Análisis de Órbita y Actitud de la Misión ALPHA3

Misión Alpha

Seminario: Electrónica para Entornos Hostiles

- Contribución de GIA (Grupo de Ingeniería Aeroespacial).
- Equipo:
  - Rafael Vázquez
  - Francisco Gavilán
  - Guillermo Pacheco
  - José Manuel Montilla
  - Gonzalo Zamora
- *16 años investigando en Espacio*:
  - Astrodinámica y Vigilancia Espacial
  - Guiado, Navegación y Control
  - Planificación de Misiones de Observación Terrestre

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- **Análisis y Diseño de Órbita**
  Selección y propagación de la órbita, traza, eclipses,
  visibilidad de estaciones terrenas, cobertura,
  tiempo de vida de la misión. Determinación de órbita.

- **Análisis de actitud: ADCS**
  Orientación (apuntamiento) del satélite.
  Modelado y simulación. Control y Estimación.

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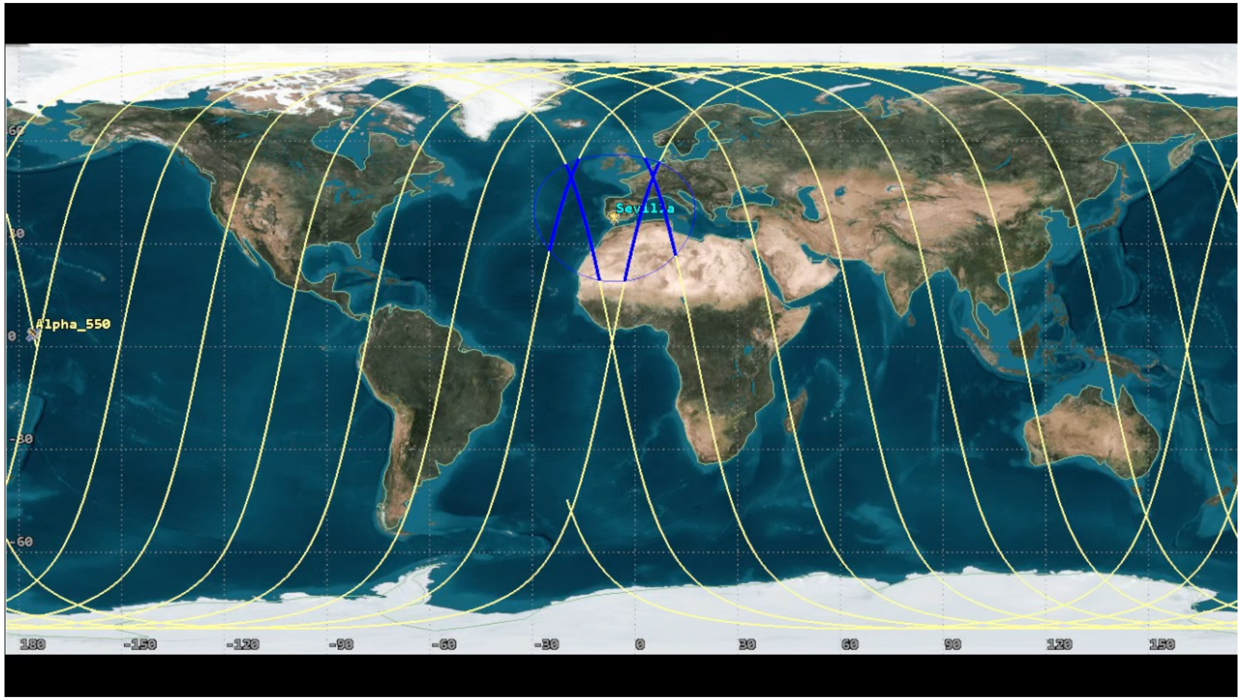
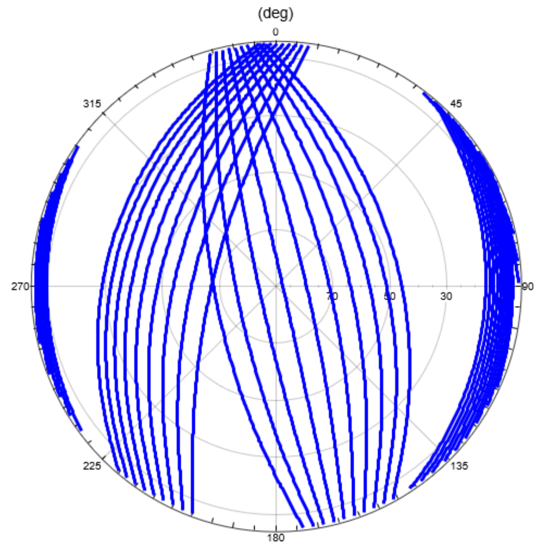
Ground track at 550 Km



Az-El Polar plot – 10 days



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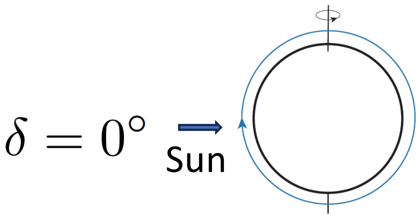
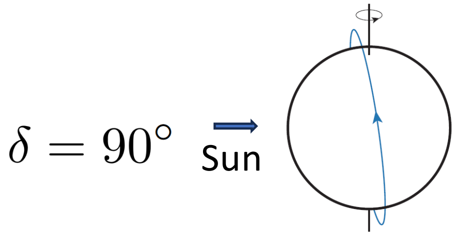
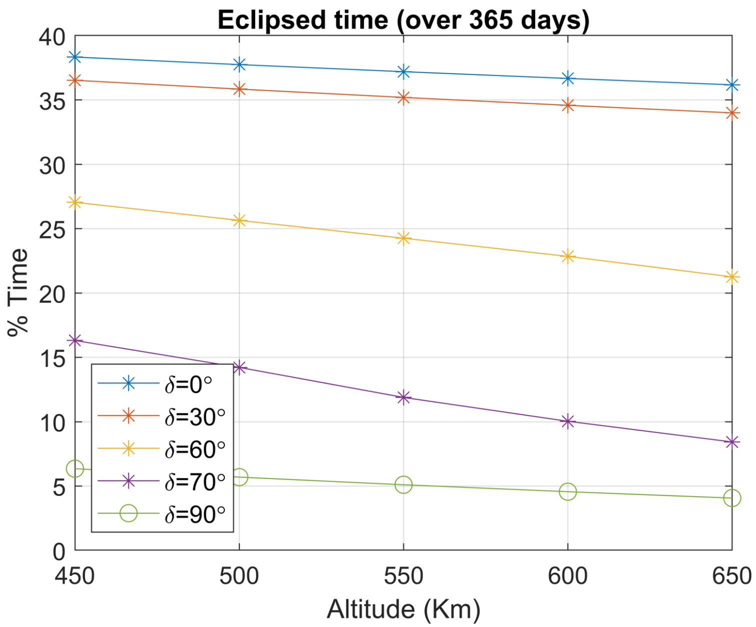
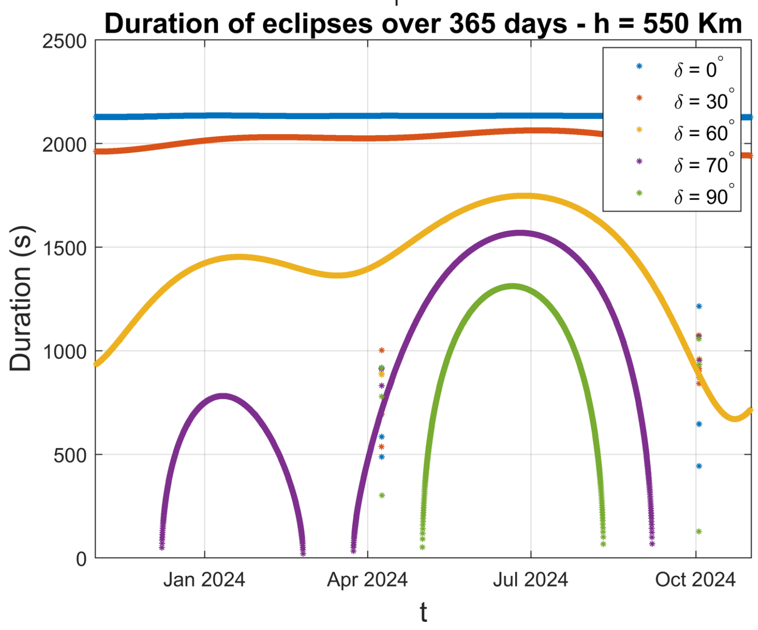




Longest Eclipse	h=450 Km	h=650 Km
$\delta = 0°$	35.6 min	35.1 min
$\delta = 30°$	34.5 min	33.7 min
$\delta = 60°$	29.7 min	27.8 min
$\delta = 90°$	23.2 min	19.1 min





Sun-synchronous → Cyclic eclipses over a year

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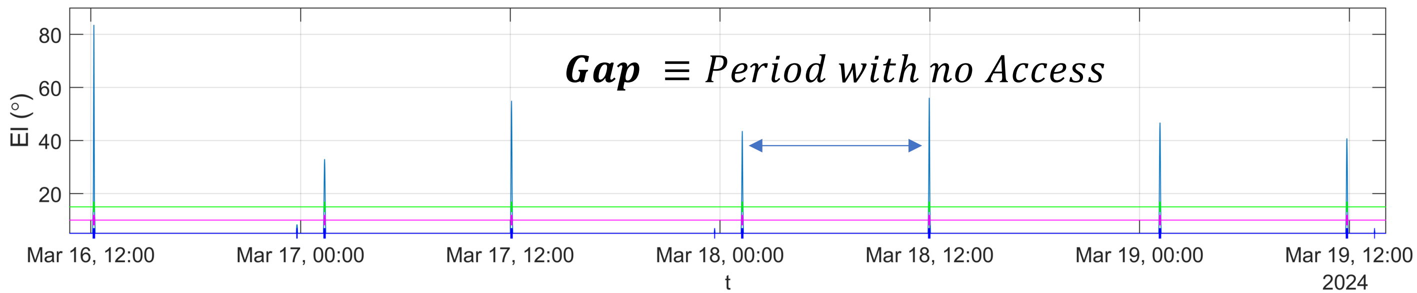
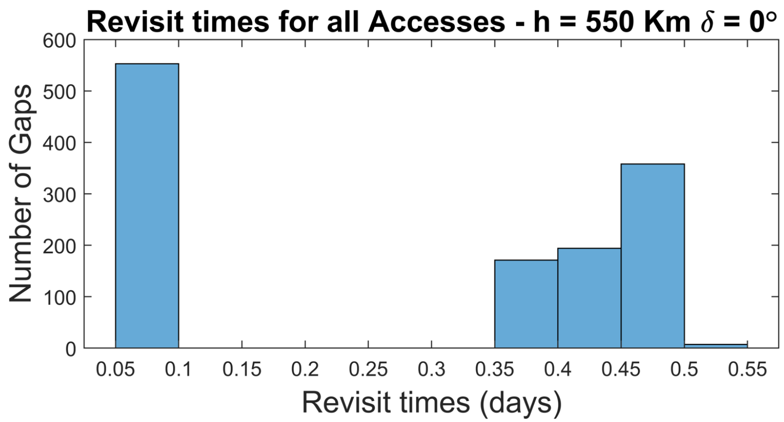
Revisit times distribution at 550 Km (over 365 days)

$$\boldsymbol{RevisitTime}_i = t_s^{(i+1)} - t_e^{(i)}$$

Elapsed time between the **end** of an access and the **start** of the next





Accesses considered	Avg. Revisit time (days)	Nº Gaps
A.Time > 0 s	0.279	1275
A.Time > 100 s	0.285	1259
A.Time > 200 s	0.303	1178
A.Time > 300 s	0.344	1038
A.Time > 400 s	0.451	808
A.Time > 500 s	**1.468**	253

Longer accesses are less frequent

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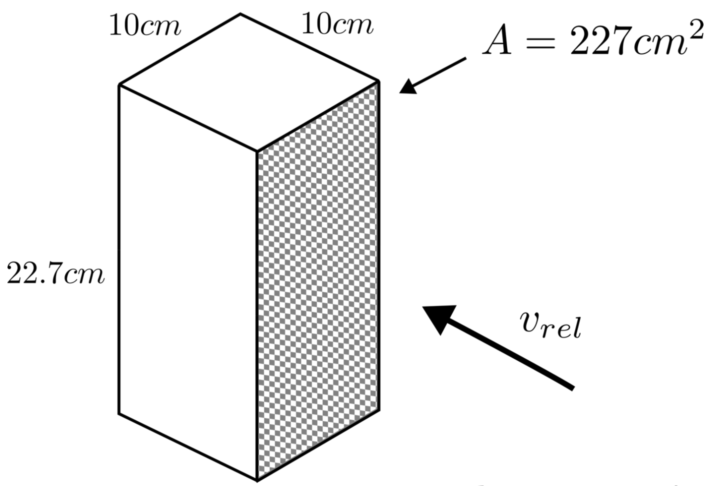
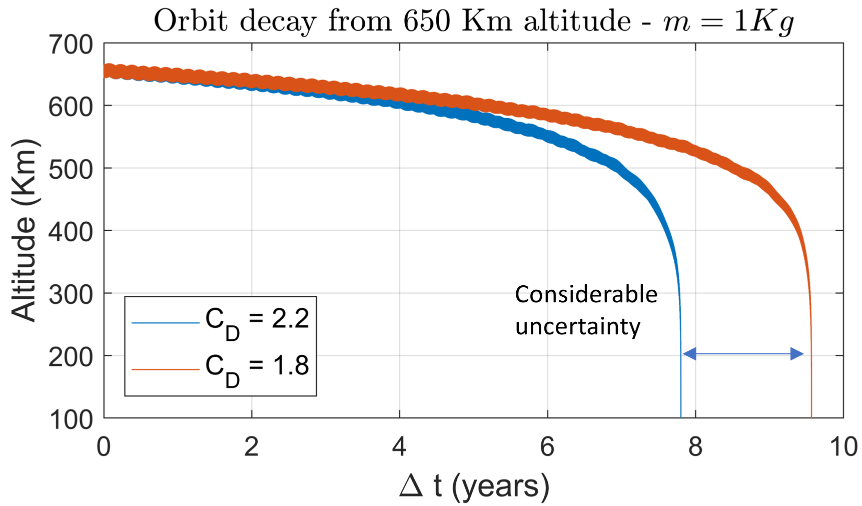
Orbit lifetime

- Fixed attitude in local axes (isotropic drag model)
- Realistic empirical atmosphere model (MSISE90) and $\boldsymbol{\delta = 0^{\circ}}$
- Range of C_D around typical value

$C_D \approx 2$

$m = 1Kg$





$h_0 = 450\ Km$
$lifetime \sim \mathbf{0.4 \pm 0.05}\ \boldsymbol{years}$

$h_0 = 550\ Km$
$lifetime \sim \mathbf{2.1 \pm 0.2}\ \boldsymbol{years}$

$$h_0 = 650\ Km\ lifetime \sim \mathbf{8.5 \pm 1}\ \boldsymbol{years}$$

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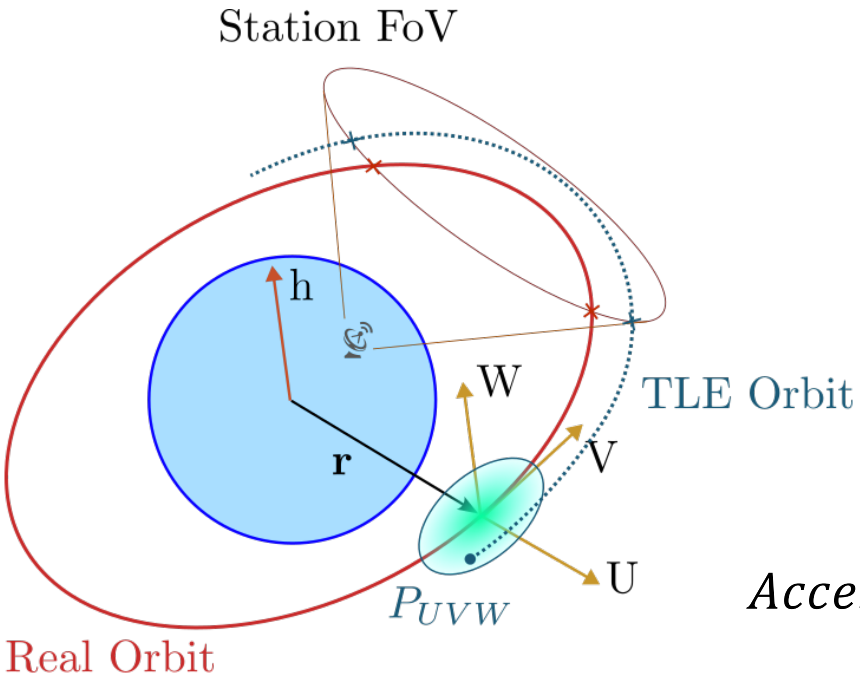
TLE uncertainty and access prediction



- Position uncertainty defined in local axis (empirical)
- Velocity error estimated from two-body dynamics

$$P_{RSW} = P_{UVW} = \begin{bmatrix} \sigma_U^2 & 0 & 0 \\ 0 & \sigma_V^2 & 0 \\ 0 & 0 & \sigma_W^2 \end{bmatrix}_{LEO}$$

$$\sigma_U = 0.102\ Km$$
$$\sigma_V = 0.417\ Km$$
$$\sigma_W = 0.126\ Km$$

- TLEs are generated every 0.7 days on average

$$Access\ Time\ differences \sim 0.2 - 3\ seconds$$

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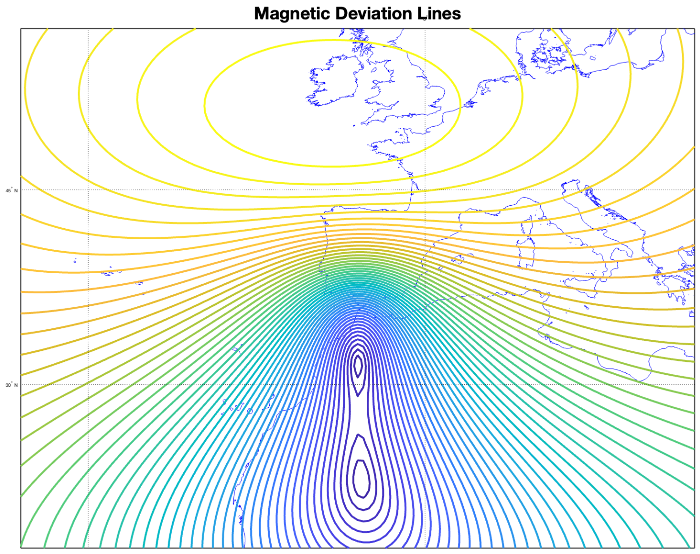
- PASSIVE ATTITUDE STABILIZATION

- Most existing examples are based on **permanent magnets and hysteresis rods: our choice**
    - ✓ Simple, reliable (no moving parts) and lightweight.
- Much lower cost, compared with active ADCS, and no power consumption
- Common choice for first developers
- Limited pointing accuracy, and potential oscillations -> only suitable for missions with bare pointing requirements.



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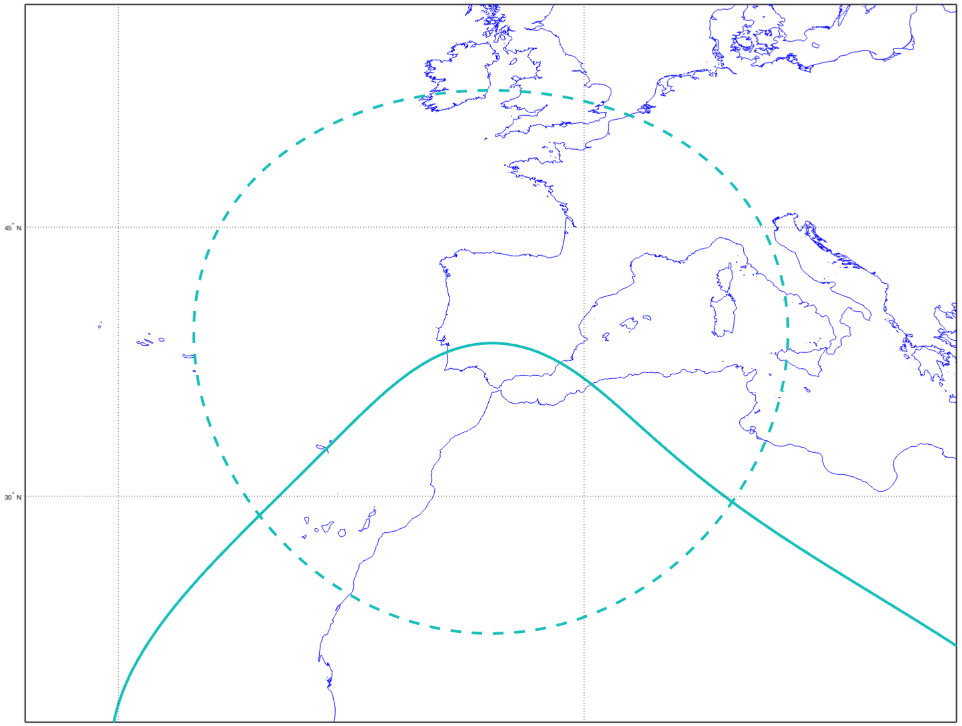
- Access computation considering 15º pointing errors

Access curve at 550 km altitude
max. magnetic deviation 50° and min. elevation 10°



- Geometrically, combining the max limits on the deviation and the min levels of visibility, at a given altitude, one can obtain a region than allows access if the satellite is flying over it.
- **Important point**: the best access opportunities will always be to the South of the Ground Station, thus it is critical to have **as much of an unblocked view to azimuths between 90 and 270 degrees as possible**

ALPHA

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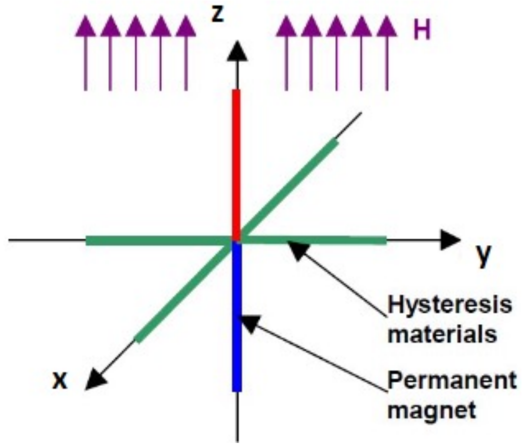
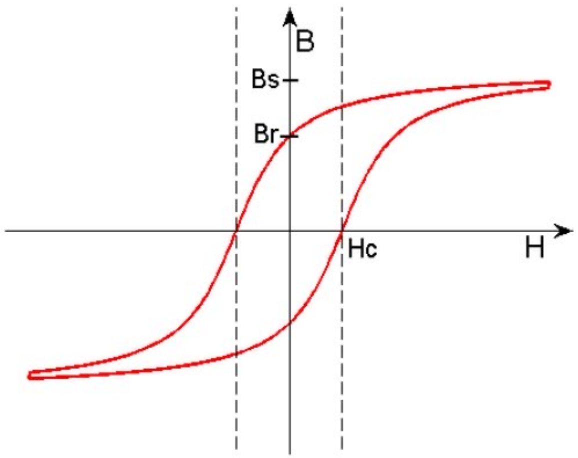
- Numerical simulation of attitude dynamics considering the following assumptions:
  - Perturbation torques: gravity gradient, aerodynamics.
  - Control torques: permanent magnet and hysteresis bars.
  - Modelling details:
    - Rigid body hypothesis.
    - World Magnetic Model (WMM) is considered for magnetic field.
    - Inverse tangent model considered for hysteresis bars.





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- Results for attitude dynamics considering:
  - 550 km SSO
  - satellite z-axis initially aligned with the magnetic field
  - initial spin of 2 deg/s