Testimony for the U.S. House Committee on Science and Technology
Energy and Environment Subcommittee

CALSTART thanks the House Committee on Science and Technology, Energy and Environment Subcommittee and its members for the opportunity to testify and share our knowledge with you on the important issue of hybrid and more efficient medium- and heavy-duty vehicles. This is a critical area of emerging capability for the U.S., both in terms of reducing fuel – and cutting costs – for users, as well as reducing urban pollution and global warming emissions. It is also an important competitive leadership issue for U.S. manufacturers building leading-edge products here and for export to the international market.

CALSTART and its Hybrid Truck Users Forum (HTUF), together with its industry, fleet and public partners, are working together to speed hybrid and advanced truck commercialization and have identified the key benefits and barriers to progress which we welcome the chance to explain. We think there is an opportunity for smart, targeted investments and partnerships between industry and government to speed these new capabilities to market.

Our testimony will follow this outline: A brief introduction to CALSTART; the Role & Goals of HTUF; the Importance of Hybrids; the State of the Industry; Gaps and Barriers; Next Steps; Future Vision.

What is CALSTART?

CALSTART is North America's leading advanced transportation technologies consortium. It is a fuel and technology neutral, participant-supported non-profit organization of more than 150 companies and agencies, dedicated to expanding and supporting a high-tech transportation industry that cleans the air, creates economic opportunity and reduces imported oil use and greenhouse gas emissions.

CALSTART serves as an unbiased, strategic broker to spur advanced transportation technologies, fuels, systems and the companies that make them. It works across four areas to expand and support this industry: operating technology development and demonstration programs with industry partners; consulting to ports, fleets and others on implementation of new fuels, vehicles and technologies; providing services to industry members to expand their capabilities; and supporting and guiding the creation of policies that increase the efficiency and reduce the emissions of U.S. transportation.

CALSTART plays a leading national role in facilitating the development of advanced propulsion systems and alternative fuels in the heavy-duty vehicle and transit industry. It helped create the capability for heavy-duty hybrid drive systems in transit buses in program partnerships with DARPA, and now leads efforts in advanced commercial vehicle hybrids, fuels cells, hydrogen and biofuels. Founded in 1992, CALSTART is headquartered in California but operates nationally and internationally in its programs.

Role and Goals of the Hybrid Truck Users Forum (HTUF)

The Hybrid Truck Users Forum (HTUF) is a national program made up of first-mover fleets and major truck and system makers to speed the commercialization of medium and heavy-duty hybrid vehicles and to build a competitive, sustainable medium- and heavy-duty hybrid vehicle market. HTUF is operated by CALSTART in a unique partnership with the U.S. Army Tank-Automotive Research, Development and

Engineering Center (TARDEC) – National Automotive Center (NAC)[1]. Additional program support has been provided by the Hewlett Foundation, with some project funding from the Department of Transportation and the Department of Energy. HTUF has proven to be a highly successful program to jump-start the commercial hybrid truck industry in North America. Its track record of success, and the results in terms of industry development and product launches, has benefited truck makers and suppliers as well as military planners keen on supporting a dual-use commercial manufacturing capability for advanced trucks. HTUF is credited with removing one to two years from the product development cycle.

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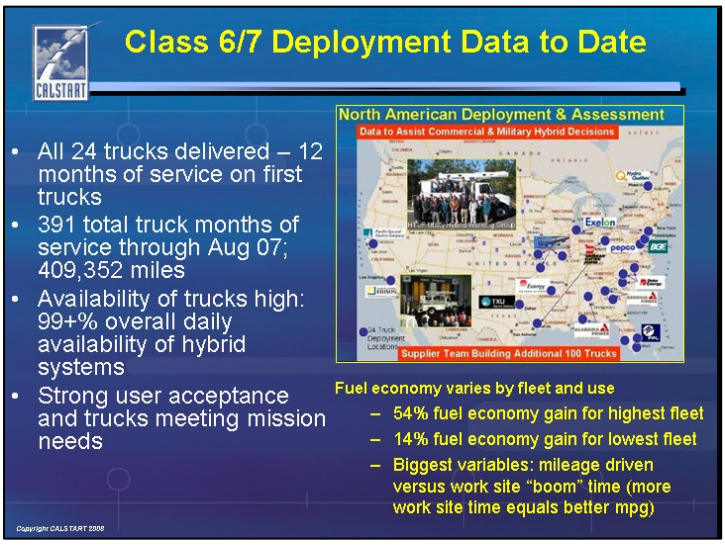
HTUF was designed to fill what was clearly a gap between technology development and products moving into the market. What was needed was a nimble, fast-track process for commercialization. HTUF's model for action focuses on truck users to create market "pull" (demand) around their needs for saving fuel, reducing emissions and noise and better performance. HTUF now works with more than 80 national fleets representing more than 1-million vehicles on the road, and all major truck makers and system suppliers. HTUF has identified the most promising early uses of hybrid technology (such as refuse, delivery and utility trucks), is working with fleet users of these vehicles to determine their common needs, and then is organizing these committed users to purchase and use commercially-built hybrids that meet these requirements. For the commercial industry, this has significantly accelerated their time to market by allowing them to focus on the most promising first markets. Product improvement is also much faster because customers share information and needs in real time with suppliers during assessment and development.

There is an additional benefit in the model – reducing cost and time for the military user. By developing a commercial manufacturing base and market for similarly sized and functioning systems, eventual costs to military users are reduced. The time to source and deploy future military systems is reduced, as well. By partnering in early commercial deployments, the military is able to assess performance, designs and architecture at extremely low cost. And by being active in the performance requirements, future military capabilities, such as silent watch, are designed into commercial systems from the start.



HTUF fleets have already launched or completed several fast track projects. Fourteen initial fleets ordered, deployed and assessed 24 utility hybrid trucks in a national pilot program, demonstrating up to 50% fuel economy improvements and exceptional reliability. This effort led directly to a follow up order of more than 100 trucks and has now helped launch early hybrid production in this class of medium-duty trucks. HTUF

[1] The NAC is the Army's outreach arm to the commercial transportation industry, and is charged with both understanding the capabilities of the commercial vehicle industry and working to increase the capabilities of the industry to build advanced vehicles and technologies that can support emerging Army and military needs.

fleet working groups in the parcel, refuse and small bus categories are launching similar pilot efforts to spread hybrid truck applications. A new working group – in full-size, Class 8 long haul trucks, plans to deploy some hybrid "big-rigs" by late 2008.As a result of the HTUF process, the commercial industry is now rapidly developing early heavy-duty hybrid products in several different market applications. First assembly line production has now started and additional product launches are pending.

Importance of Hybrids

Hybrid technology is a transformative technology for transportation. Future vehicles need to reduce urban pollution while also cutting fuel use. Few technologies can do both: hybrid can, increasing efficiency while also reducing emissions. Not only can it provide immediate benefits today, in terms of reduced fuel consumption, reduced criteria emissions and reduced greenhouse gas emissions, it also is an enabling architecture for future reductions and improvements. Once hybridized, vehicles can become more effective platforms for additional improvements, including the use of electrified, more-efficient components, the use of down-sized and optimized engines and combustion schemes, and enabling a transition to greater engine-off operation with enhanced energy storage. The stored energy can come from cleaner fuel sources – such as electricity - in plug-in variants. For the military, hybrids provide not just reduced consumption – which means a reduced supply chain and longer endurance – but also advanced capabilities. Military vehicles desperately need increased electrical power in deployed vehicles, and military users desire greater power generation in the field: both are inherent capabilities of a hybrid electric system. Military planners also seek engine-off "silent watch" functionality, which is the ability to support vehicle functions from stored energy without using the noisy – and detectable – engine. Hybrids deployed in assessment by HTUF and the NAC have already proven-out this stealth function. Advanced versions can allow "stealth" driving, as well – vehicle movement for limited distances without the engine starting.

State of the Industry

Hybrid truck technology has made significant strides in the last several years and is now on the "cusp" of commercialization. However, unlike passenger cars, where hybrid technology has been in production for a decade, first hybrid production is only now just starting in the truck industry. Integrating hybrid technology into truck platforms presents different challenges than in passenger cars, requiring different strategies, packaging and weight concerns, system designs and component sizing. The market drivers and purchase criteria are completely different in the commercial vehicle market than in the consumer market. Therefore, it is fair to think of hybrid trucks as being ten years behind the auto industry and also needing very different research, development and market acceptance tools to support them.

So far, unlike the automotive industry, the leaders in medium- and heavy-duty hybrids are U.S.-based manufacturers. This is a significant advantage to the nation. However, that leadership is not assured. More than six truck makers and ten system makers are now developing heavy hybrid prototypes or pre-production products in first applications, but the effort has not yet achieved critical mass and is at an important point in its evolution. To break out, these first efforts must succeed and expand. One of the key early barriers to success is that production volumes are low, so prices remain high.

On target with HTUF's intermediate goals, the first U.S. truck maker entered early assembly line production of hybrids in October 2007. International Truck and Engine Corporation, using an Eaton Corporation hybrid electric drive system, launched the DuraStar hybrid truck. It is now available in limited quantities from all its dealers in North America. The company can build up to one thousand trucks its first year. This capability was assisted directly from HTUF's efforts. Two other truck makers, Peterbilt and Kenworth, have announced early production plans for 2008, including hydraulic and electric hybrid offerings using Eaton systems, and Peterbilt is developing a Class 8 long-haul hybrid truck. Azure Dynamics will start producing a hybrid chassis with Ford in 2008. Freightliner has recently announced it will join International, Kenworth and Peterbilt in the medium hybrid truck market. Volvo/Mack has announced a hybrid truck capability in the 2009/2010 timeframe. Other companies are showcasing capabilities and prototypes, including Dueco with an Odyne plug-in hybrid utility truck, Oshkosh with an electric refuse collection truck, Crane Carrier with both an electric hybrid featuring an ISE driveline and a hydraulic hybrid featuring a Bosch Rexroth driveline. BAE, Allison, Parker Hannifin, Hybra-Drive, Permo-Drive, Enova Systems and ArvinMeritor are other examples of suppliers with active development efforts, some of which already produce hybrid systems for transit or other applications.

Initially there was skepticism by some whether hybrid technology would have a broad enough application to all trucks. Certainly initially, it is clear there are some first "beachhead" markets and applications for hybrids, such as refuse, urban and regional delivery, utility and similar work truck applications. However, these early markets are just the beginning, not the end pint, for hybrids. HTUF and partner testing are showing that hybrid technology delivers greater fuel economy in almost every duty cycle. The key early issue is to place hybrid vehicles where they will have the highest initial payback. However, as system costs come down with increased volume, improved system design and integration and new technologies, hybrid drivelines will steadily be applied in more and more market segments. Indeed, the next breakthrough in hybrid technology appears to be Class 8 long haul trucks, the highest fuel using truck class. Five truck makers have public or private programs to develop this capability, currently led by Peterbilt-Eaton. Hybrid systems may contribute 3-4 percent fuel economy improvements alone; combined with their built-in ability to provide idle reduction savings, this could approach 6-8 percent improvements. Hybrid technology actually shows the future capability of addressing a significant percentage of the truck fleet, building out of first markets in heavy urban work trucks.

Gaps and Barriers

Hybridizing the truck driveline is a key stepping-stone to future advanced capabilities in both hybrid and conventional trucks. If we are to reduce petroleum use (and address climate change) it is one of the key technologies to achieve that. Yet truck and system makers need public sector support and partnerships to bring these important technologies forward as quickly as the nation needs them. The industry is resource

constrained: as much as 80% of the engineering talent at the truck and engine makers has been focused, rightly, on the emission reduction requirements of 2007 and 2010. To support a parallel and fast-track effort in hybrids, critical as it is, is more than the industry can do alone. Industry needs government partnership and shared risk and investment to make it happen as fast as it is needed.

The core early barriers to fleet adoption are clearly high unit cost mostly due to low manufacturing volumes and the lack of a robust component marketplace. Assistance to help fleets cross this first market incremental price barrier would be extremely helpful. However, fleets also need additional in-use performance data and validation to help justify their capital investment in these new systems, and assistance to aggregate their demand with other fleets to speed purchases. Together with this is industry's need for additional development and testing of new components, better system integration and advanced capabilities. In essence, hybrid trucks are at the emergent stage of technology; the performance shown by early vehicles is just the beginning of what future hybrid and advanced capabilities can be.

Given these observations, CALSTART/HTUF has identified with its industry and fleet partners the core needs for continuing momentum in hybrids, and they fall along the stages of development:

- **Need for continued funding of research and development in core hybrid and advanced systems (R&D – development stage)**
- **Need for continued funding and partnership in fleet support/pre-production demonstration and pilot projects to assess and validate hybrid performance and reliability (Demonstration/Validation – pre-production stage)**
- **Need for fleet purchase assistance in the early market stage to speed introduction and rapidly increase manufacturing volume (Purchase Incentives – early market stage).**

In terms of R&D, the core technology development needs now are for improved system integration and manufacturability, reduced energy storage costs specific to commercial vehicle designs, electrified components (to enable even greater fuel economy gains in all trucks, and more capable hybrids in particular), optimized and downsized engines, advanced combustion schemes, power generation, light-weight materials, and advanced control systems.

It's important to understand that there are still technical barriers for trucks and buses that are not the same for passenger cars. For instance, there is no commercially-available electrically-driven air conditioning, steering pump or other components yet in the truck world. There are expensive prototypes, but no systems that can hold up to heavy-duty vehicle duty cycles. This is a core area of need, because their availability not only enables more-effective hybrids, they make for more efficient conventional trucks as well. Optimized engines are another good example. Specifically because a hybrid drive system allows the main engine to work differently, and usually to work less or work in a narrower power range, cleaner and more efficient engine designs are possible, such as Homogenous Charge Compression Ignition (HCCI). Such engines are more difficult to use if they must cover the full range of a conventional truck's power needs, but may be possible when functioning in a more limited power range coupled to a hybrid system.

The medium- and heavy-duty industry would greatly benefit from support across all three of the stages identified above to more rapidly improve the fuel efficiency of the

heavy truck sector, which has the highest per vehicle fuel use, and therefore the highest pay-back potential for investment. Yet investment has been sorely lacking for the commercial vehicle platforms, or applied in a less than focused way.

It is worth noting that Department of Energy projects to help develop and test early heavy hybrid technologies, managed by the National Renewable Energy Lab (NREL), were very useful and moved specific technologies forward that are in products we are now seeing today in transit hybrid buses and medium hybrid trucks. Unfortunately, most of that funding and commitment has ended.

Similarly, significant progress was made to drive the core hybrid driveline functionality via early Department of Transportation-Federal Transit Administration and Defense Advanced Research Projects Agency (DARPA) funding in the 1990s. These were exceptionally innovative programs.

Missing from all these efforts was not only a longer term duration, but support and strategies that moved technology along all the stages of development.

The commercial vehicle segment has not been a high enough priority for funding. It has also been assumed that investments made in passenger cars are sufficient to support commercial vehicle needs. The truth is, there are important differences between commercial and consumer – truck and car – hybrid vehicles in terms of duty cycles, system architectures, market needs and business cases. A portfolio of smart, targeted funding over a multi-year period and covering all the stages identified above and aimed at the needs of the commercial industry would have significant impacts.

The Army has been a great partner and leader, supports this effort and has directed internal funds to it, but resources to completely support the needs and develop new capabilities are limited by the Army's immediate priorities. Additional broader support is needed to accelerate the effort and achieve critical next steps to develop a national heavy hybrid capability.

Next Steps

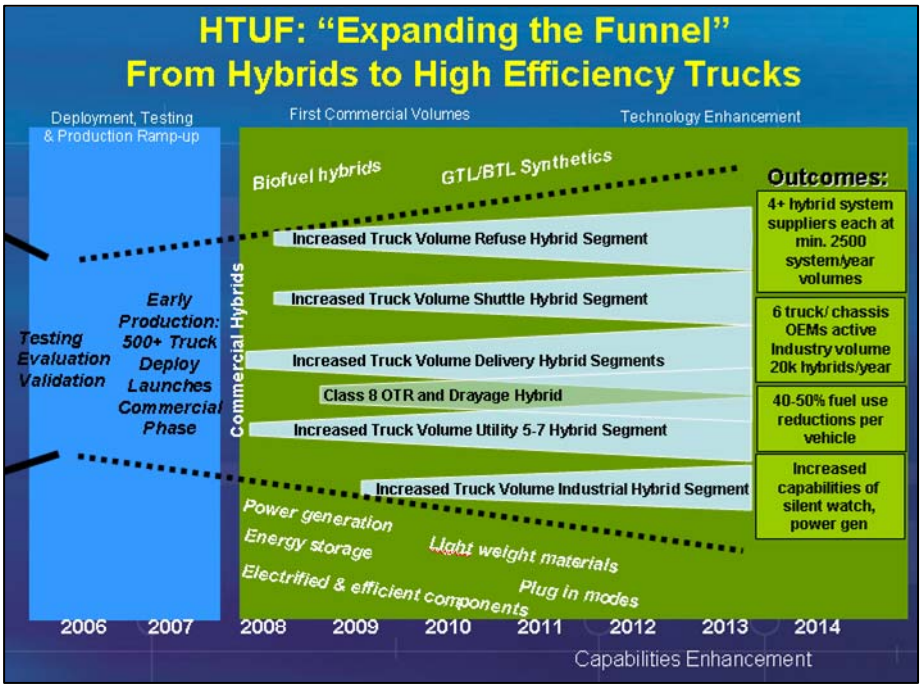
HTUF itself, together with its partners, are currently focused on a multi-year strategy that envisions creating a sustainable hybrid and high efficiency truck market over the next seven years, and working to develop the support to achieve this vision. Hybrids are the first and critical component of the move to high efficiency trucks. To achieve this will require building both market volumes in early applications, and adding new capabilities to both hybrid and conventional trucks over this time frame. To do this effectively will require government partnerships and risk sharing with the industry and fleets.

To succeed will require a robust, self-sustaining hybrid truck market, with offerings across multiple platform sizes and applications. To achieve these goals HTUF needs to continue to recruit and educate fleets in the targeted segments, and ensure that pre-production and early production commitments are achieved in these segments over the next several years. This will also entail opening new segments as price points allow, such as industrial/non-road vehicles and drayage trucks.

Hybrid alone will provide such benefits in many but not all duty cycles. It will require enhanced capabilities to achieve these levels, including optimized engines, improved energy storage, light-weight material use, more efficient components, better

aerodynamics in long haul applications, plug-in hybrid modes, and other strategies. Such enhancements enable the increased capabilities of quiet, engine-off operation and the ability of some trucks to be mobile power generators for emergency and work needs.

Importantly, these same improvements that increase the capabilities of hybrids also increase the fuel efficiency of conventional trucks. This concurrent move of hybrids into Class 8 heavy segments and the focus on improving core truck components is the leverage point to much more broadly impact the truck industry. By targeting users demanding increased fuel efficiency, working with regulatory agencies to develop accepted metrics for hybrid fuel efficiency and expanding the suite of enabling and enhancing technologies for hybrids, we will provide the platform and the pathway for measuring, delivering and expanding improved fuel efficiency in all trucks.



Future Vision

The government has a rightful and needed role to play at each stage of hybrid and high efficiency truck and technology development, and it is likely a different role at each point. If government agencies were to commit to moving forward medium- and heavy-duty hybrid and high efficiency trucks following an integrated plan and an "investment" strategy for the use of funding, that would be extremely useful and cost-effective for the industry.

In light of the growing market penetration and public acceptance of hybrid drivetrain technology in light-duty vehicles, the government can now direct a concerted focus on the medium and heavy-duty sectors to further advance the technology benefits.

It is important to note that assistance is needed now. The industry is at a critical stage and on the threshold of a successful launch. However, this launch can also be viewed more broadly as the first stage of a transformation of transportation technology. What is required is a commitment to a major program, on a par with light-duty efforts, to move medium and heavy-duty vehicle technology to the next level. Therefore, looking forward in the broadest sense, CALSTART could envision a high profile program built on these parameters:

- First, a commitment to target, support and fund over a multi-year period the steps required to achieve commercialization outlined earlier: R&D; Fleet Support and

Pre-production Demonstration; and Purchase Incentives. To get maximum effect, an integrated strategy encompassing all three is needed.

- Second, government's role and risk should be different at each stage, as is acknowledged already in most programs. However, a portfolio approach as to how much funding to apply to each stage, and a commitment to do so consistently over several years, would be most beneficial to the market. It would focus industry technology investments and engineering resource allocation as well as signal to private investors where to extend their investment into innovation in new technology. Such signals can often leverage as much private resource as direct governmental funding.

    - Research and development might rightly make up 15-20% of such a total government partnership portfolio, with pre-production demonstration, testing and validation an additional 5-10%. We can see the need for purchase incentives, based on a sliding scale determined by truck size and level of increased efficiency, and declining over time, making up as much as 70-75% of this overall portfolio.

- Third, it is highly important that research, development and demonstration activities be designed and operated to encourage competition, innovation and new players. Past efforts in some agencies have been closed to any but a handful of manufacturers and suppliers, a constraint unlikely to speed new approaches. Additionally, a commitment to spur action and achieve aggressive outcomes would add energy to the program. We can envision a ten year commitment to achieve 40-50% fuel economy gains as an average across all new trucks as a starting point for discussion.

- Fourth, such a program structure would ideally take place over a minimum of five years and be led by an agency or partnership that sees the value of and desires action to occur. Given the likely growing concerns with reducing foreign oil imports for energy security, the need for greater fuel efficiency to save truck operators money and secure jobs, and the need for significant carbon reductions in the future, a ten year program would be ideal as a clarion call to and a signal of commitment and action.

- Fifth, the level of investment should be commensurate with the needs and the challenge. California has recently enacted a high tech and fuel investment program (Assembly Bill 118) that will invest $200M per year over seven years in new transportation technology and fuels. Given this precedent in only one state, we would recommend at least a comparable federal effort, but targeting hybrid and high-efficiency medium- and heavy-duty vehicles over ten years. This can serve as a framework for the effort needed to ensure U.S. manufacturing technology leadership and meeting its energy security and greenhouse gas emissions goals. Based on the investment portfolio proposed, this could mean $40-60M per year for R&D and fleet support/pre-production deployments, and $140M per year for purchase incentives. This balance can also be modified to "front load" the investment in the early years and decline over time, from $400M/year down to $50M in the final year. Purchase incentives can also be structured to decline over time.

Such program commitments and integrated strategies are difficult to coordinate across different agencies, as demonstrated by the limited success of some previous efforts.

However, it is possible that motivated agencies can be determined to carry out segments of the total strategy. The Department of Transportation already has responsibility for setting truck fuel economy standards; its Federal Transit Administration has helped spur hybrid bus acceptance; the Environmental Protection Agency is establishing truck fuel economy testing protocols; the Department of Energy's NREL has managed R&D and testing for heavy hybrids; The Department of Defense's NAC has invested in both targeted hybrid R&D and in pre-production pilot demonstrations. A coordinated approach is critical, as is a strong and willing commitment to lead. The DoD's NAC is a good example of an agency taking a focused, outcome-oriented approach and achieving measurable results. Such characteristics have been the hallmark of past successful efforts in which we have experience.

Again, thanks to the committee, staff and members for the opportunity to provide this testimony and share the progress to date we have seen in medium- and heavy-duty hybrids, and the significant benefit we could create for our industry and nation with a focused and strategic commitment to move change in this field.