STOP ARM EFFICACY PILOT STUDY

IMPACT OF FULLY ILLUMINATING THE STOP OCTAGON

First Light Safety Products - November 2023

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Traditional retroreflective stop arm

First Light's fully illuminated stop arm

INTRODUCTION

Over half of the 49 million children attending public elementary and secondary schools in the United States are transported to and from school every day via a school bus [1]. School buses have proven to be the safest mode of transportation for children traveling to school; with less than 1% of all annual traffic fatalities involving children on school transportation vehicles. Nevertheless, this still equates to an average of 113 school bus related fatalities and thousands of injuries every year [2][3]. Concerted and continual efforts to improve school bus safety need to be made, because this number represents the "well-being of school children and because each fatality and injury involving them is particularly tragic" - NHTSA [4].

Being inside the school bus has proven to be the safest mode of transportation for children. Only 10% of all school bus related deaths affect passengers while riding on the bus. When a school bus collides with another vehicle, by far the highest percentage of deaths are occupants of the other vehicles [2]. **The greatest safety risk to child school bus riders is when they are outside the school bus–**63% of all child school bus related fatalities between 2010 and 2019 happened when another vehicle struck the child when they were outside the bus. The past decade showed the highest percentage of fatalities caused by another vehicle while outside the school bus since capturing this type of data began in 1970 [5]. These instances are often directly related to the illegal passing of a stopped school bus [5]. School buses are equipped with amber and red flashing lights and stop arms to promote proper behavior by drivers encountering a school bus in the act of loading or unloading child passengers, which is to stop and stay stopped until the bus retracts the stop arm and continues its route.

In 1991, Federal Motor Vehicle Safety Standards (FMVSS) 131 defined the stop signal arm's (commonly referred to as a stop arm) purpose as a device is "to reduce the risk to pedestrians near stopped school buses" [6]. In 2023, National Association of State Directors of Pupil Transportation Services (NASDPTS) reported a minimum of 43.5 million illegal passings of stopped school buses occurring in the United States, an increase from the 41.8 million reported in 2022 [7]. School bus stop arms share a similar purpose as traffic lights and traffic signals, which are defined as "signaling devices positioned at road intersections, pedestrian crossings, and other locations in order to control the flows of traffic" [8]. Aspects of a traffic control device are: fulfill a need, command attention, convey a clear and simple meaning, command respect from road users and give adequate time for proper response [8].

All traffic lights and signals are illuminated to ensure they are highly visible day or night. By contrast, traditional stop arms are not illuminated except for the two flashing lights, and are reliant on the headlights from oncoming vehicles to retroreflect off the decal and provide a signal. Studies have found that by adding a red LED to static stop signs on each of the eight points of its octagon, "blow-throughs" can be reduced by over half. This example provides support for the conclusion that illumination is superior over retroreflectivity in prompting a reaction by motorists' to the warning [9]. School bus stop arms, traffic lights, and signals are intended to perform the same function – to control the flows of traffic and enable safe pedestrian crossing. Over the last 25 years, however, there has been very little required changes to improve the visibility of the school bus stop signal arm. In particular, stop arms are not required to be illuminated, despite reports suggesting the benefits of illumination over retroreflectivity. In comparing the school bus to other critical vehicles on the road and referencing their lighting enhancements over the years, police vehicles can be referenced. By improving the lights on police cars within the past 20 years, officers are now safer from incidents involving passing motorists presumably because the motorists can better react to the stopped vehicle [10]. One can infer that by enhancing illumination of critical safety signage on school buses, this can also have a huge impact on keeping children safe.

By fully illuminating the stop arm octagon, which includes the white border, the word STOP, and the red backdrop [Figure 1], through an internal illumination device and diffusion panel, First Light updated the technology of the stop arm to elevate it to a level consistent with traffic signals and lights. The full

Comparison: traditional stop arm (left) vs. First Light's fully illuminated stop arm (right) in low light

illumination of the octagon increases the visibility of the word STOP on the stop arm both day and night and across a variety of atmospheric conditions and eliminates the variability in the signal an oncoming driver sees due to headlight differences and the position of the oncoming vehicle.

Despite recognition of illegal passings of school buses being an epidemic and the greatest danger to children being outside the bus, little data can be found on a proactive solution to make a measurable improvement to the problem. With dedication to the pupil transportation industry, First Light took on the task of funding this efficacy pilot study to gather information on whether fully illuminating the octagon of the stop sign made it more effective at preventing illegal passings than traditional retroreflective stop arms.

Figure 1 *- First Light's stop arm illumination features*

METHODS

Data captured by the 15 school districts in the study was independent of First Light. Each district was responsible for counting the number of stop arm violations by varying one key factor – which type of stop arm was used: First Light's fully illuminated stop arm or the traditional stop arm. All districts used a traditional metal blade stop arm for a set period of their choosing, and then replaced it with First Light's fully illuminated stop arm for a similar period of time to make the comparison. School districts either tracked violations through camera systems or drivers' reports. Certain school districts utilized a tracking sheet modeled after the NASDPTS 1 day stop arm violation survey [Figure 2]. First Light did not witness or influence the collection of data and was not involved in the recording of data. Nine of the 15 sites were also able to provide one or more comparison buses with traditional stop arms for the entire recording period. This helped identify any natural increase or decrease in stop arm violations experienced in the area to better understand the data patterns observed with the First Light technology. It must be noted that no attempt was made to match the routes across participating districts or control for variables such as traffic density, road type, or terrain, so each is essentially a case study.

RESULTS

Comparison Sample: By having comparison buses at select school districts that did not receive a fully illuminated stop arm and tested under the same parameters, it was possible to account for any natural increases or decreases in safety experienced in the area throughout the study period. Within the nine school districts that were able to provide this comparison data, seven of the nine comparison buses with traditional stop arms experienced either no change or an actual increase in illegal passings. This suggests that there was no systemic overall change in violation rates that might have been caused by general factors such as increased enforcement or a national media campaign.

Study Highlights: Fourteen of the 15 school districts reported operationally meaningful reductions in stop arm violations with First Light's fully illuminated stop arms. Fourteen of the 15 districts showed a decrease in violation rate (violations per school day of bus operation). One district showed a small increase of 15%. In the other 14 districts, violation reduction rates varied from 14% to 100%, with a median of 60%. One district showed a complete eradication of violations with 100% reduction. Where data was available to analyze special circumstances, the fully illuminated stop arm showed uniformly exceptional performance. For example, of those reporting reductions in violations on 2-lane roads, there was an average of 56% reduction. **On multi-lane highways, there was an average of 28% reduction. During low light periods, illegal passings reduced by an average of 73%.**

A subset of school districts reported whether their pick-ups/drop-offs occurred during daylight. This was to understand the effectiveness of the technology in low light conditions. Of the nine school districts that reported lighting conditions, seven picked-up and/or dropped-off during low light conditions. 100% of the buses utilizing First Light's fully illuminated stop arm saw a reduction in violations in low light conditions. In contrast, the comparison buses viewed at these same sites actually showed an increase in violations.

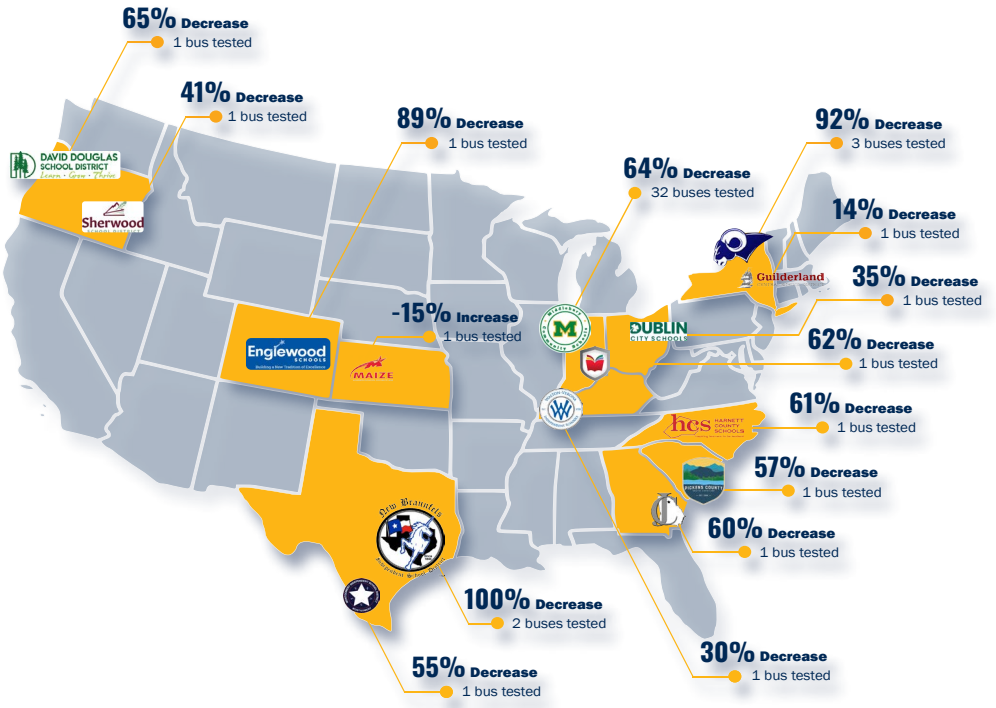
Increased visibility in low light conditions by fully illuminating the stop octagon

DATA TABLE RESULTS FROM SCHOOL DISTRICTS

Test Buses - Traditional Retroreflective Stop Arms vs. First Light's Fully Illuminated Stop Arms

				TRADITIONAL RETROREFLECTIVE STOP ARM			FIRST LIGHT'S FULLY ILLUMINATED STOP ARM			
SCHOOL DISTRICT	STATE	NUMBER OF BUSES	VIOLATION DATA SOURCE	BASELINE VIOLATIONS	SCHOOL DAYS W/TRACKING	BASELINE VIOLATIONS	TEST PERIOD	SCHOOL DAYS W/ TRACKING	TEST PERIOD VIOLATIONS	VIOLATION REDUCTION RATE
New Braunfels Independent School District	TX	2	Driver Report	01/11/2021 to 31/03/2022	87	47	01/11/2022 to 31/03/2023	87	0	↓ 100.0%
Bath Central School District	NY	3	Stop Arm Camera	07/09/2021 to 22/12/2022	73	38	06/09/2022 to 21/12/2022	73	3	↓ 92.1%
Englewood Schools	CO	1	Driver Report	01/02/2023 to 30/03/2023	33	28	04/04/2023 to 23/05/2023	33	3	↓ 89.3%
Bath Central School District	NY	3	Stop Arm Camera	07/09/2021 to 22/12/2022	73	38	04/01/2022 to 24/04/2022	73	6	↓ 84.2%
David Douglas School District	OR	1	Driver Report	01/02/2023 to 24/03/2023	35	278	03/04/2023 to 25/05/2023	35	97	↓ 65.1%
Middlebury Community School District	IN	32	Driver Report	19/10/2020 to 14/12/2020	37	22	17/10/2021 to 10/12/2021	37	8	↓ 63.6%
Dekalb County Central United School District	IN	1	Driver Report	01/02/2023 to 24/03/2023	37	8	03/04/2023 to 23/05/2023	37	3	↓ 62.5%
Harnett County Schools	NC	1	Stop Arm Camera	11/02/2021 to 21/03/2021	25	43	22/03/2022 to 31/04/2022	25	17	↓ 60.5%
Jackson County School District	GA	1	Driver Report	01/02/2023 to 27/03/2023	32	25	10/04/2023 to 23/05/2023	32	10	↓ 60.0%
Pickens County School District	SC	1	Driver Report	01/03/2022 to 29/04/2022	40	7	01/05/2022 to 31/08/2022	40	3	↓ 57.1%
Montgomery Independent School District	TX	1	Driver Report	01/02/2023 to 28/02/2023	20	11	03/04/2023 to 28/04/2023	20	5	↓ 54.5%
Sherwood School District	OR	1	Driver Report	01/02/2023 to 23/03/2023	37	143	03/04/2023 to 23/05/2023	37	84	↓ 41.3%
Dublin City Schools	OH	1	Driver Report	01/02/2023 to 31/03/2023	35	54	04/04/2023 to 24/05/2023	35	35	↓ 35.2%
Walton Verona Independent Schools	KY	1	Driver Report	13/03/2023 to 31/03/2023	15	27	10/04/2023 to 28/04/2023	15	19	↓ 29.6%
Guilderland Central School District	NY	1	Driver Report	01/02/2023 to 31/03/2023	36	177	03/04/2023 to 31/05/2023	36	152	↓ 14.1%
Maize Unified School District	KS	1	Driver Report	01/02/2023 to 31/03/2023	32	99	04/04/2023 to 25/05/2023	32	114	↑ -15.2%

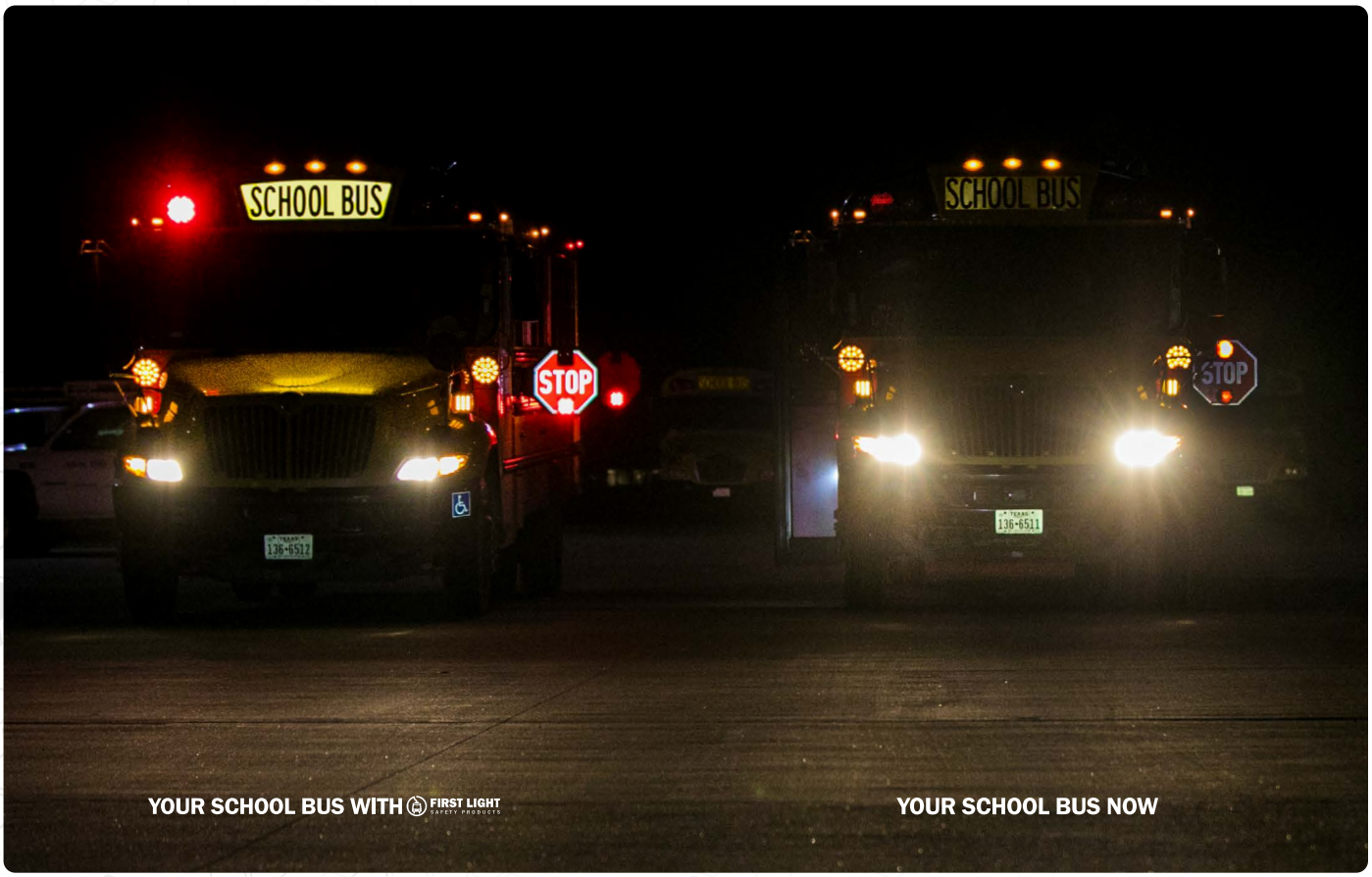
Analysis of the study data shows a reduction of violations of 60.2%. By contrast, the comparison buses experienced a median increase of 12.2%, indicating **First Light's fully illuminated stop arms were 72.4% more effective at preventing stop arm violations.**



First Light's fully illuminated stop arm data map results from school districts

Comparison Buses - Traditional Retroreflective Stop Arms

				TRADITIONAL RETROREFLECTIVE STOP ARM						
SCHOOL DISTRICT	STATE	NUMBER OF BUSES	VIOLATION DATA SOURCE	BASELINE VIOLATIONS	SCHOOL DAYS W/ TRACKING	BASELINE VIOLATIONS	TEST PERIOD	SCHOOL DAYS W/ TRACKING	TEST PERIOD VIOLATIONS	VIOLATION REDUCTION RATE
Montgomery Independent School District	TX	1	Driver Reported: First Light Tracking Sheet	01/02/2023 to 28/02/2023	20	9	03/04/2023 to 28/04/2023	20	14	↑ -55.6%
David Douglas School District	OR	1		01/02/2023 to 24/03/2023	35	32	03/04/2023 to 25/05/2023	35	45	↑ -40.6%
Englewood Schools	CO	1		01/02/2023 to 30/03/2023	33	23	04/04/2023 to 23/05/2023	33	27	↑ -17.4%
Maize Unified School District	KS	1		01/02/2023 to 31/03/2023	32	71	04/04/2023 to 25/05/2023	32	81	↑ -14.1%
Sherwood School District	OR	1		01/02/2023 to 23/03/2023	37	82	03/04/2023 to 23/05/2023	37	92	↑ -12.2%
Jackson County School District	GA	1		01/02/2023 to 27/03/2023	32	15	10/04/2023 to 23/05/2023	32	15	0.0%
Dublin City Schools	OH	1		01/02/2023 to 31/03/2023	35	98	04/04/2023 to 24/05/2023	35	98	0.0%
Guilderland Central School District	NY	1		01/02/2023 to 31/03/2023	36	183	03/04/2023 to 31/05/2023	36	142	↓ 22.4%
Dekalb County Central United School District	IN	1		01/02/2023 to 24/03/2023	37	25	03/04/2023 to 23/05/2023	37	5	↓ 80.0%



Comparison of First Light's fully illuminated stop arm vs. traditional retroreflective stop arm

CONCLUSIONS

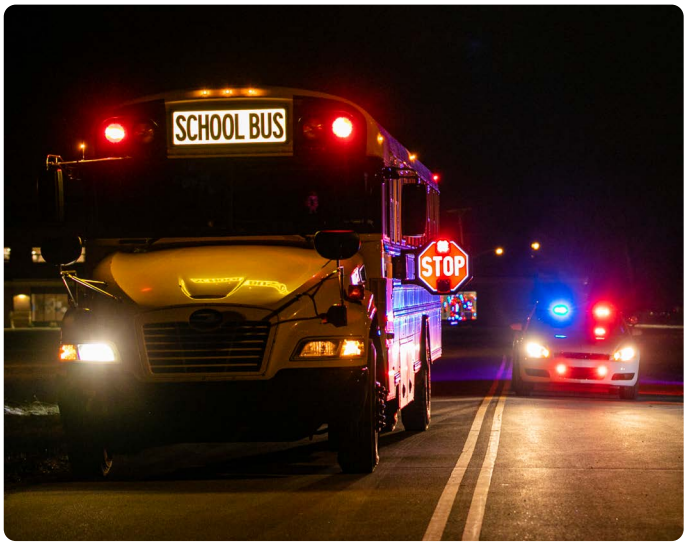
Even though the study of the fully illuminated stop arm was in a convenience sample (accessibility and willingness to participate) of school districts that used different data collection methods, the pattern of results is compelling. Fourteen of the 15 school districts reported notable decreases in stop arm violations over many days of operation. This leaves little doubt that fully illuminating the stop octagon changes the environment around a stopped school bus and likely creates higher compliance by motorists. If full illumination of the stop octagon results in motorist responses such as those observed in this pilot test, a meaningful improvement to school bus safety, particularly to fatal crashes, should be the result. Additional hypotheses that are suggested by these results and could be verified by more controlled and rigorous experiments include:

- Full illumination of the stop octagon produces a statistically significant reduction in school bus passing violations;
- Full illumination of the stop octagon produces statistically significant reductions in violations under varying operating conditions such as time of year, geography, or inclement weather;
- By fully illuminating the stop octagon, First Light's stop arm is always recognizable as a stop sign and eliminates any uncertainty of the action motorists must take.

It is also worth noting that relative to other safety technologies, the cost of outfitting 1-2 stop arms per bus is minimal. **The cost is less than 1% of the total cost of a new school bus.** For that minimal increase to a new school bus, districts can potentially make an immediate and measurable reduction in stop arm violations. Also, First Light's fully illuminated stop arms are installed and function in the same manner as traditional stop arms.

In summary, this efficacy study strongly suggests that increasing the visibility of the stop octagon by adding internal illumination positively impacts the behavior of drivers who intend to comply with the law. Although the technology eliminates any ambiguity that the motorists are approaching a stop sign on a school bus, its effectiveness will almost surely be compromised if motorists do not understand the law or do not intend to comply. Nevertheless, with over 43 million stop arm violations occurring every year, and the potential impact fully illuminating the stop arm has on decreasing illegal passings, millions of these infractions can be eliminated annually. This change would almost surely result in saving children's lives.

School buses carry the most precious cargo every single day and data-based decisions need to be made, with action-based initiatives to implement change. We, at First Light, hope that this data encourages more states to follow in the footsteps of North Carolina and South Carolina who made First Light's fully illuminated stop arms their minimum standard for new buses as of 2023.



Emergency vehicle reaction to First Light's fully illuminated stop arm

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Any comments or conclusions are those of the authors alone and do not represent the opinions of those individuals acknowledged or the school districts, companies, or organizations they represent.

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FIRST LIGHT SAFETY PRODUCTS

Stop Arm Violation Recording Sheet

District Name: _____

Route Number: _____

Bus Driver: _____

____ with FISA ____ without FISA

Thank you for your participation, you are further helping to provide the safest trip to your students and bringing light to the areas that need change.

Date	Number of Violations			Vehicles passed from each direction		Vehicle passed from which side of the bus		Number of violations on each type of roadway			
	AM	Mid-Day	PM	Front (Opposite Direction)	Rear (Same Direction)	Left (Driver Side)	Right (Passenger side)	Residential	Rural Road	2-3 Lane Hwy	4 or 4+ Lane Hwy
03/01											
03/02											
03/03											
03/06											
03/07											
03/08											
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VISIBLY changing the future of school buses

_____
Bus Driver Signature

Figure 2 *- Stop arm violation recording sheet*

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