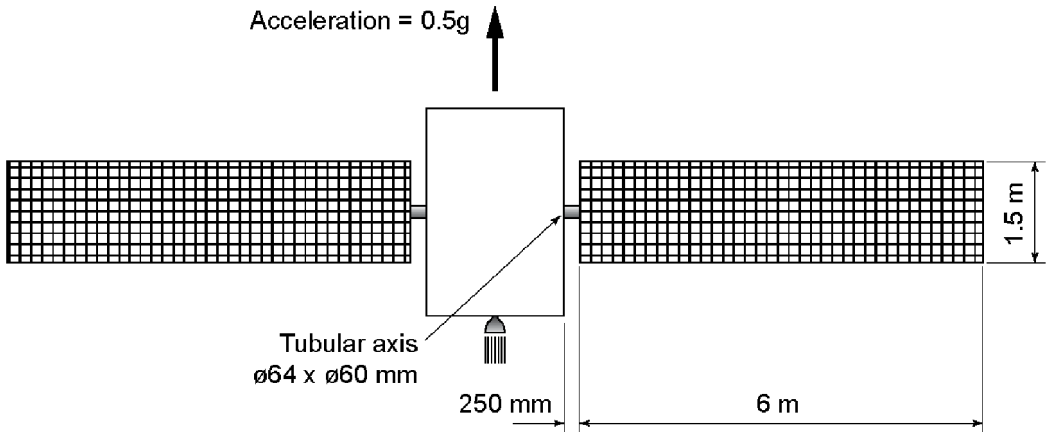
EE-580 Space Mechanisms

# Exercise 4.1 - Solar Array

v.01

## Problem Statement

The spacecraft from the picture below is submitted to a 0.5 g acceleration during a maneuver.




The solar arrays have a mass power of 45 W/kg
The energy efficiency of the solar cells is 25%

## Evaluate

1. The mass of one single solar array wing (hint: take into account the average solar constant).
2. The torque that is applied to the axis during the acceleration.
3. The maximum stress on the axis.
4. Optional: the margin of safety for the fatigue strength of an aluminum tube (A7075-T6).

The maximum allowable stress for aluminum (A7075-T6) is [Pa]:

In[•]:=
```
σal = 150 × 10^6;
```

A factor of safety (FOS) of 2 is considered.
Hint: ECSS-E-ST32C Rev.1 section 4.5.16

# Solution

Total Solar Irradiance (Solar constant) [W/m $^2$]:

In[•]:=
```
Cs = 1362;
```

Mass power [W/kg]:

In[•]:=
```
Pm = 45;
```

Energy efficiency:

In[•]:=
```
η = 0.25;
```

Size of the wing [m]:

In[•]:=
```
L = 6;
W = 1.5;
```

## Mass of the wing [kg]:

In[•]:=
```
M = L W Cs η / Pm
```

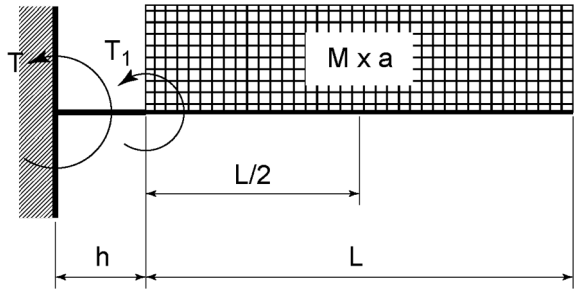
Out[•]=
```
68.1
```

Linear mass of the wing [kg/m]:

In[•]:=
```
ml = M / L
```

Out[•]=
```
11.35
```

Torque applied to the axis




Acceleration [m/s $^2$]:

In[•]:=
```
a = 0.5 × 9.81
```

Out[•]=
```
4.905
```

Length of the axis [m]:

In[•]:=
```
h = 0.25;
```

Outer diameter of the axis [m]:

In[•]:= $d_{out} = 64 \times 10^{-3};$

Inner diameter of the axis [m]:

In[•]:= $d_{in} = 60 \times 10^{-3};$

## Torques

Torque at solar array - tube interface [N·m]:

In[•]:= $T_1 = M\, a\, \frac{L}{2}$

Out[•]=

1002.09

Maximum torque [N·m]:

In[•]:= $T = M\, a\, \left(\frac{L}{2} + h\right)$

Out[•]=

1085.6

## Maximum stress

Area moment of inertia of the axis [m $^4$]:

In[•]:= $I_{axis} = \frac{\pi\, \left(d_{out}^4 - d_{in}^4\right)}{64};$

Maximum stress on the axis [Pa]:

In[•]:= $\sigma_{max} = \frac{T\, d_{out}}{2\, I_{axis}}$

Out[•]=

$1.85397 \times 10^8$

## Margin of Safety (MOS)

Factor of Safety (FOS):

In[•]:= $FOS = 2;$

Margin of Safety (MOS):

In[•]:= $MOS = \frac{\sigma_{al}}{\sigma_{max}\, FOS} - 1$

Out[•]=

−0.595463

A margin < 0 is not admissible.
Either the diameter or the material of the axis shall be changed!