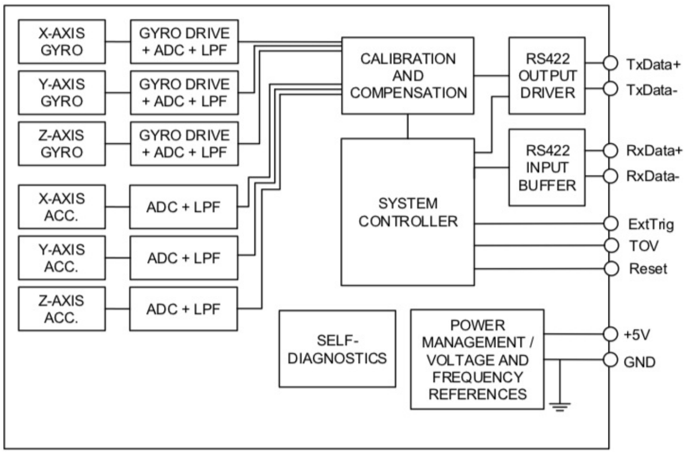
Unidades Inerciales

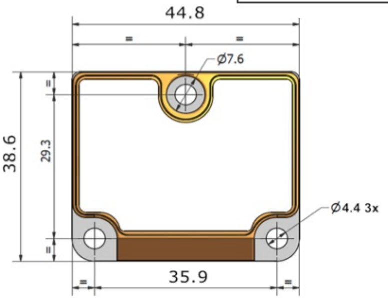
3 cm

3cm

FUNCTIONAL BLOCK DIAGRAM

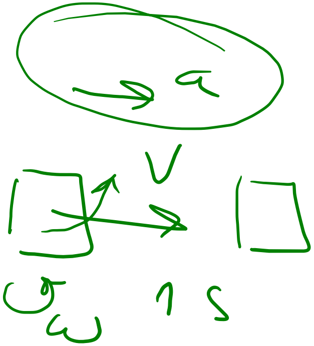


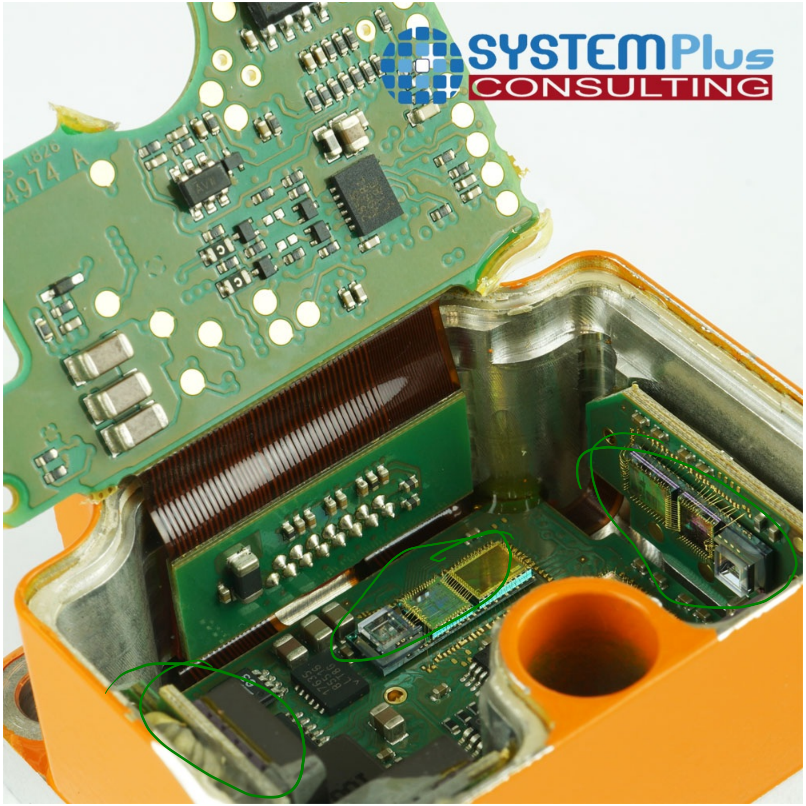
- ITAR free
- Low gyro bias instability (0.3°/h)
- Low gyro noise (0.15°/√h)
- Low accelerometer bias instability (0.003mg)
- Low accelerometer noise (0.015 m/s/√h)
- ±10g acceleration input range
- User programmable bias trim offset
- Customer configurable output format, sampling rate and filter settings
- Compensated digital output, RS422
- Continuous self-diagnostics
- Solid state - high reliability
- Insensitive to magnetic fields
- Weight: <0,13 lbs (<57g)
- Volume: <2,2 cu. in. (35cm3)



GPS → SENSOR EXT.

VEL
ACEL. } SENSOR. INTERNOS

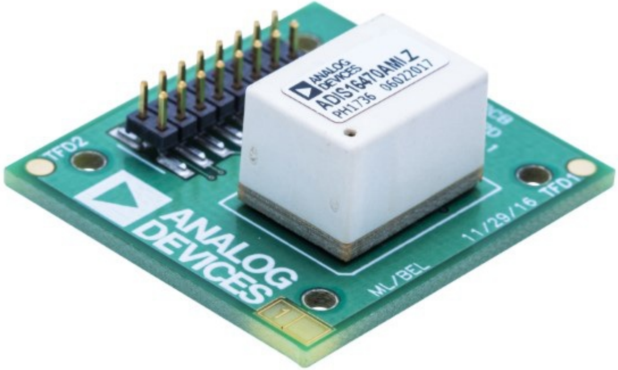



SYSTEMPlus
CONSULTING

Unidades Inerciales

Leading Inertial Measurement Unit Price to Performance
Gyro Bias Stability of 1.08 °/h
Accelerometer Bias Stability of 14.8 µg
User configurable
No Export License Required
Miniature Package 1.1 x 1.1 x 0.424 inches,
Light Weight at 20 grams

Unidades Inerciales



Triaxial, digital gyroscope

- ±125°/sec, ±500°/sec, ±2000°/sec range models
- 2°/hr in-run bias stability (ADIS16475-1)
- 0.15°/√hr angle random walk (ADIS16475-1 and ADIS16475-2)
- ±0.1° axis to axis misalignment error

Triaxial, digital accelerometer, ±8 *g*

- 3.6 μ*g* in-run bias stability

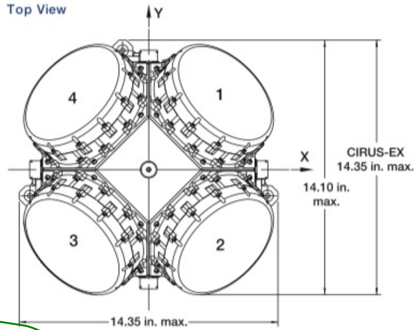
Triaxial, delta angle and delta velocity outputs

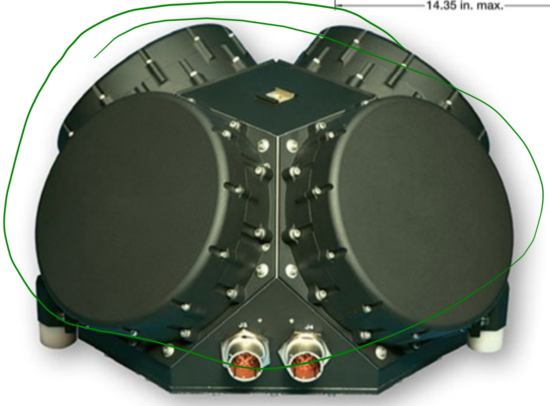
Factory calibrated sensitivity, bias, and axial alignment

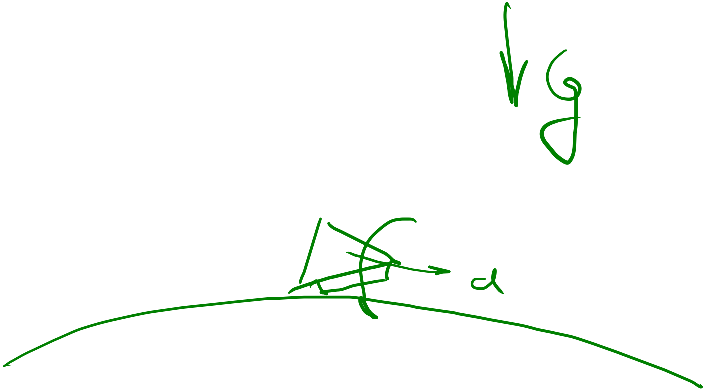
- Calibration temperature range: −40°C to +85°C

Unidades Inerciales

	CIRUS	CIRUS-EX
Bias Stability (1σ)	0.0003 °/hr.	0.0003 °/hr.
Angle Random Walk (EOL)	0.000190 °/√hr. (< 0.000150 available)	0.000125 °/√hr. (< 0.000100 available)
Angle White Noise	0.000025 arc-sec./√Hz (0.000006 typical)	0.000025 arc-sec./√Hz (0.000006 typical)
Angular Rate Range	> 30 °/sec.	> 22 °/sec.
SF Stability	±2 ppm	±2 ppm
SF Linearity (maximum)	35 ppm (3 typical)	35 ppm (3 typical)
Alignment Stability	< 3.5 arc-sec. (long term) < 20 arc-sec. (life)	< 3.5 arc-sec. (long term) < 20 arc-sec. (life)





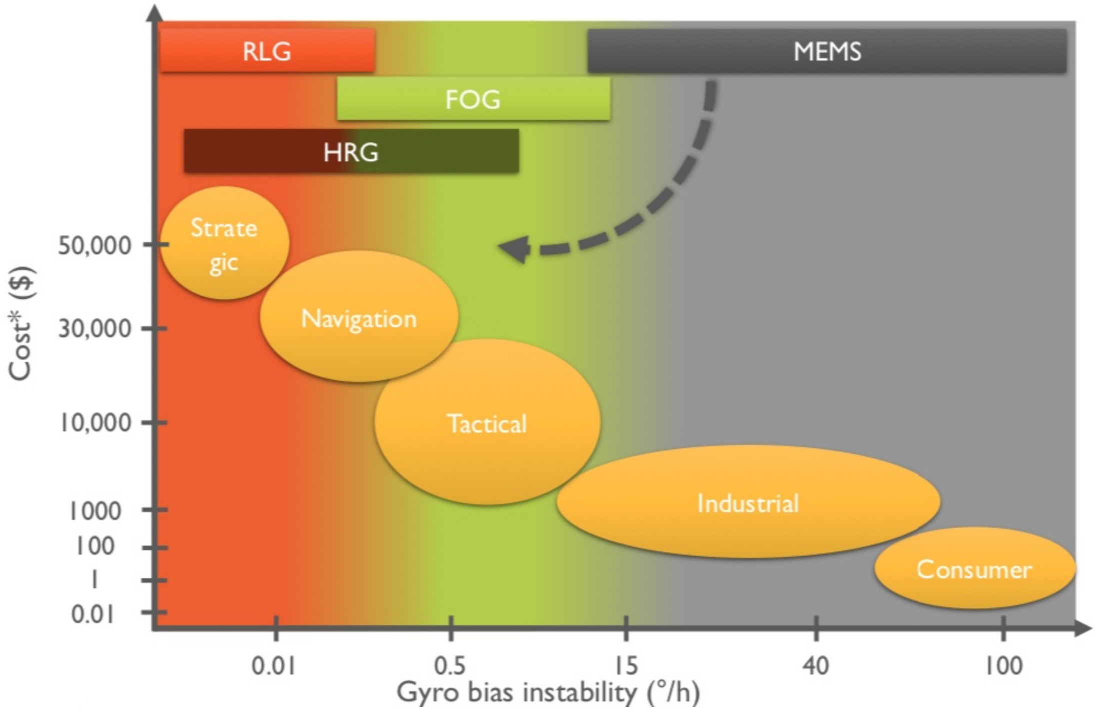

g
α

$$a_x \rightarrow \int a_x = v_x \rightarrow \int v_x = p_x$$

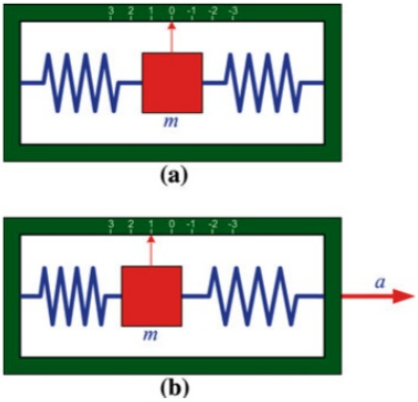
$$\int a_x + v_a = v_x + v_v$$

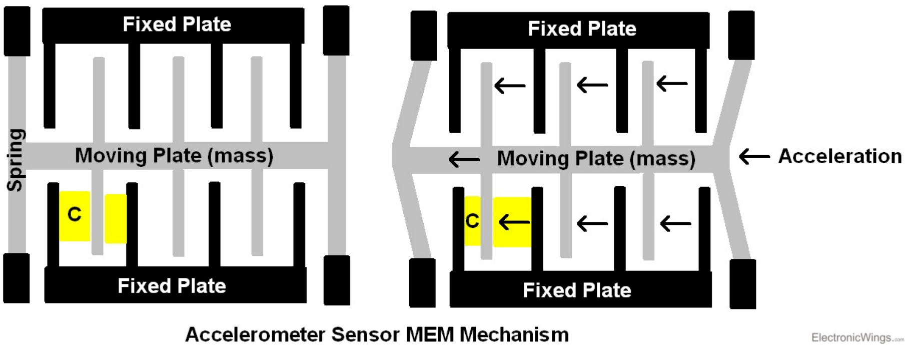
$$\int v_x + v_v = p_x + v_p$$

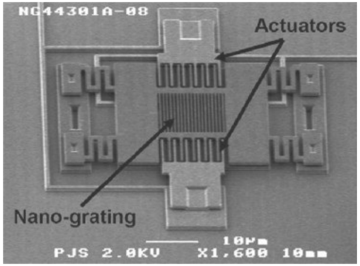
Unidades Inerciales



Acelerómetro







Acelerómetro

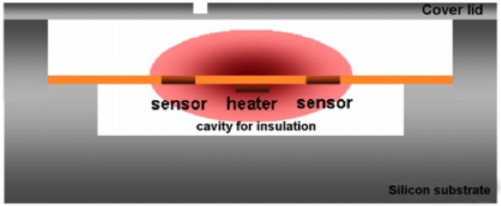
Electromecánico
Piezoeléctrico

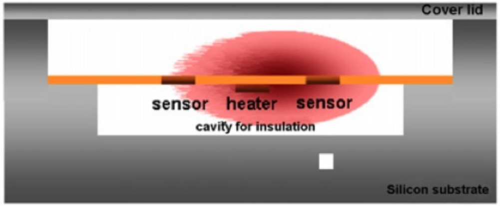
Desplazamiento / reequilibrio
de masa traslacional / pendular

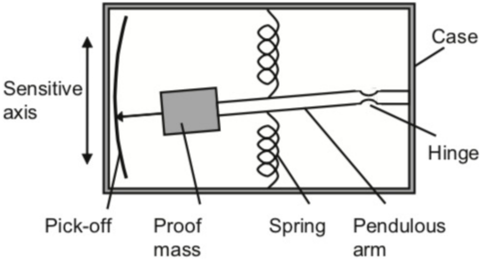
Frecuencia del elemento resonante

Térmicos

MEMS







Modelo de Medida Acelerómetro

$$\tilde{\mathbf{f}}^{b} = \mathbf{f}^{\mathbf{b}} + \mathbf{b}_{a} + S_1 \mathbf{f}^{\mathbf{b}} + S_2 {\mathbf{f}^{\mathbf{b}}}^2 + N_a \mathbf{f}^{\mathbf{b}} + \delta_{\mathbf{g}} + \epsilon_a$$

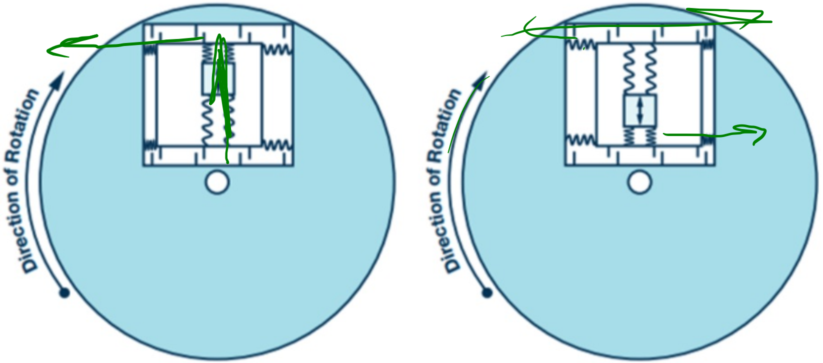
Calibración Acelerómetro

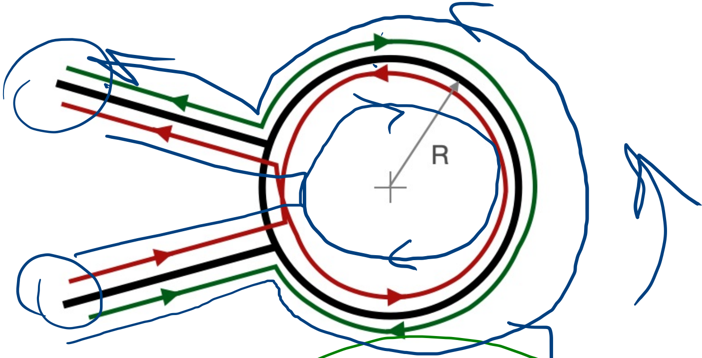
$$\tilde{\mathbf{f}}^b = \mathbf{f}^\mathbf{b} + \mathbf{b}_a + S_1\mathbf{f}^\mathbf{b} + S_2{\mathbf{f}^\mathbf{b}}^2 + N_a\mathbf{f}^\mathbf{b} + \delta_\mathbf{g} + \epsilon_a$$

$$f_{up} = b_a + (1 + S_a)g \qquad y \qquad f_{down} = b_a - (1 + S_a)g$$

Giróscopio

Fog/ HeL



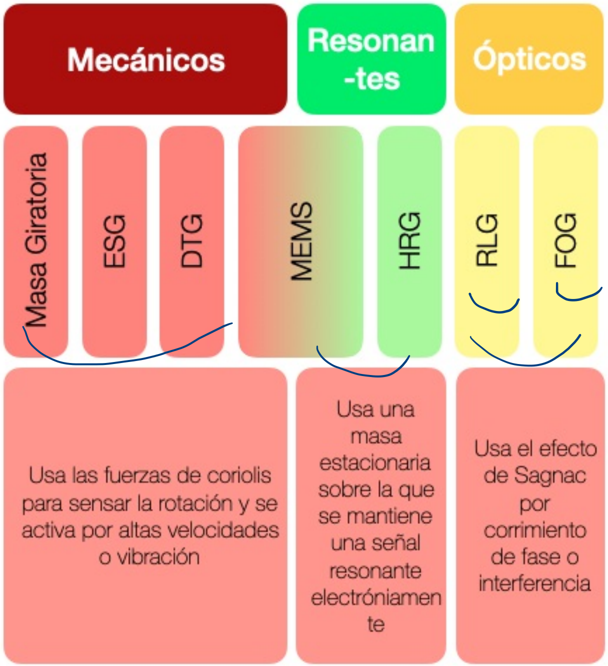


Coriolis

MEMS

SAGNAC.

Giróscopio


Mecánicos
Resonan-tes
Ópticos
Masa Giratoria
ESG
DTG
MEMS
HRG
RLG
FOG
Usa las fuerzas de coriolis para sensar la rotación y se activa por altas velocidades o vibración
Usa una masa estacionaria sobre la que se mantiene una señal resonante electróniamente
Usa el efecto de Sagnac por corrimiento de fase o interferencia

Modelo de Medida Giros

$$\tilde{\omega}_{ib}^{b} = \omega_{ib}^{b} + \mathbf{b}_{g} + S_{g}\omega_{ib}^{b} + N_{g}\omega_{ib}^{b} + \epsilon_{g}$$

Calibración Giro

$$\omega_x = 0;\ \omega_y = \omega_e \cos\phi_{lat};\ \omega_z = \omega_e \sin\phi_{lat}$$

$$\omega_{up} = b_{go} + (1+S_g)\omega_e \sin\phi_{lat} \qquad \text{y} \qquad \omega_{udown} = b_{go} - (1+S_g)\omega_e \sin\phi_{lat}$$

IMU

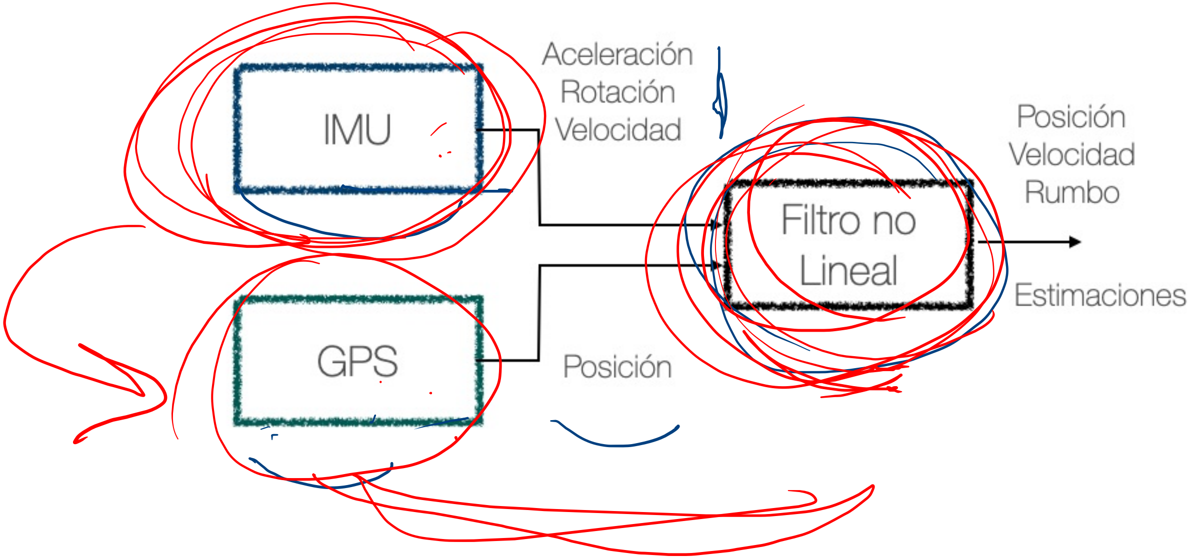
Calidad	Costo	Estabilidad del sesgo del gyro	Tiempo de navegación sin GPS	Aplicaciones
Consumo	<$10	-	-	Smartphones
Industrial	$100-$1.000	$< 10°$/hora	<1 minuto	UAV/UGV
Táctico	$5.000-$50.000	$< 1°$/hora	<10 minutos	Municiones
Navegación	$100.000	$< 0,1°$/hora	Varias horas	Militar

Calidad	Sesgo Acelerómetro (mg)	Random Walk de velocidad ($m/s/\sqrt{hr}$)	Sesgo Giro (grado/hr)	Random Walk de ángulo ($grado/\sqrt{hr}$)
Consumo	10	1	100	2
Industrial	1	0.1	10	0.2
Táctico	0.1	0.03	1	0.05
Navegación	0.01	0.01	0.01	0.01

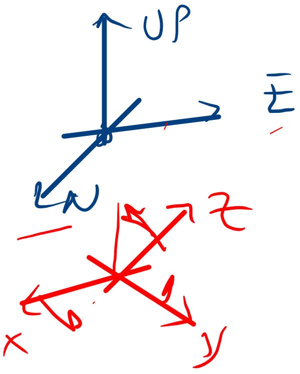
IMU

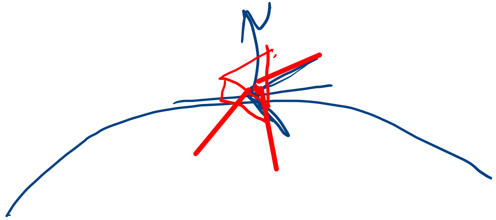
Calidad	1s	10s	60s	10min	1hr
Consumo	6cm	6.5m	400m	200km	39.000km
Industrial	6mm	0.7m	40m	20km	3.900km
Táctico	1mm	8cm	5m	2km	400km
Navegación	<1mm	1mm	50cm	100m	10km

Integración directa IMU+GPS



GPS
(NAV)

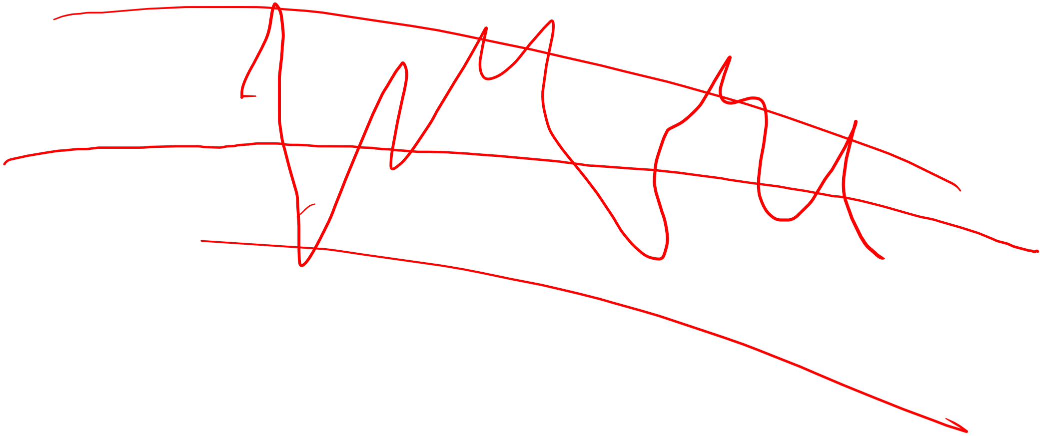




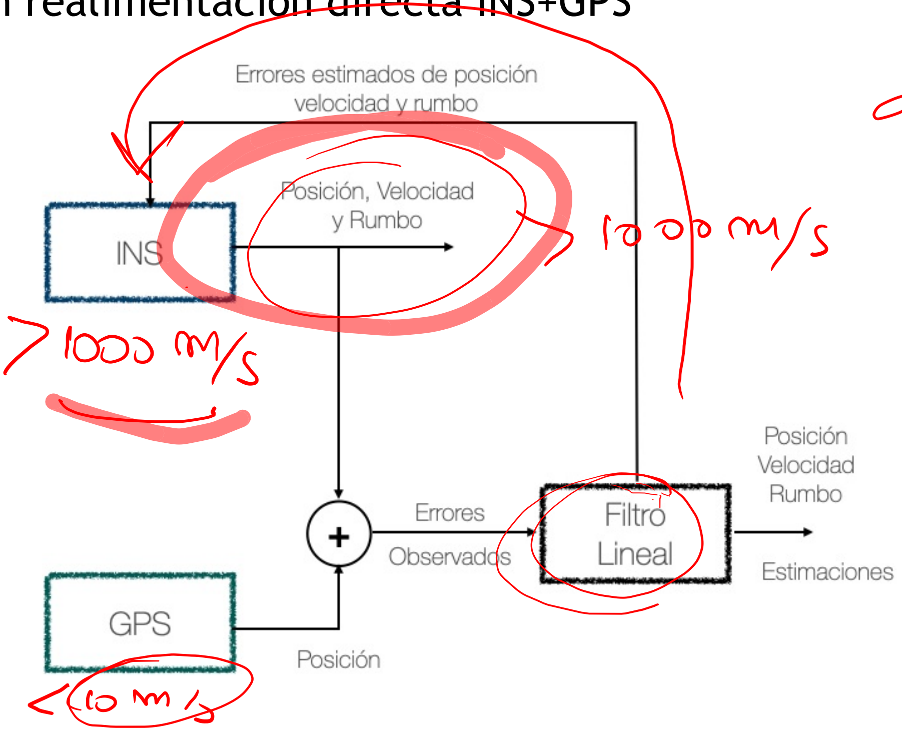
ACEL
(INERC)

GYRO

$$\int \omega_D = \varphi_D$$
$$\int \omega_A = \varphi_A$$
$$\int \omega_C = \varphi_C$$

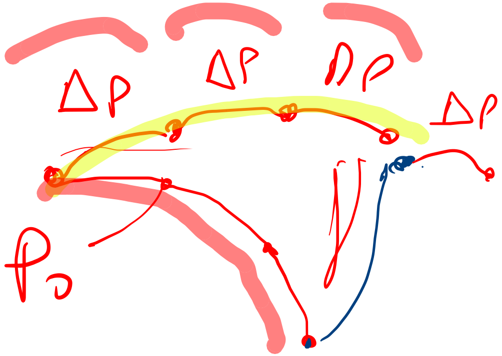


Integración realimentación directa INS+GPS

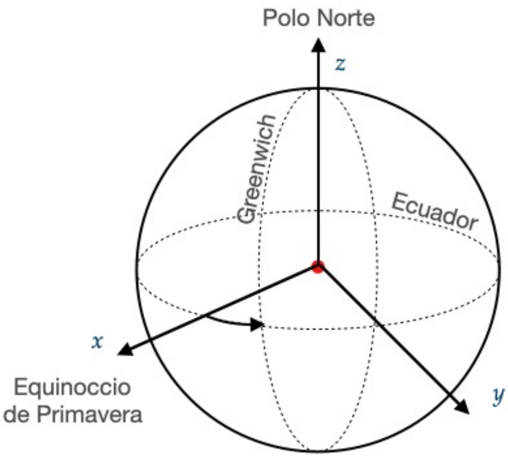


$a \to \int a = v \to \int v = p$

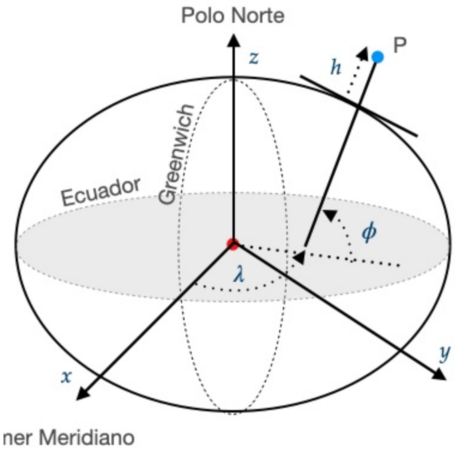
$$\int a_x = \Delta v \qquad \int \Delta v = \Delta p$$

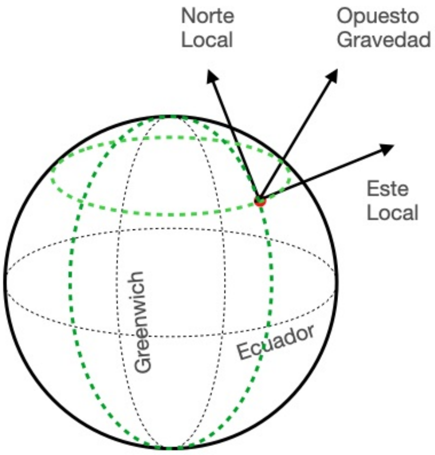


Marcos de Referencia/Ejes de Referencia



ECI





Topográfico

Teorema de Coriolis

$$\mathbf{v}_i = \mathbf{v}_e + \boldsymbol{\omega}_{ie} \times \mathbf{r}$$

Navegación en áreas locales (ERN/ERT)

$$\dot{\mathbf{v}}_{e/e} = \dot{\mathbf{v}}_{e/i} - \boldsymbol{\omega}_{ie} \times \mathbf{v}_e$$

$$\dot{\mathbf{v}}_{e/i} = \mathbf{f} - [\boldsymbol{\omega}_{ie} \times \mathbf{v}_e] + [\mathbf{g} - \boldsymbol{\omega}_{ie} \times [\boldsymbol{\omega}_{ie} \times \mathbf{r}]]$$

Propagación de la matriz de Transformación

Euler

Cosenos Directores

Cuaterníon

INERCIAL = body y

NAVEG.

Matriz de Cosenos Directores

$$C_b^n f_b = f_N$$

$$\mathbf{C}_b^n = \begin{bmatrix} \gamma_c & -\gamma_s & 0 \\ \gamma_s & \gamma_c & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \beta_c & 0 & \beta_s \\ 0 & 1 & 0 \\ -\beta_s & 0 & \beta_c \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \theta_c & -\theta_s \\ 0 & \theta_s & \theta_c \end{bmatrix}$$

$$= \begin{bmatrix} \beta_c\gamma_c & -\theta_c\gamma_s + \theta_s\beta_s\gamma_c & \theta_s\gamma_s + \theta_c\beta_s\gamma_c \\ \beta_c\gamma_s & \theta_c\gamma_c + \theta_s\beta_s\gamma_s & -\theta_s\gamma_c + \theta_c\beta_s\gamma_s \\ -\beta_s & \theta_s\beta_c & \theta_c\beta_c \end{bmatrix}$$

$$f_b = \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}$$

$\beta_c = \cos\beta$ $\quad \beta_s = \operatorname{sen}\beta$ $\quad \gamma_s = \operatorname{sen}\gamma$

$\gamma_c = \cos\gamma$

$$f_N = \begin{bmatrix} a_E \\ a_N \\ a_u \end{bmatrix} \begin{matrix} \rightarrow v_E \rightarrow \rho_E \\ \rightarrow v_N \rightarrow \rho_N \\ \rightarrow v_u \rightarrow \rho_u \end{matrix}$$

Matriz de Cosenos Directores

$$\mathbf{f}_n = \mathbf{C}_b^n(i+1)\mathbf{f}_b$$