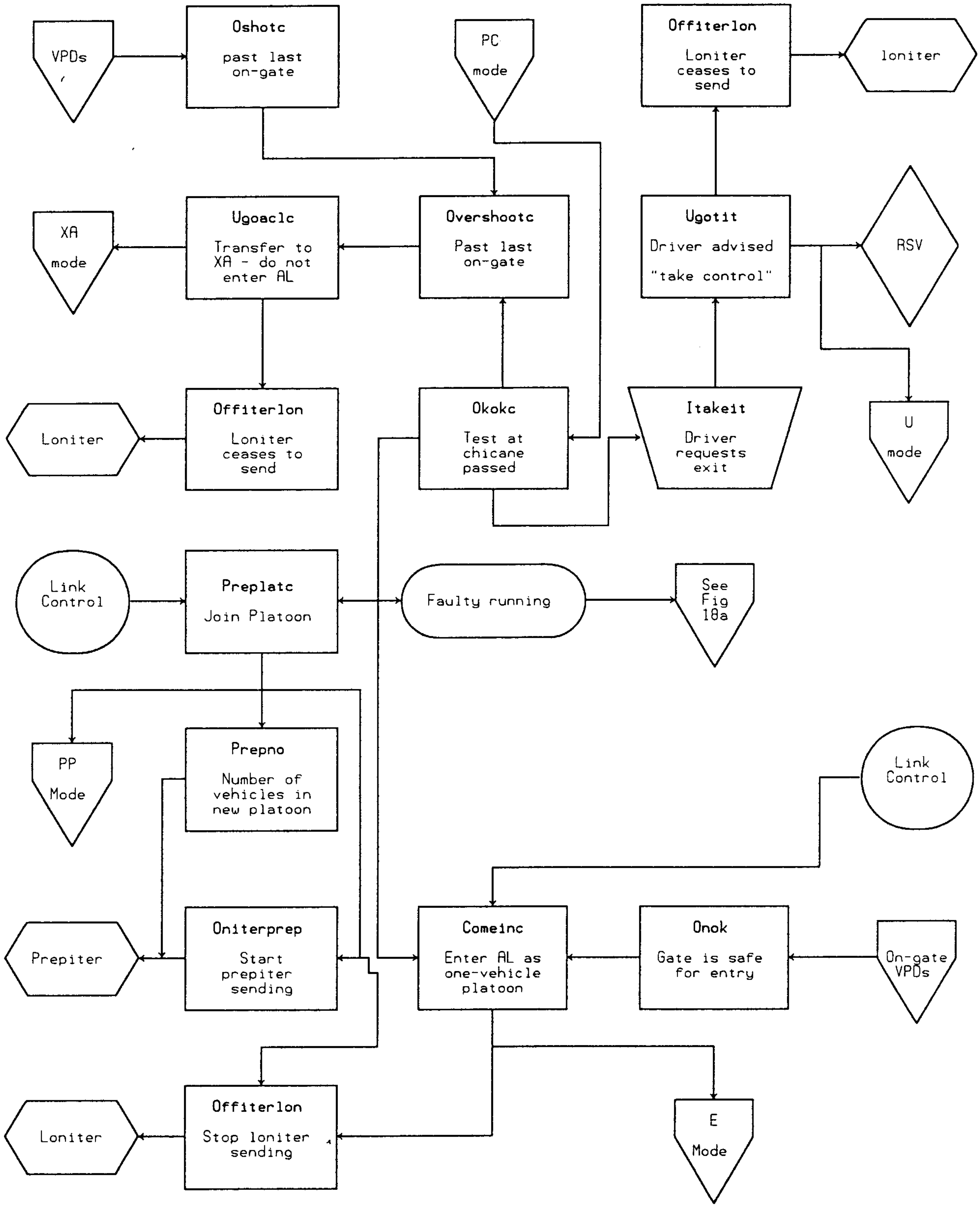
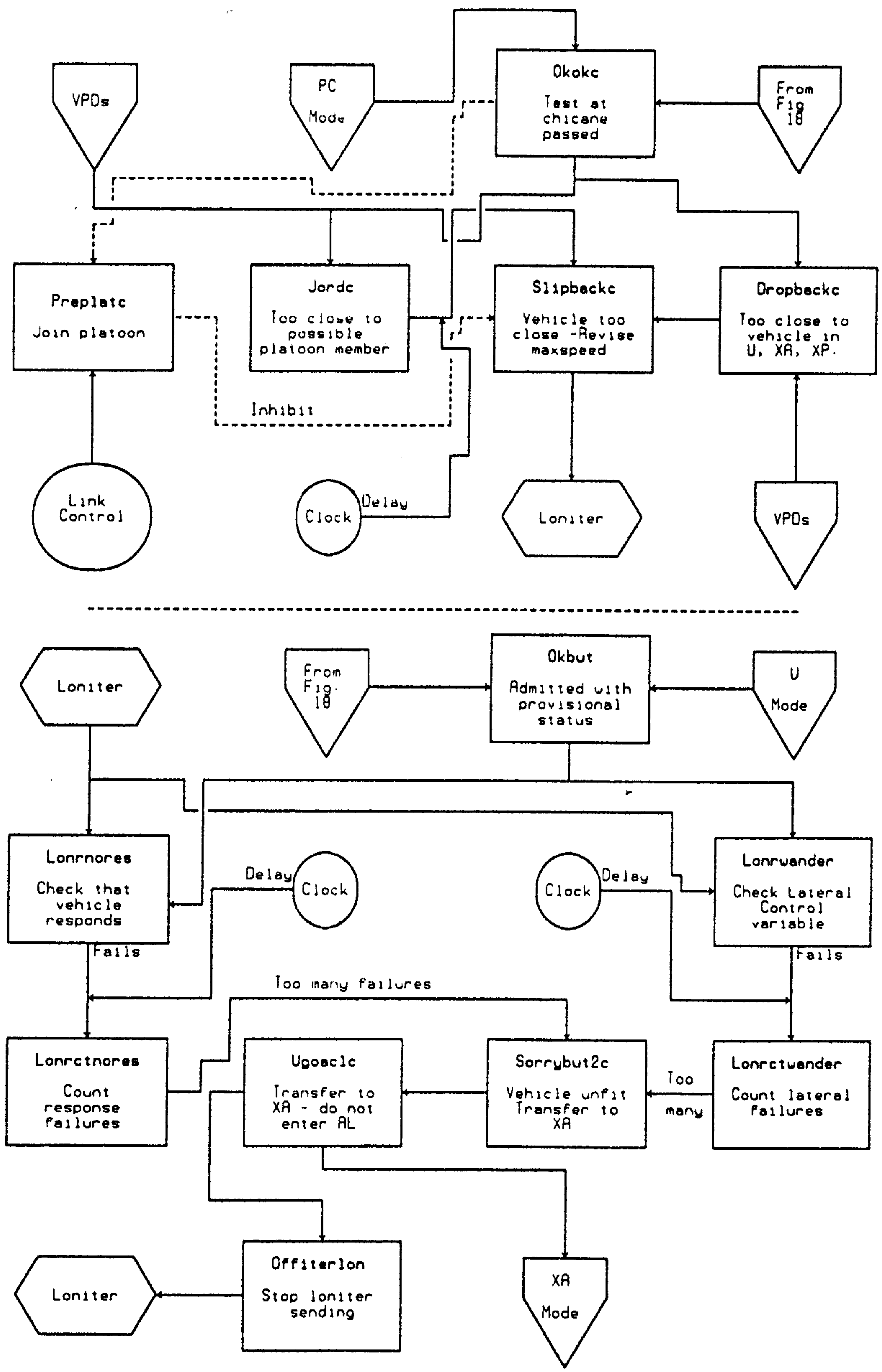


Fig 18a. Modules for Vehicles In C (continued)

(see also Fig 18)



Name: Onok | Fig: 5, 18, 20, 21, 26
Specification in: VPD control

Name: Oshotc | Fig: 3, 17, 18
Specification in: VPD control

Name: Overshootc | Fig: 17, 18, 21
To: Lonr | From: C
Admitted in: N SRC SRX S C R | Inhib in: Q
ID: Unique | Other Input: Nil
Requires: Comeinc or Onclose (Gen) or Link Control or Oshotc
If Branch: No | Condition: -
Effect: Advises self-monitor; calls Ugoaclc;

Name: Preplatc | Fig: 17, 18, 19, 20
Specification in: PC

Name: Prepno | Fig: 8, 17, 18, 19, 20
Specification in: Iter/prep

Name: Slipbackc | Fig: 7, 17, 18
Specification in: PC.

Name: Sorrybut2c | Fig: 17, 18
Specification in: PC

Name: Testresc | Fig: 17, 18, 26
Specification in: PC

Name: Testuc | Fig: 17, 18, 26
Specification in: PC

Name: Ugoaclc | Fig: 17, 18, 26
Specification in: PC

Name: Ugotitc | Fig: 16, 17, 18
Specification in: PC

Modules for Vehicles in PP (Fig. 19)

Name: Brakehard
Fig: 8, 19, 20
To: Prepiter
From: Lonr
Admitted in: N SRC Sn Cn R
Inhib in: SRX Sy Cy Q
ID: Preplatoon
Other Input: Nil
Requires: Itakeitp or Sorrybut2p
If Branch: No
Condition: -
Effect:

1 Veh identified sent to full platoon braking until it is behind its leader by a safe distance in view of its speed;
2. This veh now given Tgt speed = maxspeed = previous speed less small delta;
3. rest of platoon continues to brake until it is manual spacing behind identified veh; Ugoaclf called for identified veh; Prepno called for its followers; they get tgt speed = speed of veh ahead; their maxspeed unaltered;

Name: Chicp
Fig: 3, 19
Specification in: in VPD control

Name: Dropbackp
Fig: 3, 19, 20
Specification in: VPD control.

Name: Himon
Fig: 5, 8, 19, 20
Specification in: VPD control

Name: Itakeitp
Fig: 19, 20
To: LONR
From: Veh
Admitted in: N SRC SRX S C R
Inhib in: Q
ID: Preplatoon
Other Input: Nil
Requires: Preplatc
If Branch: No
Condition: -
Effect: Driver wishes to resume control - calls Brakehard;

Name: Jordp
Fig: 3, 19, 20
Specification in: VPD control.

Name: Metestedp
Fig: 19, 20
To: Lonr
From: Veh in PP
Admitted in: N SRC Sn Cn R
Inhib in: SRX Sy Cy Q
ID: Preplatoon
Other Input: ID sent, mode
Requires: Testup
If Branch: No
Condition: -
Effect:

1. This message is responded to by any vehicle receiving both it and a test signal for its control (and therefore at the chicane) whether the ID refers to it or no;
2. Reply gives both ID received and actual ID, as well as actual mode. If the ID's do not tally, RSV is corrected. In this case and/or if veh responding is not in PP mode, monitor is advised;
3. Test ceases if vehicle is not in PP;

Name: Offiterlon
Fig: 7,16,17,18,19,20,21,26
Specification in: Iter/lon

Name: Offiterprep
Fig: 7,19,20,21,26,27
Specification in: Iter/prep

Name: Okokp
Fig: 19, 20
To: LONR
From: LONR
Admitted in: N SRC Sn Cn R
Inhib in: SRX Sy Cy Q
ID: Preplatoon
Other Input: Nil
Requires: Tesresp
If Branch: Yes
Condition: All vehs in plat P?
Effect: Veh transfers to P; Platoon entry marker in RSV of leader (= no of vehs in platoon in PP) decremented; If this is zero, RSV marked; return;

Name: Oniterprep
Fig: 8, 17, 18, 19, 20
Specification in: Iter/prep

Name: Oshotp
Fig: 3, 19, 20
Specification in: VPD control

Name: Overshootp
Fig: 19, 20, 21
Specification in: P

Name: Prepcontact
Fig: 8, 19, 20
Specification in: Iter\prep

Fig. 19. Modules for Vehicles in PP
(see also Fig 19a)

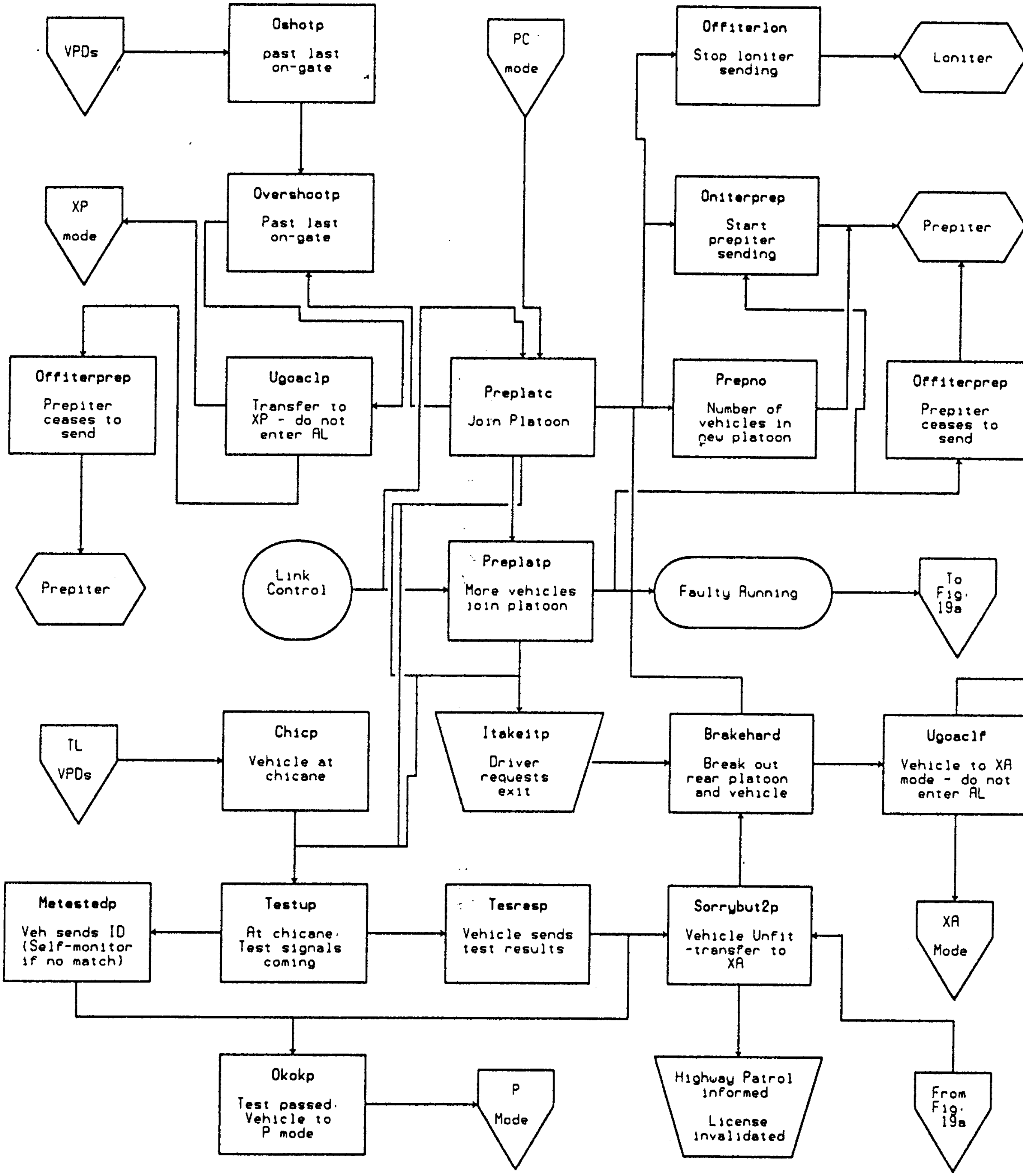
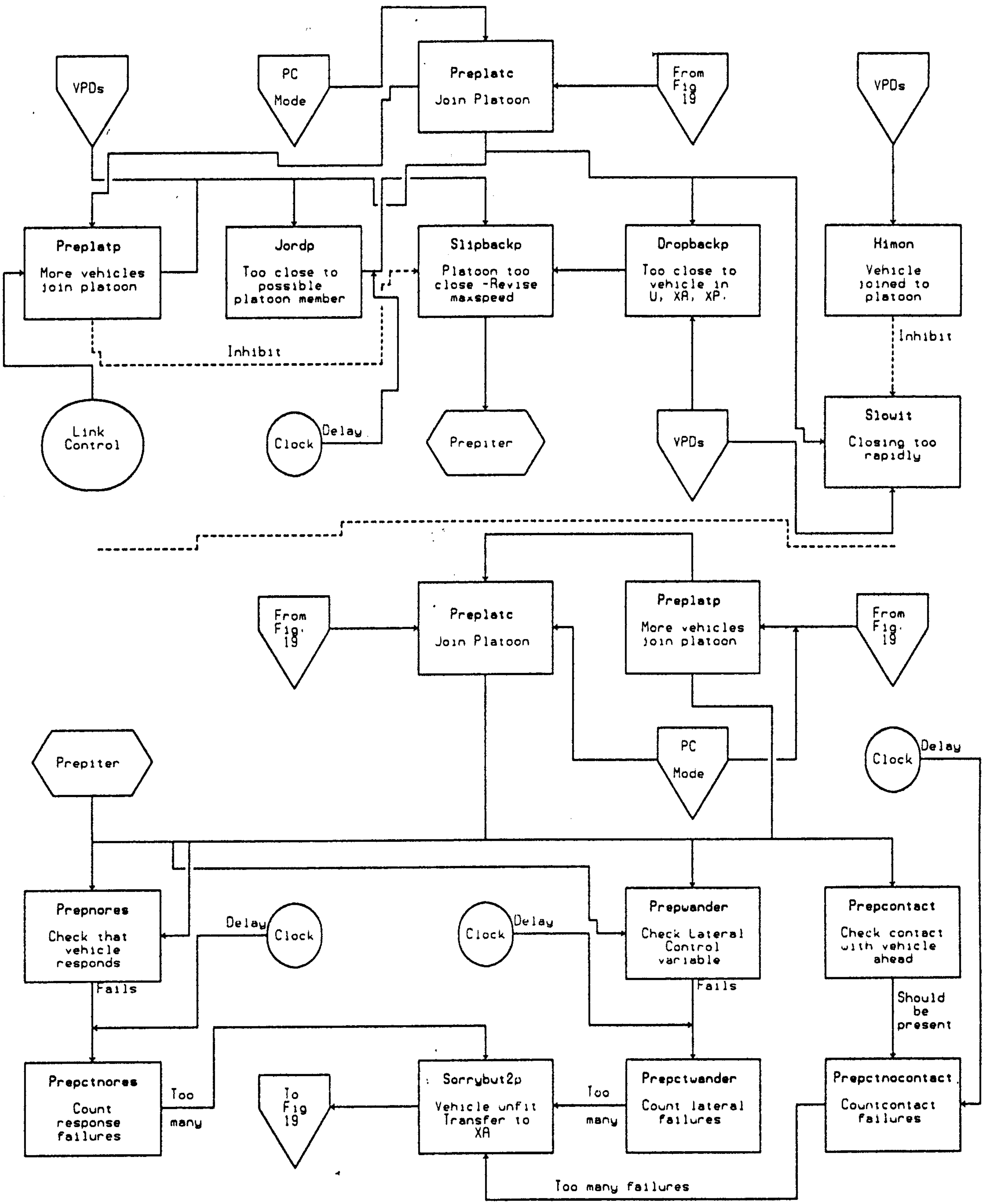


Fig 19a. Modules for Vehicles In PP (continued)

(see also Fig 19)



Name: Prepctnocontact
To: Lonr
Admitted in: **N** SRC Cn Sn R
ID: Preplatoon
Requires: Prepcontact
If Branch: Yes
Fig: 19,20
From: Lonr
Inhib in: **Q** SRX Sy Cy
Other Input: Nil
Condition: Intl vars T, N
Effect:
1. Initially T = 0.0.; N = 0;
2. If T = 0, T = present time; endif; return;
3. If (Present - T) too large, inc N; T = present; endif;
4. If N too large, call Sorrybut2p; endif; return;

Name: Prepctnores
To: Lonr
Admitted in: **N** SRC Sn Cn R
ID: Preplatoon
Requires: Prepnores
If Branch: Yes
Fig: 19, 20
From: Lonr
Inhib in: SRX Sy Cy Q
Other Input: Nil
Condition: Intl Var N too large
Effect: Intl var N initially 0. Incremented each time Prepctnores is called; if N is too big, calls Sorrybut2p; endif; return;

Name: Prepctwander
To: Lonr
Admitted in: **N** SRC Sn Cn R
ID: Preplatoon
Requires: Prepwander
If Branch: Yes
Fig: 19, 20
From: Lonr
Inhib in: SRX Sy Cy Q
Other Input: Nil
Condition: Intl var n too large
Effect:
1. Intl Var n initially 0; n is incremented each time Prepctwander called;
2. if N is too large calls Sorrybut2p; endif; return;

Name: Preplatc
Specification in: PC
Fig: 17, 18, 19, 20

Name: Preplatp
To: LONR
Admitted in: **N** SRC Sn Cn R
ID: Preplatoon
Requires: Message from link control
If Branch: Yes
Fig: 6, 7
From: Link Control
Inhib in: SRX Sy Cy Q
Other Input: Targt Speed New ID
Condition: Any intruders?
Effect:
1. On receipt of message from link control LONR verifies that platooning candidates have nothing in between. If there is, message to link control;
2. else Preplatp is called when preplatoon has to join to rear of vehicle (which receives Preplatc) or another platoon - platoon receives new ID and vehicle numbers
3. Passes notice of call to Jordp (VPD control); call Prepno; return;

Name: Prepno
Specification in: Iter/prep
Fig: **8,** 17, 18, 19, 20

Name: Prepnores
Specification in: Iter\prep
Fig: **8,** 19, 20

Name: Prepwander
Specification in: iter/prep
Fig: **8, 19, 20**

Name: Slipbackp
To: Lead veh in PP, P
Admitted in: **N** SRC Sn Cn R
ID: Preplat
Fig: **8,** 19, 20
From: LONR
Inhib in: **Q** SRX Sy Cy
Other Input: (On 1st call only) Params describing temp slowing

Requires: Dropbackp, jordp, slowit, or call from prepiter.
If Branch: **Yes.**
Condition: 1st call or manoeuvre incomplete.

Effect: Repeated calls cause vehicle to drop back from one it follows too closely. On 1st call sets params. Then always sets max speed, sets param in RSV for prepiter to cause Slipbackp called again, unless manoeuvre complete, in which case resets this param and markers in RSV for jordp and dropbackp.

Name: Slowit
Specification in: VPD control
Fig: **3, 8, 19, 20**

Name: Sorrybut2p
To: Veh in PP, P
Admitted in: **N** SRC Sn CN R
ID: Preplatoon
Fig: 19, 20
From: Lonr
Inhib in: SRX Sy Cy Q
Other Input: Nil
Requires: Tesresp or Prepctwander or Prepctnores
If: branch No
Condition: -
Effect: Message to driver - "vehicle unfit"; calls Brakehard; report to HP; Licence invalidated.

Name: Tesrresp
To: Lonr
Admitted in: **N** SRC Sn Cn R
ID: Preplatoon
Fig: 19, 20
From: Lonr
Inhib in: SRX Sy Cy Q
Other Input: Receives Metestedp output
Requires: Testup
If Branch: Yes
Condition: Test res and Metestedp output
Effect:
1. If Metestedp returns mode P, inform self-monitor; endif;
2. If test results not ok, or if no response Metestedp, call Sorrybut2p (6);
3. Else if IDs from Metestedp and Testup do not agree modify RSV; and inform self-monitor; endif; call Okokp; endif

Name: Testup
To: Veh in PP
Admitted in: N SRC Sn Cn R
ID: Preplatoon
Requires: Chicp
If Branch: No

Fig: 19, 20
From: Lonr (chicane t'mitter)
Inhib in: SRX Sy Cy Q
Other Input: Nil

Condition: -

Effect: Chicane transmitter will emit test signals, Calls for Metested from veh in , Chicane; Calls Tesrecp;

Name: Ugoaclf
To: Lofr
Admitted in: N SRC Sn Cn R
ID: Preplatoon
Requires: Brakehard
If Branch: No

Fig: 19, 20, 26
From: Lonr
Inhib in: SRX Sy Cy Q
Other Input: Nil

Condition: -

Effect: Vehicle transfers to XA; calls Offiterprep (6) and Hoouf;

Name: Ugoaclp
To: Lofr
Admitted in: N SRC Sn Cn R
ID: Preplatoon
Requires: Onclose or Overshootp
If Branch: No

Fig: 19, 20, 27
From: Lonr
Inhib in: SRX Sy Cy Q
Other Input: Nil

Condition: -

Effect: Vehicle transfers to XP: calls Offiterprep and Callpostp;

Modules for Vehicles in P (Fig. 20)

Name: Brakehard **Fig: 8,** 19, 20
Specification in: PP

Name: Comeinp **Fig: 20, 21**
To: Lonr **From:** Link control
Admitted in: N SRC Sn Cn R **Inhib in: SRX Sy Cy Q**
ID: Preplatoon **Other Input:** Nil
Requires: Okokp and message from link control and Platoon Entry marker (in RSV of leader) is reset.
If Branch: Yes **Condition: PEM** reset? Onok True?
Effect:
1. If PEM set inform self-monitor; no action;
2. Else if Onok is True, veh swings to left and prepares to switch to AL at marker point on lateral reference; at this point calls Offiterprep and attempts to enter; enters E mode; Calls Nameherp;
3. Else if last gate, call Overshootp;
4. endif; endif; endif.

Name: Dropbackp **Fig: 3,** 19, 20
Specification in: VPD control.

Name: Himon **Fig: 5, 8, 19, 20**
Specification in: VPD control

Name: Itakeitp **Fig: 19, 20**
Specification in: PP

Name: Jordp **Fig: 3,** 19, 20
Specification in: VPD control.

Name: Offiterlon **Fig:** 7,16,17,18,19,20,21,26
Specification in: Iter/lon

Name: Offiterprep **Fig: 8,** 19, 20, 21, 26,. 27
Specification in: Iter/prep

Name: Okokp **Fig: 19, 20**
Specification in: PP

Name: Oniterprep **Fig: 8, 17, 18,** 19, 20
Specification in: Iter/prep

Name: Onok
Specification in: VPD control
Fig: 5, 18, 20, 21, 26

Name: Oshotp
Specification in: VPD control
Fig: 3, 19, 20

Name: Overshootp
Fig: 19, 20, 21
To: Lonr
From: Lonr
Admitted in: N SRC SRX S C R
Inhib in: Q
ID: Preplatoon
Other Input: Nil
Requires: Comeinp or Onclose (gen) or Link control or Oshotp
If Branch: No
Condition: -
Effect: Advises self-monitor; calls Ugoaclp; return;

Name: Prepcontact
Specification in: Iter\prep
Fig: 8, 19, 20

Name: Prepctnocont
Specification in: PP
Fig: 19, 20

Name: Prepctnores
Specification in: PP
Fig: 19, 20

Name: Prepctwander
Specification in: PP
Fig: 19, 20

Name: Preplatc
Specification in: PC
Fig: 17, 18, 19, 20

Name: Preplatp
Specification in: PP
Fig: 19, 20

Name: Prepno
Specification in: Iter/prep
Fig: 8, 17, 18, 19, 20

Name: Prepnores
Specification in: Iter\prep
Fig: 8, 19, 20

Name: Prepwander
Specification in: iter/prep
Fig: 8, 19, 20

Name: Slipbackp
Specification in: PP.
Fig: 8, 19, 20

Fig. 20. Modules for Vehicles in P

(see also Fig 20a)

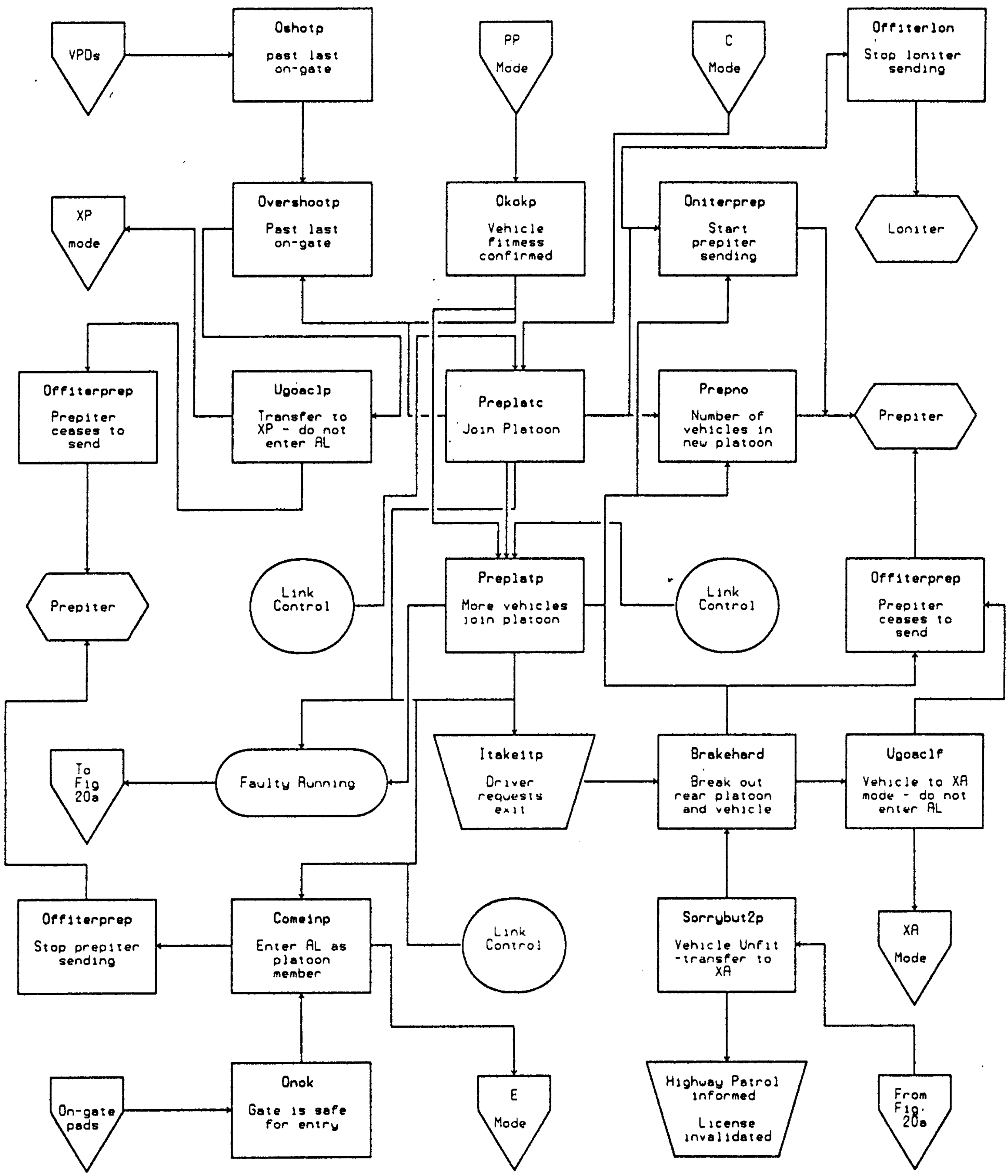
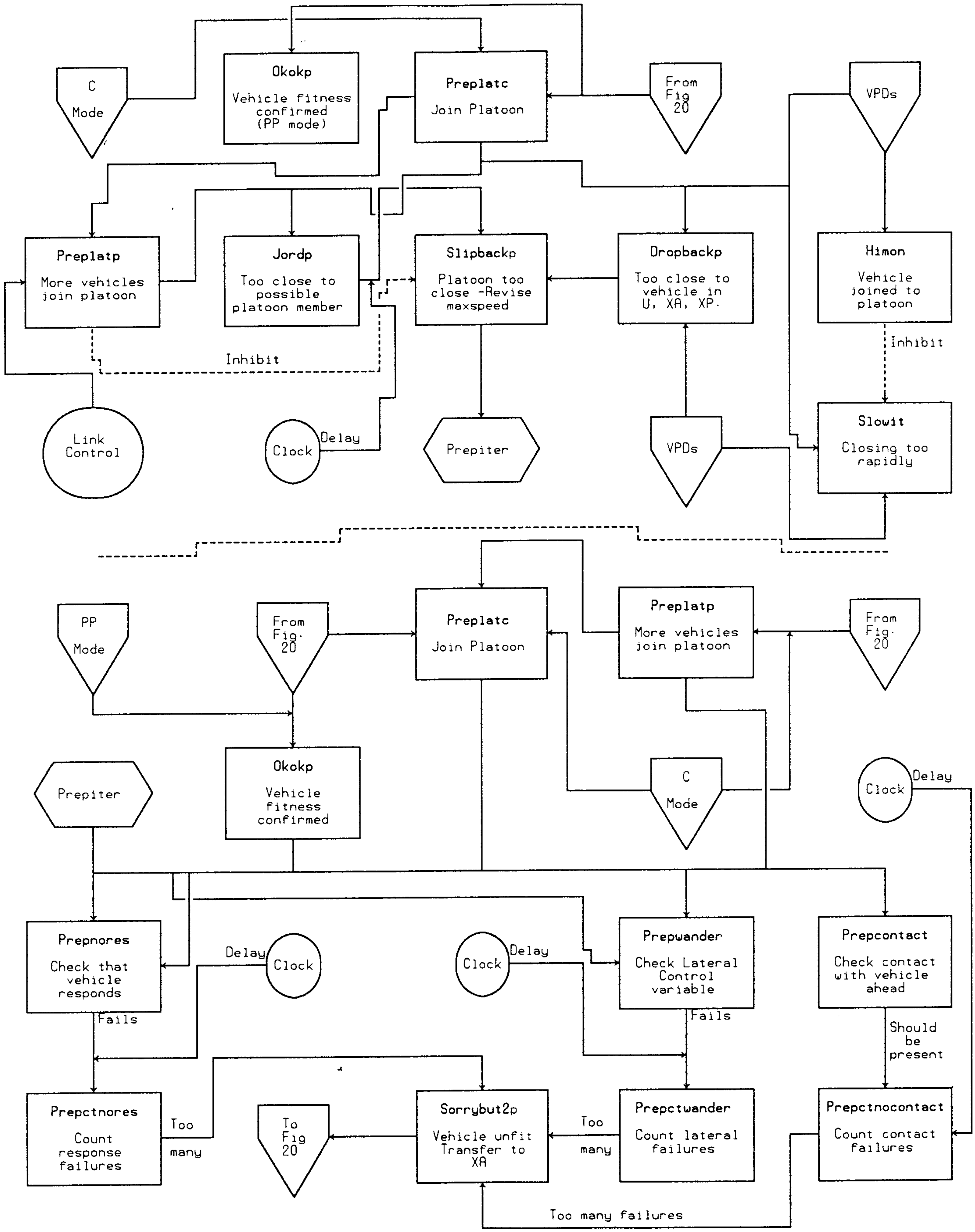


Fig 20a. Modules for Vehicles In P (continued)

(see also Fig 20)



Name: Slowit **Fig: 3, 8,** 19, 20
Specification in: VPD control

Name: Sorrybut2p **Fig: 19, 20**
Specification in: PP

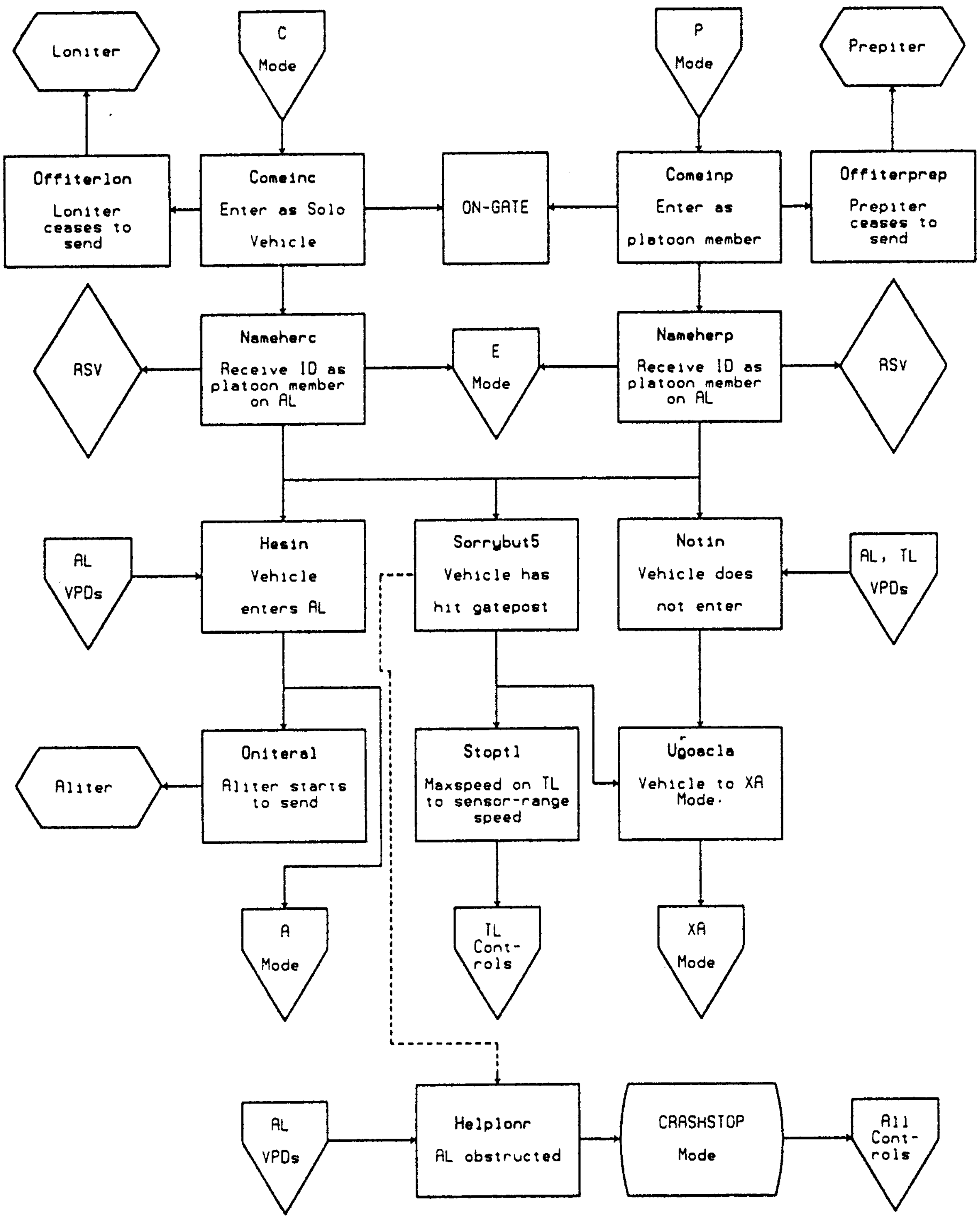
Name: Ugoaclf **Fig: 19, 20, 26**
Specification in: PP

Name: Ugoaclp **Fig: 19, 20, 27**
Specification in: PP

Modules for Vehicles in E (Fig. 21)

Name: Comeinc Specification in: C	Fig: 18, 21
Name: Comeinp Specification in: P	Fig: 20, 21
Name: Helplonr Specification: in Gen	Fig: 5, 21
Name: Hesin Specification in: VPD control	Fig: 5, 21, 22
Name: Nameherc To: Veh and RSV Admitted in: N SRC Sn Cn R ID: Unique Requires: Comeinc If Branch: No Effect: Veh receives new ID;	Fig: 4, 5, 21 From: Lonr Inhib in: SRX Sy Cy Q Other Input: New ID Condition: -
Name: Nameherp To: Vehicle and RSV Admitted in: N SRC Sn Cn R ID: Preplatoon Requires: Comeinp If Branch: No Effect: Veh receives new ID;	Fig: 4, 5, 21 From: Lonr Inhib in: SRX Sy Cy Q Other Input: New ID Condition: -
Name: Notin Specification in: VPD control	Fig: 5, 22
Name: Notinp Specification in: VPD control	Fig: 5, 22
Name: Offiterlon Specification in: Iter/lon	Fig: 7,16,17,18,19,20,21,26
Name: Offiterprep Specification in: Iter/prep	Fig: 8,18,19,20,21,26,27

Fig. 21. Modules for Vehicles in E



Name: Oniteral | Fig: 9, 21, 22, 26
Specification in: Aliter

Name: Onok | Fig: 5, 18, 20, 21, 26
Specification in: VPD control

Name: Sorrybut5 | Fig: 5, 6, 21, 23
Specification in: VPD control

Name: S toptl | Fig: 3,7,8,10,11,21,23,26
Specification in: Gen

Name: Ugoacla	Fig: 21, 23, 26
To: Lofr	From: Lonr
Admitted in: N SRC Sn Cn R	Inhib in: SRX Sy Cy Q
ID: AL	Other Input: Nil
Requires: Notin	
If Branch: No	Condition: -

Effect: Vehicle transfers to XA; calls Offiteraul and Hooua;

Modules for vehicles in A (Fig. 22)

Name: Allin
Fig: 22
To: AL
From: Alcounter
Admitted in: N SRC R
Inhib in: SRX S C Q
ID: AL
Other Input: Counts from counter
Requires: New Veh at counter
If Branch: Yes
Condition: Gap? Next after?
Effect: 1. Call Rename as each vehicle is detected; increment M in Countem. (If first after gap reset M first; endif)
2. If gap occurs call Countem; endif; return;

Name: Alcontact
Fig: 9, 22
Specification in: Iter\al

Name: Alctnocontact
Fig: 22
To: AL
From: AL
Admitted in: N SRC SRDX R
Inhib in: S C Q
ID: AL
Other Input: Nil
Requires: Alcontact
If Branch: Yes
Condition: Intl vars T, N
Effect: 1. Initially T = O.O., N = 0.
2. If T = 0, T = present time; return; endif;
3. If (Present - T) too large, inc N, T = present;
4. Else no action; endif;
5. If N too large, call Chuckim;
6. endif; return;

Name: Alctnores
Fig: 22
To: AL
From: AL
Admitted in: N SRC SRX R
Inhib in: S C Q
ID: AL
Other Input: Nil
Requires: Alnores
If Branch: Yes
Condition: Intl var N too large
Effect: 1. Intl var N initially 0. Incremented each time Alctnores is called; if N is too big, calls Chuckim; endif; return;

Fig. 22. Modules for Vehicles in A (Entry)

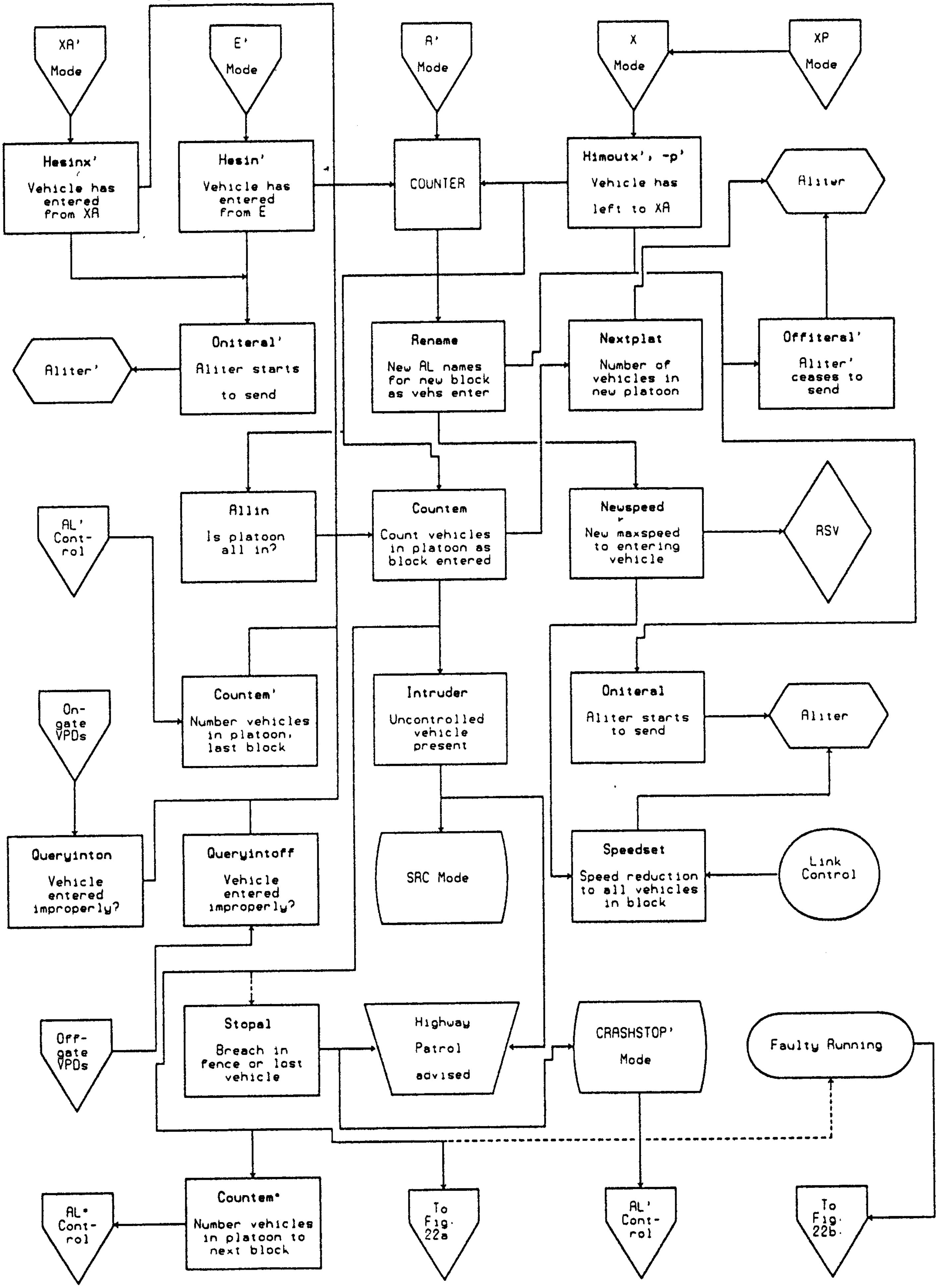


Fig. 22a. Modules for Vehicles in A (Exit)

(' indicates upstream block: • indicates downstream block)
(See also figs 22 and 22b)

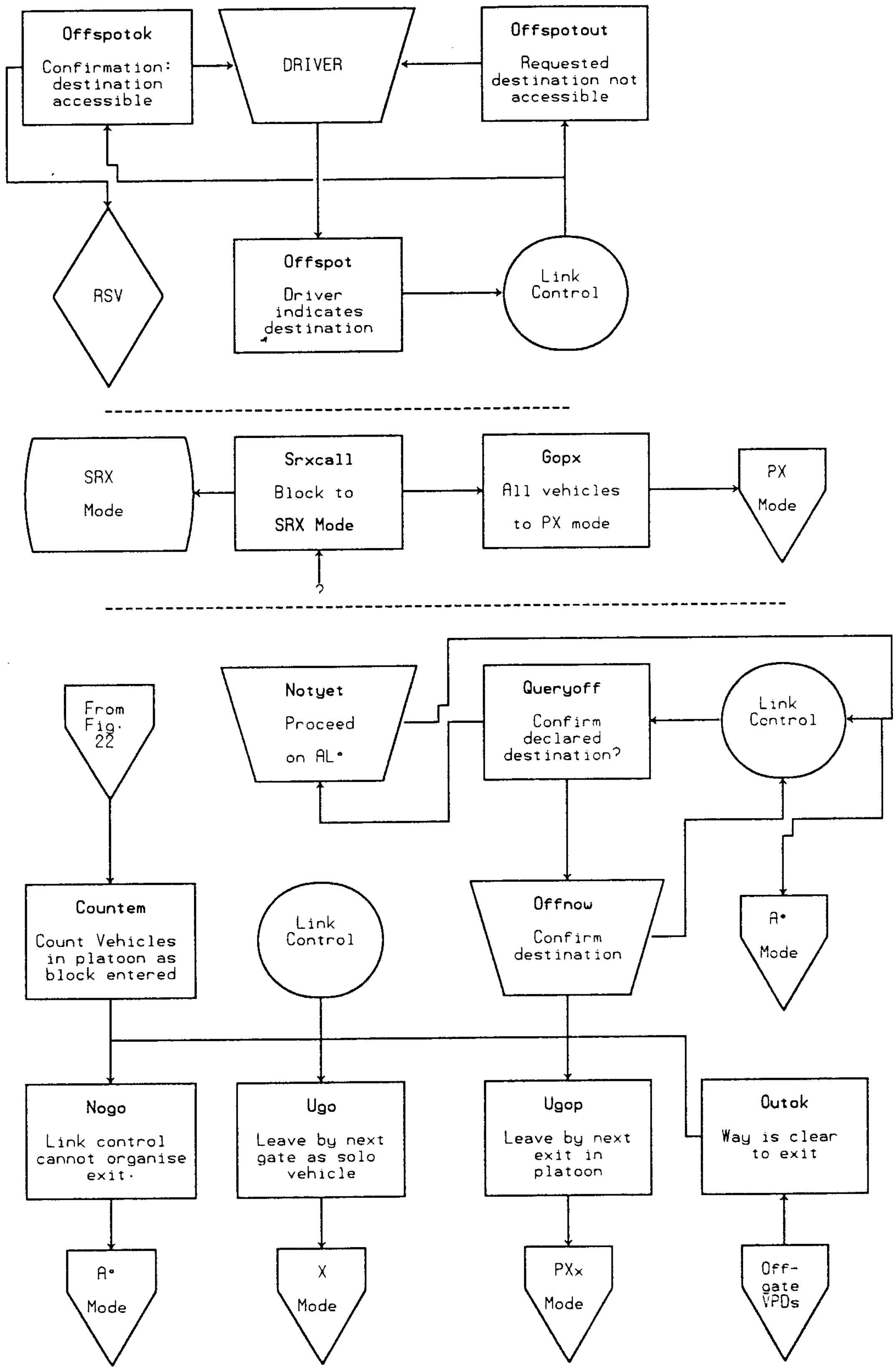
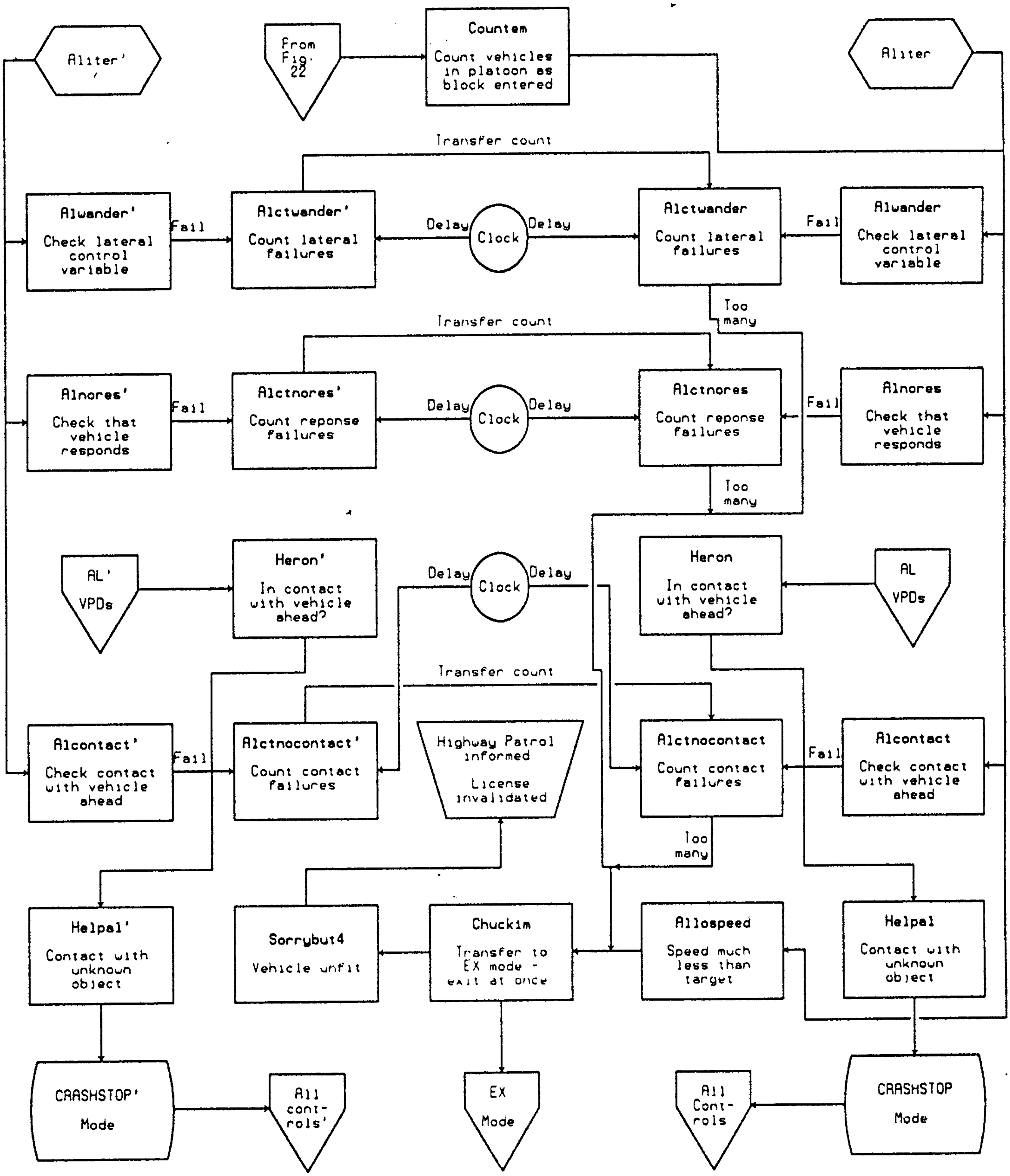


Fig. 22b. Modules for Vehicles in A (continued)

(See also figs 22 and 22a)
(' indicates upstream block: " indicates downstream block)



Name: Alctwander **Fig: 22**
To: AL **From:** AL
Admitted in: N SRC SRX R **Inhib in: S C Q**
ID: AL **Other Input:** Nil
Requires: Alwander
If Branch: Yes **Condition:** Nil
Effect: Intl Var N initially 0 is incremented each time Alctwander called; if N is too large calls Chuckim; endif; return;

Name: Allospeed **Fig: 9, 22**
Specification in: Iter\al

Name: Alnores **Fig: 9, 22**
Specification in: Iter\al

Name: Alwander **Fig: 9, 22**
Specification in: Iter\al

Name: Chuckim **Fig: 22, 24**
To: Veh in A **From: Al**
Admitted in: N SRC SRX R **Inhib in: S C** R
ID: Al **Other Input:** Nil
Requires: Allospeed or Alctwander or Alctnores or Alctnocont
If Branch: No **Condition: -**
Effect: Vehicle faulty - transferred to EX; Sends SRCcall and Sorrybut4;

Name: Countem **Fig: 9**
To: AL **From: AL**
Admitted in: N SRC SRX R **Inhib in: S C Q**
ID: AL **Other Input: See** below
Requires: Allin
If Branch: Yes **Condition:** Counts agree?
Effect: 1. RSVs contain intl var N, 1 per platoon; initially set by Nextplat'(0 for first block); is incremented by Hesinc', Hesinp', Hesinx': decremented by Himout', Himoutx'. Also intl var M, set to 1 by 1st veh in platoon at counter, and incremented as each follower passes. Also calls from Queryinton (Gen) or Queryintoff (Gen) or Countem* or HP may be received identifying a vehicle or platoon. When Allin indicates whole platoon seems to be in:
2. If call from Countem*, decrement N (intruder identified, not then removed; endif; If call from HP, increment N (intruder subsequently removed); endif;
3. If N > M, Call Intruder; if call from Queryinton or Queryintoff also received advise HP of ID; endif;
4. Else if N < M Call Stopal: Advise HP;

5. Else if call from Queryinton or Queryintoff received, advise HP with message - report not confirmed - and advise self-monitor; endif;
6. Call Nextplat; endif; endif; return;

Name: Gopx
Fig: 22, 24, 25
To: 'Vehicle
From: Gen
Admitted in: SRX
Inhib in: N SRC R S C Q
ID: None
Other Input: Nil
Requires: SRXcall
If Branch: No
Condition: -
Effect: All vehs on AL in block transfer to PX; messages to drivers - "Please resume control quickly and leave TL"; Lights by off-gates flash to warn drivers to keep away.

Name: Helpal
Fig: 9, 22
Specification in: Gen

Name: Heron
Fig: 5, 9, 22
Specification in: VPD control.

Name: Hesin
Fig: 5, 21, 22
Specification in: VPD control

Name: Hesinp
Fig: 5, 21, 22
Specification in: VPD control

Name: Hesinx
Fig: 5, 22, 24, 26
Specification in: VPD control.

Name: Himoutp
Fig: 6, 22, 25, 27
Specification in: VPD control

Name: Himoutx
Fig: 6, 22, 23, 24, 26
Specification in: VPD control

Name: Intruder
Fig: 22
To: AL
From: AL
Admitted in: N SRC SRX R
Inhib in: S C Q
ID: AL (platname)
Other Input: Nil
Requires: Countem , too many vehs present.
If Branch: No
Condition: -
Effect: Too many vehs present. Inform HP, with platoon name; Call SRCcall; Advise Countem* ;

Name: Newspeed **Fig: 22**
To: Vehicle **From: AL**
Admitted in: N SRC SRX R **Inhib in: S C Q**
ID: AL **Other Input:** Maxspeed
Requires: Rename (9)
If Branch: Yes **Condition:** First in platoon?
Effect: 1. If first in platoon, work out, using data and timing from Speedset maxspeed = tgt speed = speed to reduce headway to platoon spacing on arrival at next counter;
2. else maxspeed = tgt speed = value for 1st vehicle + small delta.

Name: Nextplat **Fig: 9, 22**
Specification in: Iter\al

Name: Nogo **Fig: 22, 24**
To: AL **From:** Link Control
Admitted in: N SRC R **Inhib in:** SRX S C Q
ID: AL **Other Input:** Nil
Requires: Veh in EX or with next gate set as exit reaches point to start exit manoeuvre and (Queroff sent and Offnow not received) or Outok not set
If Branch: Yes **Condition:** Veh in EX?
Effect: 1. Report to self-monitor;
2. If vehicle in EX, report to HP;
3. else destination (in RSV, VSV) set to next exit gate; Message to driver - "sorry cannot get off here - off at next gate unless you set a later one." Endif; endif; return;

Name: Notyet **Fig: 22**
To: Link control **From:** Veh in A
Admitted in: N SRC R **Inhib in:** SRX S C Q
ID: AL **Other Input:** (opt) destination
Requires: Queroff
If Branch: Yes **Condition:** Dest sent?
Effect: Vehicle does not wish to exit AL at this time: If dest sent, new destination is that stated. In any case, Offspot may be sent to indicate preferred destination at a later time.

Name: Offiteral **Fig: 9, 22, 23, 25, 26, 27**
Specification in: iter\al

Name: Offnow **Fig: 22**
To: Link control **From:** Veh in A
Admitted in: N SRC R **Inhib in:** SRX S C Q
ID: AL **Other Input:** Nil
Requires: Queroff
If Branch: No **Condition: -**
Effect: Indicates to link control that vehicle wishes to quit AL at gate stated in , Queroff. After this is received, further calls to Offspot may have no effect. Enables Ugo, Nogo.

Name: Offspo t **Fig: 22**
Specification in: Gen

Name: Offspotok **Fig: 22**
Specification in: Gen

Name: Offspotout **Fig: 22**
Specification in: Gen

Name: Oniteral **Fig: 9, 21, 22, 26**
Specification in: Aliter

Name: Outok **Fig: 6, 22, 25**
Specification in: VPD control

Name: Queryintoff **Fig: 6, 22**
Specification in: Gen

Name: Queryinton **Fig: 5, 22**
Specification in: Gen

Name: Queryoff **Fig: 22**
Specification in: Gen

Name: Rename **Fig: 22**
To: Vehicle in A, XP, EX **From: AL**
Admitted in: N SRC SRX R **Inhib in: S C Q**
ID: AL (from prec block) **Other Input:** Nil
Requires: Signal from Counter - next veh entered.
If Branch: Yes **Condition:** Signal from Nextplat?
Effect: 1. If signal received from Nextplat, then if number of vehicles there indicated reached,
2. cancel signal and starts new platoon name; sends vehicle this new name **ID** with number 1;

3. else any signal untouched - vehicle receives new platoon name, position in platoon; endif;
4. Calls Oniteraul and Offiteraul'; Calls Newspeed;

Name: Speedset **Fig: 9, 22**
Specification in: Iter/Al

Name: Sorrybut4 **Fig: 22**
To: Veh in A **From: AL**
Admitted in: N SRC SRX R **Inhib in: S C Q**
ID: AL **Other Input:** Nil
Requires: Chuckim
If Branch: No **Condition: -**
Effect: Message to driver - "vehicle unfit". Report to HP; Licence invalidated;

Name: Ugo **Fig: 3, 6, 22, 23, 24, 26**
To: AL **From:** Link Control
Admitted in: N SRC SRX R **Inhib in: S C Q**
ID: AL **Other Input:** Nil
Requires: (Veh is in EX or Offnow) and Outok and (preceding and following veh is not leaver)
If Branch: No **Condition: -**
Effect: Veh transfers to X mode; Veh moves to right of AL; at marker, veh turns through off gate, locates new lateral reference, continues on TL; Calls Hoou;

Name: Ugop **Fig: 3, 6, 22, 24, 25, 27**
To: AL **From:** Link Control
Admitted in: N SRC SRX R **Inhib in: S C Q**
ID: AL **Other Input:** Nil
Requires: (Offnow or veh in EX or veh in PX) and Outok and (preceding or following veh is also leaver)
If Branch: No **Condition: -**
Effect: Veh transfers to PX mode, if not already in it. Veh moves to right of Al; at marker, veh turns through off gate, locates new lateral reference, continues on TL; Enables Himoutp (VPD control)

Modules for Vehicles in X (Fig. 23)

Name: Helplofr
Specification in: Gen
Fig: 6, 23

Name: Himoutx
Specification in: VPD control
Fig: 6, 22, 23, 26

Name: Notgonx
Specification in: VPD control
Fig: 6, 23, 24

Name: Ofiteral
Specification in: iter\al
Fig: 9, 22, 23, 25, 26, 27

Name: Offiterprep
Specification in: Iter/prep
Fig: 8, 18, 19, 20, 26, 27

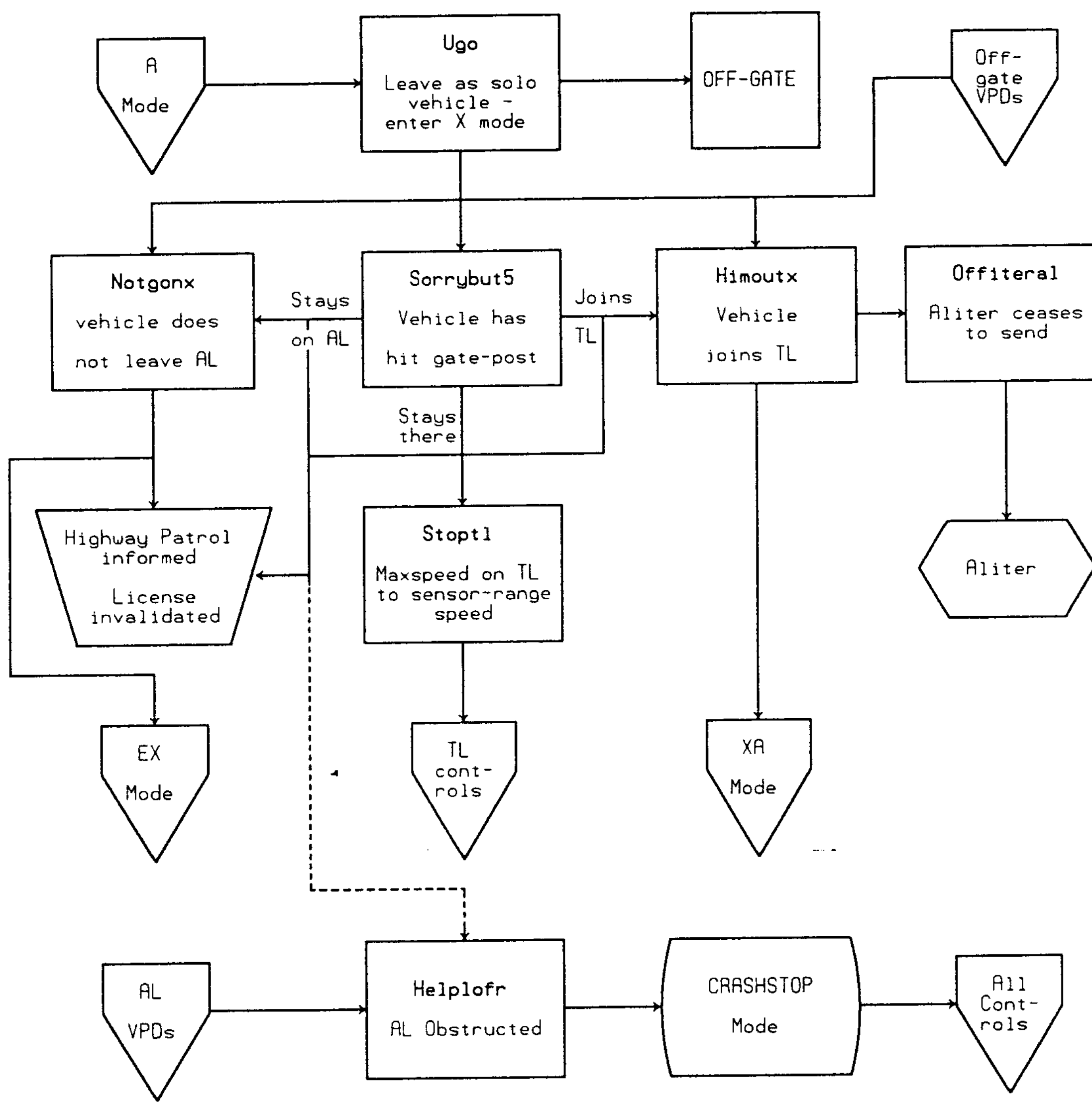
Name: Stoptl
Specification in: Gen
Fig: 3,4,7,8,10,11,21,23,26

Name: Sorrybut5
Specification in: VPD control
Fig: 5, 6, 21, 23

Name: Ugo
Specification in: AL
Fig: 3, 6, 22, 23, 24, 26

Name: Ugoacla
Specification in: E
Fig: 21, 23, 26

Fig. 23. Modules for Vehicles in X



Modules for vehicles in EX (Fig. 24)

Name: Chuckim
Specification in: AL
Fig: 5, 6, 22, 24

Name: Gopx
Specification in: AL
Fig: 22, 24, 25

Name: Hesinx
Specification in: VPD control.
Fig: 5, 22, 24, 26

Name: Himoutx
Specification in: VPD control
Fig: 6, 22, 23, 24, 26

Name: Nogo
Specification in: AL
Fig: 22, 24

Name: Notgonx
Specification in: VPD control
Fig: 6, 23, 24

Name: Ofiteral
Specification in: iter\al
Fig: 9, 22, 23, 24, 25, 26, 27

Name: Outok
Specification in: VPD control
Fig: 6, 22, 24, 25

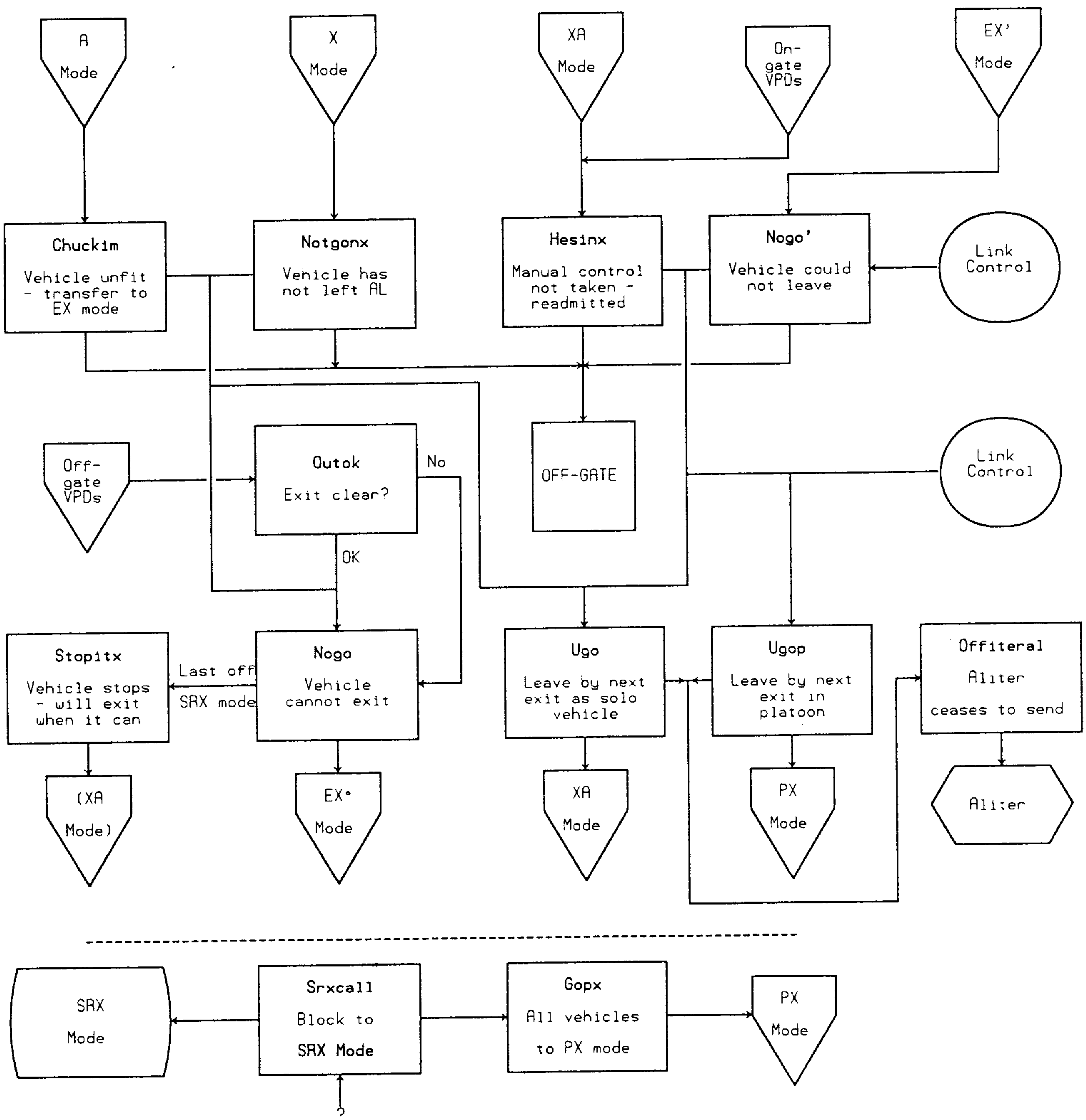
Name: S topitx
Specification in: Aliter
Fig: 9, 24

Name: Ugo
Specification in: AL
Fig: 3, 6, 22, 23, 24, 26

Name: Ugop
Specification in: AL
Fig: 3, 6, 22, 24, 25, 26, 27

Fig. 24. Modules for Vehicles in EX

(Vehicles in EX are under control of Aliter)
(' indicates upstream block: • indicates downstream block)



Modules for vehicles in PX (Fig. 25)

Name: Goonp
Fig: 25
To: AL
From: Link Control
Admitted in: N SRC SRX R
Inhib in: S C Q
ID: AL
Other Input: Nil
Requires: Vehicle at gate in platoon in PX cannot exit (Outok is reset)
If Branch: Yes
Condition: Last gate and SRX?
Effect: If last gate and SRX call Stopitp; endif;

Name: Gopx
Fig: 22, 24, 25
Specification in: AL

Name: Himoutp
Fig: 6, 22, 25, 27
Specification in: VPD control

Name: Notgonp
Fig: 6, 25
Specification in: VPD control

Name: Ofiteral
Fig: 9, 22, 23, 24, 25, 26, 27
Specification in: iter\AL

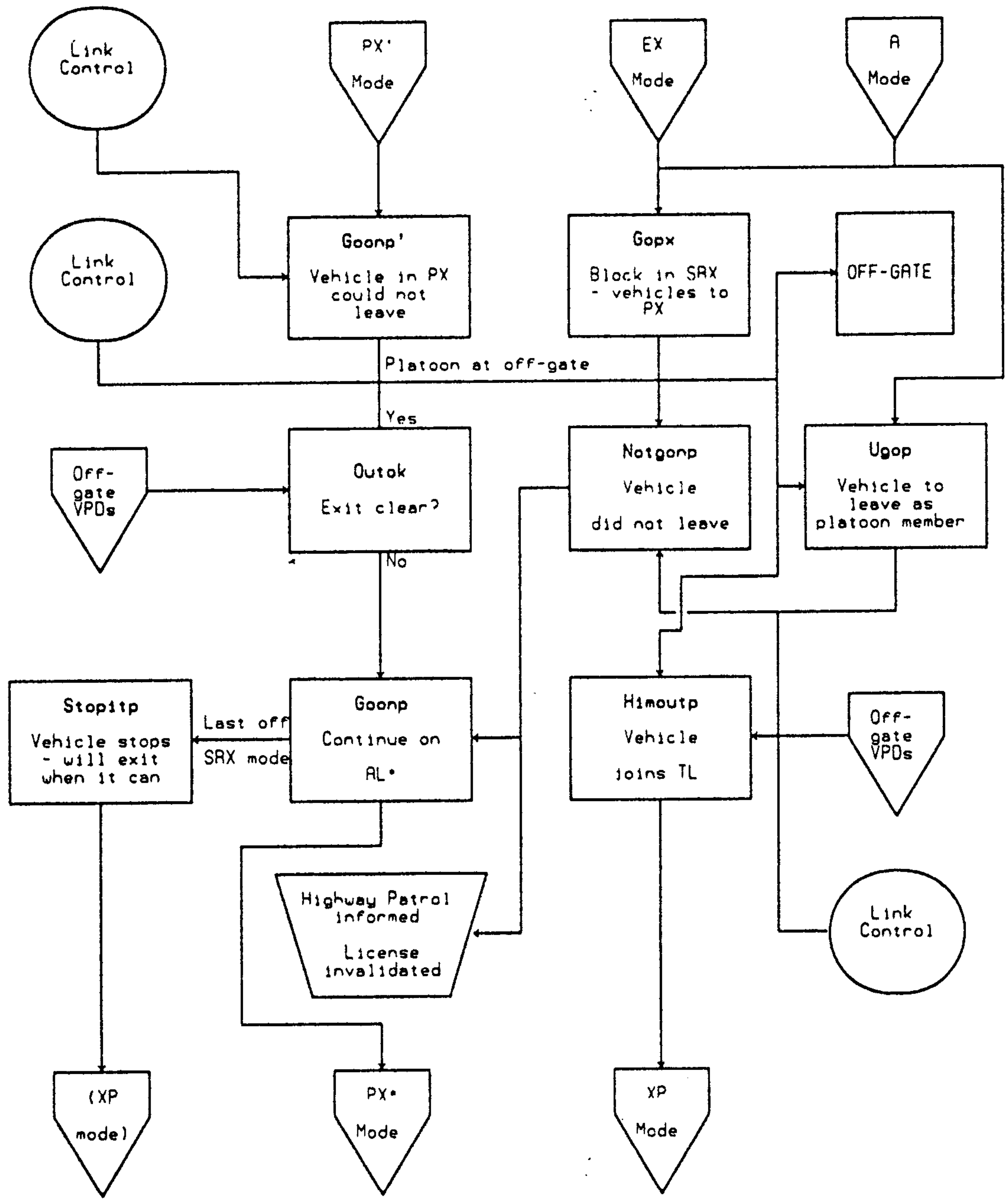
Name: Outok
Fig: 6, 22, 24, 25
Specification in: VPD control

Name: Stopitp
Fig: 9, 25
Specification in: Iter\AL

Name: Ugop
Fig: 3, 6, 22, 24, 25, 27
Specification in: AL

Fig. 25. Modules for Vehicles in PX

(Vehicles in PX are under control of aliter)
(' indicates the upstream block: • indicates the downstream block)



Modules for Vehicles in XA (Fig. 26)

Name: Atenda — Fig: 3, 26
Specification in: VPD control.

Name: Cutspeed — Fig: 10, 26
Specification in: Lofiter

Name: Dropbackx — Fig: 3, 26
Specification in: VPD control.

Name: Hesinx — Fig: 3, 22, 24, 26
Specification in: VPD control.

Name: Himoutx — Fig: 3, 22, 23, 26
Specification in: VPD control

Name: Hooua — Fig: 26
To: Veh in A — From: Lofr
Admitted in: N SRC SRX R S C — Inhib in: Q
ID: AL — Other Input: Nil
Requires: Himoutx (VPD control) or Ugoacla
If Branch: No — Condition: -
Effect: Vehicle replies with Imme - Unique ID;

Name: Hoouf — Fig: 26
To: Veh in PP — From: Lofr
Admitted in: N SRC SRX R S C — Inhib in: Q
ID: Preplatoon — Other Input: Nil
Requires: Ugoaclf
If Branch: No — Condition: -
Effect: Vehicle replies with Imme - Unique ID;

Name: Hooux — Fig: 26, 27
To: Lofr — From: Lofr
Admitted in: N SRC SRX R S C — Inhib in: Q
ID: Postplatoon — Other Input: Nil
Requires: Postoff
If Branch: No — Condition: -
Effect: Vehicle replies with Imme - unique ID;

Fig. 26. Modules for Vehicles in XA

(see also Fig. 26a)

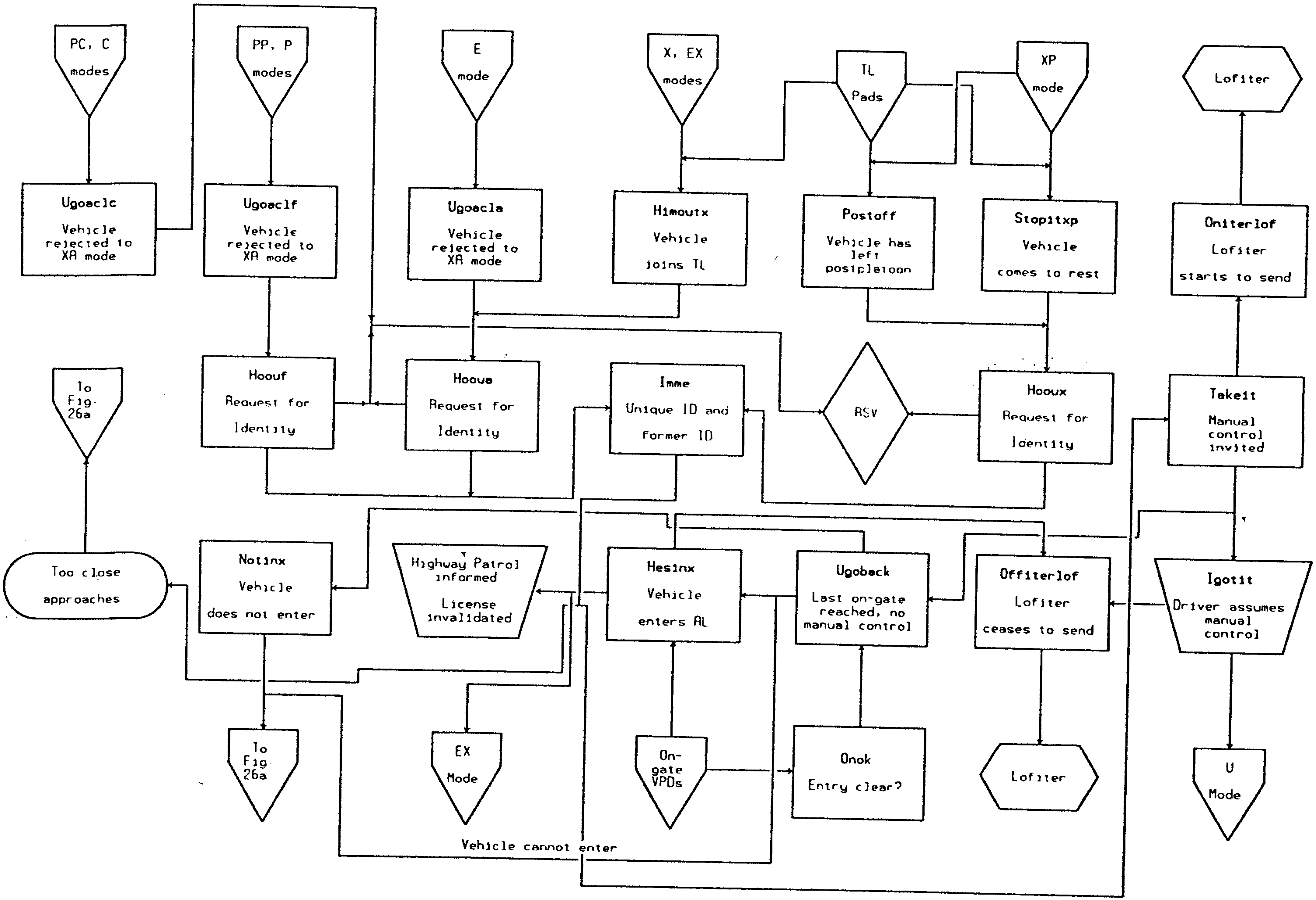
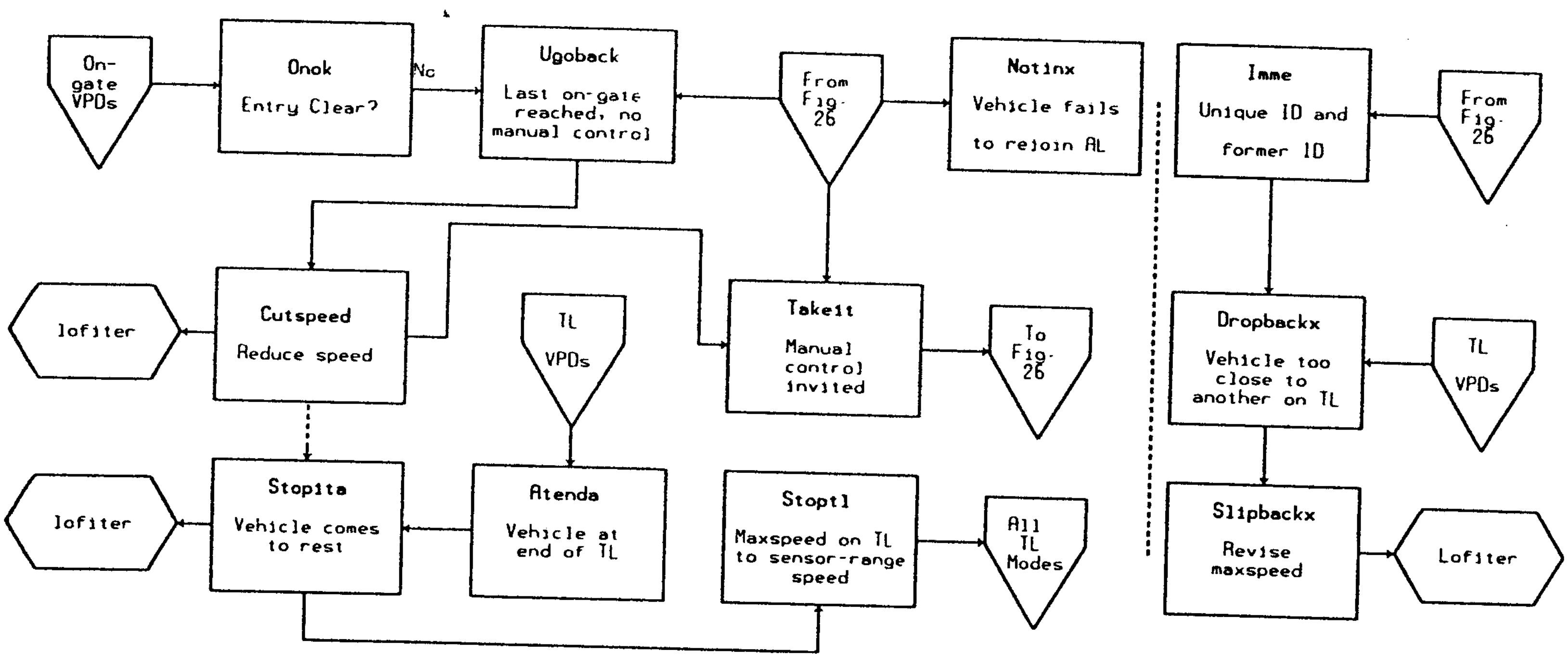


Fig. 26a. Modules for Vehicles in XA (continued)

(see also Fig 26)



Name: Igotit | Fig: 16, 26
To: Lofr | From: Veh in XA
Admitted in: N SRC SRX R S C | Inhib in: Q
ID: Unique | Other Input: Nil
Requires: Takeit
If Branch: No | Condition: -
Effect: Indicates readiness to receive manual control - Vehicle to U; Record on RSV; Calls Offiterlof;

Name: Imme | Fig: 26
To: Lofr | From: Veh in XA
Admitted in: N SRC SRX R S C | Inhib in: Q
ID: Unique | Other Input: ID in calling proc.
Requires: Hooux or Hoouf or Hooua
If Branch: No | Condition: -
Effect: Vehicle gives unique name to LOFR XA - recorded in RSV; Calls Takeit;

Name: No tinx | Fig: 5, 26
Specification in: VPD control

Name: Offiteral | Fig: 9, 22, 23, 25, 26, 27
Specification in: iter\al

Name: Offiterlof | Fig: 10, 26
Specification in: Iter/lof

Name: Offiterlon | Fig: 6,16,17,18,19,20,21,26
Specification in: Iter/lon

Name: Offiterprep | Fig: 8, 18, 19, 20, 21, 26, 27
Specification in: Iter/prep

Name: Oniteral | Fig: 9, 21, 22, 26
Specification in: Aliter

Name: Oniterlof | Fig: 10, 26
Specification in: Iter/lof

Name: Onok | Fig: 5, 18, 20, 21, 26
Specification in: VPD control

Name: Postoff
To: Lofr
Admitted in: **N** SRC SRX R S C
ID: Postplat
Requires: Droptoff (VPD control)
If Branch: No

Fig: 26, 27
From: Lofr
Inhib in: Q
Other Input: Nil

Condition: -

Effect: Vehicle transfers to XA; Calls Offiterpost and Hooux; return;

Name: Slipbackx
To: Veh in XA
Admitted in: N, SRC, SRX, S, R6
ID: Preplat

Fig: 10, 26
From: LOFR
Inhib in: Q, C
Other Input: (On 1st call only) Params describing temp slowing

Requires: Dropbackx or call from lofiter.
If Branch: Yes.

Condition: 1st call or manoeuvre incomplete

Effect: Repeated calls cause vehicle to drop back from one it follows too closely. On 1st call sets params. Then always sets max speed, sets param in lofiter to cause Slipbackx called again, unless manoeuvre complete, in which case resets this param and markers in Dropbackx.

Name: Stopita
Specification in: Iter/lof

Fig: 10, 26

Name: Stopitxp
Specification: in Iter/post

Fig: 11, 26, 27

Name: Stoptl
Specification in: Gen

Fig: 3,7,8,10,11,21,23,26

Name: Takeit
To: Veh in XA
Admitted in: **N** SRC SRX R S C
ID: Unique
Requires: Imme or Ugoaclc
If Branch: No

Fig: 26
From: Lofr
Inhib in: Q
Other Input: Nil

Condition: -

Effect: Message to Driver: "Please resume control at once"; Calls Oniterlof; return;

Name: Ugo
Specification in: AL

Fig: 3, 6, 22, 23, 24, 26

Name: Ugoacla
Specification in: E

Fig: 21, 23, 26

Name: Ugoaclc
Specification in: PC
Fig: 17, 18, 21, 26

Name: Ugoaclf
Specification in: PP
Fig: 19, 20, 21, 26

Name: Ugoback
To: Lofr
Admitted in: N SRC SRX R S C
ID: Unique
Requires: Takeit, and last on-gate approaching
If Branch: Yes
Fig: 26
From: Lofr
Inhib in: Q
Other Input: Nil
Condition: (Mode = N or DC or R or Cn or Sn) and Onok permits entry.

Effect: 1. (This arises if driver has not indicated readiness to resume control after Takeit. Link Control, other things being equal will have maintained such a speed that tail of platoon that vehicle has left is just passing this gate)
2. Informs HP; Licence is invalidated;
3. If condition holds, vehicle swings left and prepares to enter; call Nameherx; (Igotit will not now release)
4. Else, maxspeed = sensor-range speed;

Modules for Vehicles in XP (Fig. 27)

Name: Atendp **Fig:** 11, 27
Specification in VPD control.

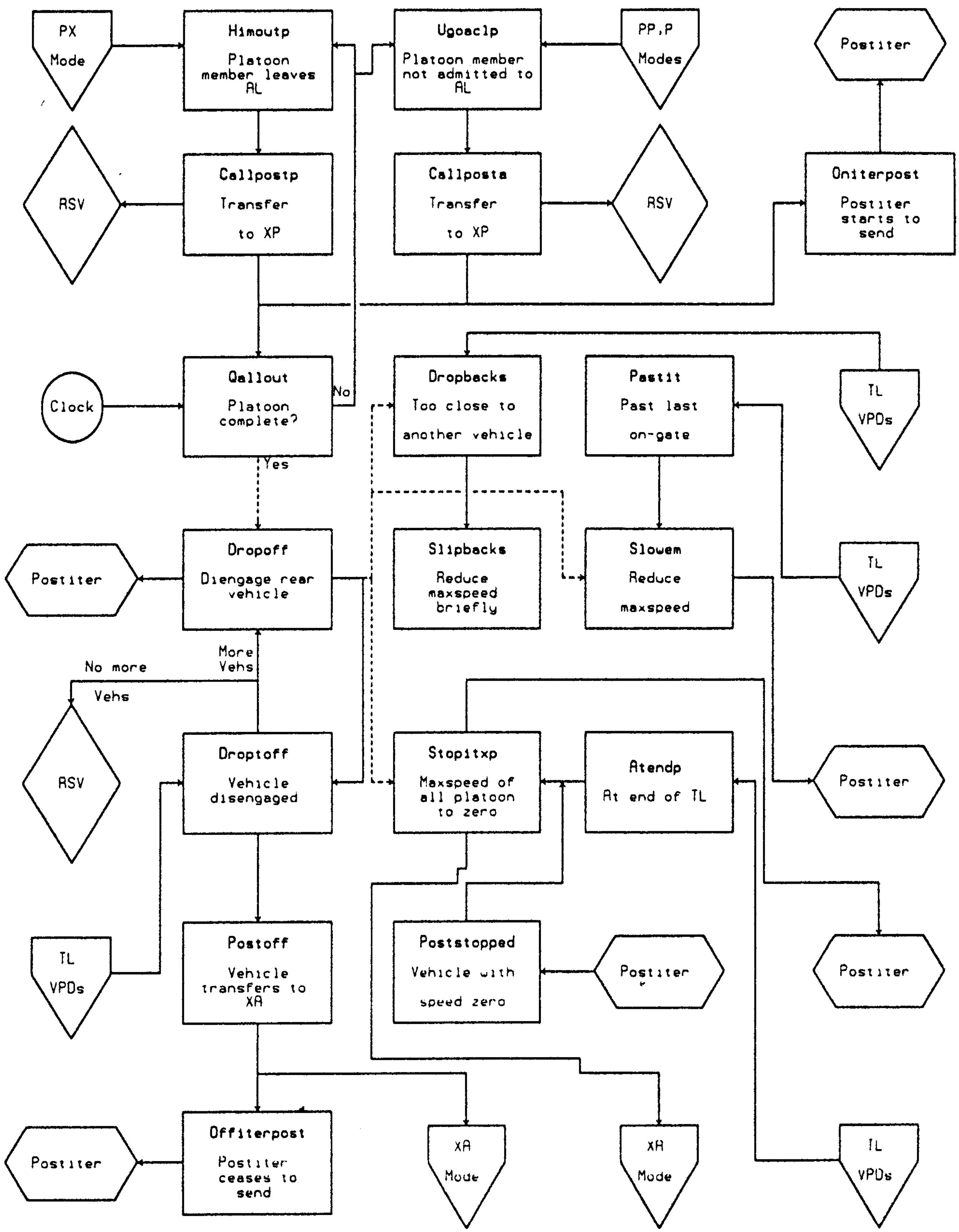
Name: Callposta **Fig: 27**
To: Lofr **From: AL**
Admitted in: N SRC SRX R S C **Inhib in: Q**
ID: AL **Other Input:** Nil
Requires: Himoutp (also from Qallout to reset N)
If Branch: Yes **Condition:** Intl var N initially zero
Effect: 1. Veh transfers to XP; increments N; if N = 0 Gives vehicle new postplatoon name, no 1.
2. else gives same name, no N.; endif.
3. Calls Oniterpost; Calls Qallout; return;

Name: Callpostp **Fig: 27**
To: Lofr **From:** Lonr
Admitted in: N SRC SRX S C R **Inhib in: Q**
ID: Preplatoon **Other Input:** Nil
Requires: Ugoaclp (6) (also from Qallout to reset N)
If Branch: Yes **Condition:** Intl var N initially zero
Effect: 1. Veh transfers to XP; increments N; if N = 1 Gives vehicle new postplatoon name, no 1;
2. Else gives same name, no N; endif.
3. Calls oniterpost; Calls Qallout; return;

Name: Dropbacks **Fig: 3, 27**
Specification in: VPD control.

Name: Dropoff **Fig:** 11, 27
To: Lofr **From:** Lofr
Admitted in: N SRC SRX R S C **Inhib in: Q**
ID: Postplatoon **Other Input: No** of vehs.
Requires: Qallout or Droptoff
If Branch: Yes **Condition:** More vehs?
Effect: 1. On first call from Qallin, no of vehs sets intl var N;
2. Veh identified put to full platoon braking; Decrement N;
3. Call from Droptoff when veh (**N** + 1) is manual spacing behind; Call Postoff and Offiterpost for it;
4. If N = 1 call Postoff and Offiterpost for lead vehicle;
5. else repeat from 2; Endif; return;

Fig. 27. Modules for Vehicles in XP



Name: Droptoff **Fig: 3, 27**
Specification in: VPD control

Name: Himoutp **Fig: 6, 22, 25, 27**
Specification in: VPD control

Name: Offiteral **Fig: 9, 22, 23, 24, 26, 27**
Specification in: iter\AL

Name: Offiterpost **Fig: 11, 27**
Specification in: Iter/post

Name: Oniterpost **Fig:** 11, 27
Specification in: Iter/post

Name: Pastit **Fig: 3, 11, 27**
Specification in: VPD control

Name: Postoff **Fig: 26, 27**
Specification in: XA

Name: Poststopped **Fig:** 11, 27
Specification in: Iter/post

Name: Qallout **Fig: 27**
To: Lofr **From:** Lofr
Admitted in: N SRC SRX R S C **Inhib in: Q**
ID: Postplatoon **Other Input:** Var N, intl to calling routine.
Requires: Call from Callposta or Callpostp
If Branch: Yes **Condition:** Call ex other caller
Effect:
1. If call from other caller without interval (see below) Maxspeed = sensor-range; endif;
2. Set interrupt to time DT after call (overwriting). On interrupt, reset N in both callers; and call Dropoff with platoon name and number.

Name: Slipbacks
To: Lead veh in XP
Admitted in: **N, SRC,** SRX, S, R
ID: Postplat

Fig: 11, 27
From: LOFR
Inhib in: Q, C
Other Input: (On 1st call only) Params describing temp slowing

Requires: Dropbacks or call from postiter.
If Branch: Yes.

Condition: 1st call or manoeuvre incomplete.

Effect: 1 Repeated calls cause vehicle to drop back from one it follows too closely. On 1st call sets params. Then always sets max speed, sets param in postiter to cause Slipbacks called again, unless manoeuvre complete, in which case resets this param and markers in dropbacks.

Name: Slowem
Specification in: VPD control
Fig: 3, 27

Name: Stopitxp
Specification in: Iter/post
Fig: 11, 26, 27

Name: Ugoaclp
Specification in: PP
Fig: 19, 20,27

Name: Ugop
Specification in: AL
Fig: 3, 6, 22, 24, 25, 27