



## Advanced Vehicle Development The Fuel Cell Bus Program

The Fuel Cell Bus Program at Georgetown is supported by grants from the Federal Transit Administration (FTA). The program draws upon a carefully structured, 20+ year legacy of technology development and verification sponsored by the U.S. Departments of Energy and Transportation, with supporting funds from DARPA and the U.S. Army's National Automotive Center (NAC).



Five fully-functional fuel cell buses have been developed and demonstrated to date. All of the buses are methanol-fueled, hybrid electric buses. In 2006, Georgetown kicked off the Generation III program, designed to capitalize on the latest advancements in methanol fuel cell technology and hybrid electric systems to take another step toward commercializing fuel cell technology for transit buses.

## Fuel Cell Bus Program Highlights & Key Features

### Efficiency

Fuel cells have higher efficiency than standard vehicle engines, and the hybrid electric drive system allows for an improved overall vehicle efficiency.

### Clean Exhaust

Methanol fuel cell buses have near-zero emissions - well below 2010 standards.

### Quietness

The buses have very low external noise; the ride inside is quiet and smooth.

### Energy Independence

Methanol is inexpensive, and can be made domestically from renewables and coal.

### Full Performance

The buses handle and accelerate as good as or better than diesel buses, and the Generation II buses have satisfactory range for a transit bus (350 miles).

## Generation I Fuel Cell Transit Buses

Three Generation I fuel cell buses were developed under contracts from the Department of Energy. In 1994, the first bus was rolled out; the following two were rolled out in 1995. These buses are 30-foot, proof-of-concept vehicles called Test Bed Buses (TBBs). These successful buses proved that liquid-fueled fuel cells could be used to power a transit bus. All three buses are still operating.



### Generation I Bus Specifications

Fuel Cell System	Fuji Electric
Fuel Cell Type	50 kW phosphoric acid
Fuel Cell System Weight	~4000 lbs.
Fuel Cell System Size	145 ft <sup>3</sup>
Bus Type	30-foot BMI bus
Seated Passengers	25
Driving Range	170 miles
Hybrid Electric Drive	Soleq / Saminco
Electric Motor	75 kW DC brush
Battery System	40 kW-hr Saft NiCd



## Generation II Fuel Cell Transit Buses

Building on the successful demonstrations of the Generation I TBBs, the FTA established a program starting in 1993 to accelerate the introduction of liquid-fueled fuel cell transit buses. Two 40-foot, fully-functional transit buses were developed under the Generation II program, using different methanol fuel cell technology. Both bus platforms are standard Nova Bus RTS models, with hybrid electric drive systems from BAE Systems. Booz Allen Hamilton and Vehicle Systems Integration, LLC completed system engineering tasks and developed the system controllers for both vehicles.

The UTC Bus was rolled out in 1998. The 100 kW fuel cell system is a downsized version of UTC's commercial PC25 (now PureCell 200) stationary electric utility power plant designed to operate on natural gas.



The X-1 Bus was rolled out in 2001. Ballard provided the 100 kW Proton Exchange Membrane (PEM) fuel cell; XCELLSiS (now NuCellSys) designed the twin methanol processing systems based on DaimlerChrysler technology.

### Generation II UTC Bus Specifications

Fuel Cell System	UTC Fuel Cells
Fuel Cell Type	100 kW phosphoric acid
Fuel Cell System Weight	~4000 lbs.
Fuel Cell System Size	215 ft <sup>3</sup>
Bus Type	40-foot Nova Bus RTS
Seated Passengers	40
Driving Range	350 miles
Hybrid Electric Drive	BAE Systems HybriDrive
Electric Motor	185 kW AC induction
Battery System	50 kW-hr Hawker lead-acid

### Generation II X-1 Bus Specifications

Fuel Cell System	Ballard / NuCellSys
Fuel Cell Type	100 kW PEM
Fuel Cell System Weight	~4000 lbs.
Fuel Cell System Size	150 ft <sup>3</sup>
Bus Type	40-foot Nova Bus RTS
Seated Passengers	40
Driving Range	350 miles
Hybrid Electric Drive	BAE Systems HybriDrive
Electric Motor	185 kW AC induction
Battery System	30 kW-hr Optima lead-acid

## Generation III Fuel Cell Transit Bus Program

Georgetown is working in partnership with EPRI, ZSW, and NuCellSys on Phase I of the Generation III program. This program will leverage the team's experience in hybrid electric vehicles, methanol fuel cell systems, and fuel cell design and testing. The objective of Phase I, expected to be completed in 2008, is to produce an advanced methanol fuel cell system that will be the basis for a next-generation fuel cell bus.

**EPRI** [Program management] – a nonprofit organization at the forefront of energy and environmental research, and a leader in researching, developing, and demonstrating plug-in hybrid electric vehicles.

**ZSW** [Fuel cell system integration] – the Center for Solar Energy and Hydrogen Research, a nonprofit research institute located in the state of Baden-Württemberg, Germany.

**NuCellSys** [Methanol processor and fuel cell system] – an equally-owned joint venture between Ford and DaimlerChrysler, and a world leader in developing and manufacturing automotive fuel cell systems and methanol fuel processors, including the systems in the Generation II X-1 Fuel Cell Bus.

### Generation III Fuel Cell Specifications

Fuel Cell Stack	Ballard
Fuel Cell System	NuCellSys / ZSW
Fuel Cell Type	60 kW PEM
Fuel Cell System Weight	~1000 lbs.
Fuel Cell System Size	20 ft <sup>3</sup>

