Rotax 912 iS
Fuel injected aircraft engine

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BRP-Powertrain

BRP – Bombardier Recreational Products

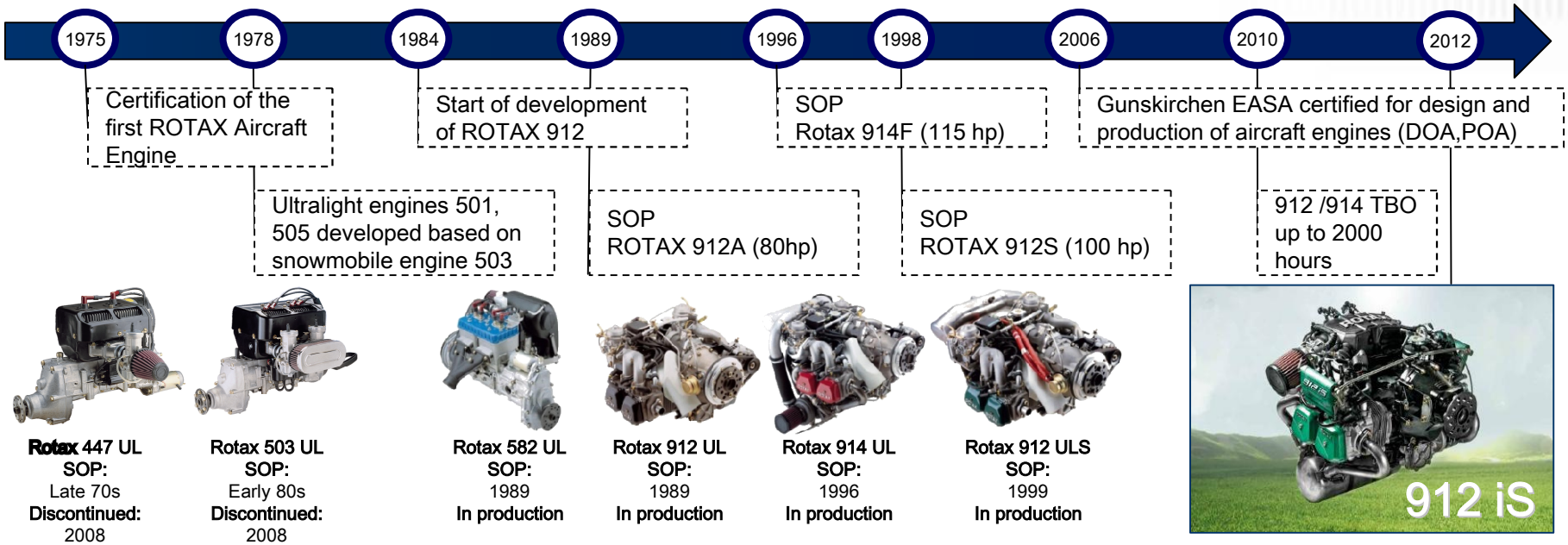
BRP is no. 1 in following markets:

- *Jetboat*
- *Boat*
- *Snowmobile*
- *Roadster*
- *Light Sport Aircraft*

BRP-Powertrain GmbH & Co KG, Gunskirchen, Austria

- 1.100 employees

Rotax Aircraft Engine Milestones



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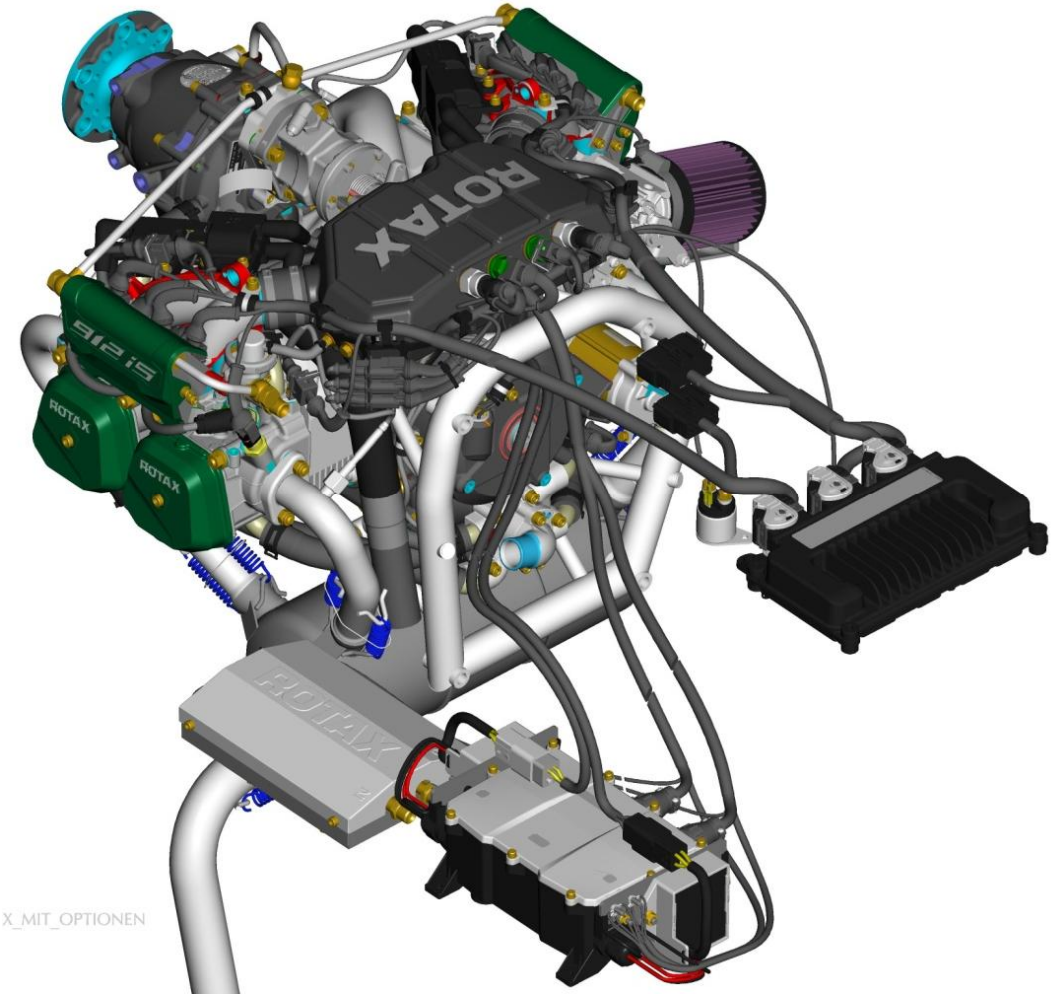
- Fuel Efficiency
- Electric & Electronics
- Control Strategy
- Mechanical Impact
- Q&A

Overview

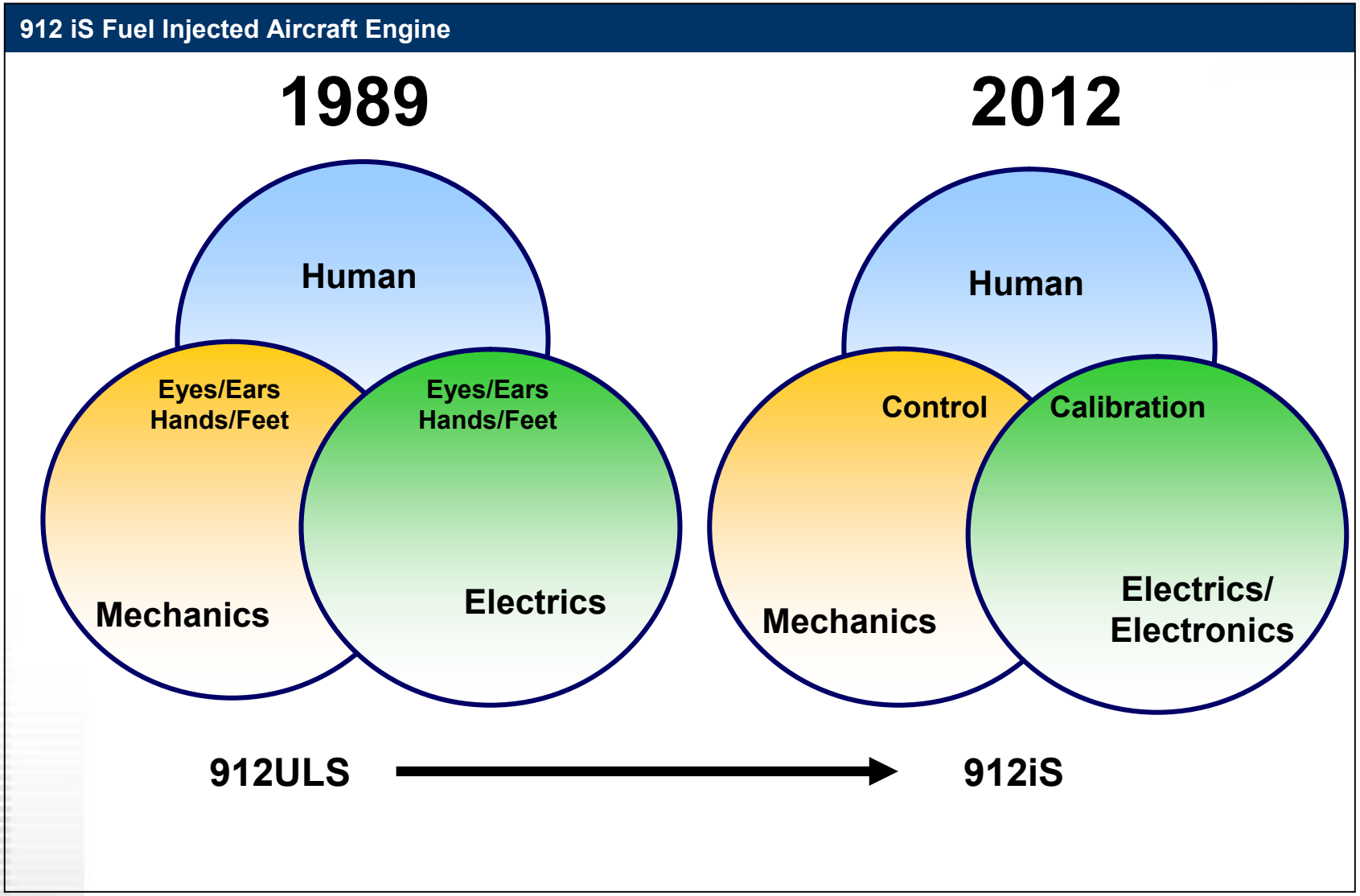
912 iS Fuel Injected Aircraft Engine

Base technical data:

- Max. Power:
  100 hp
- Max. RPM:
  5800 RPM
- Bore:
  84mm
- Stroke:
  61 mm
- Displacement:
  1352 cm³
- Compression ratio:
  10,8:1

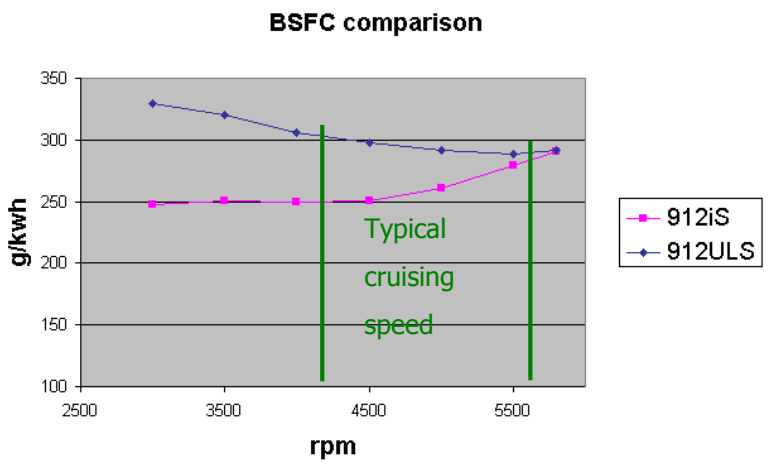


Overview


912 iS Fuel Injected Aircraft Engine
1989
2012
Human
Eyes/Ears
Hands/Feet
Eyes/Ears
Hands/Feet
Mechanics
Electrics
Human
Control
Calibration
Mechanics
Electrics/
Electronics
912ULS
912iS

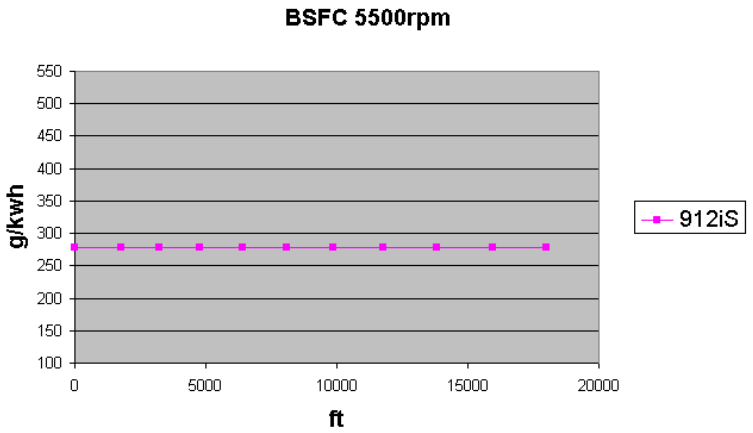
Fuel Efficiency

BSFC comparison



- Break Specific Fuel consumption comparison at sea level

BSFC in altitude



- Break Specific Fuel consumption at 5500 engine rpm over altitude

Fuel Efficiency

Test flight comparison

Measured average fuel consumption on the test aircraft:

- Benchmark engine : 17,6l/h
- EFI equipped engine: 12,3l/h.

➔ 30% fuel consumption reduction

Electric & Electronics

Requirements

Requirement:
Electronic fuel injection

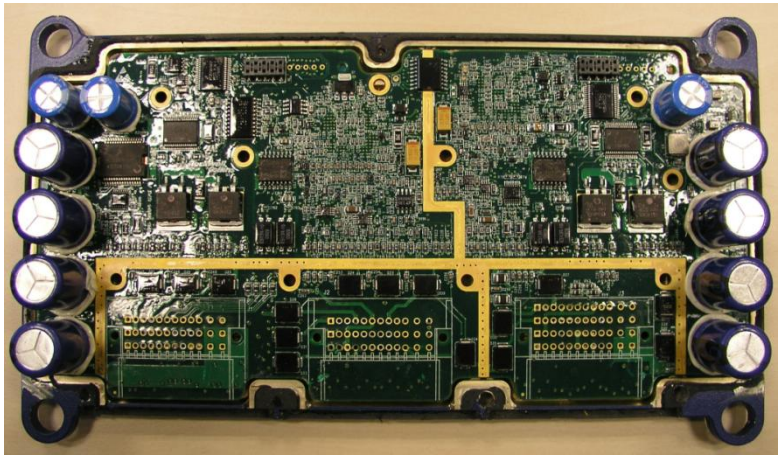
Requirement:
Aviation safety

Highly redundant
Engine Management System
with intelligent redundancy management

The 912iS Engine Management System

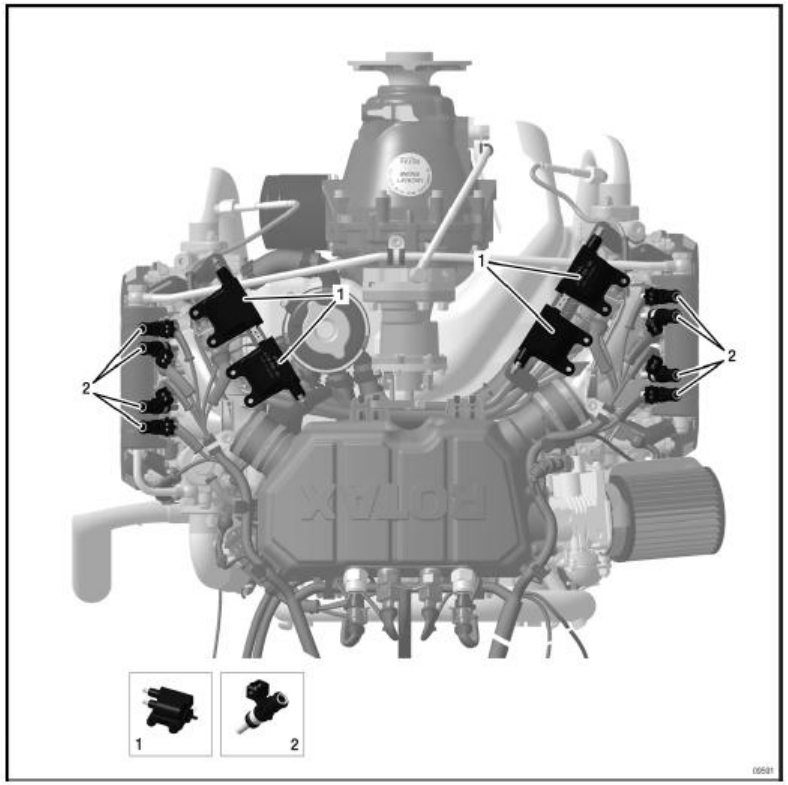
- ECU consists of two separate control units, so called “Lanes”
- Redundant engine control system is capable of managing the redundant components
- Redundant implementation of all safety-critical sensors and actuators

Lane A Lane B

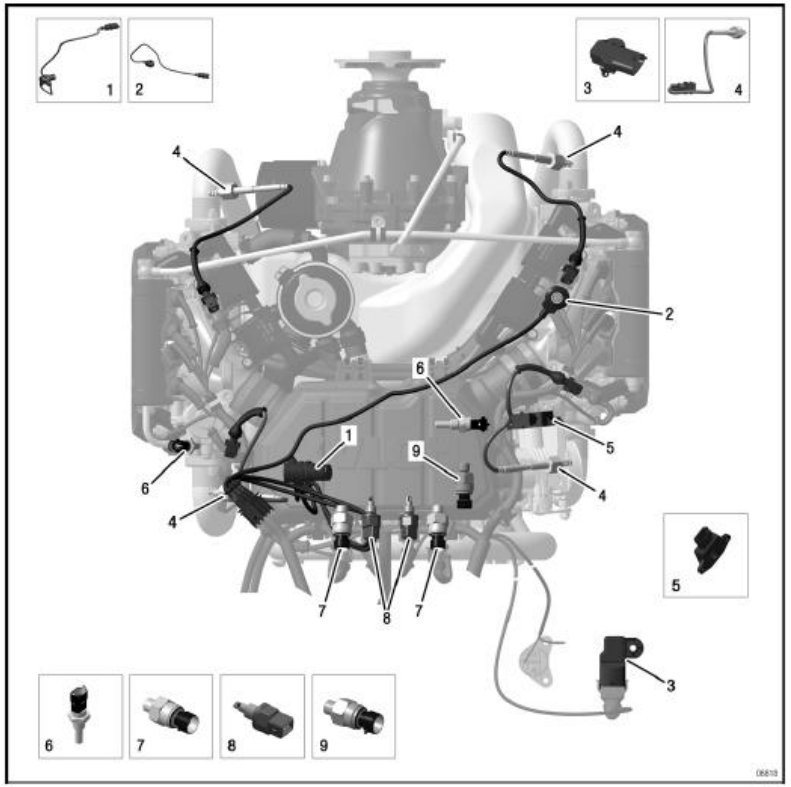


Electric & Electronics

Implementation of safety-critical sensors



Redundant actuators

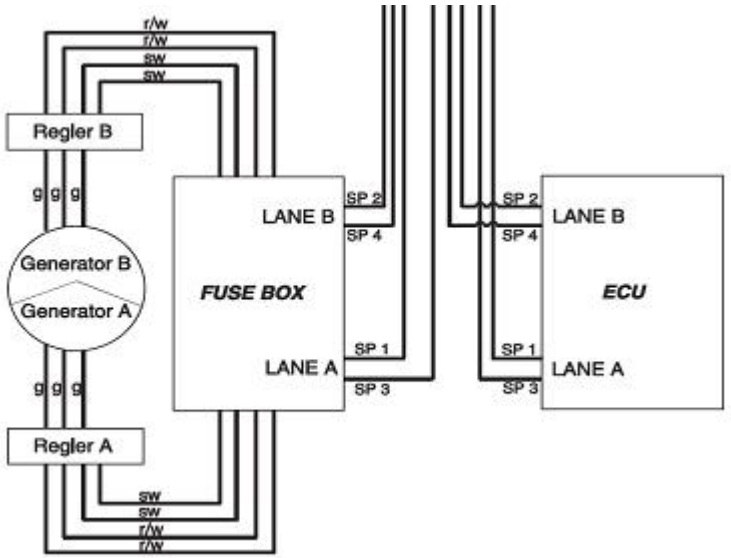


Redundant sensors

Electric & Electronics

Redundant Power Supplies

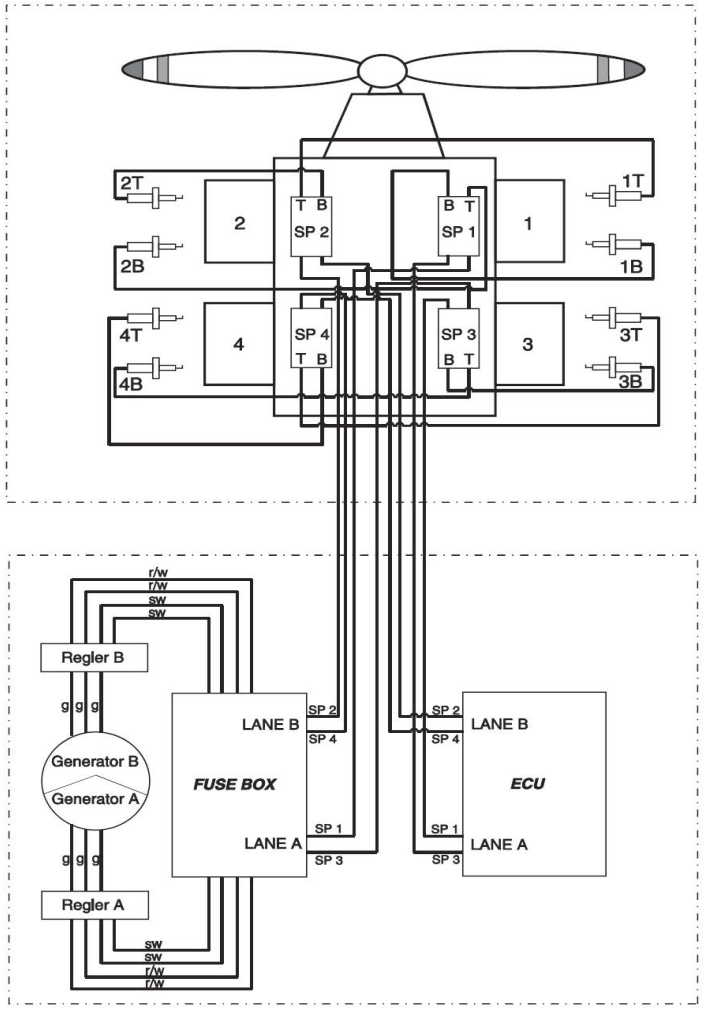
- The 912 engine management system is supplied by redundant regulated power supplies.
  - Two permanent magnet generators
  - Two independent regulators
  - Power distribution unit (Fuse Box)
- System A permanent magnet generator and regulator is assigned for supplying the EMS system only.
- System B permanent magnet generator and regulator is assigned for supplying the aircraft system.



Electric & Electronics

Ignition System

- Sp1, SP3:
  Double ignition coils assigned to Lane A
- Sp2, SP4:
  Double ignition coils assigned to Lane B
- 1B…4B:
  Spark plugs assigned to Lane A
- 1T…4T:
  Spark plugs assigned to Lane B

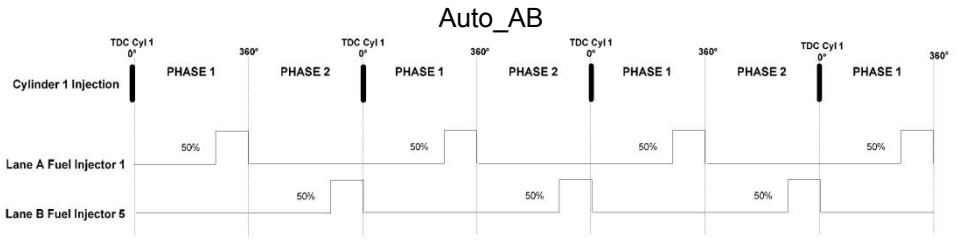


Electric & Electronics

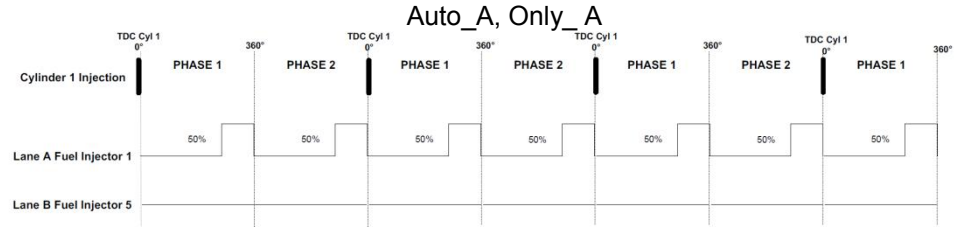
Injection system

Pair	Phase 1	Phase 2
Cylinder 1	Injector 1	Injector 5
Cylinder 2	Injector 2	Injector 6
Cylinder 3	Injector 3	Injector 7
Cylinder 4	Injector 4	Injector 8

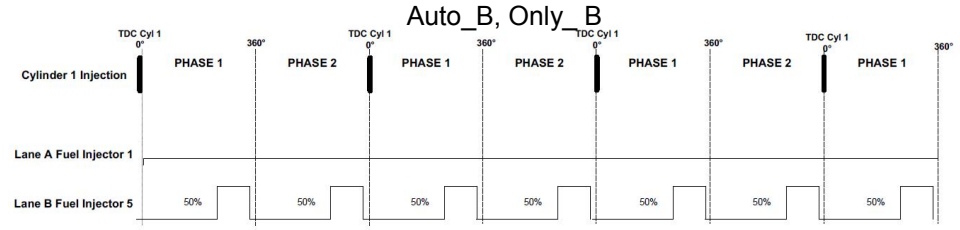
Auto AB mode



Auto A mode



Auto B mode



A single revolution of the engine is defined as one PHASE of the injection process.
50% of fuel required for cylinder 1 is injected per engine revolution

Electric & Electronics

Galvanic Separation of Engine and Aircraft

Complete separation of the EMS electrical ground from any vehicle ground

- Increased robustness against direct and indirect effects of a lightning strike
- Robustness against any type of short to vehicle failure

Control Strategy

Redundancy Management - Software algorithms

Lane declares **Fault**

- Possible loss of functionality, not significant enough
- to force a change in system mode.

Lane declares **Failure**

- Critical functionality has been lost and a change to
- a different system mode is required.

Control Strategy

Redundancy Management

System Modes

System Mode	Description
AUTO_A	Both Lanes Powered A Commands Fuel and Ignition
AUTO_B	Both Lanes Powered B Commands Fuel and Ignition
AUTO_AB	Both Lanes Powered A and B Command Fuel and Ignition A Drives B
ONLY_A	A Powered A Commands Fuel and Ignition
ONLY_B	B Powered B Commands Fuel and Ignition
INIT	A and/or B Initializing

Electric & Electronics

Redundancy Management

Warning lamp matrix:

Index	ECU operation mode Lane A	ECU operation mode Lane B	Warning Lamp Lane A Status	Warning Lamp Lane B Status
1	Off	Off	not illuminated	not illuminated
2	Boot up	Boot up	Lamp Test	Lamp Test
3	Normal	Normal	not illuminated	not illuminated
4	Normal	Off	not illuminated	continuous illuminated
5	Off	Normal	continuous illuminated	not illuminated
6	Fault	Off	flashing	continuous illuminated
7	Failure	Off	continuous illuminated	continuous illuminated
8	Off	Fault	continuous illuminated	flashing
9	Off	Failure	continuous illuminated	continuous illuminated
10	Fault	Normal	flashing	not illuminated
11	Normal	Fault	not illuminated	flashing
12	Failure	Normal	continuous illuminated	not illuminated
13	Normal	Failure	not illuminated	continuous illuminated
14	Fault	Fault	flashing	flashing
15	Fault	Failure	flashing	continuous illuminated
16	Failure	Fault	continuous illuminated	flashing
17	Failure	Failure	continuous illuminated	continuous illuminated

Mechanical Impact

Overview

The Implementation of this unique EMS System forced nearly all mechanical systems on the engine to be changed:

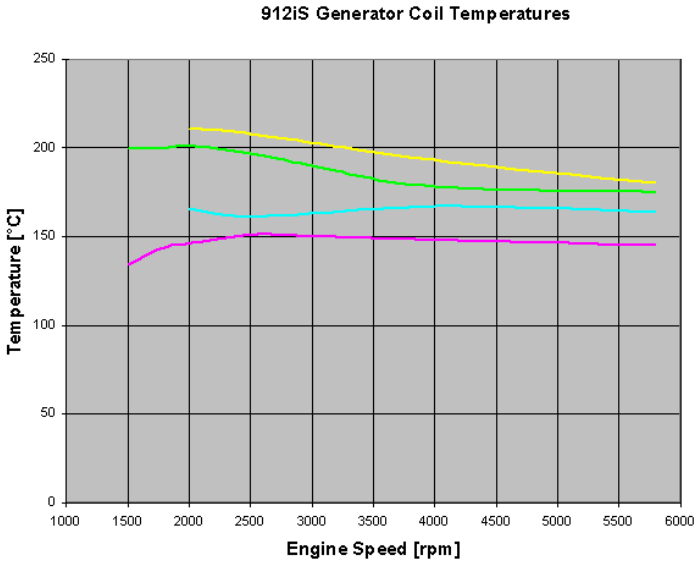
- Crankcase: changed
- Cranktrain: changed
- Cylinderhead: changed
- Gearbox/ transmission: changed
- Induction system: changed
- Fuel system: changed
- Lubrication system: changed
- Exhaust system: changed
- Engine management system: changed
- Cooling system: unchanged
- Electric components: changed

Mechanical Impact

Generator Performance

- Yellow line: Generator Lane A
- Blue line: Generator Lane B
- Pink line: Engine / EMS System need

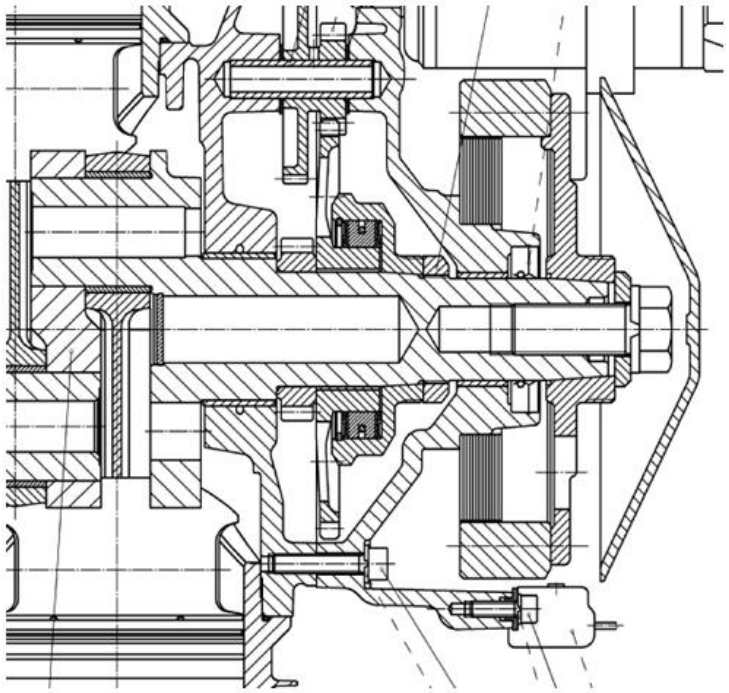
Resulting Generator Temperatures

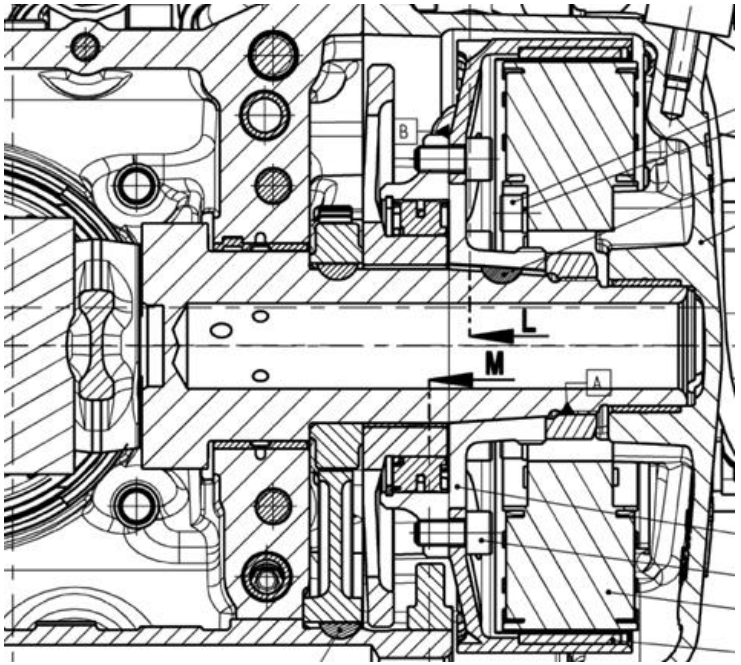


- Yellow line: Temp. Lane A, Oil 135°C
- Green line: Temp. Lane A, Oil 100°C
- Blue line: Temp. Lane B, Oil 135°C
- Pink line: Temp. Lane B, Oil 100°C

Mechanical Impact

Generator Design Changes





Base engine air cooled generator

Oil cooled generator

Questions?

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