

Summary: TRB Railroad Operational Safety Meeting, Omaha NB, July 30-31, 2013

## **Locomotive Alerter Technology Assessment**

Charles M. Oman

Man-Vehicle Laboratory, Massachusetts Institute of Technology

Currently all US passenger and most freight locomotives are equipped with some type of alerter or deadman system. This talk reviews the limitations of deadman systems, the history of locomotive alerter logic, several fatigue related accidents (e.g. Anding, MS, Macdona TX), NTSB recommendations and technology and user surveys leading to a 2007 AAR standard and the 2012 FRA rule mandating pre-emptively resettable, speed linked, control activity sensitive alerters in all freight locomotives by 2017. There are no scientific studies of alerter effectiveness, but accident data indicate they are imperfect detectors. Alternative approaches (e.g. eye, eyelid, head, EEG monitoring) also have limitations. Unless positive separation systems (e.g. PTC) are universally implemented, fatigue and alertness related accidents will continue to occur each year even in alerter equipped locomotives. The pre-emptive resetting feature encourages automatic repetitive responses. Simulations suggest that adding even a noisy image based eye perclos detector in tandem with conventional activity and speed criteria to reset locomotive alerter counter could reduce nuisance alerts tenfold at minor correct detection cost. Rather than using single camera to reliably detect eye closure even when head is turned or tilted, it may be technically easier to detect whether both eyes open and looking ahead pose and employ this as another activity indicator. Many labs continue to work on machine vision based human motion tracking using multiple cameras and model based estimation methods. We can expect gradual improvement in automobile image based distraction/drowsiness detectors. However, the cost-effectiveness of retrofitting image based sensors into twenty thousand US locomotives remains a significant issue. Nonetheless, in newer locomotives with software based alerters, simple logic improvements could be made that will likely reduce automatic resetting behavior at minor cost, and remaining within existing rules and standards.

Suported by DOT/FRA Contracts DTFR53-11-C-00016 and PR79-3389



# Locomotive Alerter Technology Assessment

**Charles M. Oman**

Man Vehicle Laboratory, Department of Aeronautics and Astronautics  
Massachusetts Institute of Technology  
Cambridge, MA 02139 USA

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The Future Locomotive:  
How to Manage What You Have Today With A View to the Future  
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Supported by DOT/FRA Contracts DTFR53-11-C-00016 and PR79-3389  
Conclusions are those of author, not DOT/ FRA.



Massachusetts Institute of Technology



Man Vehicle Laboratory

# Deadman Limitations



- Long used in Europe, and in US passenger locomotives, subways, streetcars, lawnmowers, snow throwers... .
- Simple type: Spring loaded pedal or throttle handle, lever or ring
  - If handle or pedal is released, power is cut and brake is applied after short delay.
  - However: drivers may slump on pedal and do not always relax in early phases of sleep.
- Three position, timed release pedal.
  - Driver holds pedal in intermediate position. Audible alarm every minute. Driver must release and depress to reset position within 3 sec or penalty braking is activated.
    - AKA: Driver's Safety Device in UK or Veille Automatique de Contrôle à Maintien d'Appui (VACMA) in France.
    - "it is a matter of pride amongst drivers that they can time the need to reset within a few seconds without causing an alarm." (UK Railway Techweb)
- Continuously holding handle or pedal is fatiguing, and changing seat position is difficult.

# Alerter basics



EMD SD70 cab console with software alerter.  
Timer reset button circled.



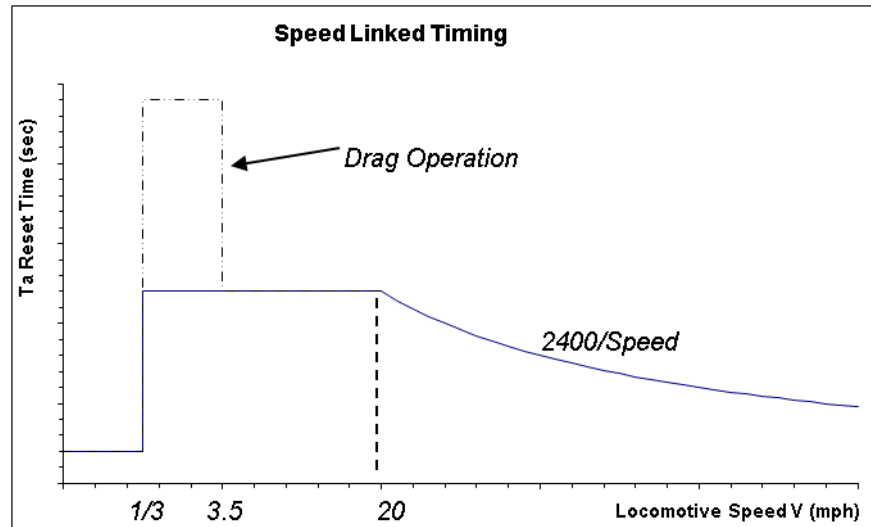
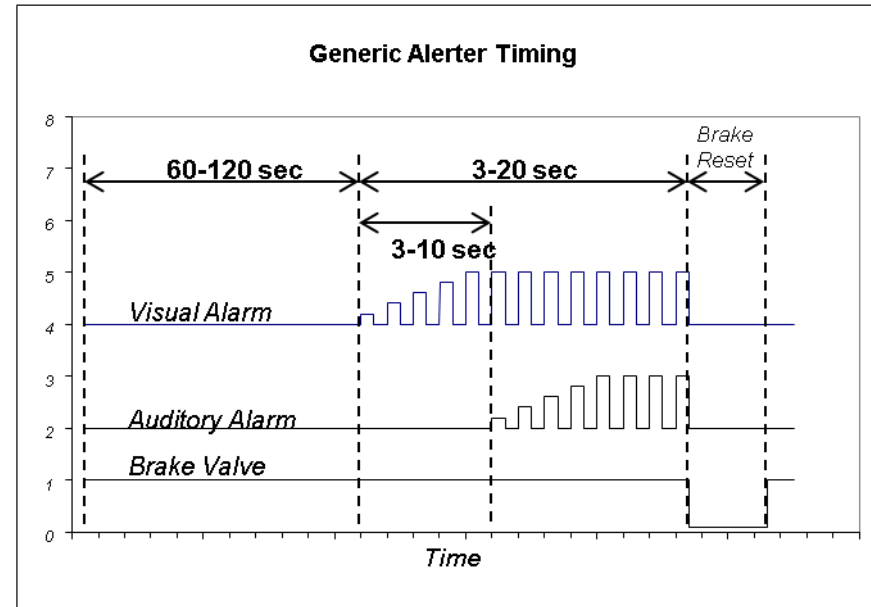
EMD F40 cab retrofit with Train Sentry III  
visual alert above forward view

- Detect operator inattention, sleepiness or incapacity without sustained physical effort.
- 60-120 sec countdown timer
- Button/lever for manual pre-emptive reset on console or stand, usually near horn or bell.
- After timeout, visual and horn alarms activate, usually successively.
- If no manual reset after alarm sequence, penalty brake and power down are initiated.
- In older equipment, visual display location varies.
- Timer duration and alarm durations were specified by customer.



# Alerter reset logic

- Time based: alert triggered every 60-120 sec if no counter reset. At 20 mph, consist travels 3500 feet. At 50 mph, almost 2 miles. >> typical stop signal overlap distance.
- Speed/distance linked timer (Westinghouse, 1961): at speeds over 20-25 mph, timer resets based on distance counter (e.g. 3500 ft).
- Activity linked timer (General Signal, 1966): any use of throttle, brakes, horn, bell, etc. also resets the timer. Reduces nuisance visual alarms.
- Drag operation switch: Timer set to 240 sec for drag operations < 3 mph. (Train Sentry III, 1989)
- Rollaway protection: preset first cycle to 10 sec when first moving off.
- Penalty brake reset time: time needed to reset brakes before moving again.



# Accidents and regulations



- 1983-1991 – Fatigue related US rail accidents, including:
  - Sullivan IN, Wiggins Valley CO, Thompsettown PA, Sugar Valley GA
- NTSB investigates, and repeatedly recommends that FRA:
  - Require alerters in all US freight and passenger locomotives.
  - Develop improved alerters that cannot be “reflexively reset”.
- 1997 - FRA decides not to invest in improved alerter development since Positive Train Separation (e.g. PTC) technologies will obviate need and market is small.
- 1999 FRA modifies 49 CFR 239 to require alerters on all US passenger trains outside cab signaled or PTS territory.
  - All freight locomotives and passenger locomotives with deadman devices built before 2003 remained exempt.
  - Promote “continuous, active attentiveness” by monitoring “select” (unspecified) operator control activities.
  - Speed linking not required.
  - Mandated audible and visual alarms, and manual preemptive reset. Timing up to operating railroad.
- Class I railroads begin to install alerters in most locomotives, and initiate fatigue management programs.





# Recent Regulatory Changes

AAR Manual of Standards and Recommended Practices  
Railway Electronics

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## LOCOMOTIVE ALERTER REQUIREMENTS

Standard  
S-5513

Adopted: November 2007

- 2007 AAR Locomotive Alerter Requirements.
    - Requires speed and activity linked alerter in all road freight locomotives built > 2009.
    - Timer reset by any of 8 activities: throttle, dynamic/automatic/independent brake, horn, bell, sander, softkeys
    - Flashing visual alert beneath speed display on operating console. 10 sec audio alert ramp in. (AAR MSRP S-591 for Operating Display)
    - Time to penalty brake numeric countdown, appearing with visual alert.
    - 120 sec timer below 20 mph, 3500 feet above 20 mph. Inop below 4 mph.
  
  - 1997-2008 Delia KS, Kelso WA, Macdona TX, Anding MS, Chatsworth CA accidents
  - 2008 - Congressional RSIA mandates interoperable PTC by 2015.
  
  - 2012 - FRA requires speed linked, activity based alerters in both passenger and freight locomotives operating > 25 mph.
    - Detect 3 or more of 6 actions: throttle, dynamic/automatic/independent brake, horn and bell.
    - Visual alert >5 sec before audio.
    - Speed linking required. Alert delay 3500 feet +/-  
No requirements for low speed features.
    - Provide manual reset capability
- Requires a pre-departure penalty braking system test.

Department of Transportation

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Federal Railroad Administration

49 CFR Parts 229 and 238

Locomotive Safety Standards; Final Rule







# How to improve current alerters ?

- FRA and AAR regulations are permissive, leaving room for improvements.
- Provide redundant visual alert displays, and adjust for ambient light.
- Be sure visual alert period long enough (> 5 sec) so busy operator has time to notice it. Make audio alert warble ramp from slow to fast.
- Install redundant control microswitches on major controls, so they function reliably. Monitor more activities (e.g. radio, touchscreen displays).
- Alerters can be a nuisance – audio alarm rate can be 30-40/hr. But alerters have low no response (i.e. false alarm) rate – only several dozen penalty brake applications occur per year in US due to inattentiveness.
- Problem sensitivity and selectivity – alerter can be slapped off by distracted (e.g. texting) driver or reflexly reset by drowsy one.
- Pre-emptive resetting feature encourages automatic operator resetting of alerter button, or throttle “notching”. Modify alerter logic to reduce operator automaticity (Haworth, 06).
  - Make pre-alarm timer interval more variable.
  - If operator pre-emptively resets timer before visual alert, lock out manual timer reset prior to visual alert on next cycle.
  - Do not initially flash visual alert - so operator must remember to look for it.
- Consider alerter a job aid. Allow operator to shorten pre alert timer cycle, or lock out pre-emptive reset.

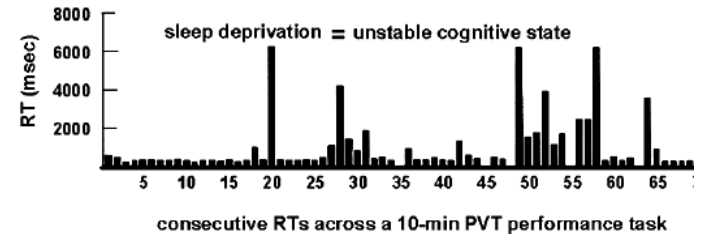




# Laboratory tests

- Response time to simple visual stimuli has scientific construct validity for assessment of mildly impaired drowsiness and cognitive function under laboratory conditions (e.g. 10 min PVT, Dinges 1985; Lim 2010 ).

However, PVT is subject's only task, and test requires 3-10 min.



- Response time to secondary task visual stimuli are frequently used to assess mental workload due to primary visual tasks and are also sensitive to fatigue in driving (Lisper, 1986) and robotics (Lowenthal, 2012) tasks. However such secondary tasks are themselves distracting, and testing also requires minutes.
- Measuring sustained eye closures (e.g. Perclos; Wierwille, 1984) or reduced eyelid reopening speed (Johns, 2005) currently appear to be the reliable non EEG methods for detecting microsleep. The challenge is to build systems which can do this reliably under operational conditions.



# Vigilance Technology

- FRA, ITSRR and RSSB initiate reviews of alerters and vigilance/drowsiness technologies: Quintec, 2002; Halcrow Pacific, 2006; Monash, 2006, ITSRR, 2006, DOT Volpe 2006, 2009.
  - Many SPaD accidents likely due to distraction, rather than fatigue. Need data on fatigue prevalence.
  - A distracted (e.g. texting) driver can simply slap off an alerter.
  - Image based percolos detectors (e.g. CoPilot) and machine vision based head pose and gaze position detectors (e.g. Facelab) are being developed for cars and trucks.
  - Some are incorporated in optional automotive fatigue detectors by e.g. Mercedes, Saab, Nissan, Toyota. Some also detect eye closure (e.g. perclos). However:
    - Most limit head pose or anthropometric operational envelope, require calibration, don't work with glasses, and have problems with stray reflections. Some require user calibration.
    - Gaze and eye closure estimates are noisy. Little data on correct/incorrect detection rate under operational conditions in auto and rail applications.



External & sunlight artifacts Dong et al 2011



# Macdona, TX (2004)



- NTSB Railroad Accident Report RAR-06/03
- 2 freight train collision @ 5:30AM; at-fault train was equipped with an alerter.
  - At-fault train did not stop to allow other train to fully enter siding.
  - NTSB report noted the engineer "... remained sufficiently alert to make train control inputs yet was unaware to respond to vitally important signal indications..."
  - Evidence suggested engineer drifted in and out of micro-sleep, while exhibiting inappropriate control activity in between episodes.
  - Conductor was probably fully asleep and alarms were not sufficient to rouse him.
- Narcoleptics, who exhibit frequent microsleep episodes, often display "Automatic Behavior Syndrome (ABS)" which typically involve the continuation of an activity that does not require extensive skill, e.g. automobile driving
  - Amnesia is a common characteristic of microsleep. "What did I do?"
  - Notion of time is "completely annihilated"

# Outlook

- Simulations suggest that adding even a noisy image based eye perclos detector in tandem with conventional activity and speed criteria to reset locomotive alerter counter could reduce alerter nuisance alerts tenfold at minor correct detection cost (Aboukhalil MIT thesis, 2005).
- Rather than using single camera to reliably detect eye closure even when head is turned or tilted, analyze for both eyes open and looking ahead pose – technically easier - and employ as another activity indicator.
- Hundreds of labs continue to work on machine vision based human motion tracking using multiple cameras and model based estimation methods. Expect gradual improvement in automobile image based distraction/drowsiness detectors.
- Regardless, cost-effectiveness of retrofitting image based sensors into 20K US locomotives remains a major barrier.
- Alerters are imperfect. They could not have prevented texting distraction accidents like Chatsworth or microsleap accidents like Macdona.
- Nonetheless, in newer locomotives with software based alerters, logic improvements could be introduced at relatively minor cost.

