Lighting in North America

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Introduction

This is the third DVN report on vehicle lighting in North America (by which is meant the U.S. and Canada, though Mexico is part of North America). The first was published in 2011, the second in 2016. To maximise value to readers, each report is deliberately different; the 2016 report is not a recycled version of the 2011 report, and this new report is not the reheated leftovers from 2016. Both of the previous reports are still worth reading—much of their content and insight remains useful today.

This present report was prepared under very unusual circumstances—namely, the coronavirus pandemic which has turned the world upside-down and largely suspended business and industry. Site visits, postponed at first, eventually had to be cancelled and interviews sharply curtailed, so we can't provide much of the originally planned you-are-there reporting from the newest factories and engineering offices of the companies working in vehicle lighting on the North American continent. That content will be provided in later reports after travel and indusry resume.

Instead, this report focusses in two parts on the topography of the North American vehicle lighting world. The first part describes the environment; that involves a critical look at the legal and regulatory circumstances that keep the latest technology out of reach of American motorists—a critique presented by way of illustrating what makes the vehicle lighting ecosystem in this part of the world tick, and why it is the way it is (and why it isn't elsewise).

The second part describes the ecosystem by profiling a diverse selection of lighting-involved companies and entities doing interesting, notable things in North America. It's by no means an exhaustive industry directory, but rather is intended—like the first part—to convey some of the salient features peculiar to the American and Canadian vehicle lighting market.

This unusual report is just right for these unusual times—as we work from home, thinking of creative ways to make the best of what we have and adapting to a less-than-optimal situation, this report describes how structural constraints baked into North America's vehicle lighting environment give rise to unique strengths and innovation opportunities.

There's also industry news. A very old name, once utterly central to the American lighting industry, has exited the business in an unusual manner and been supplanted by a different very old name; we present the details in a behind-the-scenes look. There are mergers and acquisitions to talk about. Some of the high-tech innovators we've covered in past reports are still growing and going from strength to strength. There's exciting work being done in laser technology—by more than one U.S. company. The formidably capable American human factors research community carries on turning out highly relevant science. And no matter what regulatory disappointment gets handed down, the SAE Lighting Systems Group continues devising and revising technical standards for all kinds of vehicle lighting.

It's an apt time to consider the enormous amount of vehicle lighting and driver vision expertise, talent, and skill in North America.

Executive Summary

The pandemic has created a time and space appropriate for pondering broader themes than there's usually time for, so this report aims to provide the reader with a well-rounded grasp of the many points contributing to the American market's uniqueness, on both the positive and negative sides of the ledger.

An assortment of factors make the North American vehicle lighting market the world's most unusual among developed countries. The international-consensus U.N. Regulations are not recognised, which has numerous knock-on, ripple, and feedback effects: it means a a different mix of differently-configured vehicles, a different regulatory philosophy, different ways of thinking about the subject of vehicle lighting. To be sure, this particular variety of American exceptionalism—to which Canada is more or less handcuffed, by dint of geographic proximity and relative market size—creates friction, difficulties, and costs.

But it also gives rise to opportunities, strengths, and talents that would likely have a harder time thriving if the American markets weren't dancing to its own rhythm. Standardisation and modularisation, for example, which are hot topics in today's global vehicle lighting world, have a long history in America. The regulatory system invites not just frustration (though there is plenty of that) but also creative thought. The mix of benefits and drawbacks, constraints and opportunities created by the topography of the American vehicle lighting market is intricate and complex.

American human-factors study of driver vision and vehicle lighting is prodigious and consistently excellent; two of the world's foremost research institutes in the field are in the United States. American efforts in headlight performance rating are paying off in ways that raise interesting questions about the effectiveness of regulation versus market-based incentives for lighting improvement.

A North American company is a world-renowned tooler, maker, and supplier of retro-reflectors and other precision optics for vehicles all over the world. A company set amidst fields in the American Midwest makes magic with LEDs for cars, trucks, motorcycles, off-road vehicles, and spacecraft. A company headquartered in California recently added three big new factories in the United States to their existing two in Asia. And an American small business run with great dedication and passion for their speciality has come up with an elegant solution to the intractable American ADB logjam.

Part I:
The North American Vehicle Lighting Environment

North America: A Study in Contradiction

The American lighting market pivots about a fundamental contradiction: innovation manages to thrive there—in ways, at scales, and to degrees permitted by a cultural and regulatory environment that structurally discourages innovation. In this part of the report we present a detailed look at that environment and the constraints it imposes, then we present the unintuitive opportunities it presents for innovation of certain kinds and in certain places.

North America has been described as a vehicle-lighting island, with its own regulations and specs variously out of tune with the choir of the rest of the world's mainstream. It's been that way for many decades, though the situation has been getting salient enough in recent times that perhaps a more apt analogy now would be an ice floe gradually shrinking in the ocean as the global climate changes. Ongoing internationally coöperative efforts have been making the rest of the world's lighting standards progressively more uniform. More and more countries have got onside with the global U.N. standards, each nation in whatever manner is most appropriate to its own legal system, but the United States—just about alone, now—instead clings to its own unique lighting specifications and regulations.

U.S. Regulations: Boxed In and Stuck In "Park"

There is not much appetite at NHTSA, the American regulatory agency, for touching the lighting regulation, Federal Motor Vehicle Safety Standard № 108—there never has been. The U.S. Federal Motor Vehicle Safety Standards came in response to a new Congressional mandate to address the complicated problem of unacceptably high rates of motor vehicle traffic-related death, injury, and property damage. That mandate and accompanying public demand came to force very quickly, requiring fast action without affording time that would have allowed the research, development, and formulation of safety standards based on best practices. Instead, safety standards had to be adopted and promulgated in a hurry to comply with the Congressionally-mandated timeframe.

FMVSS № 108 was among the first standards to take effect. It was, by necessity, written quickly; in its original form, it was largely a codification of existing industry practice with very few new or upgraded requirements—the notable exception being the requirement for side marker lights and reflectors.

A few years later there were significant efforts toward a more thorough revisitation and revision of the requirements for vehicle lighting, based on best practices as defined by scientific knowledge rather than on a snapshot of industry practice during a certain moment in time. These efforts were not carried through to fruition, however, and although the standard has been amended from time to time, many of its requirements are still based on industry practice of the past—as evident, for example, by its references to SAE standards so long out of date that they are sometimes difficult to obtain.

So there have been very few substantial changes to FMVSS № 108 since it first took effect at the beginning of 1968, and in context that stands to reason: regulating crash-avoidance systems like lighting is fraught, resource-intensive, and messy under the American system, which requires proof of cost-benefit before an aspect of vehicle safety can be mandated. Lighting equipment creates non-events, which cannot be calculated as to their cost, making direct cost-benefit analysis very difficult. Risk analysis may not be substituted, and the US regulatory system is configured so as to pit the regulators and the regulated industry against each other in an adversarial manner, thus it is very difficult to make the requirements more stringent: the agency must prove that a proposed increase in stringency is necessary for safety—in other words, they must prove that a light considered adequate yesterday can no longer be considered adequate tomorrow—and also that the higher stringency would have positive cost-benefit.

Given that, almost without exception, a lighting configuration or performance level, once permitted, remains permitted. Turn signals other countries started rejecting as inadequate in 1959—most countries, by 1973—are still common in the U.S., and side turn signal repeaters still aren't required. The minimum acceptable low beam performance hasn't been upgraded in forty-two years, which is (literally) striking given what we now know about the inherent inadequacy of even today's best low beams.

It's not necessarily as difficult to *permit* (without requiring) new lighting technologies and techniques, but it's not necessarily easy, either, for that way lies another wall: NHTSA must be satisfied that any new device, system, or method will not *reduce* safety in any way. This is, at least nominally, one of the hurdles that stopped ADB: in 2014 NHTSA scrutinised some European-market cars equipped with ADB, and noted that some of those systems could potentially create some glare for other drivers in certain situations. That, NHTSA decided, meant the systems would introduce a new safety threat. And so was quashed certain automakers' initially hopeful attempt to declare ADB legal under the regulation as it already exists.

For another example, the maximum allowable high beam intensity in the U.S. hasn't changed since 1978, and it's a fraction of what's permitted elsewhere—industry has petitioned for an increase, and the safety research community has put forth high-quality support for that idea, but NHTSA nixes it: greater high beam intensity would require drivers to switch to low beam earlier to avoid glare, they say, and they can't force states to legislate for a longer dimming distance, so brighter high beams could potentially cause glare and so the answer is no. Never mind that everyone agrees more light is better, never mind research demonstrating drivers dim from high to low beam at a glare-appropriate distance according to the intensity rather than according to the legally prescribed distance—the answer is still no.

Regardless of whether these constraints on upgrading the lighting standard are real, contrived, or somewhere in between, NHTSA is very reluctant to change the lighting standards at all, and when they do so it's at a snail's pace. So the fruits of technological and technical evolution, generally guided by the standards used by most of the world, have increasingly been out of reach of American motorists. For instance, the best adaptive headlighting systems available in the U.S. are close to a decade (and counting!) out of date by the standards of the rest of the world.

It's worse than just lag and stall, too; as the pace of innovation has sped up, regulatory response in America seems to have actually slowed down. Here are some examples:

• NHTSA first seriously began considering the CHMSL in 1980-'81. In October 1983, FMVSS № 108 was amended to require a CHMSL on each new passenger car from 1 September 1985. So, from first consideration to the regulation being finalised was two to three years' time, and from first consideration to the regulation's effective date was four to five years' time.

• Replaceable-bulb headlamps were first seriously considered by NHTSA in 1981, and first allowed from 1 September 1983. That's a two- to three-year timeframe.

• Visual/optical aim for headlamps was first seriously considered by NHTSA in 1994-'95, and first allowed from 1 September 1998. Here again, roughly three or four years’ time from first serious consideration to first practical permission.

The latter two examples, as fundamental changes in headlamp technology proposed as allowances but not requirements, are directly comparable to today's ADB situation. But we are about a decade out from the dawn of ADB and five years on from NHTSA's scrutiny and study of European ADB-equipped cars—and all the agency has put forth so far is a proposal so technically and practically problematic as to raise serious questions of intent, with no hope of any favourable resolution in the foreseeable future.

Why Doesn't the U.S. Join the Consensus?

It's easy to see a country with its own out-of-step regulations as just being stubborn for not acknowledging the reality of global consensus and signing on alongside the 55 countries formally applying UN Regulations (plus most of the rest of the world's nations accepting the UN regulations' technical prescriptions by means other than accedence to the 1958 Agreement that is the framework for the regs). But there is much more to it than that.

Commercial and Political Reasons Why Not

Market-specific technical regulations act as a non-tariff trade barrier. From the industry standpoint, this is both a drawback and a benefit. The drawback is obvious enough: different regulations mean extra cost, no matter which strategy is pursued: extra engineering, and content and design compromises to make a lighting system that conforms to both U.S. and U.N. standards at the same time, or duplicative R&D and manufacture. Making multiple different headlamps, tail lights, etc costs more than designing, engineering, prototyping, validating, tooling, manufacturing, stocking and cataloguing, tracking, and managing just one set of lamps for use worldwide.

The industry benefit from disparate regulations is less obvious. High-level company policy within at least some North American automakers is strongly against any move toward internationalisation of the North American regulations, which can be effectively leveraged to control what vehicles can and cannot be brought onto the North American regulatory island (or ice floe). Analysis of this reality might plausibly conclude that certain segments of the North American industry are pleased to be able to exert market control by dint of trade obstacles neatly hidden in technical regulations and defended in politically unassailable terms of safety.

That might be a realistic analysis, yet there are real, practical reasons—having little to do with what test points apply to a headlamp or the presence or absence of a side turn signal repeater—why a US automaker or regulator might strive to reject internationalisation of the American regulations. It is vital for the technical sector of the community to understand why even the most thoughtfully balanced technical specification containing best practices supported by up-to-date science and knowledge might make no headway in replacing numerous older regionally-specific standards.

In today’s world, those tariffs, local-content requirements, and other market protective measures that still exist—far fewer of them than in times past—are frequent targets for elimination in the name of “free trade”. Whether there is ever really anything such as free trade is a matter for political debate beyond the scope of this report, but national and regional self-interests are still expressed in terms of protectionist sentiment, and sometimes policy. With tariffs and local-content laws out of fashion, trade restrictions and other market control measures must be enacted in other ways, and that's easiest to do if they're not so overt.

Safety regulations offer very effective camouflage for such measures: any amount of data showing drivers’ needs for lighting and signalling aren't vastly different from one country to another cn be overruled by an appeal to emotion. All it takes is someone portraying the situation as big corporations and foreign governments conspiring to increase profits by weakening American safety standards. This kind of political takedown is particularly effective even in the extremely polarised, hyperpartisan United States; it appeals to those on the right who regard non-US governments with suspicion and scorn, as well as it appeals to those on the left who see callous profiteering by every corporation. Such a torch is reliably hoisted by US groups putatively devoted to traffic safety, every time closer coöperation in international regulation is proposed. For example, the US group Advocates for Highway and Auto Safety reliably publishes press releases saying American regulations would be “subject to significant weakening” if they were adjusted to accommodate or align with international practice.

All the foregoing has been more or less the way things are in North America for many years. The situation has changed recently, but not in a manner or direction helpful to progress: the current U.S. President and his administration are very much in favour of de-regulation. If that were all, it might create a waypath for internationalisation of American vehicle lighting practice. But the administration is also very much in favour of old-fashioned protectionism—tariffs and buy-local requirements and suchlike—so that avenue is likely foreclosed. The administration is also strenuously opposed to issuing new regulations, so since it has been determined that ADB is not legal until a new version of FMVSS 108 will be issued, it's difficult to imagine any progress on that front for between one and five years, depending on the results of the next American election.

Legal Reasons Why Not

First, consider what would happen if the US were to sign the 1958 Agreement. There would surely be benefits; the hefty capabilities of the American research community and expertise of American industry would be able to take part in developing technical standards and regulations for use all over the world. But look a little closer, and it seems this benefit brings a drawback: the US, the world’s second-largest auto market after China, has a big, major auto and supplier industry, yet would have only one vote. Standards-setting bodies within the World Forum for Harmonization of Vehicle Regulations—it's GRE, for lighting—operate on a one-vote-per-country basis. That would effectively silence the US voice on most questions, and dilute its contributions to undetectable levels. Whenever US proposals and positions would differ from European and Asian practice, the relatively enormous American industry and research community would frequently be overruled by votes from countries whose collective industry, research body, and market are tiny compared to that of the United States. The Americans would justifiably feel marginalised, and this would likely spoil all hope and efforts toward cooperative merging of the U.S. into the international consensus-building body.

That alone is enough of a(nother) deal-breaker, but there are still other factors that prevent the US signing on. The mutual recognition by all signatories of each other's type approvals would create an safety enforcement and national-sovereignty problems for the United States. Every country that signs the 1958 Agreement and adopts the UN Regulations is obligated to accept (for the regulations the country applies) the type approvals of every other signatory country. This was a key structural provision of the 1958 Agreement's original intent, to enable one car configuration to be sold throughout Europe without costly and time-consuming multiple tests and approvals.

This also means a signatory USA would be obligated to accept—for instance—a type approval granted by the Turkish Government. If a safety defect were to become evident in the US, the American Government would not be able to go to the manufacturer and order the problem fixed; the manufacturer would correctly reply that the vehicle or component was type approved, and so the American Government would have to raise the issue with the Turkish Government. If the Turks were to declare the safety problem didn’t exist, or were to decline even to investigate, there would be very little the US Government could do aside from withdrawing totally from the Agreement.

Certainly there are loopholes in the American self-certification system, but there are also comparable ones in the type-approval system. In both systems, it is possible to sneak through the cracks and loopholes and go to market with a device or vehicle that doesn’t merit its certification or type-approval. But with self-certification, there is a direct line of legal responsibility—i.e., liability—between the maker or importer of a regulated item and the government. If a safety issue arises, the American Government can go directly to the maker or importer and order the problem fixed. That's an indispensable must-have for a country with a legal system such as America's.

Attempts have been made—such as the 1997 and 1998 Agreements—to figure out how to bring more countries to the table without their being forced to abandon or wrench their legal systems. For the most part, at least in lighting these efforts have not gained traction, and the 1958 Agreement is thus awkwardly the global consensus on the technical side, but unacceptable to the world's second biggest auto market on the administrative side.

Australia has a system that strikes a balance between the benefits of self-certification and the benefits of reciprocal recognition: vehicle and equipment makers must certify that their product meets the ADRs (Australian Design Rules, the Australian national vehicle safety regulations). The ADRs' technical prescriptions are kept in close synchronisation with the U.N. Regulations. Either U.N. type approval or compliance testing without a type approval is accepted as evidence of ADR compliance, but either way, the certification must still be made and accepted at the Australian Government level. So rest-of-world vehicles and components are readily saleable on the Australian market, but if the Australian government has reason to believe there's a noncompliance, they don't have to go negotiate with whatever country granted the relevant approval; they can go directly to the maker or importer about it.

But such a solution would likely be more difficult for the U.S., where the technical requirements of the national regulations differ substantially from those of the U.N. Regulations, and—unlike in Japan, where bespoke national regulations were actively brought in line with the global regs—there is little to zero interest in altering the existing American technical requirements to align with the UN Regulations. And attempting to do so is politically treacherous: impossible to "sell" and easy to torpedo—opponents would easily sink it by describing the sign-on as a relinquishment of American sovereignty and a weakening of the vehicle safety standards. No matter whether this would really be true, there are enough plausible examples to sell the case against signing: UN Regs allow dimmer turn signals, don't require side marker lights and reflectors, etc.

And the U.N. Regulations are more specific than U.S. rules in some ways—for example, dimensionally-explicit mounting prescriptions for all lighting devices rather than the U.S. "as far apart/close to the front/close to the rear as practicable" requirement. But in other ways, the U.N. regulations aren't specific enough to meet U.S. needs. U.N. Regulation 123 requires that an ADB system be given a test drive by an individual observer with the power to give the system a thumbs-up or thumbs-down. No matter how knowledgeable the observer, this is still a subjective test. U.S. law requires each Federal Motor Vehicle Safety Standard to set forth objective requirements and objective, repeatable test procedures. So that's a major incompatibility of existing U.N. Regulation content with American legal bedrock.

Furthermore, an arrangement along Australia's model would be possible only if the US were to remain largely outside of the 1958 Agreement's requirement for mutual recognition, so the US would still be frozen out of contributing to the development of the standards. That being the case, there'd be little apparent benefit to the US, so it's difficult to imagine the US being interested in pursuing such a course.

The administrative provisions of the 1958 Agreement have long been taken for granted by contracting parties, largely because in the past most all the contracting parties' perspectives and legal systems were broadly similar. Once the 1958 Agreement was opened for sign-on by non-European countries about 25 years ago, that gradually stopped being the case. Right now, the U.N. lighting regulations are undergoing a revolutionary transformation masterfully set in motion and steered by outgoing GTB President Geoff Draper; the regs are being simplified, consolidated, and streamlined to address impediments to the ease and speed of getting new technology onto the world's roads. The first phase of this effort focussed on reorganising the technical content of the regulations, and a second phase now under way has the goal of updating and harmonising the technical requirements to make them suitable for global implementation. That could, at least in theory, go a long way toward addressing the American rejection of the U.N. Regulations.

But in and of itself, globally-acceptable technical prescriptions wouldn't address the administrative incompatibilities. It remains to be seen whether the World Forum for Harmonization of Vehicle Regulations will make a successful effort to loosen the link between the technical provisions and the administrative provisions enough to pave the way for the U.S. to adopt the technical regulations while keeping their self-certification regime. That would leave space world's politicians and diplomats to hash out the legal vagaries while the lighting community's sharp minds, freed of the dead weight of legalistic administrivia, could put their expertise to work optimising the technical regulations and making them as versatile and as broadly acceptable as possible.

A Cultural Vacuum

An indolent government thwarting progress is certainly a major factor in this American regulatory isolation; even neighbouring Canada—whose regulations are generally kept in lockstep with the American rules, in deference to automakers' strong preference—finally grew tired of waiting and okayed up-to-date adaptive driving beam systems compliant with the rest-of-world U.N. standard. But regulatory intransigence is both a cause and an effect of an American culture that generally just does not care about car lights. There is no critical mass of fascination with the subject as has been found in various parts of Europe for many years, as well as Japan; has taken root and bloomed in Korea, and is showing strong signs of emergence in China.

This wasn't always the case; in the late 1930s American engineering and innovative drive thoroughly trounced the technical problems of headlighting and gave the state of the art a huge shove forward with the sealed-beam headlamp. But then it's as if Americans decided they'd perfected car lighting and saw no need of any but minor, incremental improvements to it. Very few innovations improving the performance or style of car lights have come from America; most of them come from Europe or Asia and are adopted in America—eventually and grudgingly—to the degree necessary not to interfere overmuch with prevailing industrial practices and the ability of automakers to offer their cars on the American market. So there's not much top-down leadership; American regulators and innovators put their attentions elsewhere.

For quite awhile, that really didn't make such a big problem. In 1966 when the National Traffic and Motor Vehicle Safety Act took force to enable the U.S. Government to set and administer auto safety standards, nearly 95% of new vehicles sold in the United States were made by domestic automakers. American legislators didn't have much of any incentive to think about anyone else's practices and rules, and even if they had, auto safety regulation was in its infancy worldwide. The UNECE 1958 Agreement was initially focused not on safety but on standardisation and reciprocal approval to facilitate pan-European trade. So, the U.S. regulatory system grew up in context of a domestic makers' oligopoly that no longer exists; in 2019, U.S. automakers' share of the American market was between 31% and 44%, depending on which vehicles from what makers are counted.

There's not much American bottom-up leadership, either. American car buyers and drivers don't think a lot about car lights. Sometimes they complain they can't see well enough at night, or are glared too much, but that's about it. And there's no real support for them even at that—until sometime in the 1970s, most American states required all vehicles to go through a periodic inspection including lamp function and aim, but that is almost an extinct practice now, so the lighting consciousness in America is dominated by an aftermarket mostly orientated toward making easy money on blue-tinted bulbs, poorly-made restyled lights, and technically fraudulent HID and LED retrofits. For example: one prominent bulb supplier's North American product range contains three different lines of blue-tinted fashion/style headlight bulbs and one line of high-output bulbs with colourless glass; the same maker's European product range is exactly opposite.

It's an ugly mix of circumstances: American consumers generally don't know what good lighting is or that better lighting is possible, so they don't know to demand it. There's not much in the way of pressure away from this state of affairs; though outfits like Consumer Reports and the Insurance Institute for Highway Safety have begun to publish relevant ratings and the average motorist's awareness is perhaps beginning to rise, the fact remains most Americans cannot find a shop equipped and willing to properly aim even whatever ordinary low-tech headlamps are on their car. In a DVN survey, American auto repair shops and dealership service departments were asked how they aim headlamps. The most common responses were:

- "We don't, really, but if yours are pointing different ways we can try to level them out for you",
- "We shine them on a wall 5 or 6 feet away and aim them straight ahead", and
- "Today's headlights don't need to be aimed, they set them at the factory".

Meanwhile, there are aspects of this culture throughout the non-regulatory technical standards setting community, members of which have been heard to make such pronouncements as "If European regulations are so great, why are they always changing them?", and "Fine, ADB works in Europe; good for them. We're not in Europe". It is difficult to reconcile these attitudes with reality, but nevertheless they persist.

Deprivation At Home and Abroad

So to sum up, significant innovation in vehicle lighting is not widely prized in America; there is something of a hostile, dismissive, scornful attitude toward innovations from abroad, and there is almost no regulatory pressure toward better lighting system content or performance. Those factors combine to make a very difficult environment for substantial progress in vehicle lighting. This goes beyond just depriving American motorists of the latest and best car lights, though that certainly is a central feature. Less obviously, but no less tragically, it also effectively crimps the greeater world's ability to benefit from very real American expertise. That manifests in the lack of American participation in developing and advancing lighting standards in the World Forum for Harmonization of Vehicle Regulations, of course, and it also limits the degree to which American lighting innovation finds application elsewhere in the world. For the most part, technical innovation in vehicle lighting still comes mostly from Europe and Asia.

Signs Of Vigourous Life

Nevertheless, it surely is not the case that lighting innovation is absent from North America. Quite the contrary; there are many companies in the U.S. and Canada innovating in virtually all sectors of the lighting industry. Technical innovation might be relatively little, but technological innovation is alive and well in America. And some of the world's best academic and technical studies and experiments in fields related to car lighting are done in North America. From niche suppliers to major tier-1s and tier-2s and from product development to human factors research, there is a robust, diverse, and healthy vehicle lighting industry and community.

A sturdy case can be made that the particulars and constraints of the American regulatory and cultural milieu have promoted certain American strengths in vehicle lighting. Take, for example, the adoption of the 7-inch round sealed beam headlamp for all new vehicles starting in 1940. It gave Americans an early start toward expertise in lighting standardisation and modularisation, with periodic opportunities to advance and expand that expertise by coöperating to devise and standardise new sizes, shapes, and kinds of sealed-beam headlamps. The sealed beam mandate no longer exists, but that cultural know-how (or "tribal knowledge"), honed over the years, still expresses itself with notable skill and talent. An example is found in the standardised, modular lights that predominate on commercial and heavy vehicles in America, and this expertise is now finding increasing application in the greater passenger car arena as modularisation and standardisation are actively pursued, the world over, as means to get expensive technology onto popular-price, mass-market vehicles.

Too, the American regulatory structure encourages creative experimentation, in a manner that might not be intuitive: Because it is a self-certification regime rather than one of homologation/type-approval, it is up to the vehicle or equipment maker to determine whether their product is compliant. Many technical provisions in FMVSS № 108 are vaguely defined. To draw again from a previous example, it uses language like lamps must be mounted "as far apart as practicable" (or "as close to the front of the vehicle", "as close to the rear"…) rather than dimensionally-explicit specifications for where various lights may be mounted, as found in the U.N. Regulations. Determination of practicability is left up to the maker. Plenty of other aspects of

compliance like this are also left up to the maker to determine, and NHTSA's official and practical policy is not to question an assertion of compliance unless it is "clearly erroneous".

Opposite Principle

Significantly, the fundamental regulatory principle in the U.S. is that anything not explicitly forbidden is implicitly allowed. This is directly opposite the principle that undergirds the global U.N. Regulations (anything not explicitly allowed is implicitly forbidden). This set of circumstances has naturally stimulated in industry an exploratory creativity in interpreting the regulation and its requirements, for this is the primary path by which a novel lighting device or system can be brought onto U.S. roads: by declaring it compliant under the existing regulation. In other words, it is not necessary to wait for a revised regulation (as in the U.N. system) before doing something in a new way; all that is needed is a plausible argument that the new way doesn't violate the existing regulation. This aspect of the American system countervails a tendency for etablished practice to ossify into unquestioned or exclusive practice. Unfortunately, it has its limits; as previously mentioned, automaker efforts to declare ADB legal under the existing U.S. regulation met with official defeat. So did an argument, seemingly technically sound, that European-style sequential turn signals comply with the existing regulation because their intensity ramp-up is the same as that of a bulb-type turn signal.

Market Forces Succeed

In the absence of regulatory pressure toward better vehicle lighting, various market-based influences have arisen. The Insurance Institute for Highway Safety and Consumer Reports magazine are two very influential outfits testing and grading headlight performance in the American Market. This has not (yet?) resulted in a grand awakening of American fascination with good vehicle lighting or demand for it, these non-governmental testing schemes are definitely exerting a positive effect.

Theoretically, and intuitively, regulations provide the guarantee of an adequate minimum level of lighting performance to meet the need for traffic safety. But as American regulations fall exponentially further and further behind the state of the art, that's not happening. entities like IIHS and Consumer Reports have stated, clearly and with evidentiary support, that FMVSS № 108 fails to guarantee adequate headlight performance.

That is the rationale for these non-governmental outfits' having got into headlight testing. Recent trends validate their position and their testing programs: over the four years IIHS has been testing headlights, their tests have driven significant and substantial improvements in headlight performance. in 2016, the first year of testing, only three cars got a "good" grade and just 36 got "acceptable" grades for their headlamps; 43 got "marginal" and 142 were "poor". Those figures have gradually improved—in 2019, 68 cars were found to have "good" and 103 "acceptable", though 114 were "marginal" and 183 "poor". On thirty-one 2020-model vehicles, headlamps rated "acceptable" by IIHS are the lowest-rated ones offered, which is a seven per cent increase over 2019's figure. And thirty of the tested 2020 models can only be purchased with "poor" headlamps, down from 36 in 2019's testing. Likely at least partly in response to the IIHS tests, automakers have accelerated their progress in offering good headlamps as optional equipment. In 2016 the best available headlamps on just two of the 95 tested models—2.1 per cent—earned a "good" rating. In 2020, lamps rated "good" are available on 55 of 156 evaluated models, so that figure is up to 35 per cent. These trends all point in the same direction: better headlamps are gradually becoming easier to get on more vehicle models.

Significantly, during that same timeframe there have been no changes to FMVSS № 108, nothing at all related to the regulation that could explain the measured headlighting improvements. This demonstrates that market-based incentives are currently a more effective, more efficient tool than regulations for achieving lighting improvement in the present North American context. Even NHTSA themselves tacitly acknowledged this reality; in 2015 they proposed to award NCAP points to vehicles with headlamps and turn signals better than the legally-regulated minimum. That proposal was not enacted—likely it fell victim to the current American administration's regulatory freeze and enthusiasm for de-regulation—but it is notable that NHTSA chose to pursue lighting improvements via a market incentive (NCAP) rather than by stiffening the regulations (FMVSS).

More generally, while it seems reasonable and intuitive for regulations to be periodically upgraded to require better performance as it becomes technically feasible and cost-effective, FMVSS № 108's stagnation means that's not happening, either. Here again, the non-regulatory, non-government entities have stepped up. As automakers have risen to the challenge of getting a good grade for their headlamps, IIHS has progressively raised the bar. If they were not to do so, their entire testing efforts would no longer be of benefit on either the production or consumption side of the equation; on the one hand so many vehicles would get the top grade that it would become useless as a tool for guiding consumer choices, and on the other hand there would be no incentive for makers to keep improving. Perhaps one day in the future, all cars will have good lights. But until then, unhappy traffic fatality statistics—the pedestrian death count has been rising in the United States—mean the tests must get progressively more stringent.

So as of 2020, headlights meriting a “good” or at least “acceptable” score must be *standard* equipment, not just optional on a vehicle for it to be eligible for the Top Safety Pick+ rating, which is the IIHS' highest. Fewer 2020 vehicles than 2019 models received the Top Safety Pick+ award, and IIHS says the decrease came from the more-stringent criteria for headlamps. David Zuby, IIHS' chief research officer, says "In the past, a vehicle would get the award because it has the optional, available headlights. But this year, we want to see those headlights as standard equipment. This is a good way to encourage automakers to stop equipping vehicles with crummy headlights that don’t light the road. Decent headlights should be a given, and we hope this change to our criteria will push manufacturers to make them standard across their lineups".

Similarly, automakers have been upgrading their in-house headlighting standards with the goal of getting good grades from Consumer Reports magazine, and tier-1s have been responding to those new requirements.

All in all, then, for driving improvements in vehicle lighting in America at the present time, market-based carrots and sticks are effective where regulation is not.

Driver Vision Research: An American Strength

A great deal of high quality research on driver vision and vehicle lighting happens in America. Some highlights of the American research world include:

• Dr. John Bullough, who directs transport and safety lighting programs at the Lighting Research Center (LRC) of Rensselaer Polytechnic Institute in New York state. He conducts research on vehicle and roadway lighting, traffic signs and signals, mesopic vision, glare, and other topics related to driver vision and human factors more broadly. At the U.S. National Academy of Sciences Transportation Research Board annual conference earlier this year, Bullough gave a thorough review of recent research on the safety benefits of adaptive headlighting. He described the increasingly-sturdy consensus among researchers, regulators, and industry that adaptive headlighting systems can provide real safety benefits, discussed methods of linking headlight performance to crash reductions, and emphasised that human factors data, visual performance modelling, and statistical crash analysis all converge toward aligned conclusions. This, he explained, provides ways of realistically predicting safety benefits from advanced headlights, rather than simply looking to see if benefits were realised after a system was deployed. That is especially significant because the safety effects of crash-avoidance technology like lighting and signalling are notoriously difficult to satisfactorily model, which is one reason why it is not a favourite topic of American regulators who must work within a legislative framwork that requires concrete cost/benefit calculations.

• Dr. Michael Flannagan, an expert in human vision and psychophysics. He researches the human factors of driving at UMTRI, the University of Michigan Transportation Research Institute. He was instrumental in configuring MCity, which is UMTRI's real-size mock city, and is centrally involved in its use for research into autonomous vehicle safety performance. He's also been working on analysis of crash data to assess the safety effects of advanced adaptive headlighting and night vision systems, and on field methods for testing and evaluating such systems.

Both Flannagan and Bullough are prolific researchers whose frequent publications regularly advance the state of knowledge. They and their associates and colleagues actively participate in the world's vehicle lighting and driver vision symposia (VISION, ISAL, DVN Workshops…) as well as providing scientific voice and data to the SAE Lighting Systems Group to use in devising and updating technical standards. Between the two of them, UMTRI and LRC curate what is probably the world's largest library of vehicle lighting and driver vision related research, though the UMTRI library is no longer as readily available—its contents have been moved to deep storage and can only be accessed by request in advance and by permission, though a substantial amount of the research is available online.

• Dr. Carol Flannagan, also of UMTRI, has extensive experience in vehicle crash data analysis. She’s in charge of UMTRI’s Centre for the Management of Information for Safe and Sustainable Transport, and she developed an injury outcome model that allows for direct comparison of public health-, vehicle-, roadway-, and post-crash-based safety measures. With the increasing ascendance of crash-avoidance technology, her work has come to include lighting- and vision-related research. At the TRB Annual Conference she described her work on a major UMTRI study, sponsored by General Motors, looking at the safety benefits of systems including HID headlamps, swivelling HID headlamps, and automatic high/low beam selection systems—each independently—versus ordinary halogen headlamps with manual high/low beam switching.

• The Virginia Tech Transportation Institute and the Texas Transportation Institute also serve important roles in the American research community; both institutes have extensive facilities for testing numerous aspects of the driver-vehicle-roadway-traffic system, from road markings and signs to advanced lighting, driver assistance systems, and advanced road and vehicle lighting systems.

The SAE Lighting Systems Group

A few years ago, SAE International (the Society of Automotive Engineers) upgraded the longstanding Lighting Committee to the Lighting Systems Group. This is a standards-setting body serving functions approximate to some of those of the GRE and GTB in the U.N. regulatory world. The group meets multiple times a year; meetings are open to the public. At these meetings (and between them, in teleconferences), committees and task forces work to devise and revise SAE standards, as well as recommended practices and reports. SAE standards themselves hold no force of law, except to whatever degree some or all of any particular standard might be incorporated by NHTSA or Transport Canada into MVSS 108.

Crucially, references to SAE standards are not *ambulatory*. That is, MVSS 108 does not reference an SAE standard "as amended from time to time", but rather would reference a specifically dated version of the standard. That limits industry self-regulation, but also is a major factor in the tendency of MVSS 108 to fall behind the technological and technical state of the art. Combined with the American regulators' distaste for updating the regulation, this means the regulation contains many references to SAE standards that are many years—or even decades—out of date. It's something of a conundrum: the Lighting Systems Group dependably updates each of its standards every five years, but these updated standards have no legal effect, as they are not automatically or deliberately incorporated into the regulation.

So the Group must thread a needle by identifying and elucidating technologically and technically up-to-date best practices without unduly departing from established practice or contradicting the legal regulation. Ideally the SAE standards augment MVSS 108 by describing how to meet the regulation with modern techniques while still catering for legacy methods. There are consistent efforts to harmonize the SAE standards with their counterpart U.N. Regulations, though this cannot always be done easily or smoothly.

The periodic Lighting Systems Group meetings are held in various locations, often to take advantage of nearby relevant events or facilities. The most recent meeting was scheduled for Charlotte, North Carolina, and was to have featured a demonstration of a new approach to evaluating ADB systems in a manner that could address the American legal requirement for objective, repeatable tests without getting bogged down in NHTSA's cumbersome, impracticable test protocol. More detail is presented later in this report.

Members of the Group volunteer to take on various responsibilities. The "sponsor" of a document, for example, shepherds it through the process of development or update. This includes writing or re-writing the document, initiating discussion and soliciting comments on it, preparing it for ballot (members can vote "approve" or "disapprove" and explain their votes), responding to ballot comments, revising the document, re-balloting it, and iterating this process until suitable consensus is achieved.

Group membership is open to all who wish to attend and participate, and substantially comprises engineers and compliance officers from automakers and suppliers; researchers, and consultants. One notable member of the Group is Michael Larsen, General Motors' longstanding Global Exterior Lighting Technical Lead. He chairs the Adaptive Driving Beam task force, and in that role he responded to NHTSA's request and headed a herculean effort—including leading 110 hours' worth of 34 meetings—to translate the subjective provisions of UN Regulations 48 and 123 (such as "any obvious malfunctions shall be contested") into the objective terms required of vehicle safety standards under U.S. law, while maintaining minimal divergence from the effective technical requirements of the UN regulations so as to assure the greatest possible harmonisation. The result of this effort is SAE J3069®, the SAE standard for ADB systems.

As the document sponsor, it was Larsen's responsibility to determine an appropriate philosophical approach for it. He took the position that ADB is optional, so any improvement it offers in a driver's ability to see at night is a benefit. So Larsen's task force prioritised glare control rather than seeing light performance. And while a dynamic system like ADB means thousands of different driving scenarios could be evaluated, the SAE task force worked to boil them down to the minimum count crucial to demonstrating appropriate system performance, and standardising as many aspects as possible of the testing (and of safety non-critical aspects), keeping in mind that it's not necessarily needed or beneficial to write in controls for every possible aspect of a device or system. Importantly, Larsen and the task force looked at requirements present in regulations simply by dint of inertia imparted by past practices, and pared those from their proposed standard if they weren't helpful.

Despite Larsen's and his committee's speedy, efficient diligence, NHTSA decided not to adopt J3069. Discussions and document developments are still ongoing. Meanwhile, Transport Canada accepted J3069 as one of two allowable specifications for ADB systems in Canada (the other being the UN R48/R123 systems permitted everywhere else).

Another recent activity of the SAE Lighting Systems Group has been updating the requirements for reversing lamps. The existing specifications, which have not changed in many years, have been proving inadequate to modern needs. Specifically, they don't provide a distribution of light that caters for camera-based rear vision systems—which are mandatory in America. So the Group set about coördinating research on what is needed and how to specify it. Automakers contributed by describing their in-house standards, research was conducted on the effects of reversing lamp mounting height and nearby brake lights on effective light distribution and resultant in-car display image quality, and now a new optional photometric table is being added to the SAE standard for reversing lamps.

The Group is also at work devising a technical standard for LED bulbs intended to directly replace halogen headlight bulbs ("LED H7", etc). This presents many photometric, optical, electrical, thermal, and physical challenges, but progress is being made.

Part II:
The North American Vehicle Lighting Ecosystem
Profiles of Selected North American Companies

J.W. Speaker

A 3rd-generation, family-owned, private company now in their 85th year, J.W. Speaker make high-tech lights and lamps at their expansive state-of-the-art facility in the U.S. state of Wisconsin, for a constellation of market sectors including speciality automotive; public transit; motorcycle and powersport; agriculture, material handling, and construction; and even spacefaring—the American space agency NASA has put J.W. Speaker lights on spacecraft including the Mars Rover.

The company's first high-volume product was a tiny portable can opener issued to American soldiers starting in the Second World War. Speaker's product focus shortly put down roots in the automotive realm, and lighting products became central by the early 1960s. These were generally low-cost items of conventional technology until the late 1990s, when the company made an HID headlamp for Harley-Davidson motorcycles. This was followed by some initial LED efforts, and by the early 2000s Speaker had chosen to dedicate themselves to high-tech lighting. Through constant innovation and a steady stream of new product launches, Speaker have successfully positioned themselves as one of the world's great specialist brands.

Dr. Dragan Popovic is the company's formidable Chief Technical Officer. He actively participates in DVN Workshops and other technical conferences, serves in a leadership role in the SAE Lighting Systems Group's development of motorcycle lighting standards, and takes a very hands-on, involved approach to the constant expansion of their product range and ongoing improvement of the products themselves.

Speaker pride themselves on artful achievements like self-contained adaptive lighting and tail lights that provide a U.N./U.S.-compliant yellow turn signal through a fully-red lens. The list of Speaker "firsts" is full of significant developments, including:

• First credible LED headlamp designed to replace sealed beams in the 7-inch-round format (which still has a large installed base despite dating back to 1939)

• First complete range of LED headlamps in all widely-used standard sizes—these are regularly updated to incorporate even more firsts; for example, the newest generation is the first of its kind to qualify for a top ranking on the headlamp evaluation test proposed by NHTSA for inclusion in NCAP.

• First adaptive LED motorcycle headlamps that automatically compensate for bank angle, solving the very old problem of the motorcyclist's seeing distance going to zero when turning or following a curved road. The lamp is self-contained; it requires no external hardware or sensors. It acts to fill in the void of light to the left or right of themotorcycle dynamically and in a manner so as not to cause glare or other safety hazards. The unit's advanced electronics and embedded sensors calculate bank angles in real time, automatically directing a light array angling up or down in the foreground as the motorcycle leans. This product has been the subject of several presentations at DVN Workshops, and is now in its second generation.

• First LED headlamps with integrated intelligent heaters which activate automatically when ambient conditions present a risk of lens frost-up

• First architectural (nonstandard shape/size) LED front combination lamp purpose-built for public transit buses, providing low and high beam, turn signal, DRL, and front position light functions

• First LED safety lights for warehouse vehicles such as forklifts—a brilliant, colored spot or line is projected a distance in front of the moving vehicle to warn others of safety exclusion zone

The Speaker list of firsts is still very actively growing. One recently-launched product added several items to the list, all in one go: It's the first headlamp with bluetooth connectivity and user-selectable on- and off-road modes, the first with its own smartphone app, and the first of its size format to include inbuilt turn signal and cornering light functions. It's the 7-inch round 8700 Evolution J3, and it boasts all-new optics for a substantial boost in low and high beam performance versus the previous J2 model. The beams are intense, broad, punchy, and well focused. The J3 has an appealing hook-shaped element that lights in white for the front position light, bright white for the DRL, and bright amber for the turn signal. It's available for left or (worldwide) right-hand traffic, with or without a SmartHeat™ lens.

There's on-road mode, a variety of off-road modes that add a selectable amount of extra foreground light on high beam for rock-crawling and other difficult trails, and a switchable cornering lamp to provide extra lateral illumination for slow and twisty going. There's a "guide mode" which strobes the turn signals to lead the way on trails, and a "party mode" which sets the lamp's various LEDs flashing and dancing in four selectable patterns.

While the Evo J3 is marketed primarily at owners of JK-series (2007-'18) Jeep Wranglers, it will fit any of the extremely numerous vehicles made all over the world in the last *eighty-one years* that take 7-inch round headlamps—as long as it has a 12-volt electrical system.

Along with the new lamp, Speaker have introduced their new J-Link app, available for Android and Apple iOS. It's an impressively well polished and intuitive, multifunctional app that allows the lamp's various modes to be selected. In the J-Link app, the user sets an identity for themself, their vehicle, the two headlamps, and the two JW Speaker Trail 6 Pro auxiliary lamps if the vehicle is equipped; additional drivers with their own smartphones can be added, giving the needed levels of convenience and security (so nearby unauthorised persons can't maliciously seize control of the lamps). J-Link even has an inbuilt headlamp aim assistant that works by holding up the phone, camera looking forward, while sitting in the driver seat.

The Evo J3 lamps are also remarkably slim, with a front-to-back depth of just 100.3 mm including the convexity of the lens face. They're sold as a left/right pair; the fish hook position/DRL/turn signal array is horizontally mirrored in the left vs right lamps for a pleasing installed appearance; the lamps look designed-in rather than added-on.

J.W. Speaker have recently launched a range of high-tech retrofit headlamps for heavy-duty trucks.

The lamp shown here goes directly in place of the halogen/incandescent headlamp on a popular semi-tractor model. It's a full-LED combination lamp providing low and high beam, front position and daytime running light, front and side turn signal, and side marker light and retro-reflector. All functions meet both North American MVSS and global U.N. regulations. It features a state-of-the-art high-performance Bi-LED projector (900 road lumens in low beam; 1,400 in high beam) and stylish optical blade technology for the DRL-front position-turn signal array inboard of the projector.

It's available in three models:

• Basic, as described so far
• With digital swivelling and sequential turn signal
• With digital swivelling, sequential turn signal, and laser high beam booster

Optional on all models is a high-performance SmartHeat™ lens heater with at-a-glance operation indicator. At ambient temperatures below freezing, it very rapidly raises and keeps the lens above the frost threshold.

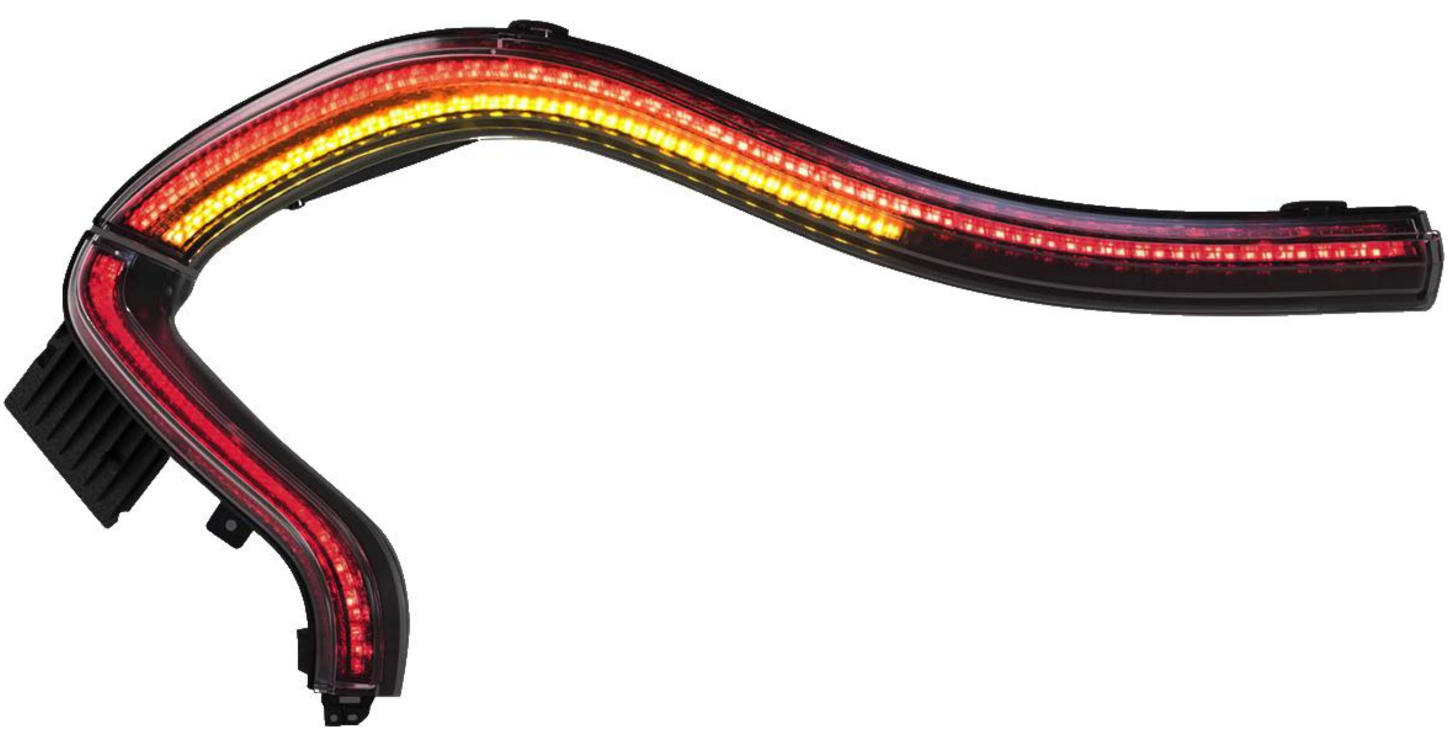
Speaker excel at finding niches that have tended to languish, in terms of technology and performance, and quickly setting about remedying that. For example, recreational and utility all-terrain vehicle drivers long had to put up with weak lighting. J.W. Speaker came along and offered stylish, rugged, high-performance LED ATV/UTV lights, and now three out of every four side-by-side ATV/UTV headlamps are supplied by Speaker.

One of Speaker's latest niche innovations is their new snow plow light: plow lights have long been clunky add-ons giving minimal performance—the opposite of what's needed in the poor visibility conditions that usually accompany the need for plowing snow—and with purely functional design. The new Speaker lamp redefines the product category. It's a solid-optics design providing extra-wide low (1,000-lumen) and high (1,500-lumen) beams, front position and daytime running lights, and front turn signal, in full-LED technology, and a rapid high-performance SmartHeat™ lens with indicator—all in a sturdy yet sleek oblong housing. Its novel feature is what Speaker call "Edge View": special optics on the sides of the headlamp light the full width of the plow blade and immediate work area for the operator's safety, comfort, and crash avoidance.

Another unserved need—quite a bit larger than a niche—is neatly filled by Speaker's new CHMSL with inbuilt high-definition camera to facilitate trailer operation and reversing manœuvres. The camera is adjustable to allow for various mounting heights, can be triggered by the vehicle's reversing light circuit, and can be used with OE displays or Speaker's own line of colour screens. Like the majority of Speaker's products, it meets all worldwide regulations.

J.W. Speaker have applied their know-how to the ever-increasing demand for modularised lighting systems. The latest additions to their range of self-contained light modules are these square and rectangular units. Shown here from left to right are work/scene lights in 4,000- and 2,000-lumen versions, a 500-lumen high beam module, and low beam (spread, 700-lumen and kink/hot spot, 250-lumen). There's also a DRL-position-turn signal module; all can be tiled or arrayed to unlock new design and performance potential in specialty vehicles.

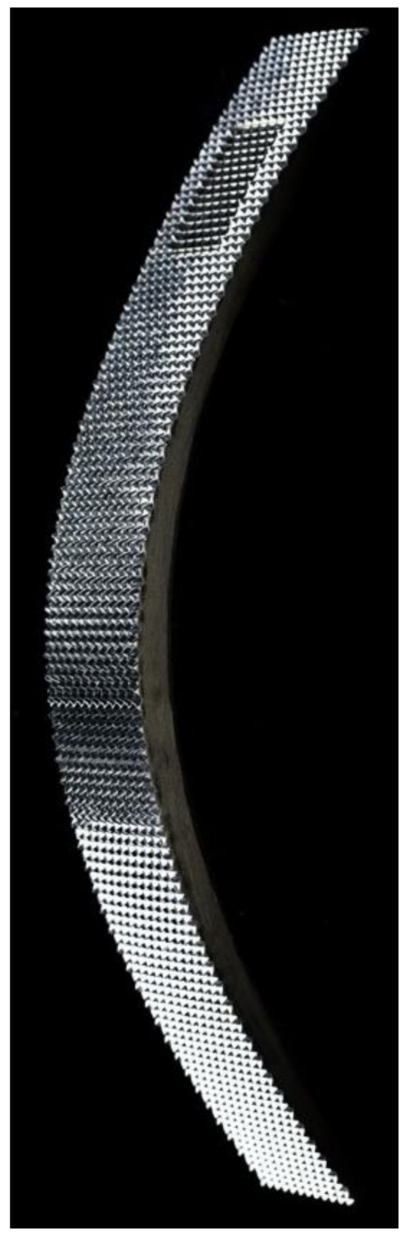
In addition to motorcycles, ATVs, trucks, buses, and commercial vehicles, J.W. Speaker make magic lights for hypercars, too. This slinky charmed-snake LED rear combination lamp engineered and made by Speaker for the McLaren P1 is worldwide approved, highly performant…and sexy!



DBM

The DBM Group, a Canadian company, got started in Quebec in 1972. Their first products were nickel needles to mould catadioptric inserts for vehicle retro-reflectors. Over the years, DBM have grown into world leaders in precision tooling and manufacture of optical components; by the early 1980s, DBM Reflex began manufacturing injection moulds for retro-reflectors, and in the late '90s DBM began designing optical systems for their customers. In 2007 they started making optical components for non-automotive companies, and later expanded that service to include automotive customers.

DBM's mainstay is vehicle lighting and signalling. There are two main activities grouped under the names DBM Reflex and DBM Optix. From DBM Reflex come moulds and tools; from DBM Optix come optical components.



The company's physical plant expanded last April, with the electroforming and plating activities moving to a well-equipped new state-of-the-art facility. Other production departments include mouldmaking and optical insert manufacturing. There's a new white room for optical machining and a metrology area for high-precison measurements on moulded optics and mould inserts.

There are also two DBM Optix sites. One is dedicated to thick lenses, silicone optics, and special products. The second plant is dedicated to light pipes and light screens. There are two photometric laboratories fully equipped to measure according to any standard or regulation. There are also three diamond machining centres, which are housed in a room with the temperature controlled to within ±0.1 °C.

DBM have developed their own optical simulation software, called SIMOPTIC, for the development of optical lenses and light guides. It's a powerful, versatile package with tools to make correlations between moulded parts and actual lab results.

SIMOPTIC and the company's expertise allow them to machine free-form surfaces with mirrored finishes—R_a up to 3.0 nm—and precison of 0.15 mm peak to valley. This same expertise is applied to make the inserts required for complex and precise optical shape moulding, as required for light pixelisation solutions. Electroforming from single mandrels, machined with great precision, is one of DBM's techniques for reproducing the surface of an original piece with nanometre-scale fidelity.

Ribs, shapes and roughness are measured on both inserts and moulded plastic parts. For this, the available equipment includes high-precision coördinate-measuring equipment, laser scanning microscopes, and contactless dot scanning for the measurements of transparent parts.

DBM's Dual-Step™ technology is one of their tools for moulding thick optical lenses in extremely short cycle times making for easy high-volume production. Thirty of the latest injection machines are on site, ranging from 100 to 650 tons and with one to three sleeves. Laser degating is used on most of the products, and artificial vision to exclude appearance flaws.

DBM can also do compression moulding, as necessary for parts with large thickness variations. Silicone optic moulding is another DBM speciality; they offer one-stop shopping: the tooling, the optical insert, and the production of moulded parts are all handled in-house.

Sapphire Technical Solutions

Sapphire Technical Solutions was founded on the drive and will of Michael Piscitelli. He saw a need going unfilled, and he set out to fix that. after years of experience as a product, software, and electrical engineer installing photometric testing systems in a variety of industries, in 2005 he decided the world needed more tailored light-measuring equipment than was generally available, so he began building custom photogoniometer systems, including his own proprietary software. By 2011, Sapphire had more than tripled their customer base, and some of those customers are very big names: since 2013, STS has served as Transport Canada's for compliance testing of lights and retro-reflectors. Late last year, NHTSA joined in—they now use STS to testing devices for conformance with FMVSS № 108 as well as FMVSS № 125 (warning devices).

Piscitelli brings his see-a-need-and-fill-it approach to the SAE Lighting Systems Group, contributing his broad and deep technical understanding and experience to improve the standards related to how lights and reflectors should work, how they can most clearly be described in the technical standards, and how the device-testing standards should be written.

And now he might very well have devised the key that unlocks the door to ADB in the USA, as well: it's called RITT, the Road Illumination Testing Trailer, and it's a self-contained portable all-in-one trailer populated with all the lights and sensors needed to imitate a car as required to test ADB systems. It serves as a test mule to imitate the front or back of a vehicle, with automated software and photometers that cover all aspects of SAE J3069 and creates the dummy lights.

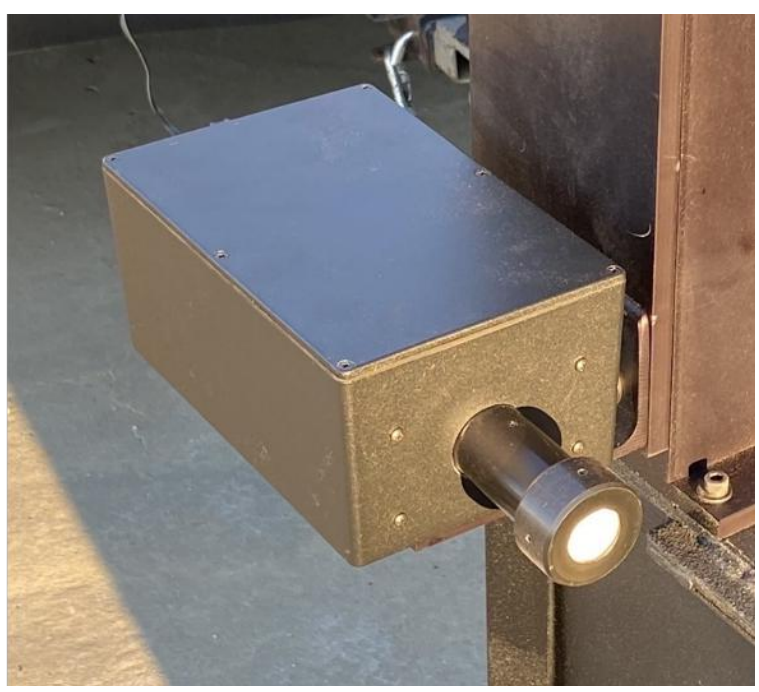
The SAE Lighting Systems Group meeting was scheduled for Charlotte, North Carolina—STS' home turf—and a venue had been rented and arrangements made for a demonstration of the system. The pandemic quashed those plans, as the meeting had to be cancelled. Piscitelli says "Our biggest concern right now is that NHTSA, while they hadn't committed to coming to the demo, they didn't say they wouldn't come. The forum was going to happen right when they're interested in testing ADB systems, and we were hoping they would get to see that this test is valid and does what they want, and can be augmented…versus their own test proposal which is just not practicable. The RITT makes for very repeatable tests, it's easy to use, doesn't take up 22 parking lots worth of space…it's a tool that you can drive out onto the course and do the test in an hour, then pack it up easily."

Piscitelli hastens to explain that the point wasn't to position STS as an exclusive source for a testing system; in fact, it was opposite: the point STS want to make to NHTSA is that an objective, repeatable, accurate and adequate ADB test doesn't need to be cumbersome or difficult. The RITT effectively replaces the subjective human observer specified in UN Regulation 123—which NHTSA can't accept—with an objective, automatic, electric observer.

It's not just a trailer with some photometers and lights thrown on—far from it. Making the RITT required methodically addressing a daunting stack of challenges. NHTSA and some automakers fretted about making ADB test lights that would dependably serve to validate ADB system performance, so Piscitelli and his team created just what was needed: lights that simulate the worst-case headlamp and worst-case tail light. These lamps were difficult to make, because the headlamp, for example, must emit 300 cd very uniformly and with very little tolerance throughout the entire specified angular range. "Make a dim light" sounds simple, but it has to be highly precise so ADB cameras won't latch onto artifacts within the test light's beam—relatively bright or dim areas—in ways that could skew the system's behaviour from what's being tested.

The RITT is versatile in terms of its configuration. Provisions are made for other kinds of light sources, so the hardware is of modular design: test lights can be removed and installed on a drop-in basis. It's not exclusively for American standards; it caters for aspects of the UN R123 test that don't appear in J3069. Piscitelli says "J3069 doesn't test ADB performance with bicyclists, but UN R123 does, and you can just drop the 'bicycle light' filter in front of one of the trailer lights and run the test." The system is highly automated—there's a remote control and a GPS unit for the driver of the test car to start the data collection and keep track of the vehicle distance to the trailer. The trailer's test lights can be activated by an assistant at the trailer itself, or remotely.

The RITT generates highly complete data and automatically formats it for easy, unambiguous interpretation, Piscitelli says, so it allows for valid performance comparisons between and across different ADB systems. This test gives conclusive apple/apple comparison of system performance. Piscitelli says the RITT could easily augment or even supplant the observer test in UN R123, which could well be of interest as the UN lighting standards undergo their modernisation, which includes a move toward objective test protocols. Whether or not that happens, the RITT solution means American automakers and tier-1s can validate a UN R123 ADB system with the trailer and pass their type approval tests on the first try.

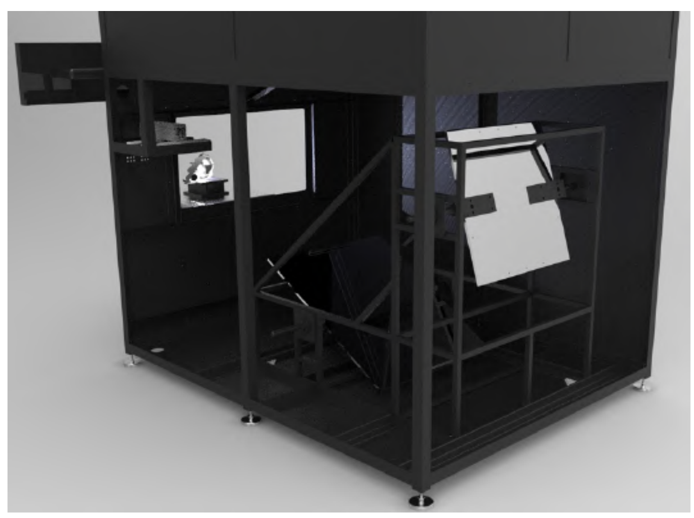


The RITT neatly solves other issues with the NHTSA test, as well. Pisciteli applied his experience in writing accurate test standards: "One of the problems is that [NHTSA's test] doesn't specify that you can't put lights and cameras on tripods. Some automakers are saying that's a problem: a tripod isn't a car; it has no bulk, no body, so why would they make their ADB system see it? The RITT imitates the metal and mass of a vehicle so a vehicle's sensor array—lidar, etc—can lock onto it as a car.

It's not a one-trick pony, either. It can just as easily perform the tests required to validate automatic high/low beam switching systems, which are increasingly in demand as headlight testing programs like IIHS' give extra credit for it.

Their newest photogoniometer, the AP-80, was released last fall as STS' largest model. It has a full turning circle diameter of 203 cm, allowing extremely large lamps to be tested without having to be cut down or measured in odd fixture positions—an important capability given the design trend towards lamps that span the entire width of a vehicle's front or back end.

Sapphire's VOA-100 camera-based photometer was impressive in the company's expo booth at the 2019 DVN US Workshop. Now they've merged the VOA-100 with their photogoniometer hardware to arrive at the VOA-200. It provides large, high-resolution beam distribution measurements taken in seconds compared to the traditional goniophotometer taking hours. A live-aiming view allows the operator to do aiming and pass/fail evaluation in real-time, compared to having to run the goniophotometer over and over after making changes to the lamp.



Their VOA-160 (above) is another camera-based photometer. It's fully portable and meant to be used in the field or at a proving ground to measure the aim parameters of forward lighting. This can help to pre-aim vehicles that are about to be used for night drives or other performance-based evaluations. And the VOA-400 (right) is a forward lighting production testing station. It has a full 7.6-metre testing distance, but only takes up a floor space of 2.4 × 1.8 metres. The software is fully automated and can allow the operator to aim lamps, or evaluate the aiming and performance of lamps on the production floor.

Then there's the BeamScaleHF software package, which can open and combine IES (photometric distribution) files from STS photogoniometers, camera-based photometers, or any other system or software that can create industry-standard IES files . The software can automatically evaluate the forward lighting performance based on the IIHS or Consumer Reports protocols or any other points that the operator might want to evaluate. Any combination of lamps can be virtually re-aimed to optimise the evaluation, and a full report is easily generated with beam distributions, calculated illuminance of the IIHS (etc) test runs over distance on straights and curves, bird’s eye / isolux plots, and more.

All STS photogoniometers are CE marked, as is Sapphire's Our VTM-100 vibration/impact test machine when used in the available sound-reduction enclosure.

SLD Laser

SLD Laser work magic with laser diode light sources. They're a spinoff from Dr. Shuji Nakamura's Soraa, who likewise work magic with white LEDs. This past January, SLD put

on a nighttime ride-and-drive demonstration adventure at an off-road vehicle trail about half an hour's drive outside of Las Vegas. At the trail facility were big and small trucks equipped with off-road lights built with SLD laser diode light sources. Attendees could get in the trucks, driven by experienced off-road race drivers, to see firsthand the performance of the lights. They're tight spotlights, in accord with one of the main strengths of the tiny, high-luminance laser diode light source. The photo here is a view from the front seat of the equipped truck, showing the spots shining on a hillside about 2.4 km away.

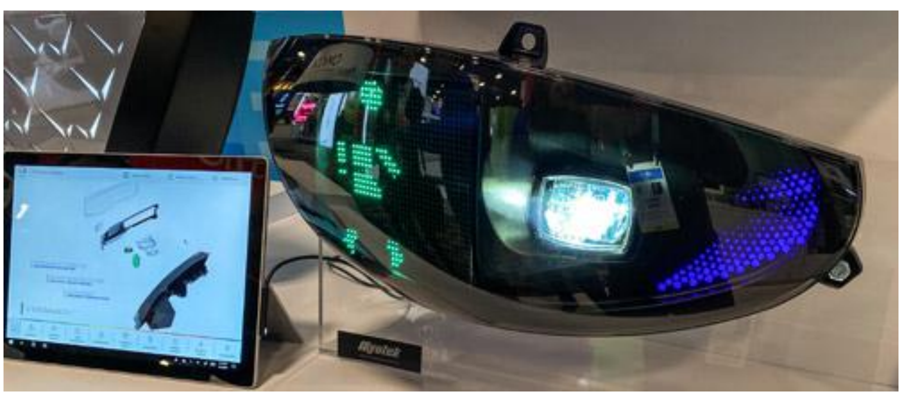
Also on scene were drones equipped with SLD technology, demonstrating ultra high intensity search light functionality, as well as handheld laser torches (flashlights).

SLD's other innovations include laser-lit light guides; laser-lit high/low beam headlamps with ADB capability, laser-lit projectors (built, for example, into the underside of a side-view mirror) giving super-sharp, high-contrast images, and high-performance laser-lit LiFi with blistering speeds of over 20 gigabytes per second at application-realistic distances of a few metres between transceivers.

Myotek

Myotek are a nimble supplier of high-tech, high-content fog lamps and other lights to U.S. and global OEMs. Their corporate headquarters and tech centre is in Irvine, California. Recently, they've added enormously to their American manufacturing footprint; aside from their factories in Taiwan and China, they now have two plants in Michigan and one in Tennessee. These three new American factories—which, like all Myotek factories, are IATF certified—comprise 20,500 m2 of manufacturing space, with facilities including:

• Low- and high-volume custom injection moulding equipment with numerous machines ranging from 75 to 1,500 tons
• Vehicle lighting and custom module assembly
• Fully automated lamp assembly, UV and thermal paint coating and curing
• Five state-of-the-art metallising machines
• Insert moulding
• Ultrasonic welding
• Foil stamping
• In-house electronics manufacturing and circuit board assembly



Over the last year, Myotek have devised their own "stimulus package" of design and technology innovation and new approaches to illumination, centred on the company's core product of fog lamps. Design and Innovation VP Robert Miller says "Light is critical for designs, and these designs must involve more functionality and purpose for the vehicle … lighting needs to be smart and provide more than just pretty looks". So Myotek decided fog lamps could play a major part in the overall design of a vehicle if they had more purpose—more functionality with sensing and pedestrian communication options to meet the needs of the nascent CASE (connected, autonomous, shared, and electric) vehicle revolution.

To that end, Myotek have developed a series of innovations for exterior and interior illumination. New concepts include fog lamps that communicate to pedestrians with icons and symbols—Myotek's pedestrian communication fog lamp using the world's first automotive qualified LED matrix array—cameras and sensing technologies, and integrated DLP light projection. Myotek have partnered with Covestro to design an EV grille integrating all the elements needed for this future market, including super slim fog lamps. The company also have developed new animated lighting approaches for automaker badging, and perfected super high resolution puddle lamp projection that portend many other applications in, on, and around the vehicle.

Tungsram

Longtime Hungarian lighting supplier Tungsram and venerable American industrial powerhouse GE has had such a long and complex affiliation with Tungsram that it's hard to keep track and trace them all, but GE bought Tungsram in 1989 when Eastern Europe was beginning to open up, then GE gradually sourced most of their automotive and miniature light bulbs to Tungsram's production lines in Hungary, then in late 2018 GE sold the remains of their vehicle lighting business to Tungsram.

Until the mid-late 1980s, GE was a major force in the American vehicle lighting industry. The sealed-beam headlamp was invented at GE, for example. Many renowned vehicle lighting engineers and researchers worked at GE, including the inimitable Bart Terburg.

But GE let the wind out of their own sales. Rick Bar is Tungsram's North American sales and marketing lead. GE gave away automotive market share, he explains; they didn't invest in new factories, tooling, or sourcing. "They were milking the product line down to extinction—that was their plan: squeeze it as much as they could and then close it down or sell it. When [Tungsram CEO] Joerg Baur bought GE Lighting back, GE threw in their American auto lighting business", because by that time GE were making virtually no vehicle lighting products in North America; it was almost all Tungsram-made product already.

So Tungsram, are effectively a startup in North America. It has startup challenges like supply chain flexibility and brand recognition. "GE vehicle lighting had a marketing budget of zero", Bar says. "Tungsram is spending close to a million dollars this year on brand recognition projects."

At the same time, they're aggressively gunning for their competitors, Sylvania and Philips. There's an enormous market for car bulbs in North America, and Tungsram are hard at work rebranding existing GE products and launching numerous new ones to compete on a 1:1, product-for-product basis. More than that, they're offering product varieties not available from the big two. LED retrofit bulbs for interior applications in a choice of 4,000K or 6,000K, for example. They're offering LED retrofit bulbs designed to replace halogen bulbs like H7, H11, and HB4—like Philips and Sylvania, they're packaging and promoting them as intended for fog lamps (with a wink and a nudge); headlight bulbs are federally regulated in the United States, but fog lamps are not. "Our engineers are really proud of those LED bulbs", says Bar.

And compared to Philips and Sylvania, Tungsram has a much more complete range of LED sealed beams. They're from Taiwan, and won the AutoCare Associations's Best New Product Award in the automotive lighting category at last year's AAPEX automotive aftermarket parts trade show in Las Vegas.

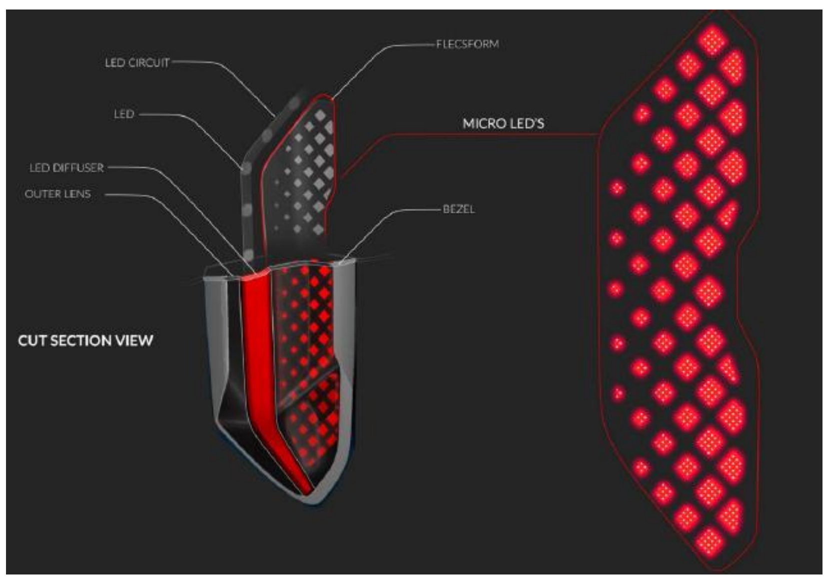
"There are challenges for a European company relaunching a major product line in North America", says Bar. "There are diferent dynamics, and we have to convince them back in Europe of what the American market is like, how it's different, how they should invest. Automotive retailers here—it's pay to play. We've got a good product and price, but we have to be willing to buy their old-brand inventory so everybody's happy".

Magna Lighting

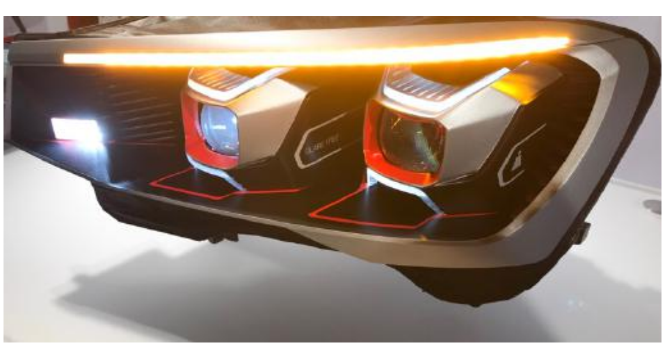
Magna International are a major global auto supplier and builder headquartered in Ontario, Canada. Over the years they have grown their lighting operations organically and by strategic acquisitions including Canadian-based lighting tier-1 Autosystems/Decoma. In 2018 Magna bought Olsa, a market leader in rear lighting technology. Then last year, Magna bought Wipac Czech, a premium vehicle lighting engineering firm located in Czechia specialised in forward lighting for premium brands including Aston Martin, Bentley, Rolls Royce, McLaren, Lamborghini, Bugatti, Audi, Daimler, BMW, and Porsche.

Late last year, Magna announced the opening of a new electronics manufacturing facility in Grand Blanc Township, Michigan. The new plant consolidates three nearby locations into a single site which occupies 21,000 m^2.

With an investment of USD $50m, Magna will be using the new facility to accelerate large-scale deployment of technologies such as ADAS, robotics, and advanced lighting. Apart from microLED vehicle lighting, Magna also are developing ADAS technology by combining cameras with other sensors such as radars and lidars crucial to AV development.



Two of their newest lighting technologies are FlecsForm and InVision. Their FlecsForm technology uses high-speed direct transfer of microLEDs onto flexible circuits to enable thinner, more efficient lighting solutions that enhance styling. Competitive advantages and differentiators are the uniform lighting in an extremely thin package, and the flexible substrate to enable complex shapes. FlecsForm also provides styling freedom for signature lighting, a robust and affordable OLED alternative, and communication display capabilities. Envisioned applications include tail, stop, rear turn signal, and reverse light functions.



Magna's InVision glare-free high beam system is a scalable matrix technology allowing unique lighting features for improved driver visibility.

InVision comes in two versions: entry-level with an 11-segment single projector, and high-performance with a 60-segment, dual projector glare-free high beam with added functionalities of virtual dynamic bending, sign de-glare, hazard detection/targeting, dynamic city/urban roadway, and more.

Interview: Cole Cunnien, Magna Lighting's Global Director of Engineering

DVN: Magna are a major worldwide supplier. What distinguishes the lighting operations in North America? Is it a competence centre for particular skills or particular techniques?

Cole Cunnien: With the acquisition of Olsa Lighting in 2018, we are now a global lighting supplier with five technical centres and 11 Plants throughout the global major markets. We have six manufacturing plants and two engineering technical centres strategically located across North America. We have just under 3,000 employees with just over 150 Design and Development team members in this region. We are proud of our multiple awards from our OEM customers. We develop and manufacture high volume exterior lighting products ranging from side reflex reflectors and cargo lamps all the way to LED headlamps and all lamps in between. Our focus is on our customers: delivery of competitive products using the latest technologies, on time, exceeding quality metrics, at a great price. Our 'secret sauce' is our transparency with our customers. Whether we are dealing with technical, commercial, or delivery issues (everyone has them) we believe open lines of communication allow us to be true partners in this challenging automotive product category. We take technology, lessons learned, and best practices from all Magna divisions and apply them to lighting where practical. The results speak for themselves as we have grown 350% in lighting sales over the past eight years.

DVN: Approximately what is Magna's market share with OEMs in the North American market?

C.C.: By volume, approximately 10% headlamps; over 12% for tail and other lamps.

DVN: What are the best lighting innovations Magna has brought out in the last few years?

CC: I'll be happy to list some for you:

• 'D-Optic' LED headlamps (photo, right) as launched on the Chevy Traverse. This modular technology allows OEMs to offer multiple performance levels and appearances without investing in unique tooling for each version.

• Bi-LED Projector with a robust 'Good' IIHS rating allowing OEMs multiple mounting height options and generous aiming tolerances.

• Two signal lighting technologies: Micro (Mini) LED Flecsform and Surface Element.

DVN: There is a sense that most suppliers have ADB systems developed and ready to roll if and when NHTSA says OK—is that the case with Magna? In your opinion, to what degree does a supplier hesitate to invest in ADB R&D because there's no certainty that NHTSA will approve it (or what the requirements will be if they do)?

C.C.: Yes, we have entry level ADB technology ready to introduce to the US market if/when regulations change. We are under development of higher end systems that this market will embrace once the benefits of ADB become a consumer expectation and more features are desired. Most Lighting suppliers are global so there should be no hesitation on investment towards ADB technology as all major markets except the U.S. allow it.

DVN: Aside from the obvious ones (more LEDs...) what trends do you see in the North American market for vehicle lighting? What's changing in terms of how OEMs approach you, and what they're asking for?

C.C.: More decoration/appearance options such as custom graining patterns for lens and bezels. Films that can provide appearance finishes, colours, and patterns that cannot be done with traditional molding processes, and allow for tool-free appearance changes. But the biggest near term trend we see is the blurring of lines of distinction between lighting and exterior body panels such as fascia, fender, grille, daylight opening, liftgate etc. Lighting just doesn't want to 'colour between the lines' any more and exist within its own traditional real estate on vehicles. We believe Magna offers OEMs full system solutions to these body part and lighting integration challenges. The Lighting and Exteriors divisions at Magna have been collaborating for some time on this and will be showing some very interesting production-ready technology that is in line with the latest concept cars. Some of the challenges here are not just technical but are systemic issues with the OEMs' vehicle planning and sourcing of the various components. We have all the technologies, manufacturing processes, logistics and relations with OEMs to transform concept vehicles into dealer showroom realities.

DVN: If you could wave a magic wand, what changes would you make to the North American vehicle lighting market? Could be anything—regulations, demand patterns, anything at all.

C.C.: Adopt ECE Regulations and 3rd party certification. Not because they are safer or I prefer them, but because they are the most adopted requirements globally and they are the most relevant to lighting technology available today. This will reduce costs for everyone in the global automotive marketplace and allow U.S. vehicles to compete globally. There are too many materials, lighting functions, and technologies available today that are forbidden from usage in US due to NHTSA regulations. This puts U.S. automakers at a disadvantage for feature and safety offerings compared to Asian and European OEMs. This would also be a win for US consumers as well.

Flex-N-Gate

Flex-N-Gate are a very large, privately-owned, diversified tier-1 supplier centred and headquartered in the USA. They make plastic and metal parts, body structure components, mechanical assemblies, and, more recently, lighting components. They are one of the only—if not the only—American-owned, American-centred, full-line vehicle lighting tier-1 supplier.

The company got started in the mid-1950s making an aftermarket livestock cage for pickup trucks, with a flexible, roll-up rear gate—it and the company alike were named Flex-N-Gate . By 1968, the company were moving into the original-equipment realm, producing bumpers for pickup trucks. In the 1990s Flex-N-Gate expanded their manufacturing operations for OEMs building cars in America. By 2012, Flex-N-Gate parts were to be found on nearly 70% of the cars and trucks sold in the United States.

The 2000s brought aggressive diversification on two simultaneous tracks: organic growth and strategic acquisition. That's when Flex-N-Gate first became involved with lighting: they bought Meridian, a manufacturer specialising in bumper fascias but who also made vehicle signal lights after their own acquisition of Lescoa. Lescoa, in turn, were a venerable (founded in 1945) maker of vehicle lights. Chrysler and GM were longtime customers, though Lescoa also made lights for such lofty OEMs as Bentley. In the final years of Lescoa's independent operations, they had a technology-sharing agreement with ZKW, had ventured successfully into headlamps, and had grown to achieve revenue of some USD $220m and 2,000 employees by the time founder Leslie Tassell sold Lescoa to Meridian in 1999. By buying Meridian, Flex-N-Gate—already supplying enormous volumes of product to American automakers—added signal lighting to their product portfolio.

Flex-N-Gate's value proposition and quality pleased their OEM customers, who bought enough lighting from Flex-N-Gate to make a noticeable boost in the supplier's fortunes, and who persistently asked for expanded lighting activities. By and by, Flex-N-Gate acted to realise that goal: in May of 2012, Flex-N-Gate arranged to purchase the lighting business of ACH (Automotive Component Holdings), a Ford-owned company that had taken on the US operations of Visteon—itself formerly a division of Ford. That purchase included plants in Sandusky (121,000 m2) and Bellevue, Ohio. Then in 2013, Flex-N-Gate put over $16m into a major lighting-centred expansion of their plastics facility near Grand Rapids, Michigan. From 2012 to 2016, Flex-N-Gate's lighting engineer count doubled.

There are extensive testing and validation facilities on site at the Sandusky and other lighting plants. Comprehensive equipment includes:

• A very large, state-of-the-art vibration and moisture test rig for complete fascia systems with lights, which enables torture-testing of front end assemblies with multi-axis vibration regimes in accord with OEM requirements—and all that shaking can be done in a wide range of climatic conditions;

• Water-spray chambers for complying with Japanese requirements;

• Thermal-cycling chambers;

• A full complement of simulation and CAE tools, also physical tools like digital scanners and specialised microscopes for close scrutiny of subcomponents and surfaces, and

• Light tunnels over 30 m long, equipped with goniophotometer systems from DVN Gold member Sapphire Technical Solutions. Flex-N-Gate are moving to standardise on Sapphire equipment across all their lighting facilities, in some cases replacing older

Hoffman systems. Sapphire can log into Flex-N-Gate's systems for easy on-the-fly assessment and advice in real time, and the equipment's connectivity also allows various Flex-N-Gate facilities to talk to one another.

Ford are a top customer for Flex-N-Gate's lights—which is only natural, given the sequence of parent companies that gave rise to Flex-N-Gate's lighting activities in the first place. Up to about 70% of the lights on Ford's North American-made vehicles presently come from Flex-N-Gate. A few notable recent Flex-N-Gate Ford lights include:

• The first-of-its-kind LED headlamp on the Ford F150 pickup truck, with thick plastic unitised optics and homogeneously-lit wraparound DRL (and then additional versions of that lamp for other Ford trucks);

• The high-content LED rear lighting systems on the Ford Taurus and Lincoln Navigator;

• The first-of-its-kind Quad Dual Beam halogen headlamp for Ford F-Series pickup trucks;

• The tail lamp family for the Ford F150 truck, which comprises numerous different variant versions;

• The Ford Edge LED tail lamps, (photo) whose beautiful design and sparkling performance DVN considered a best-in-show when the Edge was launched.

Flex-N-Gate maintain keen competencies in integration. They produce more than 90% of automotive vehicle exterior locations where production volume sensor integration is possible, and they're already a leading sensor integrator ready to meet the needs of automakers preparing for mass production. They're actively hard at work developing lighting system improvements for when autonomous vehicles are ready for consumers. They've got an animated multi-colour lit grill and emblem, for example, integrating a multifunctional ADB utilising lightweight materials, and there's a show-'n'-tell video of it **online**.

At the most recent CES in Las Vegas, Flex-N-Gate demonstrated a production intent sensor integration solution, with special attention to the competing goals of robust thermal management, minimal loss of lens intensity, wide field of view, and manufacturability. Several features equip the demonstration vehicle a headlamp with integral Ouster OS1 lidar (the screen on the wall above the truck mockup below shows what the lidar sees) and ADB functionality; animated light bars and badge lighting, and a low-mass fog lamp.

Ouster’s OS1 lidar is a multi-beam, high resolution, high reliability, compact and lightweight (<400g) flash lidar that Flex-N-Gate found easy to integrate. Headlamp lens intensity loss is minimal, thanks to an AR coating tuned to the OS1's specific wavelength, IR transparent PC, and a 10-year hardcoat (which apparently *does* exist!).
Flex-N-Gate have further cost efficiencies in mind by using a lidar heatsink specifically optimised for the headlamp.

Texas Instruments

Texas Instruments—a firm established in 1951 and long known for high quality semiconductors and integrated circuits (they were first to commercialise a silicon transistor, in 1954)—also have great expertise in projecting light. In 1987 they invented their digital light processing device, or DLP chip. Initially used in cinematic and entertainment projectors, it has come into its own as a highly practical solution for advanced vehicle headlamps. Their DLP5531-Q1 automotive chipset, with an extended high-temperature operating range and over 1.3 million micromirrors, is configured to maximise optical efficiency and enable compact system packaging. It is fully programmable and offers the highest resolution available with over a million addressable pixels per headlamp; it's used as the light engine in high-specification headlamps made by setmakers including Marelli.

It transforms headlight systems into communication channels by projecting relevant information on the road (guidance lines, image) that can enhance communication between drivers, pedestrians and other vehicles, allowing automakers and tier-1s to maximise usable intensity, minimise glare, and optimise smooth object motion.

This technology is subtractive in that micromirrors in their "off" state to control the shape of the beam *subtract* light from the overall beam. TI's position is that the net effect on total efficiency is overstated in conversations on the topic, because very little subtracting actually happens in real-world situations.

Future improvements under active development include:

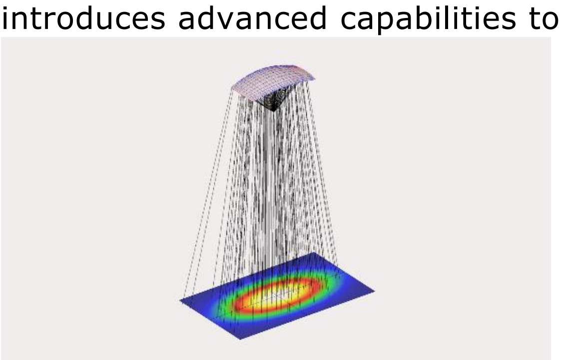
• mixing high-luminance sources and LEDs to improve low-beam efficiency: during low-beam-only operation, a majority of illuminator power is directed to the cutoff region where most of the light is needed, and the broader-coverage LEDs are operated at reduced current;

• mild segmentation of LEDs, closely optimising situational power consumption and allowing for up/down left/right source power optimization—this way, high density microLED technology is not required, a few dimming zones is enough.

Synopsys

Synopsys, the world's 15th-largest software company, support innovative companies developing electronic products and software applications. Their LightTools product is a 3D optical engineering and design software suite that supports virtual prototyping, simulation, optimisation, tolerancing, and photorealistic renderings of illumination applications.

Last Autumn, the company announced version 8.7 of their LightTools® illumination design software for the modeling, analysis, and optimising of illumination optics. LightTools 8.7 introduces advanced capabilities to help optical designers and to correct stray light issues, including ghost images and flare—early in the design process.



Designers can quickly prototype their opto-mechanical systems, explore the interactions of light with system components, and identify sources of unwanted surface interactions that impact system performance. LightTools' stray light analysis is particularly useful for improving the design of next-generation illumination optics used in space-borne telescopes, infrared optical systems, consumer electronics, autonomous vehicles, and AR/VR/MR applications.

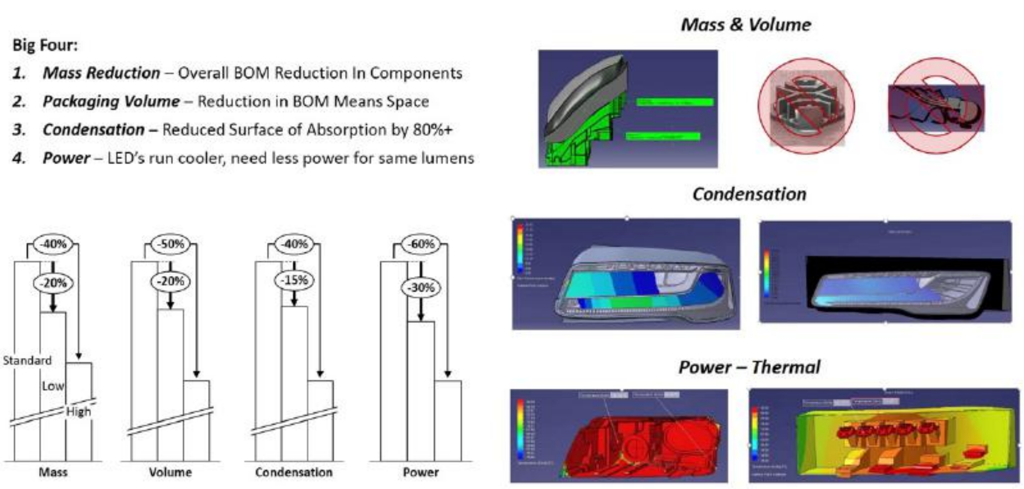
"The latest LightTools release represents a major advance in stray light analysis, with versatile features such as new scattering models to accurately simulate opto-mechanical surface characteristics and filters to identify sources of unanticipated stray light effects," said George Bayz, VP of Synopsys' Optical Solutions Group.

LightTools' unique modeling capabilities for freeform optics in illumination systems have been enhanced with design features to correct distortion caused by secondary optics, such as cover plates, turn mirrors, and projection assemblies.

Singh Vision Systems

Singh Vision Systems, headquartered in Kalamazoo, Michigan with manufacturing and engineering near Detroit in Warren, specialise in advanced structural lighting components based on thixo-moulded magnesium. Specifically, they're specialists in low- to medium-volume, mass-critical programs wherein they realise difficult new kinds of headlamps, tail lights and other signal lights, interior lighting, as well as non-automotive optics and lighting. Related services on offer include optical and thermal engineering, simulation, and design.

Singh's Michael Pickholz has decades of experience engineering and designing vehicle lighting, with strong emphasis on making advanced techniques ready for commercialisation, and particular expertise in lightweighting, integration, and simplification. He pioneered the effective application of injection-moulded thixotropic magnesium (magnesium thixomoulding) to LED lighting, where it offers enormous benefits. A thixomoulded magnesium part can serve as reflector, housing, heat sink, bracket, and stressed structural member all at once. This brings major weight, packaging, and cost savings; better performance versus separate components of whatever other material, and moisture exclusion much better than plastic, which greatly reduces condensation-management hassle and expense.



With thixo-mag technology, lamp size limitations no longer apply—which is significant and timely, in context of today's strong trends toward full-width-of-car lighting. "Plastic is too willowy; when moulded at those sizes and aspect ratios, you need a lot of stiffening ribs and supports, then you wind up with a heavy, massive, dimensionally-unstable part that will absorb moisture and aggravate condensation problems", Pickholz says. "Moisture comes through plastic, regardless of breathing/sealing strategies. That doesn't happen with thixo-mag".

All in all, the thixo-mag technology and technique Pickholz and the Singh team offer brings a healthy list of advantages:

• Magnesium is abundant on Earth (it's 8% of the planet's crust), 100% recyclable, and non-toxic.

• It's affordable. Magnesium imported to the U.S. from China is subject to a 113% import tariff, so at about USD $4/kg (including tariff), imported magnesium is more expensive than plastics in this market, but duty-free North American magnesium would drop the price to under $2/kg—more economical than plastic on a one-to-one basis.

• It's the only metal which can be injection molded—aluminium cannot—and it's structural, thus providing the ability to replicate any plastic design in metal at tenfold strength.

• Minimum wall thickness is a gossamer 0.5 mm, compared to the much bulkier 2.5 mm practical minimum of plastics. For a given design, a magnesium lamp housing can reduce mass by at least 40 per cent versus plastic.

• Design simplification: other materials need added-on heat sinks to properly cool LEDs and electronics inside the housing. Magnesium's high thermal conductivity means the housing itself becomes the heat sink. This lowers complexity, tooling, assembly, and piece costs.

• Dimensional stability—thixomoulded magnesium is far more dimensionally stable than injection moulded plastics or die-cast metal.

• Net shape moulding eliminates machining operations. Like plastics, Thixomolding yields a ready-to-use part requiring no further machining.

In the past, thixo-mag technology was constrained to smaller parts, but that's no longer so, as evidenced by thixo-mag spare-tire carriers on the current Jeep Wrangler and forthcoming Ford Bronco—and it's impossible to avoid the natural close comparison of the size of these carriers to that of a large headlamp.

Pickholz says "The new 3-function Ford F150 fog/DRL/cornering lamp is an excellent example; the more complex the lamp, the greater the benefits due to the superior cooling. This lamp has three separate PCBs, one for each lighting feature, due to thermal issues. We can certainly bring it down to two, and likely to only one, for a significant cost reduction. Mass will of course be lower as well, with no decrease in functionality; in fact we will likely decrease the power consumption by keeping the LEDs substantially cooler.

Sea Link International

Sea Link International are a tier-2 specialist in aluminum and magnesium casting, magnesium thixomoulding, plastic injection moulding, reflector manufacturing, metallization, stampings, and integrated subassemblies. They have particular expertise in design for manufacturing and in the vehicle lighting industry as a whole.

The company were early to the U.S. market with bulb shields for halogen lamps, starting not long after the sealed beam mandate ended in the mid-1980s; their diligence in building know-how had them taking a leadership role in devising best practices in the bulb shield sector. Over the years they've expanded their expertise. Current areas of excellence include:

• Unitary headlight bracket-heat sink assemblies, which provide superior thermal and vibration properties while serving as a sturdy structural carrier for the components inside the headlamp. Sea Link say magnesium can reduce heat sink and bracket weights by 33 to 50 per cent versus aluminum, as well as reducing complexity and tolerance stack-ups and facilitating single-tool manufacture.

• Thixo-moulded magnesium structures ranging from a small optical spacer bracket for a 90-LED matrix beam system to large support brackets. Advantages over other materials and processes include thin-wall capabilities, tighter tolerances versus castings, ready integration of complex integrated features, and reduced tooling costs.

• Heat sinks with top-mount LEDs (i.e., LEDs mounted directly to the heat sink). This strategy is generating interest in the tier-1 setmaker community, and Sea Link already have a top-mount design in production for a major OEM headlamp program. Meanwhile, they are evaluating a variety of designs to optimise performance and manufacturability, and to closely quantify real system costs.

• Stampings—Sea Link still make bulb shields in huge variety and great volume for numerous different halogen headlamps.

• Infotainment system components, as a new application area for thixo-moulded magnesium brackets, back covers, and support plates. As automakers increase the size of the navigation and entertainment screens in vehicles, the need for superior structure and thermal dissipation also increases. Thixo-moulded magnesium facilitates large designs with integral heat sinks, thin walls, and complex mounting and interface featurs. Sea Link will launch several Infotainment projects over the next year and expect the demand for thixo-moulded magnesium to increase in this sector.

List of DVN Gold Members

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Honda
Hyundai Motor
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Mitsubishi
NBHX Trim
Novem
Osram
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Recticel
Sensata
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Valeo
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Bee Lighing
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Farba
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Grakon,
Grote
Hascovision
Hella
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Darmstadt university
DEKRA laboratory
Franhofer FEP
Fudan university
GranStudio
Hannover Leibniz
University (HOT)
Institut d'Optique
Karlsruhe Lighting
Institute
LAB
Light Sight Safety
Nuremberg university
Pacific Insight
Parma university
Rensselaer university
SLD Laser
UMTRI
University of California,
Santa Barbara
YoungNam University
Mr Shunxing Wang

Lighting Suppliers

3M
A2Mac1
AML Systems
Aspöck Systems
ASYST Technologies
Auer-Lighting
Bicomoptics
Bühler Alzenau
Covestro
Dajac
DBM Reflex
Delvis
DesignLED
Docter Optics
EcoGlass
Elmos
Enmech-Mektec
GXC Coatings
Holophane
IMS
Infineon
Inova Semiconductors
Instrument Systems
Jenoptik
Keboda
Less
LMT
Luminit
Luminus
Lumitex
Maxell Joei Tech
Mentor Graphics
Mitsubishi Electric
Myotek Industries
Nalux
NXP
ON Semiconductor
Optoflux
Panasonic
Proper Group
Red Spot
Sabic
Sapphire
Sea Link International
Synopsys
TechnoTeam
Texas Instruments
TQ Technology
Weidplas CH
WL Gore
Zollner

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