ON-STREET SYSTEM MASTER

This specification is fully met by the following Econolite models:

ASC/2M-1000 Zone Master

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1. HARDWARE

1.1 Enclosure

1.1.1 The system master shall be compact so as to fit in limited cabinet space. It shall be installable on a shelf that is not more than 7" deep. External dimensions shall not be larger than 9" x 15" x 9-1/2" (H x W x D).

1.1.2 The enclosure shall be constructed of sheet aluminum and shall be finished with an attractive and durable protective coating. Model, serial number, and program information shall be permanently displayed on the top surface.

1.1.3 The enclosure shall open along a vertical stainless steel hinge so as to provide ready access to the electronics in case of service.

1.2 Electronics

1.2.1 The electronics shall be modular and shall consist of vertical circuit boards. Horizontal circuit cards shall not be acceptable.

1.2.2 A microprocessor shall be used for all timing and control functions. Continuing operation of the microprocessor shall be verified by an independent monitor circuit, which shall set an output to FALSE and indicate an error message if a pulse is not received from the microprocessor within a selectable period.

1.2.3 In the interest of reliability, sockets shall only be used for components with 20 pins or more.

1.2.4 A built-in, high-efficiency switching power supply shall generate all required internal voltages as well as 24 VDC output. All voltages shall be regulated and shall be monitored with control signals. Fuses shall be mounted on the front of the system master for 120 VAC input and 24 VDC output.

1.2.5 Timing of the system master shall be derived from the 120 VAC power line. A 5-year lithium battery shall maintain the time-of-day clock and digital data during a power outage lasting up to 30 days. Lead-acid, nickel-cadmium, or alkaline batteries shall not be acceptable.

1.2.6 User-programmed settings shall be stored in an electrically erasable programmable read-only memory (EEPROM). Designs using a battery to maintain user data shall not be acceptable.

1.2.7 To facilitate the transfer of data from one system master to another, the EEPROM shall be mounted on an easily removable sub-module, which shall be connected to the processor module via a DIN printed circuit board connector.

1.2.8 All printed circuit boards shall meet the requirements of the NEMA Standard plus the following requirements to enhance reliability:

a. All plated-through holes and exposed circuit traces shall be plated with solder.
b. Both sides of the printed circuit board shall be covered with a solder mask material.
c. The circuit reference designation for all components and the polarity of all capacitors and diodes shall be clearly marked adjacent to the component. Pin 1 for all integrated circuit packages shall be designated on both sides of all printed circuit boards.
d. All electrical mating surfaces shall be gold-plated.
e. All printed circuit board assemblies, except power supplies, shall be coated on both sides with a clear moisture-proof and fungus-proof sealant.

1.3 Front Panel and Connectors

1.3.1 The front of the system master shall consist of a panel for the display and keyboard plus a separate panel for the connectors.

1.3.2 A 16-line by 40-character/line alphanumeric liquid crystal display (LCD) shall show program and status information. The display area shall have nominal measurements of 2 1/2" x 4 1/2" (H x W) or larger. For ease of viewing, backlighting by light emitting diodes and multiple levels of contrast adjustment shall be provided.

1.3.3 Front-panel operator inputs shall be via clearly labeled and environmentally-sealed elastomeric keys. These shall include a 10-digit numeric keypad, ten function keys, an oversize ENTER key, and an oversize four-arrow cursor control key.

1.3.4 Eight of the function keys shall be labeled F1 through F8 and provide the following functions:

F1 - Main Menu-Pressing the F1 key shall display the main menu.
F2 - Next Screen-Pressing the F2 key shall display the next screen, thus allowing rapid advancement from screen to screen.
F3 - Sub Menu-Pressing the F3 key from any data screen shall display the current sub-menu.
F4 - Next Data-Pressing the F4 key shall search for the first non-zero data field, thus allowing rapid search for valid entries.
F5 - Display Adjust-Pressing the F5 key shall adjust the contrast of the display.
F6 - Next Page-Pressing the F6 key shall advance to the previous or next group of data entry screens in a sub-menu.
F7 - Status Display-Pressing the F7 key shall present the status display.
F8 – Help-Pressing the F8 key at any data entry field shall display a help screen about that field.

1.3.5 Special Function**.** A key marked "special function" shall be provided to lock out data changes if an access code is present and to enter hexadecimal characters.

1.3.6 Clear. A key marked "clear" shall be provided to abort a data entry and restore the current value.

1.4 Telemetry

1.4.1 Up to two channels of telemetry utilizing time division multiplex/frequency shift keying (TDM/FSK) techniques shall be provided depending on system requirements.

1.4.2 The modems for each channel shall provide full-duplex communications over four-wire Type 3002 telephone lines between the system master and local controllers.

1.4.3 The transmitter shall be a digital-to-FSK modulator. A digital HIGH shall result in a frequency of 2200 Hz, and a digital LOW shall result in a frequency of 1200Hz. At the point of frequency shift, the signal shall be phase coherent. The nominal output level shall be 0dBm into a 600ohm load.

1.4.4 The receiver shall be an FSK-to-digital demodulator. A frequency of 2200 Hz shall result in a digital HIGH, and a frequency of 1200 Hz shall result in a digital LOW. The receiver sensitivity shall be set at -34dBm and shall be adjustable from -40 to +6dBm.

1.5 Serviceability

1.5.1 All electronic modules other than the power supply shall be easily removable from the front of the system master using a standard screwdriver as the only tool. All power and signal connections to the circuit boards shall be via plug-in connectors.

1.5.2 The system master layout shall allow the removal and replacement of any circuit board without unplugging or removing other circuit boards. All boards shall be keyed to prevent improper installation. No more than two boards shall be attached together to form a circuit assembly. Attaching hardware shall use captive screws or 1/4-turn fasteners to secure circuit assemblies to the enclosure.

1.5.3 The system master enclosure shall allow complete disassembly using a standard screwdriver. It shall be designed so that one side of any circuit board is completely accessible for troubleshooting and testing while the unit is still in operation. This capability shall be accomplished without the use of extender cards or card pullers.

2. FUNCTIONAL OPERATION

2.1 The system master shall control the operation of a traffic system or zone containing up to 24 intersections by specifying the operation of the intersection controllers based on processed detector data, time-of-day/day-of-week/ week-of-year scheduling, manual operator selection, or external commands.

2.2 The control signals shall consist of traffic plans that specify a coordination program that commands one of six cycle lengths, one of five offsets, one of four splits; system free; or zone plan, and up to four special functions.

2.3 The system master shall provide for a communication link to a monitor computer to upload/download controller data bases, to transfer events and detector data for storage, and to provide data on a one-second basis for real-time displays.

2.4 There shall be optional capability for telemetry interconnect and for a remote or local data terminal.

3. PROGRAM SELECTION

3.1 The default program in effect shall be selected on a priority basis. Priorities shall be as follows:

a. Manual entry from keyboard
b. External command from a master
c. Time-of-day/day-of-week schedule
d. Traffic responsive

3.2 Manual entry from the keyboard shall override programs from all other sources. It shall be used as the default when automatic selection fails and time-of-day/day-of-week backup is not enabled.

3.3 Provision shall be made for program commands from an external master. The external command inputs shall be usable for crossing artery synchronization.

4. TIME-OF-DAY/DAY-OF-WEEK PROGRAMMING

4.1 Up to 150 program steps shall be available for time-of-day/day-of-week (TOD) scheduling. Up to 16 TOD programs shall be possible. The TOD programs shall be scheduled on a repeating basis by assignment to the week of year and day of week. Special TOD programs shall be assignable by month and day on a one-time or repeating basis for implementing holiday programs or special events.

4.2 TOD program selection or special function scheduling shall be enabled separately for override of traffic responsive commands. It shall be possible to enable a traffic responsive default function that allows TOD operation to take effect only if traffic responsive operation fails.

4.3 TOD operation shall be controlled by a calendar and clock that compensates automatically for leap year and daylight savings time (if enabled). Each TOD program step shall consist of the following:

a. Program number.
b. Begin time (hour and minute).
c. Traffic plan consisting of cycle, offset and split; system free; or zone plan command (see 5.9).
d. Enable special functions.
e. Enable maintenance call operation.
f. Enable traffic responsive operation.
g. Auto program override (if cycle length is higher).
h. Command non-interconnected coordination operation.
i. Enable crossing artery synchronization.
j. Specify sample period for traffic responsive plan.
k. System detector log interval.
l. Sample period log interval.

4.4 Power OFF for longer than the capability of the power-down timer shall inhibit TOD operation. TOD operation shall be enabled when time is updated.

5. TRAFFIC RESPONSIVE PROGRAMMING

5.1 Traffic plan selection in the traffic responsive mode shall be performed at user specified intervals. The plan selection interval shall be specified in minutes or cycles.

5.2 Raw sensor data consisting of volume counts and presence measurement from up to 32 detectors shall be processed into scaled volume and scaled occupancy traffic parameter values for use in traffic responsive plan selection. The volume and occupancy scale factors shall be specified for each detector and also for the system. If individual values are not specified, the system value shall be used.

5.3 The sensors shall be assignable to eight detector groups, each of which shall contain up to four detectors. A minimum number of operable detectors required for valid operation shall be user specified. Each group of detectors shall be assignable to any combination of the following functions:

a. Level selection
b. Direction 1 traffic
c. Direction 2 traffic
d. Split demand A
e. Split demand B
f. Arterial demand
g. Non-arterial demand

5.4 For each detector group assignment, the user shall be able to specify that the highest, second highest or average of all scaled sensor data be used as the detector group output. The output parameter of each detector group shall be volume, occupancy, or concentration (which is the higher of volume or occupancy).

5.5 The data processing of the detector group outputs assigned to each function shall be specified as follows:

a. Parameter (volume, occupancy, or concentration).
b. Highest, second highest, or average output of the detector groups assigned to the function.
c. Factor used in a first-order smoothing algorithm.

d. Update predictor value that will bypass data smoothing for a predetermined increase.

5.6 Computed level shall be determined by comparing the processed level selection detector group outputs to user specified threshold values. Provision shall be made for determining up to five computed levels. The threshold values between adjacent levels shall overlap to provide a hysteresis effect to minimize oscillation. It shall be possible to inhibit access to higher levels by entering an out-of-range threshold value.

5.7 Arterial directional preference shall be determined by computing the difference between the processed direction 1 data and direction 2 data. Computed offset shall be determined by comparing the arterial directional values to user specified threshold values. The computed offset shall be either the direction 1 preference, direction 2 preference, or average. The threshold values between adjacent computed offsets shall overlap to provide a hysteresis effect to minimize oscillation.

5.8 Based on computed level and computed offset, one of fifteen traffic plans shall be selected. Traffic plans shall provide for one of the following:

a. A coordination plan consisting of:
One of six cycle lengths
One of five offsets
One of four splits or four computed split/special function programs
b. System free
c. Zone plan command
Up to four special functions shall be available for each traffic plan.

5.9 Zone plan commands 1 through 32 from the master shall select command programs 1 through 32 at each intersection controller. It shall be possible to group intersections as necessary for traffic patterns providing multiple sub-zone coordination or independent operation within a zone. As an example, zone plan command 1 shall be able to specify the following zone operation:

a. Intersection 1 through 8, command program 1 calling for cycle 2, offset 3, and split 1.
b. Intersection 9 through 16, command program 1 calling for cycle 3, offset 2, and split 2.
c. Intersection 17 through 20, command program 1 calling for free mode.

5.10 If, due to failed detectors or improper data entries, the computed level or computed offset cannot be determined, the previously selected traffic responsive plan shall be retained for a period specified by the operator. A default traffic plan shall be used if valid computed level and offset have not been determined before the expiration of the retention period.
5.11 The default plan shall be selected from one of three sources as determined by operator entries.

a. TOD scheduling shall be used if traffic responsive backup is enabled.
b. Manual plan.
c. System free.

5.12 Computed split/special function program shall be determined by computing the difference between the processed split demand B data and split demand A data. One of four programs consisting of one of four splits and any special function shall be selected by comparing the difference to user specified values. The threshold values between adjacent splits shall overlap to provide a hysteresis effect.

5.13 Five additional traffic plans shall be selectable based on computed level and nonarterial preference. A nonarterial preference ratio shall be determined by computing the difference between the processed nonarterial demand data and arterial demand data. Either arterial or nonarterial preference shall be selected by comparing the difference to user specified threshold values. The threshold values shall overlap to provide a hysteresis effect. It shall be possible to specify that any of the non-arterial traffic plans shall defer to the arterial plans at the same computed level.

6. CROSSING ARTERIAL SYNCHRONIZATION

6.1 Provision shall be made for crossing arterial synchronization in two independent system masters. Synchronization shall be established through the common intersection of both systems in order to maintain simultaneous, coordinated traffic flow along each of the arterials.

6.2 Crossing arterial synchronization shall be enabled by the time-of-day scheduler and shall occur when the traffic pattern commanded by each of the system masters has the same cycle information.

6.3 Crossing arterial synchronization shall be enabled as long as both system master cycle commands are the same and shall remain in effect for as long as traffic demand warrants this mode. To prevent oscillation, it shall be possible to "lock in" this mode for a user-programmable period from 0-30 cycles.

7. POWER FAIL RESTART

A second set shall provide for diagnostic values to be specified for each system detector individually. The individual value shall be used if it is longer than the system diagnostic interval. When no individual value is specified for a system detector test, the system diagnostic value shall be used.

The system detector diagnostic tests shall be as follows:

a. **No Activity** - Two intervals from 0 to 255 minutes between vehicle counts shall be settable by time of day for no-activity diagnostics on a system basis. A diagnostic interval shall begin each time a vehicle count occurs. If a vehicle count is not received during the diagnostic interval, the detector shall be failed. No-activity diagnostics shall be inhibited if the volume from a majority of unfailed system detectors is below a system-specified threshold value from 0 to 255 counts per minute.
b. **Maximum Presence** - An interval from 0 to 30 minutes shall be specified for maximum presence diagnostics. A continuous detector call for the diagnostic interval shall cause the detector to be failed.
c. **Minimum Presence** - An interval from 0 to 15 minutes and a minimum average presence time from 0 to 30 occupancy counts, where each count is 16 2/3 milliseconds, shall be specified for minimum presence diagnostics. A detector shall be failed if the occupancy per vehicle count averaged over a one minute period is less than the specified average presence time for the diagnostic interval.
d. **Excessive Counts** - A diagnostic count from 0 to 180 counts per minute and diagnostic interval from 0 to 30 consecutive minutes shall be specified. If the detector count is equal to or greater than the diagnostic count for the diagnostic interval the detector shall be failed.

7.1 Speed trap detector status shall be tested for no-activity. If a speed trap readback does not contain a speed for the current no-activity period, the speed trap shall be failed.

7.2 Failed detectors shall be automatically returned to service if no failure condition exists for a 0 to 15 minute detector recovery interval.

7.3 A display showing diagnostic status for system detectors shall be provided. The diagnostic status of four system detectors shall be displayed simultaneously. Displayed information for each system detector shall include: enable, telemetry, no activity, max presence, min presence, and excessive counts.

8. TELEMETRY DIAGNOSTICS

8.1 Diagnostics shall be required for systems having optional telemetry interconnect. The diagnostics shall monitor readbacks for no-response conditions. Channel diagnostics and local telemetry shall be included.

a. **Channel** - A transceiver failure shall be detected if a telemetry channel is enabled, but no telemetry module is present. A loop failure shall be detected when no readbacks are received on a telemetry channel for 3 seconds. The telemetry channel shall be automatically returned to service and the status of all devices connected to the channel shall be cleared when readbacks are received for 3 consecutive seconds following either failure.
b. **Local Telemetry** - A local telemetry failure shall be detected when a device has not responded with a valid readback for 5 consecutive seconds. This failure shall be identified with controllers and system detectors only. The device shall be automatically returned to service and the device status cleared when valid readbacks have been received for 5 consecutive seconds following a local telemetry failure.

8.2 A diagnostic display showing enable status, loop error and transceiver error for two channels simultaneously shall be provided.

9. INTERSECTION DIAGNOSTICS

Diagnostics shall be provided for intersections with telemetry interconnect. Intersection status conditions shall be available for diagnostic display and logging.

9.1 Controller readbacks shall provide data for determining the following intersection conditions:

a. **Conflict Flash** - A minimum flash interval from 0 to 30 seconds shall be specified. If an intersection readback indicates a CMU flash for a period in excess of the minimum flash interval, the intersection shall be **failed** and the intersection status shall indicate a conflict flash condition.
b. **Local Flash** - If an intersection readback indicates flash, CMU flash is OFF, and flash is not commanded from the master, the intersection status shall indicate a local flash condition and the intersection shall be considered **off-line**.
c. **Commanded flash** - If an intersection readback indicates flash, CMU flash is OFF, and flash is commanded from the master, the intersection status shall indicate a commanded flash condition and the intersection shall be considered **off-line**.
d. **Maintenance required** - If an intersection readback indicates a maintenance required condition, the intersection shall be **failed** and the intersection's status shall indicate a maintenance required condition.
e. **Cycle Fail** - If the readback from a coordinated intersection indicates that a sum check is present and there has not been a phase change for two cycles if coordinated or three minutes if non-coordinated, the intersection shall be **failed** and the intersection status shall indicate a cycle fail condition.
f. **Coordination alarm** - If an intersection readback indicates a coordination alarm, the intersection shall be **failed** and the intersection status shall indicate a coordination alarm condition.
g. Local Free, Commanded Free, Coordination Error, or **Preempt** - If an intersection readback indicates any of these conditions, the intersection status shall indicate the condition and the intersection shall be considered **off-line**.
h. **On-line** - When a failure or off-line condition is removed, the indication shall be removed from the intersection status, and the intersection shall be recorded on-line if no other failure or off-line condition is present.

9.2 Supplemental status readback shall provide data for determining the following local vehicle detector conditions:

a. **No Activity** - Same as for the system detector, except that no individual detector value is specified.
b. **Max Presence** - Same as for the system detector.

9.3 Supplemental status readback shall indicate when a minimum of two user-defined alarms go On or OFF. The alarm condition shall be indicated in the intersection status.

9.4 A display showing diagnostic status for intersections shall be provided. The diagnostic status for a minimum of four intersections shall be displayed simultaneously. Displayed information for each intersection shall include: enable, telemetry, cycle fail, CMU flash, maintenance required, coordination alarm, alarm 1, and alarm 2.

10. SYSTEM MANAGEMENT

10.1 Provision shall be made for keyboard control of the following system management functions, which deal with system configuration, operational status, and status monitoring:

a. Add/delete telemetry connected controllers
b. Add/delete telemetry connected system detectors
c. Alter telemetry channel command sequence
d. Enable/disable telemetry channel
e. Enable/disable controller
f. Enable/disable system detector

10.2 Provision shall be made for status displays of the following categories:

a. **General status** - Shall display master number, time-of-day, date, day-of-week, program in effect, cycle countdown, special function, time-of-day interval and plan, and overall diagnostic status. In addition, plan and selected cycle length of manual, external, time-of-day, and traffic-responsive plans shall be displayed.
b. System detector current sample - Shall display actual and scaled volume and occupancy for all system detectors in groups of eight.
c. **Sample period results** - Shall display current plan selected by traffic responsive calculations. Intermediate results shall also be displayed including all eight detector group computed values.
d. **Controller status** - Shall display information retrieved from intersection controllers through telemetry channels. Current phase 1 - 8 green, vehicle detector 1 - 8 status, overlap A-D green, and alarm status shall be displayed on one screen.
e. Detector presence and speed traps - Shall display system detectors 1 - 32 actuation status and speed traps 1 - 8 speed on one screen.

11. EVENT RECORDING

11.1 An event recording function shall be provided for the occurrence of events relating to system operation. Events shall include the following:

a. Program and mode changes
b. Device diagnostics
c. System events

11.2 Events shall be recorded as they occur. It shall be possible to enable/disable any event and to assign event priorities to control automatic reporting to a monitor computer on the following basis:
Priority 1 - reports immediately
Priority 2 - reports after 0 - 255 minute delay
Priority 3 - reports with higher-priority reports

11.3 An event buffer shall be provided for 250 events. Provision shall be made for the event buffer to be printed out on command and for the event buffer to be cleared.

11.4 Event messages shall include the master number, event priority, date and time, a brief description of the event, and identification of the system device if applicable.

11.5 Information shall be recorded as follows for program or mode change events, which may occur automatically as a result of traffic computations, on a TOD scheduled basis, or due to a manual or external command:

a. In-effect program change
Program source
Program cycle, offset, split and cycle length
b. Traffic responsive program change
Computed selection parameters-level, offset, split
Nonarterial preference
Program cycle, offset, and split
c. Special function change
Change source
Special function number with ON/OFF status
d. Time-of-day program step change
TOD program step number
e. Intersection mode change
Intersection no.Change source
Intersection mode number with ON/OFF status

11.6 Device diagnostics previously defined shall be continuously executed and be recorded as events occur.

11.7 System events shall include the following:

a. **Power Off** - A power OFF event shall be recorded when power is removed. The event message shall be printed out when power is restored. Date, time and traffic responsive program shall be preserved in memory for a minimum of 30 days during power OFF. A 72 hour power down timer shall be enabled when loss of power is detected so that the day and time may be corrected when power is restored.
b. **Power On** - A power ON message shall indicate the time power was restored. The date and time shall be corrected if power has been off less than 72 hours.
c. **Power Interrupt** - A power interrupt event shall indicate that power was off for less than 0.75 seconds.
d. **Clock error** - A clock error message shall indicate the date and time is incorrect. This event occurs at initial power ON prior to the date and time being set and if power has been OFF in excess of 72 hours. A clock error shall inhibit TOD operation.

11.8 A telephone number entry shall be programmable to allow event reporting to a monitor computer. Another telephone number shall be programmable to report device failures or optionally all priority 1 events to a separate maintenance computer or to a terminal. Event reports to a maintenance computer or terminal shall be done only when

scheduled by a TOD entry. If the monitor computer, maintenance computer or terminal is busy or off-line, a reporting system master shall repeatedly attempt to call at a user-programmable retry interval.

12. LOGS AND REPORTS

12.1 Logs and reports shall be generated in response to operator requests. The reports shall consist of the following:

a. Current status
b. System detector log
c. Speed log
d. Sample period log
e. Detector buffer data

12.2 Current status reports shall be available for request by the operator on a one-time basis. The following status reports shall be provided:

a. Zone status consisting of:
Program-in-effect and source
Auto program (if not program-in-effect)
Special function status
Intersection mode
Telemetry channel status:
On-line
Off-line
Failed
Controller status:
On-line
Off-line
Failed
System detector status:
On-line
Off-line
Failed
Local detector status:
Failed
b. Summary of currently failed controllers and failure cause.
c. Summary of currently failed system detectors and failure cause.
d. Current 15-minute system detector log.
e. Contents of event buffer.

12.3 System detector logs shall be available for all system detectors. The logs shall present actual volume, actual occupancy and computed speed. The logging interval shall be selectable as 15, 30 or 60 minutes as scheduled by TOD entries. The operator shall be able to enable or disable the log without affecting the previous selections. It shall be possible to specify that speed be computed in miles per hour or kilometers per hour. The log shall be reported to the monitor computer on a real-time basis.

12.4 A speed log shall tabulate in three speed bands the number of vehicles detected by each speed trap assigned to log. Up to 8 speed traps shall be independently specified as a measure of effectiveness (using nominal progression speed for each active cycle and offset program as a reference) or as a programmable speed band. The measure of effectiveness method shall provide a speed offset below and a speed offset above the nominal speed for establishing

speed bands, whereas the programmable speed band method shall provide two independent speeds to define three speed bands. The logging interval shall be the same as for system detector logs and shall report to the monitor computer on a real-time basis.

12.5 A sample period log shall be available to allow the user to evaluate traffic responsive system control. It shall be possible for the operator to adjust detector scale factors, computational parameters, smoothing factors and thresholds, and to monitor the resultant effect on program selection. It shall be possible for the operator to specify the log printout on a multiple of sample periods from 1 to 15 as scheduled by TOD entries; or, alternatively to print out the sample period log when a change occurs to computed level, offset, split or nonarterial preference. The operator shall be able to enable or disable the log without affecting previous selections. The sample period log shall consist of the following parameters:

a. Scaled volume and occupancy from enabled system detectors
b. Volume for each detector group
c. Occupancy for each detector group
d. Concentration for each detector group
e. Current value of each program selection function
f. Smoothed value of each program selection function
g. Computed program selection parameters
h. Selected auto program
i. In-effect program and cycle length

The sample period log shall be reported to the monitor computer on a real-time basis.

12.6 A user-enabled log buffer shall accumulate data from enabled system detectors and speed traps for each logging interval. Contents of the log buffer shall be transferred at 6, 12 or 24 hour intervals to the monitor computer for storage. A separate telephone number shall be provided for calling the monitor computer via an external modem using the dial-up telephone network. This telephone number shall also be used for real-time logs.

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