

*High Pressure Turbocharging
for SOFC/ Hybrid Fuel Cell Systems*

*Steve Berenyi
Rolls-Royce
Allison Mobile Power Systems*

*3rd Annual DOD/U. N. Hybrid Power Systems
Conference and Workshop
May 13-15, 2003*

6/9/2003

Allison Mobile Power Systems (AMPS) Organization

Organization

- Integral part of Rolls-Royce
- Off-site location in Indianapolis
- UAW-integrated team
- Marketing/design/procure
- Fab/assembly/test

Configurations

- 10-300 kW
- 1 & 2 shaft
- Turbogenerators
- Shaft power
- APUs



Technologies

- Ceramics
- Combustion
- Rotor/bearing systems
- High speed generators
- Small components
- Insulation
- Systems

Customers

- Dept of Energy
- NASA
- US Military
- Commercial
- RR Fuel Cell Systems

Allison Mobile Power Systems (AMPS) Markets



Stationary Power Gen



Automotive

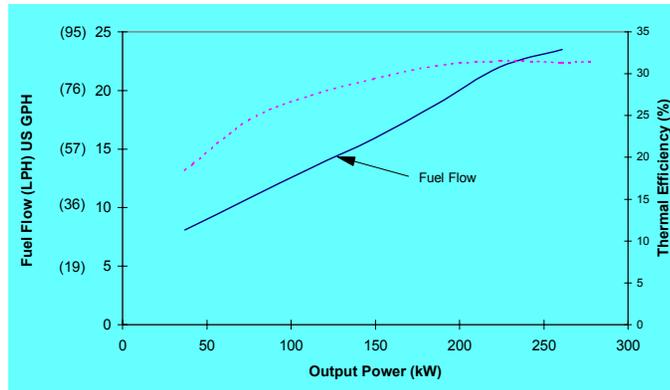
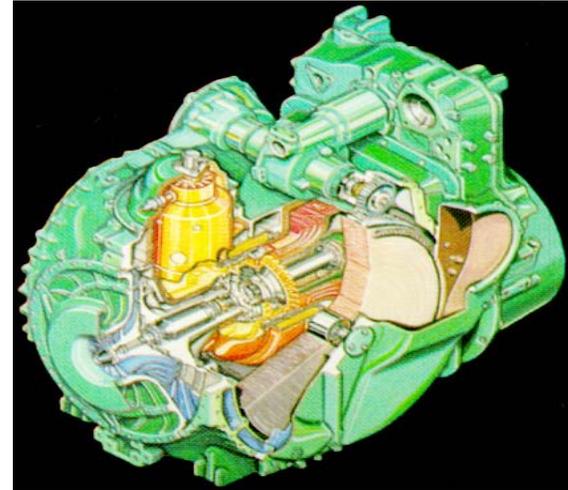


Military Mobile



Marine

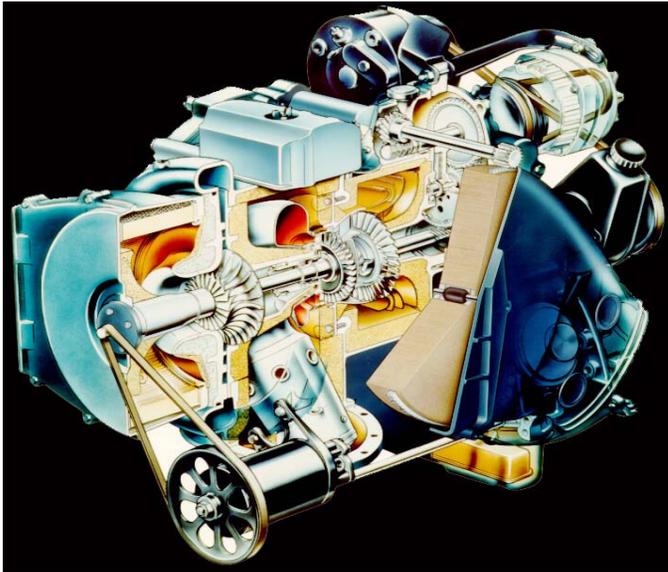
Industrial -- IGT 404 Engine



270 kW turbogenerator

- **Generator set**
- **Used in Patriot Missile System**
- **40''H x 32''W x 47''L
(1016 x 813 x 1192mm)**
- **1800 lb (815kg)**

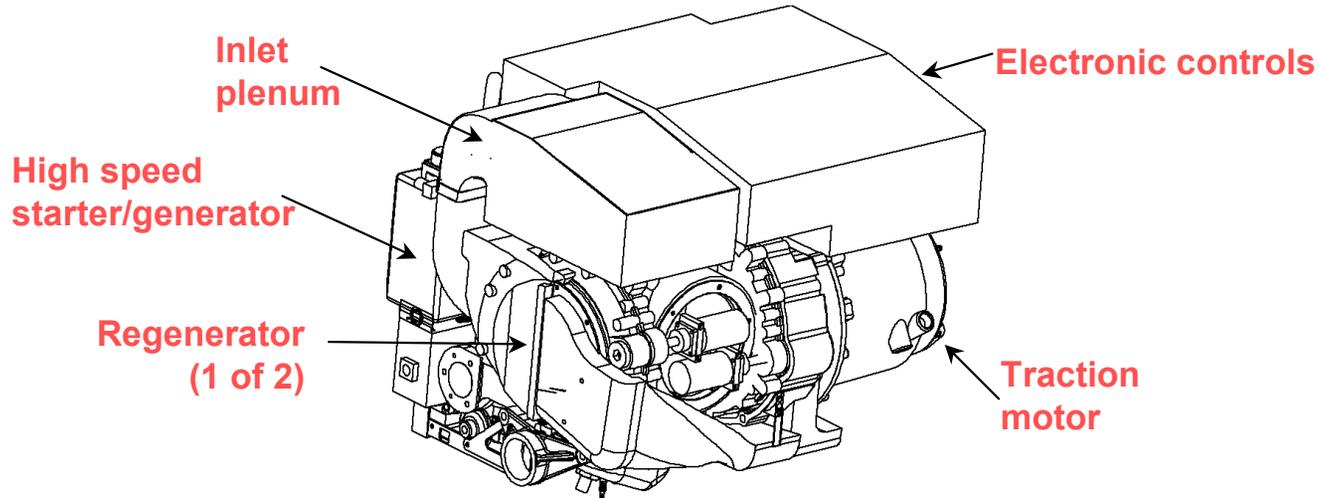
Automotive -- AGT-5 Engine



150 kW turboshaft

- Prime power source
- Automotive application
- 23"H x 27"W x 28"L
(584 x 685 x 711 mm)
- 250 lb (114 kg)

Automotive Turbo Generator -- TG1140 Engine



30 kW turbogenerator

- **High speed starter/generator**
- **Hybrid vehicle application**
- **26"H x 21.5"W x 19"L
(661 x 546 x 483mm)**
- **220 lb (100kg)**

High Temperature Ceramic Materials Applications



Ceramic insulation

AS 800 silicon nitride combustor

SN 252 silicon nitride scroll



Kyocera rotor

MAS regenerator

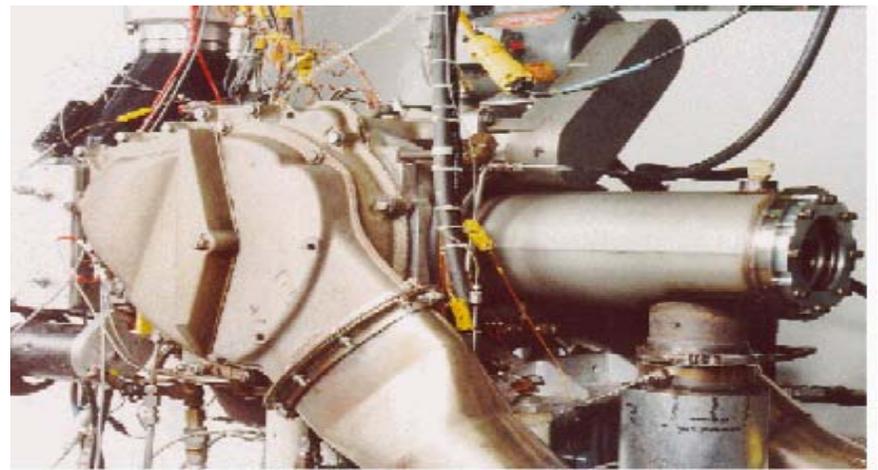
Ceramic engine test rig



Kyocera rotor



MAS regenerator

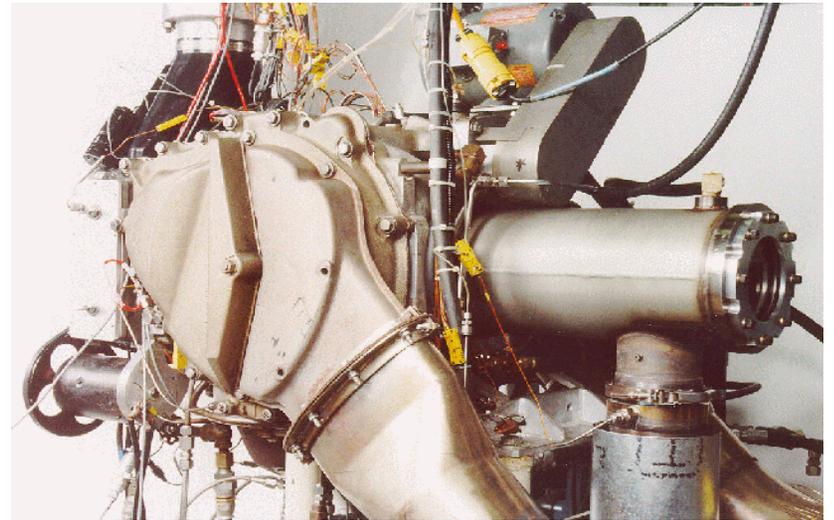


Ceramic engine test rig

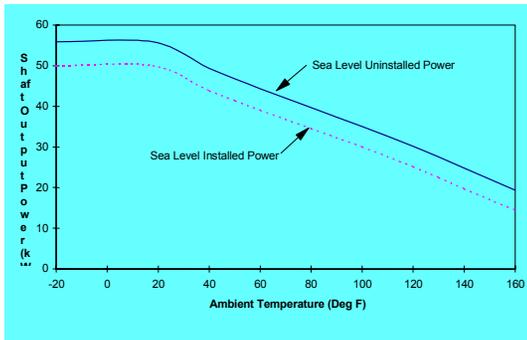
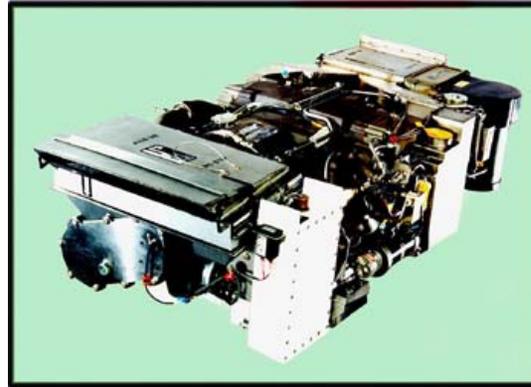


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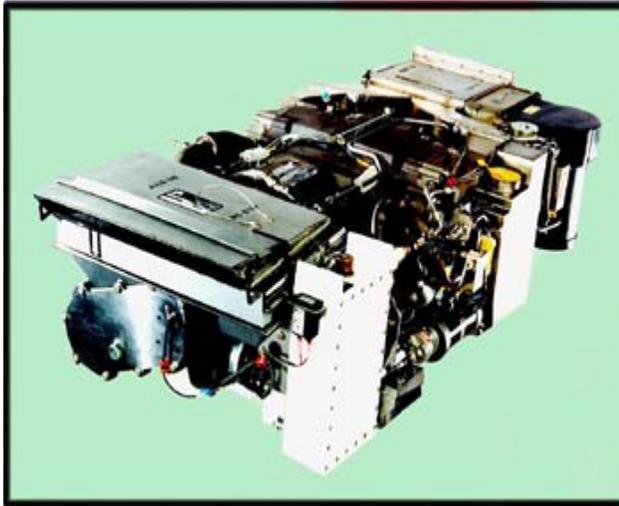
Military Turboshaft APU -- TS1230A Engine



20 kW turboshaft

- Auxiliary power unit
- M1A2 tank application
- 24VDC & hydraulic output
- 12"H x 22"W x 49"L
(305 x 533 x 1244mm)
- 550 lb (200kg)

M1 Auxiliary Power Unit (TS1230A Engine)



Rolls-Royce APU major components

- Regenerated turbine engine power
- Eaton/Vickers hydraulic pump
- Niehoff military qualified electrical generator
- Donaldson precleaner and air filter

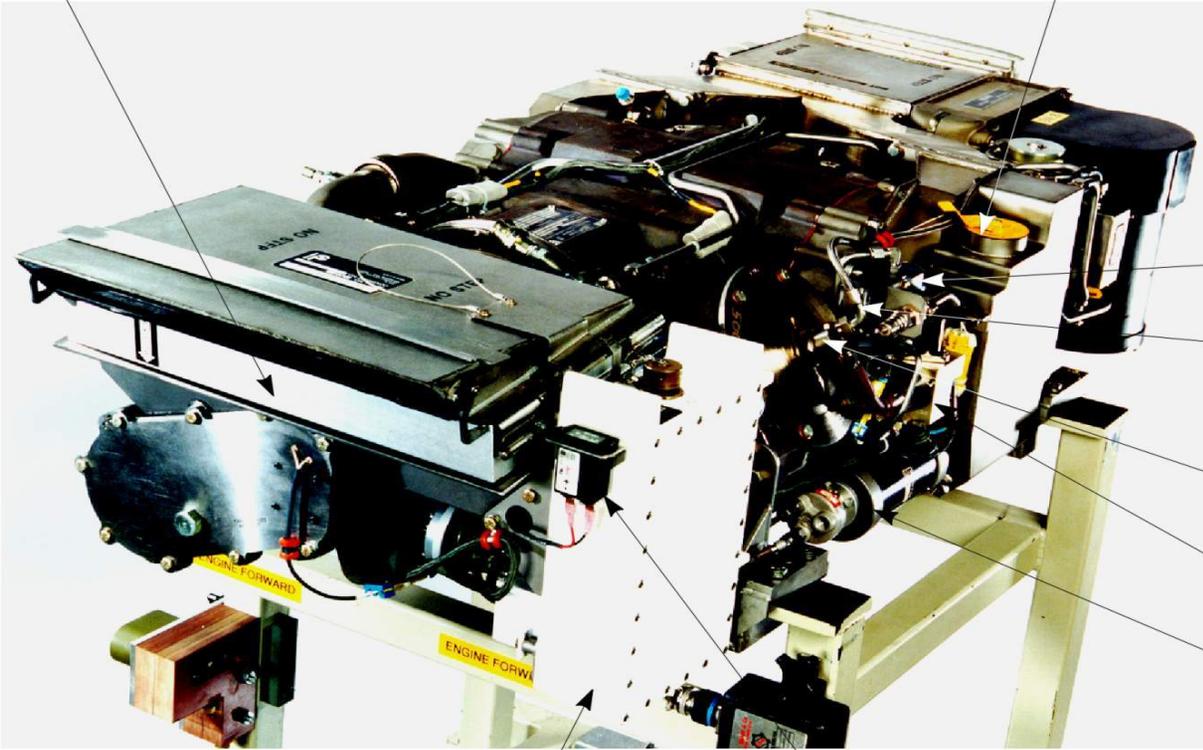
Functions

- Provides electrical and hydraulic power
- Reduces main engine operating hours and vehicle fuel consumption
- Provides electrical power to charge main batteries
- Provides power for the thermal management cooling system
- Provides 6 kW (214 A at 28 Vdc) electrical power
- Provides 10 kW (1650 psig at 14.1 gpm) hydraulic power

Integrated APU System Components

Air filter element

Oil tank,
fill and dipstick



Fuel
filter

Ignitor

Injection
nozzle

Fuel
control
module

Fuel
pump

ECM box

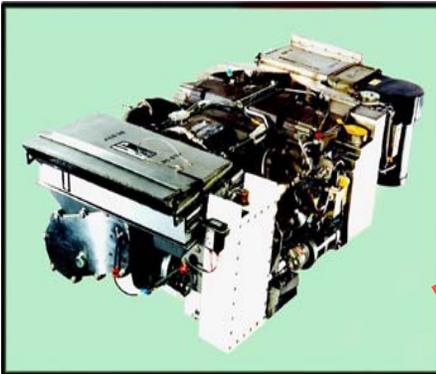
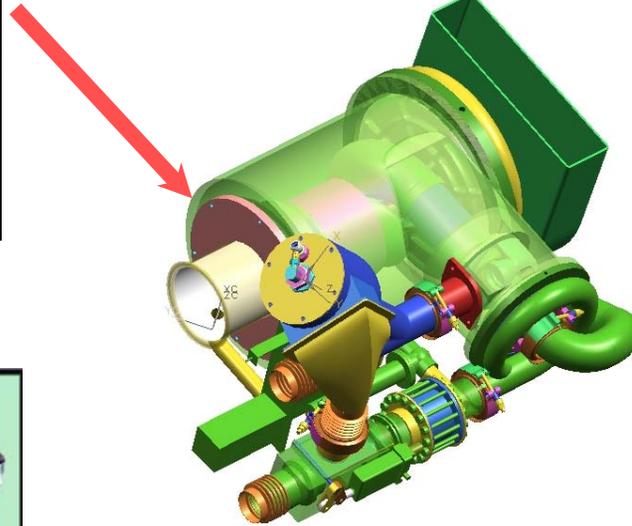
Hour meter

TE99-954

Rolls-Royce Fuel Cell Hypercharger's Heritage



Durability



Extreme environments

Rolls-Royce Fuel Cell Hypercharger's Heritage



Durability

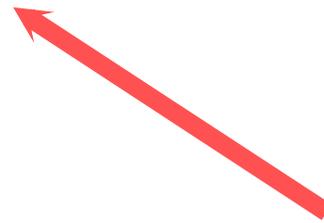
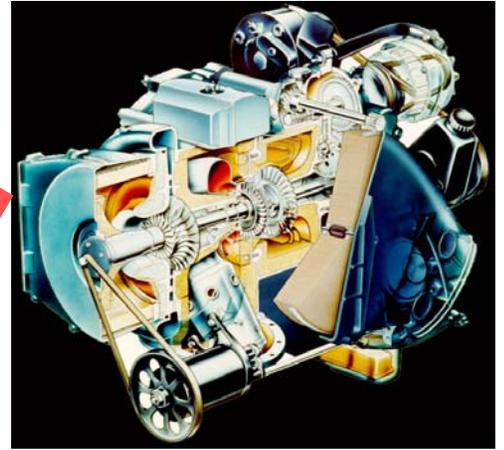
Low cost

**Extreme
environments**

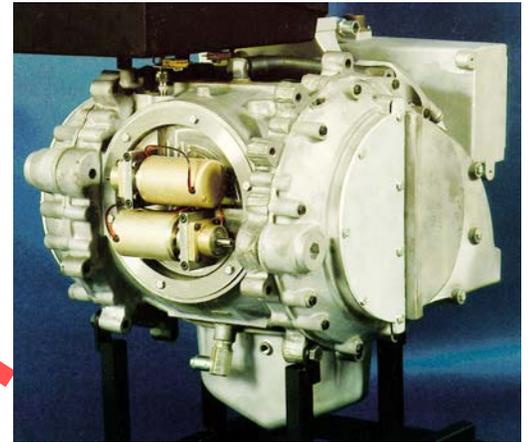
**Advanced
technologies**

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Low cost

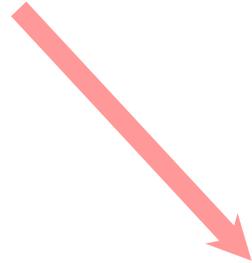


Advanced technologies

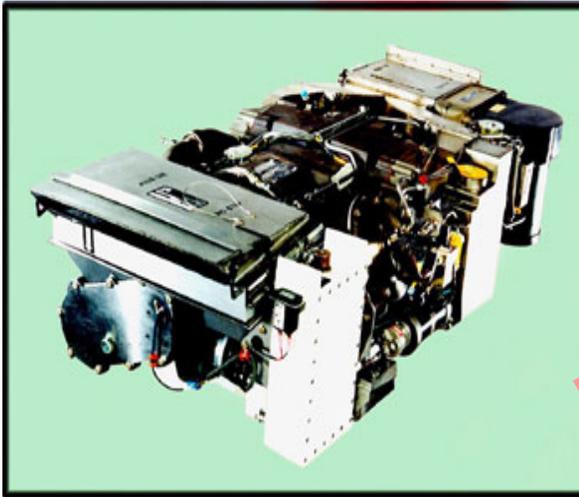


Rolls-Royce Fuel Cell Hypercharger's Heritage

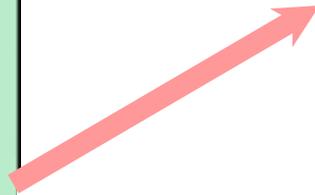
Durability



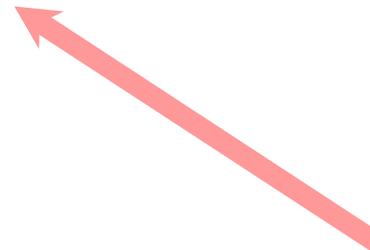
Low cost



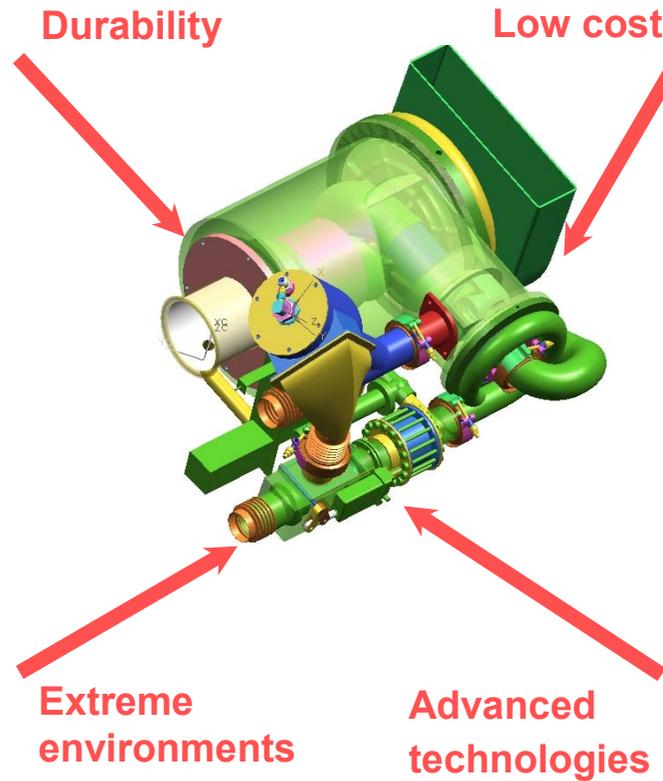
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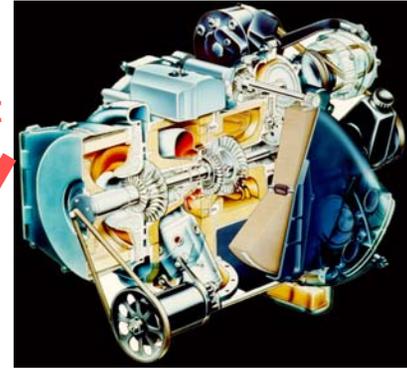
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Rolls-Royce Fuel Cell Hypercharger's Heritage

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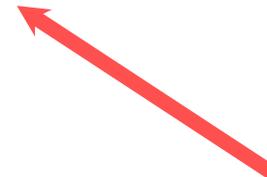
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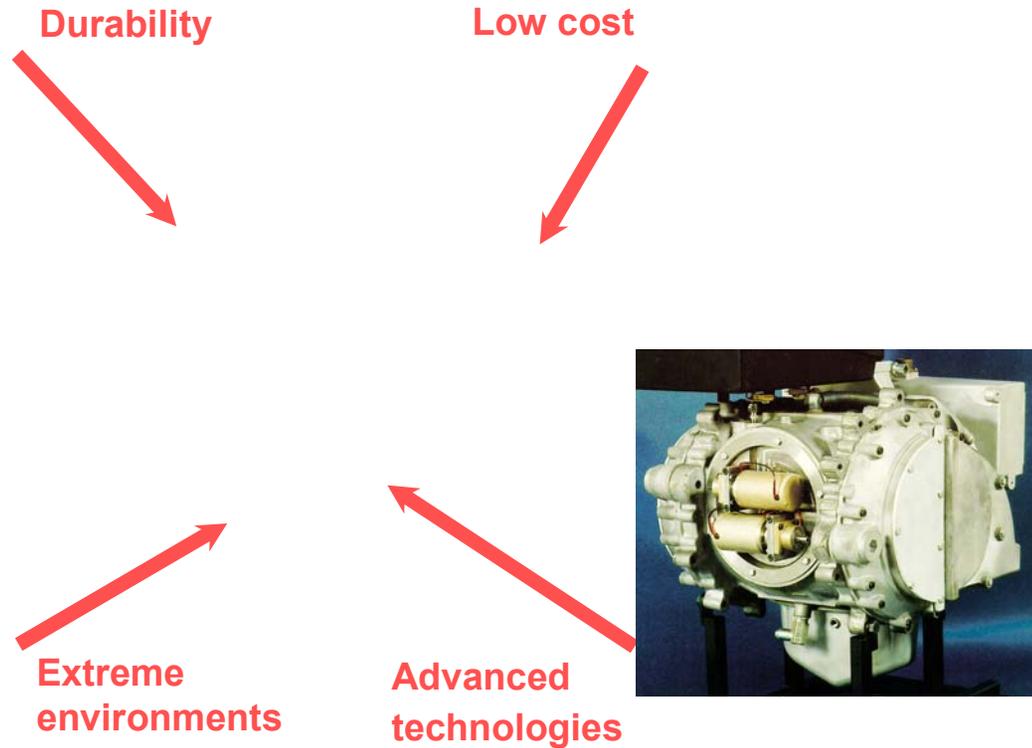


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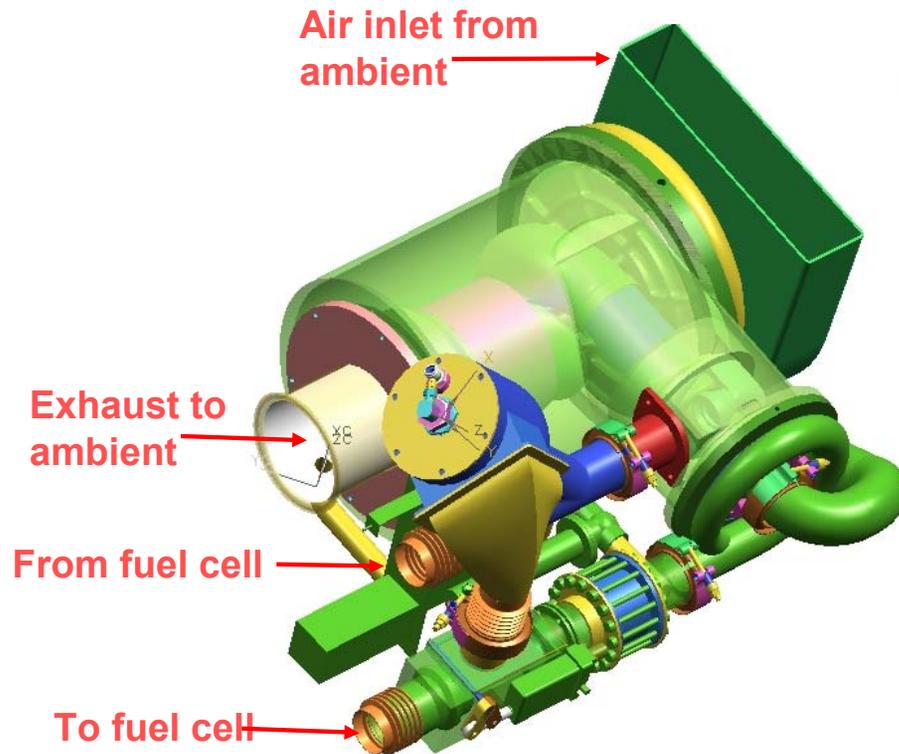
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Rolls-Royce Fuel Cell Hypercharger's Heritage



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Rolls-Royce Hypercharger Configuration



Features

- Two shaft rotor system
- High pressure ratio
- Integrated package
 - High speed generator
 - Self starter
 - Start combustor
 - Thermal insulation
 - Digital controls

Technology Transfers from Previous Programs

- **Similar to industrial IGT 404**
 - Rugged design features for durability
 - Serviceability
- **Similar to US military M1 APU**
 - Flows
 - Pressures
 - Speeds
 - Structures
 - Packaging
 - Controls
- **Similar to automotive AGT 5 & 6**
 - Ceramic components & insulation
 - Low cost automotive design features
 - Start system
- **Similar to automotive hybrid**
 - High speed generator
 - Electric power conversion
 - Auxiliary systems

Primary Remaining Challenges

- **Long term operational durability**
- **Adaptation of “non-contact” bearing systems**
- **Start up and shut down transients**
- **Integrated fuel cell/hypercharger system packaging**
- **Integrated fuel cell/hypercharger control systems**
- **High speed generator power conversion and control**

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