



Role of Thermoelectrics in Vehicle Efficiency Increase

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Market Forces are Changing

Emissions reductions are being introduced worldwide

Great external pressures to increase fuel economy

- Customer demands to reduce operating costs
- Customer concerns with fuel supply availability and possible needs for fuel allocation
- Government demands for fuel economy increase/CO₂ reduction

It may not be acceptable to throw away power contained in vehicle exhaust

Why Thermoelectrics?

Solid-state cooling, heating and power generation

Small, light-weight. Potentially very reliable and rugged

Electrically powered with very few (or no) moving parts

Distributed (and spot) cooling/heating/temperature control

No gaseous pollutants

Waste power recovery easily adaptable to varied form factors and thermal power influx

What Has Limited Usage?

Power generation efficiency has been less than 5%

- Inadequate for many high-power applications
- Limits usage to small applications
- Too inefficient for auxiliary power generation and automotive use

Thermal flux density has been low

- Volume and weight too great at high power levels
- Form factor not readily adaptable to some application needs
- Poor interface to high-power density applications

Lack of design knowledge and effective simulation tools

- Performance often poorer than predicted
- Characteristics and, hence response, can be a strong function of operating conditions

TE System Performance Gains

Since 2000

Materials

BiTe Thermoelectrics (1960s)

Heterostructures (2000-2002)

Baseline
+70 to 160%

Materials/Design

Incremental improvements
(1960-2002)

5 to 15%

New ancillary materials and
components (1960-2002)

5 to 10%

Thermodynamic Cycle

Isolated Element (2000-2002)

100 to 120%

Convection (2001-2002)

30 to 80%

Power Density

Sintered micropower (2002)

Up to 25 X Increase

Heterostructure (2001)

30 to 300 X Increase

Vehicle Related TE Development Initiatives

US Government

- DARPA- TE materials and subsystem technology
- ONR- TE materials and system technology
- DOE- Waste heat recovery systems
- JPL, Others- Power generation materials and systems

Japan

- NEDO- TE power generation materials
- Trash incineration waste heat demonstration programs

Company Initiatives

- GM- DOE, materials
- Visteon- DOE, cooling/heating
- Delphi- Materials
- Denso- Power generation, cooling/heating
- UTRC- DOE, cooling/heating
- Catapillar- Waste heat recovery

Europe

- Collaboration with NEDO of Japan
- BMW- DOE
- Smaller varied initiatives

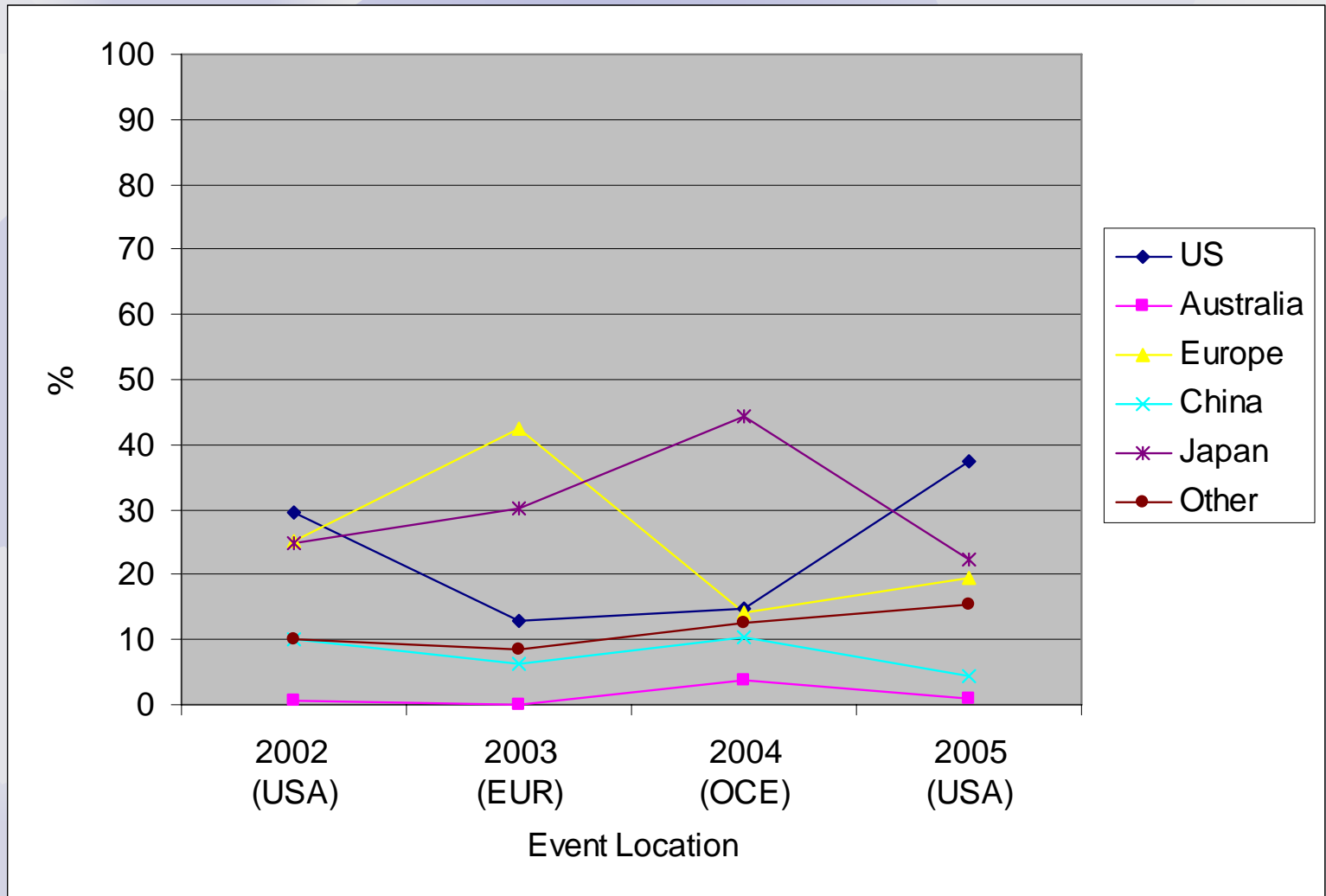
Vehicle Related Applications

Application	Status	Program Objective
Cooling/Heating		
Occupant local temperature control	Concept evaluation	Increased occupant comfort
Beverage heating/ cooling	Under development	Convenience
Power electronics cooling	Concept evaluation	Performance, reliability increase, cost reduction
Auxiliary heating/cooling	Under development	Increased occupant comfort
Seat heating/cooling	In production	Increased occupant comfort, energy savings
Power Generation		
Coolant waste heat recovery	Concept evaluation	1-3% mileage increase in automobiles
Exhaust waste heat recovery	Under development	8-12% mileage increase in automobiles
Other (transmission, brakes)	Concept evaluation	Mileage increase

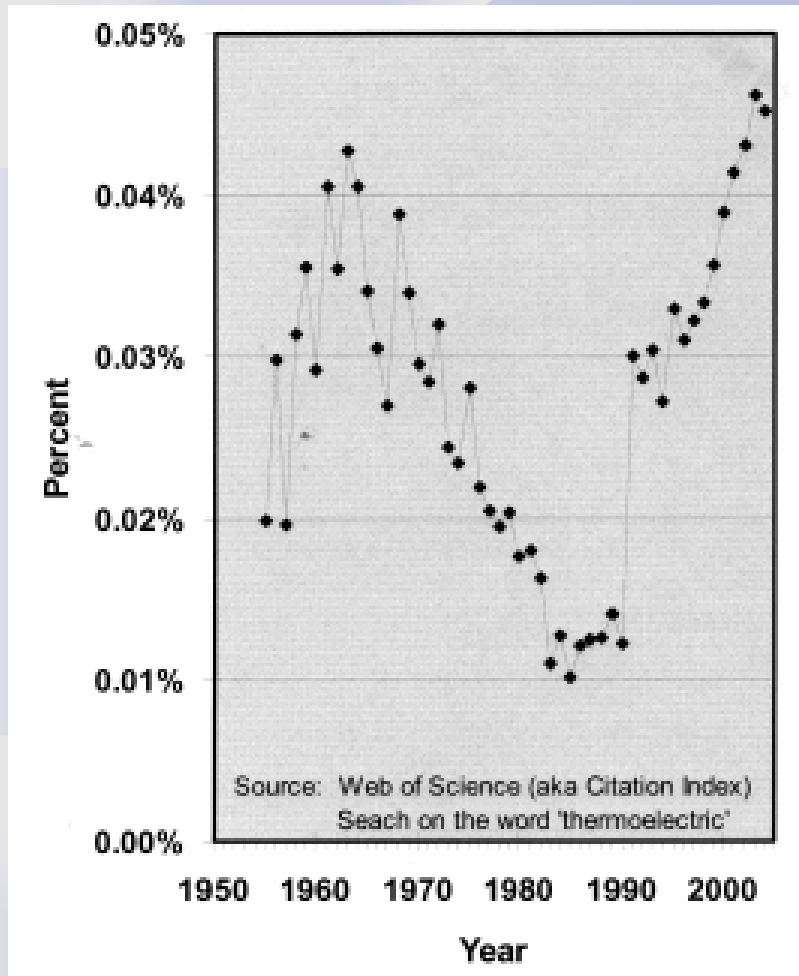
Advanced Materials Development

USA	Materials		Peak Demonstrated Performance	
	Cooling/ Heating	Power Generation	Cooling/ Heating	Power Generation
JPL	No	Yes	N/A	ZT \approx 1.4
Lincoln Labs	Yes	Yes	ZT > 1.6	ZT > 2.0
MSU (Tellurex)	Possible	Yes	?	ZT \approx 1.8
RTI	Yes	Yes	ZT \approx 1.6	ZT \approx 2.6
Teledyne	No	Yes	N/A	ZT \approx 1.4
Japan				
Komatsu LTD	No	Yes	N/A	ZT \approx 1.2
Osaka University	No	Yes	N/A	ZT \approx 1.2
Europe				
Fraunhofer-Institut	Yes	No	ZT \approx 0.7	N/A
IOFFE Institute	No	Yes	N/A	ZT \approx 1.1

TE Papers by Region



TE Intellectual Property Activity



Results of patent abstracts, key words search shows spike in TE related patent applications

Recently, about 2/3 from Japanese applicants

Majority focus on power generation material and component design

Source: Cronin Vining, ICT 2004



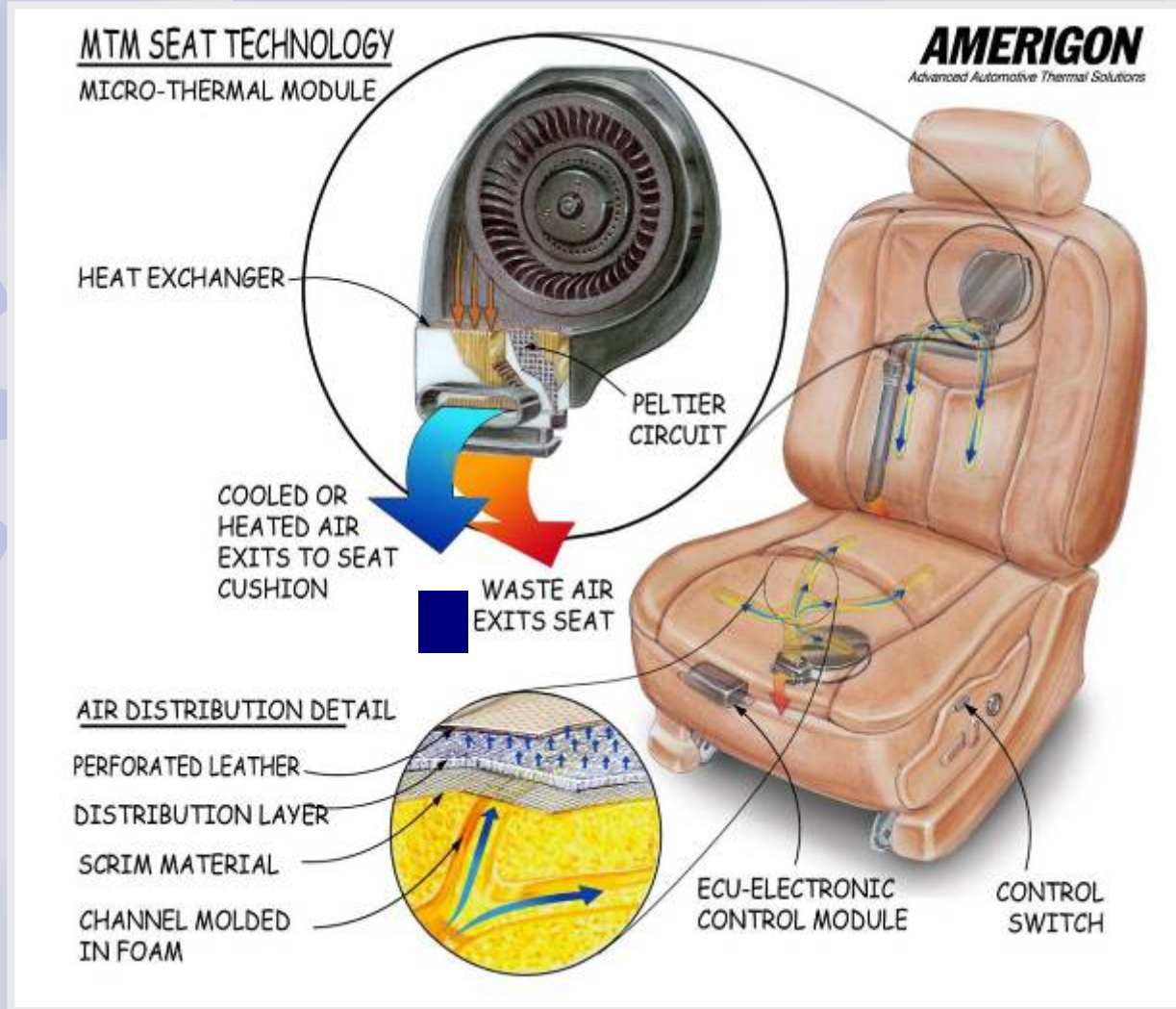
CCS™- Successful TE-Based Product

CCS- Climate control in seats; adds cooling and ventilation to seat heating function

Standard and optional system for cars, vans, light trucks and SUVs

Potential to reduce climate control system energy consumption in both cooling and heating modes

CCS™ Seat Design



Amerigon Current CCS™ Vehicle Lines



Cadillac Deville



Cadillac XLR



Mercury Monterey



Escalade ESV*



Infiniti M45



Lincoln Navigator



Ford Expedition



Lincoln Aviator



Nissan Fuga



Infiniti Q45



Toyota Celsior*



Lincoln LS



Nissan Cima
2005 DEER Conference



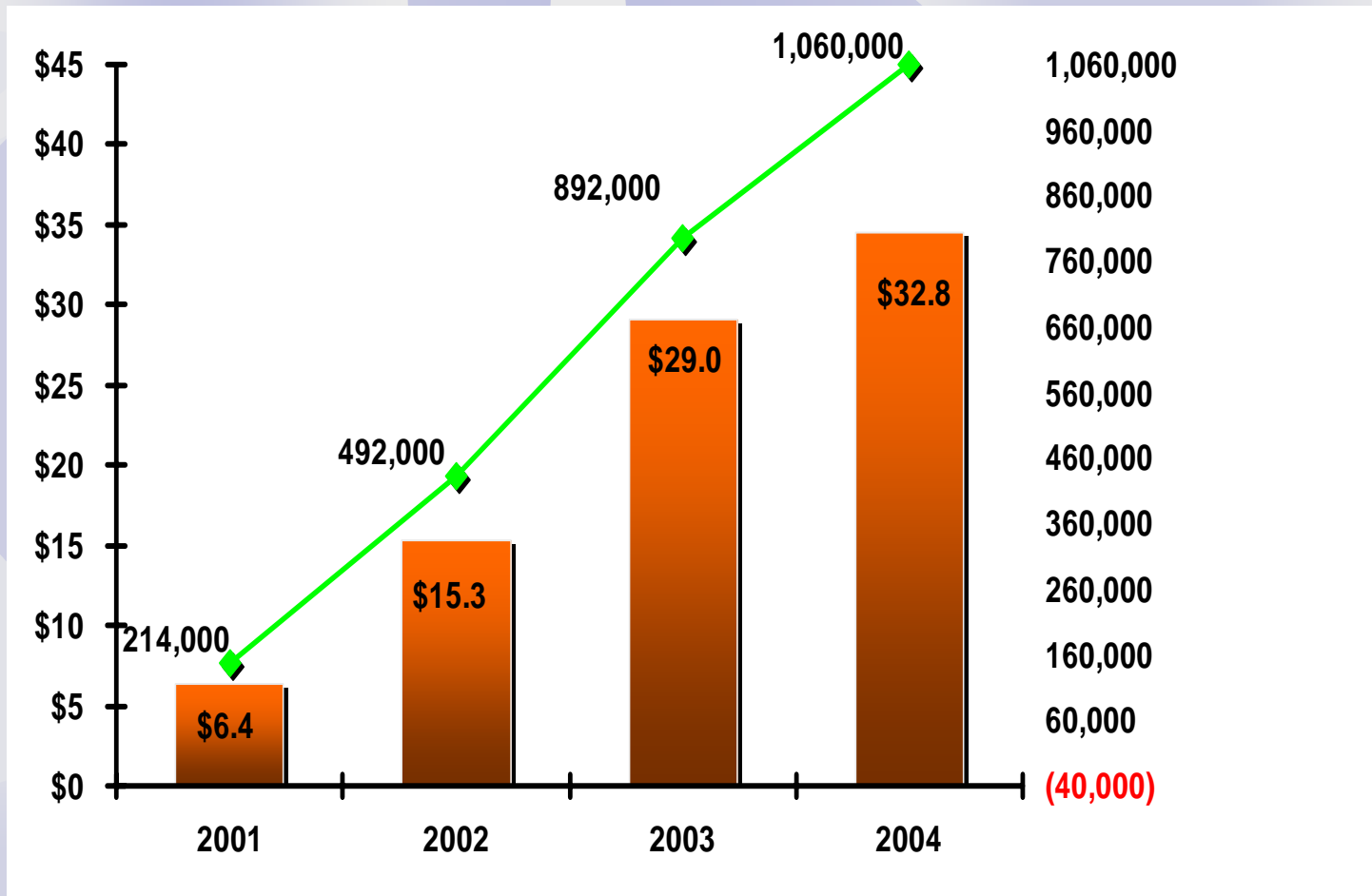
Hyundai Equus*



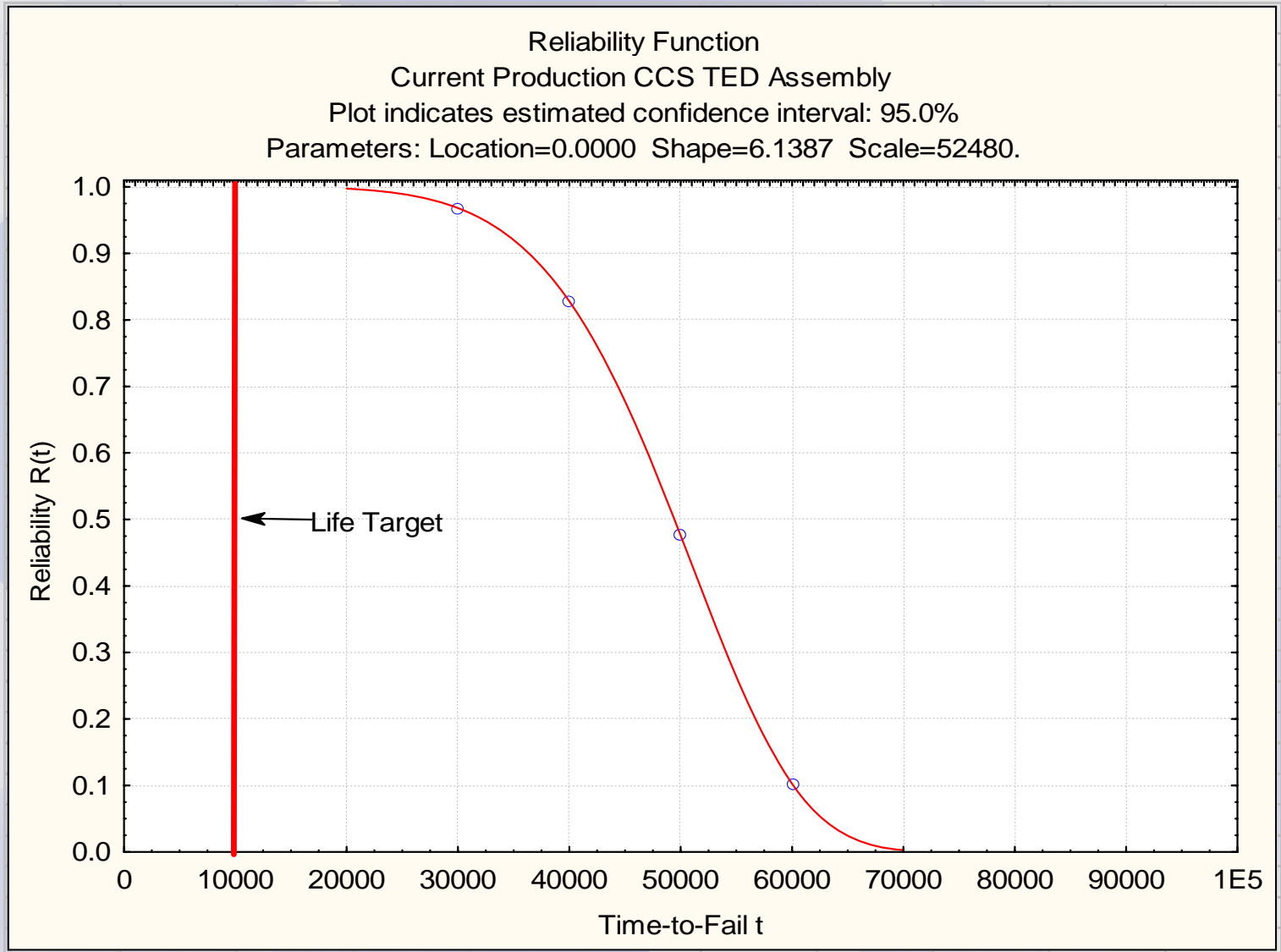
Lexus LS 430*

Amerigon Growth Rates

Sales/TE Module Deliveries



Usage Experience



Summary Slide

TE devices are expected to be significant contributors to meeting today's needs for increased fuel economy, reduced harmful emissions and improved operating reliability.

A technology race has started in the US, Asia and Europe to commercialize TE-based energy saving systems for vehicle applications.

Positive results would give early adapters a significant advantage in a marketplace affected by emerging long-term global forces to reduce fuel consumption and harmful emissions.