AIRCRAFT HYDRAULIC SYSTEM TECHNOLOGIES

WIEFP2016 – 3rd Workshop on
Innovative Engineering for Fluid Power

Magnus Landberg, Birgitta Lantto

DISPOSITION

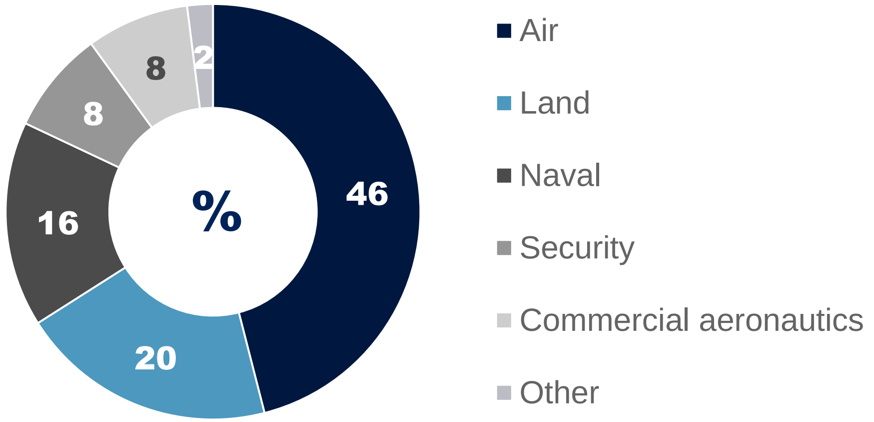
- Intro Saab Company
- Design Philosophy - Aircraft Hydraulic Supply System
- Monitoring Hydraulic Systems
  - Leakage Monitoring
  - Pump Monitor for Early Fault Detection

AN **OVERVIEW** OF OUR COMPANY (2015)

SALES

27,186

MSEK



14,700

EMPLOYEES

100

CUSTOMER COUNTRIES

OUR **PERFORMANCE** IS STRONG

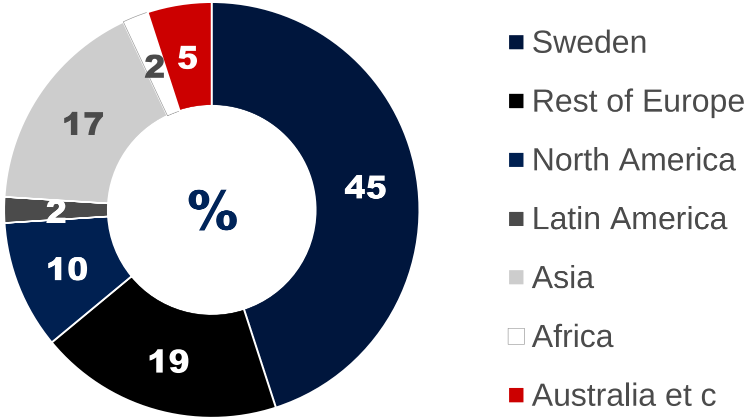
2015

- Record high order backlog
- Sales increase by 16 percent, with growth in all business areas
- Gripen to Brazil
- A26 submarine to Sweden
- Airborne early warning and control to United Arab Emirates
- Continued investments in T-X program
- Focus on execution of large projects

Order backlog, MSEK	**113,834**
Sales, MSEK	**27,186**
Operating income*, MSEK	**1,900**
R&D, share of sales %	**25**

* EBIT

Geographic distribution of sales



SAAB IN **LATIN AMERICA**

Headed by
Bo Torrestedt

Head office in Brasilia, Brazil

Local office in Chile

A few examples:

- 36 Gripen NG to Brazil
- Erieye operational in Mexico and Brazil
- RBS 70 sold to Brazil and other countries
- Ground combat in use in several countries
- Training and simulation used by several armed forced
- Traffic Management to several countries

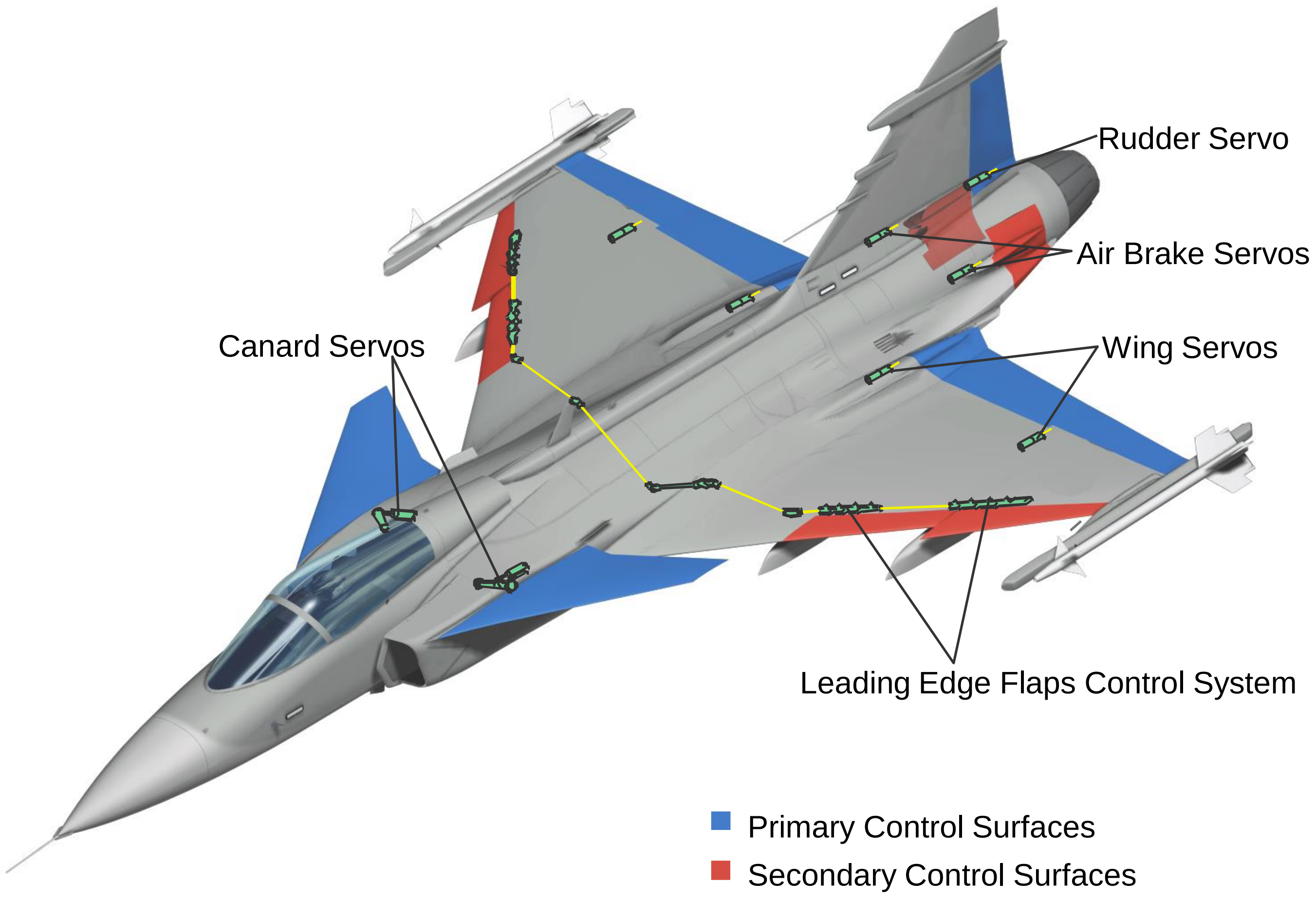
Share of global defence materiel spending 2016 – 2020	**3 %**
Average annual market growth 2016 – 2020	**3 %**
Saab employees in this region	**18**

SYSTEM DESIGN DRIVERS

The hydraulic system shall meet the requirements on function and performance with the following “constraints”:

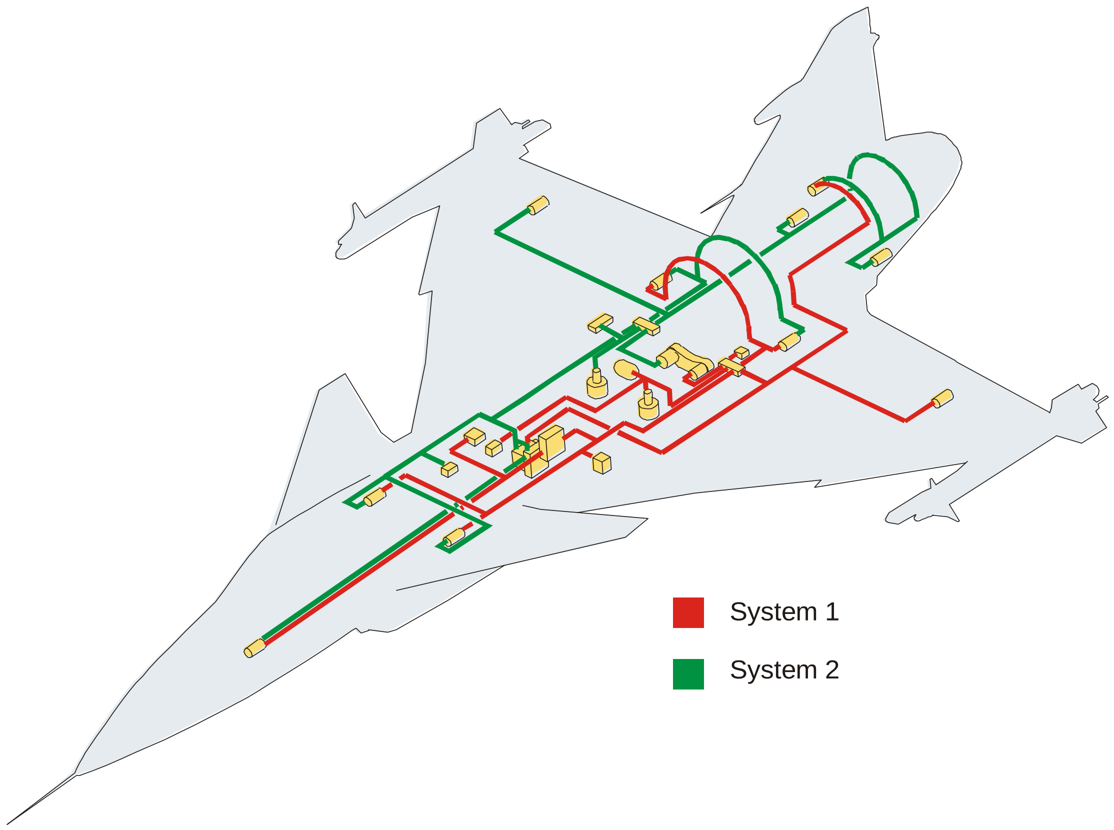
- High reliability
  - Flight critical systems
- Low life cycle cost
  - Low maintenance, few inspections
  - Increased MTBF, efficient fault localization, good accessibility
- Low weight and volume
  - Compact installation and highly integrated solutions

GRIPEN FLIGHT CONTROL SYSTEM

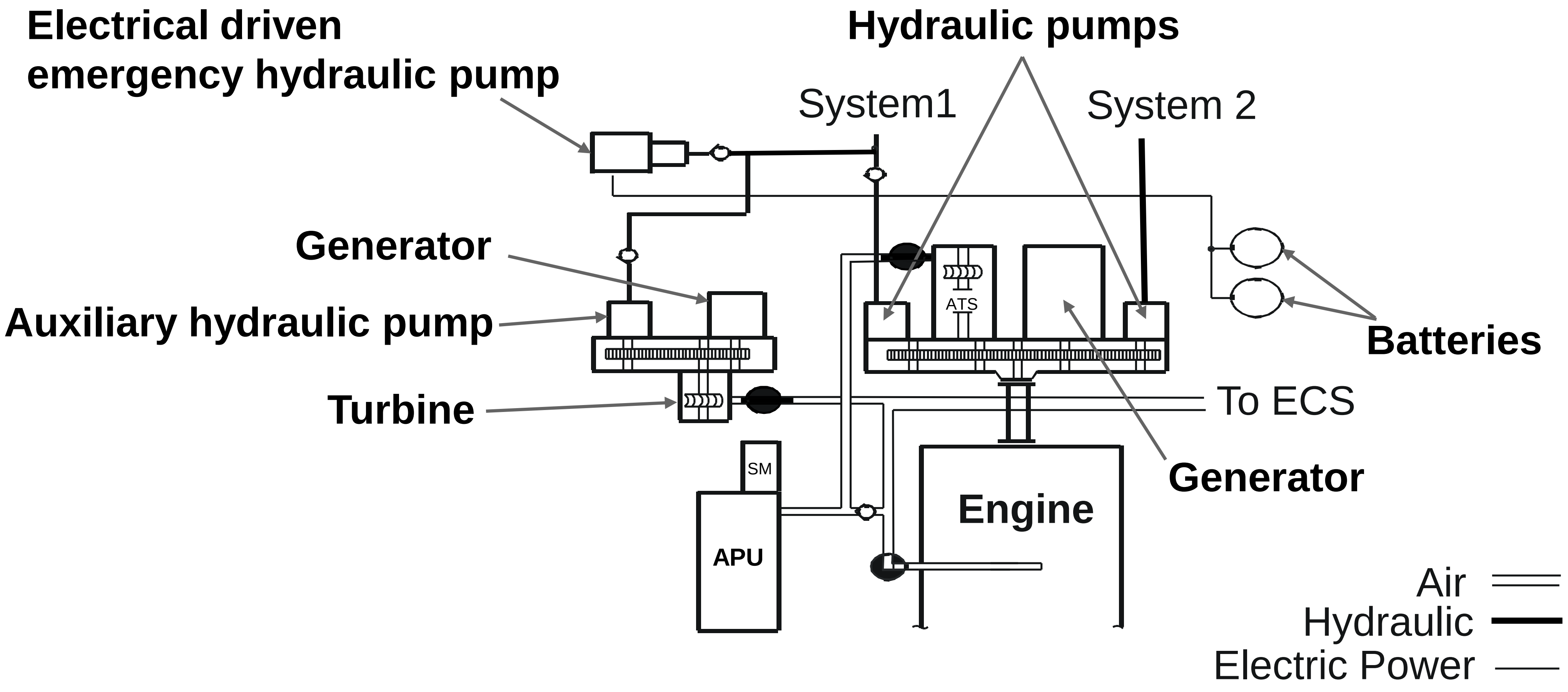


HYDRAULIC SYSTEM

- Two independent, separated hydraulic systems installed one at each side of the aircraft
- Redundant supply to flight controls, landing gear and brakes
- Auxiliary and Emergency back up system
- Level and leakage monitoring
- Pressure and temperature monitoring



SYSTEM LAYOUT



OVERVIEW FUNCTION

The hydraulic supply system shall provide flow to:

- Primary and secondary flight control actuators
- Landing gear system
- Brakes
- Fuel pumps
- Aerial refueling receptacle

Leakage detection and means to isolate the leakage

PERFORMANCE DESIGN PHILOSOPHY

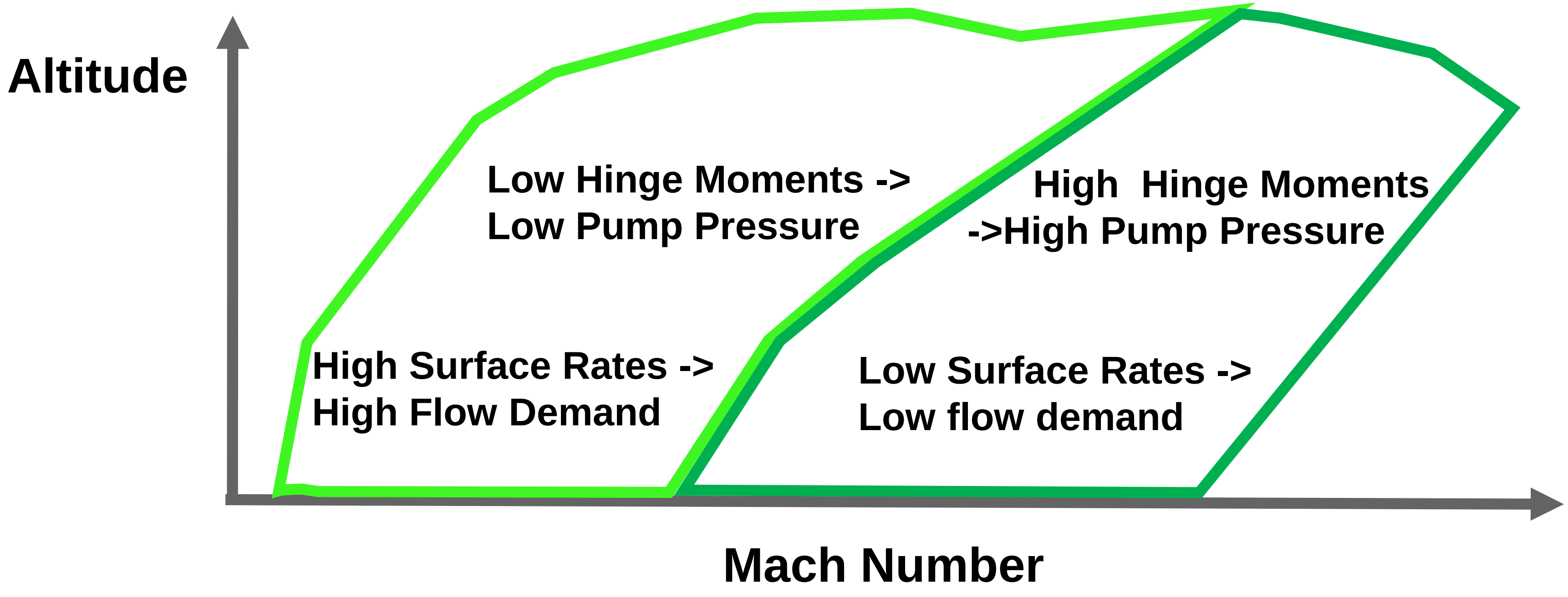
- **Power = flow x pressure = angular rate x moment**

- The pumps for normal and degraded modes is designed with a “constant torque“ regulator/variable pressure whereby a minimum torque level is required from the power sources.

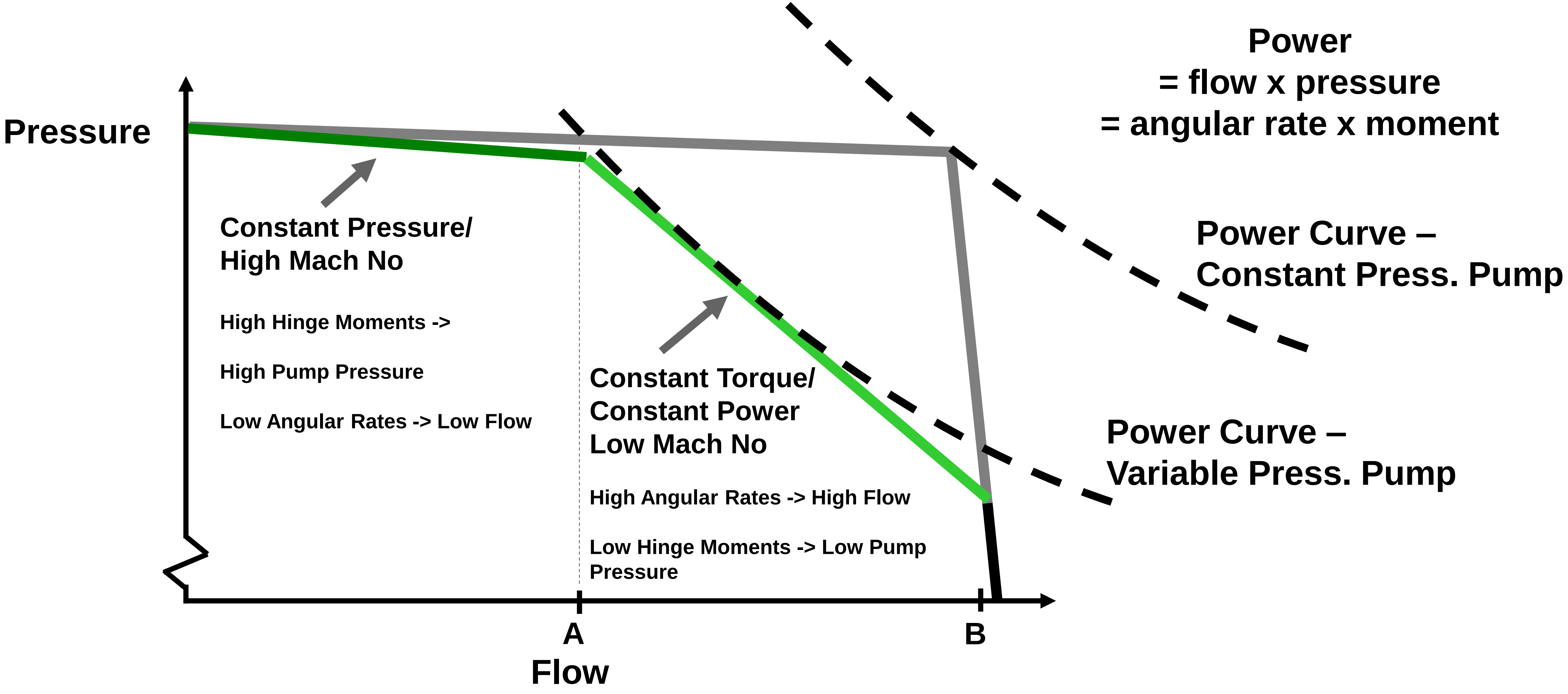
- This is made possible due to that the flight control system hydraulic power requirements changes with operation conditions, Altitude versus Mach No

PERFORMANCE REQUIREMENTS ON HYDRAULIC SUPPLY

Flight Envelope



CHARACTERISTICS FOR HYDRAULIC PUMP



VARIABLE PRESSURE PUMP DESIGN

Benefits with small variable pressure pumps:

- Decreased Hydraulic Power -> Smaller Gear Box -> Less Take Off Power From Engine
- Decreased Energy & Fuel Consumption -> Lower Heat Rejection & Lower Losses -> Smaller Heat Exchangers
- Decreased MHP Weight, MHP Volume & MHP Costs

MULTI USE OF POWER ACCUMULATORS

The Power Accumulators are used in different situations:

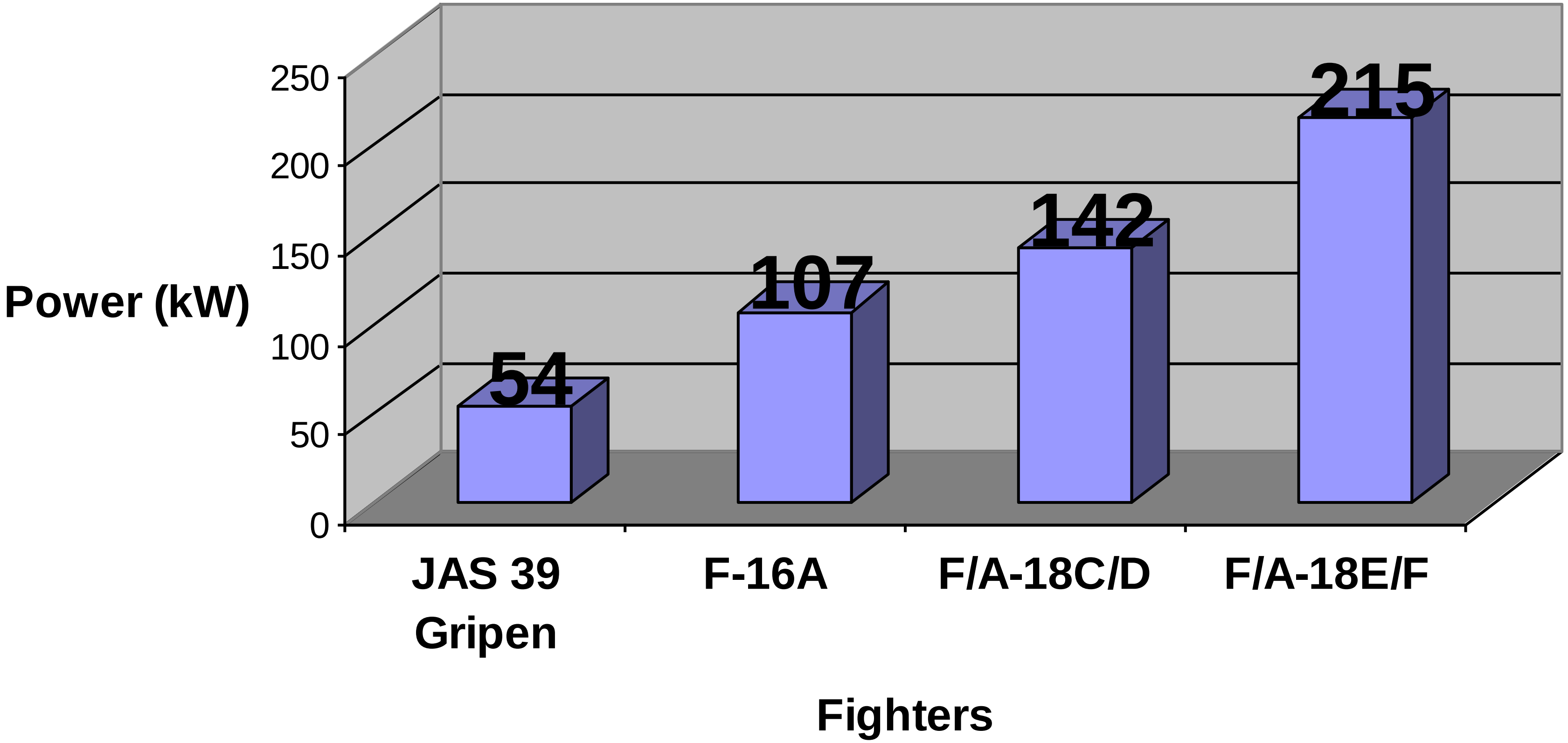
- The primary tasks are in normal flight to support the hydraulic pump to compensate for heavy flow demand during short time periods. The pump characteristic is designed for accumulator supply.

- To provide continuous hydraulic power to provide emergency backup for any hydraulic systems required for flight control movement necessary to maintain controlled flight in the event of engine failures.

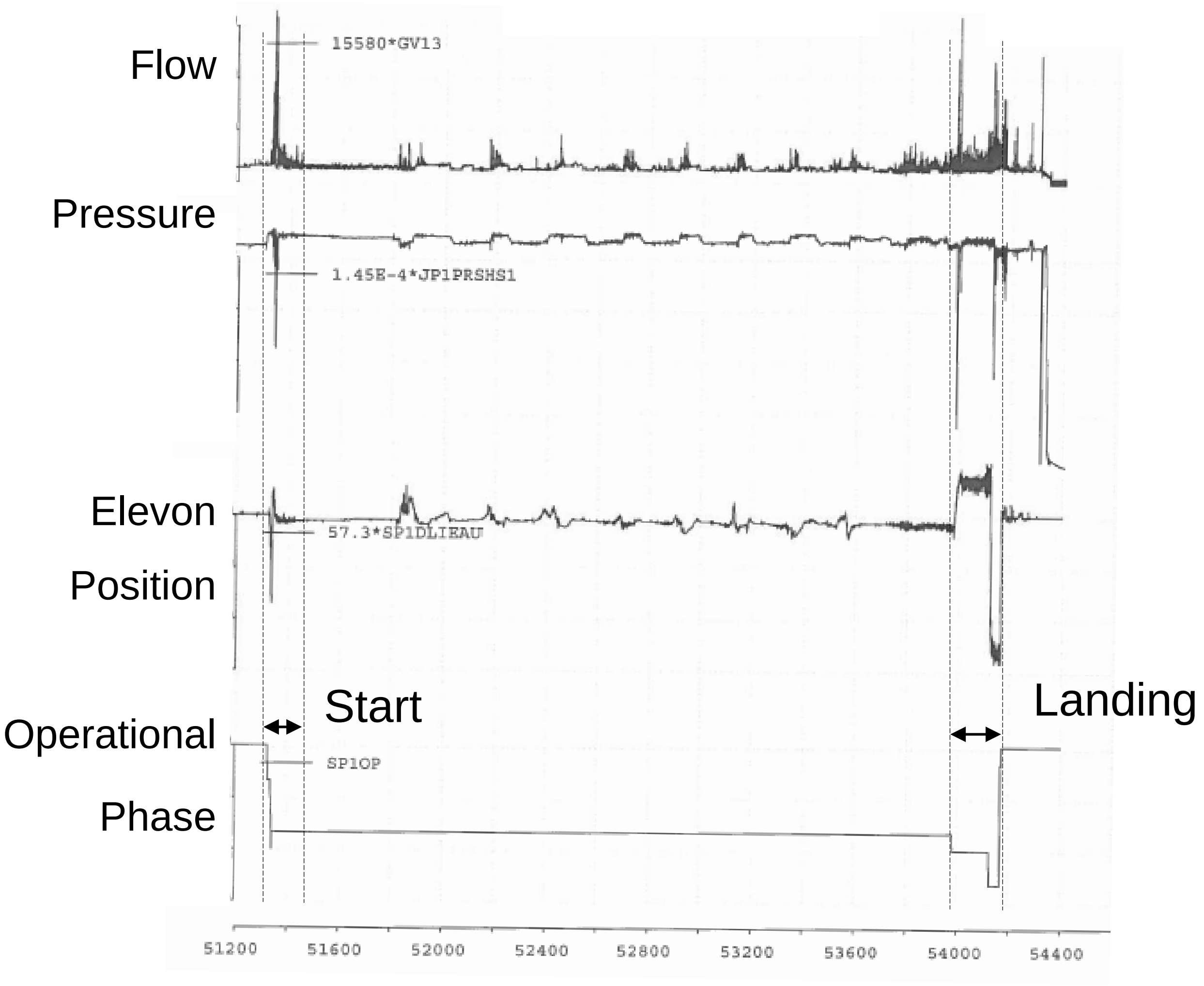
- To keep the respective systems pressurised when the engines are shut down.

- Supply the parking/towing brake with hydraulic pressure when the engines are shut down.

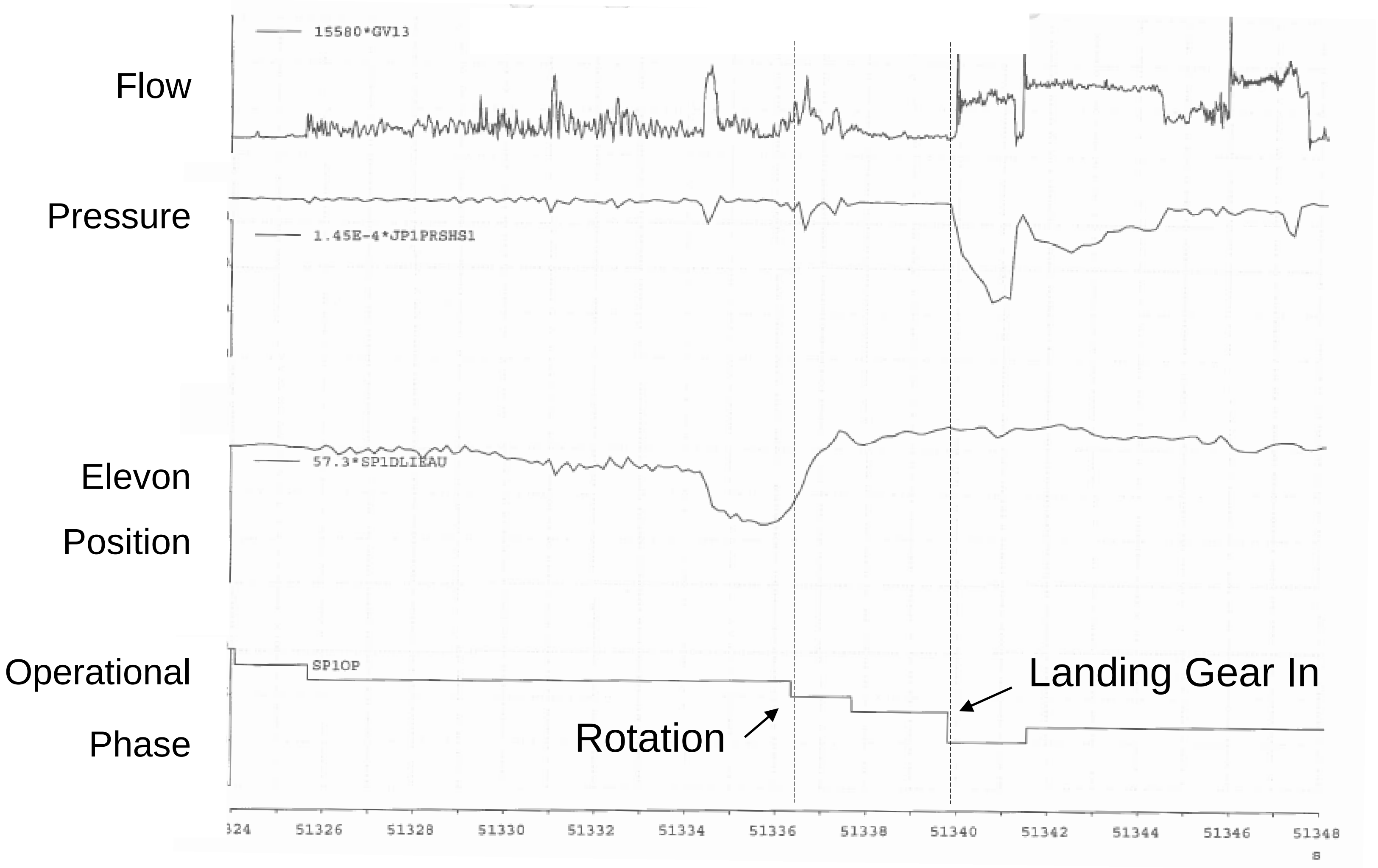
COMPARISON HYDRAULIC POWER JAS 39 GRIPEN, F-16 & F-18



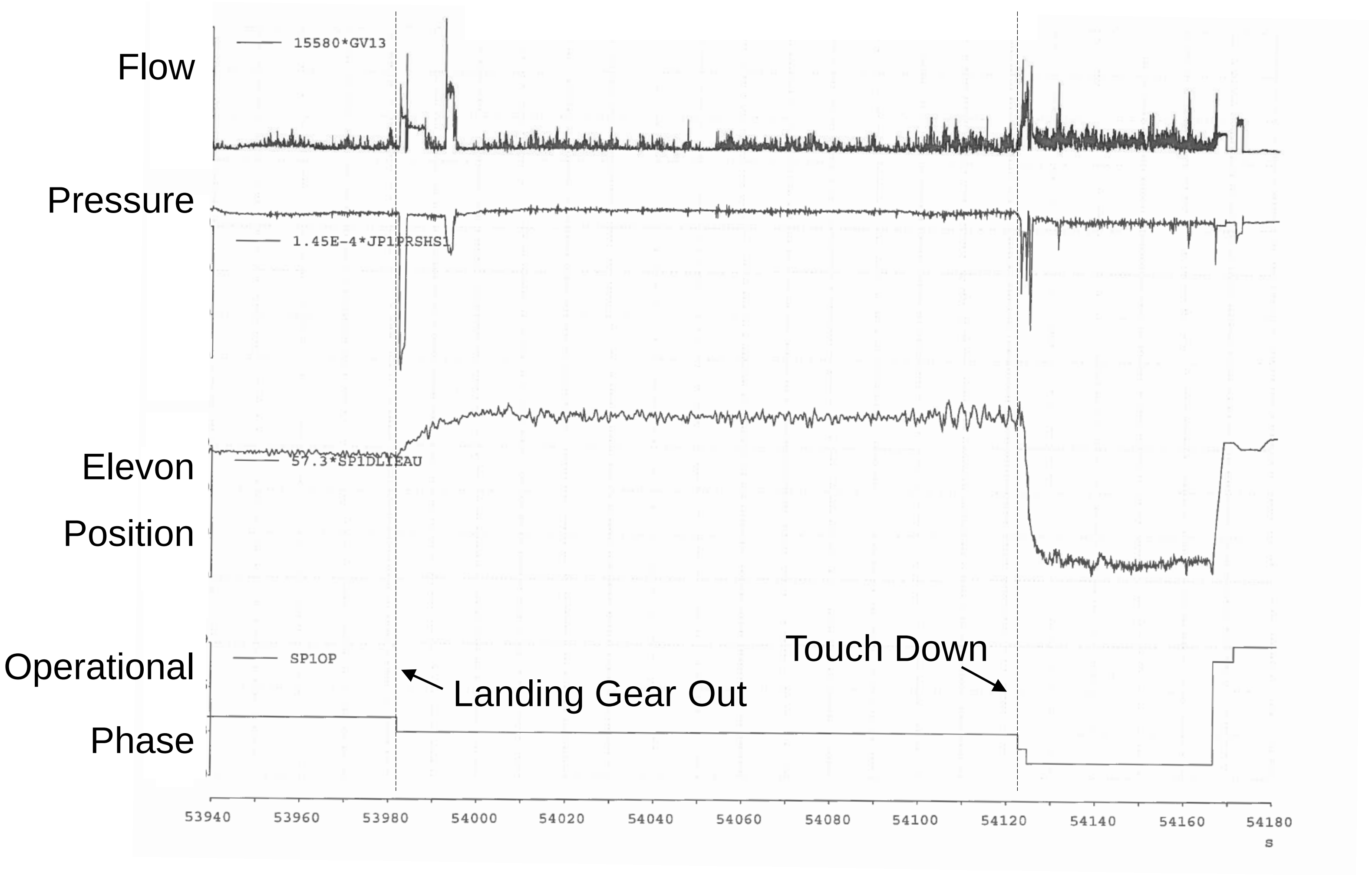
NORMAL FLIGHT



START


Flow
15580*GV13
Pressure
1.45E-4*JP1PRSHS1
Elevon
Position
57.3*SP1DLIEAU
Operational
Phase
SP1OP
Landing Gear In
Rotation
51326
51328
51330
51332
51334
51336
51338
51340
51342
51344
51346
51348
s

LANDING


Flow
15580*GV13
Pressure
1.45E-4*JP1PRSHS1
Elevon
Position
57.3*SP1DLIEAU
Operational
Phase
SP1OP
Touch Down
Landing Gear Out
53940
53960
53980
54000
54020
54040
54060
54080
54100
54120
54140
54160
54180
s

MONITORING HYDRAULIC SYSTEMS

- Start Up Check
- Continously functional monitoring
- Leakage monitoring
- Pump monitoring

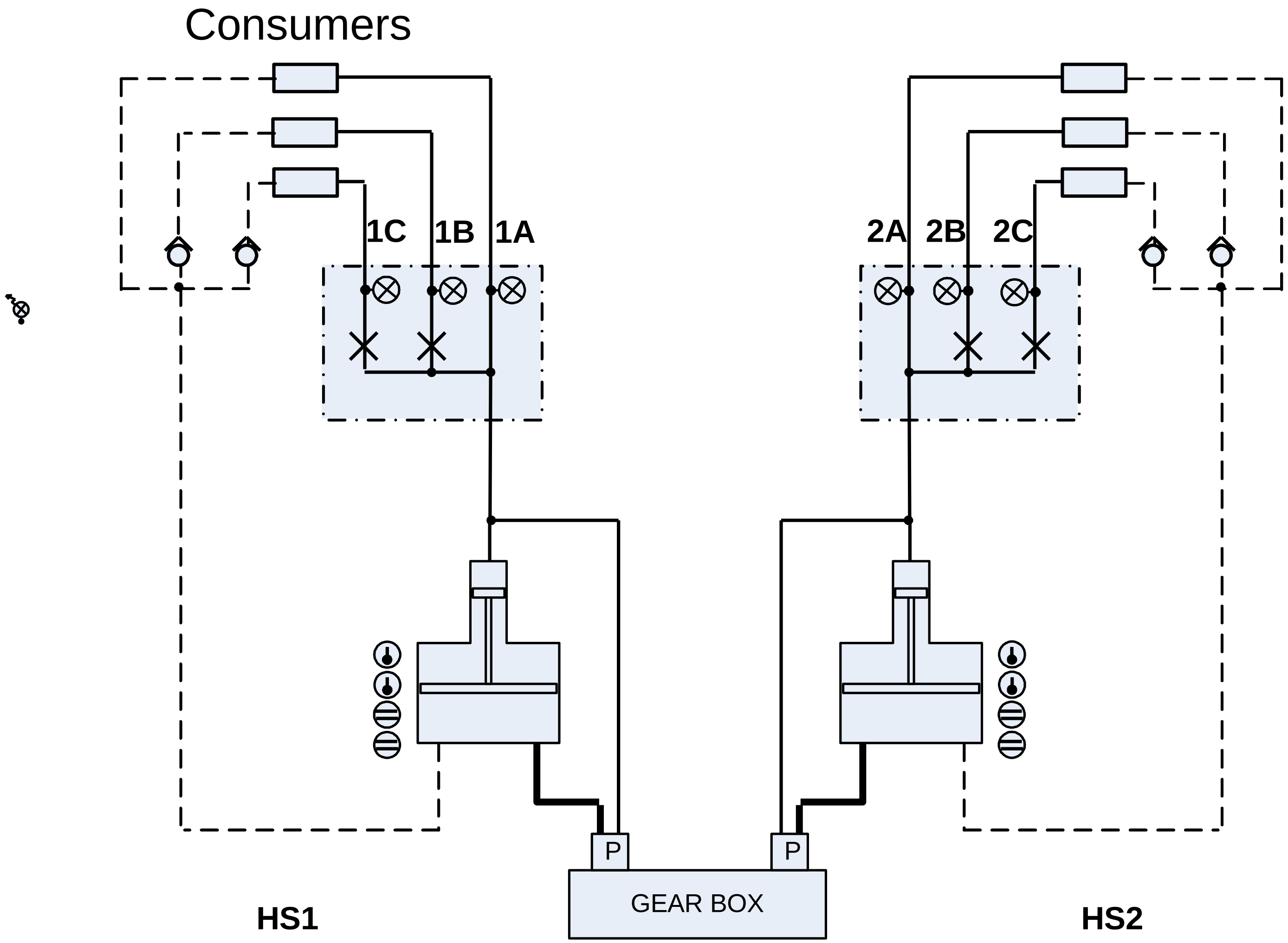
AUTOMATIC START UP CHECK DURING A/C START-UP

- Test routines at power-up ensure correct hydraulic power supply at mission start.
  - Each time the power is switched on, the GECU performs an internal Start Up Check (SC).
  - Hydraulic pump capacity is tested with the pumps remaining in the aircraft. This test is run with active avionics and flight control system.
- The start up check is administered by the GECU. The pilot is informed of the result via cockpit displays

CONTINOUSLY FUNCTIONAL MONITORING

- Functional monitoring in GECU during operation and consists of:
  - Monitoring of the pressure level in the systems
  - Monitoring of the Reservoir level and isolation of branch circuits shut-off valves in the event of leakage
  - Monitoring of the oil temperature
  - Monitoring of the GECU and its sensors and valves (electrical function), for fault detection and fault location
- Warning and Cautions are controlled by signals from the GECU to the FMC via the RTHI Databus

LEAKAGE MONITORING (1/4)



LEAKAGE MONITORING (2/4)

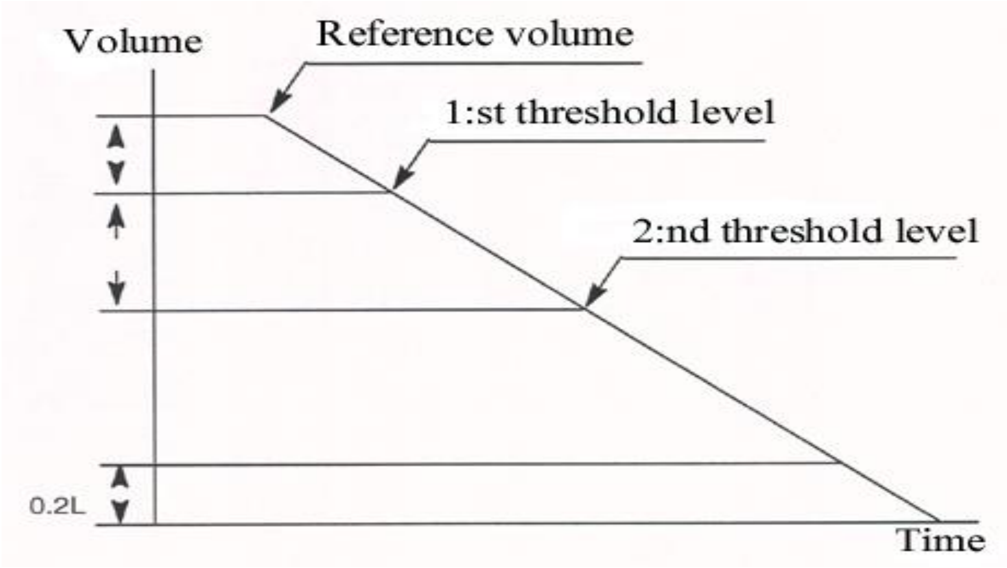
- The HS leakage monitoring starts when the GECU is powered (once GECU Start Up Check is found OK)
- A reference volume is selected twice prior to take off. First time is when the GECU is powered, the second after entering stick mode in FCS
- The system volumes are continuosly monitored and compared to the reference volume, stored at ground prior to take off. If a leakage occurs, the system volume will decrease and when the first threshold level is reached, the first Branch Shut-off Valve is closed.
  - If the system volume stabilizes, the Shut-off Valve will be kept closed until the aircraft is de-powered on ground.
  - If not, the closed Branch Shut-off Valve will be opened and the second Branch Shut-off valve will be closed instead.

LEAKAGE MONITORING (3/4)

- If the leakage cannot be isolated, due to that it is located in branch A or the supply circuit, the second Branch Shut-off Valve will be opened when the Reservoir is empty to enable leakage isolation in the other system
- The hardware safety logic in GECU prevents closure of more than one Branch Shut-off Valve at a time.

LEAKAGE MONITORING (4/4)

	HS1	Branch	HS2	Branch
1:st Threshold level (lit)	1.0	1B	1.0	2B
2:nd Threshold level	+2.0	1C	+2.0	2C



- During normal LDG extension/retraction the threshold level in HS1 is lowered
- If the leak rate is large the second threshold level is not used

PUMP MONITOR FOR EARLY FAULT DETECTION

- There is a need to find a method for minimizing expensive repairs on hydraulic pumps

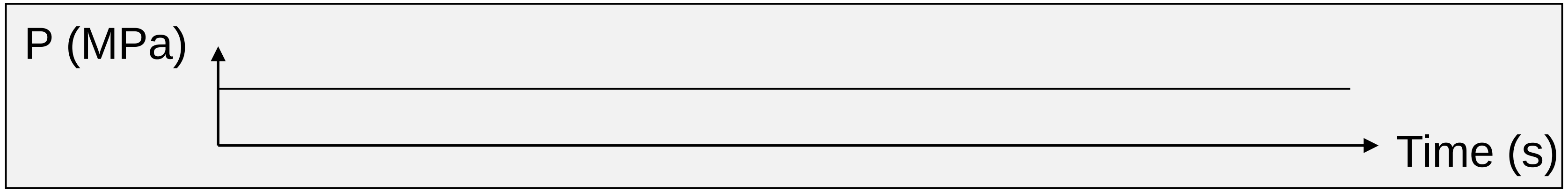
- A need to identify pump individuals which show signs of malfunction in early stages

PUMP MONITOR FEATURES

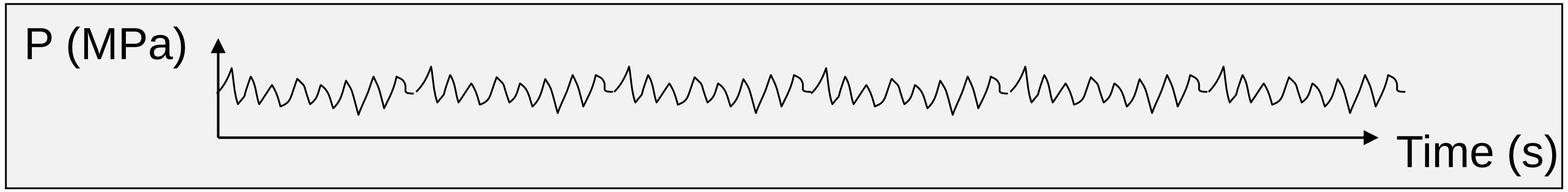
- Simple, robust and reliable algorithm
- The monitor has been in operation for years and has identified a number of malfunctioning pumps in early stages
- The monitor increases the availability
- The monitor is general - it is suitable for implementation on different pumps
- The patented monitor can be implemented in existing aircraft fleet (retro mod) because even the most older operational A/C´s have the required computer capacity and pressure sensors
- Alternative solutions are complex and expensive to implement in aircraft.
  They uses FFT techniques. Requirements: Fsampl = 5-10 kHz

BAKGROUND

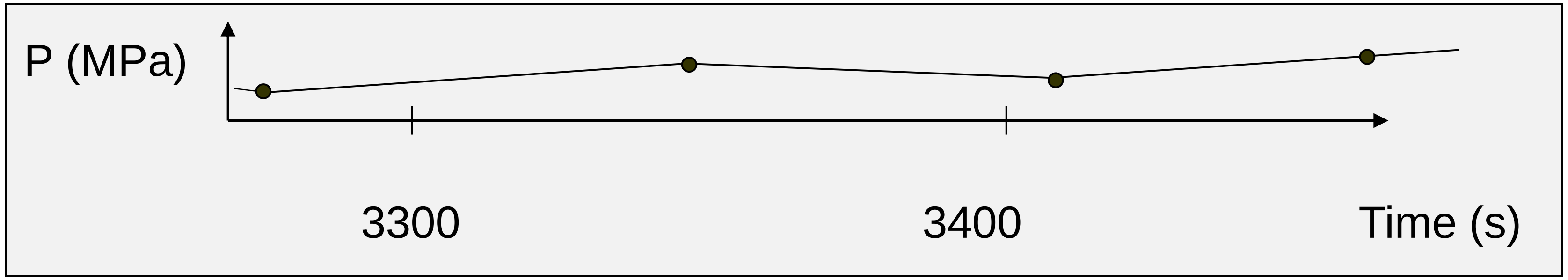
When flying wings level, ie when the rudders basically at standstill, the pump pressure is constant for a normal functioning of the pump.



A malfunctioning pump in the same flying mode generates pressure ripple

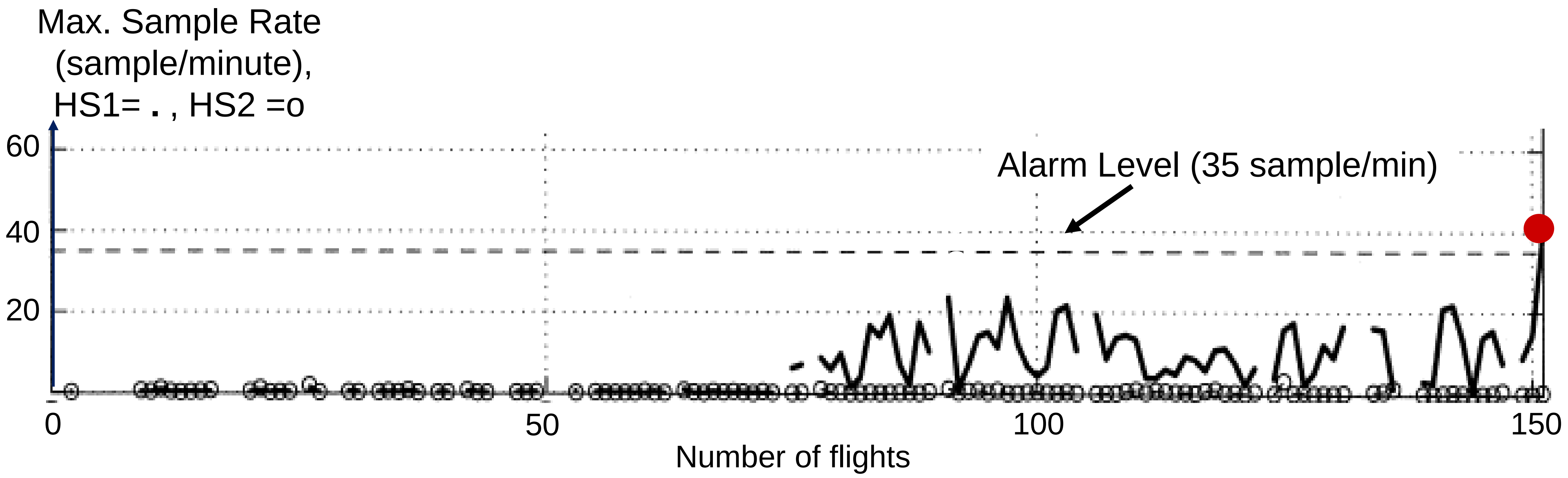


THE MONITOR OPERATION



- The pressure data is stored when the hydraulic pressure changes
- The limit for storing pressure sample is a 0,25 MPa change
- The monitor counts the number of pressure sample/minute when flying wings-level. Normally very few sample/minute
- The monitor alarms when the number of pressure sample exceeds a predefined level

EXAMPLE


Max. Sample Rate
(sample/minute),
HS1= . , HS2 =o
60
40
20
Alarm Level (35 sample/min)
0
50
100
150
Number of flights

THANK YOU FOR LISTENING!

Magnus Landberg
Saab Aeronautics
Phn +46 734 18 57 20
magnus.landberg@saabgroup.com