Electrified Guideways: A More Realistic Vision than the "Freedom Car"

by Bruce A. McHenry SM '97

Hydrogen Hokum

While politicians of both stripes promote the hydrogen-powered "Freedom Car" as a solution to many of the ills associated with gasoline-dependent vehicles, serious automotive and aerospace engineers, acutely aware of stubborn problems involved in its development, are less optimistic. On-board hydrogen storage is highly problematic. Prototypes shown at a recent conference used either liquid hydrogen in a thermos at -420°F or gas pressurized to 90,000 psi. The vehicle with liquid storage had to "burp off" the entire tank within a week. Both approaches entail high energy costs and would inevitably result in some unplanned simulations of rocket motor firings, especially during crashes involving small vehicles. The more stable metal hydride storage might someday come down to 100lb/gallon of gasoline equivalent. Even if future scientific advances should make hydrogen containment practical, the energy input to electrolyzing water will always be considerably greater than the energy returned.

What's more, liquid hydrogen has lower energy density than gasoline or liquid natural gas largely because an energy loss is incurred when stripping the hydrogen off carbon atoms. This loss is dictated by the laws of thermodynamics and is not offset by the efficiency of hydrogen fuel cells, now approaching 60%. So it turns out that internal combustion in a hybrid vehicle will still be more efficient than a catalyst/fuel-cell combo and the Freedom Car would come at big increase in fueling expenses, especially if heavily subsidized corn derived alcohol is used. Obviously, such approaches would be of scant help in the effort to diminish the unearned dollars overflowing into terrorist coffers.

e-Guideways and Dualmode Cars

Instead, several serious entrepreneurs propose building guideways and electrifying them. While these could be powered by a variety of high efficiency approaches - including renewable sources like wind, or an

entirely new generation of meltdown proof and disposal facilitating uranium pebble based reactors - there would be many possible benefits besides cleaning the air and switching the fuel source away from oil. Separation from cross traffic, people and other animals would make it possible to greatly reduce the potential for accidents so that long, aerodynamic car-trains could be dynamically assembled under computer control. The smooth guideways would also allow harder wheels with low rolling resistance so that even 100MPH at 100MPG equivalent energy consumption may be attainable in minivan sized vehicles and without magnetic levitation. Using ultra high strength permanent magnets to suspend the cars has the potential to improve economy slightly more but, at such speeds, air friction dominates the drag forces so that any energy gains will be marginal. Magnetic levitation could be awesome in an evacuated tunnel spanning the continent as Swissmetro proposes to do for Switzerland, but we need to focus on problems that we may solve in the coming decades. Smooth guideways and streamlined car-trains will yield two to four times the running efficiency. Though hybrid-electric cars are about 25% efficient, which is a big improvement over regular internal combustion engine (ICE) car efficiency of 15%, new gas-fired electric power plants are 50% efficient. Though transmission and electric motor losses may cut the gain from 100% to 50%, the running efficiency gains will provide an overall gain of three to six times in miles per gallon equivalent. At $0.11 per kWh, the cost to travel 100 miles at 100 MPH in a mid-size vehicle would be $2 to $4 depending mostly on its aerodynamics.

Some guideway vehicles may, like public transit, only go station-to-station located at guideway exits. However, people generally demand door-to-door service so most cars would be "dualmode" and able to travel at least short distances on the road as well. Most trips are within and between metropolitan areas and could be served by dualmode cars that are 100% electric since they could be recharged directly from the guideway and would never be far from one. Also, the greatly reduced risk of higher speed accidents could favor the use of much smaller cars that, together with digitally precise (and fault tolerant) merges, could push guideway throughput beyond 500 vehicles/direction/minute, at least ten times more than a freeway lane.

A New System for Collision Prevention

Such large volume also suggests a need for an overhaul of the operational régime on city streets. In order to handle some 50 cars/minute coming off the ramps, the e-cars may be made to form short trains on the avenues. These closely packed clumps of cars known as platoons will be made possible by car-following cruise control. While this feature is available on high end cars today, it would need to be adapted so that lead cars also transmit their control inputs, permitting following distances to be less than one foot up to 35 MPH. In order to make it safe for platoons – which would involve multiple cars in collisions – the most common and dangerous kind of intersection crash must be rigorously prevented.

To prevent intersection collisions, we can invent a kind of TCAS (Traffic Alert and Collision Avoidance, now in jets) for cars. Beacons placed in order to provide reliable radio reception and relay along lines of sight would augment Global Positioning Systems in cities so that each car can continuously broadcast position, velocity and intentions. Priority may then be dynamically negotiated according to speed and traffic volume with signals made to reflect this more intelligent decision making process. Hence, traffic could bunch up into pods that move faster as they grow like drops of rain on a windowpane, but which anticipate cross traffic approaching on the streets ahead and negotiate speeds accordingly. The mandatory but inexpensive retrofits of the TCAS on older cars would merely recommend speeds and provide warnings of impending collisions, but the platooning e-cars could actually take over braking if there happened to be a vehicle around the corner heading through a red light, or if you happened to be the errant driver yourself. It is conceivable that the cost/benefit of such inexpensive electronics would be comparable to seat belts and far better than air bags and ought to be mandated. But traffic collision avoidance will be particularly necessary when cars platoon.

Platooning will allow streets to handle far more cars. But once much of the traffic diverts to the guideway, another possibility appears: dramatically reducing the speed limit in denser areas within about 10 blocks of the guideway. 10 MPH is almost 3 blocks per minute if the pace is maintained by negotiating right-of-way in advance. Densely packed, low speed but relatively short platoons will allow much more frequent opportunities for crossing while greatly reducing the risks for pedestrians and human powered vehicles (HPVs).

Benefits of a National e-Guideway Network

On a 100MPH interstate guideway network, one could go door-to-door from the Boston area to New York area in about 2.5 hours. This is as fast as taking taxis from the respective downtowns to a plane yet should cost less than bus fare, which is currently $10 from both cities' Chinatown districts. Of course, one could also depart at any time and work, play, eat and sleep comfortably during the trip. Seats that recline flat for sleeping would offer a whole new way to see and cross the country. One could hop across the USA in three nights, stopping to see friends and take in national parks along the way. People would still fly for speed but since automobiles are already a potent substitute for air travel up to 1000 miles, we can safely estimate that comfortable and driverless e-cars would substitute for at least 50% of all domestic flights.

There would be many knock-on effects. A guideway network would hugely facilitate freight by packing most of it into smaller vehicles for direct delivery to supermarkets, stores and neighborhoods. Such vehicles would quickly be fully automated, making use of both the e-guideways and the prevalence of platoons, which could be automatically joined using computer vision systems long before such systems fully take over driving. Internet retailing would be greatly facilitated but, more importantly in this author's mind, California produce could be picked ripe for a smooth one-day journey the East Coast.

There would of course be undesirable results too. Cars led to urban decay in the 1950's and 1960's as families moved away from the noise and the smog and into larger homes. Though guideways could greatly improve the quality of city life by diverting traffic from the streets and even substantially lowering speed limits in dense areas, the improvements might not offset the increased allure that the mobility gives to bigger plots of land even further from the urban cores.

e-Cars Facilitate Car Sharing and "Mass Transit"

Such e-cars under the new signaling system would almost never get into accidents. They would be far less prone to maintenance without high speed salt spray and traditional car parts like mufflers, non-regenerative brakes, transmissions, valves, fuel pumps, injection and ignition systems, all of which are prone to failure. E-cars will also be much easier to deliver to the curbside where they are needed via platoon. If cars are re-used in this manner like taxis, they will require less parking. These factors suggest that car sharing would become strongly competitive with car ownership, even for daily users.

Before providing door-to-door service, private e-cars and e-vans will ply bus routes offering much more frequent service with far fewer stops. Even subway tracks, which have a maximum capacity comparable to guideways, should eventually be converted to the technology because it offers on-demand, non-stop service. Rides that require a transfer and take 45 minutes to cover ten miles would instead take less than ten minutes.

A New Look for the Cities

Placing guideways along major avenues will have a major visual impact. They will often be elevated where riders can enjoy the view, but they will more likely evoke the sweeping steel and concrete of modern highway interchanges than the squalor of rusty steel frames supporting the mostly bygone elevated subway tracks. The guideways will be much narrower, cast small shadows and may be incorporated into landscaping. They may also go underground, through and over buildings, be hidden from street sight-lines in back alleys, and be placed inside earthen berms. The latter concept could include a parallel bikeway that would benefit from the wind created by the guideway traffic.

Since much of the traffic which formerly traveled on the street would move to the guideways, some of the grand public spaces that are now dominated by cars could be returned to pedestrians, reversing the concession made almost a century ago. If the average commuter vehicle is also smaller and able to self-park, the existing parking facilities will be used much more efficiently so that street parking may be reduced or eliminated.

e-Guideway Construction Cost Estimated at $1 Trillion
The cost is considerable and consists of 1) doubling the US electricity generating capacity (now 3.2 billion mWh) due largely to the projected popularity of traveling in e-cars (from today's 15,000 miles/vehicle/year and 3 million million passenger-miles to 30,000 miles/vehicle/year and 6 million million passenger-miles) and 2) the cost of constructing the guideways. The former can be paid off by the revenues for electricity and, interestingly, excess demand can be reduced to supply by slowing the guideways. We can only estimate the guideway cost at this time. Sextupling the estimates of the two leading entrepreneurs (RUF International and MegaRail Transportation Systems) to reach $40 million per customized metro mile, of which some 20,000 miles would be needed in addition to 40,000 miles paralleling the remaining Interstate, which might be built for only $5 million per mile, leads to a total estimate of $1 trillion.

However, this construction expense of $100 billion per year over some 10 years fits in the context of transportation related goods and services that contributed 1.047 trillion dollars to the GDP in 2001 and averaged $7800 for 109 million households ($850 billion).

Estimating the value of e-guideway benefits, such as reduced cost of freeway accidents, which - if not incalculable due to the lives saved and permanent injuries avoided - would be about $80 billion, gained productivity of time formerly spent driving ($140B), reduction of time lost to congestion ($125B), the costs saved by car sharing ($50B), reduced maintenance and increased vehicle longevity ($200B) total about $600 billion per year - without allowing for the military expense of ensuring stability in the oil producing regions. While it would be impossible and undesirable for the operators of the guideways to capture all the value in order to attempt to recoup their investments in two years, it is reassuring to know that a good case could be made for private financing of the construction - unlike almost all other "mass transit" projects.

First: A Ten-Year, $10-50 Billion Design Effort
A system to be built on a national - indeed continental and even global - scale should be designed with the utmost care. The structure of that effort ought to include adequate incentives for pioneers like Palle Jensen of RUF and Kirston Henderson of MegaRail to enter their

patents into a series of engineering bake-offs. With adequate investments and commitments from foreign, federal, state and local entities, the first functioning metropolitan e-guideway could be built on Oahu – an island with significant commuter problems but where design errors will not propagate - by about 2015.

The creation, funding and staffing of a megaproject to create designs for e-guideways and e-cars is the kind of thing that MIT alumni do, and that is why you are reading this article in What Matters. To see an evolving public domain slide show, visit www.discussIT.org or email bmchenry@alum.mit.edu.

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Images courtesy of RUF International and MegaRail Transportation Systems.

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