



# MATLAB EXPO 2018

## STEERING COLUMN

Predevelopment Methodology

Isabel Ramirez Ruiz

CAE Engineer in Ferrari Vehicle Department





## Key Takeaways

1. Complex **mechanisms** require specialized and sophisticated calculation tools to guide the implementation, with the goal to be **friendly** and **robust**.
2. An example is presented with the vehicle **steering column mechanism** for improvement of the driver steering feeling.
3. First, it is created the mechanism with **Simscape Multibody** library.
4. After, the Simscape Multibody model is **exported** like a **.dll** embedded code to be **integrated** into an **Excel** calculation sheet.



# Innovation Challenges and Achievements

- **Excel manage the input variables** of coordinates and angles, runs the .dll code, and finally the **exported MATLAB data are visualized into Excel.**
- As a result, the end users of the calculation program need to install **Excel** and **MathWorks Component Runtime - MCR** (free download).



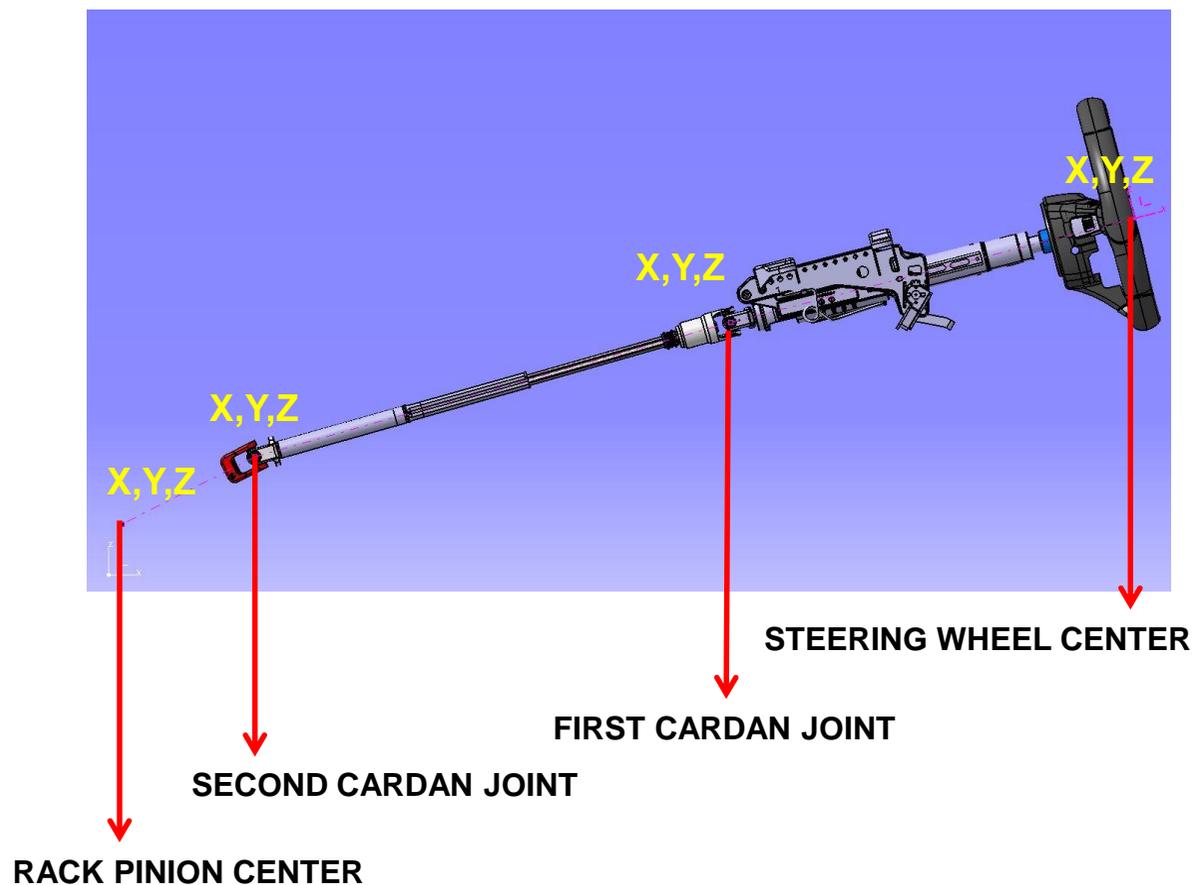
# From the concept to the realization



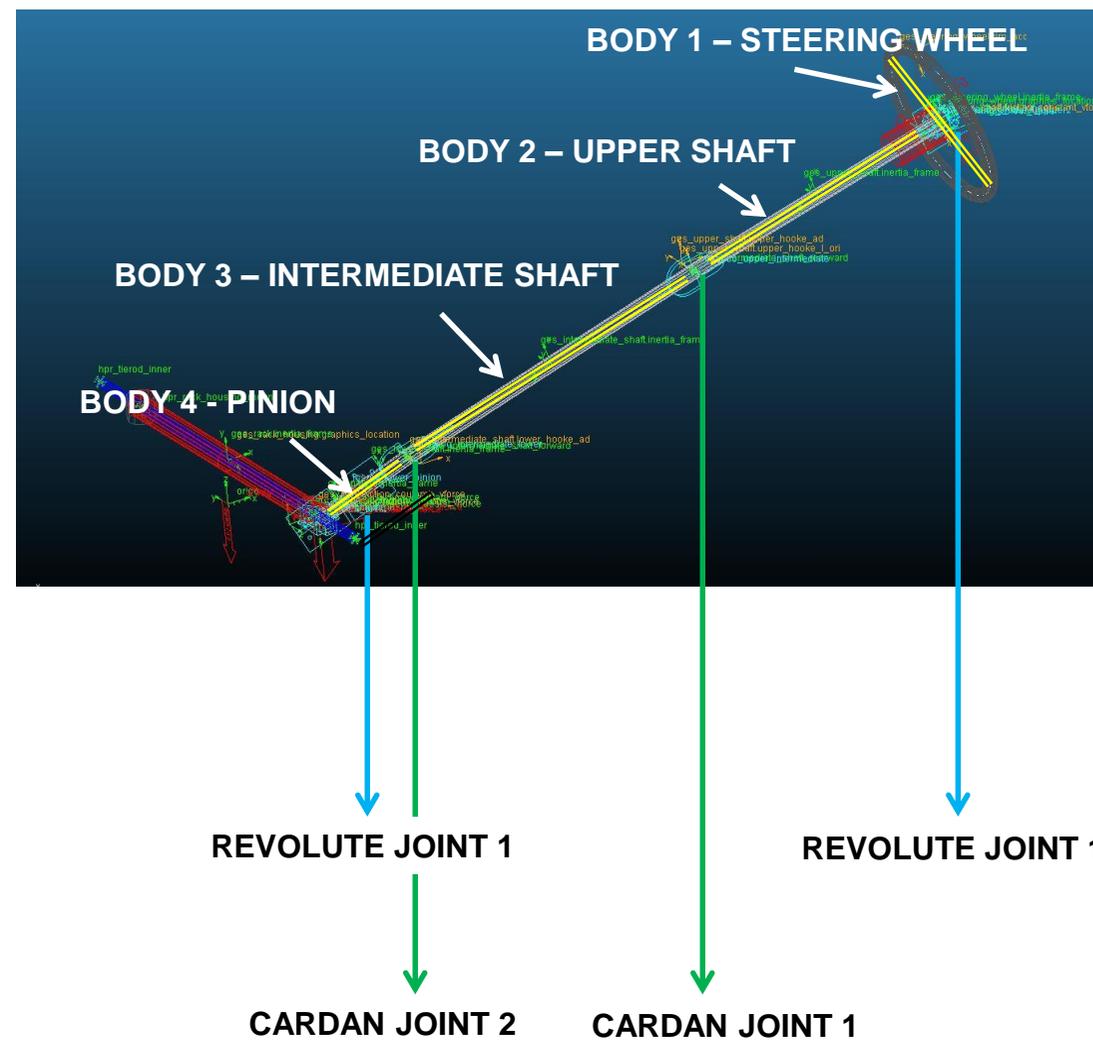


# Schema of the Steering Column Mechanism

## 3D REPRESENTATION OF THE STEERING COLUMN MECHANISM



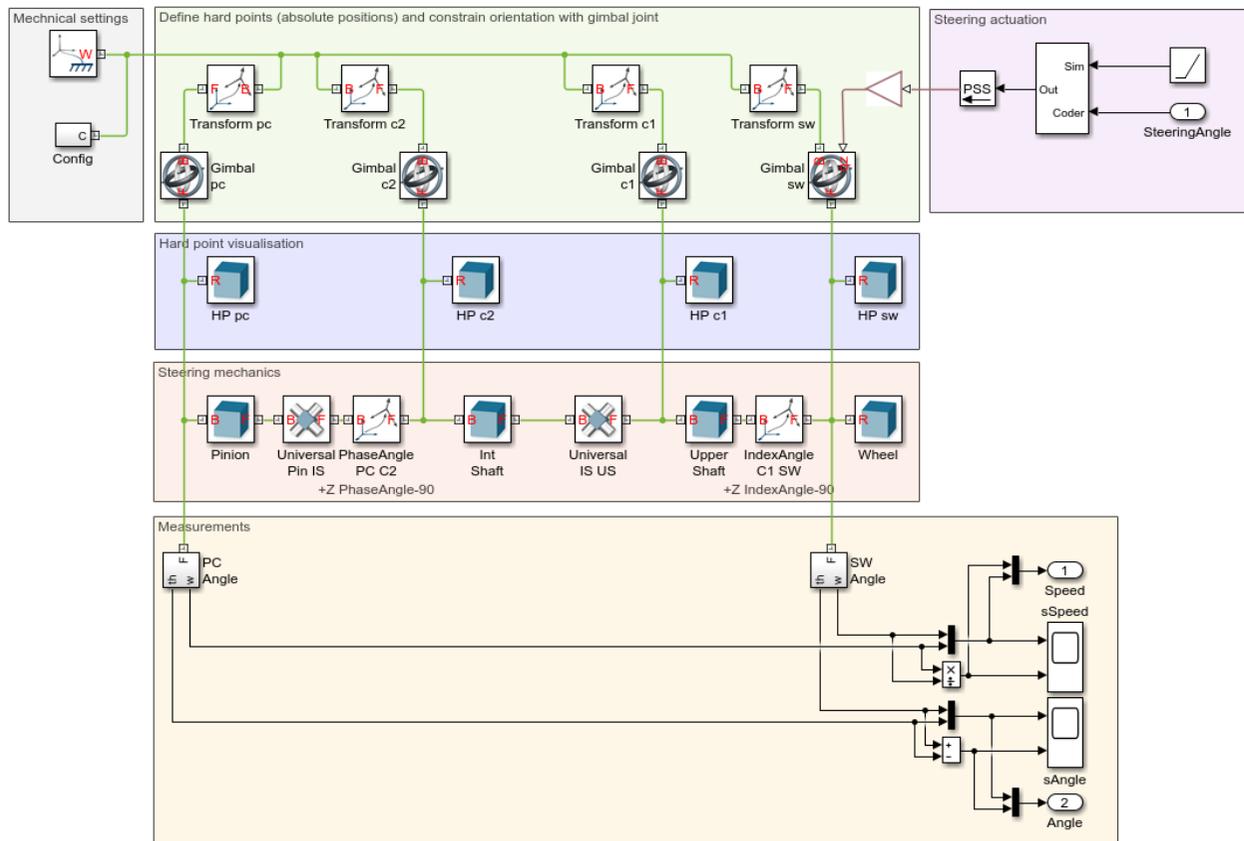
MATLAB EXPO 2018





# 3D MECHANISM WITH SIMULINK / SIMSCAPE MULTIBODY

## SIMSCAPE MULTIBODY MODEL



## MODEL PARAMETERS

```

1  pc = [19.2 -340 73.4]; % in mm, PinionCenter
2  c2 = [209.5 -385.4 170.4]; % in mm, SecondCardanicJoint
3  c1 = [892.7 -375 364.2]; % in mm, FirstCardanicJoint
4  sw = [1473.9 -375 514.6]; % in mm, SteeringWheelCenter
5
6  IndexAngle = 40; % in deg
7  PhaseAngle = 90; % in deg
8
9  rcyl1 = 15;
10 denisty_cylinder = 7800; % kg/m^3
11
12 len_p = norm(c2-pc);
13 len_i = norm(c1-c2);
14 len_u = norm(sw-c1);
15
16
17

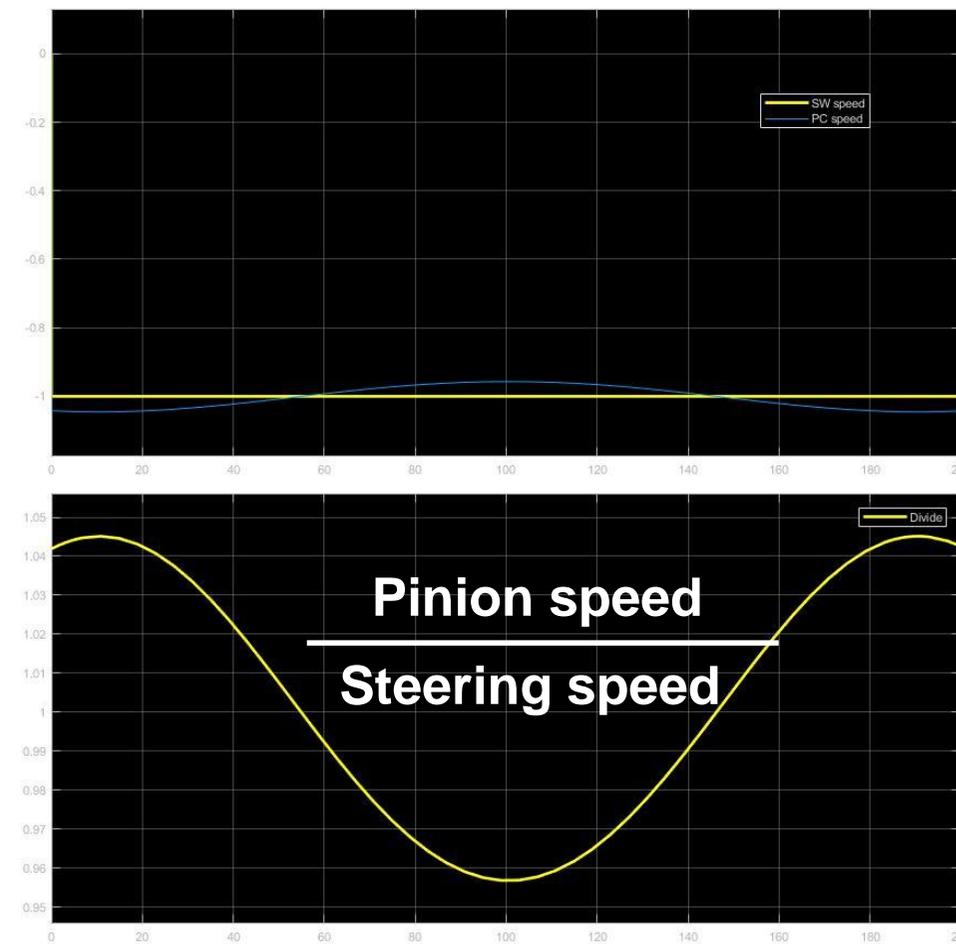
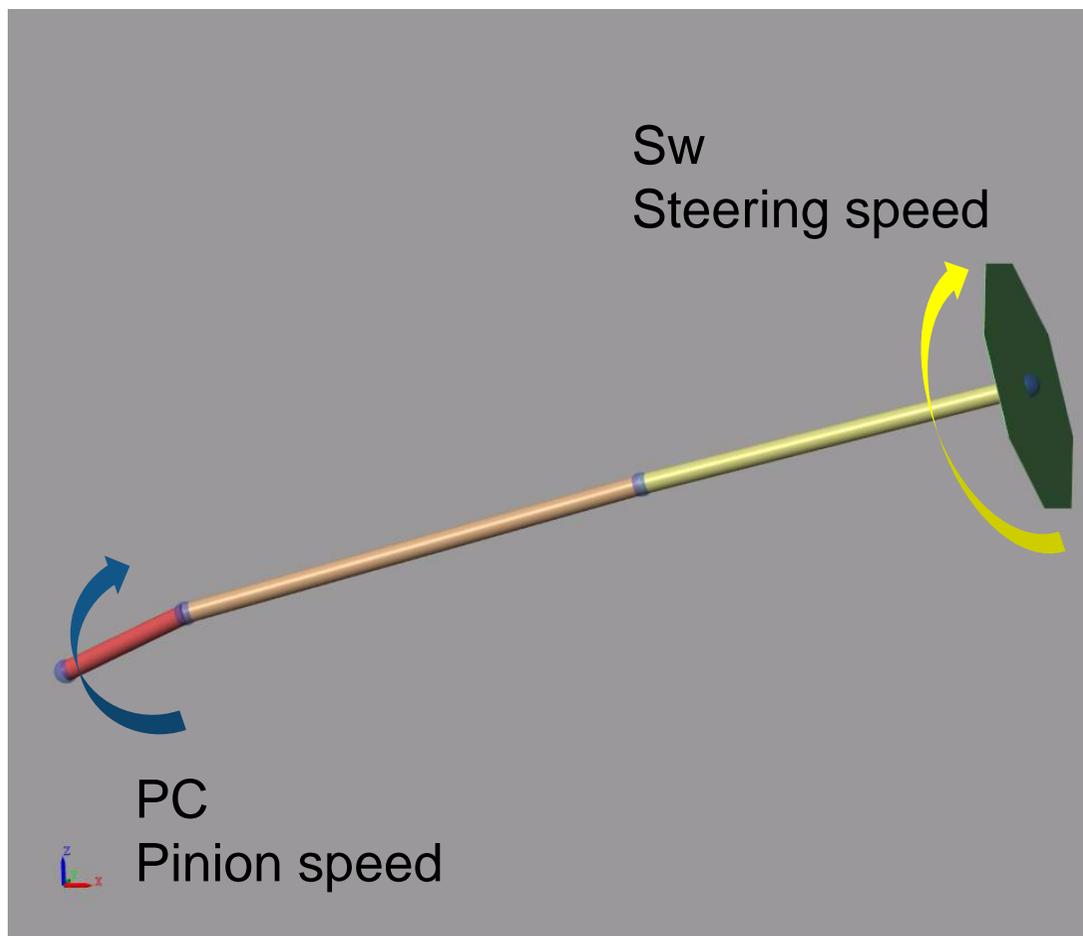
```

4 bodies  
space location

Cardan joint  
installation  
angles



# 3D MECHANISM OUTPUTS – SPEED DISCONTINUITY



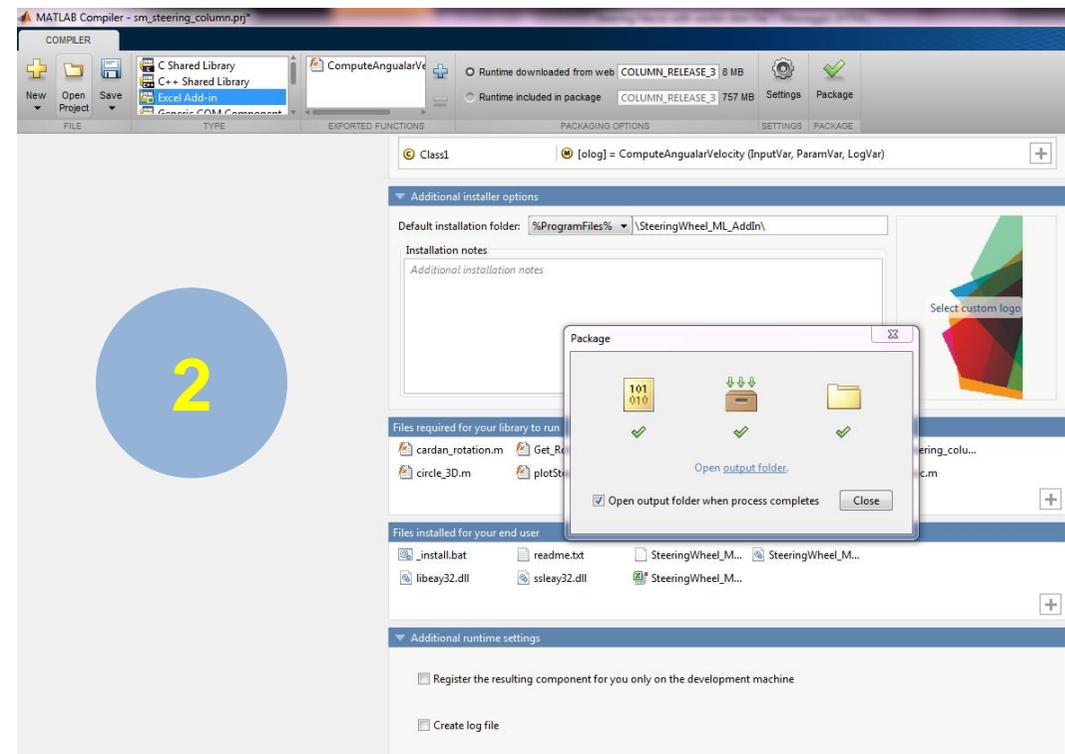


# MODEL DEPLOYMENT

1. Run BuildExportModel('sm\_steering\_column')
2. Run Compiler - Excel Add-in
3. Software created STEERING\_COLUMN\_RELEASE\_3.exe

```

Editor - D:\Isabel\CD002880\FERRARI\COMPONENTS\STEERING_COLUMN\y20180518 Ferrari - OK Release 3 - per conference\vis-plugin\StartupSteering.m
Command Window
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(289) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(289) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
cl -c -DCRTAPI1=cdecl -DCRTAPI2=cdecl -nologo -GS -D_AMD64_=_1 -DWIN64 -D_WIN64 -DWIN32 -D_WIN32 -W4 -D_WINNT -D_WIN32_WINNT=0x0502 -I
sm_steering_column_40669a9_1_gateway.c
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(288) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(289) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
cl -c -DCRTAPI1=cdecl -DCRTAPI2=cdecl -nologo -GS -D_AMD64_=_1 -DWIN64 -D_WIN64 -DWIN32 -D_WIN32 -W4 -D_WINNT -D_WIN32_WINNT=0x0502 -I
rt_bac
cl -c -DCRTAPI1=cdecl -nologo -GS -D_AMD64_=_1 -DWIN64 -D_WIN64 -DWIN32 -D_WIN32 -W4 -D_WINNT -D_WIN32_WINNT=0x0502 -I
rt_for
cl -c -DCRTAPI1=cdecl -nologo -GS -D_AMD64_=_1 -DWIN64 -D_WIN64 -DWIN32 -D_WIN32 -W4 -D_WINNT -D_WIN32_WINNT=0x0502 -I
rt_lu
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(288) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(289) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
cl -c -DCRTAPI1=cdecl -DCRTAPI2=cdecl -nologo -GS -D_AMD64_=_1 -DWIN64 -D_WIN64 -DWIN32 -D_WIN32 -W4 -D_WINNT -D_WIN32_WINNT=0x0502 -I
rt_matrixlib_dbl.c
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(288) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(289) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
cl -c -DCRTAPI1=cdecl -DCRTAPI2=cdecl -nologo -GS -D_AMD64_=_1 -DWIN64 -D_WIN64 -DWIN32 -D_WIN32 -W4 -D_WINNT -D_WIN32_WINNT=0x0502 -I
sm_steering_column.c
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(288) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(289) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
cl -c -DCRTAPI1=cdecl -DCRTAPI2=cdecl -nologo -GS -D_AMD64_=_1 -DWIN64 -D_WIN64 -DWIN32 -D_WIN32 -W4 -D_WINNT -D_WIN32_WINNT=0x0502 -I
sm_steering_column_data.c
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(288) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
C:\Program Files (x86)\Microsoft Visual Studio 12.0\VC\INCLUDE\math.h(289) : warning C4005: 'isnan' : macro redefinition
command-line arguments : see previous definition of 'isnan'
### Creating shared library ".\sm_steering_column_win64.dll" ...
link /RELEASE /INCREMENTAL:NO /NOLOGO -subsystem:console,5.02 kernel32.lib ws2_32.lib mswsock.lib advapi32.lib -dll -def:sm_steering
Creating library ..\sm_steering_column_win64.lib and object ..\sm_steering_column_win64.exp
### Created: ..\sm_steering_column_win64.dll
### Successfully generated all binary outputs.
### Successful completion of build procedure for model: sm_steering_column
  
```





# EXCEL CALCULATION SHEET

The code generates an Excel file:

- Input parameters: 4 bodies space coordinates; and two cardan joints angle installation
- Outputs: curve of the velocity discontinuity (pinion velocity divided the steering angle velocity)
- A schematic representation helps to understand the geometries

Excel interface showing the calculation sheet and results.

**Run MATLAB Macro**

	X	Y	Z
Centro volante	1473.90	-375.00	514.60
Primo cardano	892.70	-375.00	364.20
Secondo cardano	209.50	-385.40	170.40
Centro pignone	19.20	-340.00	73.40
Fase iniziale	40		
Torsione	90		

steering angle: min -90.00, step 0.10, max 90.00

**Irregolarità Sterzo**

Limite Superiore	7%	-90	93%	107%
Limite Inferiore	7%	90	93%	107%
Mezzeria		0	1.1	
		0	0.9	

**Vista volante**

**Fase iniziale**  
Angolo relativo forcella solidale piantone del 1° cardano rispetto lo "0" volante (piano verticale), senso orario positivo visto dal volante

**Torsione**  
Angolo relativo 2° forcella del collassabile rispetto la 1° forcella, senso orario positivo visto dal volante



## Concluding Remarks

- The mechanism is well represented by Simulink / Simscape / Multibody library
- As soon the model is compiled with **Excel Add-in** it generates a software to distribute for installation to the **End Users**
- The Excel calculation sheet is easy to use, and the graphical representation helps to the proper placement into the space the steering column mechanism