Unmanned Aerial Vehicles

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Intro, sensors, systems, …

Content

- Definitions
- Sensors
- Systems

- Iran Air 655
  - A300, Bandar Abbas to Dubay

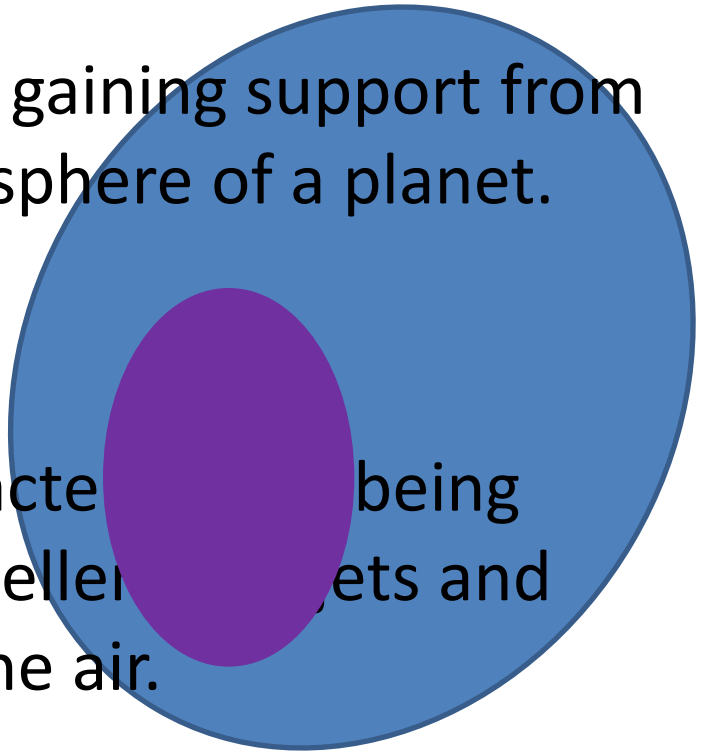
Repetition

An aircraft

- is a vehicle that is able to fly by gaining support from the air, or, in general, the atmosphere of a planet.
  - balloon (buoyancy), airship

An airplane

- is a type of aircraft that is characte being heavier than air, driven by propelle ets and having wings which keep it in the air.
  - Fixed-wing aircraft



Repetition

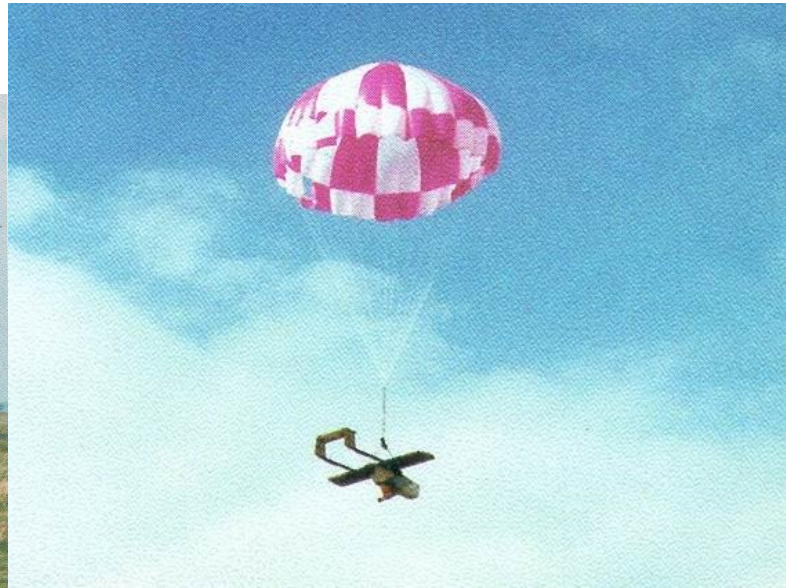
- UA – Unmanned aircraft
- UAV - Unmanned Aerial Vehicle
  - Autonomous aircraft
  - RPA – Remotely piloted aircraft
    - Aircraft Model

Airplane without pilot onboard

- Law No. 49/1997 Sb. about civil aviation, § 52
- CAA -> Permit to Fly
  - Requirements?

Repetition

- UAS – Unmanned aircraft system
  - UAV
  - Control station
  - Other devices (launch, landing, com. …)
  - RPAS – Remotely piloted aircraft system
  - RPS – Remote pilot station



- Pilot and the UA has to be approved by CAA
  - i.e. he is registered and fulfills requirements
  - Registration is valid just for one type of UA
  - Registration is valid for 2 years
  - Expect to a model aircraft up to MTOW 20 kg

Repetition

Maximum take-off mass

- Mass of the aircraft with all equipment, consumables, load, …
- Maximal take-off weight approved in the type certificate or flight approval

UA

- MTOM < 150 kg

Minimal (stall) Speed

The minimal speed (CAS) of the aircraft that is still under pilot's control when:

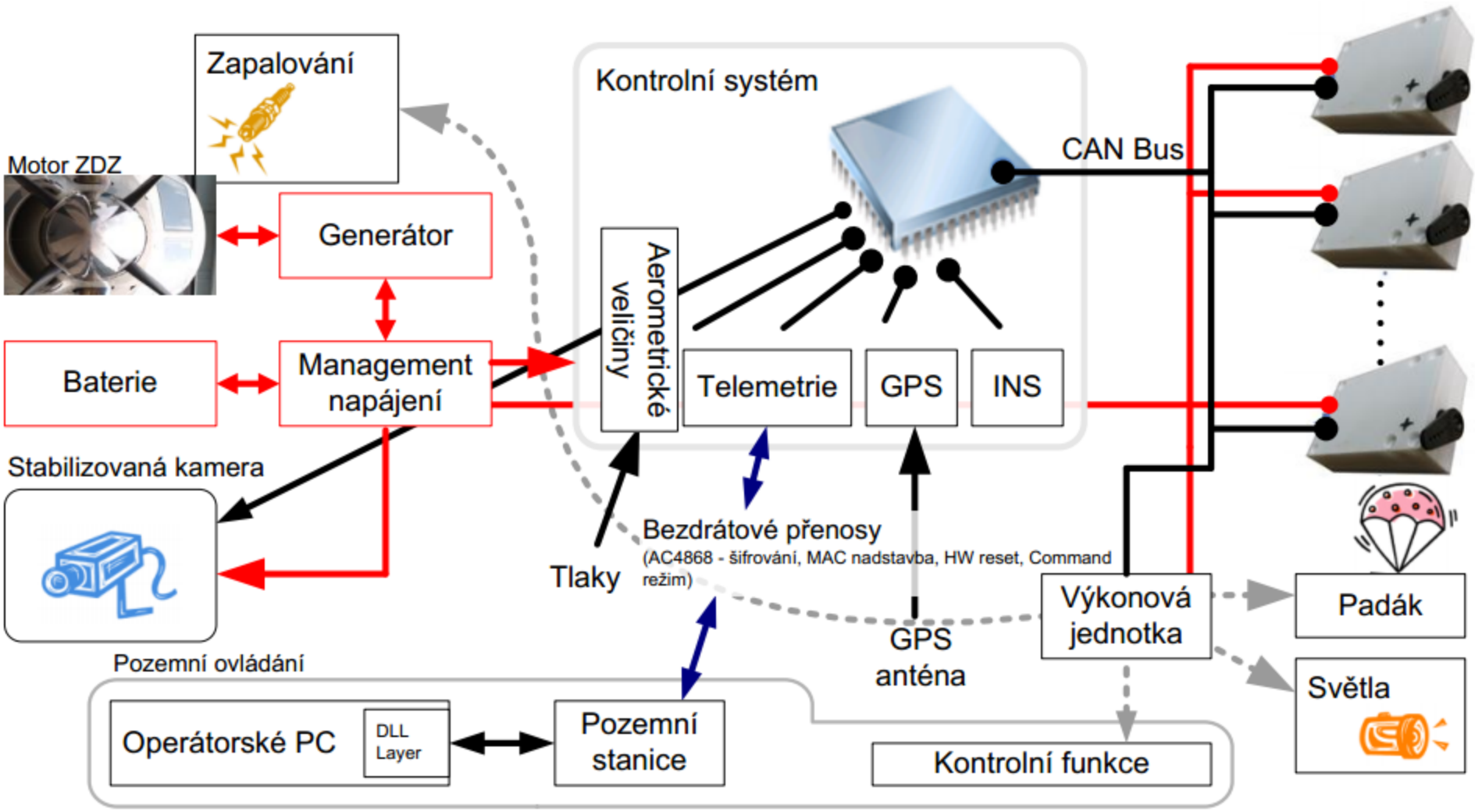
- Propeller is in take-off configuration
- Landing gear is down
- Flaps in landing configuration
- Center of gravity in the worst (but allowed) position
- At maximal weight

Main components

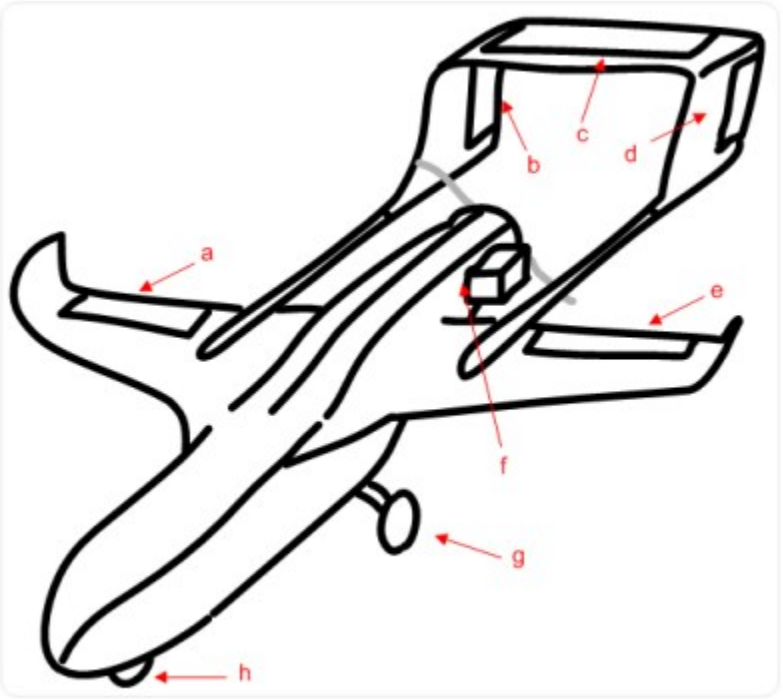
- Fuselage
- Engine + propeller (piston or jet engine, fuel or electric)
- Parts and appliances

- Vibrations
- Noise (max 96 dB, measured 3 m far from an airplane)
- Speed range
- Altitudes
- Maneuvers

Basic Block Diagram

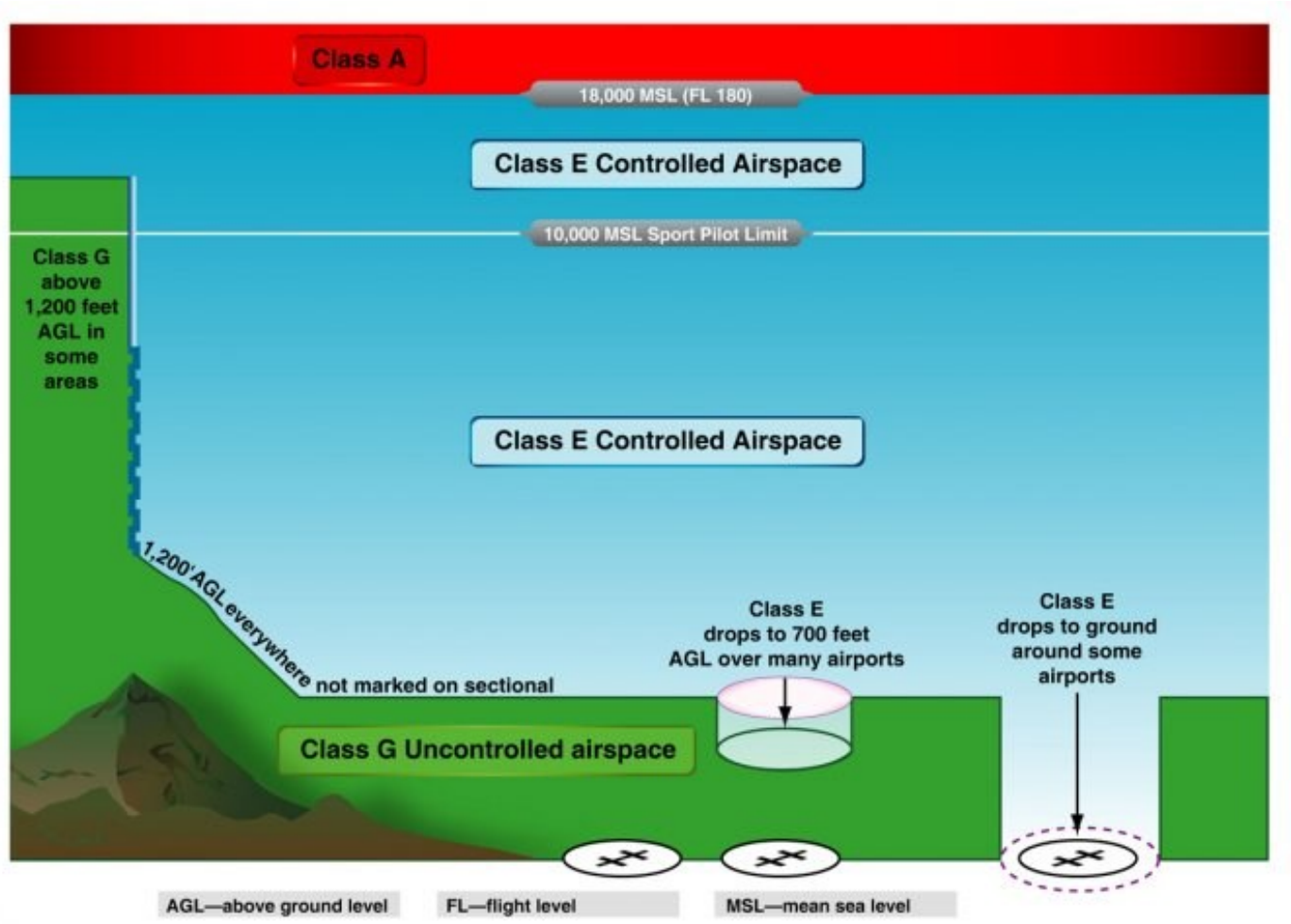


UAS Example



Airspace

Where does the UAV fly?



http://aviation-elearning.com/airspace/

Requirements

- Ranges of sensors
- Properties of sensors
- Properties of servos
- Collapsible gear control
- Breaking control (ABS)

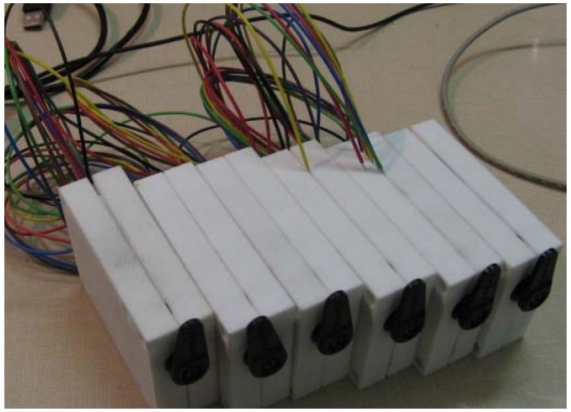
Fail Safe system

Backup for communication channel loss.

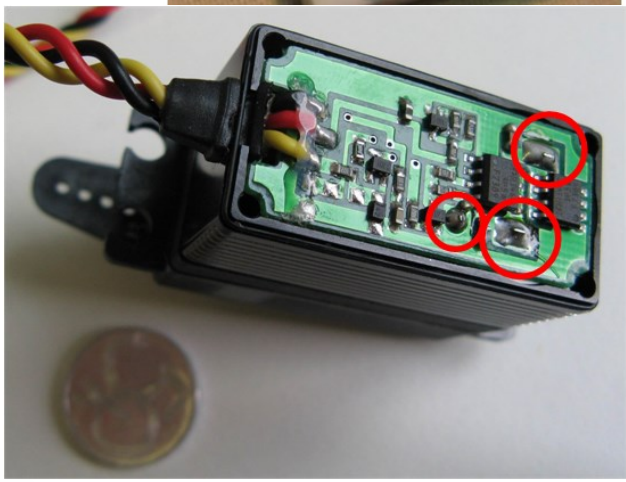
Protection against threatening of persons, property and environment :

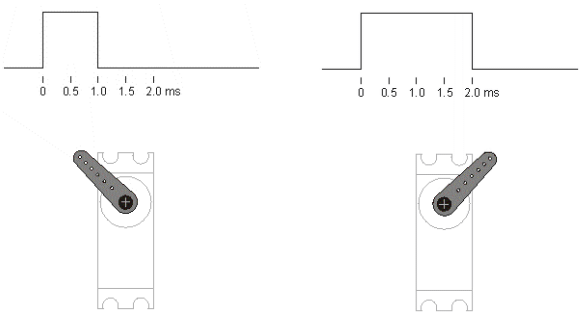
- Flight behind the range of the com. Channel
  - Automatic engine stop
- After the system start procedure to finish the flight
  - Different means (parachute, airbag, ….

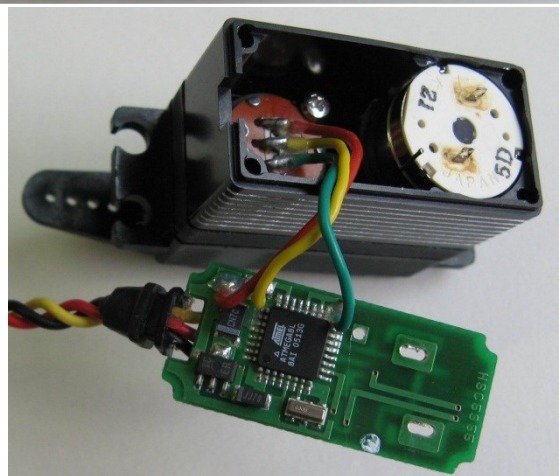
Servo

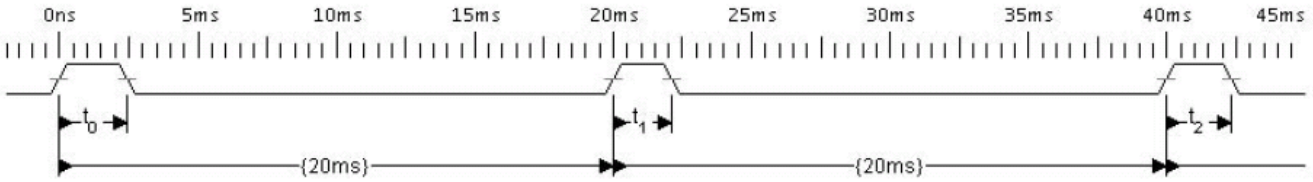


- Délka pulsu:
  od 0.9 ms do 2.1 ms,
  hodnota 1.5 ms
  je vyhodnocena jako střední hodnota.
- periodou 50 Hz (20ms)

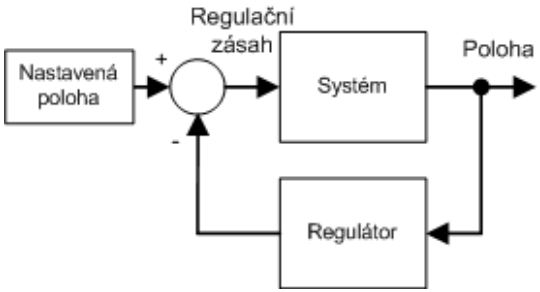


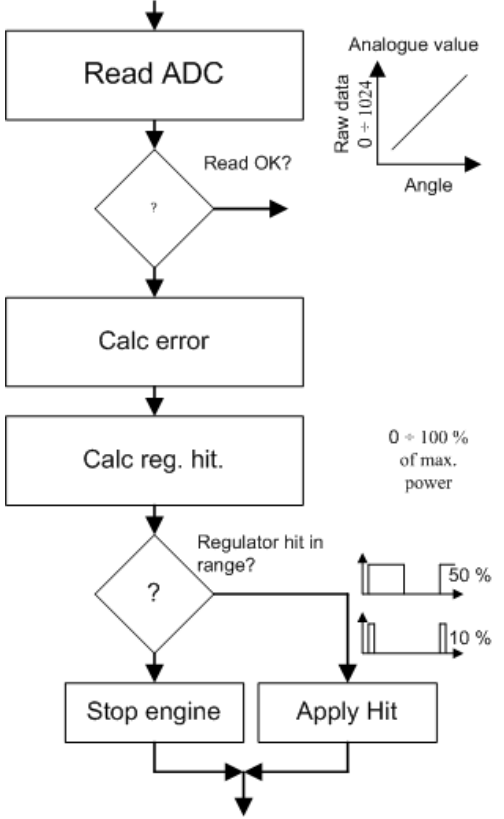




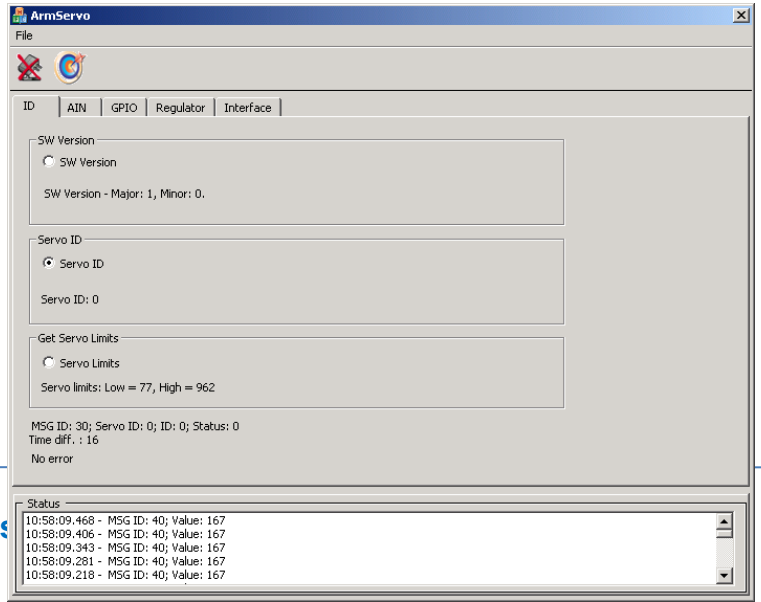


Smart Servo

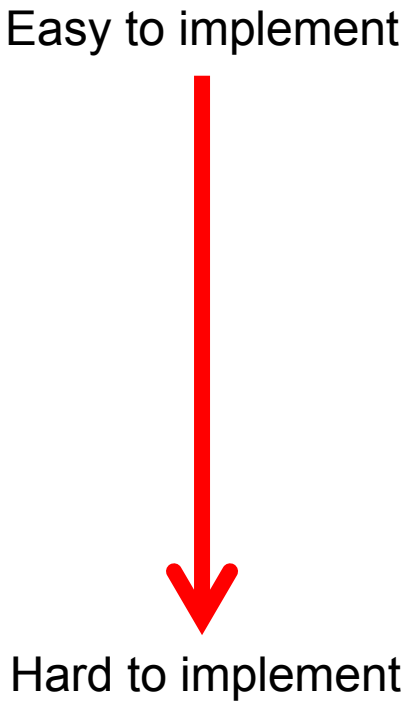




- Digital bus – CAN bus
- Internal diagnostic
- External Test Software
- Possibility to change SW functionality
- Possibility to address the servo on the airplane
  - Position is determined by a resistor at its input
- Possibility to connect other sensors
  - Engine rotation
  - Speed on the wheel
    - Anti Block System (ABS)



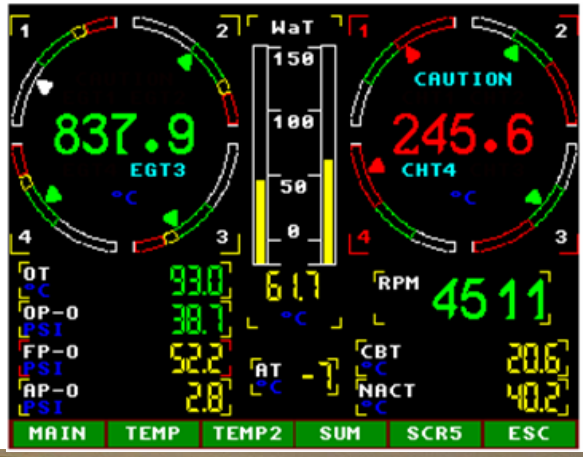
- Sensors
  - Engine parameters
  - Air Data
  - Position
    - GPS – stable error
    - INS – error grooving in time

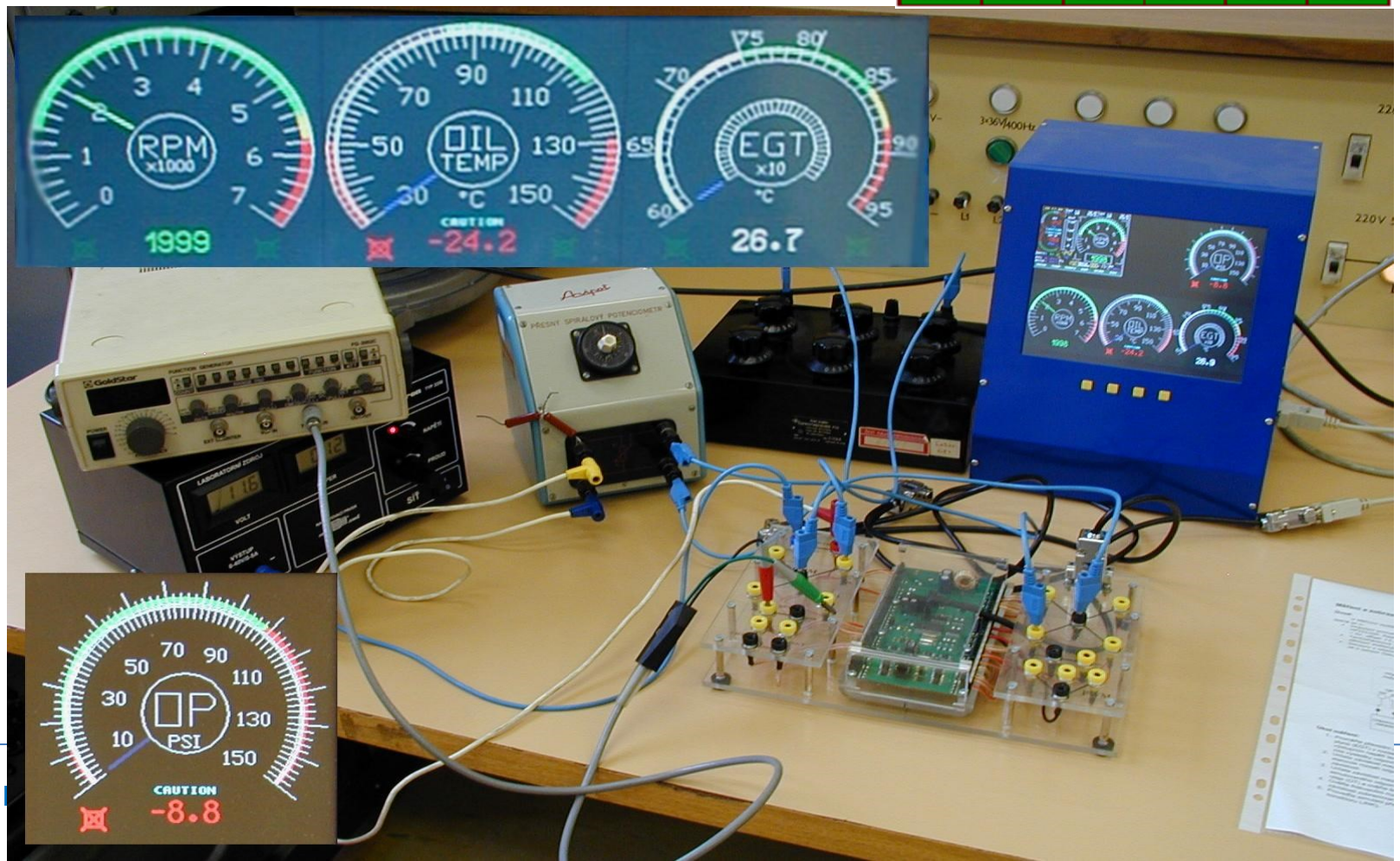


Engine parameters

Tabulka parametrů měřených na motoru UL letadla a jejich limitů			
Senzor	Rozsah signálu	Položka	Limity
Termočlánky (Typ J nebo typ K)	0 – 45 mV	Teplota hlav válců (4x)	0 ÷ 400 °C
		Teplota výstupních plynů (4x)	0 ÷ 1000 °C
Odporové teploměry	0 – 250 Ω	Tlak oleje	0 ÷ 500 kPa
		Tlak paliva	15 ÷ 40 kPa
		Tlak vzduchu	
		Množství paliva	
NTC termistor	0 – 10 kΩ	Teplota chladicí kapaliny (2x)	-20 ÷ 150 °C
		Teplota vzduchu v karburátoru	-25 ÷ 50 °C
		Teplota oleje	-20 ÷ 150 °C
PWM senzor	TTL	Teplota vzduchu	-25 ÷ 50 °C
		Teplota studeného konce	
		Teplota v motorové gondole	max. 80°C
		Teplota v kabině letadla	
Pulzní signál	TTL (2000-15000) $imp.l^{-1}$	Průtok paliva	3 – 30 $l.h^{-1}$
	TTL (1 || 6) $imp.ot^{-1}$	Otáčky	0 ÷ 10000 $ot.min^{-1}$
Analogový signál	0 – 5 V DC	Napětí palubní sítě	8 ÷ 20 V
		Tlak oleje	0 ÷ 500 kPa
		Tlak paliva	15 ÷ 40 kPa
		Tlak vzduchu	
		Množství paliva	

EMS


WaT
837.9
EGT3
CAUTION
245.6
CHT4
OT
OP-O
FP-O
AP-O
RPM
4511
CBT
NACT
MAIN
TEMP
TEMP2
SUM
SCR5
ESC


RPM
x1000
OIL
TEMP
EGT
x10
1999
-24.2
26.7
OP
PSI
CAUTION
-8.8

International Standard Atmosphere

- Standardized distribution of pressure, temperature and air density
- Defined by ICAO
- ISA zero altitude = defined as middle sea layer at 45°lattitude

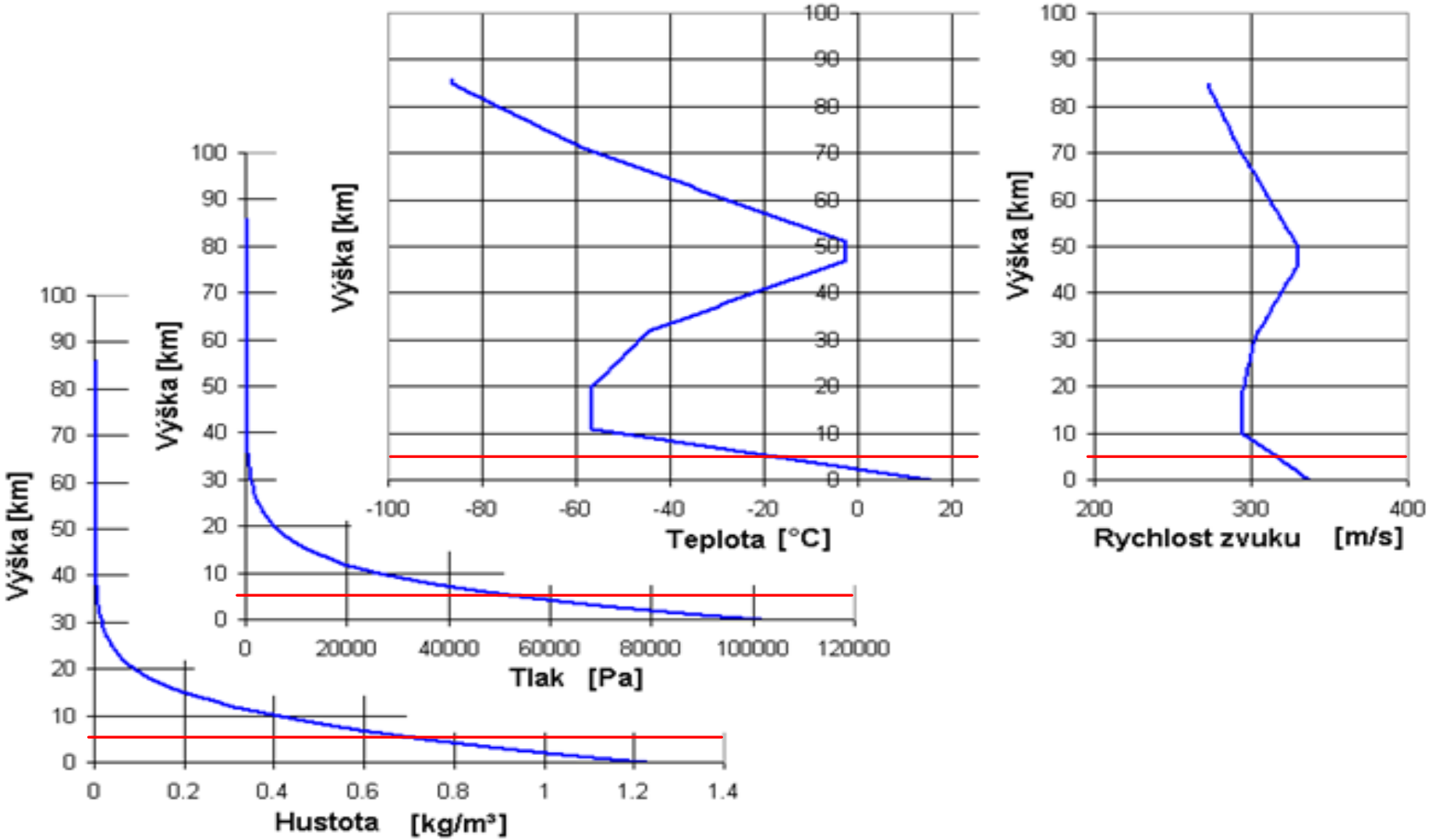
Altitude measurement

- Barometric method
  known dependence of the static pressure with altitude
- Radiometric method
  Uses reflection of radio waves from Earth surface
- Inertial method
  Uses double integration of vertical acceleration – relative measurement linked to the origin – highly dependent on the quality of sensors.
- Parametric method
  measures amount of gas atoms by a radioactive transmitter and particle counter

Definition of altitudes

- Absolute altitude
  with reference level at 45° latitude
- Relative altitude
  the reference level is selectable
- True altitude
  altitude measured from the terrain
- Flight Level
  reference level is given by atmospheric pressure 1013,25 mb (QNE).

Standard Atmosphere



Standard Atmosphere

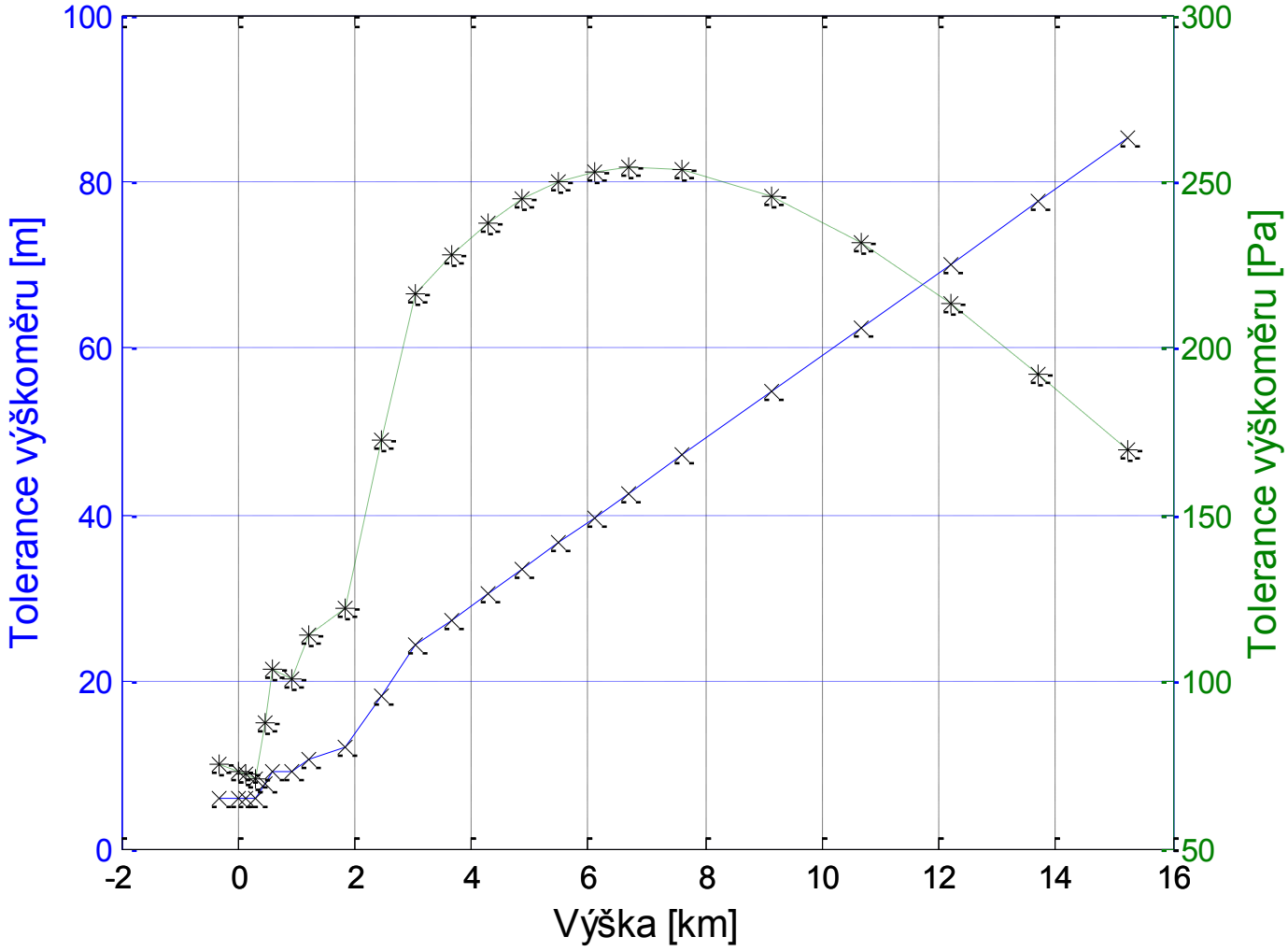
Barometric Equation

$$H = \frac{T_0}{\tau}\left(\left[\frac{p_0}{p_h}\right]^{R\tau} - 1\right) = 44{,}33 \cdot 10^3\left(1 - \left[\frac{p_h}{p_0}\right]^{0{,}19026}\right)$$

Kde

H	je výška měřená od referenční hladiny dané tlakem p_0 [m],
p_0	tlak referenční (vztažné) hladiny, 101,325 [kPa],
p_h	tlak odpovídající výšce H [kPa],
T_0	teplota odpovídající nulové výšce MSA, 288,15 [K],
τ	teplotní konstanta pro rozsah výšek od 0 do 11 km, $6{,}5 \cdot 10^{-3}$ [K m^{-1}] a
R	korigovaná vzduchová konstanta 29,3 [m·K^{-1}].

Altimeter Precission



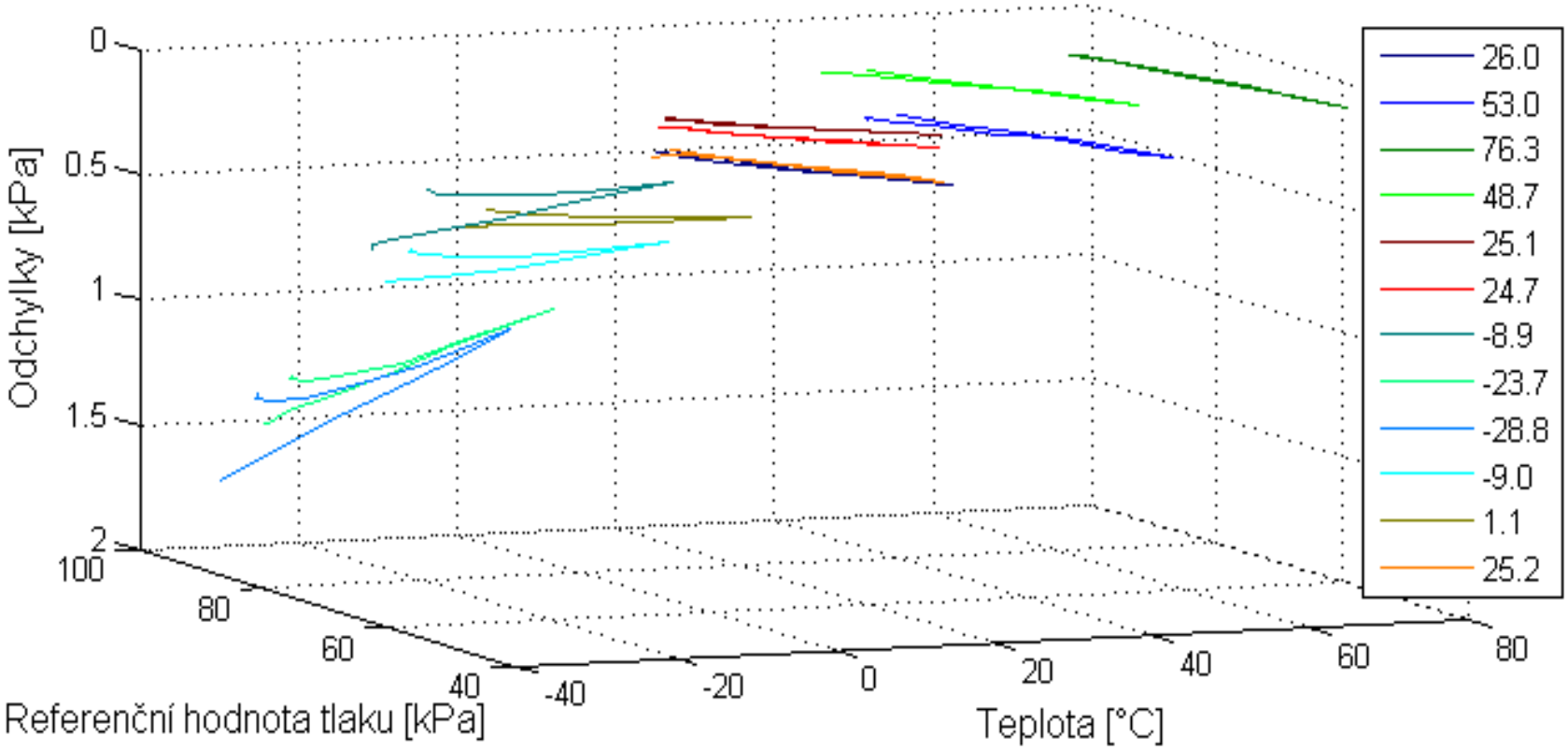
Basic definition

- Resolution
- Precision
- Linearity error
- Offset
- Scale factor
- Other effects

Sensors For Altitude Meas.

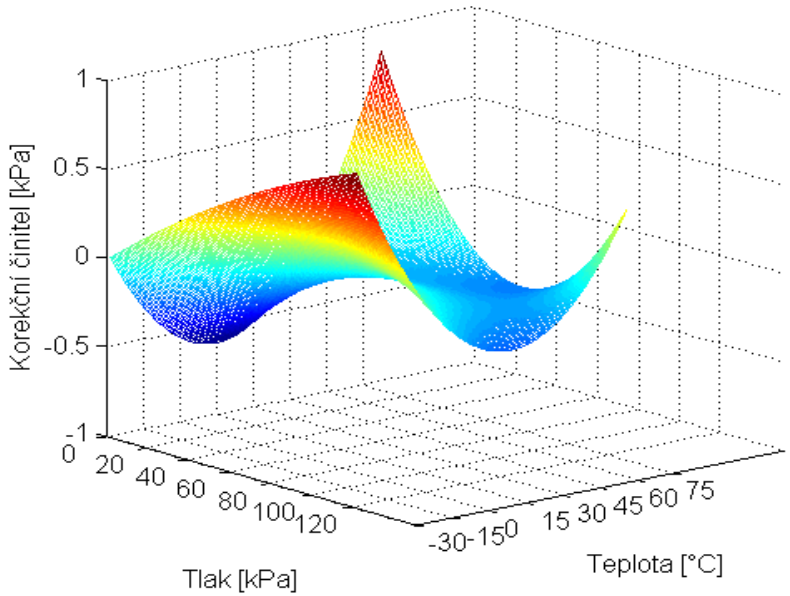
Basic parameters of selected sensors					
Senzor	Range	Package	Price (€)	Output	Precission
MPX4115AP	15-115 kPa	Plastikové	8	Analog	± 1.5 % FS
MPX4100AP	20-105 kPa	Plastikové	9	Analog	± 1.8 % FS
MPXAZ6115A	15-115 kPa	Plastikové	10	Analog	± 1.5 % FS
SP 80	1 bar	Kovové	100	Analog	± 0.2 % FS
HCA0611ARH	600-1100 mbar	Plastikové	10	Digital	± 1.0 % FS
MS5534BM	10 - 1100 mbar	Plastikové	40	Digital	0.1 mbar
ADC1 (MPX4115AP)	15-115 kPa	-	-	Digital	-
ADC2 (SP80)	1 bar	- [29]	~400	Digital	EASA CS23 (viz obr. 5.10 a 5.32)
Reference senzor DPI145 (RPT200)	35 - 3500 bar	- [29]	~1600	Digital	0,025 % RDG

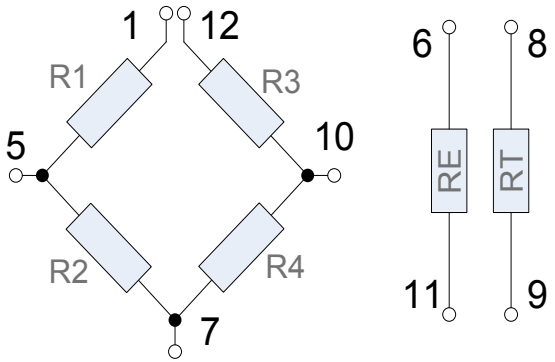
Temperature effects



Temperature effects

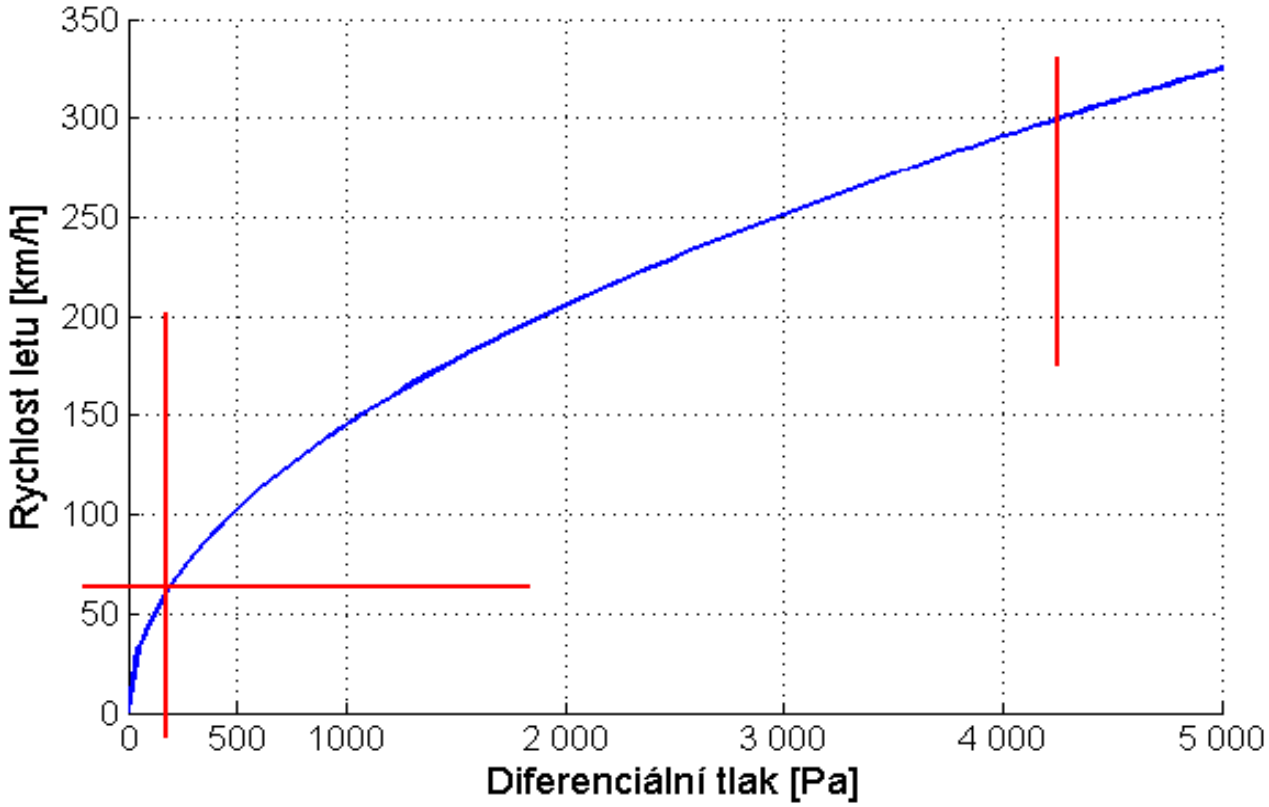
- Internal heating
- Calibration





Air Speed

- IAS, CAS, EAS, TAS?



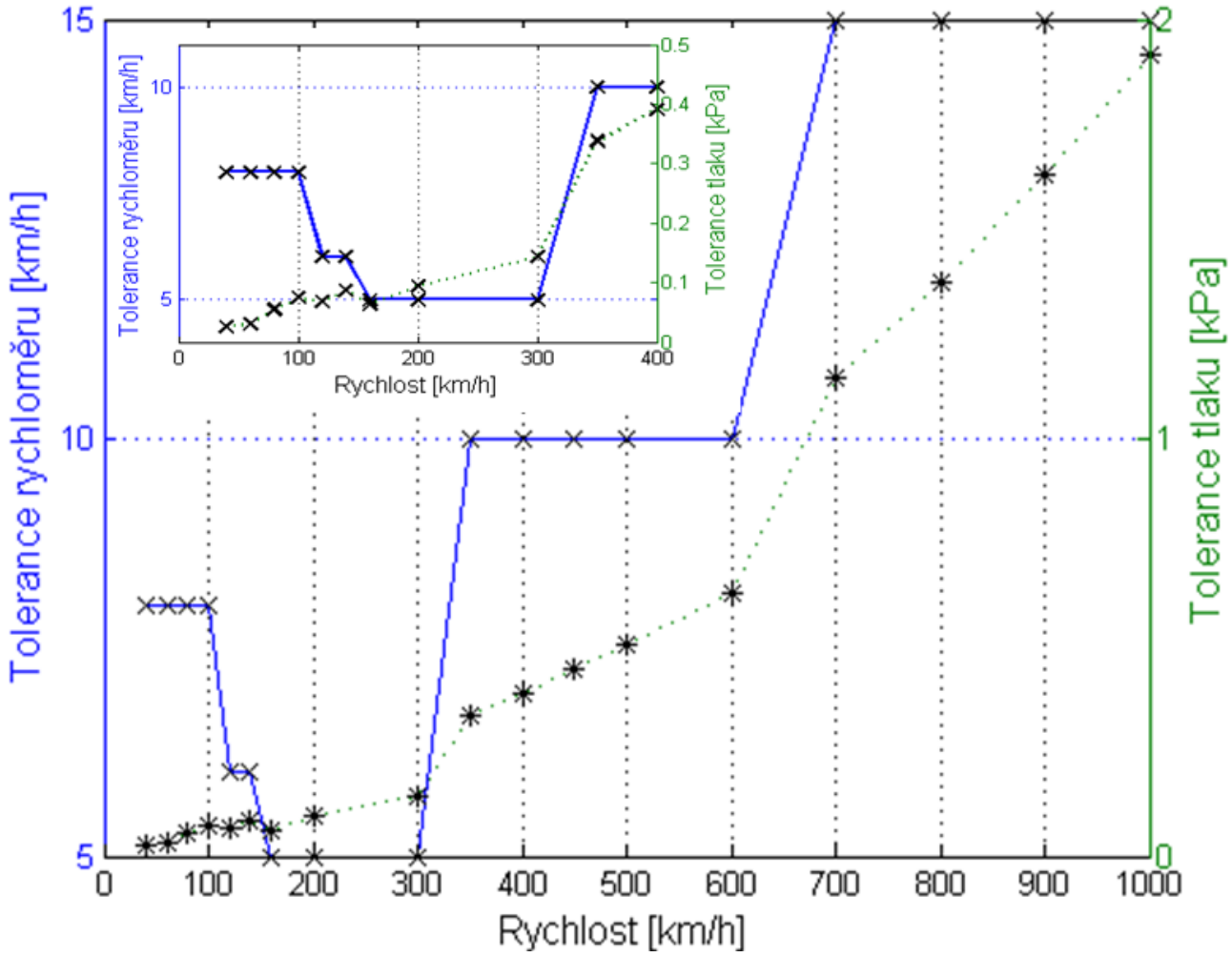
$$F_y = \frac{1}{2} c_y \rho v^2 S.$$

$$v = \sqrt{\frac{2mg}{c_y \rho S}}.$$

$$p_C - p_S = p_D,$$

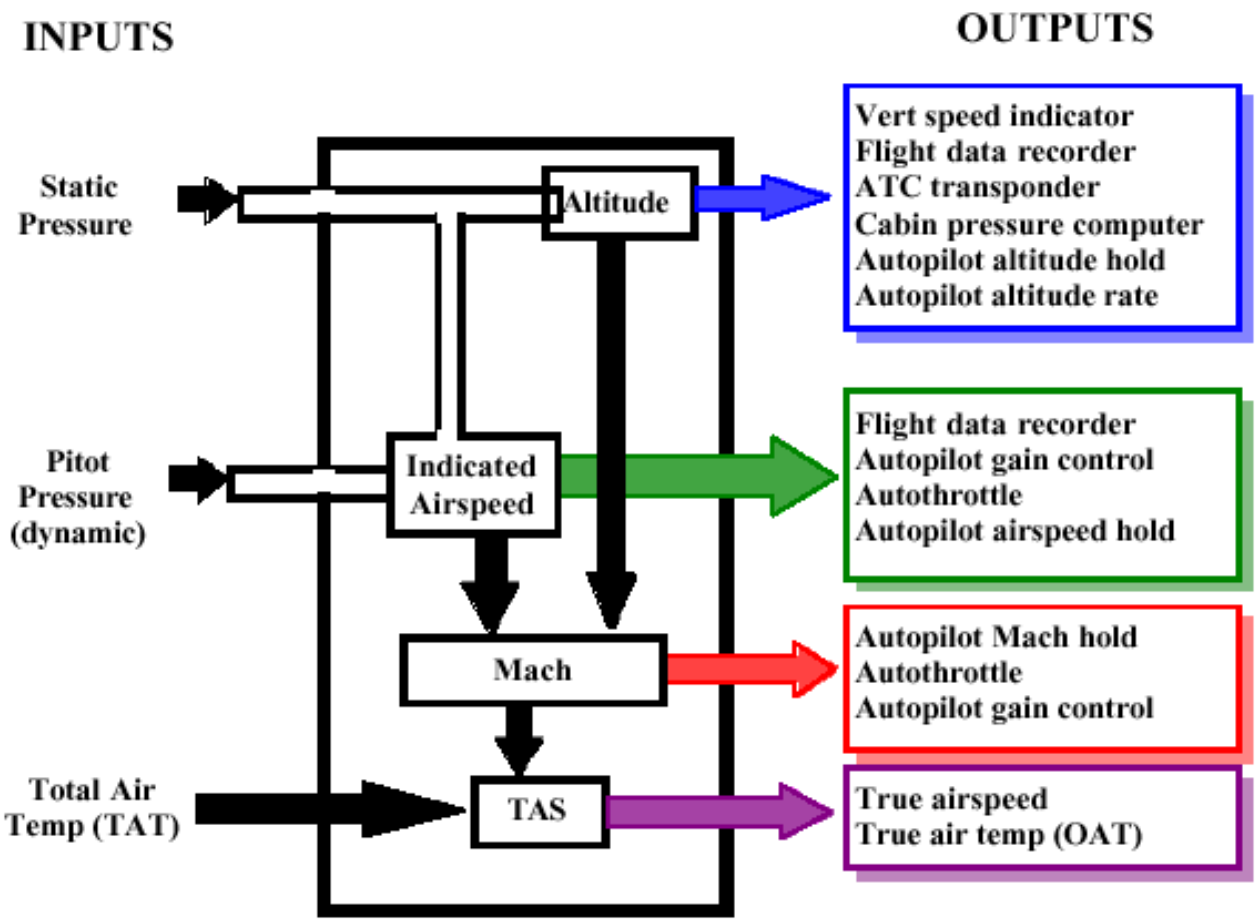
$$v = \sqrt{\frac{2p_D}{\rho}}.$$

Air Speed Instrument Precision



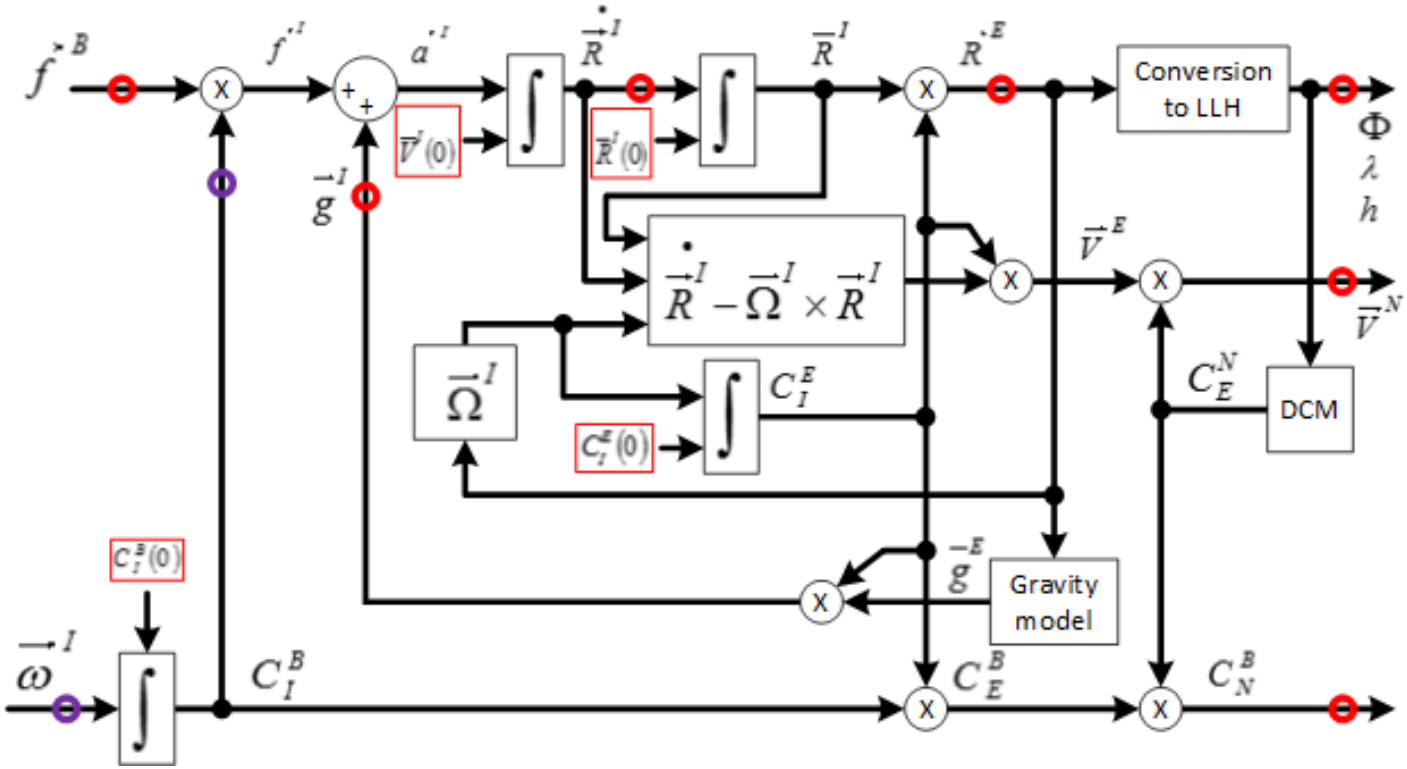
Air Data Computer

- TSO device



Určování polohy

- Absolutní a relativní způsob měření
- Systém GPS
- Inerciální senzory
- Zpracování dat


Conversion to LLH
DCM
Gravity model